Introduction to the New Mainframe: z/OS Basics

An introduction to mainframe computing on the IBM zSeries platform

z/OS concepts and facilities for students and beginners

zSeries hardware and peripheral devices

Mike Ebbers
Wayne O'Brien
Bill Ogden

ibm.com/

International Technical Support Organization

z/OS Basics

March 2005

SG24-6366-00

Note: Before using this information and the product it supports, read the information in “Notices” on page -1.

First Edition (March 2005)

Contents

Preface

This text provides students of information systems technology with the background knowledge and skills necessary to begin using the basic facilities of a mainframe computer.

For optimal learning, students are assumed to have successfully completed an introductory course in computer system concepts, such as computer organization and architecture, operating systems, data management, or data communications. They should also have successfully completed courses in one or more programming languages, and be PC literate.

Note that this text can also be used as a prerequisite for courses in advanced topics such as compiler algorithms, or for internships and special studies.

Others who will benefit from this text include data processing professionals who have experience with non-mainframe platforms, or who are familiar with some aspects of the mainframe but want to become knowledgeable with other facilities and benefits of the mainframe environment.

When moving through this text, instructors are encouraged to alternate between text, lecture, discussions, and hands-on exercises. The instructor-led discussions and hands-on exercises are an integral part of the learning experience, and can include topics not covered in this text.

After reading this text, students will have received:

- A general introduction to mainframe concepts, usage, and zSeries® architecture
- A comprehensive overview of z/OS®, a widely used mainframe operating system
- An understanding of mainframe workloads and an overview of the major middleware applications in use on mainframes today
- The basis for subsequent course work in more advanced, specialized areas of z/OS, such as system administration or application programming

How this text is organized

This text is organized in four parts, as follows:

- **Part 1. "Introduction to z/OS and the mainframe environment"** provides an overview of the types of workloads commonly processed on the mainframe, such as batch jobs and online transactions. This part of the text helps students explore the user interfaces of z/OS, a widely used mainframe operating system. Discussion topics include TSO/E and ISPF, UNIX® interfaces, job control language, file structures, and job entry subsystems. Special attention is paid to the users of mainframes and to the evolving role of mainframes in today's business world.

- **Part 2. "Application programming on z/OS"** introduces the tools and utilities for developing a simple program to run on z/OS. This part of the text guides the student through the process of application design, choosing a programming language, and using a runtime environment.
- **Part 3. "Online workloads for z/OS"** examines the major categories of real time workloads processed by z/OS, such as transaction processing, database management, and Web-serving. This part of the text includes discussions of network communications and several popular middleware products, including DB2®, CICS®, and WebSphere Application Server®.
- **Part 4. "System programming on z/OS"** provides topics to help the student become familiar with the role of the z/OS system programmer. This part of the text includes discussions of system libraries, starting and stopping the system, security, and the clustering of multiple systems. Also provided is an overview of mainframe hardware systems, including processors and I/O devices.

In this text, we use simplified examples and focus mainly on basic system functions. Hands-on exercises are provided throughout the text to help students explore the mainframe style of computing. Exercises include entering work into the system, checking its status, and examining the output of submitted jobs.

How each chapter is organized

Each chapter follows a common format:

- Objectives for the student
- Topics that teach a central theme related to mainframe computing
- Summary of the main ideas of the chapter
- A list of key terms introduced in the chapter
- Questions for review to help students verify their understanding of the material
- Topics for further discussion to encourage students to explore issues that extend beyond the chapter objectives
- Hands-on exercises intended to help students reinforce their understanding of the material

Acknowledgements

Special thanks to the following people for their contributions to this project.

Rama Ayyar is a Senior IT Specialist with the IBM® Support Center in Sydney, Australia. He has 20 years of experience with the MVS™ operating system and has been in the IT industry for over 30 years. His areas of expertise include TCP/IP, security, storage management, configuration management, and problem determination. Rama holds a Master's degree in Computer Science from the Indian Institute of Technology, Kanpur.

Emil T. Cipolla is an information systems consultant in the United States. He has more than 40 years of experience in information systems. He holds Masters degrees in Mechanical Engineering and Business Administration from Cornell University. Emil is currently an adjunct instructor at the college level.

Myriam Duhamel is an IT Specialist in Belgium. She has 19 years of experience in application development and has worked at IBM for 11 years. Her areas of expertise include development in different areas of z/OS (such as COBOL, PL/I, CICS, DB2, and WebSphere MQ). Myriam currently teaches courses in DB2 and WebSphere MQ.

Mike Ebbers has worked with mainframe systems at IBM for 31 years. For part of that time, he taught hands-on mainframe classes to new hires just out of college. Mike currently creates IBM Redbooks™, a popular set of product documentation that can be found at http://www.ibm.com/redbooks.

Per Fremstad is an IBM-certified I/T Specialist from the IBM Systems and Technology group in IBM Norway. He has worked for IBM since 1982 and has extensive experience with zSeries and z/OS. His areas of expertise include the Web, WebSphere for z/OS and Web enabling of the z/OS environment. He teaches frequently on z/OS, zSeries and WebSphere for z/OS topics. Per holds a BSc from the University of Oslo, Norway.

Luis Martinez Fuentes is a Certified Consulting IT Specialist (Data Integration discipline) with Systems and Technology Group, IBM Spain. He has 18 years of experience with IBM mainframes, mainly in the CICS and DB2 areas. He is currently working in technical sales support for new workloads on zSeries. Luis is a member of the Iberia Technical Expert Council, which is affiliated with the IBM Academy of Technology. Luis teaches about mainframes at two universities in Madrid.

Miriam Gelinski is a staff member of Maffei Consulting Groupin Brazil, where she is responsible for supporting customer planning and installing zSeries software. She has five years of experience in mainframes. She holds a Bachelor's degree in Information Systems from Universidade São Marcos in Sao Paulo. Her areas of expertise include the z/OS operating system, its subsystems, and TSO and ISPF. Miriam has written extensively on z/OS in the IBM RedBook series *ABCs of z/OS System Programming*.

Michael Grossmann is an IT Education specialist in Germany with eight years of experience as a z/OS system programmer and instructor. His areas of expertise include z/OS education for beginners, z/OS operations, automation, zSeries hardware and Parallel Sysplex®.

Olegario Hernandez is a former IBM Advisory Systems Engineer in Chile. He has more than 35 years of experience in application design and development projects in the z/Operating Systems arena. He has written extensively on CICS/Application Interface, systems management and grid computing. Olegario holds a degree in Chemical Engineering from Universidad de Chile.

Roberto Yuiti Hiratzuka is an MVS system programmer in Brazil. He has 15 years of experience as a mainframe system programmer. Roberto holds a degree in Information Systems from Faculdade de Tecnologia Sao Paulo (FATEC-SP).

John Kettner is a Consulting Software Architect in the zSeries Advanced Architecture Group. He has 30 years of mainframe experience and holds a BS in Computer Science from L.I.U. His specialties are zSeries internals, Websphere product integration, and capacity planning. John has written several redbooks and contributes to various education programs throughout IBM.

Georg Müller is a student at the University of Leipzig in Germany. He has three years of experience with z/OS and mainframe hardware. He plans to complete his study with a Master's degree in computer science next year. For this textbook, Georg wrote topics on WebSphere MQ and HTTP Server, wrote sample programs, and helped to verify the final sequence of learning modules.

Rod Neufeld is a Senior Technical Services Professional in Canada. He has 25 years of experience in MVS and z/OS system programming. His areas of expertise include z/OS systems software and support, Parallel Sysplex, and business continuance and recovery. Rod holds an Honors Bachelors degree in Science from the University of Manitoba.

Paul Newton is a Senior Software Engineer in the Dallas, Texas, IBM Developer Relations Technical Support Center. He has 25 years of experience with IBM mainframe operating systems, subsystems and data networks. Paul holds a degree in Business Administration from the University of Arizona.

Wayne O'Brien is an Advisory Software Engineer at IBM Poughkeepsie. He has 16 years of experience in developing user assistance manuals and online help for a variety of software products. Wayne holds a Master of Science degree in Technical Communications from Rensselaer Polytechnic Institute (RPI) of Troy, New York.

Bill Ogden is a retired IBM Senior Technical Staff Member. He holds BSEE and MS (Computer Science) degrees and has worked with mainframes since 1962 and with z/OS since it was known as OS/360 Release 1/2. Since joining the ITSO in 1978, Bill has specialized in encouraging users new to the operating system and associated hardware.

Bill Seubert is a zSeries Software Architect in the United States. He has over 20 years experience in mainframe and distributed computing. He holds a Bachelors of Science degree in Computer Science from the University of Missouri--Columbia. His areas of expertise include z/OS, WebSphere integration software, and software architecture. Bill speaks frequently to IBM clients on the topics of zSeries basics, integration architecture, and Enterprise Modernization.

Andy R. Wilkinson is an IT Specialist in the United Kingdom. He has 25 years of experience in reservation systems and z/OS system programming, and has worked at IBM for five years. His areas of expertise include hardware configuration and SMP/E. Andy holds a degree in Materials Science and Technology from the University of Sheffield and a degree in Computing from the Open University.

Special thanks to the editors at the ITSO center in Poughkeepsie, New York:

Terry Barthel

Ella Buslovich (graphics editor)

Alfred Schwab

Comments welcome

Your comments are important to us!

We want our Redbooks to be as helpful as possible. Send us your comments about this or other Redbooks in one of the following ways:

- Use the online **Contact us** review form found at:

  ibm.com/redbooks

- Send your comments in an e-mail to:

  redbook@us.ibm.com

- Mail your comments to:

  IBM Corporation, International Technical Support Organization
  Dept. HYJ Mail Station P099
  2455 South Road
  Poughkeepsie, NY 12601-5400

Part 1

Introduction to z/OS and the mainframe environment

Welcome to mainframe computing! We begin this text with an overview of the mainframe computer and its place in today's information technology (IT) organization. We explore the reasons why public and private enterprises throughout the world rely on the mainframe as the foundation of large scale computing. We discuss the types of workloads commonly processed on the mainframe, such as batch jobs and online (real time) transactions, and the unique manner in which this work is processed by a widely-used mainframe operating system, z/OS.

Special attention is paid to the people who use mainframes and to the evolving role of mainframes in today's business world.

1

Introduction to the new mainframe

Objective: As a technical professional in the world of mainframe computing, you will need to understand how mainframe computers support your company's IT infrastructure and business goals. You also need to know the job titles of the various members of your company's mainframe support team.

After completing this chapter, you will be able to:

- List ways in which the mainframe of today challenges the traditional thinking on centralized computing versus distributed computing.
- Explain how businesses make use of mainframe processing power, the typical uses of mainframes, and how mainframe computing differs from other forms of computing.
- Outline the major types of workloads for which mainframes are best suited.
- Name five jobs or responsibilities related to mainframe computing.
- List four mainframe operating systems.

1.1 The new mainframe

Today, mainframe computers play a central role in the daily operations of most of the world's largest corporations, such as Fortune 1000 companies. While other forms of computing are used extensively in business in various capacities, the mainframe occupies a coveted place in today's e-business environment. In banking, finance, health care, insurance, utilities, government, and a multitude of other public and private enterprises, the mainframe computer continues to form the foundation of modern business.

The long-term success of mainframe computers is without precedent in the information technology (IT) field. Periodic upheavals shake world economies. Continuous, often wrenching, change in the Information Age have claimed many once compelling innovations as victims in the relentless march of progress. As emerging technologies leap into the public eye, most are, it seems, just as suddenly rendered obsolete by some even newer advancement. Yet today, as in every decade since the 1960s, mainframes and the mainframe *style* of computing dominate the landscape of large-scale business computing.

Why has this one form of computing taken hold so strongly among the world's largest corporations? The mainframe computer began its initial growth spurt in the 1960s. At that time, mainframes were the *only* type of computers, and few businesses could afford them. Of the small number sold at the time, each mainframe was uniquely tailored to match a customer's primary (and often only) business application.

In 1964, however, things changed dramatically when mainframe manufacturers began to standardize the hardware and software they offered to customers[1]. This change signaled the start of the age of the *general purpose computer*. With standardized mainframes to run their workloads, customers could, in turn, write business applications without need for specialized hardware or software. Moreover, customers were free to upgrade to newer and more powerful processors without concern for incompatibility problems with their existing applications. The first wave of customer business applications were mostly written in COBOL, FORTRAN, or PL/1, and many of these older programs or *legacy applications* are still in use today.

In the decades since the 1960s, mainframe computers have steadily grown to achieve enormous processing capabilities. Mainframes of today have an unrivaled ability to serve end users by the tens of thousands, manage petabytes of data, and reconfigure hardware and software resources to match changes in workload--all from a single point of control.

1.2 Evolving architecture

Starting with the first large machines (which arrived on the scene in the 1960s and evenutally became known as “big iron” in contrast to smaller departmental system), each

[1] IBM introduced System/360™ (or S/360™), the first general purpose computing architecture, in 1964.

new generation of mainframes has added improvements in one or more of the following areas:[2]

- More and faster processors
- More physical memory and greater memory addressing capability
- Dynamic capabilities for upgrading both hardware and software
- More sophisticated automated hardware error checking and recovery
- Enhanced devices for input/output (I/O) and more and faster paths (*channels*) between I/O devices and processors
- Sophisticated I/O attachments, such as LAN adapters with extensive inboard processing
- Increased ability to divide the resources of one machine into multiple, logically independent and isolated systems, each running its own operating system
- Enhanced clustering technologies, such as *Parallel Sysplex,* and the ability to share data among multiple systems.

Despite the continual change, mainframes remain the most stable, secure and compatible of all computing platforms. The latest models can handle the most advanced and demanding customer workloads, yet continue to run many applications that were written in the 1970s or earlier.

How is it possible that a technology can change so much, yet remain so stable? By evolving to meet new challenges; for example, in the early 1990s, the client/server model of computing, with its distributed nodes of less powerful computers, emerged to challenge the dominance of mainframes. Industry pundits predicted a swift end for the mainframe and called it a "dinosaur." In response, mainframe designers did what they have always done when confronted with changing times and changing user requirements: They designed new mainframe computers to meet the demand. With a tip of the hat to the dinosaur naysayers, IBM, a leading manufacturer of mainframes, even code-named its newest, most powerful mainframe *T-Rex.*

With expanded functions and added tiers of data processing capabilities such as Web-serving, autonomics, disaster recovery, and grid computing, the mainframe is once again poised to ride the next wave of growth in the IT industry. Mainframe manufacturers such as IBM are once again reporting annual sales growth in double digits.

And the evolution continues. While the mainframe has retained its traditional, central role in the IT organization, that role is now defined to include being the primary hub in the largest distributed networks. In fact, the Internet itself is based largely on many interconnected mainframes serving as major hubs and routers.

---

[2] Since the introduction of S/360 in 1964, IBM has significantly extended the platform roughly every ten years: System/370™ in 1970, System/370 Extended Architecture (370-XA) in 1983, Enterprise Systems Architecture/390® (ESA/390) in 1990, and z/Architecture™ in 2000. For more information about earlier mainframe hardware systems, see Appendix A, "A brief look at IBM mainframe history".

As the image of the mainframe continues to change, you might ask: Is the mainframe a self-contained computing environment, or one part of the puzzle in distributed computing? The answer is that the new mainframe is both: A self-contained processing center, powerful enough to process the largest workloads in one secure "footprint," but one that is also just as effective when implemented as the primary server in a corporation's distributed server farm. In effect, the new mainframe is the ultimate server in the client/server model of computing.

1.3 Mainframes in our midst

Despite the predominance of mainframes in the business world, these machines are largely invisible to the general public, the academic community, and indeed many experienced IT professionals. Instead, other forms of computing attract more attention, at least in terms of visibility and public awareness. That this is so is perhaps not surprising. After all, who among us needs direct access to a mainframe? And, if we did, where would we find one to access? In truth, we are *all* mainframe users, whether we realize it or not (more on this later).

Most of us with some PC literacy (and sufficient funds) can purchase a notebook computer and quickly put it to good use—running software, browsing Web sites, and perhaps even writing papers for college professors to grade. With somewhat greater effort and technical prowess, we can delve more deeply into the various facilities of a typical Intel®-based workstation and learn its capabilities through direct, hands-on experience—with or without help from any of a multitude of readily available information sources in print or on the Web.

Mainframes, however, tend to be hidden from the public eye. They do their jobs dependably—indeed, with almost total reliability—and are highly resistant to most forms of insidious abuse that afflict PCs, such as e-mail-borne viruses, Trojan Horses, and the like. By performing stably, quietly, and with negligible downtime, mainframes are the example by which all other computers are judged. But at the same time, this lack of attention tends to allow them to fade into the background.

Furthermore, in a real world IT setting, mainframes share space with lots of other hardware devices: External storage devices, hardware network routers, channel controllers, automated tape library "robots," and so on. The new mainframe is no larger than many of these devices and generally do not stand out from the crowd of peripheral devices.

So, how can we explore a mainframe's capabilities in the real world? How can we learn to interact with the new mainframe, learn its capabilities, and understand its importance to the business world? Major corporations are eager to hire new mainframe professionals, but there's a catch: A little previous experience would help.

Would we even know a mainframe if we saw one, given that these machines have in fact evolved to flourish in the jungles of the twenty-first century IT organization? What we need is an experienced guide to lead us on a *dinosaur safari*, which is where this textbook comes in!

1.4 What is a mainframe?

First, let's tackle the terminology. Today, computer manufacturers don't always use the term *mainframe* to refer to mainframes. Instead, most have taken to calling any commercial-use computer—large or small—a *server*, with the mainframe simply being the largest type of server in use today. IBM, for example, now refers to its mainframes as zSeries servers. We use the term mainframe in this textbook to refer to computers that can support dozens of applications and input/output devices to simultaneously serve thousands of users.

Servers are proliferating. A business might have a collection of transaction servers, database servers, e-mail servers, Web servers, and so on. Larger collections of servers are sometimes called *server farms* (in fact, some data centers cover areas measured in *acres*). The hardware required to perform a server function can range from little more than a cluster of rack-mounted personal computers to the most powerful mainframes manufactured today.

A mainframe is the central data repository or *hub* in a corporation's data processing center, linked to users through less powerful devices such as workstations or terminals. The presence of a mainframe often implies a centralized form of computing, rather than a distributed form of computing. Having data centralized in a single mainframe repository saves customers from having to manage updates to more than one copy of their business data. This increases the likelihood that the data is current.

This distinction, however, is rapidly blurring as smaller machines continue to gain in processing power, and mainframes become ever more flexible and multi-purpose. Market pressures require that today's businesses continually reevaluate their information technology (IT) infrastructures to find ways of better supporting a changing marketplace. As a result, mainframes are now frequently used in combination with networks of smaller servers in a multitude of configurations. Also, the ability to dynamically reconfigure a mainframe's hardware and software resources (such as processors, memory, and device connections), while applications continue running, further underscores the flexible, evolving nature of the modern mainframe.

While mainframe hardware has become harder to pigeon-hole, so, too, have the operating systems that run on mainframes. Many years ago, in fact, the terms defined each other: A mainframe was any hardware system that ran a major IBM operating system.[3] This

[3] The name was also traditionally applied to large computer systems produced by other vendors.

meaning has been blurred in recent years because these operating systems can be run on very small systems.

IT professionals often use the term *platform* to refer to a general computer architecture (hardware and software). For example, a zSeries machine and its operating system (and their predecessors[4]) is considered a platform; UNIX on a RISC machine is considered a platform, somewhat independent of exactly which RISC machine is involved; personal computers can be seen as several platforms, depending on which operating system is being used.

So, let's return to our question now: "What is a mainframe?" Today, the term *mainframe* can be better used to describe a *style* of operation, applications and operating system facilities. To start with a working definition, "a mainframe is what businesses use to host the commercial databases, transaction servers, and applications that require a greater degree of security and availability than is commonly found on smaller-scale machines."

Early mainframe systems were housed in enormous, room-filling metal boxes or frames, and this is probably how the term mainframe originated. The mainframe required large amounts of electrical power and air-conditioning, and the room was occupied mostly by I/O devices. Also, a typical installation had several mainframes installed with most of the I/O devices connected to all of the mainframes. During their largest period in terms of physical size, a typical mainframe occupied 2000-10,000 square feet, with some installations being *much* larger than this.

Starting around 1990, mainframe processors and most of the I/O devices became physically smaller, while their functionality and capacity continued to grow. Mainframe systems today are much smaller than earlier systems--about the size of a large refrigerator.

Further, it is now possible in some cases to run a mainframe operating system on a PC that emulates a zSeries processor. Such emulators are useful for developing and testing business applications before moving them to a mainframe production system.

[4] IBM System/390® (S/390®) refers to a specific series of machines, and these have been superseded by the zSeries. Nevertheless, many S/390 systems are still in use. Therefore, keep in mind that although we discuss the zSeries systems in this course, almost everything discussed also applies to S/390 machines as well. The most obvious exception is the use of 64-bit addressing, which is used only with zSeries machines.

Clearly, the term "mainframe" has expanded beyond merely describing the physical characteristics of a system. Instead, the word typically applies to some combination of the following attributes:

- Compatibility with mainframe operating systems, applications, and data.
- Centralized control of resources.
- Hardware and operating systems that can share access to disk drives with other systems, with automatic locking and protection against destructive simultaneous use of disk data.
- A *style* of operation, often involving dedicated operations staff who use detailed *operations procedure books* and highly organized procedures for backups, recovery, training, and disaster recovery at an alternate site.
- Hardware and operating systems that routinely work with hundreds or thousands of simultaneous I/O operations.
- Clustering technologies that allow the customer to operate multiple copies of the operating system as a single system. This configuration, known as Parallel Sysplex, is analogous in concept to a UNIX cluster, but allows for systems to be added or subtracted as needed while applications continue to run. This flexibility allows mainframe customers to introduce new applications, or discontinue using existing applications, in response to changes in business activity.
- Additional data and resource sharing capabilities. In a Parallel Sysplex, for example, it is possible for users across multiple systems to access the same databases concurrently, with database access controlled at the *record level*.

1.5 Who uses mainframe computers?

So, who uses mainframes? Just about *everyone* has used a mainframe computer at one point or another. If you have ever used an *automated teller machine* (ATM) to interact with your bank account, for example, you've used a mainframe.

Today, mainframe computers play a central role in the daily operations of most of the world's largest corporations. While other forms of computing are used extensively in business in various capacities, the mainframe occupies a coveted place in today's e-business environment. In banking, finance, health care, insurance, utilities, government, and a multitude of other public and private enterprises, the mainframe computer continues to be the foundation of modern business.

In fact, until the mid-1990s, mainframes provided the *only* acceptable way of handling the data processing requirements of a large business. These requirements were then (and are often now) based on large and complex batch jobs, such as payroll and general ledger processing.

The mainframe owes much of its popularity and longevity to its inherent reliability and stability, a result of careful and steady technological advances since the introduction of System/360 in 1964. No other computer architecture in existence can claim as much continuous, evolutionary improvement, while maintaining compatibility with previous releases.

Because of these design strengths, the mainframe is often used by IT organizations to host the most important, *mission-critical* applications. These applications typically include customer order processing, financial transactions, production and inventory control, payroll, as well as many other types of work.

A common impression of a mainframe user interface is the 80x24 character "green screen" terminal, named for the old CRT-based computer terminals from years ago that glowed green. However, current mainframe interfaces can look much the same as those for personal computers or UNIX systems. When a business application is accessed through a Web browser, there is often a mainframe computer providing crucial function "behind the scenes."

Many of today's busiest Web sites store their production databases on a mainframe host. New mainframe hardware and software are ideal for Web transactions because they are designed to allow huge numbers of users and applications to rapidly and simultaneously access the same data without interfering with each other. This security, scalability, and reliability is critical to the efficient and secure operation of contemporary information processing.

Corporations use mainframes for applications that depend on scaleability and reliability. For example, a banking institution could use a mainframe to host the database of its customer accounts, for which transactions can be submitted from any of thousands of ATM locations worldwide.

Businesses today rely on the mainframe to:

- Perform large-scale transaction processing (thousands of transactions per second)
- Support thousands of users and application programs concurrently accessing many resources
- Manage terabytes of information in databases
- Handle large-bandwidth communications

The roads of the information superhighway often lead to a mainframe.

1.6 Factors contributing to mainframe use

The reasons for mainframe use are many, but most generally fall into one or more of the following categories:

- Reliability, availability, serviceability

- Security
- Scalabilty
- Continuing compatibility
- Evolving architecture

Let’s look at each of these categories in more detail now.

1.6.1 Reliability, availability, and serviceability

Reliability, availability, and *serviceability* (often grouped together as “RAS”) have always been important in data processing. When we say that a particular computer system “exhibits RAS characteristics,” we mean that its design places a high priority on the system remaining in service at all times. Ideally, RAS is a central design feature of all aspects of a computer system, including the applications.

RAS has become accepted as a collective term for many qualities of hardware and software that are prized by users of mainframes. The terms are defined as follows:

Reliability Involves the use of high-quality components. In addtion, hardware components have extensive self-checking and self-recovery. Software reliability involves extensive testing and quick updates for detected problems.

Availability The ability to recover from a failed component without impacting the rest of the running system. This applies to hardware recovery (by automatically replacing failed elements with spares) and software recovery (through layers of error recovery provided by the operating system).

Serviceability Allows for the replacement of elements (hardware and software) while impacting as little of the operational system as possible. It also implies well-defined units of replacement, either hardware or software.

A computer system is available when its applications are available. An available system is one that is reliable, that is, it rarely requires downtime for upgrades or repairs. And, if the system is brought down by an error condition, it must be serviceable -- easy to fix -- within a relatively short period of time.

Along with the hardware, mainframe operating systems exhibit RAS through such features as storage protection and a controlled maintenance process. These features allow a mainframe to run for months and even years before requiring an unscheduled outage or upgrade.

Beyond RAS, a state-of-the-art mainframe system might be said to provide *high availability* and *fault tolerance*. Redundant hardware components in critical paths, enhanced storage protection, a controlled maintenance process, and system software designed for unlimited availability all help to ensure a consistent, highly available environment for business applications in the event that a system component fails. Such an approach allows the system designer to minimize the risk of having a *single point of failure* undermine the overall RAS of a computer system.

1.6.2 Security

One of a firm's most valuable resources is its data: Customer lists, accounting data, employee information, and so on. This critical data needs to be securely managed and controlled, and, simultaneously, made available to those users authorized to see it. Mainframe computers have extensive capabilities to simultaneously share, but still protect, the firm's data among multiple users.

In an IT environment, *data security* is defined as protection against unauthorized access, transfer, modification, or destruction, whether accidental or intentional. To protect data and to maintain the resources necessary to meet the security objectives, customers typically add a sophisticated security manager product to their mainframe operating system. The customer's security administrator often bears the overall responsibility for using the available technology to transform the company's security policy into a usable plan.

A secure computer system prevents users from accessing or changing any objects on the system, including user data, except through system-provided interfaces that enforce authority rules. Mainframe computers can provide a very secure system for processing large numbers of heterogeneous applications that access critical data. In this text, we discuss one example of a mainframe security system in Chapter 17, "Security on z/OS" .

1.6.3 Scalability

It has been said that the only constant is *change.* Nowhere is that statement truer than in the information technology industry. In business, positive results can often trigger a growth in IT infrastructure to cope with increased demand. The degree to which the IT organization can add capacity without disruption to normal business processes or without incurring excessive overhead (nonproductive processing) is largely determined by the *scalability* of the particular computing platform.

By scalability we mean the ability of the hardware, software, or a distributed system to continue to function well as it is changed in size or volume; for example, the ability to retain performance levels when adding processors, memory, and storage. A scalable system can efficiently adapt to work, with larger or smaller networks performing tasks of varying complexity.

zSeries mainframes exhibit scalability characteristics in both hardware and software, with the ability to run multiple copies of the operating system software as a single entity called a system complex or sysplex. We further explore mainframe clustering technology and its uses in Chapter 20, "Parallel Sysplex" .

1.6.4 Continuing compatibility

Mainframe customers tend to have a very large financial investment in their applications and data. Some applications have been developed and refined over decades. Some applications were written many years ago, while others may have been written "yesterday."

The need to support applications of varying ages imposes a strict compatibility demand on mainframe hardware and software, which have been upgraded many times since the first System/360 mainframe computer was shipped in 1964. Applications *must* continue to work properly. Thus, much of the design work for new hardware and system software revolves around this compatibility requirement.

The overriding need for compatibility is also the primary reason why many aspects of the system work as they do, for example, the syntax restrictions of the job control language (JCL) used to control batch jobs. Any new design enhancements made to JCL must preserve compatibility with older jobs so that they can continue to run without requiring modifications. The desire and need for continuing compatibility is one of the defining characteristics of mainframe computing.

Absolute compatibility across decades of changes and enhancements is not possible, of course, but the designers of mainframe hardware and software make it a top priority. When an incompatibility is unavoidable, the designers typically warn users *at least a year* in advance that software changes might be needed.

1.7 Typical mainframe workloads

Most mainframe workloads fall into either of two categories: batch processing and online transactional processing, including Web-based applications (Figure 1-1).

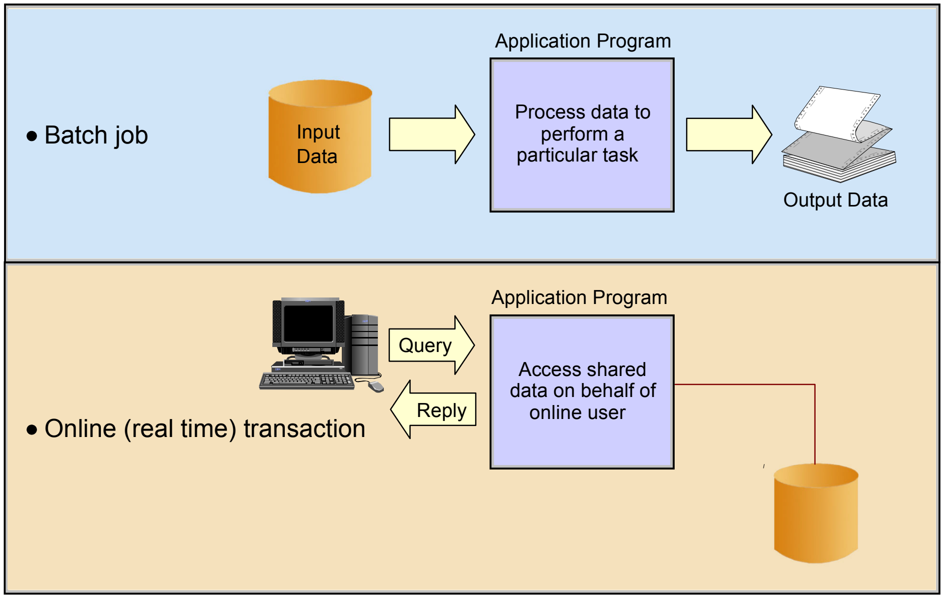


Figure 1-1 Typical mainframe workloads

These workloads are discussed in several chapters in this textbook; the following sections provide an overview.

1.7.1 Batch processing

One key advantage of a mainframe is its ability to process terabytes of data from high-speed storage devices and produce valuable output. For example, mainframe systems make it possible for banks and other financial institutions to produce end-of-quarter processing when such reporting is necessary to customers (such as quarterly stock statements or pension statements) or to the government (financial results). With mainframe systems, retail stores can generate and consolidate nightly sales reports for review by regional sales managers.

The applications that produce these statements are *batch* applications--they are processed on the mainframe without user interaction. A *batch job* is submitted on the computer, reads and processes data in bulk, and produces output, such as customer billing statements. An equivalent concept can be found in a UNIX script file or Windows .cmd file, but some z/OS batch job can jobs last for many hours..

While batch processing is possible on distributed systems, it is not as commonplace as on mainframes because distributed systems often lack:

- Sufficient data storage

- Available processor capacity or *cycles*
- Sysplex-wide management of system resources and job scheduling.

Mainframe operating systems are usually equipped with sophisticated job scheduling software that allows data center staff to submit, manage, and track the execution and output of batch jobs[5].

Batch processes have the following characteristics:

- Large amounts of input data are processed, stored records accessed, and a large volume of output is produced.
- Interactive response time is usually not the primary requirement. However, batch jobs often must complete within a "batch window," a period of less intensive online activity prescribed by a service level agreement.
- Information is generated about large numbers of users.
- A scheduled batch process can consist of the execution of hundreds or thousands of jobs in a pre-established sequence.

During batch processing, many types of work can be generated. Consolidated information such as profitability of investment funds, scheduled database back-ups, processing of daily orders and updating of inventories are typical examples of batch processing.

Figure 1-2 shows a number of batch jobs running in a typical mainframe environment.

[5] In the early days of the mainframe, punched cards were often used to enter jobs into the system for execution. "Keypunch operators" used card punches to enter data, and decks of cards (or batches) were produced. These were fed into card readers, which read the jobs and data into the system. As you can imagine, this process was cumbersome and error-prone. Nowadays, it is possible to FTP the equivalent of punched card data to the mainframe in a PC text file. We discuss various ways of introducing work into the mainframe in Chapter 5, "Batch processing and JES" .

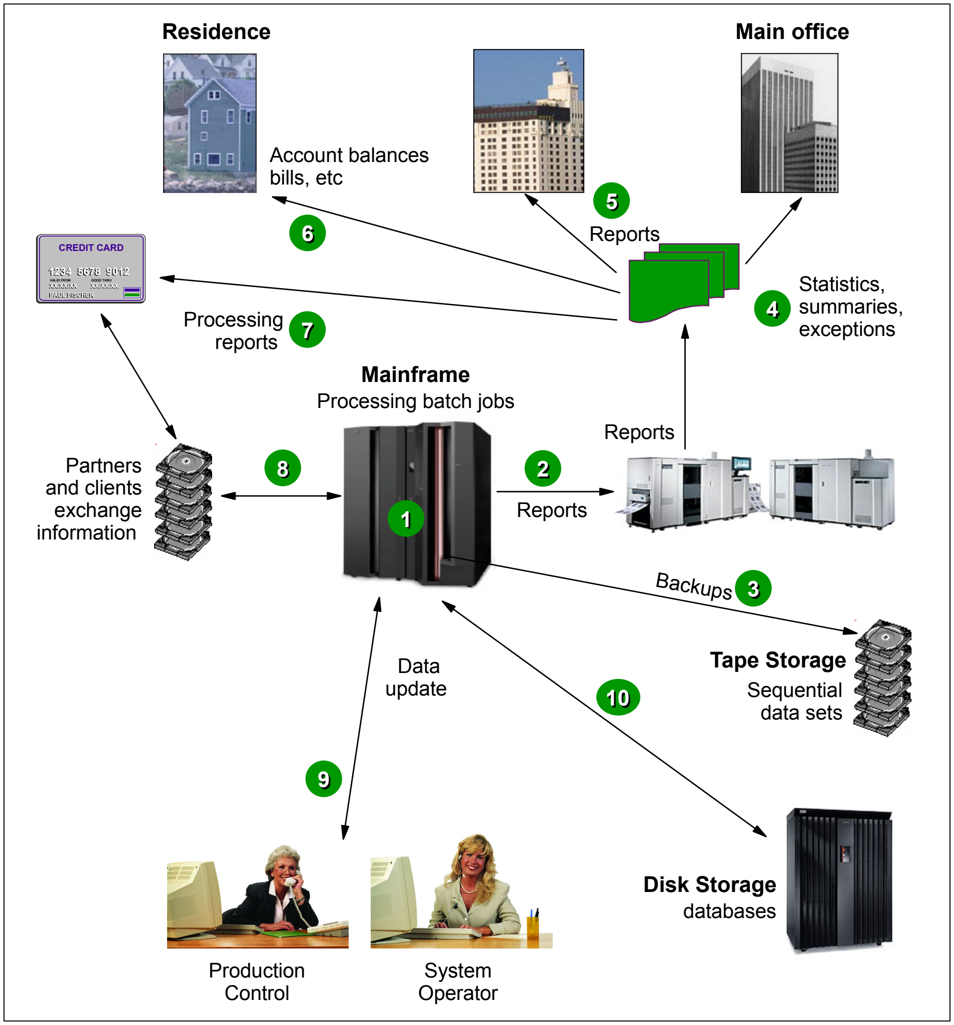


Figure 1-2 Typical batch use

In Figure 1-2, consider the following elements at work in the scheduled batch process:

1. At night, many batch jobs executing programs and utilities are processed. These jobs consolidate the results of the online transactions executed during the day.
2. The batch jobs generate reports of business statistics.
3. Backups of critical files and databases are made before and after the batch window.
4. Reports with business statistics are sent to a specific area for analysis during the following day.
5. Reports with exceptions are sent to the branch offices.

6. Monthly account balance reports are generated and sent to all bank customers.
7. Reports with processing summary are sent to the partner credit card company.
8. A credit card transaction report is received from the partner company.
9. In the production control department, the operations area is monitoring the messages on the system console and the execution of the jobs.
10. Jobs and transactions are reading or updating the database (the same database used by online transactions) and many files are written to tape.

1.7.2 Online transactional processing

Mainframes serve a vast number of *online transaction processing* (OLTP) systems. These are often mission-critical applications that businesses depend on for their core functions. Some industry uses of online systems:

- Banks – ATMs, teller systems for customer service
- Insurance – Agent systems for policy management and claims processing
- Travel and transport – Airline reservation systems
- Manufacturing – Inventory control, production scheduling
- Government – Tax processing, license issuance and management.

How might someone in one of these industries interact with their mainframe system? Many factors influence the design of a company's transaction processing workload, including:

- Number of users interacting with the system at any one time
- Number of *transactions per second* (TPS)
- Availability requirements of the application (for example, must the application be available 24 hours a day, seven days a week, or can it be brought down briefly one night each week?)

Before personal computers and intelligent workstations became popular, the most common way to communicate with online mainframe applications was with 3270 terminals. They were sometimes known as "dumb" terminals, but they had enough intelligence to collect and display a full screen of data rather than interacting with the computer for each keystroke, saving processor cycles. The characters were green on a black screen, so the mainframe applications were nicknamed "green screen" applications.

Based on these factors, user interactions vary from installation to installation. With applications now being designed, many installations are reworking their existing mainframe applications to include Web browser-based interfaces for users. This work sometimes requires new application development, but can often be done with vendor software purchased to "re-face" the application. Here, the end user often does not realize that there is a mainframe behind the scenes. In this textbook, there is no need to describe the process of interacting with the mainframe through a Web browser, as it is exactly the same as any interaction a user would have through the Web. The only difference is the machine at the other end!

Online transactions are familiar to many people. Examples include:

- ATM machine transactions such as deposits, withdrawals, inquiries, and transfers
- Supermarket payments with debit or credit cards
- Purchase of merchandise over the Internet.

Online transactions usually have the following characteristics:

- Small amount of input data, few stored records accessed and processed, and small amount of data as output.
- Rapid response time, usually less than one second.
- Large numbers of users involved in large numbers of transactions.
- Round-the-clock availability of the transactional interface to the user.
- Assurance of security for transactions and user data.

In a bank branch office, for example, customers use online services when checking account balance or making an investment.

Figure 1-3 shows a series of common online transactions using a mainframe.

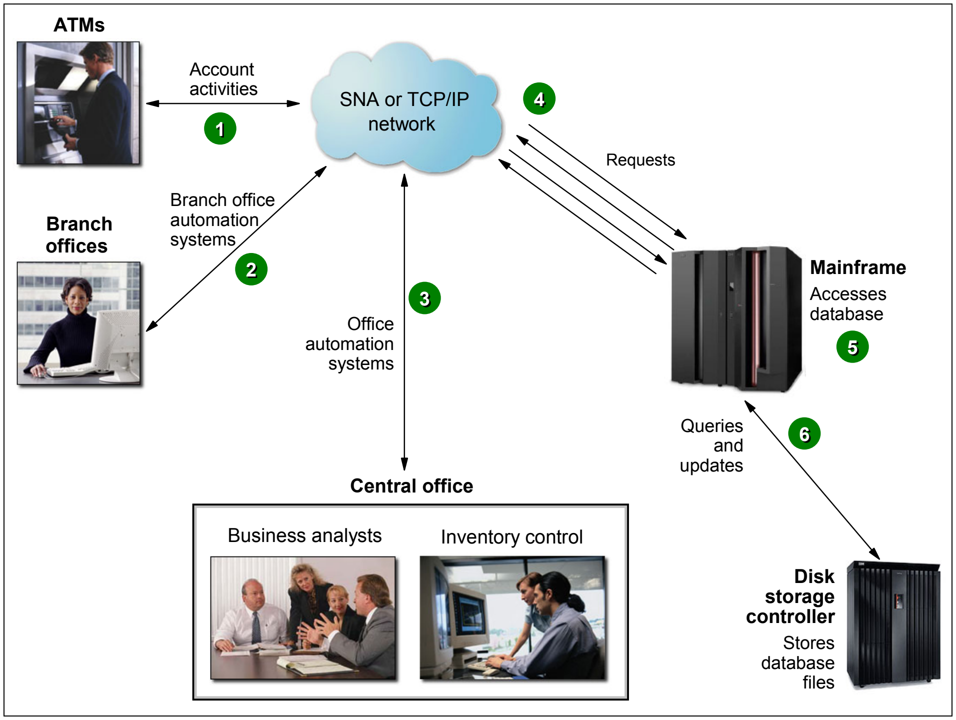


Figure 1-3 Typical online use

1. A customer uses an ATM, which presents a user-friendly interface for various functions: Withdrawal, query account balance, deposit, transfer, or cash advance from a credit card account.
2. Elsewhere in the same private network, a bank employee in a branch office performs operations such as consulting, fund applications, and money ordering.
3. At the bank's central office, business analysts tune transactions for improved performance. Other staff use specialized online systems for office automation to perform customer relationship management, budget planning, and stock control.
4. All requests directed to the mainframe computer for processing.
5. Programs running on the mainframe computer perform updates and inquires to the database management system (for example, DB2).
6. Specialized disk storage systems store the database files.

1.8 Roles in the mainframe world

Mainframe systems are designed to be used by large numbers of people. Most of those who interact with mainframes are end users – the people who use the applications hosted on the system. However, because of the large number of end users, applications running on the system, and the sophistication and complexity of the system software that supports the users and applications, a variety of roles are needed to support and operate the system.

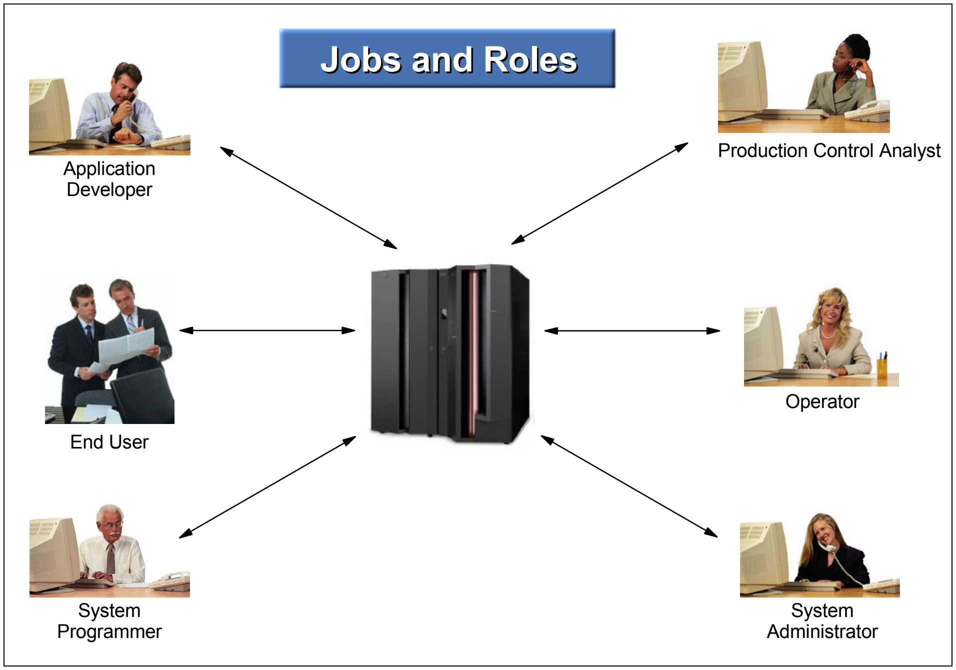


Figure 1-4 Who's who in the mainframe world?

In mainframe computing, these roles have many different titles; this text uses the following:

- System programmers
- System administrators
- Application designers and programmers
- System operators
- Production control analysts

In the distributed systems world, many of the same roles are needed as in the mainframe environment. However, the job responsibilities are often not as well-defined. Since the 1960s, mainframe roles have evolved and expanded to provide an environment in which the system software and applications can function smoothly and effectively and efficiently serve huge numbers of users. While it may seem that the size of the mainframe support staff is large and unwieldy, the numbers become comparatively small when one considers the number of users supported, the number of transactions run, and the high business value of the work performed on the mainframe.

This section concentrates on the system programmer and application programmer roles in the mainframe environment. However, there are many other important roles involved in the "care and feeding" of the mainframe, and this chapter touches on some of these to give a better idea of what's going on behind the scenes.

Mainframe activities, such as the following, often require cooperation between the various roles:

- Installing and configuring system software
- Designing and coding new applications to run on the mainframe
- Introduction and management of new workloads on the system, such as batch jobs and online transaction processing
- Operation and maintenance of the mainframe software and hardware.

In the following sections, we describe each role in more detail.

1.8.1 Who is the system programmer?

In a mainframe IT organization, the system programmer (or *systems* programmer) plays a central role. The system programmer installs, customizes, and maintains the operating system, and also installs or upgrades products that run on the system. The system programmer might be presented with the latest version of the operating system to upgrade the existing systems. Or, the installation might be as simple as upgrading a single program, such as a sort.

In any case, the system programmer must perform tasks like the following:

- Planning software and hardware system upgrades and changes in configuration
- Training system operators and application programmers
- Automating operations
- Capacity planning
- Running installation jobs and scripts
- Performing installation-specific customization tasks
- Integration-testing the new products with existing applications and user procedures
- System-wide performance tuning to meet required levels of service.

The system programmer must be skilled at debugging problems with system software. These problems are often manifested by software system images, sometimes known as *dumps*, that have been produced by the software products or in user jobs or transactions. Armed with dumps and specialized debugging tools, the system programmer can determine where the components have failed. When the error has occurred in a software product, the system programmer works directly with the software vendor's support representatives to discover whether the problem cause is known and whether a patch is available.

System programmers are needed to install and maintain the *middleware* on the mainframe, such as database management systems, online transaction processing systems, Web servers, and so forth. Middleware is a software "layer" between the operating system and the end user or end-user application. It supplies major functions not provided by the operating system. Major middleware products such as DB2, CICS, and IMS™ can be as complex, if not more so, than the operating system itself.

There are a wide variety of system configuration options to be maintained, in addition to the daily monitoring and debugging of the system. And, on the database side, the database administrator (DBA) is also present to ensure the integrity and smooth operation of the data that is stored in the database management systems. These roles are not necessarily unique to the mainframe environment, but they are key to its smooth operation nonetheless.

1.8.2 Who is the system administrator?

The distinction between "system programmer" and "system administrator" varies widely among mainframe sites. In many smaller IT organizations, where one person might be called upon to perform several roles, the terms may be used interchangeably.

In larger IT organizations with multiple departments, the job responsibilities tend to be more clearly separated. System administrators perform more of the day-to-day tasks related to maintaining the critical business data that resides on the mainframe, while the system programmer focuses on maintaining the system itself. One reason for the separation of duties is to comply with auditing procedures, which often require that no one person in the IT organization be allowed to have unlimited access to sensitive data or resources. Examples of system administrators include database administrators and security administrators.

While system programmer expertise lies mainly in the mainframe hardware and software areas, system administrators are more likely to have experience with the applications. They often interface directly with the application programmers and end users to ensure that the administration aspects of the applications are met.

In larger IT organizations, the system administrator maintains the system software environment for business purposes, including the day-to-day maintenance of systems to keep them running smoothly.

Other examples of common system administrator tasks can include:

- Installing software
- Adding and deleting users and maintaining user profiles
- Maintaining security resource access lists
- Managing storage devices and printers
- Managing networks and connectivity
- Monitoring system performance.

In matters of problem determination, the system administrator generally relies on the software vendor support center personnel to diagnose problems, read dumps, and identify corrections for cases in which these tasks aren't performed by the system programmer.

1.8.3 Who are the application designers and programmers?

The application designer and application programmer (or *developer*) design, build, test, and deliver mainframe applications for the company's end users and customers. Based on requirements gathered from business analysts and end users, the designer creates a design specification from which the programmer constructs an application. The process includes many iterations of code changes and compiles, application builds, and unit testing.

During the application development process, the designer and programmer must interact with other roles in the enterprise. For example, the programmer often works on a team of other programmers who are building code for related application program modules. When completed, each module is passed through a testing process that can include function, integration, and system-wide tests. Following the tests, the application programs must be acceptance tested by the user community to determine whether the code actually satisfies the original user requirement.

Besides creating new application code, the programmer is responsible for maintaining and enhancing the company's existing mainframe applications. In fact, this is frequently the primary job for many application programmers on the mainframe today. While many mainframe installations still create new programs with COBOL or PL/I, languages such as Java™ have become popular for building new applications on the mainframe, just as on distributed platforms.

Widespread development of mainframe programs written in high-level languages such as COBOL and PL/I continues at a brisk pace, despite rumors to the contrary. Many thousands of programs are in production on mainframe systems around the world, and these programs are critical to the day-to-day business of the corporations that use them. COBOL and other high-level language programmers are needed to maintain existing code and make updates and modifications to existing programs. Also, many corporations continue to build new application logic in Common Business Oriented Language (COBOL) and other traditional languages, and IBM continues to enhance the high-level language compilers to include new functions and features that allow those languages to continue to exploit newer technologies and data formats.

1.8.4 Who is the system operator?

The system operator monitors and controls the operation of the mainframe hardware and software. The operator starts and stops system tasks, monitors the system consoles for unusual conditions, and works with the system programming and production control staff to ensure the health and normal operation of the systems.

Console messages are often cryptic and can be so voluminous that the operator has a difficult time in determining when a situation is really a problem. In recent years, however, tools to reduce the volume of messages and automate message responses to routine situations have made it easier for operators to concentrate on unusual events that might require human intervention.

The operator is also responsible for starting and stopping the major subsystems, such as transaction processing systems, database systems, and the operating system itself. These restarts are not nearly as commonplace as they once were, as the availability of the mainframe has improved dramatically over the years. But the operator is still required to perform an orderly shutdown and startup of the system and its workloads when and if required.

In case of a failure or an unusual situation, the operator communicates with system programmers, who assist the operator in determining the proper course of action, and with the production control analyst, who works with the operator to ensure that production workloads are completing properly.

1.8.5 Who is the production control analyst?

The production control analyst is responsible for ensuring that batch workloads run to completion--without error or delay. Many mainframe installations run interactive workloads for online users, followed by batch updates that run after the prime shift when the online systems are not running. While this execution model is still common, world-wide operations at many companies--with live, Internet-based access to production data--are finding the “daytime online/night time batch” model to be obsolete. Batch workloads continue to be a part of information processing, however, and skilled production control analysts play a key role.

A common complaint about mainframe systems is that they are inflexible and hard to work with, specifically in terms of implementing changes. The production control analyst often bears the brunt of this type of complaint because this person is responsible for maintaining rigorous change control procedures. Using fairly structured rules and procedures to control changes that are introduced to the system and to the production run-time libraries helps the production control analyst prevent outages. In fact, one reason that mainframes have attained a strong reputation for high levels of availability and performance is that there are controls on change and it is difficult to introduce change without proper procedures.

1.8.6 What role do vendors play?

A number of vendor roles are commonplace in the mainframe shop. Because most mainframe computers are sold by IBM and the operating systems and primary online systems are also provided by IBM, most vendor contacts are IBM employees. However, there are also *independent software vendor* (ISV) products that are used in the IBM mainframe environment, and many customers also use original *equipment manufacturer* (OEM) hardware, such as disk and tape storage devices.

Following are typical vendor roles:

- Hardware support or Customer Engineer

  Hardware vendors usually provide on-site support for hardware devices. The IBM hardware maintenance person is often referred to as the *Customer Engineer* (CE). The CE provides installation and repair service for the mainframe hardware and peripherals. The CE usually works directly with the operations teams when hardware fails or new hardware is being installed.

- Software support

  A number of vendor roles exist to support software products on the mainframe[6]. IBM provides a centralized *Support Center* that gives entitled and/or extra-charge support for software defects or usage assistance. There are also information technology specialists and architects who can be engaged to provide additional pre- and post-sales support for software products, depending upon the size of the customer and the particular customer situation.

- Sales support

  For larger mainframe accounts, IBM and other vendors provide face-to-face sales support. The sales representatives specialize in various types of hardware or software product families and call on the part of the customer organization that influences the product purchases. In larger mainframe accounts, IBM frequently assigns a "client representative" to work exclusively with one or two customers in the same industry and is attuned to the business issues in that particular customer or industry sector. The client representative also acts as the general "single point of contact" between the customer and the many different roles and organizations within IBM.

1.9 z/OS and other mainframe operating systems

Much of this textbook is concerned with teaching you the fundamentals of z/OS, which is IBM's foremost mainframe operating system. We begin discussing z/OS concepts in Chapter 2, "z/OS overview" . It is useful for mainframe students, however, to have a working knowledge of other operating systems available for mainframes. One reason is that a given mainframe computer might run multiple operating systems. For example, the use of z/OS, z/VM®, and Linux® on the same mainframe is common.

Mainframe operating systems are sophisticated products with substantially different characteristics and purposes, and each could justify a separate book for a detailed introduction. Besides z/OS, four other operating systems dominate mainframe usage: z/VM, VSE, Linux for zSeries, and z/TPF.

[6] This textbook does not examine the marketing and pricing of mainframe software. However, the availability and pricing of middleware and other program products is a critical factor affecting the growth and use of mainframes.

1.9.1 z/VM

z/Virtual Machine (z/VM) has two basic components: A c*ontrol program* (CP) and a single-user operating system, CMS.

As a control program, z/VM is a *hypervisor* because it runs other operating systems in the virtual machines it creates. The control program artificially creates multiple virtual machines from the real hardware resources. To the user it appears as if they have dedicated use of the shared real resources. The shared real resources include printers, disk storage devices, and the CPU. The control program ensures data and application security among the virtual machines, which are called *guest systems.* The real hardware can be shared among the guests, or dedicated to a single guest for performance reasons. The system programmer allocates the real devices among the guests. For most customers, the use of guest systems allows them to avoid having larger hardware configurations.

The second major component of z/VM is CMS or *Conversational Monitor System*. This component of z/VM runs in a virtual machine and provides both an interactive end-user interface and the general z/VM application programming interface.

1.9.2 VSE

Virtual Storage Extended (VSE) is popular with users of smaller mainframe computers. Many of these customers eventually migrate to z/OS when they grow beyond the capabilities of VSE.

Compared to z/OS, the VSE operating system provides a smaller, less complex base for batch processing and transaction processing. The design and management structure of VSE is excellent for running routine production workloads consisting of multiple batch jobs (running in parallel) and extensive, traditional transaction processing. In practice, most VSE users also have the z/VM operating system and use this as a general terminal interface for VSE application development and system management.

This operating system was originally known as *Disk Operating System* (DOS), and was the first disk-based operating system introduced for the System 360 mainframe computers. DOS was seen as a temporary measure until OS/360 would be ready. However, many mainframe customers liked its simplicity (and small size) and decided to remain with it after OS/360 became available. DOS became known as DOS/VS (when it started using virtual storage), then VSE/SP, and later VSE/ESA™. The name VSE is often used collectively to reference any of the more recent versions.

1.9.3 Linux for zSeries

Several Linux distributions can be used on a mainframe. These distributions are not from IBM. Two generic names are used for these distributions:

- Linux for S/390 (uses 31-bit addressing and 32-bit registers)

- Linux for zSeries (uses 64-bit addressing and registers)

The phrase *Linux on zSeries* is used to refer to Linux running on an S/390 or zSeries system, when there is no specific need to refer explicitly to either the 31-bit version or the 64-bit version.

We assume students are generally familiar with Linux and therefore we mention only those characteristics that are relevant for mainframe usage. These include the following:

- Linux uses traditional count key data (CKD) disk devices and SAN-connected SCSI type devices. Other mainframe operating systems can recognize these drives as Linux drives, but cannot use the data formats on the drives. That is, there is no sharing of data between Linux and other mainframe operating systems.
- Linux does not use 3270 display terminals, while all other mainframe operating systems use 3270s as their basic terminal architecture.[7] Linux uses X Windows® based terminals or X Windows emulators on PCs; it also supports typical ASCII terminals, usually connected through telnet.
- With the proper setup, a Linux system under z/VM can be quickly cloned to make another, separate Linux image. The z/VM emulated LAN can be used to connect many Linux images and to provide an external LAN route for them. Read-only file systems, such as a typical /usr file system, can be shared by many Linux images.
- Linux on a mainframe operates with the ASCII character set, not the EBCDIC[8] form of stored data that is typically used on mainframes. Here, EBCDIC is used only when writing to character-sensitive devices such as displays and printers. The Linux drivers for these devices handle the character translation.

1.9.4 z/TPF

The z/*Transaction Processing Facility* (z/TPF) operating system is a special purpose system used by companies that require very high volume transactions, such as credit card companies and airline reservation systems. z/TPF was once known as Airline Control Program (ACP). It is still used by airlines and has been extended for other very large systems with high-volume transaction processing requirements.

z/TPF can use multiple mainframes in a loosely-coupled environment to routinely handle tens of thousands of transactions per second while experiencing uninterrupted availability measured in years. Very large terminal networks, including special-protocol networks used by portions of the reservation industry, are common.

[7] There is a Linux driver for minimal 3270 operation, in very restrictive modes, but this is not commonly used.

[8] EBCDIC, which stands for extended binary coded decimal interchange code, is a coded character set of 256 8-bit characters developed for the representation of textual data. EBCDIC is not compatible with ASCII character coding. For a handy conversion table, see Appendix D, “EBCDIC - ASCII table”.

1.10 Summary

Today, mainframe computers play a central role in the daily operations of most of the world's largest corporations, such as Fortune 1000 companies. While other forms of computing are used extensively in business in various capacities, the mainframe occupies a coveted place in today's e-business environment. In banking, finance, health care, insurance, utilities, government, and a multitude of other public and private enterprises, the mainframe computer continues to form the foundation of modern business.

The mainframe owes much of its popularity and longevity to its inherent reliability and stability, a result of continuous technological advances since the introduction of the IBM System/360 in 1964. No other computer architecture in existence can claim as much continuous, evolutionary improvement, while maintaining compatibility with existing applications.

The term *mainframe* has gradually moved from a physical description of IBM's larger computers to categorization of a style of computing. One defining characteristic of the mainframes has been a continuing compatibility spanning decades.

The roles and responsibilities in a mainframe IT organization are wide and varied. It takes a lot of different resources to keep a mainframe computer running smoothly and reliably. It might seem that there are far more resources needed in a mainframe environment than with small, distributed systems. But, if roles are fully identified on the distributed systems side, many of the same roles exist there as well.

Several operating systems are currently available for mainframes. This textbook concentrates on one of these, z/OS. However, mainframe students should be aware of the existence of the other operating systems and understand their position relative to z/OS

Key terms in this chapter				
application programmer	architecture	batch processing	compatibility	e-Business
EBCDIC	high availability	infrastructure	mainframe	online processing
platform	production control	punched card	RAS (reliability, availability, and serviceability)	scalabilty
server farm	system administrator	system operator	system programmer	transaction processing

1.11 Topics for further discussion

1. What is a mainframe today? How did the term arise? Is it still appropriate?
2. Why not simply change existing applications to use improved interfaces (such as friendlier job control language)? Why not simply support the existing characteristics and also support a new, better version?
3. Describe how running a mainframe can be cost-effective, given the large number of roles needed to run a mainframe system.
4. What characteristics, good or bad, exist in a mainframe processing environment because of the roles that are present in a mainframe shop? (Efficiency? Reliability? Scalability?)
5. Most mainframe shops have implemented very rigorous systems management, security, and operational procedures. Have these same procedures been implemented in distributed system environments? Why or why not?
6. Can you find examples of mainframe use in your everyday experiences? Describe them and the extent to which mainframe processing is apparent to end users. Examples might include the following:
   - Popular Web sites that rely on mainframe technology as the back-end server to support online transactions and databases.
   - Mainframes used in your locality. These might include banks and financial centers, major retailers, transportation hubs, and the health and medical industries.

2

z/OS overview

Objective: As the newest member of your company's mainframe IT group, you will need to know the basic functional characteristics of the mainframe operating system. The operating system taught in this course is z/OS, the most widely used of all mainframe operating systems. z/OS is known for its ability to serve thousands of users concurrently and for processing very large workloads in a secure, reliable, and expedient manner.

After completing this chapter, you will be able to:

- Give examples of how z/OS differs from a single-user operating system.
- List the major types of storage used by z/OS.
- Explain the concept of virtual storage and its use in z/OS.
- State the relationship between pages, frames, and slots.
- List several defining characteristics of the z/OS operating system.
- List several software products used with z/OS to provide a complete system.
- Describe several differences and similarities between the z/OS and UNIX operating systems.

2.1 What is an operating system?

In simplest terms, an *operating system* is a collection of programs that manage the internal workings of a computer system. Operating systems are designed to make the best use of the computer's various resources, and ensure that the maximum amount of work is processed as efficiently as possible. Although an operating system cannot increase the speed of a computer, it can maximize its use, thereby making the computer seem faster by allowing it to do more work in a given period of time.

A computer's *architecture* consists of the functions the computer system provides. The architecture is distinct from the physical design, and, in fact, different machine designs might conform to the same computer architecture. In a sense, the architecture is the computer as seen by the user, such as a system programmer. For example, part of the architecture is the set of machine instructions that the computer can recognize and execute.

In a mainframe environment, the system software and hardware comprise a highly advanced computer architecture, the result of decades of continuous technological innovation.

2.2 What is z/OS?

The operating system we discuss in this course is z/OS[1], the most widely used of all mainframe operating systems. z/OS is designed to offer a stable, secure, and continuously available environment for applications running on the mainframe.

To understand how and why z/OS functions as it does, it is important to understand the environment in which it functions. The special features that make z/OS unique reflect the computer environments that z/OS manages.

In most early operating systems, requests for work entered the system one at a time. The operating system processed each request or *job* as a unit, and did not start the next job until the one ahead of it had completed. This arrangement worked well when a job could execute continuously from start to completion. But often a job had to wait for information to be read in from, or written out to a device such as a tape drive or a printer. Input and output (I/O) take a long time compared to the electronic speed of the processor. When a job waited for I/O, the processor was idle.

Finding a way to keep the processor working while a job waited would increase the total amount of work the processor could do without requiring additional hardware. z/OS gets work done by dividing it into pieces and giving portions of the job to various system

[1] z/OS is designed to take advantage of the IBM zSeries architecture, or zArchitecture, which was introduced in 2000.

components and subsystems that function interdependently. At any point in time, one component or another gets control of the processor, makes its contribution, and then passes control along to a user program or another component.

2.2.1 Hardware resources used by z/OS

The z/OS operating system executes in a processor and resides in processor storage during execution. z/OS is commonly referred to as the *system* software.

Mainframe hardware consists of processors and a multitude of peripheral devices such as disk drives (called direct access storage devices or *DASD*), magnetic tape drives, and various types of user consoles; see Figure 2-1. Tape and DASD are used for system functions and by user programs executed by z/OS.

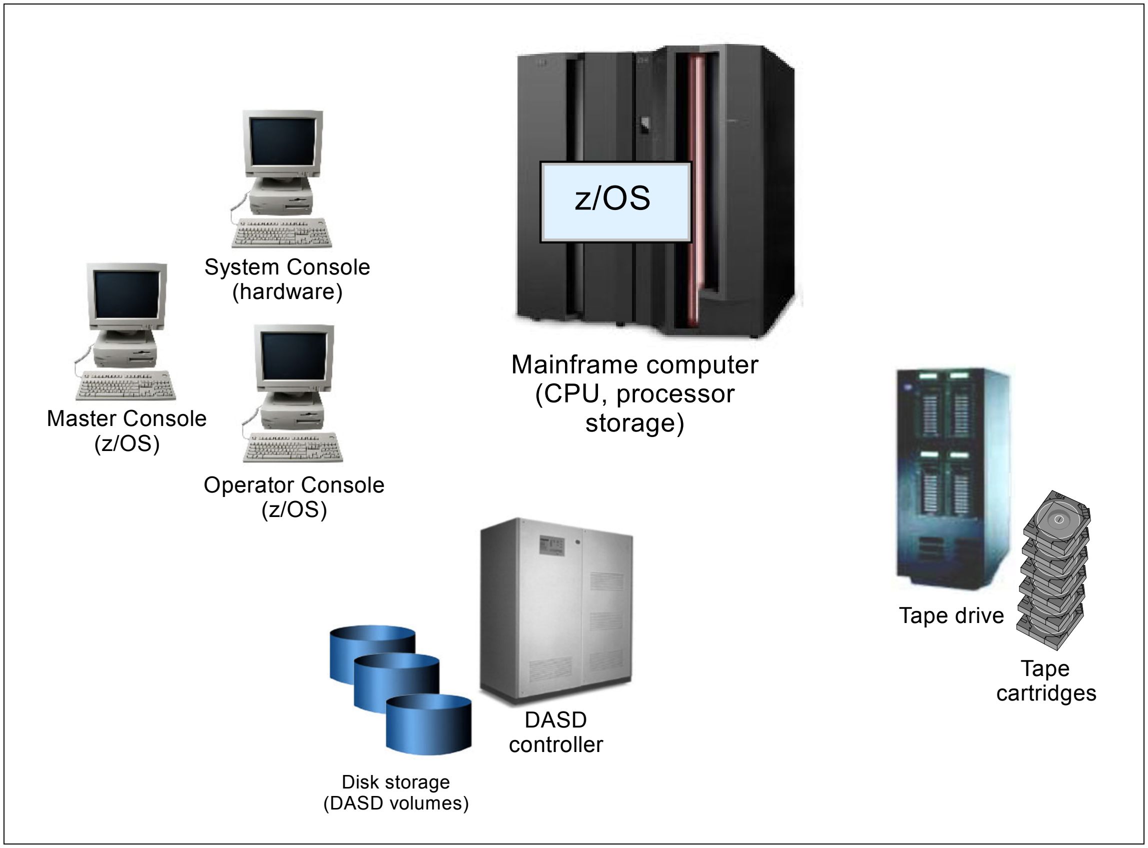


Figure 2-1 Hardware resources used by z/OS

To fulfill a new order for a z/OS system, IBM ships the system code to the customer through the Internet or (depending on customer preference) on physical tape cartridges.

At the customer site, a person such as the z/OS system programmer receives the order and copies the new system to DASD devices (volumes). After the system is customized and ready for operation, system consoles are required to start and operate the z/OS system.

The z/OS operating system is designed to make full use of IBM zSeries mainframe hardware and its many sophisticated peripheral devices. Figure 2-1 on page 2-3 presents a simplified view of mainframe concepts that students will build upon throughout this course:

- Software - The z/OS operating system consists of load modules or *executable code.* During the install process, the system programmer copies these load modules to *load libraries* residing on DASD volumes.
- Hardware - The system hardware consists of all the devices, controllers, and processors that constitute a mainframe environment.
- Peripheral devices - These include tape drives, DASD devices, and consoles. There are many other types of devices, some of which are discussed later in the text.
- Processor storage - Often called real or central storage (or memory), this is where the z/OS operating system executes. Also, all user programs share the use of processor storage with the operating system.

As a “Big Picture” of a typical mainframe hardware configuration, Figure 2-1 is far from complete. Not shown, for example, are the hardware control units that connect the mainframe to the other tape drives, DASD devices, and consoles.

While this text is primarily concerned with teaching the z/OS system software, it is important for students to understand that many z/OS design characteristics exist to take advantage of ongoing mainframe hardware innovations. A more detailed description of zSeries hardware is provided in Chapter 19, “Hardware systems and LPARs” .

2.2.2 Modules and macros

z/OS is made up of programming instructions that control the operation of the computer system. These instructions ensure that the computer hardware is being used efficiently and allow application programs to run. z/OS includes sets of instructions that, for example, accept work, convert work to a form that the computer can recognize, keep track of work, allocate resources for work, execute work, monitor work, and handle output.

A group of related instructions is called a *routine* or *module*. A set of related modules that make a particular possible is called a *system component*. The component known as z/OS Workload Manager (WLM), for instance, controls system resources, while the recovery termination manager (RTM) handles recovery for the system.

Sequences of instructions that perform frequently used system functions can be invoked with executable macro instructions, or *macros*. z/OS macros exist for functions such as opening and closing data files, loading and deleting programs, and sending messages to the computer operator.

2.2.3 Program status word

The program status word (PSW) is a 64-bit data area in the processor that, along with control registers, timing registers, and prefix registers, provides details crucial to both the hardware and the software. The current PSW includes the address of the next program instruction and control information about the program that is running. Each processor has only one current PSW. Thus, only one task can execute on a processor at a time.

2.2.4 Multiprogramming and multiprocessing

z/OS is capable of *multiprogramming,* or executing many programs concurrently, on behalf of many users at once. In multiprogramming, when a job cannot use the processor, the system can suspend, or *interrupt*, the job, freeing the processor to work on another job.

z/OS makes multiprogramming possible by capturing and saving all the relevant information about the interrupted program before allowing another program to execute. When the interrupted program is ready to begin executing again, it can resume execution just where it left off. Multiprogramming allows z/OS to run hundreds of programs simultaneously for users who might be working on different projects at different physical locations around the world.

z/OS can also perform *multiprocessing,* which is the simultaneous operation of two or more processors that share the various hardware resources, such as memory and external disk storage devices.

The techniques of multiprogramming and multiprocessing make z/OS ideally suited for processing workloads that require many I/O operations. Typical mainframe workloads include long-running applications that write updates to millions of records in a database, and online applications for thousands of interactive users at any given time.

By way of contrast, consider the operating system that might be used for a single-user computer system. Such an operating system would need to execute programs on behalf of one user only. In the case of a personal computer (PC), for example, the entire resources of the machine are at the disposal of one user.

Many users running many separate programs means that, along with large amounts of complex hardware, z/OS users need large amounts of memory to ensure suitable system performance. Large companies run sophisticated business applications that access large databases and industry-strength middleware products. Such applications require the operating system to protect privacy among users, as well as enable the sharing of databases and software services.

Thus, multiprogramming, multiprocessing, and the need for a large amount of memory means that z/OS must provide function beyond simple, single-user applications. The sections that follow explain, in a general way, the attributes that enable z/OS to manage complex computer configurations. Subsequent portions of this text explore these features in more detail.

2.2.5 Control blocks

As instructions execute the work of a computer system, they keep track of this work in storage areas known as *control blocks*. Generally speaking, there are three types of z/OS control blocks:

- System-related control blocks
- Resource-related control blocks
- Task-related control blocks

Each system-related control block represents one z/OS system and contains system-wide information, such as how many processors are in use. Each resource-related control block represents one resource, such as a processor or storage device. Each task-related control block represents one unit of work.

Control blocks serve as vehicles for communication throughout z/OS. Such communication is possible because the structure of a control block is known to the programs that use it, and thus these programs can find needed information about the unit of work or resource.

Control blocks representing many units of the same type may be chained together on queues, with each control block pointing to the next one in the chain. The operating system can search the queue to find information about a particular unit of work or resource, which might be:

- An address of a control block or a required routine
- Actual data, such as a value, a quantity, a parameter, or a name
- Status flags (usually single bits in a byte, where each bit has a specific meaning)

2.2.6 Physical storage used by z/OS

Conceptually, mainframes and all other computers have two types of physical storage.

- The physical storage located with the mainframe processor itself. This is called processor storage or *real storage;* think of it as *memory* for the mainframe.
- The physical storage external to the mainframe, including storage on direct access devices, such as disk drives and tape drives. This storage is called *auxiliary storage.*

The primary difference between the two kinds of storage relates to the way in which it is accessed, as follows:

- Real storage is accessed synchronously with the processor. That is, the processor must wait while data is retrieved from real storage.
- Auxiliary storage is accessed asynchronously. The processor accesses auxiliary storage through an input/output (I/O) request, which is scheduled to run amid other work requests in the system. During an I/O request, the processor is free to execute other, unrelated work.

As with memory for a personal computer, mainframe real storage is tightly integrated with the processor itself. In contrast, mainframe auxiliary storage is located on (comparatively) slower external disk and tape drives. Because real storage is more closely integrated with the processor, it takes the processor much less time to access data from real storage than from auxiliary storage. However, the processor is free to do other work while waiting for an I/O request to be satisfied. Auxilliary storage is less expensive than real storage, so it provides the capability for many jobs to be running while keeping real storage costs down.

2.3 Virtual storage and other mainframe concepts

z/OS uses both types of physical storage (real and auxiliary) to enable another kind of storage called *virtual storage*. In z/OS, each user has access to virtual storage, rather than physical storage.

This use of virtual storage is central to the unique ability of z/OS to interact with large numbers of users concurrently, while processing the largest workloads. To make virtual storage possible, z/OS requires sufficient amounts of real storage and many billions of bytes of auxiliary storage. z/OS uses a system of tables and special settings (bit settings) to relate the location of data on disk storage and real storage, and keep track of the identity and authority of each user or program. z/OS uses a variety of storage manager components to manage virtual storage. This chapter briefly covers the key points in the process.

2.3.1 What is virtual storage?

Virtual storage means that each running program can assume it has access to all of the storage defined by the architecture's addressing scheme. The only limit is the number of bits in a storage address. This ability to use a large number of storage locations is important because a program may be long and complex, and both the program's code and the data it requires must be in real storage for the processor to access them.

z/OS supports 64-bit long addresses, which allows a program to address up to 18,446,744,073,709,600,000 bytes (16 EX) of storage locations. In reality, the mainframe might have *much less* real storage installed. How much less depends on the model of computer and the system configuration.

To allow each user to act as though this much storage really exists in the computer system, z/OS keeps only the active portions of each program in real storage. z/OS keeps the rest of the code and data in files called *paging data sets* on auxiliary storage, which usually consists of a number of high-speed direct access storage devices (DASDs).

Virtual storage, then, is this combination of real and auxiliary storage. z/OS uses a system of tables and bit settings to relate the auxiliary storage locations to real storage locations and keep track of the identity and authority of each program. This process is shown in more detail in 2.4, "Virtual storage overview" on page 2-9.

2.3.2 What is an address space?

The range of virtual addresses that the operating system assigns to a user (or separately running program) is called an *address space.* This is the area of contiguous virtual addresses available for executing instructions and storing data. The range of virtual addresses in an address space starts at zero and can extend to the highest address permitted by the operating system architecture.

z/OS provides each user with a unique address space and maintains the distinction between the programs and data belonging to each address space. Within each address space the user can start multiple tasks, using *task control blocks* or *TCBs* that allow user multiprogramming.

In some ways an address space in z/OS is analogous to a UNIX process ID (PID) and the TCBs are like threads, in that the UNIX kernel supports multiple threads at once. The use of address spaces in z/OS, however, holds some special advantages. Unlike UNIX, z/OS allows users to access other users' address spaces directly with *cross-memory services.* This method allows efficient and secure access to data owned by others, data owned by the user but stored in another address space for convenience, and for rapid and secure communication with services like transaction managers and database managers.

Address spaces provide isolation of private areas in different address spaces (and this provides much of the operating system's security), yet each address space also contains a common area that is accessible to every other address space.

Because it maps all of the available addresses, an address space includes system code and data as well as user code and data. Thus, not all of the mapped addresses are available for user code and data.

The ability of many users to share the same resources implies the need to protect users from one another and to protect the operating system itself. Along with such methods as "keys" for protecting real storage and code words for protecting data files and programs, separate address spaces ensure that users' programs and data do not overlap.

An active z/OS system uses many address spaces. There is at least one address space for each job in progress and one address space for each logged-on user. There are many address spaces for operating system functions, such as operator communication, automation, networking, security, and so on.

Each student in this course causes at least one address space to be created whenever they log on to z/OS.

2.4 Virtual storage overview

Recall that for the processor to execute a program instruction, both the instruction and the data it references must be in real storage. The convention of early operating systems was to have the entire program reside in real storage when its instructions were executing. However, the entire program does not really need to be in real storage when an instruction executes. Instead, by bringing pieces of the program into real storage only when the processor is ready to execute them—moving them out to auxiliary storage when it doesn’t need them, an operating system can execute more and larger programs concurrently.

How does the operating system keep track of each program piece? How does it know whether it is in real storage or auxiliary storage, and where? It is important for z/OS professionals to understand how the operating system makes this happen.

Physical storage is divided into areas, each the same size and accessible by a unique address. In real storage, these areas are called *frames*; in auxiliary storage, they are called *slots.*

Similarly, the operating system can divide a program into pieces the size of frames or slots and assign each piece a unique address. This arrangement allows the operating system to keep track of these pieces. In z/OS, the program pieces are called *pages*. These areas are discussed further in 2.4.5, “Frames, pages, and slots” on page 2-13.

The addresses of pages are called *virtual addresses*. From the time a program enters the system until it completes, the virtual address of the page remains the same, regardless of whether the page is in real storage or auxiliary storage. Each page consists of individual locations called bytes, each of which has a unique virtual address.

2.4.1 What is paging?

z/OS maintains tables to determine whether a page is in real or auxiliary storage, and where. To find a page of a program, z/OS checks the table for the virtual address of the page, rather than searching through all of physical storage for it. z/OS then transfers the page into real storage or out to auxiliary storage as needed. This movement of pages between auxiliary storage slots and real storage frames is called *paging.* Paging is key to understanding the use of virtual storage in z/OS.

z/OS paging is transparent to the user. During job execution, only those pieces of the application that are required are brought in, or *paged in*, to real storage. The pages remain in real storage until no longer needed, or another page is required by the same application or a higher priority application, and no empty real storage is available.

To select pages for paging out to auxiliary storage, z/OS follows a "Least Frequently Used" algorithm. That is, z/OS assumes that a page that has not been used for some time will not be used in the near future.

2.4.2 What is a virtual storage address?

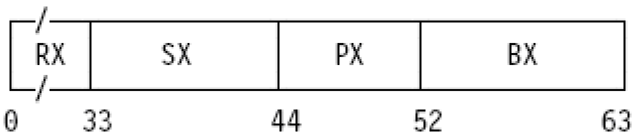
Think of virtual storage as an illusion created by the architecture, in that the system seems to have more memory than it really has. Each user or program gets an address space, and each address space contains the same range of storage addresses. Only those portions of the address space that are needed at any one point in time are actually loaded into real storage. z/OS keeps the inactive pieces of address spaces in auxiliary storage.

z/OS manages address spaces in units of various sizes, as follows:

Page:	Address spaces are divided into 4-kilobyte units of virtual storage called pages.
Segment:	Address spaces are divided into 1-megabyte units called segments. A segment is a block of sequential virtual addresses spanning megabytes, beginning at a 1-megabyte boundary. A 2-gigabyte address space, for example, consists of 2048 segments.
Region:	Address spaces are divided into 2-8 gigabyte units called regions. A region is a block of sequential virtual addresses spanning 2-8 gigabytes, beginning at a 2-gigabytes boundary. A 2-terabyte address space, for example, consists of 2048 regions.

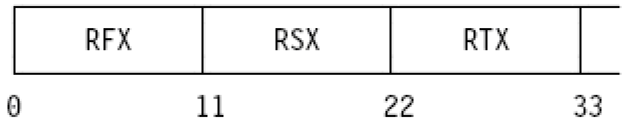
A virtual address, accordingly, is divided into four principal fields. Bits 0-32 are called the region index (RX), bits 33-43 are called the segment index (SX), bits 44-51 are called the page index (PX), and bits 52-63 are called the byte index (BX).

A virtual address has the following format:



As determined by its address-space-control element, a virtual address space can be a 2G-byte space consisting of one region, or it may be up to a 16-exabyte space consisting of up to 8G regions. The RX part of a virtual address applying to a 2G-byte address space must be all zeros; otherwise, an exception is recognized.

The RX part of a virtual address is itself divided into three fields. Bits 0-10 are called the region first index (RFX), bits 11-21 are called the region second index (RSX), and bits 22-32 are called the region third index (RTX). Bits 0-32 of the virtual address have the following format:



A virtual address in which the RTX is the left most significant part (a 42-bit address) is capable of addressing 4T bytes (2K regions), one in which the RSX is the left most significant part (a 53-bit address) is capable of addressing 8P bytes (4M regions), and one in which the RFX is the lifetimes significant part (a 64-bit address) is capable of addressing 16E bytes (8G regions).

2.4.3 What is dynamic address translation?

Dynamic address translation, or *DAT*, is the process of translating a virtual address during a storage reference into the corresponding real address. The virtual address can be a primary virtual address, secondary virtual address, AR-specified virtual address, or home virtual address. If the virtual address is already in real storage, the DAT process is accelerated through the use of a translation lookaside buffer; if the virtual address is not in real storage, a hardware page fault interrupt occurs, z/OS is notified, and z/OS brings the page in from auxiliary storage.

DAT allows a single copy of the program to be loaded into any available real storage location. Otherwise, there would have to be many copies of the program, one for each possible frame in real storage. DAT is implemented by both hardware and software through the use of page tables, segment tables, region tables and translation lookaside buffers.

2.4.4 How does virtual storage work?

Figure 2-2 shows the virtual storage concept at work in z/OS.

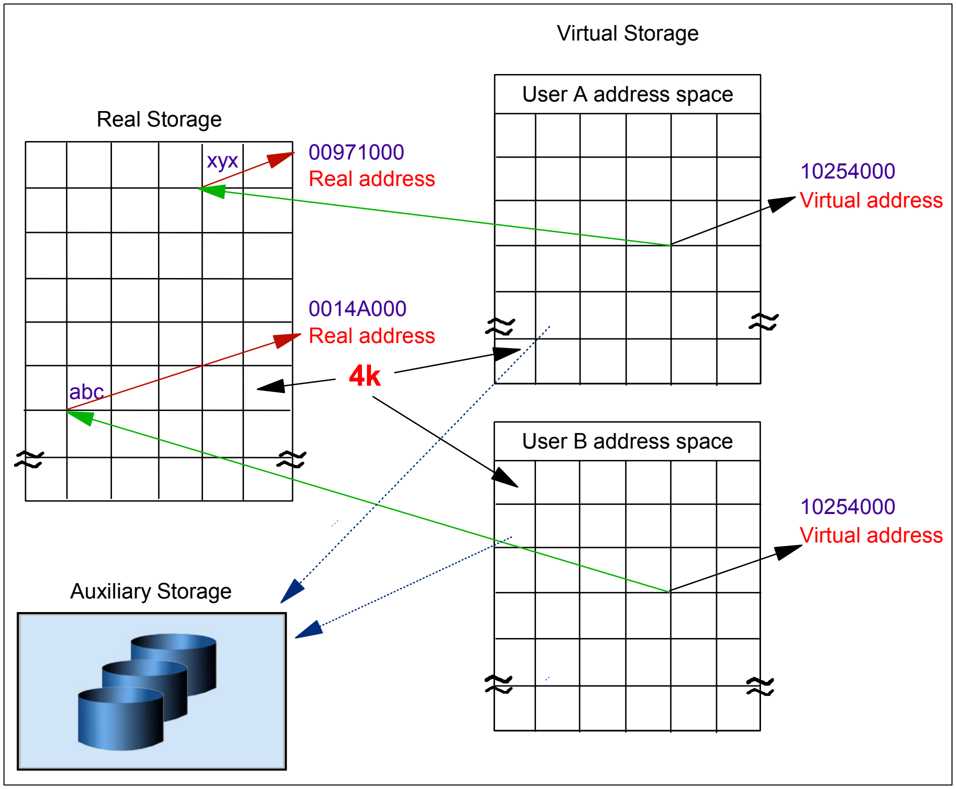


Figure 2-2 Real and auxiliary storage combine to create the illusion of virtual storage

In Figure 2-2, note the following:

- An address is an identifier of a required piece of information, but not a description of where in real storage that piece of information is. This allows the size of an address space (that is, all addresses available to a program) to exceed the amount of real storage available.
- All real storage references are made in terms of virtual storage addresses.
- A hardware mechanism is used to map the virtual storage address to a physical location in real storage. As shown in Figure 2-2, the virtual address 10254000 can exist more than once, because each virtual address maps to a different address in real storage.
- When a requested address is not in real storage, a hardware interruption is signaled to z/OS and the operating system brings the required instructions and data into real storage.

Terms: The terms *real storage*, *real memory*, *central storage*, and *main storage* are used interchangeably. Likewise, *virtual memory* and *virtual storage* are used synonymously.

In summary, the use of virtual storage in z/OS means that only the pieces of a program that are currently active need to be in real storage at processing time. The inactive pieces are held in auxiliary storage.

2.4.5 Frames, pages, and slots

When a program is selected for execution, the system brings it into virtual storage, divides it into pages of 4 kilobytes (4K), transfers the pages into real storage for execution, and transfers pages that are not needed out to auxiliary storage.

To the programmer, the entire program appears to occupy contiguous space in real storage at all times. Actually, not all pages of a program are necessarily in real storage, and the pages that *are* in real storage do not necessarily occupy contiguous space.

The pieces of a program executing in virtual storage must be moved between real and auxiliary storage. To allow this, z/OS manages storage in units, or *blocks*, of 4 kilobytes. The following blocks are defined:

- A block of real storage is a *frame*.
- A block of virtual storage is a *page*.
- A block of auxiliary storage is a *slot*.

A page, a frame, and a slot are all the same size: 4096 bytes (4 kilobytes). An active virtual storage page resides in a real storage frame. A virtual storage page that becomes inactive resides in an auxiliary storage slot (in a paging data set). Figure 2-3 shows the relationship of pages, frames, and slots in the system.

In Figure 2-3, z/OS is performing paging for a program running in virtual storage. The lettered boxes represent parts of the program. In this simplified view, program parts A, E, F, and H are active and running in real storage frames, while parts B, C, D, and G are inactive and have been moved to auxiliary storage slots. All of the program parts, however, reside in virtual storage and have virtual storage addresses.

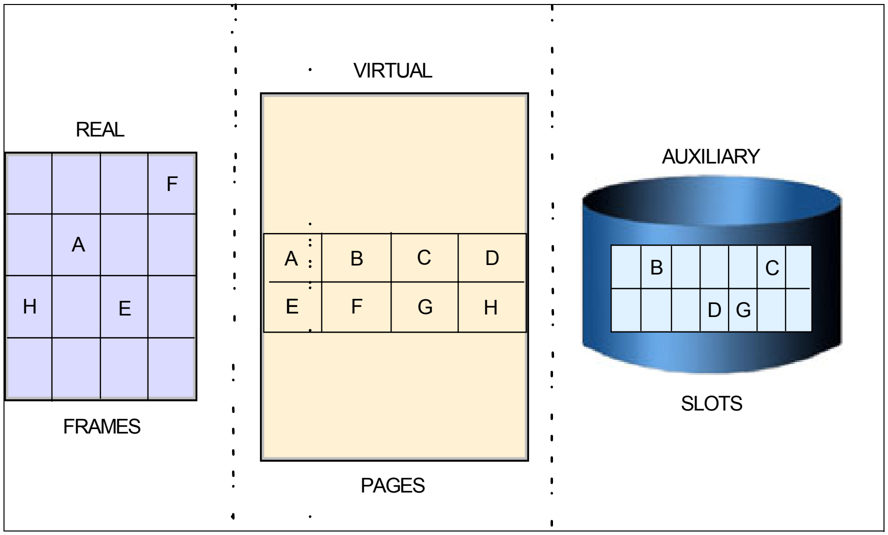


Figure 2-3 Frames, pages, and slots

2.4.6 Page stealing

z/OS tries to keep an adequate supply of available real storage frames on hand. When a program refers to a page that is not in real storage, z/OS uses a real storage page frame from a supply of available frames.

When this supply becomes low, z/OS uses *page stealing* to replenish it, that is, it takes a frame assigned to an active user and makes it available for other work. The decision to steal a particular page is based on the activity history of each page currently residing in a real storage frame. Pages that have not been accessed for a relatively long time are good candidates for page stealing.

z/OS uses a sophisticated paging algorithm to efficiently manage virtual storage based on which pages were most recently used. z/OS also uses various storage managers to keep track of all pages, frames, and slots in the system.

2.4.7 Swapping

Swapping is the process of transferring all of the most recently valid pages of an address space between real storage and auxiliary storage. This has the effect of moving an entire address space into, or out of, real storage. It is one of several methods that z/OS uses to balance the system workload and ensure that an adequate supply of available real storage frames is maintained.

A swapped-in address space is active, having pages in real storage frames and pages in auxiliary storage slots. A swapped-out address space is inactive; the address space resides on auxiliary storage and cannot execute until it is swapped in. Swapping is performed in response to recommendations from the z/OS Workload Manager (WLM) component. WLM is described in 5.8, “What is Workload Manager?” on page 5-16.

2.4.8 A brief history of virtual storage and 64-bit addressability

In 1970, IBM introduced System/370, the first of its architectures to use virtual storage and address spaces. Since that time, the operating system has changed in many ways. One key area of growth and change is addressability.

System/370 defined storage addresses as 24 bits in length, which meant that the highest accessible address was 16,777,216 bytes (or 2^{24} bytes). The use of 24-bit addressability allowed MVS/370, the operating system at that time, to allot to each user an address space of 16 MB.

Over the years, as MVS/370 gained more functions and was asked to handle more complex applications, even access to 16 MB of virtual storage fell short of user needs.

With the release of the System/370-XA architecture in 1983, IBM extended the addressability of the architecture to 31 bits. With 31-bit addressing, the operating system (now called MVS Extended Architecture or MVS/XA™) increased the addressability of virtual storage from 16 MB to 2 gigabytes (2 GB). In other words, MVS/XA provided an address space for users that was 128 times larger than the address space provided by MVS/370. The 16 MB address became the dividing point between the two architectures and is commonly called the *line* (see Figure 2-4).

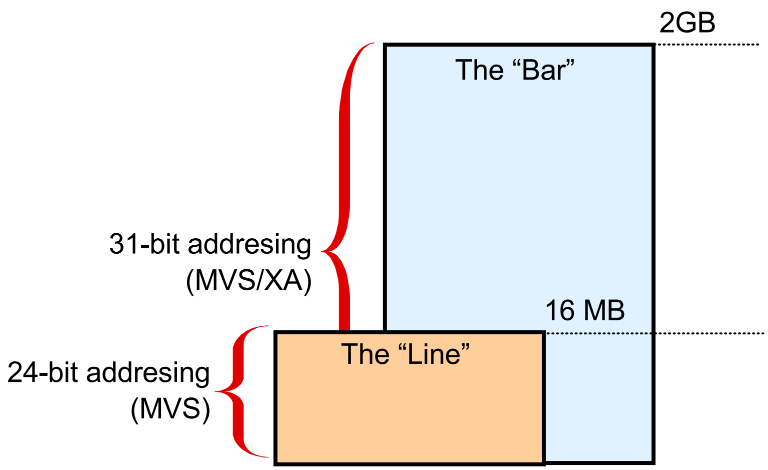


Figure 2-4 31-bit addressability allows for 2 gigabyte address spaces in MVS/XA

The new architecture did not require customers to change existing application programs. To maintain compatibility for existing programs, MVS/XA remained compatible for programs originally designed to run with 24-bit addressing on MVS/370, while allowing application developers to write new programs to exploit the 31-bit technology.

To preserve compatibility between the different addressing schemes, MVS/XA did not use the *high-order bit* of the address (Bit 32) for addressing. Instead, MVS/XA reserved this bit to indicate how many bits would be used to resolve an address: 31-bit addressing (Bit 32 on) or 24-bit addressing (Bit 32 off).

With the release of zSeries mainframes in 2000, IBM further extended the addressability of the architecture to 64 bits. With 64-bit addressing, the potential size of a z/OS address space expands to a size so vast that we need new terms to describe it. Each address space, called a 64-bit address space, is 16 exabytes (EB) in size; an exabyte is slightly more than one billion gigabytes. The new address space has logically 2^{64} addresses. It is 8 billion times the size of the former 2 GB address space. The number is 16 with 18 zeros after it: 16,000,000,000,000,000,000 bytes, or 16 EB (see Figure 2-5).

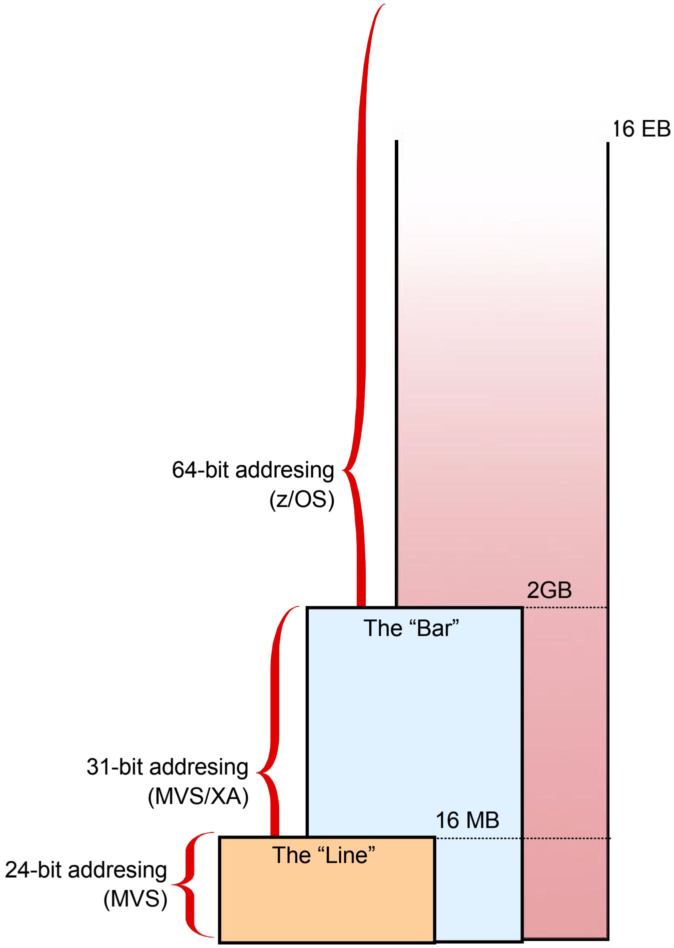


Figure 2-5 64-bit addressability allows for 16 exabytes of addressable storage

We say that the potential size is 16 exabytes because z/OS, by default, continues to create address spaces with a size of 2 GB. The address space exceeds this limit only if a program running in it allocates virtual storage above the 2 GB address. If so, the z/OS operating system increases the storage available to the user from 2 GB to 16 EB.

Programs running on z/OS and zSeries mainframes can run with 24-, 31-, or 64-bit addressing (and can switch among these if needed). Programs can use a mixture of instructions with 64-bit operands or 32-bit operands or other operands.

For compatibility, the layout of the storage areas for an address space is the same below 2 GB, providing an environment that can support both 24-bit and 31-bit addressing. The area that separates the virtual storage area below the 2 GB address from the user private area is called *the bar*, as shown in Figure 2-6. The user private area is allocated for application code rather than operating system code.

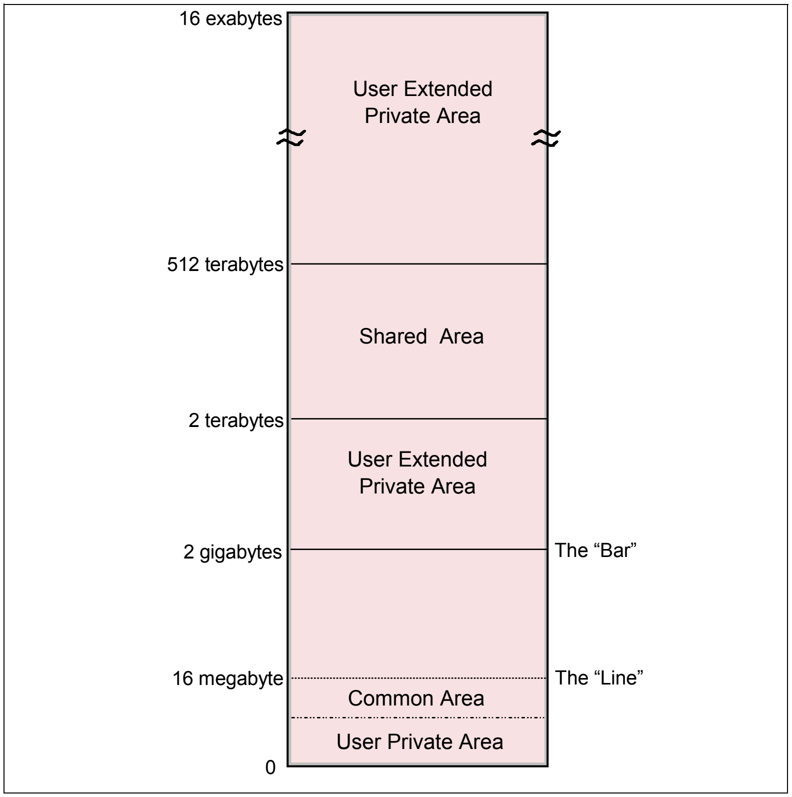


Figure 2-6 Storage map for a 64-bit address space

0 to 2^{31}	The layout is the same; see Figure 2-6.
2^{31} to 2^{32}	From 2 GB to 4 GB is considered the *bar*. Below the bar can be addressed with a 31-bit address. Above the bar requires a 64-bit address.
2^{32} - 2^{41}	The low non-shared area (user private area) starts at 4 GB and extends to 2^{41}.
2^{41} - 2^{50}	Shared area (for storage sharing) starts at 2^{41} and extends to 2^{50} or higher, if requested.
2^{50} - 2^{64}	High non-shared area (user private area) starts at 2^{50} or wherever the shared area ends and goes to 2^{64}.

In a 16-EB address space with 64-bit virtual storage addressing, there are three additional levels of translation tables, called region tables. They are called region third table (R3T), region second table (R2T), and region first table (R1T). The region tables are 16 KB in length, and there are 2048 entries per table. Each region has 2 GB.

Segment tables and page table formats remain the same as for virtual addresses below the bar. When translating a 64-bit virtual address, once the system has identified the corresponding 2 GB region entry that points to the Segment table, the process is the same as that described previously.

2.4.9 What's in an address space?

Another way of thinking of an address space is as a programmer's map of the virtual storage available for code and data. An address space provides each programmer with access to all of the addresses available through the computer architecture.

z/OS provides each user with a unique address space and maintains the distinction between the programs and data belonging to each address space. Because it maps all of the available addresses, however, an address space includes system code and data as well as user code and data. Thus, not all of the mapped addresses are available for user code and data.

Understanding the division of storage areas in an address space is made easier with a diagram. The diagram shown in Figure 2-7 on page 2-20 is more detailed than needed for this part of the course, but is included here to show that an address space maintains the distinction between programs and data belonging to the user, and those belonging to the operating system.

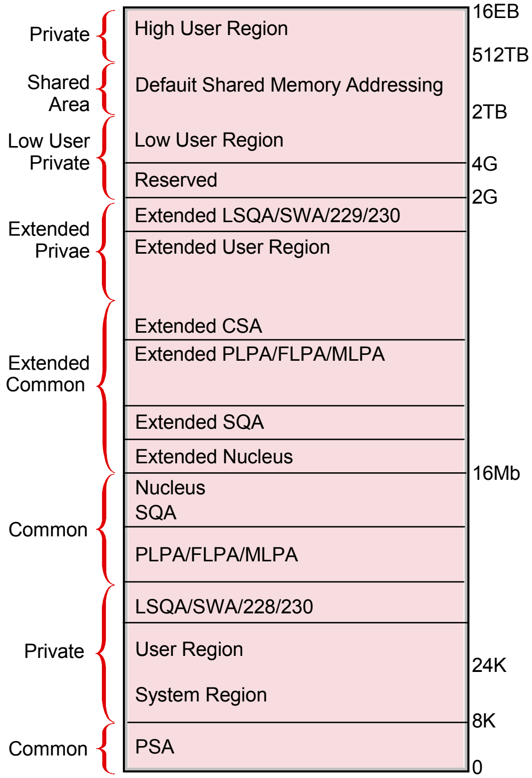


Figure 2-7 Storage areas in an address space

Given the vast range of addressable storage in an address space, the drawing in Figure 2-7 is not to scale.

2.4.10 z/OS system address spaces

Many z/OS system functions run in their own address spaces. When you start z/OS, for example, master scheduler initialization routines initialize system services such as the system log and communications task, and start the master scheduler address space (*MASTER*). Each address space created has a number associated with it, called the address space ID (or ASID).

Because the master scheduler is the first address space created in the system, it becomes address space number one (ASID=1). Other system address spaces are then started during the initialization process of z/OS.

At this point, you need only understand that z/OS and its related subsystems require address spaces of their own to provide a functioning operating system. A short description of each type of address space follows:

- System

  z/OS system address spaces are started after initialization of the master scheduler. These address spaces perform functions for all the other types of address spaces that start in z/OS.

- Subsystem

  z/OS requires the use of various subsystems, such as a primary job entry subsystem or *JES (*described in Chapter 5, “Batch processing and JES”). Also, there are address spaces for middleware products such as DB2, CICS, and IMS.

- TSO/E logon

  TSO/E address spaces are created for every user who logs on to z/OS (described in Chapter 3, “TSO/E, ISPF, and UNIX: Interactive facilities of z/OS”).

- Batch job

  An address space is created for every batch job that runs on z/OS. Batch job address spaces are started by JES, as described in Chapter 5, “Batch processing and JES” .

2.5 How peripheral storage is managed in z/OS

In an operating system, management of peripheral storage devices involves file allocation, placement, monitoring, migration, backup, recall, recovery, and deletion. These activities can be done either manually or through the use of automated processes. When storage management is automated, the system determines object placement, and automatically manages object backup, movement, space, and security. A typical z/OS production system includes both manual and automated processes for managing storage.

Depending on how a z/OS system and its storage devices are configured, a user or program can directly control many aspects of storage use, and in the early days of the operating system, users were required to do so. Increasingly, however, z/OS installations rely on installation-specific settings for data and resource management, and add-on storage management products to automate the use of storage. The primary means of managing storage in z/OS is through the DFSMS component, which is discussed in 4.3, “How is data managed?” on page 4-2.

2.6 Summary of z/OS facilities

An extensive set of system facilities and unique attributes makes z/OS well suited for processing large, complex workloads—those that require many I/O operations, access to large amounts of data, and comprehensive security. Typical mainframe workloads include long-running applications that write updates to millions of records in a database, and online applications that can serve many thousands of users concurrently.

Figure 2-8 provides a "snapshot" view of the z/OS operating environment.

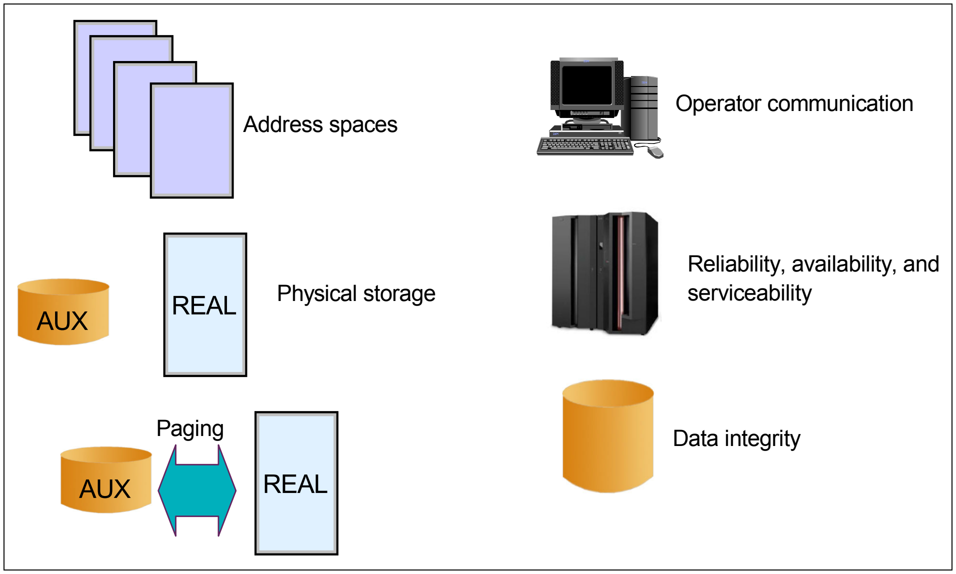


Figure 2-8 What's in an operating system?

These facilities are explored in greater depth in the remaining portions of this text, but are summarized as follows:

- An address space describes the virtual storage addressing range available to an online user or a running program.
- Two types of physical storage are available: real storage and auxiliary storage (AUX). Real storage is also referred to as real memory or central storage.
- z/OS moves programs and data between real storage and auxiliary storage through a process called paging.
- z/OS dispatches work for execution. That is, it selects programs to be run based on priority and ability to execute and then loads the program and data into real storage. All program instructions and data must be in real storage when executing.
- An extensive set of facilities manages files stored on direct access storage device (DASD) or tape cartridges.

- Operators use consoles to start and stop z/OS, enter commands, and manage the operating system.
- z/OS provides operational facilities such as security, recovery, data integrity and workload management.

2.7 Defining characteristics of z/OS

The defining characteristics of z/OS are summarized as follows:

- The use of address spaces in z/OS holds many advantages: Isolation of private areas in different address spaces provides for system security, yet each address space also provides a common area that is accessible to every address space.
- The system is designed to preserve *data integrity*, regardless of how large the user population might be. z/OS prevents users from accessing or changing any objects on the system, including user data, except by the system-provided interfaces that enforce authority rules.
- The system is designed to manage a large number of concurrent batch jobs, with no need for the customer to externally manage workload balancing or integrity problems that might otherwise occur due to simultaneous and conflicting use of a given set of data.
- The security design extends to system functions as well as simple files. Security can be incorporated into applications, resources, and user profiles.
- The system allows multiple communications subsystems at the same time, permitting unusual flexibility in running disparate communications-oriented applications (with mixtures of test, production, and fall-back versions of each) at the same time. For example, multiple TCP/IP stacks can be operational at the same time, each with different IP addresses and serving different applications.
- The system provides extensive software recovery levels, making unplanned system restarts very rare in a production environment. System interfaces allow application programs to provide their own layers of recovery. These interfaces are seldom used by simple applications—they are normally used by more sophisticated applications.
- The system is designed to routinely manage very disparate workloads, with automatic balancing of resources to meet production requirements established by the system administrator.
- The system is designed to routinely manage large I/O configurations that might extend to thousands of disk drives, multiple automated tape libraries, many large printers, large networks of terminals, and so forth.
- The system is controlled from one or more operator terminals, or from application programming interfaces (APIs) that allow automation of routine operator functions.

- The operator interface is a critical function of z/OS. It provides status information, messages for exception situations, control of job flow, hardware device control, and allows the operator to manage unusual recovery situations.

2.8 Program products for z/OS

A z/OS system usually contains additional program products (priced products) that are needed to create a practical working system, such as a security manager product and a database manager product. When talking about z/OS, people often assume the inclusion of these program products. This is normally apparent from the context of a discussion, but it might sometimes be necessary to ask whether a particular function is part of "the base z/OS" or is an add-on product.

We won't attempt to list all of the z/OS program products in this text (hundreds exist); some common choices include:

- A security system

  z/OS provides a framework for customers to add security through the addition of a security management product (IBM's program product is *Resource Access Control Facility or RACF*®). Non-IBM security system program products are also available.

- Compilers

  z/OS includes an assembler and a C compiler. Other compilers, such as the COBOL compiler, are offered as separate products.

- A relational database, such as DB2

  Other types of database products, such as hierarchical databases, are also available.

- Transaction processing facilities

  IBM offers several, including:

  – Customer Information Control System (CICS)
  – Information Management System (IMS)
  – WebSphere Application Server (WAS)

- A sort program

  Fast, efficient sorting of large amounts of data is highly desirable in batch processing. IBM and other vendors offer sophisticated sorting products.

- A large variety of utility programs

  For example, the System Display and Search Facility (SDSF) program that we use extensively in this course to view output from batch jobs is a program product. Not every installation purchases SDSF; alternative products available.

- A large number of other products are available from various i*ndependent software vendors* (commonly called ISVs in the industry).

2.9 Middleware for z/OS

Middleware is typically something between the operating system and an end user or end-user applications. It supplies major functions not provided by the operating system. As commonly used, the term usually applies to major software products such as database managers, transaction monitors, Web servers, and so forth. *Subsystem* is another term often used for this type of software. These are usually program products, although there are notable exceptions, such as the HTTP Server.

z/OS is a base for using many middleware products and functions. It is commonplace to run a variety of diverse middleware functions, with multiple instances of some. The routine use of wide-ranging workloads (mixtures of batch, transactions, Web serving, database queries and updates, and so on) is characteristic of z/OS.

Typical z/OS middleware includes:

- Database systems
- Web servers
- Message queueing and routing functions
- Transaction managers
- Java virtual machines
- XML processing functions

A middleware product often includes an *application programming interface* (API). In some cases, applications are written to run completely under the control of this middleware API, while in other cases it is used only for unique purposes. Some examples of mainframe middleware APIs include:

- The WebSphere suite of products, which provides a complete API that is portable across multiple operating systems. Among these, WebSphere MQ provides cross-platform APIs and inter-platform messaging.
- The DB2 database management product, which provides an API (expressed in the SQL language) that is used with many different languages and applications.

A Web server is considered to be middleware and Web programming (Web pages, CGIs, and so forth) is largely coded to the interfaces and standards presented by the Web server instead of the interfaces presented by the operating system. Java is another example in which applications are written to run under a *Java Virtual Machine* (JVM)[2] and are largely independent of the operating system being used.

[2] A JVM is not related to the virtual machines created by z/VM.

2.10 Interfaces for z/OS application programmers

When operating systems are developed to meet the needs of the computing marketplace, applications are written to run on those operating systems. Over the years, many applications have been developed that run on z/OS and, more recently, UNIX. To accommodate customers with UNIX applications, z/OS contains a full UNIX operating system in addition to its traditional z/OS interfaces. The z/OS implementation of UNIX interfaces is known collectively as z/OS UNIX System Services, or z/OS UNIX for short.

The most common interface for z/OS developers is through TSO/E and its panel-driven interface, ISPF, using a 3270 terminal. Generally, developers use 3270 terminal emulators running on personal computers, rather than actual 3270 terminals. Emulators can provide developers with auxiliary functions, such as multiple sessions, and uploading and downloading code and data from the PC. TSO/E and other z/OS user interfaces are described in Chapter 3, "TSO/E, ISPF, and UNIX: Interactive facilities of z/OS" .

Program development on z/OS typically involves the use of a line editor to manipulate source code files, the use of batch jobs for compilation, and a variety of mechanisms for testing the code. Interactive debuggers, based on 3270 terminal functions, are available for common languages. This text introduces the tools and utilities for developing a simple program to run on z/OS in Part 2. "Application programming on z/OS."

Development using only the z/OS UNIX portion of z/OS can be through Telnet sessions (from which the vi editor is available) through 3270 and TSO/E using other editors, or through X windows sessions from personal computers running X servers. The X server interfaces are less commonly used.

Alternate methods are available in conjunction with various middleware products. For example, the WebSphere products provide GUI development facilities for personal computers. These facilities integrate TCP/IP links with z/OS to automatically invoke mainframe elements needed during development and testing phases for a new application.

This text discusses the use of online applications and middleware products in Part 3. "Online workloads for z/OS," which includes topics on network communications, database management and Web serving.

2.11 A brief comparison of z/OS and UNIX

What would we find if we compared z/OS and UNIX? In many cases, we'd find that quite a few concepts would be mutually understandable to users of either operating system, despite the differences in terminology.

For experienced UNIX users, Table 2-1 provides a small sampling of familiar computing terms and concepts. As a new user of z/OS, many of the z/OS terms will sound unfamiliar to you. As you work through this course, however, the z/OS meanings will be explained and you will find that many elements of UNIX have analogs in z/OS.

A major difference for UNIX users moving to z/OS is the idea that the user is just one of *many* other users. In moving from a UNIX system to the z/OS environment, users typically ask questions such as *"Can I have the root password because I need to do ....."* or *“Would you change this or that and restart the system?"* It is important for new z/OS users to understand that potentially thousands of other users are active on the same system, and so the scope of user actions and system restarts in z/OS and z/OS UNIX are carefully controlled to avoid negatively effecting other users and applications.

Under z/OS, there does not exist a single root password or root user. User IDs are external to z/OS UNIX System Services. User IDs are maintained in a security database that is shared with both UNIX and non-UNIX functions in the z/OS system, and possibly even shared with other z/OS systems. Typically, some user IDs have root authority, but these remain individual user IDs with individual passwords. Also, some user IDs do not normally have root authority, but can switch to “root” when circumstances require it.

Table 2-1 Mapping UNIX to z/OS terms and concepts

Term or concept	UNIX	z/OS
Start the operating system	Boot the system.	IPL (initial program load) the system.
Virtual storage given to each user of the system	Users get whatever virtual storage they need to reference, within the limits of the hardware and operating system.	Users each get an address space, a range of addresses extending to 2 GB of virtual storage (though some of this storage contains system code that is common for all users).
Data storage	Files	Data sets (sometimes called files)
Data format	Byte orientation; organization of the data is provided by the application.	Record orientation; often an 80-byte record, reflecting the traditional punched card image.
System configuration data	The /etc file system controls characteristics.	Parameters in PARMLIB control how the system IPLs and how address spaces behave.
Scripting languages	Shell scripts, Perl, awk, and other languages	CLISTS (command lists) and REXX execs

Term or concept	UNIX	z/OS
Smallest element that performs work	A thread. The kernel supports multiple threads.	A task or a service request block (SRB). The z/OS base control program (BCP) supports multiple tasks and SRBs.
A long-running unit of work	A daemon	A started task or a long-running job
Order in which the system searches for programs to run	Programs are loaded from the file system according to the user's PATH environmental variable (a list of directories to be searched).	The system searches the following libraries for the program to be loaded: TASKLIB, STEPLIB, JOBLIB, LPALST, and LNKLST.
Using the system interactively	Users *log in* to systems and execute shell sessions in the shell environment. They can issue the **rlogin** or **telnet** commands to connect to the system. Each user can have many login sessions open at once.	Users *log on* to the system through TSO/E and its panel-driven interface, ISPF. A user ID is limited to having only one TSO/E logon session active at a time.
Editing data or code	Many editors exist, such as vi, ed, sed, and emacs.	ISPF editor[a]
Source and destination for input and output data	stdin and stdout	SYSIN and SYSOUT ► SYSUT1 and SYSUT2 are used for utilities. ► SYSTSIN and SYSTSPRT are used for TSO/E users.
Managing programs	The **ps** shell command allows users to view processes and threads, and kill jobs with the **kill** command.	SDSF allows users to view and terminate their jobs.

a. There is also a TSO editor, though it is rarely used. For example, when sending e-mail via TSO, the SENDNOTE exec opens a TSO EDIT session to allow the user to compose the e-mail.

2.12 Summary

An operating system is a collection of programs that manage the internal workings of a computer system. The operating system taught in this course is z/OS, the most widely used mainframe operating system.

The z/OS operating system's use of multiprogramming and multiprocessing, and its ability to access and manage enormous amounts of storage and I/O operations, makes it ideally suited for running mainframe workloads.

The concept of virtual storage is central to z/OS. Virtual storage is an illusion created by the architecture, in that the system seems to have more storage than it really has. Virtual storage is created through the use of tables to map virtual storage pages to pages in real storage or slots in auxiliary storage. Only those portions of a program that are needed are actually loaded into real storage. z/OS keeps the inactive pieces of address spaces in auxiliary storage.

z/OS is structured around address spaces, which are ranges of addresses in virtual storage. Each user of z/OS gets an address space containing the same range of storage addresses. The use of address spaces in z/OS allows for isolation of private areas in different address spaces for system security, yet also allows for inter-address space sharing of programs and data through a common area accessible to every address space.

In common usage, the terms real storage, real memory, central storage, and real storage are used as synonyms and are used interchangeably. Likewise, virtual memory and virtual storage are used interchangeably.

The amount of real storage needed to support the virtual storage in an address space depends on the working set of the application being used, and this varies over time. A user does not automatically have access to all the virtual storage in the address space. Requests to use a range of virtual storage are checked for size limitations and then necessary paging table entries are constructed to create the requested virtual storage.

Programs running on z/OS and zSeries mainframes can run with 24-, 31-, or 64-bit addressing (and can switch among these if needed). Programs can use a mixture of instructions with 24-bit, 64-bit, or 32-bit operands, and can switch among these if needed.

Mainframe operating systems seldom provide complete operational environments. They depend on program products for middleware and other functions. Many vendors, including IBM, provide middleware and various utility products.

Middleware is a relatively recent term that can embody several concepts at the same time. A common characteristic of middleware is that it provides a programming interface, and applications are written (or partially written) to this interface.

Key terms in this chapter			
address space	addressability	auxiliary storage	dynamic address translation (DAT)
frame	input/output (I/O)	middleware	multiprocessing
multiprogramming	page / paging	program product	real storage
slot	UNIX	virtual storage	z/OS

2.13 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. How does z/OS differ from a single-user operating system? Give two examples.
2. z/OS is designed to take advantage of what mainframe architecture? In what year was it introduced?
3. List the three major types of storage used by z/OS.
4. What is "virtual" about virtual storage?
5. How does z/OS use virtual storage to support very large workloads and many thousands of users simultaneously?
6. Match the following terms:

a. Page	__ Auxiliary storage
b. Frame	__ Virtual storage
c. Slot	__ Real storage

7. List several defining characteristics of the z/OS operating system.
8. List three types of software products that might be added to z/OS to provide a complete system.
9. List several differences and similarities between z/OS and UNIX operating systems.
10. Which of the following is/are not considered to be middleware in a z/OS system?
    a. Web servers
    b. Transaction managers
    c. Database managers
    d. Processor storage
    e. DASD devices

2.14 Topics for further discussion

Further exploration of z/OS concepts could include the following areas of discussion:

1. z/OS offers 64-bit addressing. Suppose you want to use this capability to work with a large virtual storage area. You would use the proper programming interface to obtain, say, a 30 GB area of virtual storage and you might write a loop to initialize this area for your application. What are some of the probable side effects of these actions? When is this design practical? What external circumstances need to be considered? What would be different on another platform, such as UNIX?
2. Why might moving programs and data blocks from below the line to above the line be complicated for application owners? How might this be done without breaking compatibility with existing applications?
3. An application program can be written to run in 24-, 31-, or 64-bit addressing mode. How does the programmer select this? In a high-level language? In assembler language? You have started using ISPF. What addressing mode is it using?
4. Will more real storage allow a system to run faster? What measurements indicate that more real storage is needed? When is no more real storage needed? What might change this situation?
5. If the current z/OS runs only in zArchitecture mode, why do we mention 24-, 31-, and 64-bit operation? Why mention 32-bit operands?
6. Why bother with allocation for virtual storage? Why not build all the necessary paging tables for all of virtual storage when an address space is first created?
7. Why are program products needed? Why not simply include all of the software with the operating system?

3

TSO/E, ISPF, and UNIX: Interactive facilities of z/OS

Objective: In working with the z/OS operating system, you will need to know its end-user interfaces. Chief among these is TSO and its menu-driven interface, ISPF. These programs allow you to log on to the system, run programs, and manipulate data files. Also, you will need to know the interactive facilities of the z/OS implementation of UNIX interfaces, known collectively as z/OS UNIX System Services, or z/OS UNIX for short.

After completing this chapter, you will be able to:

- Log on to z/OS
- Run programs from the TSO READY prompt
- Navigate through the menu options of ISPF
- Use the ISPF editor to make changes to a file
- Use the UNIX interfaces provided on z/OS, including the z/OS UNIX command shell.

3.1 How do we interact with z/OS?

z/OS provides a number of facilities to allow users to interact directly with the operating system. This chapter provides an overview of each facility, as follows:

- "TSO overview" on page 3-2 shows how to logon to z/OS and describes the use of a limited set of basic TSO commands available as part of the core operating system. Interacting with z/OS in this way is called using TSO in its *native mode.*
- "ISPF overview" on page 3-6 introduces the ISPF menu system, which is what many people use exclusively to perform work on z/OS. ISPF menus list the functions that are most frequently needed by online users.
- "z/OS UNIX interactive interfaces" on page 3-24 explores the z/OS UNIX shell and utilities. This facility allows users to write and invoke shell scripts and utilities, and use the shell programming language.

Hands-on exercises are provided throughout the chapter to help students develop their understanding of these important facilities.

3.2 TSO overview

Time Sharing Option/Extensions (TSO/E) allows users to create an interactive session with the z/OS system. TSO[1] provides a single-user logon capability and a basic command prompt interface to z/OS.

Most users work with TSO through its menu-driven interface, *Interactive System Productivity Facility* (ISPF). This collection of menus and panels offers a wide range of functions to assist users in working with data files on the system. ISPF users include system programmers, application programmers, administrators, and others who access z/OS. In general, TSO and ISPF make it easier for people with varying levels of experience to interact with the z/OS system.

In a z/OS system, each user is granted a user ID and a password authorized for TSO logon. Logging on to TSO requires a 3270 display device or, more commonly, a TN3270 emulator running on a PC.

During TSO logon, the system displays the TSO logon screen on the user's 3270 display device or TN3270 emulator. The logon screen serves the same purpose as a Windows logon panel.

z/OS system programmers often modify the particular text layout and information of the TSO logon panel to better suit the needs of the system's users. Therefore, the screen

[1] Most z/OS users refer to TSO/E as simply "TSO," and that is how it is called in this textbook. Also, the word "user" is synonymous with "end user."

captures shown in this book will likely differ from what you might see on a real-life production system.

Figure 3-1 shows a typical example of a TSO logon screen.

```
------------------------------- TSO/E LOGON -----------------------------------


   Enter LOGON parameters below:                  RACF LOGON parameters:

   Userid    ===> ZPROF

   Password  ===>                                 New Password ===>

   Procedure ===> IKJACCNT                        Group Ident  ===>

   Acct Nmbr ===> ACCNT#

   Size      ===> 860000

   Perform   ===>

   Command   ===>

   Enter an 'S' before each option desired below:
           -Nomail         -Nonotice        -Reconnect        -OIDcard

PF1/PF13 ==> Help    PF3/PF15 ==> Logoff    PA1 ==> Attention    PA2 ==> Reshow
You may request specific help information by entering a '?' in any entry field
```

Figure 3-1 Typical TSO/E logon screen

Many of the screen capture examples used in this textbook show program function (PF) key settings. Because it is common practice for z/OS sites to customize the PF key assignments to suit their needs, the key assignments shown in this textbook might not match the PF key settings in use at your site.

A list of the PF key assignments used in this textbook is provided in 3.3.1, “Keyboard mapping used in this course” on page 3-12.

3.2.1 Using TSO commands in native mode

Most z/OS sites prefer to have the TSO user session automatically switch to the ISPF interface after TSO logon. This section, however, briefly discusses the limited set of basic TSO commands available independent of other complimentary programs, such as ISPF. Using TSO in this way is called using TSO in its *native mode.*

When a user logs on to TSO, the z/OS system responds by displaying the READY prompt, and waits for input, such as in Figure 3-2.

```
ICH70001I ZPROF  LAST ACCESS AT 17:12:12 ON THURSDAY, OCTOBER 7, 2004
ZPROF LOGON IN PROGRESS AT 17:12:45 ON OCTOBER 7, 2004
You have no messages or data sets to receive.
READY
```

Figure 3-2 TSO logon READY prompt

The READY prompt accepts simple line commands such as HELP, RENAME, ALLOCATE, and CALL. Figure 3-3 shows an example of an ALLOCATE command that creates a data set on disk.

```
READY
 alloc dataset(zschol.test.cntl) volume(test01) unit(3390) tracks space(2,1)
recfm(f) lrecl(80) dsorg(ps)
READY
listds
 ENTER DATA SET NAME -
zschol.test.cntl
 ZSCHOL.TEST.CNTL
  --RECFM-LRECL-BLKSIZE-DSORG
    F     80    80      PS
 --VOLUMES--
   TEST01
 READY
```

Figure 3-3 Allocating a data set from the TSO command line

Native TSO is similar to the interface offered by the native DOS prompt. TSO also includes a very basic line mode editor, in contrast to the full screen editor offered by ISPF.

Figure 3-4 is another example of the line commands a user might enter at the READY prompt. Here, the user is entering commands to sort data.

```
 READY
ALLOCATE DATASET(AREA.CODES) FILE(SORTIN)    SHR
 READY
ALLOCATE DATASET(*)          FILE(SORTOUT)   SHR
 READY
ALLOCATE DATASET(*)          FILE(SYSOUT)    SHR
 READY
ALLOCATE DATASET(*)          FILE(SYSPRINT)  SHR
 READY
ALLOCATE DATASET(SORT.CNTL)  FILE(SYSIN)     SHR
 READY
CALL 'SYS1.SICELINK(SORT)'

 ICE143I 0 BLOCKSET     SORT  TECHNIQUE SELECTED
 ICE000I 1 - CONTROL STATEMENTS FOR Z/OS DFSORT V1R6
            SORT FIELDS=(1,3,CH,A)
 201  NJ
 202  DC
 203  CT
 204  Manitoba
 205  AL
 206  WA
 207  ME
 208  ID
 ***
```

Figure 3-4 Using native TSO commands to sort data

In this example, the user entered several TSO ALLOCATE commands to assign inputs and outputs to the workstation for the sort program. The user then entered a single CALL command to run the sort program. This sort from ICE is an optional software product.

Each ALLOCATE command requires content (specified with the DATASET operand) associated with the following:

- SORTIN - in this case AREA.CODES
- SORTOUT - in this case *, which means the terminal screen
- SYSOUT
- SYSPRINT
- SYSIN

Following the input and output allocations and the user-entered CALL command, the sort program displays the results on the user's screen. As shown in Figure 3-4, the sort fields control statement causes the results to be sorted by area code. For example, NJ (New Jersey) has the lowest number telephone area code, 201.

Native TSO screen control is very basic. For example, when a screen fills up with data, three asterisks (***) are displayed to indicate a full screen. Here, you must press the Enter key to clear the screen of data and allow the screen to display the remainder of the data.

3.2.2 Using CLISTs and REXX under TSO

With native TSO, it is possible to place a list of commands, called *a command list* or *CLIST* (pronounced “see list”) in a file, and execute the list as if it were one command. When you invoke a CLIST, it issues the TSO/E commands in sequence. CLISTs are used for performing routine tasks; they enable users to work more efficiently with TSO.

For example, suppose that the commands shown in Example 3-4 on page 3-5 were grouped in a file called AREA.CODES. The user could then achieve the same results by using just a single command to execute the CLIST, as follows:

```
EXECUTE ‘CLIST AREA.CODES’
```

TSO users create CLISTs with the CLIST command language. Another command language used with TSO is called *Restructured Extended Executor* or *REXX*. Both CLIST and REXX offer shell script-type processing. These are *interpretive* languages, as opposed to *compiled* languages (although REXX can be compiled as well). This textbook discusses CLIST and REXX in more detail in Chapter 8, “Using programming languages on z/OS” .

Some TSO users write functions directly as CLISTs or REXX programs, but these are more commonly implemented as ISPF functions, or by various software products. CLIST programming is unique to z/OS, while the REXX language is used on many platforms.

3.3 ISPF overview

After logging on to TSO, users typically access the ISPF menu. In fact, many use ISPF exclusively for performing work on z/OS. ISPF handles all of the necessary file allocations, program calls, and execution of interpretive routines. ISPF menus list the functions that are most frequently needed by online users.

Figure 3-5 shows the allocate procedure to create a data set using ISPF.

```
 Menu  RefList  Utilities  Help
 ---------------------------------------------------------------------------
Allocate New Data Set
 Command ===>
Data Set Name  . . . : ZCHOL.TEST.CNTL
Management class . . .                (Blank for default management class)
 Storage class  . . . .                (Blank for default storage class)
  Volume serial . . . . TEST01         (Blank for system default volume) **
  Device type . . . . .                (Generic unit or device address) **
 Data class . . . . . .                (Blank for default data class)
  Space units . . . . . TRACK          (BLKS, TRKS, CYLS, KB, MB, BYTES
                                        or RECORDS)
  Average record unit                  (M, K, or U)
  Primary quantity  . . 2              (In above units)
  Secondary quantity    1              (In above units)
  Directory blocks  . . 0              (Zero for sequential data set) *
  Record format . . . . F
  Record length . . . . 80
  Block size  . . . . .
  Data set name type  :                (LIBRARY, HFS, PDS, or blank)  *
                                       (YY/MM/DD, YYYY/MM/DD
  Expiration date . . .                 YY.DDD, YYYY.DDD in Julian form
 Enter "/" to select option             DDDD for retention period in days
    Allocate Multiple Volumes           or blank)

 ( * Specifying LIBRARY may override zero directory block)

 ( ** Only one of these fields may be specified)
  F1=Help F2=Split F3=Exit F7=Backward F8=Forward F9=Swap F10=Actions  F12=Cancel
```

Figure 3-5   Allocating a data set using ISPF panels

Figure 3-6 shows the results of allocating a data set using ISPF panels.

```
Data Set Information
Command ===>

Data Set Name  . . . : ZCHOL.TEST.CNTL

General Data                          Current Allocation
 Volume serial . . . : TEST01          Allocated tracks  . : 2
 Device type . . . . : 3390            Allocated extents . : 1
 Organization  . . . : PS
 Record format . . . : F
 Record length . . . : 80
 Block size  . . . . : 80             Current Utilization
 1st extent tracks . : 2               Used tracks . . . . : 0
 Secondary tracks  . : 1               Used extents  . . . : 0

 Creation date . . . : 2005/01/31
 Referenced date . . : 2005/01/31
 Expiration date . . : ***None***

 F1=Help F2=Split F3=Exit F7=Backward  F8=Forward   F9=Swap F12=Cancel
```

Figure 3-6   Result of data set allocation using ISPF

Figure 3-7 shows the ISPF menu structure.

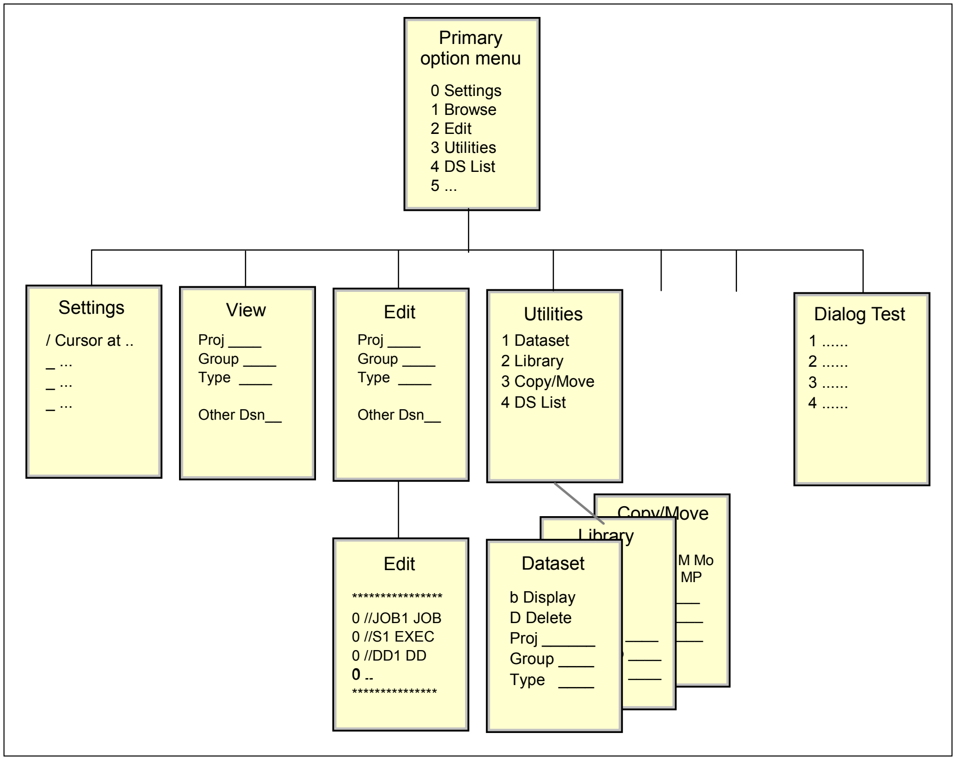


Figure 3-7 ISPF menu structure

To access ISPF under TSO, the user enters a command such as **ISPPDF** from the READY prompt to display the ISPF Primary Option Menu.

Figure 3-8 shows an example of the ISPF Primary Menu.

```
Menu  Utilities  Compilers  Options  Status  Help
------------------------------------------------------------------------------
                           ISPF Primary Option Menu
Option ===>

0  Settings      Terminal and user parameters          User ID . : ZPROF
1  View          Display source data or listings       Time. . . : 17:29
2  Edit          Create or change source data          Terminal. : 3278
3  Utilities     Perform utility functions             Screen. . : 1
4  Foreground    Interactive language processing       Language. : ENGLISH
5  Batch         Submit job for language processing    Appl ID . : PDF
6  Command       Enter TSO or Workstation commands     TSO logon : IKJACCT
7  Dialog Test   Perform dialog testing                TSO prefix: ZPROF
8  LM Facility   Library administrator functions       System ID : SC04
9  IBM Products  IBM program development products      MVS acct. : ACCNT#
10 SCLM          SW Configuration Library Manager      Release . : ISPF 5.2
11 Workplace     ISPF Object/Action Workplace
M  More          Additional IBM Products

Enter X to Terminate using log/list defaults

 F1=Help F2=Split F3=Exit F7=Backward F8=Forward F9=Swap F10=Actions  F12=Cancel
```

Figure 3-8 ISPF Primary Option Menu

The ISPF panel can be customized with additional options by the local system programmer. Therefore, it can vary in features and content from site to site.

To reach the ISPF menu selections shown in Figure 3-9, you enter `M` on the option line.

```
   Menu  Help
 ------------------------------------------------------------------------------
                           IBM Products Panel
                                                                  More:     +
 1  SMP/E       System Modification Program/Extended
 2  ISMF        Integrated Storage Management Facility
 3  RACF        Resource Access Control Facility
 4  HCD         Hardware Configuration Dialogs
 5  SDSF        Spool Search and Display Facility
 6  IPCS        Interactive Problem Control System
 7  DITTO       DITTO/ESA for MVS Version 1
 8  RMF         Resource Measurement Facility
 9  DFSORT      Data Facility Sort
 10 OMVS        MVS OpenEdition
 11 DB2         Data Base Products
 12 RRS         Resource Recovery Services
 13 DB2ADM      Data Base Admin Tool
 14 QMF         Query Management Facility
 15 MQ          WMQ Series Operations and Control
 16 FMN         File Manager 3.1.Operations and Control
 17 WLM         Workload Manager
 18 PE          Performance Expert






 Option ===> 9
  F1=Help      F2=Split     F3=Exit      F7=Backward  F8=Forward   F9=Swap
 F10=Actions  F12=Cancel
```

Figure 3-9   More ISPF options displayed

In Figure 3-9, SORT is offered as ISPF option 9. We will select it now as a useful example of the ISPF panel-driven applications.

Figure 3-10 shows the panel that would be displayed for option 9 of ISPF.

```
DFSORT PRIMARY OPTION MENU
ENTER SELECTION OR COMMAND ===>

SELECT ONE OF THE FOLLOWING:

  0  DFSORT PROFILE              - Change DFSORT user profile
  1  SORT                        - Perform Sort Application
  2  COPY                        - Perform Copy Application
  3  MERGE                       - Perform Merge Application
  X  EXIT                        - Terminate DFSORT

            \-----------------------------------------------------/
            | \-------------------------------------------------/ |
            | |      Licensed Materials - Property of IBM       | |
            | |                                                 | |
            | |  5740-SM1 (C) Copyright IBM Corp. 1988, 1992.   | |
            | |   All rights reserved.  US Government Users     | |
            | |    Restricted Rights - Use, duplication or      | |
            | |   disclosure restricted by GSA ADP Schedule     | |
            | |           Contract with IBM Corp.               | |
            | /-------------------------------------------------\ |
            /-----------------------------------------------------\

USE HELP COMMAND FOR HELP; USE END COMMAND TO EXIT.

 F1=HELP     F2=SPLIT    F3=END      F4=RETURN   F5=RFIND    F6=RCHANGE
 F7=UP       F8=DOWN     F9=SWAP    F10=LEFT    F11=RIGHT   F12=CURSOR
```

Figure 3-10 SORT panel

Recall that 3.2.1, "Using TSO commands in native mode" on page 3-3 showed an example of how a TSO user might perform a simple sort operation by entering TSO commands in TSO native mode. Here, the same sort function is available through ISPF as a menu-selectable option. Through the SORT option, the user can allow ISPF to handle the TSO allocations, create the SORT control statement, and call the SORT program to produce the results of the sort.

Notice the keyboard program function key (PF key) selections at the bottom of each panel; using PF3 (END) returns the user to the previous panel.

3.3.1 Keyboard mapping used in this course

Many of the screen capture examples used in this textbook show ISPF program function (PF) key settings at the bottom of the panel. As previously mentioned, because it is common for z/OS users to customize the PF key assignments to suit their needs, the key assignments shown in this textbook might not match the PF key settings in use on your system. Actual function key settings vary from customer to customer.

Table 3-1 lists some of the most frequently used PF keys and other keyboard functions and their corresponding keys.

Table 3-1 Keyboard mapping

Function	Key
Enter	Ctrl (right side)
Exit, end, or return	PF3
Help	PF1
PA1 or Attention	Alt-Ins or Esc
PA2	Alt-Home
Cursor movement	Tab or Enter
Clear	Pause
Page up	PF7
Page down	PF8
Scroll left	PF10
Scroll right	PF11
Reset locked keyboard	Ctrl (left side)

The examples in this textbook use these keyboard settings. For example, directions to press Enter mean that you should press the keyboard's control key (Ctrl) at the lower right. If the keyboard locks up, press the control key at the lower left.

3.3.2 Using PF1-HELP and the ISPF tutorial

From the ISPF Primary Menu, press the PF1 HELP key to display the ISPF tutorial. New users of ISPF should acquaint themselves with the tutorial (Figure 3-11) and with the extensive online help facilities of ISPF.

```
 Tutorial --------------------- Table of Contents -------------------- Tutorial

                  ISPF Program Development Facility Tutorial

 The following topics are presented in sequence, or may be selected by entering
 a selection code in the option field:
      G  General      - General information about ISPF
      0  Settings     - Specify terminal and user parameters
      1  View         - Display source data or output listings
      2  Edit         - Create or change source data
      3  Utilities    - Perform utility functions
      4  Foreground   - Invoke language processors in foreground
      5  Batch        - Submit job for language processing
      6  Command      - Enter TSO command, CLIST, or REXX exec
      7  Dialog Test  - Perform dialog testing
      9  IBM Products - Use additional IBM program development products
      10 SCLM         - Software Configuration and Library Manager
      11 Workplace    - ISPF Object/Action Workplace
      X  Exit         - Terminate ISPF using log and list defaults
      The following topics will be presented only if selected by number:
      A  Appendices   - Dynamic allocation errors and ISPF listing formats
      I  Index        - Alphabetical index of tutorial topics

F1=Help      F2=Split     F3=Exit      F4=Resize    F5=Exhelp    F6=Keyshelp
  F7=PrvTopic  F8=NxtTopic  F9=Swap     F10=PrvPage  F11=NxtPage  F12=Cancel
```

Figure 3-11 ISPF Tutorial Main Menu

You will most likely only use a fraction of content found in the entire ISPF tutorial.

Besides the tutorial, you can access online help from any of the ISPF panels. When you invoke help, you can scroll through information. Press the PF1-HELP key for explanations of common ISPF entry mistakes, and examples of valid entries. ISPF Help also contains help for the various functions found in the primary option menu.

3.3.3 Navigating through ISPF menus

ISPF includes a text editor and browser, and functions for locating and listing data sets and performing other utility functions. This textbook has not yet discussed *data sets*, but you will need at least a working understanding of data sets to begin the lab exercises in this chapter.

For now, think of a data set as a file used on z/OS to store data or executable code. A data set can have a name up to 44 characters in length, such as ZSCHOLAR.TEST.DATA. Data sets are described in more detail in Chapter 4, "Working with data sets" .

A data set name is usually segmented, with one or more periods used to create the separate data set *qualifiers* of 1 to 8 characters. The first data set qualifier is the high level qualifier or HLQ. In this example, the HLQ is the ZSCHOLAR portion of the data set name.

z/OS users typically use the ISPF data set list utility to work with data sets. To access this utility from the ISPF Primary Option Menu, select **Utilities**, then select **Dslist** to display the Utility Selection Panel, which is shown in Figure 3-12.

```
Menu  RefList  RefMode  Utilities  Help
------------------------------------------------------------------------------
                            Data Set List Utility
Option ===> ____________________________________________________________

   blank Display data set list              P Print data set list
       V Display VTOC information          PV Print VTOC information

Enter one or both of the parameters below:
  Dsname Level . . . ZPROF________________________
   Volume serial  . .  ______
Data set list options
   Initial View . . . 1  1. Volume       Enter "/" to select option
                         2. Space        /  Confirm Data Set Delete
                         3. Attrib       /  Confirm Member Delete
                         4. Total        /  Include Additional Qualifiers

When the data set list is displayed, enter either:
  "/" on the data set list command field for the command prompt pop-up,
  an ISPF line command, the name of a TSO command, CLIST, or REXX exec, or
  "=" to execute the previous command.

 F1=Help F2=Split F3=Exit F7=Backward  F8=Forward   F9=Swap F10=Actions  F12=Cancel
```

Figure 3-12 Using the Data Set List utility

In the panel, you can use the Dsname Level data entry field to locate and list data sets. To search for one data set in particular, enter the complete (or *fully qualified*) data set name. To search for a range of data sets, such as all data sets sharing a common HLQ, enter only the HLQ in the Dsname Level field.

Qualifiers can be specified fully, partially, or defaulted. At least one qualifier must be partially specified. To search for a portion of a name, specify an asterisk (*) before or after part of a data set name. Doing so will cause the utility to return all data sets that match the search criteria. Avoid searching on * alone, because TSO has many places to search in z/OS so this could take quite awhile.

In the majority of ISPF panels, a fully qualified data set name needs to be enclosed in single quotes. Data set names not enclosed in single quotes will, by default, be prefixed with a high level qualifier specified in the TSO PROFILE. This default can be changed using the Profile Prefix command. In addition, an exception is ISPF option 3.4 DSLIST; do not enclose Dsname Level in quotes on the ISPF option 3.4 DSLIST panel.

For example, if you enter *ZPROF* in the Dsname field, the utility lists all data sets with *ZPROF* as a high-level qualifier. The resulting list of data set names (see Figure 3-13) allows the user to edit or browse the contents of any data set in the list.

```
 Menu  Options  View  Utilities  Compilers  Help
 ------------------------------------------------------------------------------
DSLIST - Data Sets Matching ZPROF                                   Row 1 of 4
Command ===>                                                     Scroll ===> PAGE

Command - Enter "/" to select action                  Message           Volume
-------------------------------------------------------------------------------
         ZPROF                                                        *ALIAS
         ZPROF.JCL.CNTL                                               EBBER1
         ZPROF.LIB.SOURCE                                             EBBER1
         ZPROF.PROGRAM.CNTL                                           EBBER1
         ZPROF.PROGRAM.LOAD                                           EBBER1
         ZPROF.PROGRAM.SRC                                            EBBER1
***************************** End of Data Set list ****************************


F1=Help F2=Split F3=Exit F5=Rfind F7=Up F8=Down F9=Swap F10=Left F11=Right F12=Cancel
```

Figure 3-13 Data set list results for Dsname ZPROF

To see all of the possible actions you might take for a given data set, specify a forward slash (/) in the command column to the left of the data set name. ISPF will display a list of possible actions, as shown in Figure 3-14.

```
Menu  Options  View  Utilities  Compilers  Help
- +-------------------------------------------------------------+ ----------
D !                   Data Set List Actions                     ! Row 1 of 4
C !                                                             !  ===> PAGE
  ! Data Set: ZPROF.PROGRAM.CNTL                              !
C !                                                             !    Volume
- ! DSLIST Action                                               ! -----------
  ! __  1.  Edit                    12. Compress                !    *ALIAS
/ !     2.  View                    13. Free                    !    EBBER1
  !     3.  Browse                  14. Print Index             !    EBBER1
  !     4.  Member List             15. Reset                   !    EBBER1
* !     5.  Delete                  16. Move                    ! ***********
  !     6.  Rename                  17. Copy                    !
  !     7.  Info                    18. Refadd                  !
  !     8.  Short Info              19. Exclude                 !
  !     9.  Print                   20. Unexclude 'NX'          !
  !     10. Catalog                 21. Unexclude first 'NXF'   !
  !     11. Uncatalog               22. Unexclude last 'NXL'    !
  !                                                             !
  ! Select a choice and press ENTER to process data set action.  !
  !  F1=Help        F2=Split       F3=Exit        F7=Backward     !
  !  F8=Forward     F9=Swap       F12=Cancel                     !
  +-------------------------------------------------------------+

F1=Help F2=Split F3=Exit F5=Rfind F7=Up F8=Down F9=Swap F10=Left F11=Right F12=Cancel
```

Figure 3-14 Displaying the Data Set List actions

3.3.4 Using the ISPF editor

To edit a data set's contents, enter an `e` (edit) to the left of the data set name. In a data set, each line of text is known as a *record.*

You can perform the following tasks:

- To view a data set's contents, enter a `v` (view) as a line command in the column.
- To edit a data set's contents, enter an `e` (edit) as a line command in the column.
- To edit the contents of a data set, move the cursor to the area of the record to be changed and type over the existing text.
- To find and change text, you can enter commands on the editor command line.
- To insert, copy, delete, or move text, place these commands directly on the line numbers where the action should occur.

To commit your changes, use PF3 or save. To exit the data set without saving your changes, enter `Cancel` on the edit command line.

Figure 3-15 shows the contents of data set *ZPROF*.PROGRAM.CNTL(SORTCNTL) opened in edit mode.

```
 File  Edit  Edit_Settings  Menu  Utilities  Compilers  Test  Help
-------------------------------------------------------------------------------
 EDIT       ZPROF.PROGRAM.CNTL(SORTCNTL) - 01.00        Columns 00001 00072
 Command ===>                                                  Scroll ===> CSR
 ****** ***************************** Top of Data *****************************
 000010 SORT FIELDS=(1,3,CH,A)
 ****** **************************** Bottom of Data ***************************
```

Figure 3-15 Edit a data set

Take a look at the line numbers, the text area, and the editor command line. Primary command line, line commands placed on the line numbers, and text overtype are three different ways in which you can modify the contents of the data set. Line numbers increment by 10 with the TSO editor so that the programmer can insert nine additional lines between each current line without having to renumber the program.

3.3.5 Using the online help

Remember your private tutor, F1=Help, when editing data sets. PF1 in edit mode displays the entire editor tutorial (Figure 3-16).

```
TUTORIAL -------------------------- EDIT ----------------------------- TUTORIAL
OPTION  ===>

                     -----------------------------------
                     |              EDIT               |
                     -----------------------------------

  Edit allows you to create or change source data.

The following topics are presented in sequence, or may be selected by number:
  0 - General introduction              8 - Display modes (CAPS/HEX/NULLS)
  1 - Types of data sets                9 - Tabbing (hardware/software/logical)
  2 - Edit entry panel                 10 - Automatic recovery
  3 - SCLM edit entry panel            11 - Edit profiles
  4 - Member selection list            12 - Edit line commands
  5 - Display screen format            13 - Edit primary commands
  6 - Scrolling data                   14 - Labels and line ranges
  7 - Sequence numbering               15 - Ending an edit session

The following topics will be presented only if selected by number:
 16 - Edit models
 17 - Miscellaneous notes about edit


 F1=Help      F2=Split     F3=Exit      F4=Resize    F5=Exhelp    F6=Keyshelp
 F7=PrvTopic  F8=NxtTopic  F9=Swap     F10=PrvPage  F11=NxtPage  F12=Cancel
```

Figure 3-16 Edit Help Panel and Tutorial

During the lab, you will edit a data set and use F1=Help to explore the Edit Line Commands and Edit Primary Commands functions. Within the help function, select and review the FIND, CHANGE, and EXCLUDE commands. This lab is important for developing further skills in this course.

A subset of the line commands includes:

i	insert a line
Enter key	Press Enter without entering anything to escape insert mode
i5	obtain 5 input lines
d	delete a line
d5	delete 5 lines
dd/dd	delete a block of lines
r	repeat a line

rr/rr	repeat a block of lines
c, then **a** or **b**	copy a line after or before
c5, then **a** or **b**	copy 5 lines after or before
cc/cc, then **a** or **b**	copy a block of lines after or before
m, **m5**, **mm/mm**	to move lines
x	exclude a line

3.3.6 Customizing your ISPF settings

The command line for your ISPF session might appear at the bottom of the display, while your instructor's ISPF command line might appear at the top. This is a personal preference, but traditional usage places it at the top of the panel.

If you want your command line to appear at the top of the panel, do the following:

1. Go to the ISPF primary option menu.
2. Select option **0** to display the Settings menu, as shown in Figure 3-17 on page 3-21.
3. In the list of Options, remove the "/" on the line that says "Command line at bottom." Use the Tab or New line key to move the cursor.

```
 Log/List  Function keys  Colors  Environ  Workstation  Identifier  Help
-------------------------------------------------------------------------------
                                ISPF Settings
 Command ===>

 Options                                   Print Graphics
   Enter "/" to select option                Family printer type 2
   _  Command line at bottom                 Device name . . . .
   /  Panel display CUA mode                 Aspect ratio  . . . 0
   /  Long message in pop-up
   _  Tab to action bar choices
   _  Tab to point-and-shoot fields        General
   /  Restore TEST/TRACE options             Input field pad . . B
   _  Session Manager mode                   Command delimiter . ;
   /  Jump from leader dots
   _  Edit PRINTDS Command
   /  Always show split line
   _  Enable EURO sign

 Terminal Characteristics
   Screen format   2  1. Data    2. Std     3. Max     4. Part

   Terminal Type   3    1. 3277       2. 3277A      3. 3278       4. 3278A
                        5. 3290A      6. 3278T      7. 3278CF     8. 3277KN
                        9. 3278KN    10. 3278AR    11. 3278CY    12. 3278HN
                       13. 3278HO    14. 3278IS    15. 3278L2    16. BE163
                       17. BE190     18. 3278TH    19. 3278CU    20. DEU78
                       21. DEU78A    22. DEU90A    23. SW116     24. SW131
                       25. SW500
```

Figure 3-17 ISPF settings

While in this menu, you can change some other parameters that you will need later:

- Remove the "/" from `Panel display CUA mode`.
- Change the `Terminal Type` to 4. This provides 3270 support for symbols used by the C language.
- Move the cursor to the `Log/List` option in the top line and press Enter.
  - Select **1** (Log Data set defaults).
  - Enter Process Option 2 (to delete the data set without printing).
  - Press PF3 to exit.

- Move the cursor to the `Log/List` option again.

– Select **2** (List Data set defaults).
– Enter Process Option 2 to delete the data set without printing.
– PF3 to exit.

- Press PF3 again to exit to the primary menu.

The actions in the bar across the top usually vary from site to site.

Another way to customize ISPF panels is with the **`hilite`** command, as shown in Figure 3-18. This command allows you to tailor various ISPF options to suit the needs of your environment.

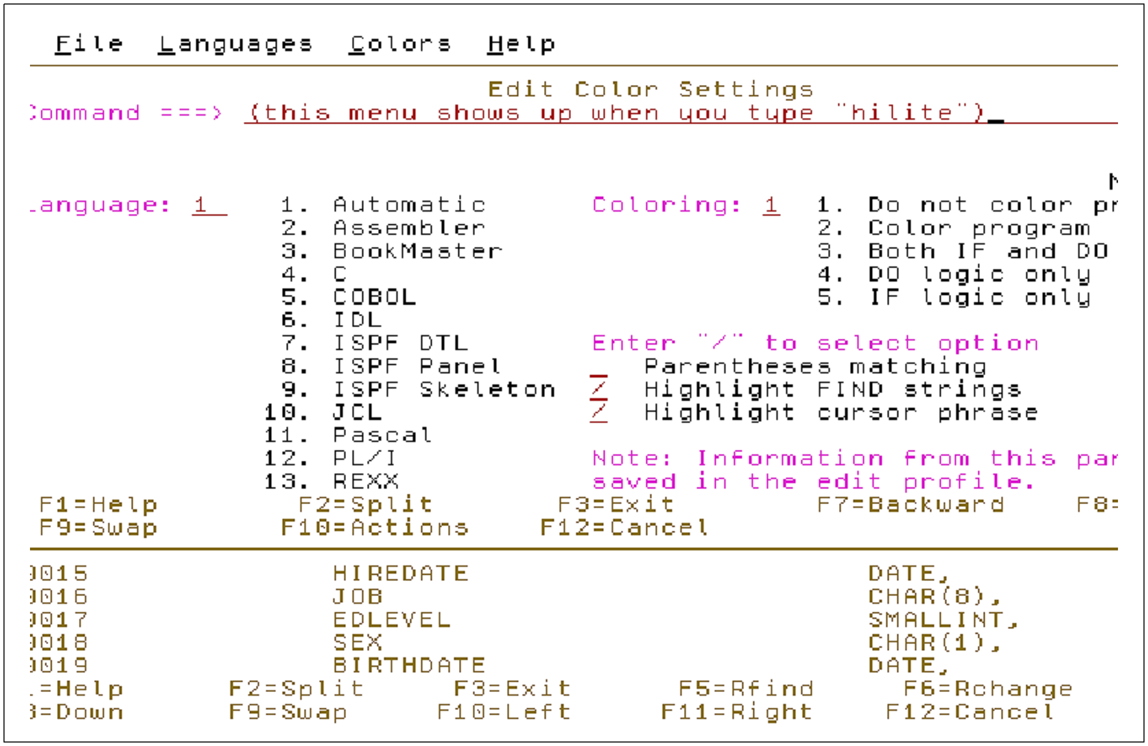


Figure 3-18 Using the hilite command

3.3.7 Adding a GUI to ISPF

ISPF is a full panel application navigated by keyboard. You can, however, download and install a variety of ISPF graphical user interface (GUI) clients to include with a z/OS system. After installing the ISPF GUI client, it is possible to use the mouse.

Figure 3-19 shows an example of an ISPF GUI.

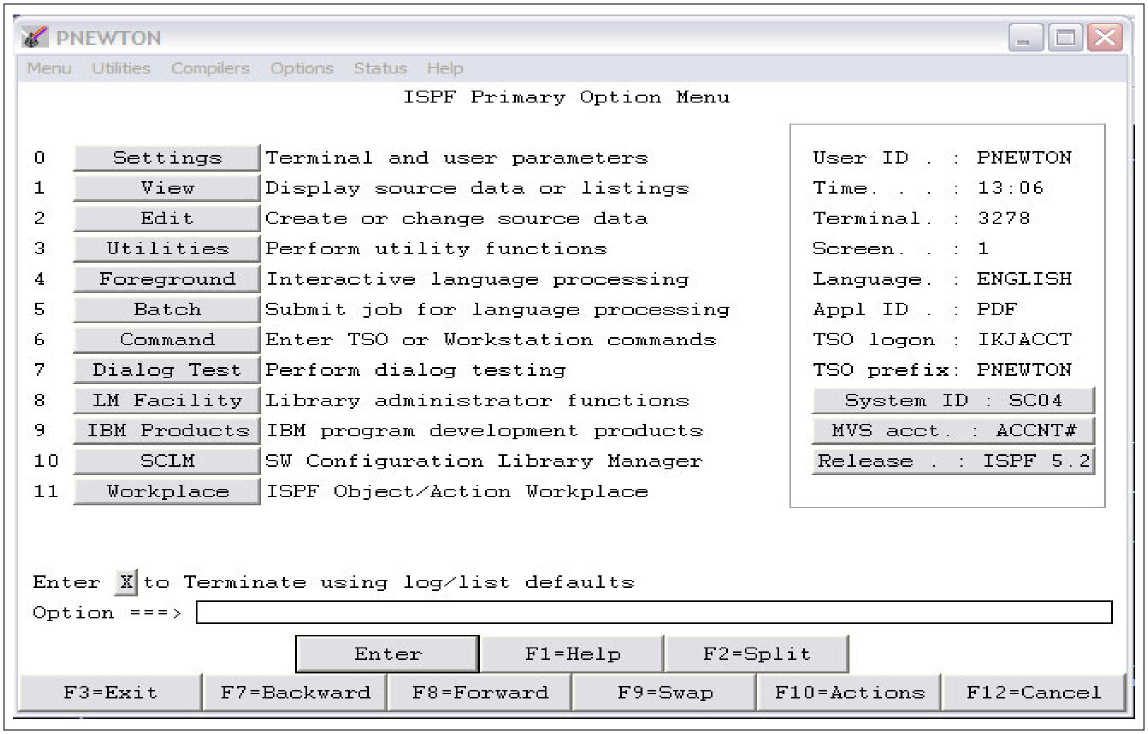


Figure 3-19 ISPF GUI

The drop-down entries at the top of the ISPF panels require you to place the cursor on the selection and press Enter. Move the ISPF GUI client mouse pointer across the drop-down selections to display the respective sub-selections. Also available in the GUI are Enter and PF key boxes.

3.4 z/OS UNIX interactive interfaces

The z/OS UNIX shell and utilities provide an interactive interface to z/OS. The shell and utilities can be compared to the TSO function in z/OS.

To perform some command requests, the shell calls other programs, known as *utilities*. The shell can be used to:

- Invoke shell scripts and utilities.
- Write shell scripts (a named list of shell commands, using the shell programming language).
- Run shell scripts and C language programs interactively, in the TSO background or in batch.

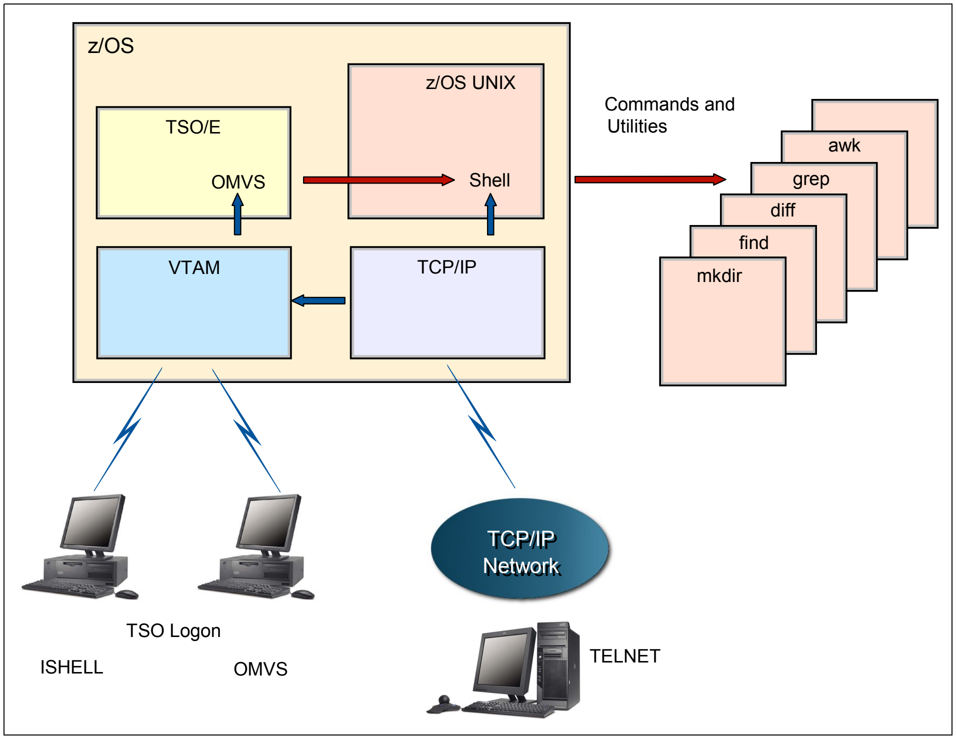


Figure 3-20 Shell and utilities

A user can invoke the shell in the following ways:

- From a 3270 display or a workstation running a 3270 emulator
- From a TCP/IP-attached terminal, using the **`rlogin`** and **`telnet`** commands
- From TSO by entering the OMVS command or the ISHELL command.

Figure 3-21 shows an overview of the two interactive interfaces, the z/OS UNIX shell and the ISHELL command. Also, there are some TSO/E commands that support z/OS UNIX, but they are limited to functions such as copying files and creating directories.

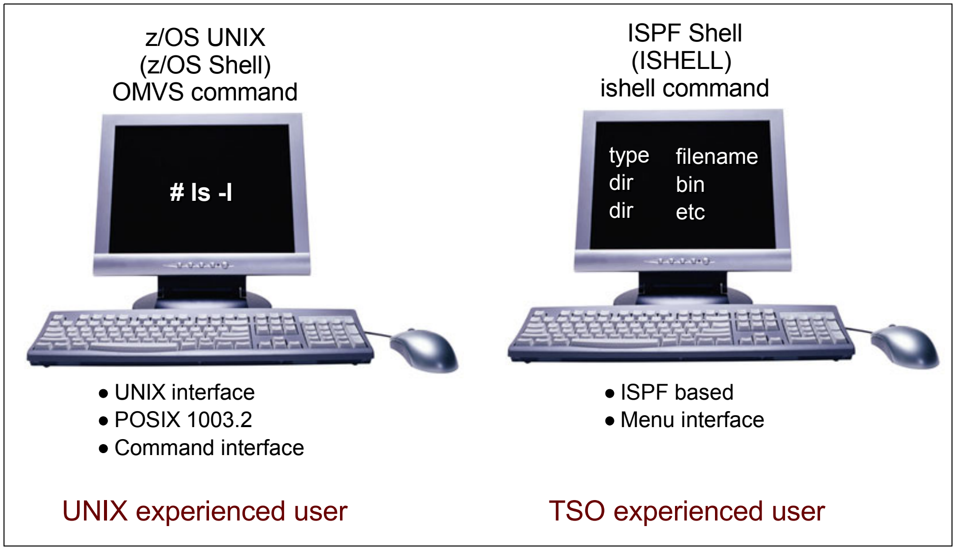


Figure 3-21 z/OS UNIX interactive interfaces

The z/OS UNIX shell is based on the UNIX System V shell and has some of the features from the UNIX Korn shell. The POSIX standard distinguishes between a *command*, which is a directive to the shell to perform a specific task, and a *utility*, which is the name of a program callable by name from the shell. To the user, there is no difference between a command and a utility.

The z/OS UNIX shell provides the environment that has the most functions and capabilities. Shell commands can easily be combined in pipes or shell scripts, and thereby become powerful new functions. A sequence of shell commands can be stored in a text file that can be executed. This is called a *shell script*. The shell supports many of the features of a regular programming language.

The TSO commands used with z/OS UNIX are:

ISHELL The ISHELL command invokes the ISPF shell. ISHELL is a good starting point for users familiar with TSO and ISPF who want or need to use z/OS UNIX. ISHELL provides panels where users can work with the hierarchical file system. There are also panels for mounting and unmounting file systems and for doing some z/OS UNIX administration.

Programmers whose primary interactive computing environment is TSO/E and ISPF can do much of their work in that environment.

OMVS The OMVS command is used to invoke the z/OS UNIX shell.

Programmers whose primary interactive computing environment is a UNIX workstation find the z/OS UNIX shell programming environment familiar.

3.4.1 ISHELL command (ish)

Figure 3-22 shows the ISHELL or ISPF Shell panel displayed as a result of the ISHELL or ISH command being entered from ISPF Option 6.

```
  File  Directory  Special_file  Tools  File_systems  Options  Setup  Help
 --------------------------------------------------------------------------
                        UNIX System Services ISPF Shell

Enter a pathname and do one of these:

    - Press Enter.
    - Select an action bar choice.
    - Specify an action code or command on the command line.

Return to this panel to work with a different pathname.
                                                             More:     +
   /u/rogers_________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
```

Figure 3-22 Panel displayed after issuing the ISH command

3.4.2 ISHELL - user files and directories

To search a user's files and directories, type the following and then press Enter:

```
/u/userid
```

For example, Figure 3-23 shows the files and directories of user `rogers`.

```
                              Directory List

 Select one or more files with / or action codes.  If / is used also select an
 action from the action bar otherwise your default action will be used.  Select
 with S to use your default action.  Cursor select can also be used for quick
 navigation.  See help for details.
 EUID=0   /u/rogers/
   Type  Perm  Changed-EST5EDT   Owner      ------Size  Filename    Row 1 of 9
 _ Dir    700  2002-08-01 10:51  ADMIN            8192  .
 _ Dir    555  2003-02-13 11:14  AAAAAAA             0  ..
 _ File   755  1996-02-29 18:02  ADMIN             979  .profile
 _ File   600  1996-03-01 10:29  ADMIN              29  .sh_history
 _ Dir    755  2001-06-25 17:43  AAAAAAA          8192  data
 _ File   644  2001-06-26 11:27  AAAAAAA         47848  inventory.export
 _ File   700  2002-08-01 10:51  AAAAAAA            16  myfile
 _ File   644  2001-06-22 17:53  AAAAAAA         43387  print.export
 _ File   644  2001-02-22 18:03  AAAAAAA         84543  Sc.pdf
```

Figure 3-23 Display of a user's files and directories

From here, you use action codes to do any of the following:

b Browse a file or directory
e Edit a file or directory
d Delete a file or directory
r Rename a file or directory
a Show the attributes of a file or directory
c Copy a file or directory

3.4.3 OMVS command shell session

You use the OMVS command to invoke the z/OS UNIX shell. Shell commands often have options (also known as *flags*) that you can specify, and they usually take an argument, such as the name of a file or directory. The format for specifying the command begins with the command name, then the option or options, and finally the argument, if any.

For example, in Figure 3-24 on page 3-28 the following command is shown:

```
ls -al /u/rogers
```

where `ls` is the command name, and `-al` are the options.

```
ROGERS @ SC43:/>ls -al /u/rogers
total 408
drwx------    3 ADMIN    SYS1        8192 Aug  1  2002 .
dr-xr-xr-x   93 AAAAAAA  TTY            0 Feb 13 11:14 ..
-rwxr-xr-x    1 ADMIN    SYS1         979 Feb 29  1996 .profile
-rw-------    1 ADMIN    SYS1          29 Mar  1  1996 .sh_history
-rw-r--r--    1 AAAAAAA  SYS1       84543 Feb 22  2001 Sc.pdf
drwxr-xr-x    2 AAAAAAA  SYS1        8192 Jun 25  2001 data
-rw-r--r--    1 AAAAAAA  SYS1       47848 Jun 26  2001 inventory.export
-rwx------    1 AAAAAAA  SYS1          16 Aug  1  2002 myfile
-rw-r--r--    1 AAAAAAA  SYS1       43387 Jun 22  2001 print.export
```

Figure 3-24 OMVS shell session display after issuing the OMVS command

This command lists the files and directories of the user. If the pathname is a file, `ls` displays information on the file according to the requested options. If it is a directory, `ls` displays information on the files and subdirectories therein. You can get information on a directory itself by using the `-d` option.

The shell is a command processor that you use to:

- Invoke shell commands or utilities that request services from the system.
- Write shell scripts using the shell programming language.
- Run shell scripts and C-language programs interactively (in the foreground), in the background, or in batch.

If you do not specify any options, `ls` displays only the file names. When `ls` sends output to a pipe or file, it writes one name per line; when it sends output to the terminal, it uses the `-C` (multi-column) format.

3.4.4 Direct login to the shell

To login directly to the z/OS UNIX shell, use one of the following solutions:

rlogin When the *inetd daemon* is set up and active, you can rlogin to the shell from a workstation that has rlogin client support and is connected through TCP/IP to the z/OS system (Figure 3-25 on page 3-29). To log in, use the **`rlogin`** (remote log in) command syntax supported at your site.

telnet The telnet support comes with the TCP/IP z/OS UNIX feature. It also uses the inetd daemon, which must be active and set up to recognize and receive the incoming telnet requests.

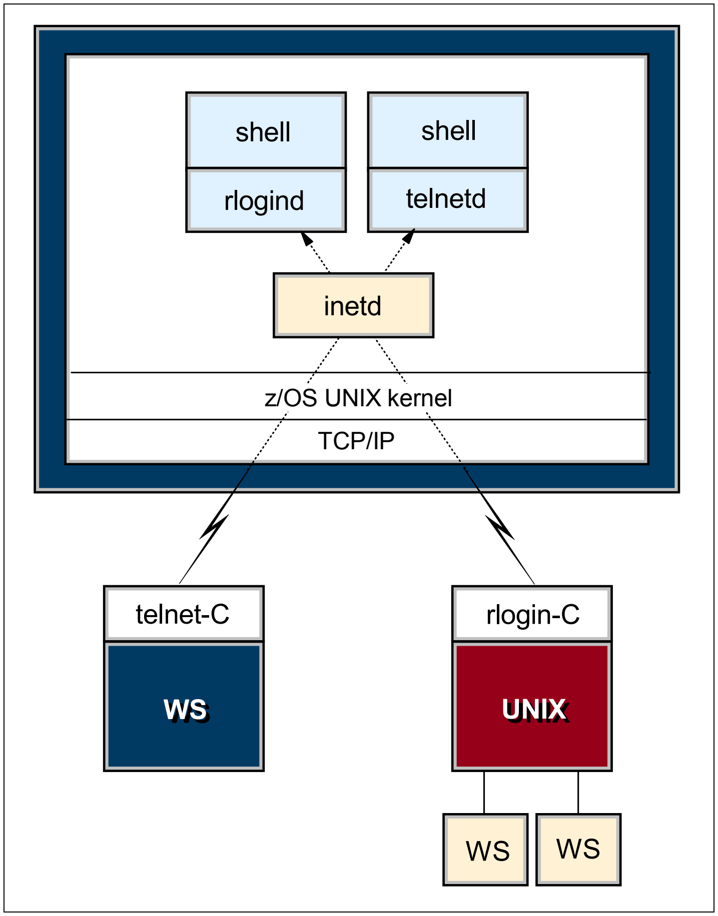


Figure 3-25 Diagram of a login to the shell from a terminal workstation

Figure 3-26 shows the z/OS shell after login through telnet.

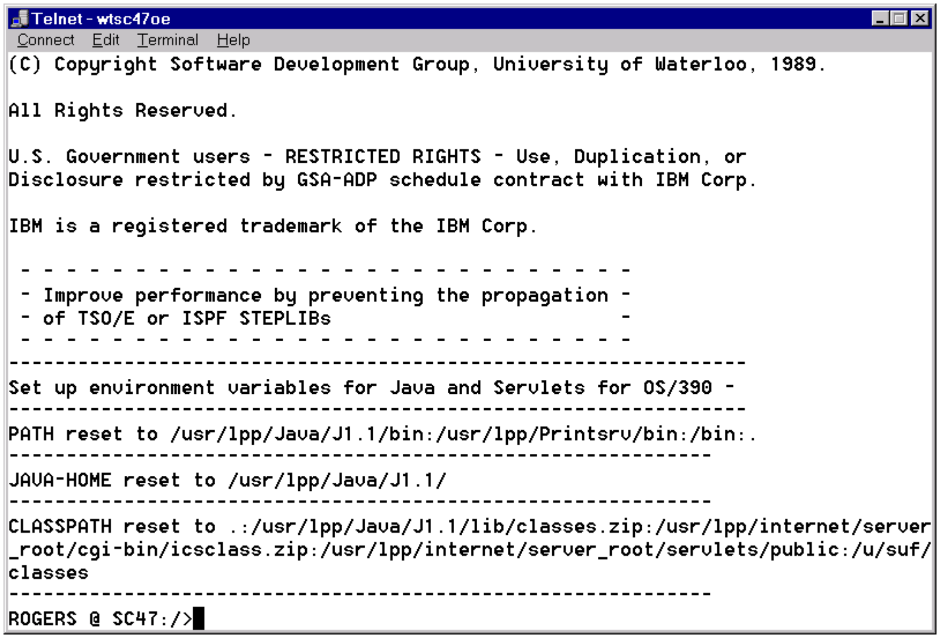


Figure 3-26 Telnet login to the shell screen

There are some differences between the asynchronous terminal support (direct shell login) and the 3270 terminal support (OMVS command):

- You cannot switch to TSO/E. However, you can use the TSO SHELL command to run a TSO/E command from your shell session.
- You cannot use the ISPF editor (this includes the **oedit** command, which invokes ISPF edit).

3.5 Summary

TSO allows users to logon to z/OS and use a limited set of basic commands. This is sometimes called using TSO in its native mode.

ISPF is a menu-driven interface for user interaction with a z/OS system. The ISPF environment is executed from native TSO.

ISPF provides utilities, an editor and ISPF applications to the user. To the extent permitted by various security controls an ISPF user has full access to most z/OS system functions.

TSO/ISPF should be viewed as a system management interface and a development interface for traditional z/OS programming.

The z/OS UNIX shell and utilities provide a command interface to the z/OS UNIX environment. You can access the shell either by logging on to TSO/E or by using the remote login facilities of TCP/IP (rlogin).

If you use TSO/E, a command called OMVS creates a shell for you. You can work in the shell environment until exiting or temporarily switching back to the TSO/E environment.

Key terms in this chapter		
3270 emulator	CLIST	ISHELL
ISPF	logon	native mode
READY prompt	record	Restructured Extended Executor (REXX)
path	OMVS command	password
	root	SDSF
shell	Time Sharing Option / Extensions (TSO/E)	user ID

3.6 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. If you want more information about a specific ISPF panel or help with a user error, what should be your first action?
2. Why is the ISPF command pfshow on/off useful?
3. ISPF is a full screen interface with a full screen editor and TSO is a command line interface with only a line editor. The TSO line editor is rarely used. Can you think of a situation which would require the use of the TSO line editor?
4. Can the IBM-provided panels of ISPF be customized?
5. Name the two z/OS UNIX interactive interfaces and explain some of the differences between the two.

3.7 Exercises

The lab exercises in this chapter will help you develop skills in using TSO, ISPF and the z/OS UNIX command shell. These skills are required for performing lab exercises in the remainder of this text.

To perform the lab exercises, each student or team will require a TSO user ID and password (for assistance, see the instructor).

The lab exercises are intended to teach TSO and ISPF through trial and error, so mistakes are expected. Do not get frustrated. Instead, discuss the exercises with your classmates and work through them in teams, as needed.

The exercises teach the following:

- "Logging on to z/OS and entering TSO commands" on page 3-32
- "Navigating through the ISPF menu options" on page 3-32
- "Using the ISPF editor" on page 3-33
- "Using SDSF" on page 3-34
- "Opening the z/OS UNIX shell and entering commands" on page 3-35
- "Using the OEDIT and OBROWSE commands" on page 3-35

3.7.1 Logging on to z/OS and entering TSO commands

Establish a 3270 connection with z/OS using a workstation 3270 emulator and log on with your user ID (*yourid*). From the TSO `READY` prompt (=x will exit out of ISPF), enter the following commands:

`PROFILE` What is the prefix value? Make a note of this; it is your user ID on the system.

`PROFILE NOPREFIX LISTC`
Display the list of catalog entries. Your 3270 emulator will have a PA1 (attention) key. Find and send PA1 to the system to end the command output.
Note: *** indicates full screen; press Enter or PA1.

`PROFILE PREFIX(`*`yourid`*`)LISTC ISPF`
What is displayed?

3.7.2 Navigating through the ISPF menu options

From the ISPF Primary Option Menu, do the following:

1. Select Utilities, then select **Dslist** from the Utility Selection Panel.

2. Enter SYS1 on the Dsname Level input field and press Enter. What is displayed? Use PF8 to page down or forward, PF7 to page up or backward, PF10 to shift left and PF11 to shift right. Exit with PF3.
3. Enter SYS1.PROCLIB on Dsname Level input field and press Enter. What is displayed?
4. Enter v in the command column (left of) SYS1.PROCLIB. This is a partitioned data set with numerous members. Place an s to the left of any member to select the member for viewing. Press PF1. What specific help is provided?
5. Enter =0 on the ISPF command or option line. What is the first option listed in this ISPF Settings panel? Change your settings to place command line at bottom of panel. It is effective upon exit from the Settings panel.

> **Tip:** As you become more familiar with ISPF, you will learn the letters and numbers for some of the commonly used options. Preceding an option with the = key takes you directly to that option, bypassing the menus in between.
>
> You can also go directly to nested options with the = sign. For example, =P.3.4 takes you directly to a commonly-used data set utility menu.

6. Enter PFSHOW OFF and then PFSHOW ON. What is the difference? How is this useful?
7. Exit back to the ISPF Primary Option Menu. What value is used to select Utilities? Select **Utilities**.
8. In the Utilities Selection Panel, what value is used to select Dslist? Exit back to the ISPF Primary Option Menu. On the option line, enter the Utilities selection value followed by a period, then enter the Dslist selection value. What panel is displayed?
9. Exit back to the ISPF Primary Option Menu. Place the cursor on the Status entry at the very top of the panel and press Enter. Select the Calendar value and press Enter, then select the Session value. What changed?

3.7.3 Using the ISPF editor

From the ISPF Primary Option Menu, do the following:

1. Go to Dslist Utility Panel and enter *yourid***.**JCL in the Dsname Level field.
2. Place e (edit) to the left of *yourid***.**JCL. Place s (select) to the left of member EDITTEST. Enter PROFILE on the edit command line, observe the data is preceded by profile and message lines. Read the profile settings and messages, then enter RESET on the command line. What is the result?
3. Enter any string of characters and the end of the first data line, then press Enter. On the command line, enter CAN (cancel). Again, edit EDITTEST in the data set. Were your changes saved?

4. Move the cursor to one of the top lines on your display. Press PF2. The result is a second ISPF panel. What occurs when PF9 is entered repeatedly?
5. Using PF9, switch to the ISPF Primary Option Menu, then press PF1 to display the ISPF Tutorial panel.
6. From the ISPF Tutorial panel, select **`Edit`**, select **Edit Line Commands**, then select **Basic Commands**. Press Enter to scroll through the basic commands tutorial. As you do so, frequently switch (PF9) to the edit session and exercise the commands in `EDITTEST`. Repeat this same scenario for Move/Copy Commands and Shifting Commands.
7. From the ISPF Tutorial panel, select **`Edit`**, select **Edit Primary Commands**, then select **FIND/CHANGE/EXCLUDE commands**. Press Enter to scroll through the FIND/CHANGE/EXCLUDE commands tutorial. As you do so, frequently switch (PF9) to the edit session and exercise the commands in `EDITTEST`.
8. Enter `=X` on the ISPF help panel to end the second ISPF panel session. Save and exit the Edit Panel (PF3) to return to the ISPF *Primary Option Menu.*

3.7.4 Using SDSF

From the ISPF Primary Option Menu, locate and select System Display and Search Facility (SDSF), a utility that lets you look at output data sets. The ISPF Primary Option Menu typically includes more selections than those listed on first panel, with instructions on how to display the additional selections.

1. Enter `LOG`, then shift left (PF10), shift right (PF11), page up (PF7) and page down (PF8). Enter `TOP`, then `BOTTOM` on the command input line. Enter `DOWN 500` and `UP 500` on the command input line. You will learn how to read this system log later.
2. Observe the SCROLL value to the far left on the command input line.

   Scroll ===> PAGE

   Tab to the SCROLL value. The values for SCROLL can be:

C - CSR	cursor
P - PAGE	page
H - HALF	half-page

   You will find the SCROLL value on many ISPF panels, including the editor. You can change this value by entering the first letter of the scroll mode over the first letter of the current value. Change the value to CSR, place the cursor on another line in the body of the system log, and press PF7. Did it place the line with the cursor at the top?
3. Enter `ST` (status) on the SDSF command input line, then enter `SET DISPLAY ON`. Observe the values for Prefix, Dest, Owner, and Sysname. To display all of the current values for each, enter * as a filter, for example:

   ```
   PREFIX *
   OWNER *
   ```

```
DEST
```

The result should be:

```
PREFIX=*  DEST=(ALL)  OWNER=*
```

4. Enter `DA`, to display all active. Enter `ST` to retrieve the status of all jobs in input, active, and output queue. Once again, press PF7 (page up), PF8 (page down), PF10 (shift left), and PF11 (shift right).

3.7.5 Opening the z/OS UNIX shell and entering commands

From the ISPF Primary Option Menu, select Option 6 “z/OS UNIX” and enter the OMVS command.

From your home directory, enter the following shell commands:

`id`	Shows your current id.
`date`	Shows time and date.
`man date`	Manual of the **`date`** command. You can forward the panels by pressing Enter. Enter `quit` to exit.
`man man`	Help for the manual.
`env`	Environment variables for this session.
`type read`	Identifies whether read is a command, a utility, an alias, and so forth.
`type man`	
`type date`	
`ls`	List a directory.
`ls -l`	List the current directory.
`ls -l /etc`	List the directory /etc.
`cal`	Display a calender of the current month.
`cal 2005`	Display a calender of the year 2005.
`cal 1752`	Display the calender for the year 1752. Is September missing 13 days? All UNIX calendars have 13 days missing from September 1752. Optional - Do you know why? (Hint: Ask a History major!)
`exit`	End the OMVS session.

3.7.6 Using the OEDIT and OBROWSE commands

Another way to start the OMVS shell is by entering the TSO OMVS command on any ISPF panel. From your home directory, enter the following shell commands:

`oedit myfile`	This opens the ISPF edit panel and creates a new text file in the current path. Write some text into the editor. Save and exit(PF3).
`ls`	
`ls -l`	
`type myfile`	*myfile* can be any file you choose to create.
`obrowse myfile`	Browse the file you just created.
`exit`	End the OMVS session

4

Working with data sets

Objective: In working with the z/OS operating system, you must understand *data sets*, which contain programs and data. The data set characteristics of traditional z/OS data sets differ considerably from the file systems used in UNIX and PC systems.

After completing this chapter, you will be able to:

- Explain what a data set is
- Describe data set naming conventions and record formats
- List some access methods for managing data and programs
- Explain what catalogs and VTOCs are used for
- Create, delete and modify data sets

4.1 What is a data set?

A data set is a collection of logically related data records stored on one disk storage volume or a set of volumes. A data set can be, for example, a source program, a library of macros, or a file of data records used by a processing program. You can print a data set or display it on a terminal. The logical record is the basic unit of information used by a program running on z/OS[1].

4.2 How is data stored?

In a z/OS system, data can be stored on a direct access storage device (DASD), magnetic tape volume, or optical media. The term *DASD* applies to disks or simulated equivalents of disks. All types of data sets can be stored on DASD, but only sequential data sets can be stored on magnetic tape. We discuss the types of data sets later in this chapter.

z/OS allows you to store and retrieve records either directly or sequentially. You use DASD volumes for storing data and executable programs, including the operating system itself, and for temporary working storage. You can use one DASD volume for many different data sets, and reallocate or reuse space on the volume.

4.3 How is data managed?

In a z/OS system, data management involves allocation, placement, monitoring, migration, backup, recall, recovery, and deletion. These activities can be done either manually or through the use of automated processes. When data management is automated, the operating system determines object placement, and automatically manages object backup, movement, space, and security. A typical z/OS production system includes both manual and automated processes for managing data sets.

Depending on how a z/OS system and its storage devices are configured, a user or program can directly control many aspects of data set use, and in the early days of the operating system, users were required to do so. Increasingly, however, z/OS customers rely on installation-specific settings for data and resource management, and additional storage management products, such as DFSMS, to automate the use of storage for data sets.

Data management includes these main tasks:

- Sets aside (allocates) space on DASD volumes
- Automatically retrieves cataloged data sets by name

[1] z/OS UNIX files are different from the typical data set because they are byte oriented rather than record oriented.

- Mounts magnetic tape volumes in the drive
- Establishes a logical connection between the application program and the medium
- Controls access to data
- Transfers data between the application program and the medium

4.3.1 What is system-managed storage?

The primary means of managing storage in z/OS is through the DFSMS component of the operating system. DFSMS performs the essential data, storage, program, and device management functions of the system. DFSMS is a set of products, and one of these products, DSFMSdfp, is required for running z/OS. DFSMS, together with hardware products and installation-specific settings for data and resource management, provides system-managed storage in a z/OS environment.

The heart of DFSMS is the Storage Management Subsystem (SMS). Using SMS, the system programmer or storage administrator defines policies that automate the management of storage and hardware devices. These policies describe data allocation characteristics, performance and availability goals, backup and retention requirements, and storage requirements for the system. SMS governs these policies for the system and the Interactive Storage Management Facility (ISMF) provides the user interface for defining and maintaining the policies.

The data sets allocated through SMS are called system-managed data sets or SMS-managed data sets.

When you allocate or define a data set to use SMS, you specify your data set requirements by using a data class, a storage class, and a management class. Typically, you do not need to specify these classes because a storage administrator has set up automatic class selection (ACS) routines to determine which classes to use for a data set.

DFSMS uses a set of constructs, user interfaces, and routines (using the DFSMS products) that allow the storage administrator to better manage the storage system. The core logic of DFSMS, such as the ACS routines, ISMF code, and constructs, is located in DFSMSdfp™. DFSMShsm™ and DFSMSdss™ are involved in the management class construct.

With DFSMS, the z/OS system programmer or storage administrator can define performance goals and data availability requirements, create model data definitions for typical data sets, and automate data backup. DFSMS can automatically assign, based on installation policy, those services and data definition attributes to data sets when they are created. IBM storage management-related products determine data placement, manage data backup, control space usage, and provide data security.

4.4 What are access methods?

An access method defines the technique that is used to store and retrieve data. Access methods have their own data set structures to organize data, system-provided programs (or *macros*) to define data sets, and utility programs to process data sets.

Access methods are identified primarily by the data set organization. z/OS users, for example, use the basic sequential access method (BSAM) or queued sequential access method (QSAM) with sequential data sets.

However, there are times when an access method identified with one organization can be used to process a data set organized in a different manner. For example, a sequential data set (not extended-format data set) created using BSAM can be processed by the basic direct access method (BDAM), and vice versa. Another example is UNIX files, which you can process using BSAM, QSAM, basic partitioned access method (BPAM), or virtual storage access method (VSAM).

This text does not describe all of the access methods available on z/OS. Commonly used access methods include the following:

QSAM	Queued Sequential Access Method (heavily used)
BSAM	Basic Sequential Access Method (for special cases)
BDAM	Basic Direct Access Method (becoming obsolete)
BPAM	Basic Partitioned Access Method (for libraries)
VSAM	Virtual Sequential Access Method (more complex)
VTAM	Virtual Telecommunications Access Method (terminals)
EXCP	Execute Channel Program (not really an access method)
TCP/IP	Not a traditional access method

4.5 How are DASD volumes used?

DASD volumes are used for storing data and executable programs (including the operating system itself), and for temporary working storage. One DASD volume can be used for many different data sets, and space on it can be reallocated and reused.

Data sets in a z/OS system are organized on DASD volumes. The name of a data set must be unique on a volume. A data set can be located by device type, volume serial number, and data set name. This is unlike the file tree of a UNIX system. The basic z/OS file structure is not hierarchical. z/OS data sets have no equivalent to a path name.

Although DASD volumes differ in physical appearance, capacity, and speed, they are similar in data recording, data checking, data format, and programming. The recording surface of each volume is divided into many concentric *tracks*. The number of tracks and their capacity vary with the device. Each device has an access mechanism that contains read/write heads to transfer data as the recording surface rotates past them.

4.5.1 DASD terminology for UNIX and PC users

The disk and data set characteristics of zSeries hardware and software differ considerably from UNIX and PC systems, and carry their own specialized terminology. Throughout this text, the following terms are used to describe various aspects of storage management on z/OS

- *Direct Access Storage Device* (DASD) is another name for a disk drive.
- A disk drive is also known as a disk volume, a disk pack, or a *Head Disk Assembly* (HDA). We use the term *volume* in this text except when discussing physical characteristics of devices.
- A disk drive contains cylinders.
- Cylinders contain tracks.
- Tracks contain data records and are in *Count Key Data* (CKD) format.[2]
- Data blocks are the units of recording on disk.

4.5.2 What are DASD labels?

The operating system uses groups of labels to identify DASD volumes and the data sets they contain. Customer application programs generally do not use these labels directly. DASD volumes must use standard labels. Standard labels include a volume label, a data set label for each data set, and optional user labels. A volume label, stored at track 0 of cylinder 0, identifies each DASD volume.

A utility program initializes each DASD volume before it is used on the system. The initialization program generates the volume label and builds the volume table of contents (VTOC). The VTOC is a structure that contains the data set labels (VTOCs are described later in this chapter).

4.6 Allocating a data set

To use a data set, you first allocate it (establish a link to it), then access the data using macros for the access method that you have chosen.

The *allocation* of a data set means either or both of two things:

- To set aside (create) space for a new data set on a disk.
- To establish a logical link between a job step and any data set.

At the end of this chapter, we follow an exercise to allocate a data set using ISPF panel option 3.2. Other ways to allocate a data set include the following methods:

---

[2] Current devices actually use *Extended Count Key Data* (ECKD™) protocols, but we use CKD as a collective name in the text.

Access Method Services	You can allocate data sets through a multifunction services program called access method services. Access method services include commonly used commands for working with data sets, as ALLOCATE, ALTER, DEKETE, and PRINT.
ALLOCATE command	You can use the TSO ALLOCATE command to allocate data sets.
Using JCL	You can use job control language to allocate data sets (we discuss the use of JCL in Chapter 6, “Using JCL and SDSF”

4.7 Allocating space on DASD volumes

You can specify the amount of space required in blocks, records, tracks, or cylinders. When creating a DASD data set, you specify the amount of space needed explicitly (by using the SPACE parameter), or implicitly (by using the information available in a data class).

The system can use a data class if SMS is active even if the data set is not SMS managed. For system-managed data sets, the system selects the volumes, saving you from having to specify a volume when you allocate a data set.

If you specify your space request by average record length, space allocation is independent of device type. Device independence is especially important to system-managed storage.

4.7.1 Logical records and blocks

A logical record (LRECL) is a unit of information about a unit of processing (for example, a customer, an account, a payroll employee, and so on). It is the smallest amount of data to be processed, and it is comprised of fields which contain information recognized by the processing application.

Logical records, when located in DASD, tape, or optical devices, are grouped in physical records named blocks (BLKSIZE). Each block of data on a DASD volume has a distinct location and a unique address, thus making it possible to find any block without extensive searching. Logical records can be stored and retrieved either directly or sequentially.

The maximum length of a logical record (LRECL) is limited by the physical size of the used media.

When the amount of space required is expressed in blocks, you must specify the number and average length of the blocks within the data set.

We have not yet discussed JCL, but here is a typical example of how space is allocated on a DASD volume through JCL:

```
//  DD SPACE=(300,(5000,100)), ...
```

In this example, the values indicate a storage request as follows:

- 300 = average block length in bytes
- 5000 = primary quantity (number of blocks)
- 100 = secondary quantity, to be allocated if the primary quantity is not enough (in blocks)

From this information, the operating system estimates and allocates the number of tracks required.

4.7.2 Data set extents

Space for a disk data set is assigned in *extents*. An extent is a *contiguous* number of disk drive tracks (or cylinders). Data sets can increase in extents as they grow. Older types of data sets can have up to 16 extents per volume. Newer types of data sets can have up to 128 or 255 extents.

In z/OS, a data set organization based on extents is designed to maximize disk performance. Reading or writing contiguous tracks is faster than reading or writing tracks scattered over the disk, as might be the case if tracks were allocated dynamically.

4.8 Data set record formats

Traditional z/OS data sets are *record oriented*. In normal usage, there are no byte stream files such as are found in PC and UNIX systems. (z/OS UNIX has byte stream files, and byte stream functions exist in other specialized areas. These are not considered to be traditional data sets.)

In z/OS, there are no new line (NL) or carriage return and line feed (CR+LF) characters to denote the end of a record. Records are either fixed length or variable length in a given data set. When editing a data set with ISPF, for example, each line is a record.

Traditional z/OS data sets have one of five record formats, as shown in Figure 4-1 on page 4-8. We must stress the difference between a block and a record. In this discussion, a block is what is written on disk, while a record is a logical entity.

The data set record formats are as follows:

F - Fixed This means that one physical block on disk is one logical record and all the blocks/records are the same size. This format is seldom used.

FB - Fixed Blocked This means that several logical records are combined into one physical block. This can provide efficient space utilization and operation. This format is commonly used for fixed-length records.

V - Variable This format has one logical record as one physical block. The application is required to insert a four-byte Record Descriptor Word (RDW) at the beginning of the record. The RDW contains the length of the record plus the four bytes for the RDW. This format is seldom used.

VB - Variable Blocked This format places several variable-length logical records (each with an RDW) in one physical block. The software must place an additional Block Descriptor Word (BDW) at the beginning of the block, containing the total length of the block.

U - Undefined This format consists of variable-length physical records/blocks with no predefined structure. Although this format may appear attractive for many unusual applications, it is normally used only for executable modules.

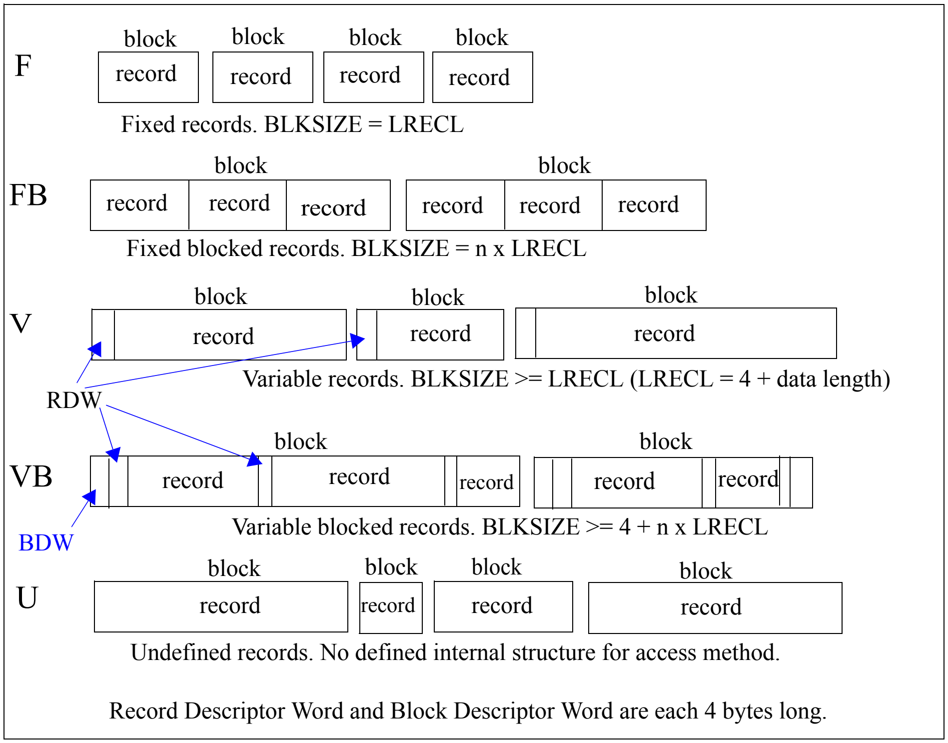


Figure 4-1 Basic record formats

The terminology here is pervasive throughout z/OS literature. The key terms are:

- Block Size (BLKSIZE) is the physical block size written on the disk for F and FB records. For V, VB, and U records it is the maximum physical block size that can be used for the data set.
- Logical Record Size (LRECL) is the logical record size (F, FB) or the maximum allowed logical record size (V, VB) for the data set. Format U records have no LRECL.
- Record Format (RECFM) is F, FB, V, VB, or U as just described.

These terms are known as data control block (DCB) *characteristics*, named for the control block where they may be defined in an assembly language program. The user is often expected to specify these parameters when creating a new data set.

4.9 Types of data sets

There are many different types of data sets in z/OS, and different methods for managing them. This chapter discusses three types: sequential, partitioned, and VSAM. These are all used for disk storage; we mention tape data sets briefly as well.

4.9.1 What is a sequential data set?

The simplest data structure in a z/OS system is a sequential data set. It consists of one or more records that are stored in physical order and processed in sequence. New records are appended to the end of the data set.

An example of a sequential data sets might be an output data set for a line printer or a deck of punch cards.

A z/OS user defines sequential data sets through job control language (JCL) with a data set organization of PS (DSORG=PS), which stands for physical sequential. In other words, the records in the data set are physically arranged one after another.

Tape data sets

This chapter covers mainly disk data sets, but mainframe applications might also use tape data sets for many purposes. Tapes store sequential data sets. Mainframe tape drives have variable-length records (blocks). The maximum block size for routine programming methods is 65K bytes. Specialized programming can produce longer blocks. There are a number of tape drive products with different characteristics.

4.9.2 What is a PDS?

A *partitioned data set* adds a layer of organization to the simple structure of sequential data sets. A PDS is a collection of sequential data sets, called *members.* Each member is like a sequential data set and has a simple name, which can be up to eight characters long.

A PDS also contains a directory. The directory contains an entry for each member in the PDS with a reference (or pointer) to the member. Member names are listed alphabetically in the directory, but members themselves can appear in any order in the library. The directory allows the system to retrieve a particular member in the data set.

A partitioned data set is commonly referred to as a *library.* In z/OS, libraries are used for storing source programs, system and application control parameters, JCL, and executable modules. There are very few system data sets that are not libraries.

A PDS loses space whenever a member is updated or added. As a result, z/OS users regularly need to compress a PDS to recover the lost space.

A z/OS user defines a PDS through JCL with a data set organization of PO (DSORG=PO), which stands for partitioned organization.

Why is a PDS structured like that?

The PDS structure was designed to provide efficient access to libraries of related members, whether they be load modules, program source modules, JCL or many other types of content.

Many system data sets are also kept in PDS data sets, especially when they consist of many small, related files. For example, the definitions for ISPF panels are kept in PDS data sets.

A primary use of ISPF is to create and manipulate PDS data sets. These data sets typically consist of source code for programs, text for manuals or help screens, or JCL to allocate data sets and run programs.

Advantages of a PDS

A PDS data set offers a simple and efficient way to organize related groups of sequential files. A PDS has the following advantages for z/OS users:

- Grouping of related data sets under a single name makes z/OS data management easier. Files stored as members of a PDS can be processed either individually or all the members can be processed as a unit.
- Because the space allocated for z/OS data sets always starts at a track boundary on disk, using a PDS is a way to store more than one small data set on a track. This saves you disk space if you have many data sets that are much smaller than a track. A track is 56,664 bytes for 3390 disk device.

- Members of a PDS can be used as sequential data sets, and they can be appended (or *concatenated*) to sequential data sets.
- Multiple PDS data sets can be concatenated to form large libraries.
- PDS data sets are easy to create with JCL or ISPF; they are easy to manipulate with ISPF utilities or TSO commands.

Disadvantages of a PDS

PDS data sets are simple, flexible, and widely used. However, some aspects of the PDS design affect both performance and the efficient use of disk storage, as follows:

- **Wasted space.** When a member in a PDS is replaced, the new data area is written to a new section within the storage allocated to the PDS. When a member is deleted, its pointer is deleted too, so there is no mechanism to reuse its space. This wasted space is often called *gas* and must be periodically removed by reorganizing the PDS, for example, by using the utility IEBCOPY to compress it.
- **Limited directory size.** The size of a PDS directory is set at allocation time. As the data set grows, it can acquire more space in units of the amount you specified as its secondary space. These extra units are called *secondary extents*.

  However, you can only store a fixed number of member entries in the PDS directory because its size is fixed when the data set is allocated. If you need to store more entries than there is space for, you have to allocate a new PDS with more directory blocks and copy the members from the old data set into it. This means that when you allocate a PDS, you must calculate the amount of directory space you need.
- **Lengthy directory searches.** As mentioned earlier, an entry in a PDS directory consists of a name and a pointer to the location of the member. Entries are stored in alphabetical order of the member names. Inserting an entry near the front of a large directory can cause a large amount of I/O activity, as all the entries behind the new one are moved along to make room for it.

  Entries are also searched sequentially in alphabetical order. If the directory is very large and the members small, it might take longer to search the directory than to retrieve the member when its location is found.

4.9.3 What is a PDSE?

A PDSE is a partitioned data set extended. It consists of a directory and zero or more members, just like a PDS. It can be created with JCL, TSO/E, and ISPF, just like a PDS, and can be processed with the same access methods. PDSE data sets are stored only on DASD, not tape.

The directory can expand automatically as needed, up to the addressing limit of 522,236 members. It also has an index, which provides a fast search for member names. Space from deleted or moved members is automatically reused for new members, so you do not have to compress a PDSE to remove wasted space. Each member of a PDSE can have up to 15,728,639 records. A PDSE can have a maximum of 123 extents, but it cannot extend beyond one volume.

When a directory of a PDSE is in use, it is kept in processor storage for fast access.

PDSE data sets can be used in place of nearly all PDS data sets that are used to store data. But PDSE format is not intended as a PDS replacement. A PDSE cannot be used to store load modules, but it can be used to contain programs in structures called *program objects*.

PDS versus PDSE

In many ways, a PDSE is similar to a PDS. Each member name can be eight bytes long. For accessing a PDS directory or member, most PDSE interfaces are indistinguishable from PDS interfaces. Both PDS and PDSE data sets are processed using the same access methods (BSAM, QSAM, BPAM).

However, PDSE data sets have a different internal format, which gives them increased usability. You can use a PDSE in place of a PDS to store data, or to store programs in the form of program objects. A program object is similar to a load module in a PDS. A load module cannot reside in a PDSE and be used as a load module. One PDSE cannot contain a mixture of program objects and data members.

PDSE data sets have several features that can improve user productivity and system performance. The main advantage of using a PDSE over a PDS is that a PDSE automatically reuses space within the data set without the need for anyone to periodically run a utility to reorganize it.

Also, the size of a PDS directory is fixed regardless of the number of members in it, while the size of a PDSE directory is flexible and expands to fit the members stored in it.

Further, the system reclaims space automatically whenever a member is deleted or replaced, and returns it to the pool of space available for allocation to other members of the same PDSE. The space can be reused without having to do an IEBCOPY compress.

Other advantages of PDSE data sets follow:

- PDSE members can be shared. This makes it easier to maintain the integrity of the PDSE when modifying separate members of the PDSE at the same time.
- Reduced directory search time. The PDSE directory, which is indexed, is searched using that index. The PDS directory, which is organized alphabetically, is searched sequentially. The system might cache in storage directories of frequently used PDSE data sets.
- Creation of multiple members at the same time. For example, you can open two DCBs to the same PDSE and write two members at the same time.

- PDSE data sets contain up to 123 extents. An extent is a continuous area of space on a DASD storage volume, occupied by or reserved for a specific data set.
- When written to DASD, logical records are extracted from the user's blocks and reblocked. When read, records in a PDSE are reblocked into the block size specified in the DCB. The block size used for the reblocking can differ from the original block size.

4.10 What is VSAM?

The term *Virtual Storage Access Method* (VSAM) applies to both a data set type and the access method used to manage various user data types.

As an access method, VSAM provides much more complex functions than other disk access methods. VSAM keeps disk records in a unique format that is not understandable by other access methods.

VSAM is primarily for applications. It is not used for source programs, JCL, or executable modules. VSAM files cannot be routinely displayed or edited with ISPF.

You can use VSAM to organize records into four types of data sets: key-sequenced, entry-sequenced, linear, or relative record. The primary difference among these types of data sets is the way their records are stored and accessed.

VSAM data sets are briefly described as follows:

- *Key Sequence Data Set* (KSDS). This is the most common use for VSAM. Each record has one or more key fields and a record can be retrieved (or inserted) by key value. This provides random access of data. Records are variable length.
- *Entry Sequence Data Set* (ESDS). This form of VSAM keeps records in sequential order. Records can be accessed sequentially, directly by relative byte address (RBA) or by one or more VSAM alternate indexes. It is used by IMS, DB2, and z/OS UNIX.
- *Relative Record Data Set* (RRDS). This VSAM format allows retrieval of records by number; record 1, record 2, and so forth. This provides random access and assumes the application program has a way to derive the desired record numbers.
- *Linear Data Set* (LDS). This is, in effect, a byte-stream data set and is the only form of a byte-stream data set in traditional MVS. A number of z/OS system functions use this format heavily but it is rarely used by application programs.

There are several additional methods of accessing data in VSAM that are not listed here. Most application use of VSAM is for keyed data.

VSAM works with a logical data area known as a Control Interval (CI) that is diagrammed in Figure 4-2. The default CI size is 4K bytes, but it can be up to 32K bytes.

The CI contains data records, unused space, Record Descriptor Fields (RDF), and a CI Descriptor Field.

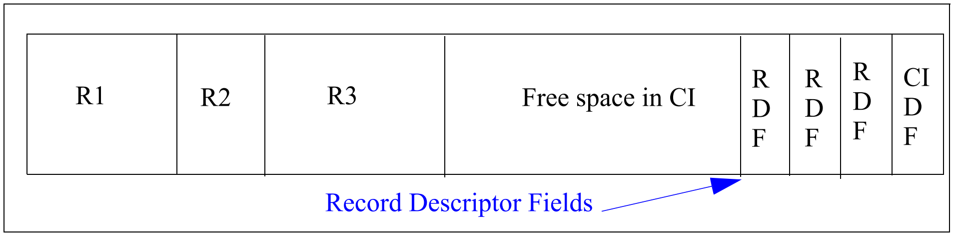


Figure 4-2 Simple VSAM control interval

A control interval may be constructed from smaller disk blocks, but this level of detail is internal to VSAM. Multiple control intervals are placed in a Control Area (CA). A VSAM data set consists of control areas and index records. One form if index record is the sequence set, which is the lowest-level indexes pointing to control intervals.

Typical use of VSAM permits an application to insert new records in a data set. The structure that permits this is interesting:

- KSDS records in a control interval are in ascending order, based on the primary key of the records. A given control interval contains all the data set records between the record with the lowest key and the record with the highest key in that control interval.
- The RDF fields contain the length of each logical record and the offset (into the CI) for that record. The CIDF contains information about the free space in the CI.
- When the VSAM data set is first allocated, the user can specify the amount of free space to leave in each control interval. A percentage of free (empty) control intervals in each control area can also be specified.
- When a new record is to be inserted (in key order) VSAM uses the key records to determine the control interval holding records in the appropriate key range.
- If the control interval has sufficient free space the logical records in the control interval are shifted (if necessary) and the new record is inserted.
- If the control interval does not have sufficient space, a control interval split occurs. A free control interval (in the same control area) is located and approximately half the records in the data control interval are moved to the empty control interval and the new record is inserted into the original control interval.
- Index pointers are adjusted as necessary to include the newly used control interval.
- If no free control interval is found in the control area, a control area split occurs. This follows roughly the same logic as a control interval split. If a free control area does not exist (or cannot be added to the data set), the data insert fails and the application most likely fails.

VSAM data is always variable length and records are automatically blocked in control intervals. The RECFM attributes (F, FB, V, VB, U) do not apply to VSAM, nor does the BLKSIZE attribute.

The Access Method Services (AMS) utility is used to define and delete VSAM structures, such as files and indexes. Example 4-1 shows an example.

Example 4-1 Defining a VSAM KSDS using AMS

```
DEFINE CLUSTER -
(NAME(VWX.MYDATA) -
VOLUMES(VSER02) -
RECORDS(1000 500)) -
 DATA -
(NAME(VWX.KSDATA) -
 KEYS(15 0) -
RECORDSIZE(250 250) - FREESPACE(20 10) -
BUFFERSPACE(25000) ) -
INDEX -
(NAME(VWX.KSINDEX) -
CATALOG (UCAT1)
```

There are many details of VSAM processing that are not included in this brief description. Most processing is handled transparently by VSAM; the application program merely retrieves, updates, deletes or adds records based on key values.

4.11 How data sets are named

When you allocate a new data set (or when the operating system does), you must give the data set a unique name.

A data set name can be one name segment, or a series of joined name segments. Each name segment represents a level of qualification. For example, the data set name VERA.LUZ.DATA is composed of three name segments. The first name on the left is called the high-level qualifier (HLQ), the last name on the right is the lowest-level qualifier (LLQ).

Segments or *qualifiers* are limited to eight characters, the first of which must be alphabetic (A to Z) or *special* (# @ $). The remaining seven characters are either alphabetic, numeric (0 - 9), special, a hyphen (-). Name segments are separated by a period (.).

Including all name segments and periods, the length of the data set name must not exceed 44 characters. Thus, a maximum of 22 name segments can make up a data set name.

For example, the following names are not valid data set names:

- Name with a qualifier that is longer than eight characters (HLQ.ABCDEFGHI.XYZ)
- Name containing two successive periods (HLQ..ABC)
- Name that ends with a period (HLQ.ABC.)
- Name that contains a qualifier that does not start with an alphabetic or special character (HLQ.123.XYZ)

The HLQ for a user's data sets is typically controlled by the security system. There are a number of conventions for the remainder of the name. These are *conventions*, not rules, but are widely used. They include the following:

- The letters LIB somewhere in the name indicate that the data set is a library. The letters PDS are a lesser-used alternative for this.
- The letters CNTL, JCL, or JOB somewhere in the name typically indicate the data set contains JCL (but might not be exclusively devoted to JCL.)
- The letters LOAD, LOADLIB, or LINKLIB in the name indicate that the data set contains executables. (A library with z/OS executable modules must be devoted solely to executable modules.)
- The letters PROC, PRC, or PROCLIB indicate a library of JCL procedures. These are described in 6.6, "JCL procedures (PROCs)" on page 6-9.
- Various combinations are used to indicate source code for a specific language, for example COBOL, Assembler, FORTRAN, PL/I, JAVA, C, or C++.
- A portion of a data set name may indicate a specific project, such as PAYROLL.
- Using too many qualifiers is considered poor practice. For example,

  ```
  P390A.A.B.C.D.E.F.G.H.I.J.K.L.M.N.O.P.Q.R.S
  ```
  is a valid data set name (upper case, does not exceed 44 bytes, no special characters) but it is not very meaningful. A good practice is for a data set name to contain three or four qualifiers.

4.12 Catalogs and VTOCs

z/OS uses a catalog and a volume table of contents (VTOC) on each DASD to manage the storage and placement of data sets; these are described in the sections that follow:

- What is a VTOC?
- "What is a catalog?" on page 4-17

z/OS also makes it possible to group data sets based on historically related data, as described in "What is a generation data group?" on page 4-20.

4.12.1 What is a VTOC?

z/OS requires a particular format for disks, which is shown in Figure 4-3 on page 4-17. Record 1 on the first track of the first cylinder provides the label for the disk. It contains the 6-character volume serial number (volser) and a pointer to the *Volume Table Of Contents* (VTOC), which can be located anywhere on the disk.

The VTOC lists the data sets that reside on its volume, along with information about the location and size of each data set, and other data set attributes. A standard z/OS utility program, ICKDSF, is used to create the label and VTOC.

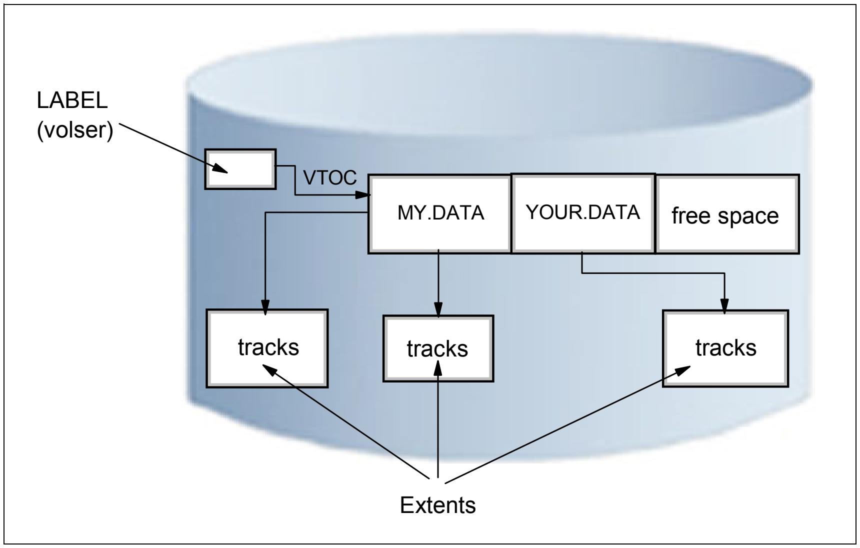


Figure 4-3 Disk label, VTOC, extents

When a disk volume is initialized with ICKDSF, the owner can specify the location and size of the VTOC. The size can be quite variable, ranging from a few tracks to perhaps 100 tracks, depending on the expected use of the volume. More data sets on the disk volume require more space in the VTOC.

The VTOC also has entries for all the free space on the volume. Allocating space for a data set (described later) causes system routines to examine the free space records, update them, and create a new VTOC entry. Data sets are always an integral number of tracks (or cylinders) and start at the beginning of a track (or cylinder).

4.12.2 What is a catalog?

A catalog describes data set attributes and indicates the volumes on which a data set is located. Data sets can be cataloged, uncataloged, or recataloged. All system-managed DASD data sets are cataloged automatically in a catalog. Cataloging of data sets on magnetic tape is not required but usually it simplifies users jobs. All data sets can be cataloged in a catalog.

In z/OS, the master catalog and user catalogs store the locations of data sets by name. This means that data set names must be unique. Both disk and tape data sets can be cataloged.

To find a data set that you have requested, z/OS must know three pieces of information:

- Data set name
- Volume name
- Unit (the volume device type, such as a 3390 disk or 3590 tape)

You can specify all three values on ISPF panels or in JCL. However, the unit device type and the volume are often not relevant to an end user or application program. A system catalog is used to store and retrieve UNIT and VOLUME location of a data set. In its most basic form a catalog can provide the unit device type and volume name for any data set that is cataloged. A system catalog provides a simple look up function. With this facility the user need only provide a data set name.

Master catalogs and user catalogs

A z/OS system always has at least one master catalog. If a z/OS system has a single catalog, this catalog would be the master catalog and the location entries for all data sets would be stored in it. A single catalog, however, would be neither efficient nor flexible, so a typical z/OS system uses a master catalog and numerous *user catalogs* connected to it as shown in Figure 4-4.

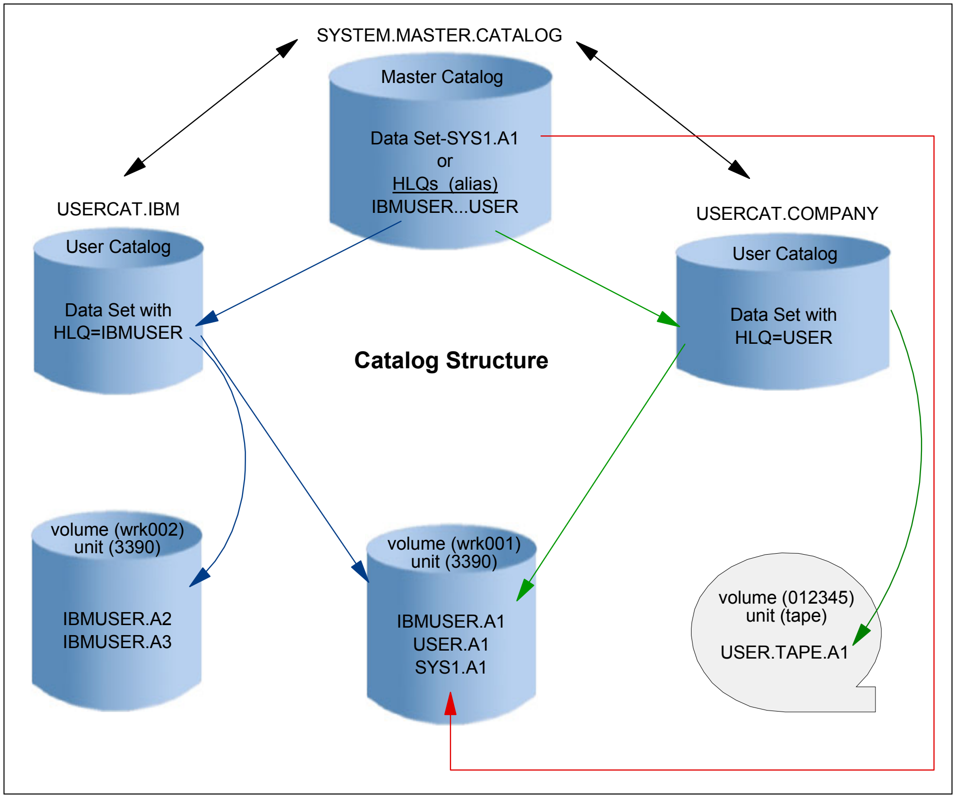


Figure 4-4 Catalog concept

A user catalog stores the name and location of a data set (dsn/volume/unit). The master catalog usually stores only a data set HLQ with the name of the user catalog, which contains the location of all data sets prefixed by this HLQ. The HLQ is called an alias.

In Figure 4-4, the data set name of the master catalog is `SYSTEM.MASTER.CATALOG`. This master catalog stores the full data set name and location of all data sets with a SYS1 prefix such as SYS1.A1. Two HLQ (alias) entries were defined to the master catalog, IBMUSER and USER. The statement that defined that IBMUSER included the data set name of the user catalog containing all the fully qualified IBMUSER data sets with their respective location. The same is true for USER HLQ (alias).

When SYS1.A1 is requested, the master catalog returns the location information, volume(WRK001) and unit(3390), to the requestor. When IBMUSER.A1 is requested, the master catalog redirects the request to USERCAT.IBM, then USERCAT.IBM returns the location information to the requestor.

Take, as a further example, the define statements below.

```
DEFINE  ALIAS ( NAME ( IBMUSER ) RELATE ( USERCAT.IBM ) )
DEFINE  ALIAS ( NAME ( USER ) RELATE ( USERCAT.COMPANY ) )
```

These are used to place IBMUSER and USER alias names in the master catalog with the name of the user catalog that will store the fully qualified data set names and location information. If IBMUSER.A1 is cataloged, a JCL statement to allocate it to the job would be:

```
//INPUT DD DSN=IBMUSER.A1,DISP=SHR
```

If IBMUSER.A1 is not cataloged, a JCL statement to allocate it to the job would be:

```
//INPUT DD DSN=IBMUSER.A1,DISP=SHR,VOL=SER=WRK001,UNIT=3390
```

As a general rule, all user data sets in a z/OS installation are cataloged. Uncataloged data sets are rarely needed and their use is often related to recovery problems or installation of new software. Data sets created through ISPF are automatically cataloged.

What is a generation data group?

In z/OS, it is possible to catalog successive updates or generations of related data. They are called generation data groups (GDGs).

Each data set within a GDG is called a generation data set (GDS) or generation. A generation data group (GDG) is a collection of historically related non-VSAM data sets that are arranged in chronological order. That is, each data set is historically related to the others in the group.

Within a GDG, the generations can have like or unlike DCB attributes and data set organizations. If the attributes and organizations of all generations in a group are identical, the generations can be retrieved together as a single data set.

There are advantages to grouping related data sets. For example:

- All of the data sets in the group can be referred to by a common name.
- The operating system is able to keep the generations in chronological order.
- Outdated or obsolete generations can be automatically deleted by the operating system.

Generation data sets have sequentially ordered absolute and relative names that represent their age. The operating system's catalog management routines use the absolute generation name. Older data sets have smaller absolute numbers. The relative name is a signed integer used to refer to the latest (0), the next to the latest (-1), and so forth, generation.

For example, a data set name LAB.PAYROLL(0) refers to the most recent data set of the group; LAB.PAYROLL(-1) refers to the second most recent data set; and so forth. The relative number can also be used to catalog a new generation (+1). A generation data group (GDG) base is allocated in a catalog before the generation data sets are cataloged. Each GDG is represented by a GDG base entry.

Note: For new non-system-managed data sets, if you do not specify a volume and the data set is not opened, the system does not catalog the data set. New system-managed data sets are always cataloged when allocated, with the volume assigned from a storage group.

4.13 z/OS UNIX file systems

z/OS UNIX System Services (z/OS UNIX) allows z/OS to access UNIX files. UNIX applications also can access z/OS data sets. You can use the hierarchical file system (HFS), z/OS Network File System (z/OS NFS), zSeries File System (zFS), and temporary file system (TFS) with z/OS UNIX.

A z/OS UNIX file system is hierarchical and byte-oriented. Finding a file in the file system is done by searching a directory or a series of directories (see Figure 4-5). There is no concept of a z/OS catalog that points directly to a file.

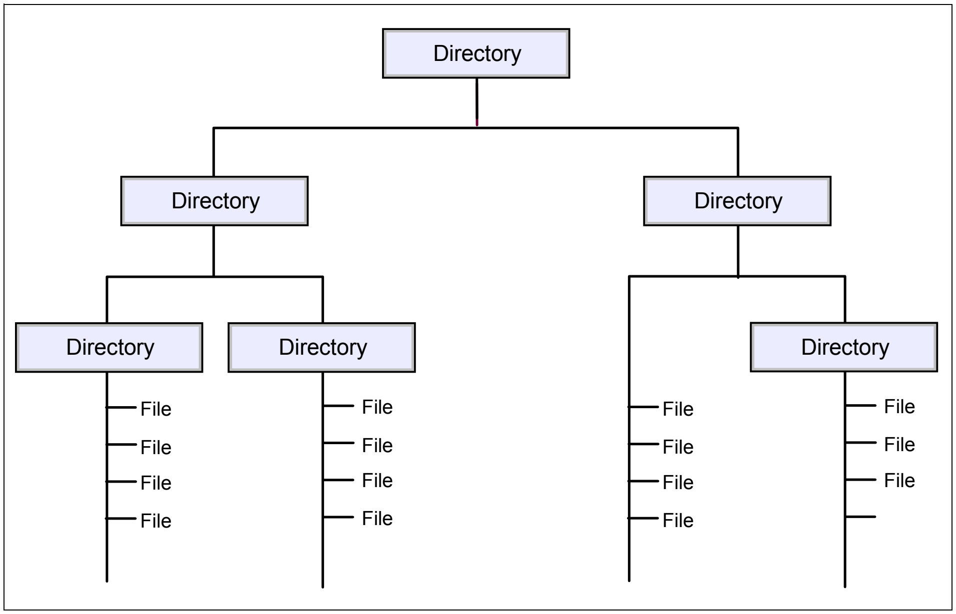


Figure 4-5 Hierarchical file system structure

A path name identifies a file and consists of directory names and a file name. A fully qualified file name, which consists of the name of each directory in the path to a file plus the file name itself, can be up to 1023 bytes long. The hierarchical file system allows for file names in mixed case.

The path name is constructed of individual directory names and a file name separated by the forward-slash character, for example:

/dir1/dir2/dir3/MyFile

Like UNIX, z/OS UNIX is case-sensitive for file and directory names. For example, in the same directory, the file MYFILE is a different file than MyFile.

The files in the hierarchical file system are sequential files, and are accessed as byte streams. A record concept does not exist with these files other than the structure defined by an application.

The *hierarchical file system* (HFS) data set which contains the hierarchical file system is a z/OS data set type. HFS data sets and z/OS data sets can reside on the same DASD volume. Example 4-2 shows the defining of an HFS data set.

Example 4-2 Creating an HFS data set using JCL

```
//FSJOB JOB
//STEP1 EXEC PGM=IEFBR14
//MKFS1 DD DSNAME=FILE.SYSTEM.FS001,
//     DISP=(NEW,KEEP),
//     DSNTYPE=HFS,
//     SPACE=(CYL(100,100,1)),
//     DATACLAS=FILESYS,
// MGMTCLAS=NEVER,STORCLAS=SECURE
```

The integration of the HFS file system with existing z/OS file system management services provides automated file system management capabilities that might not be available on other UNIX platforms. This integration allows file owners to spend less time on tasks such as backup and restore of entire file systems.

4.13.1 z/OS data sets versus file system files

Many elements of UNIX have analogs in the z/OS operating system. Consider, for example, that the organization of a user catalog is analogous to a user directory (/u/ibmuser) in the file system.

In z/OS, the user prefix assigned to z/OS data sets points to a user catalog. Typically, one user owns all the data sets whose names begin with his user prefix. For example, the data sets belonging to the TSO/E user ID IBMUSER all begin with the high-level qualifier (prefix) IBMUSER. There could be different data sets named IBMUSER.C, IBMUSER.C.OTHER and IBMUSER.TEST.

In the UNIX file system, ibmuser would have a user directory named /u/ibmuser. Under that directory there could be a subdirectory named /u/ibmuser/c, and /u/ibmuser/c/pgma would point to the file pgma (see Figure 4-6).

Of the various types of z/OS data sets, a partitioned data set (PDS) is most like a user directory in the file system. In a partitioned data set such as IBMUSER.C, you could have members (files) PGMA, PGMB, and so on. For example, you might have IBMUSER.C(PGMA) and IBMUSER.C(PGMB). Along the same lines, a subdirectory such as /u/ibmuser/c can hold many files, such as pgma, pgmb, and so on.

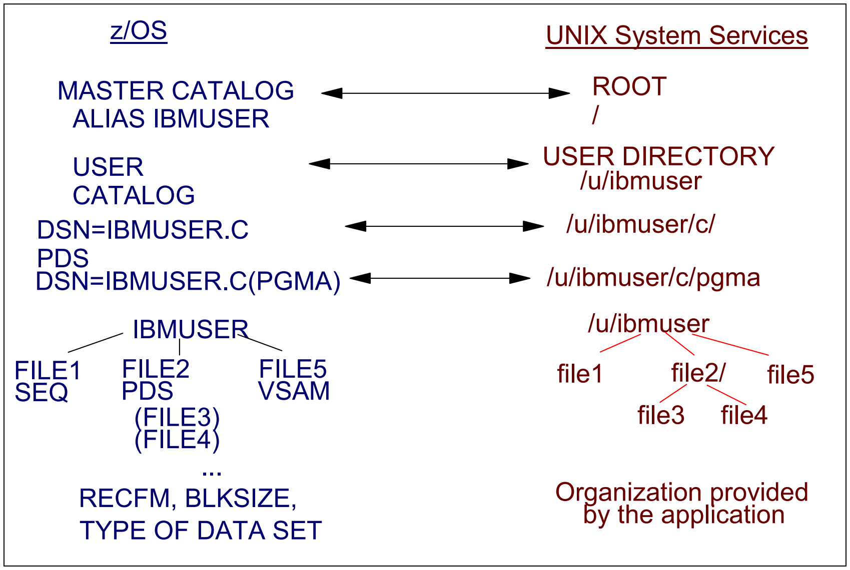


Figure 4-6 Comparison of z/OS data sets and file system files

All data written to the hierarchical file system can be read by all programs as soon as it is written. Data is written to a disk when a program issues an **fsync()**.

4.14 Summary

A data set is a collection of logically related data; it can be a source program, a library of programs, or a file of data records used by a processing program. *Data records* are the basic unit of information used by a processing program.

z/OS data sets are allocated in contiguous extents on a disk to enhance performance. Users must define the amount of space to be allocated for a data set (before it is used). A data set may occupy more than one extent and extents may be added dynamically.

Almost all z/OS data processing is record-oriented. Byte stream files are not present in traditional processing, although they are a standard part of z/OS UNIX. z/OS records (and physical blocks) are in one of several well-defined formats. Most data sets have DCB attributes that include the record format (RECFM—F, FB, V, VB, U), the maximum logical record length (LRECL), and the maximum block size (BLKSIZE).

z/OS data sets have names with a maximum of 44 uppercase characters, divided by periods into qualifiers with a maximum of 8 bytes per qualifier name. The high-level qualifier (HLQ) may be fixed by system security controls, but the rest of a data set name is assigned by the user. A number of conventions exist for these names.

An existing disk data set can be located when the data set name, volume and device type are known. These requirements can be shortened to knowing only the data set name if the data set is cataloged. The system catalog is a single logical function, although its data may be spread across the master catalog and many user catalogs. In practice, almost all disk data sets are cataloged. One side effect of this is that all (cataloged) data sets must have unique names.

Virtual storage access method (VSAM) is an access method that provides much more complex functions than other disk access methods. VSAM is primarily for applications and cannot be edited through ISPF.

z/OS libraries are known as partitioned data sets (PDS or PDSE) and contain members. Source programs, system and application control parameters, JCL, and executable modules are almost always contained in libraries.

A file in the UNIX file system can be either a text file or a binary file. In a text file each line of text is separated by a newline delimiter. A binary file consists of sequences of binary words (byte stream), and no record concept other than the structure defined by an application exists. An application reading the file is responsible for interpreting the format of the data.

z/OS treats an entire UNIX file system hierarchy as a collection of data sets. Each data set is a mountable file system.

Key terms in this chapter		
block size	catalog	data set
high level qualifier or HLQ	library	logical record length or LRECL
member	PDS and PDSE	record format or RECFM
system managed storage or SMS	virtual storage access method or VSAM	VTOC

4.15 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What is a data set? What types of data sets are used on z/OS?
2. Why are unique data set names needed by z/OS?
3. Why is a PDS used?
4. Do application programs use libraries? Why or why not?
5. What determines the largest file a traditional UNIX system can use? Is there an equivalent limit for z/OS?
6. Do you see any patterns in temporary data set names?
7. What special characters are used to identify a temporary data set in a JCL stream?
8. The data set information provided by ISPF 3.4 is helpful. Why not display all the information on the basic data set list panel?
9. We created a source library in one of the exercises and specified fixed-length 80-byte records. Why?
10. The disk volume used for class exercises is *WORK02*. Can you allocate a data set on other volumes? On any volume?
11. What information about a data set is stored in a catalog? What DD operands would be required if a data set were not in the catalog?
12. What is the difference between the master catalog and a user catalog?

4.16 Exercises

The lab exercises in this chapter help you develop skills in working with data sets through ISPF. These skills are required for performing lab exercises in the remainder of this text.

To perform the lab exercises, you or your team require a TSO user ID and password (for assistance, see the instructor).

The exercises teach the following:

- "Exploring ISPF Option 3.4" on page 4-26
- "Allocating a data set with ISPF 3.2" on page 4-27
- "Copying a source library" on page 4-28
- "Working with data set members" on page 4-28
- "Listing a data set (and other ISPF 3.4 options)" on page 4-29
- "Performing a catalog search" on page 4-30

4.16.1 Exploring ISPF Option 3.4

One of the most useful ISPF panels is Option 3.4. This terminology means, starting from the ISPF primary option menu, select Option 3 (Utilities) and then Option 4 (Dslist, for data set list). This sequence can be abbreviated by entering `3.4` in the primary menu, or `=3.4` from any panel.

Many ISPF users work almost exclusively within the 3.4 panels. We cover some of the 3.4 functions here and others in subsequent exercises in this text. Use care in working with 3.4 options; they can effect changes on a individual or system-wide basis.

z/OS users typically use ISPF Option 3.4 to check the data sets on a DASD volume or examine the characteristics of a particular data set. Users might need to know:

- What data sets are on this volume?
- How many different data set types are on the volume?
- What are the DCB characteristics of a particular file?

Let's answer these questions using *WORK02* is a sample volume, or another volume as specified by your instructor:

1. In the 3.4 panel, enter *WORK02* in the Volume Serial field. Do not enter anything on the Option==> line or in the Dsname Level field.
2. Use PF8 and PF7 to scroll through the data set list that is produced.
3. Use PF11 and PF10 to scroll sideways to display more information. This is not really scrolling in this case; the additional information is obtained only when PF11 or PF10 are used.

   The first PF11 display provides tracks, percent used, XT, and device type. The XT value is the number of *extents* used to obtain the total tracks shown. The ISPF utility functions can determine the amount of space actually used for some data sets and this is shown as a percentage when possible.

   The next PF11 display shows the DCB characteristics: DSORG, RECFM, LRECL, and BLKSIZE.

PS	Sequential data set (QSAM, BSAM)
PO	Partitioned data set
VS	VSAM data set
blank	Unknown organization (or no data exists)

   RECFM, LRECL, and BLKSIZE should be familiar. In some cases, usually when a standard access method is not used or when no data has been written, these parameters cannot be determined. VSAM data sets have no direct equivalent for these parameters and are shown as question marks.

Look at another volume for which a larger range of characteristics can be observed. The instructor can supply volume serial numbers.

4.16.2 Allocating a data set with ISPF 3.2

ISPF provides a convenient method for allocating data sets. In this exercise, you create a new library that you can use later in the course for storing program source data. The new data sets should be placed on the *WORK02* volume and should be named *yourid*.LIB.SOURCE (where *yourid* is your student user ID).

For this exercise, assume that 10 tracks of primary space and 5 tracks for secondary extents is sufficient, and that 10 directory blocks is sufficient. Furthermore, we know we want to store 80-byte fixed-length records in the library. We can do this as follows:

1. Start at the ISPF primary menu.
2. Go to option 3.2 - or go to option 3 (Utilities) and then go to option 2 (Data Set).
3. Type the letter `A` in the Option ==> field, but do not press Enter yet.
4. Type the name of the new data set in the Data Set Name field, but do not press Enter yet. The name can be with single quotes (for example, '*yourid*.LIB.SOURCE') or without quotes (LIB.SOURCE) so that TSO/ISPF automatically uses the current TSO user ID as the HLQ.
5. Enter *WORK02* in the Volume Serial field and press Enter.
6. Complete the indicated fields and press Enter:
   - Space Units = TRKS
   - Primary quantity = 10
   - Secondary quantity = 5
   - Directory blocks = 10
   - Record format = FB
   - Record length = 80
   - Block size = 0 (this tells z/OS to select an optimum value)
   - Data set type = PDS

This should allocate a new PDS on *WORK02*. Check the upper right corner, where the following message appears:

```
Menu  RefList  Utilities  Help
------------------------------------------------------------------------
------
                               Data Set Utility            Data set
allocated
Option ===>

    A Allocate new data set                C Catalog data set
.....
```

4.16.3 Copying a source library

A number of source programs are needed for exercises in *ZPROF*.ZSCHOLAR.LIB.SOURCE on *WORK02*. There are several ways to copy data sets (including libraries). We can use the following:

1. Go to ISPF option 3.3 (Utilities, Move/Copy).
2. On the first panel:
   - Type `C` in the Option==> field.
   - Type `'`*`ZPROF`*`.ZSCHOLAR.LIB.SOURCE'` in the Data Set Name field. The single quotes are needed in this case.
   - The Volume Serial is not needed because the data set is cataloged.
   - Press Enter.
3. On the second panel:
   - Type `'`*`yourid`*`.LIB.SOURCE'` in the Data Set Name field and press Enter.
4. This should produce a panel listing all the members in the input library:
   - Type `S` before every member name and then press Enter.

This copies all the indicated members from the source library to the target library. We could have specified `'`*`ZPROF`*`.ZSCHOLAR.LIB.SOURCE(*)'` for the input data set; this would automatically copy all the members. This is one of the few cases where *wild cards* are used with z/OS data set names.

4.16.4 Working with data set members

There are several ways to add a new member to a library. We want to add a member named `TEST2` to your library that we previously edited:

1. From the ISPF primary menu, use option 2.
2. Enter the name of your library without specifying a member name, for example *yourid*.JCL.
3. This provides a list of member names already in the library.
4. Verify that member `EDITTEST` has the same contents you used earlier:
   - If necessary, scroll so you can see member name `EDITTEST`.
   - Move the cursor to the left of this line.
   - Type `S` and press the 3270 Enter key.
   - Look at your earlier work to assure yourself it is unchanged.
   - Press PF3 to exit ("back out of") member `EDITTEST`. You will see the library member name list again.

5. Enter `S TEST2` in the command line at the top of the screen and press 3270 Enter. (`S TEST2` can be read as "select TEST2.") This creates member TEST2 and places the screen in input mode.
6. Enter a few lines of anything, using the commands and functions we discussed earlier.
7. Press PF3 to save `TEST2` and exit from it.
8. Press PF3 again to exit from the ISPF Edit function.

Hereafter we will simply say "Enter xxx" when editing something or using other ISPF functions. This means (1) type `xxx`, and (2) press the 3270 Enter key. The New Line key (which has Enter printed on it) is used only to position the cursor on the screen.

> **Tip:** The 3270 Enter key and the PC Enter key can be confusing. Most 3270 emulators permit the user to assign these functions to any key on the keyboard, and we assume that the 3270 Enter function is assigned to the right-hand Ctrl key. Some zSeries users prefer to have the large PC Enter key perform the 3270 Enter function and have Shift-Enter (and/or perhaps the numeric Enter key) perform the 3270 New Line function.

4.16.5 Listing a data set (and other ISPF 3.4 options)

Go to the ISPF 3.4 panel. Enter *yourid* in the Dsname Level field and press Enter. This should list all the cataloged data sets in the system with the indicated HLQ. An alternative is to leave the Dsname Level field blank and enter *WORK02* in the Volume Serial field; this lists all the data sets on the indicated volume. (If both fields are used, the list will contain only the cataloged data sets with a matching HLQ that appear on the specified volume.)

A number of functions can be invoked by entering the appropriate letter before a data set name. For example:

Position the cursor before one of the data set names and press PF1 (Help).

The Help panel lists all the line commands that can be used from the data set name list of the 2.4 panel. Do not experiment with these without understanding their functions. Not all of these functions are relevant to this class. The relevant commands are:

E Edit the data set.
B Browse the data set.
D Delete the data set.
R Rename the data set.
Z Compress a PDS library to recover lost space.
C Catalog the data set.
U Uncatalog the data set.

When a member list is displayed (as when a library is edited or browsed) several line commands are available:

S Select this member for editing or browsing.
R Rename the member.
D Delete the member.

4.16.6 Performing a catalog search

The ISPF 3.4 option can be used for catalog searches on partial names. Use PF-1 Help to learn more about this important function, as follows:

1. Select option 3.4.
2. Press PF1 for help and select **Display a data set list**. Press Enter to scroll through the information panels.
3. Then select **Specifying the DSNAME LEVEL**. Press Enter to scroll through the information panels.
4. Press PF3 to exit from the Help function.

Notice that the 3.4 DSNAME LEVEL field does not use quotes and the current TSO/E user ID is not automatically used as a prefix for names in this field. This is one of the few exceptions to the general rule for specifying data set names in TSO.

5

Batch processing and JES

Objective: As a mainframe professional, you will need to understand the ways in which the system processes your company's core applications, such as payroll. Such workloads are usually performed through *batch processing,* which involves executing one or more *batch jobs* in a sequential flow.

Further, you will need to understand how the *job entry subsystem* (JES) enables batch processing. JES helps z/OS receive jobs, schedule them for processing, and determine how job output is processed.

After completing this chapter, you will be able to:

- Give an overview of batch processing and how work is initiated and managed in the system.
- Explain how JES governs the flow of work through a z/OS system.

5.1 What is batch processing?

There is no direct counterpart to z/OS batch processing in PC or UNIX systems. Batch processing is for those frequently used programs that can be executed with minimal human interaction. They are typically executed at a scheduled time or on an as-needed basis. Perhaps the closest comparison is with processes run by an AT or CRON command in UNIX, although the differences are significant.

Work running on z/OS is called a *job*, and job control language or JCL is used to describe certain attributes of the job to z/OS. A z/OS batch job consists of programs that run in environments described by JCL. After the JCL is submitted to the system, there is normally no further human interaction with the job until it is complete.

The use of JCL is covered in detail in Chapter 6, “Using JCL and SDSF” , but for now understand that JCL is the means by a batch job requests resources and services from the operating system.

5.2 What is JES?

z/OS uses a *job entry subsystem* or *JES* to manage the flow of work in the system. More specifically, JES manages the input and output job queues and data.

For example, JES handles the following aspects of batch processing for z/OS:

- Receive jobs into the operating system
- Schedule them for processing by z/OS
- Control their output processing

JES is the component of the operating system that provides supplementary job management, data management, and task management functions such as scheduling, control of job flow, and spooling.

z/OS has two versions of job entry systems: JES2 and JES3. Of these, JES2 is most common by far and is used throughout this text. JES2 and JES3 have many functions and features, but their most basic functions are as follows:

- Accept jobs submitted in various ways:
  - From ISPF through the SUBMIT command
  - Over a network
  - From a running program, which can submit other jobs through the JES internal reader
  - From a card reader (very rare!)
- Queue jobs waiting to be executed. Multiple queues can be defined for various purposes.

- Queue jobs for an *initiator,* which is a JES program that requests the next job in the appropriate queue.
- Accept printed output from the job while it is running and queue the output.
- Optionally, send output to a printer, or save it on *spool* for PSF, InfoPrint, or another output manager to retrieve.

JES uses one or more disk data sets for *spooling*. JES combines multiple spool data sets (if present) into a single conceptual data set. The internal format is not in a standard access-method format and is not written or read directly by applications. Input jobs and printed output from many jobs are stored in the single (conceptual) spool data set. In a small z/OS system the spool data sets might be a few hundred cylinders of disk space; in a large installation they might be many complete volumes of disk space.

Spool simply means to queue and hold data in card-image format (for input) or printed format (for output). JES2 is described more fully in 5.5, “Job and output management with JES” on page 5-6.

The basic elements of batch processing are shown in Figure 5-1.

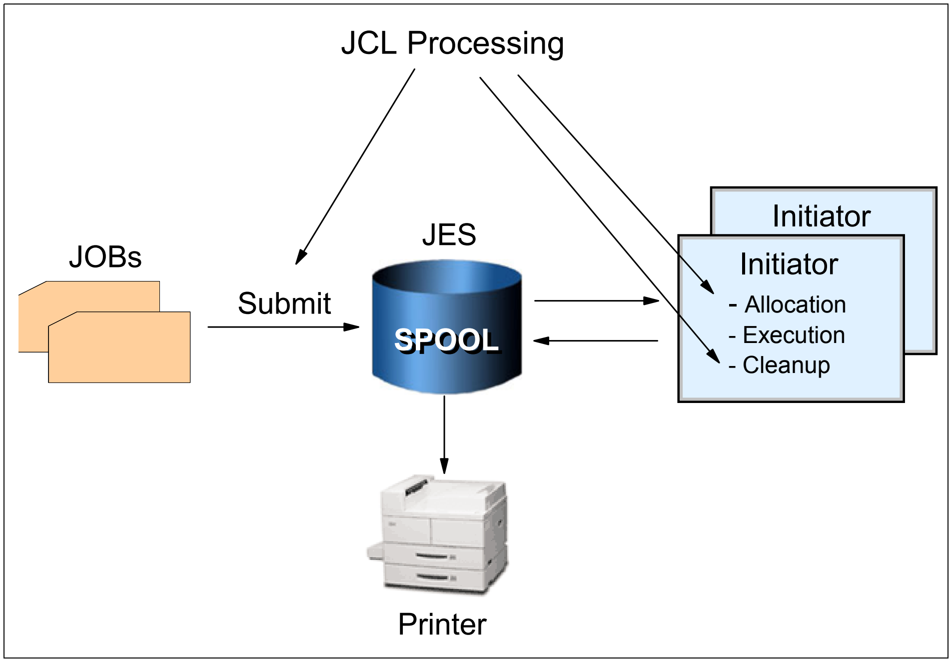


Figure 5-1 Basic batch flow

The *initiator* is an integral part of z/OS that reads, interprets, and executes the JCL. It is normally running in several address spaces (as *multiple initiators*). An initiator manages the running of batch jobs, one at a time, in the same address space. If ten initiators are active (in ten address spaces), then ten batch jobs can run at the same time. JES does some JCL processing, but the initiator does the key JCL work

The jobs in Figure 5-1 on page 5-3 represent JCL and perhaps data intermixed with the JCL. Source code input for a compiler is an example of data (the source statements) that might be intermixed with JCL. Another example is an accounting job that prepares the weekly payroll for different divisions of a firm (presumably, the payroll application program is the same for all divisions, but the input and master summary files may differ).

The diagram represents the jobs as punched cards (using the conventional symbol for punched cards) although real punched card input is very rare now. Typically, a job consists of card images (80-byte fixed-length records) in a member of a partitioned data set.

5.3 What an initiator does

To run multiple jobs asynchronously, the system must perform a number of functions:

- Select jobs from the input queues (JES does this).
- Ensure that multiple jobs (including TSO users and other interactive applications) do not conflict in data set usage.
- Ensure that single-user devices, such as tape drives, are allocated correctly.
- Find the executable programs requested for the job.
- Clean up after the job ends and then request the next job.

Most of this work is done by the initiator, based on JCL information for each job. The most complex function is to ensure there are no conflicts due to data set utilization. For example, if two jobs try to write in the same data set at the same time (or one reads while the other writes), there is a conflict.[1] This event would normally result in corrupted data. The primary purpose of JCL is to tell an initiator what is needed for the job.

The prevention of conflicting data set usage is critical to z/OS and is one of the defining characteristics of the operating system. When the JCL is properly constructed (which is the usual case) the prevention of conflicts is automatic. For example, if job A and job B must both write to a particular data set, the system (through the initiator) does not permit both jobs to run at the same time. Instead, whichever job starts first causes an initiator attempting to run the other job to wait until the first job completes.

[1] There are cases where such usage is correct and JCL can be constructed for these cases. In the case of simple batch jobs, such conflicts are normally unacceptable.

5.4 Why z/OS uses symbolic file references

z/OS normally uses a symbolic file system,[2] and this is another defining characteristic of this operating system. It applies a naming redirection between a data set-related name used in a program and the actual data set used during execution of that program. This is illustrated in Figure 5-2 on page 5-5.

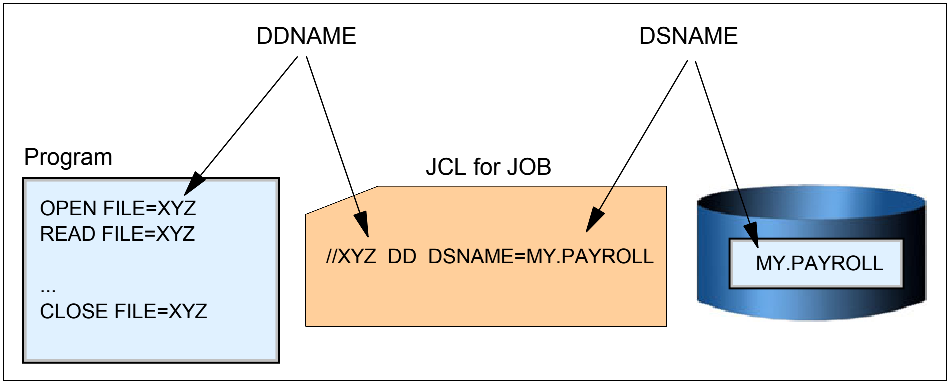


Figure 5-2 DDNAME and DSNAME

In this illustration we have a program, in some arbitrary language, that needs to open and read a data set.[3] When the program is written, the name XYZ is arbitrarily selected to reference the data set. The program can be compiled and stored as an executable. When someone wants to run the executable program, a JCL statement must be supplied that relates the name XYZ to an actual data set name. This JCL statement is a DD statement. The symbolic name used in the program is a DDNAME and the real name of the data set is a DSNAME.

The program can be used to process different input data sets simply by changing the DSNAME in the JCL. This becomes significant for large commercial applications that might use dozens of data sets in a single execution of the program. A payroll program for a large corporation is a good example. This can be an exceptionally complex application that might use hundreds of data sets. The same program might be used for different divisions in the corporation by running it with different JCL. Likewise, it can be tested against special test data sets by using a different set of JCL.

[2] This applies to normal traditional processing. Some languages, such as C, have defined interfaces that bypass this function.

[3] The pseudo-program uses the term *file*, as is common in most computer languages.

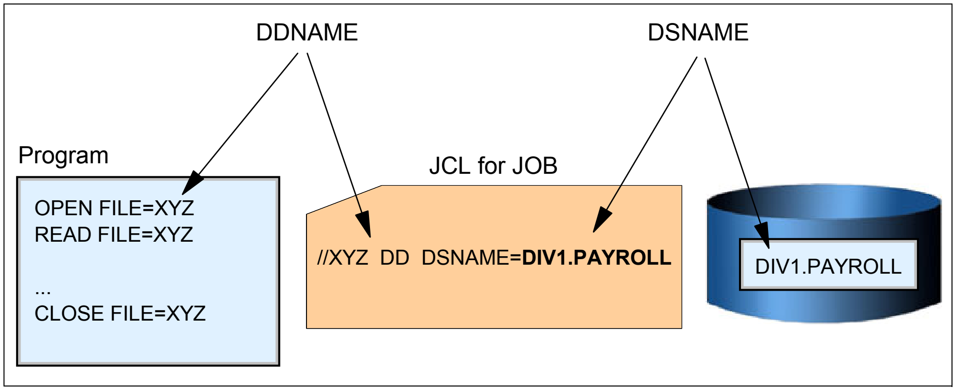


Figure 5-3 Symbolic file name - same program, but another data set

The firm could use the same company-wide payroll application program for different divisions and only change a single parameter in the JCL card (the `DD DSN=DIV1.PAYROLL`). The parameter value DIV1.PAYROLL would cause the program to access the data set for Division 1. This example demonstrates the power and flexibility afforded by JCL and symbolic data set names.

This DDNAME--JCL--DSNAME processing applies to all traditional z/OS work although it might not always be apparent. For example, when ISPF is used to edit a data set, ISPF builds the internal equivalent of a DD statement and then opens the requested data set with the DD statement. The ISPF user does not see this processing—it takes place "transparently."[4]

5.5 Job and output management with JES

Let us further explore the JES concept through two scenarios.

5.5.1 *Scenario 1*

Imagine that you are a z/OS application programmer and you are developing a program for non-skilled users. Your program is supposed to read a couple of files, write to another couple of files, and produce a printed report. This program will run as a batch job on z/OS.

What sorts of functions are needed in the operating system to fulfill the requirements of your program? And, how will your program access those functions?

[4] Again, we are ignoring some of the operational characteristics of the z/OS UNIX interfaces of z/OS. The discussion here applies to all traditional z/OS usage.

First, you need a sort of special language to inform the operating system about your needs. On z/OS, this is *Job Control Language* (JCL). The use of JCL is covered in detail in Chapter 6, "Using JCL and SDSF" , but for now assume that JCL provides the means for you to request resources and services from the operating system for a batch job.

Specifications and requests you might make for a batch job include the functions you need to compile and execute the program, and allocate storage for the program to use as it runs.

With JCL, you can specify the following:

- Who you are (important for security reasons).
- Which resources (programs, files, memory) and services are needed from the system to process your program. You might, for example, need to do the following:
  - Load the compiler code in memory.
  - Make accessible to the compiler your source code, that is, when the compiler asks for a read, your source statements are brought to the compiler memory.
  - Allocate some amount of memory to accommodate the compiler code, I/O buffers, and working areas.
  - Make accessible to the compiler an output disk data set to receive the object code.
  - Make accessible to the compiler a print file where it will tell you your eventual mistakes.
  - Conditionally, have z/OS load the newly created object code into memory (but skip this step if the compilation failed).
  - Allocate some amount of memory for your program to use.
  - Make accessible to your program all the input and output files.
  - Make accessible to your program a printer for eventual messages.

In turn, you require the operating system to:

- Understand JCL (correcting eventual errors).
- Convert JCL to control blocks that describe the required resources.
- Allocate the required resources (programs, memory, files).
- Schedule the execution on a timely basis, for example, your program only runs if the compilation succeeds.
- Free the resources when the program is done.

The parts of z/OS that perform these tasks are JES and a batch initiator program.

Think of JES as the manager of the jobs waiting in a queue. It manages the priority of the set of jobs and their associated input data and output results. The initiator uses the statements on the JCL cards to specify the resources required of each individual job once it has been released (dispatched) by JES.

Your JCL as described is called a job—in this case formed by two sequential steps, the compilation and execution. The steps in a job are always executed sequentially. The job must be submitted to JES in order to be executed. In order to make your task easier, z/OS provides a set of procedures in a data set called SYS1.PROCLIB. A procedure is a set of JCL statements that are ready to be executed.

Example 5-1 on page 5-8 shows a JCL procedure that can compile, link-edit and execute a program (these steps are described later in Chapter 7, “Designing and developing applications for z/OS”). The first step identifies the COBOL compiler, as declared in `//COBOL  EXEC  PGM=IGYCRCTL`. The statement `//SYSLIN  DD` describes the output of the compiler (object module).

The object module is the input for the second step, which performs link-editing (through program IEWL). Link-editing is needed to resolve external references and *bring in* or *link* the previously developed common routines (a type of code re-use).

In the third step, the program is executed.

Example 5-1   Procedure to compile, linkedit, and execute programs

```
//IGYWCLG PROC LNGPRFX='IGY.V3R2M0',SYSLBLK=3200,
//             LIBPRFX='CEE',GOPGM=GO
//*
//**********************************************************************
//*                                                                    *
//*  Enterprise COBOL for z/OS and OS/390                              *
//*                 Version 3 Release 2 Modification 0                 *
//*                                                                    *
//*  LICENSED MATERIALS - PROPERTY OF IBM.                             *
//*                                                                    *
//*  5655-G53 5648-A25 (C) COPYRIGHT IBM CORP. 1991, 2002              *
//*  ALL RIGHTS RESERVED                                               *
//*                                                                    *
//*  US GOVERNMENT USERS RESTRICTED RIGHTS - USE,                      *
//*  DUPLICATION OR DISCLOSURE RESTRICTED BY GSA                       *
//*  ADP SCHEDULE CONTRACT WITH IBM CORP.                              *
//*                                                                    *
//**********************************************************************
//*
//COBOL  EXEC PGM=IGYCRCTL,REGION=2048K
//STEPLIB  DD  DSNAME=&LNGPRFX..SIGYCOMP,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,UNIT=SYSDA,
//             DISP=(MOD,PASS),SPACE=(TRK,(3,3)),
//             DCB=(BLKSIZE=&SYSLBLK)
//SYSUT1   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//LKED   EXEC PGM=HEWL,COND=(8,LT,COBOL),REGION=1024K
//SYSLIB   DD  DSNAME=&LIBPRFX..SCEELKED,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
```

```
//SYSLIN   DD  DSNAME=&&LOADSET,DISP=(OLD,DELETE)
//         DD  DDNAME=SYSIN
//SYSLMOD  DD  DSNAME=&&GOSET(&GOPGM),SPACE=(TRK,(10,10,1)),
//             UNIT=SYSDA,DISP=(MOD,PASS)
//SYSUT1   DD  UNIT=SYSDA,SPACE=(TRK,(10,10))
//GO     EXEC PGM=*.LKED.SYSLMOD,COND=((8,LT,COBOL),(4,LT,LKED)),
//             REGION=2048K
//STEPLIB  DD  DSNAME=&LIBPRFX..SCEERUN,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//CEEDUMP  DD  SYSOUT=*
//SYSUDUMP DD  SYSOUT=*
```

To invoke a procedure, you need to write some simple JCL as shown in Example 5-2. In this JCL we are adding other DD statements, one of which is:

```
//COBOL.SYSIN DD *
```

It contains the COBOL source code.

Example 5-2 COBOL program

```
//COBOL1 JOB (POK,999),MGELINSKI,MSGLEVEL=(1,1),MSGCLASS=X,
//  CLASS=A,NOTIFY=&SYSUID
/*JOBPARM SYSAFF=*
// JCLLIB   ORDER=(IGY.SIGYPROC)
//*
//RUNIVP EXEC IGYWCLG,PARM.COBOL=RENT,REGION=1400K,
//             PARM.LKED='LIST,XREF,LET,MAP'
//COBOL.STEPLIB DD DSN=IGY.SIGYCOMP,
//             DISP=SHR
//COBOL.SYSIN DD *
       IDENTIFICATION DIVISION.
       PROGRAM-ID.    CALLIVP1.
       AUTHOR.       STUDENT PROGRAMMER.
       INSTALLATION.  MY UNIVERSITY
       DATE-WRITTEN.  JUL 27, 2004.
       DATE-COMPILED.
       /
       ENVIRONMENT DIVISION.
       CONFIGURATION SECTION.
       SOURCE-COMPUTER.  IBM-390.
       OBJECT-COMPUTER.  IBM-390.

       PROCEDURE DIVISION.
           DISPLAY "***** HELLO WORLD *****" UPON CONSOLE.
           STOP RUN.

//GO.SYSOUT DD SYSOUT=*
```

```
000028 //
```

During the execution of a step, the program is controlled by z/OS, not by JES (Figure 5-4). Also, a spooling function is needed at this point in the process.

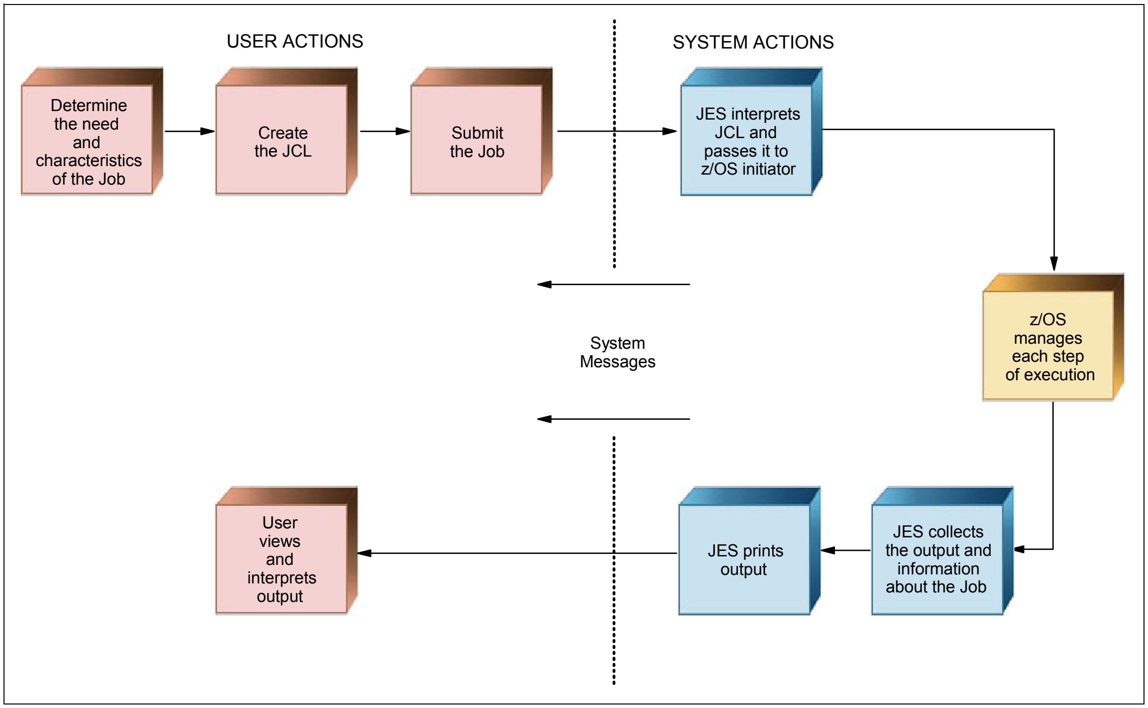


Figure 5-4 Related actions with JCL

Spooling is the means by which the system manipulates its work, including:

- Using storage on *direct access storage devices* (DASD) as buffer storage to reduce processing delays when transferring data between peripheral equipment and a program to be run.
- Reading and writing input and output streams on an intermediate device for later processing or output.
- Performing an operation such as printing while the computer is busy with other work.

There are two sorts of spooling: input and output. Both improve the performance of the program reading the input and writing the output.

To implement input spooling in JCL, you declare `// DD *`, which defines one file whose content records are in JCL between the `// DD *` statement and the `/*` statements. All the logical records must have 80 characters. In this case this file is read and stored in a specific JES2 spool area (a huge JES file on disk) as shown in Figure 5-5.

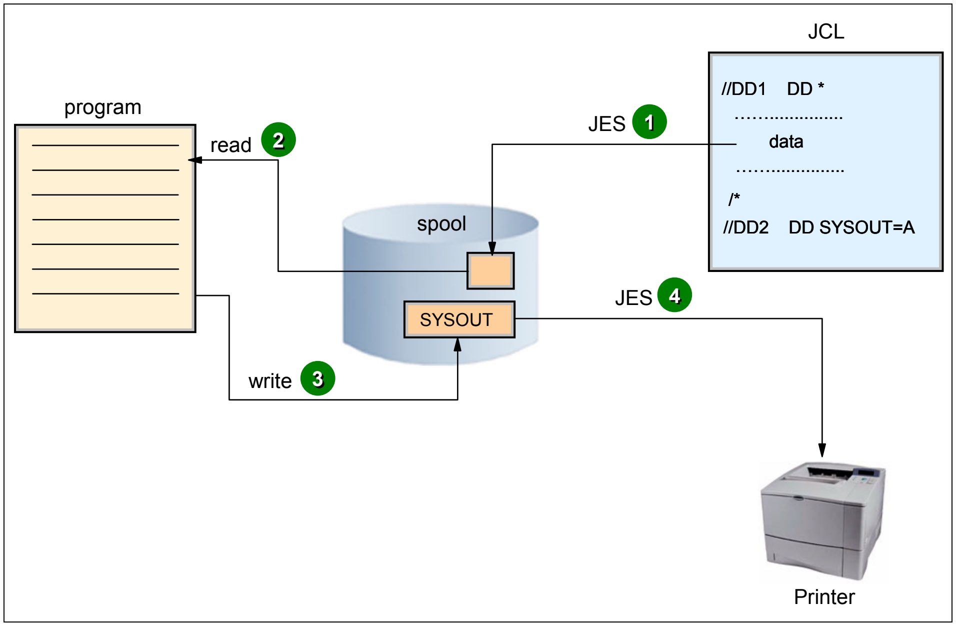


Figure 5-5 Spooling

Later, when the program is executed and asks to read this data, JES2 picks up the records in the spool and delivers them to the program (at disk speed).

To implement output spooling in JCL, you specify the keyword SYSOUT on the DD statement. SYSOUT defines an empty file in the spool, allocated with logical records of 132 characters in a printed format (EBCDIC/ASCII/UNICODE). This file is allocated by JES when interpreting a DD card with the SYSOUT keyword, and used later for the step program. Generally, after the end of the job, this file is printed by a JES function.

5.5.2 *Scenario 2*

Suppose now that you want to make a backup of one master file and then update the master file with records read-in from another file (the *update* file). If so, you need a job with two steps. In Step 1, your job reads the master file, and writes it to tape. In Step 2, another program (which can be written in COBOL) is executed to read a record from the update file and searches for its match in the master file. The program updates the existing record (if it finds a match) or adds a new record if needed.

In this scenario, what kind of functions are needed in the operating system to meet your requirements?

Build a job with two steps that specify the following:

- Who you are
- What resources are needed by the job, such as the following:
  - Load the backup program (that you already have compiled).
  - How much memory the system needs to allocate to accommodate the backup program, I/O buffers, and working areas.
  - Make accessible to the backup program an output tape data set to receive the backup, a copy, and the master file data set itself.
  - At program end indicate to the operating system that now your update program needs to be loaded into memory (however, this should not be done if the backup program failed).
  - Make accessible to the update program the update file and master file.
  - Make accessible to your program a printer for eventual messages.

Your JCL must have two steps, the first one indicating the resources for the backup program, and the second for the update program (Figure 5-6).

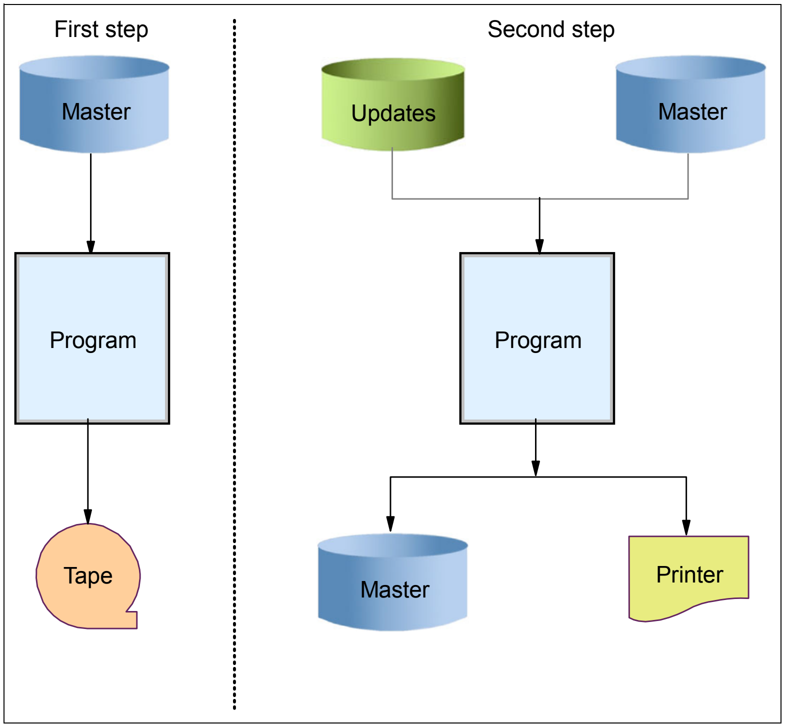


Figure 5-6 Scenario 2

Logically, the second step will not be executed if the first one fails for any reason. The second step will have a `// DD SYSOUT` statement to indicate the need for output spooling.

The jobs are only allowed to start when there are enough resources available. In this way, the system is made more efficient: JES manages jobs before and after running the program; the base control program manages jobs during processing.

Two types of job entry subsystems are offered with z/OS: JES2 and JES3. This section discusses JES2. For a brief comparison of JES2 and JES3, see 5.7, "JES2 compared to JES3" on page 5-16.

5.6 Job flow through the system

Let us look in more detail at how a job is processed through the combination of JES and a batch initiator program.

During the life of a job, JES2 and the base control program of z/OS control different phases of the overall processing. The job queues contain jobs that are waiting to run, currently running, waiting for their output to be produced, having their output produced, and waiting to be purged from the system.

Generally speaking, a job goes through the following phases:

- Input
- Conversion
- Processing
- Output
- Print/punch (hard copy)
- Purge

Figure 5-7 on page 5-14 shows the different phases of a job during batch processing.

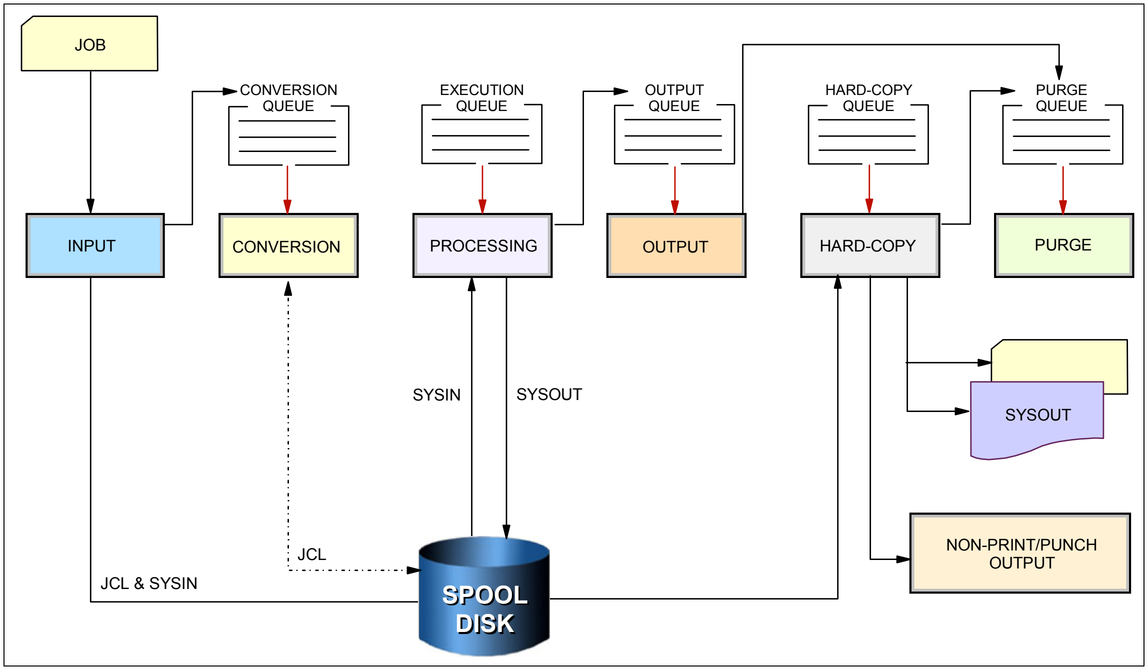


Figure 5-7 Job flow through the system

1. Input phase

   JES2 accepts jobs, in the form of an input stream, from input devices, from other programs through internal readers, and from other nodes in a job entry network.

   The internal reader is a program that other programs can use to submit jobs, control statements, and commands to JES2. Any job running in z/OS can use an internal reader to pass an input stream to JES2. JES2 can receive multiple jobs simultaneously through multiple internal readers.

   The system programmer defines internal readers to be used to process all batch jobs other than *started Tasks* (STCs) and TSO requests.

   JES2 reads the input stream and assigns a job identifier to each JOB JCL statement. JES2 places the job's JCL, optional JES2 control statements, and SYSIN data onto DASD data sets called spool data sets. JES2 then selects jobs from the spool data sets for processing and subsequent running.

2. Conversion phase

   JES2 uses a converter program to analyze a job's JCL statements. The converter takes the job's JCL and merges it with JCL from a procedure library. The procedure library can be defined in the JCLLIB JCL statement, or system/user procedure libraries can be defined in the PROCxx DD statement of the JES2 startup procedure. Then, JES2 converts the composite JCL into converter/interpreter text that both JES2 and the initiator can recognize. Next, JES2 stores the converter/interpreter text on the spool data set. If JES2 detects any JCL errors, it issues messages, and the job is queued for output processing rather than execution. If there are no errors, JES2 queues the job for execution.

3. Processing phase

   In the processing phase, JES2 responds to requests for jobs from the initiators. JES2 selects jobs that are waiting to run from a job queue and sends them to initiators.

   An initiator is a system program belonging to z/OS, but controlled by JES or by w*orkload manager* (WLM) that starts a job allocating the required resources to allow it to compete with other jobs that are already running (WLM is described in 5.8, “What is Workload Manager?” on page 5-16).

   JES2 initiators are initiators that are started by the operator or by JES2 automatically when the system initializes. They are defined to JES2 through JES2 initialization statements. The installation associates each initiator with one or more job classes in order to obtain an efficient use of available system resources. initiators select jobs whose classes match the initiator-assigned class, obeying the priority of the queued jobs.

   WLM initiators are started by the system automatically based on performance goals, relative importance of the batch workload, and the capacity of the system to do more work. The initiators select jobs based on their service class and the order they were made available for execution. Jobs are routed to WLM initiators through a JOBCLASS JES2 initialization statement.

4. Output phase

   JES2 controls all SYSOUT processing. SYSOUT is system-produced output; that is, all output produced by, or for, a job. This output includes system messages that must be printed, as well as data sets requested by the user that must be printed or punched. After a job finishes, JES2 analyzes the characteristics of the job’s output in terms of its output class and device setup requirements; then JES2 groups data sets with similar characteristics. JES2 queues the output for print or punch processing.

5. Hardcopy phase

   JES2 selects output for processing from the output queues by output class, route code, priority, and other criteria. The output queue can have output that is to be processed locally or at a remote location. After processing all the output for a particular job, JES2 puts the job on the purge queue.

6. Purge phase

   When all processing for a job completes, JES2 releases the spool space assigned to the job, making the space available for allocation to subsequent jobs. JES2 then issues a message to the operator indicating that the job has been purged from the system.

5.7 JES2 compared to JES3

As previously mentioned, IBM provides two kinds of job entry subsystems: JES2 and JES3. In many cases, JES2 and JES3 perform similar functions. They read jobs into the system, convert them to internal machine-readable form, select them for processing, process their output, and purge them from the system.

In a mainframe installation that has only on processor, JES3 provides tape setup, dependent job control, and deadline scheduling for users of the system, while JES2 in the same system would require its users to manage these activities through other means.

In an installation with a multi-processor configuration, there are noticeable differences between the two, mainly in how JES2 exercises independent control over its job processing functions. That is, within the configuration, each JES2 processor controls its own job input, job scheduling, and job output processing.

In cases where multiple z/OS systems are clustered (a *sysplex*), it is possible to configure JES2 to share spool and checkpoint data sets with other JES2 systems in the same sysplex. This configuration is called *Multi-Access Spool* (MAS).

In contrast, JES3 exercises centralized control over its processing functions through a single global JES3 processor. This global processor provides all job selection, scheduling, and device allocation functions for all the other JES3 systems. The centralized control that JES3 exercises provides increased job scheduling control, deadline scheduling capabilities, and increased control by providing its own device allocation.

Most installations use JES2, as do the examples in this text.

5.8 What is Workload Manager?

The workload manager (WLM) component of z/OS manages the processing of workload in the system according to the company's business goals, such as response time. WLM also manages the use of system resources, such as processors and storage, to accomplish these goals.

Before the introduction of WLM, the only way to inform z/OS about the company's business goals was for the system programmer to translate from high-level objectives about what work needs to be done into the extremely technical terms that the system can understand. This translation required highly skilled staff, and could be protracted, error-prone, and eventually in conflict with the original business goals.

Further, it was often difficult to predict the effects of changing a system setting, which might be required, for example, following a system capacity increase. This could result in unbalanced resource allocation, that is, feeding work one resource while starving it of another. This way of operation, known as compatibility mode, was becoming unmanageable as new workloads were introduced, and as multiple systems were being managed together in parallel sysplex processing and data sharing environments.

When in goal mode system operation, WLM provides fewer, simpler, and more consistent system externals that reflect goals for work expressed in terms commonly used in business objectives, and WLM and Service Request Manager (SRM) match resources to meet those goals by constantly monitoring and adapting the system. Workload Manager provides a solution for managing workload distribution, workload balancing, and distributing resources to competing workloads.

5.9 Summary

Batch processing is the most fundamental function of z/OS. Many batch jobs are usually run in parallel and JCL is used to control the operation of each job. Correct use of JCL parameters (especially the DISP parameter in DD statements) allows parallel, asynchronous execution of jobs that may need access to the same data sets.

An *initiator* is a system program that processes JCL, sets up the necessary environment in an address space, and runs a batch job in the same address space. Multiple initiators (each in an address space) permit the parallel execution of batch jobs.

A goal of an operating system is to process work while making the best use of system resources. To achieve this goal, resource management is needed during key phases:

- Before job processing, reserve input and output resources for jobs
- During job processing, manage spooled SYSIN and SYSOUT data
- After job processing, free all resources used by the completed jobs, making the resources available to other jobs.

z/OS shares with JES the management of jobs and resources. JES receives jobs into the system, schedules them for processing by z/OS, and controls their output processing. JES is the manager of the jobs waiting in a queue. It manages the priority of the jobs and their associated input data and output results. The initiator uses the statements in the JCL records to specify the resources required of each individual job after it is released (dispatched) by JES.

During the life of a job, both JES and the z/OS base control program control different phases of the overall processing. Jobs are managed in queues: Jobs that are waiting to run (conversion queue), currently running (execution queue), waiting for their output to be produced (output queue), having their output produced (hard-copy queue) and waiting to be purged from the system (purge queue).

Key terms in this chapter		
alias	batch processing	execution
initiator	job entry subsystem or JES	output
procedure	purge	queue
spool	symbolic file system	workload manager or WLM

5.10 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What is batch processing?
2. What are two defining characteristics of z/OS that are discussed in this chapter?
3. Why does z/OS need a JES?
4. During the life of a job, what types of processing does JES2 typically perform?
5. What role does WLM play in a z/OS system?

6

Using JCL and SDSF

Objective: As a technical professional in the world of mainframe computing, you will need to know JCL, the language that tells z/OS which resources will be needed to process a batch job or start a system task.

After completing this chapter, you will be able to:

- Explain how JCL works with the system, an overview of JCL coding techniques, and a few of the more important statements and keywords
- Create a simple job and submit it for execution
- Check the output of your job through SDSF

6.1 What is JCL?

Job Control Language (JCL) is used to tell the system what program to execute, followed by a description of program inputs and outputs. It is possible to *submit* JCL for batch processing or *start* a JCL PROC, which is considered a started task. The details of JCL can be complicated but the general concepts are quite simple. Also, a small subset of JCL accounts for at least 90% of what is actually used. This chapter discusses selected JCL options.

While application programmers need some knowledge of JCL, the production control analyst responsible must be *highly* proficient with JCL, to create, monitor, correct and re-run the company's daily batch workload.

There are three basic JCL statements:

JOB Provides a name to the system for this batch workload. It can optionally include accounting information and a few job-wide parameters.

EXEC Provides the name of a program to execute. There can be multiple EXEC statements in a job. Each EXEC statement within the same job is a *job step*.

DD The Data Definition provides inputs and outputs to the execution program on the EXEC statement. This statement links a data set or other I/O device or function to a DDNAME coded in the program. DD statements are associated with a particular job step.

Figure 6-1 shows the basic JCL coding syntax.

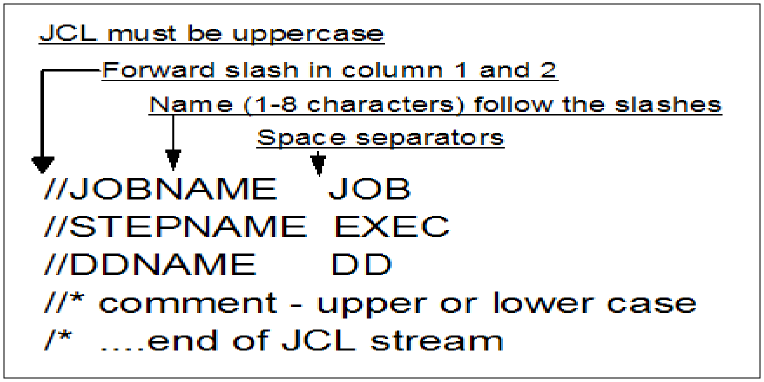


Figure 6-1 Basic JCL coding syntax

Example 6-1 shows some sample JCL.

Example 6-1 JCL example

```
//MYJOB     JOB 1
//MYSORT    EXEC PGM=SORT
//SORTIN    DD DISP=SHR,DSN=ZPROF.AREA.CODES
//SORTOUT   DD SYSOUT=*
//SYSOUT    DD SYSOUT=*
//SYSIN     DD *
  SORT FIELDS=(1,3,CH,A)
/*
```

In Chapter 3, "TSO/E, ISPF, and UNIX: Interactive facilities of z/OS" , we executed the same routine from the TSO READY prompt. Each JCL DD statement is equivalent to the TSO ALLOCATE command. Both are used to associate a z/OS data set with a *ddname,* which is recognized by the program as an input or output. The difference in method of execution is that TSO executes the sort in the foreground while JCL is used to execute the sort in the background, or *batch*.

When submitted for execution:

MYJOB Is a job name the system associates with this workload.

MYSORT Is the stepname, which instructs the system to execute the SORT program.

SORTIN On the DD statement, this is the ddname. The SORTIN ddname is coded in the SORT program as a program input. The data set name (DSN) on this DD statement is *ZPROF*.AREA.CODES. The data set can be shared (DISP=SHR) with other system processes. The data content of *ZPROF*.AREA.CODES is SORT program input.

SORTOUT This ddname is the SORT program output.

SYSOUT SYSOUT=* specifies to send system output messages to the Job Entry Subsystem (JES) print output area. It is possible to send the output to a data set.

SYSIN DD * is another input statement. It specifies that what follows is data or control statements. In this case, it is the sort instruction telling the SORT program which fields of the SORTIN data records are to be sorted.

We use *JCL statements* in this text; some z/OS users use the older term *JCL card,* even though the JCL resides in a disk library.

6.2 JOB, EXEC, and DD operands

The JOB, EXEC and DD statements have many operands to allow the user to specify instructions and information. Describing them all would fill an entire book (such as the IBM publication, *z/OS JCL Reference*).

This section provides only a brief description of a few of the more commonly used operands for the JOB, EXEC, and DD statements.

6.2.1 JOB operands

JOB JCL statement `//MYJOB JOB 1` is a job card with name `MYJOB`. The `1` is a job card accounting field that can be subject to system exits that might be used for charging system users. Some common JOB card operands that could be included are:

REGION=	Value requesting specific memory resources allocated to this job
NOTIFY=	Message can be sent to a TSO user ID, following job completion
USER=	Job will assume the authority of the user ID specified
TYPRUN=	It is possible to submit the job on HOLD, to be released later
CLASS=	Direct job JCL statement to a specific input queue, installation specific
MSGCLASS=	Direct job output to a specific output queue, installation specific
MSGLEVEL=	Controls amount of system message to be received

Example:

```
//MYJOB JOB 1,NOTIFY=&SYSUID,REGION=6M
```

6.2.2 EXEC operands

The EXEC JCL statement `//MYSTEP EXEC` has a *stepname* of `MYSTEP`. Following the EXEC is either `PGM=`(executable program name) or a JCL PROC name. When a JCL PROC is present, then the operands will be the variable substitutions required by the JCL PROC. Common operands found on the `EXEC PGM=` statement are:

PARM=	Parameters known by and passed to the program.
COND=	Boolean logic for controlling execution of other EXEC steps in this job....IF, THEN, ELSE JCL statements exist that are superior to using COND; however, lots of old JCL may exist in production environments using this statement.
TIME=	Imposes a time limit.

Example:

```
//MYSTEP EXEC PGM=SORT
```

6.2.3 DD operands

The DD JCL statement `//MYDATA DD` has a ddname of `MYDATA`.

DD, the Data Definition, has significantly more operands than the JOB or EXEC statements. The DD JCL statement can be involved with many aspects of defining or describing attributes of the program inputs or outputs. Some common DD statement operands are:

DSN=	The name of the data set; this can include creation of temporary data sets or a reference back to the data set name.
DISP=	Data set disposition at step start (new, shr, old, mod), at step end (catlg, keep, delete, pass) and if the step abnormally ends (catlg, keep, delete, pass).
SPACE=	Amount of disk storage requested for a new data set.
SYSOUT=	Defines a print location (and the output queue or data set).
VOL=SER=	Volume name, disk name or tape name
UNIT=	System disk, tape, special device type, or esoteric (local name).
DEST=	Routes output to a remote destination.
DCB=	Data set control block, numerous sub operands. Most common suboperands: LRECL= Logical record length. Number of bytes/characters in each record. RECFM= Record format, fixed, blocked, variable, etc. BLOCKSIZE= Store records in a block of this size, typically a multiple of LRECL. A value of 0 will let the system pick the best value. DSORG= Data set organization—sequential, partitioned, etc.
LABEL=	Tape label expected (No Label or Standard Label followed by data set location). A tape can store multiple data sets; each data set on the tape is in a file position. The first data set on tape is file 1.
DUMMY	Results in a null input or throwing away data written to this ddname.
*	Input data or control statements follow—a method of passing data to a program from the JCL stream.
*,DLM=	Everything following is data input (even //) until the two alphanumeric or special characters specified are encountered in column 1.

6.3 Data set disposition, DISP operand

All JCL parameters are important, but the DISP function is perhaps the most important for DD statements. Among its other uses, the DISP parameter advises the system about data set enqueuing needed for this job to prevent conflicting use of the data set by other jobs.

The complete parameter has these fields:

```
DISP=(status,normal end,abnormal end)
DISP=(status,normal end)
DISP=status
```

where status can be NEW, OLD, SHR, or MOD:

NEW	Indicates that a new data set is to be created. This job has exclusive access to the data set while it is running. The data set must not already exist.
OLD	Indicates that the data set already exists and that this job is to have exclusive access to it while it is running.
SHR	Indicates that the data set already exists and that several concurrent jobs can share access while they are running. All the concurrent jobs must specify SHR.
MOD	Indicates that the data set already exists and the current job must have exclusive access while it is running. If the current job opens the data set for output, the output will be appended to the current end of the data set.

The *normal end* parameter indicates what to do with the data set (the *disposition*) if the current job step ends normally. Likewise, the abnormal end parameter indicates what to do with the data set if the current job step abnormally ends.

The options are the same for both parameters:

DELETE	Delete (and uncatalog) the data set at the end of the job step
KEEP	Keep (but not catalog) the data set at the end of the job step
CATLG	Keep and catalog the data set at the end of the job step
UNCATLG	Keep the data set but uncatalog it at the end of the job step
PASS	Allow a later job step to specify a final disposition.

The default disposition parameters (for normal and abnormal end) are to leave the data set as it was before the job step started. (The catalog function was described previously in 4.12.2, "What is a catalog?" on page 4-17.)

6.3.1 Creating new data sets

If the DISP parameter for a data set is NEW, you must provide more information, including:

- A data set name.
- The type of device for the data set.
- A volser if it is a disk or labeled tape.
- If a disk is used, the amount of space to be allocated for the primary extent must be specified.
- If it is a partitioned data set, the size of the directory must be specified.
- Optionally, DCB parameters can be specified. Alternately, the program that will write the data set can provide these parameters.

The DISP and data set names have already been described. Briefly, the other parameters are:

Volser — The format for this in a DD statement is VOL=SER=xxxxxx, where xxxxxx is the volser. The VOL parameter can specify other details, which is the reason for the format.

Device type — There are a number of ways to do this, but UNIT=xxxx is the most common. The xxxx can be an IBM device type (such as 3390), or a specific device address (such as 300), or an *esoteric name* defined by the installation (such as SYSDA). A common convention uses SYSDA to represent any available disk volume.

Member name — Remember that a library (or partitioned data set, PDS) member can be treated as a data set by many applications and utilities. The format DSNAME=*ZPROF*.LIB.CNTL(TEST) is used to reference a specific member. If the application or utility program is expecting a sequential data set, then either a sequential data set or a member of a library must be specified. A whole library name (without a specific member name) can be used only if the program/utility is expecting a library name.

Space:

The SPACE DD parameter is required for allocating data sets on DASD. It identifies the space required for your data set. Before a data set can be created on disk, the system must know how much space the data set requires and how the space is to be measured.

There are a number of different formats and variations for this. Common examples are:

`SPACE=(TRK,10)`	10 tracks, no secondary extents
`SPACE=(TRK,(10,5))`	10 tracks primary, 5 tracks for each secondary extent
`SPACE=(CYL,5)`	Can use CYL (cylinders) instead of TRK
`SPACE=(TRK,(10,5,8))`	PDS with 8 directory blocks
`SPACE=(1000,(50000,10000))`	Primary 50000 records@1000 byte each

In the basic case, SPACE has two parameters. These are the unit of measure and the amount of space. The unit of measure can be tracks, cylinders, or the average block size.[1]

The amount of space typically has up to three subparameters:

- The first parameter is the primary extent size, expressed in terms of the unit of measure. The system will attempt to obtain a single extent (contiguous space) with this much space. If the system cannot obtain this space in not more than five extents (on a single volume) before the job starts, the job is failed.
- The second parameter, if used, is the size of each secondary extent. The system does not obtain this much space before the job starts and does not guarantee that this space is available. The system obtains secondary extents dynamically, while the job is

[1] The unit of measure can also be KB and MB but these are not as commonly used.

executing. In the basic examples shown here the secondary extents are on the same volume as the primary extent.

- The third parameter, if it exists, indicates that a partitioned data set (library) is being created. This is the only indication that a PDS is being created instead of another type of data set. The numeric value is the number of directory blocks (255 bytes each) that are assigned for the PDS directory. (Another JCL parameter is needed to create a PDSE instead of a PDS).

If the space parameter contains more than one subparameter, the whole space parameter must be inclosed in parentheses.

6.4 Continuation and concatenation

As a consequence of the limitations of the number of characters that could be contained in single 80-column punched cards used in earlier systems, z/OS introduced the concepts of continuation and concatenation. Therefore, z/OS retained these conventions in order to minimize the impact on previous applications and operations.

Continuation of JCL syntax involves a comma at the end of the last complete operand. The next JCL line would include // followed by at least one space, then the additional operands. JCL operand syntax on a continuation line must begin on or before column sixteen.

```
//JOBCARD JOB 1,REGION=8M,NOTIFY=ZPROF
```

The JCL statement above would have the same result as the following continuation JCL:

```
//JOBCARD JOB 1,
//        REGION=8M,
//        NOTIFY=ZPROF
```

An important feature of DD statements is the fact that a single ddname can have multiple DD statements. This is called *concatenation*.

The following JCL indicates that data sets are concatenated:

```
//DATAIN DD DISP=OLD,DSN=MY.INPUT1
//       DD DISP=OLD,DSN=MY.INPUT2
//       DD DISP=SHR,DSN=YOUR.DATA
```

Concatenation applies only to input data sets. The data sets are automatically processed in sequence. In the example, when the application program reads to the end of `MY.INPUT1`, the system will automatically open `MY.INPUT2` and start reading it. The application program is not aware that it is now reading a second data set. This continues until the last data in the concatenation is read; at that time the application receives an end-of -file indication.

6.5 Reserved DDNAMES

A programmer can select *almost* any name for a DD name, however, using a meaningful name (within the 8-character limit) is recommended.

There are a few reserved DD names that a programmer cannot use (all of these are optional DD statements):

```
//JOBLIB DD ...
//STEPLIB DD ...
//JOBCAT DD ...
//STEPCAT DD ...
//SYSABEND DD ...
//SYSUDUMP DD ...
//SYSMDUMP DD ...
//CEEDUMP DD ...
```

A JOBLIB DD statement, placed just after a JOB statement, specifies a library that should be searched first for the programs executed by this job. A STEPLIB DD statement, placed just after an EXEC statement, specifies a library that should be searched first for the program executed by the EXEC statement. A STEPLIB overrides a JOBLIB if both are used.

The JOBCAT and STEPCAT are used to specify private catalogs, but these are rarely used (the most recent z/OS releases no longer support private catalogs). Nevertheless, these DD names should be treated as reserved names.

The SYSABEND, SYSUDUMP, SYSMDUMP, and CEEDUMP DD statements are used for various types of memory dumps that are generated when a program abnormally ends (or *ABENDs*.)

6.6 JCL procedures (PROCs)

Some programs and tasks require a larger amount of JCL than a user can easily enter. JCL for these functions can be kept in procedure libraries. A procedure library member contains *part* of the JCL for a given task -- usually the fixed, unchanging part of JCL. The user of the procedure supplies the variable part of the JCL for a specific job.

Such a procedure is sometimes known as a *cataloged procedure*. A cataloged procedure is not related to the system catalog; rather, the name is a carryover from another operating system.

Example 6-2 shows an example of a JCL PROC or JCL procedure.

Example 6-2 Example JCL procedure

```
//MYPROC    PROC
//MYSORT    EXEC PGM=SORT
//SORTIN    DD DISP=SHR,DSN=&SORTDSN
//SORTOUT   DD SYSOUT=*
//SYSOUT    DD SYSOUT=*
//          PEND
```

Much of this JCL should be recognizable now. New JCL functions presented here include:

- PROC and PEND statements are unique to procedures. They are used to identify the beginning and end of the JCL procedure.
- The PROC is preceded by a label or name; the name defined in Example 6-2 is MYPROC.
- JCL variable substitution is the reason JCL PROCs are used. &SORTDSN is the only variable in Example 6-2.

In Example 6-3 we include the inline procedure in Example 6-2 in our job stream.

Example 6-3 Sample inline procedure

```
//MYJOB     JOB 1
//*---------------------------------*
//MYPROC    PROC
//MYSORT    EXEC PGM=SORT
//SORTIN    DD DISP=SHR,DSN=&SORTDSN
//SORTOUT   DD SYSOUT=*
//SYSOUT    DD SYSOUT=*
//          PEND
//*---------------------------------*
//STEP1     EXEC MYPROC,SORTDSN=ZPROF.AREA.CODES
//SYSIN     DD *
  SORT FIELDS=(1,3,CH,A)
```

- When MYJOB is submitted, the JCL from Example 6-2 on page 6-9 is effectively substituted for EXEC MYPROC. The value for &SORTDSN must be provided.
- SORTDSN and its value were placed on a separate line, a continuation of the EXEC statement. Notice the comma after MYPROC.
- //SYSIN DD * followed by the SORT control statement will be appended to the substituted JCL.

6.6.1 JCL PROC statement override

When an entire JCL PROC statement needs to be replaced, then a JCL PROC override statement can be used. An override statement has the following form:

```
//stepname.ddname DD ...
```

Example 6-4 shows an example of overriding the SORTOUT DD statement in MYPROC. Here, SORTOUT is directed to a newly created sequential data set.

Example 6-4 Sample procedure with statement override

```
//MYJOB     JOB 1
//*---------------------------------*
//MYPROC    PROC
//MYSORT    EXEC PGM=SORT
//SORTIN    DD DISP=SHR,DSN=&SORTDSN
//SORTOUT   DD SYSOUT=*
//SYSOUT    DD SYSOUT=*
//          PEND
//*---------------------------------*
//STEP1     EXEC MYPROC,SORTDSN=ZPROF.AREA.CODES
//MYSORT.SORTOUT DD DSN=ZPROF.MYSORT.OUTPUT,
//          DISP=(NEW,CATLG),SPACE=(CYL,(1,1)),
//          UNIT=SYSDA,VOL=SER=SHARED,
//          DCB=(LRECL=20,BLKSIZE=0,RECFM=FB,DSORG=PS)
//SYSIN     DD *
  SORT FIELDS=(1,3,CH,A)
```

6.6.2 How is a job submitted for batch processing?

Using UNIX and AIX® as an analogy, a UNIX process can be processed in the background by appending an ampersand (&) to the end of a command or script. Pressing Enter then submits the work as a background process.

In z/OS terminology, work (a job) is submitted for batch processing. Batch processing is a rough equivalent to UNIX background processing. The job runs independently of the interactive session. The term batch is used because it is a large collection of jobs that can be queued, waiting their turn to be executed when the needed resources are available.

Commands to submit jobs might take any of the following forms:

ISPF editor command line	SUBmit and press Enter.
ISPF command shell	SUBmit ‘USER.JCL’ where the data set is sequential.
ISPF command line	TSO SUBmit 'USER.JCL’ where the data set is sequential.
ISPF command line	TSO SUBmit ‘USER.JCL(MYJOB)’ where the data set is a library or partitioned data set containing member MYJOB.

6.7 Using SDSF

After submitting a job, it is common to use *System Display and Search Facility* (SDSF)[2] to review the output for successful completion or review and correct JCL errors. SDSF is a software product whose primary purpose is to display printed output held in the JES spool area. Much of the printed output sent to JES by batch jobs (and other jobs) is never actually printed. Instead it is inspected using SDSF and deleted or used as needed.

SDSF provides a number of additional functions, including:

- Viewing the system log and searching for any literal string
- Entering system commands
- Controlling job processing (hold, release, cancel, and purge jobs)
- Monitoring jobs while they are being processed
- Displaying job output before deciding to print it
- Controlling the order in which jobs are processed
- Controlling the order in which output is printed
- Controlling printers and initiators

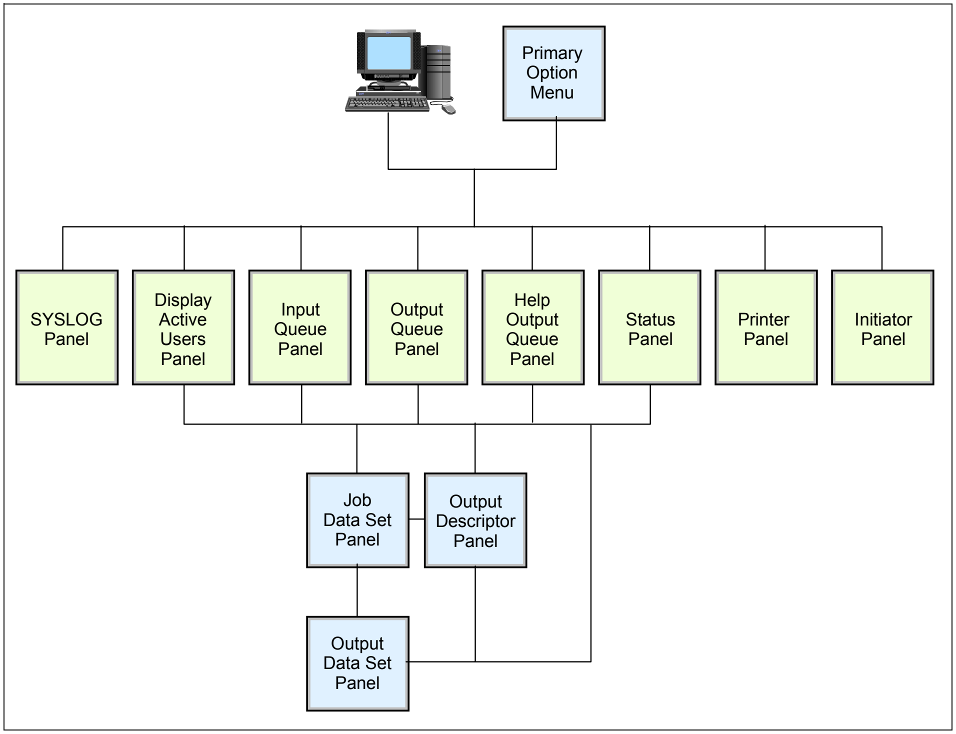


Figure 6-2 SDSF panel hierarchy

[2] As with so many software products, the name conveys no useful information about its purpose.

View the JES2 output files

You can see the JES output data sets created during the execution of your batch job. They are saved on the JES spool data set. You can see the JES data sets in any JES queue:

I Input
DA Execution queue
O Output queue
H Held queue
ST Status queue

For output and held queues, you cannot see those JES data sets you requested to be automatically purged by setting a MSGCLASS out sysout CLASS that has been defined to not save output. Also, depending on the MSGCLASS you chose on the JOB card, the sysouts can be either in the Output queue or in the Held queue.

Screen 1

```
  Display  Filter  View  Print  Options  Help
-------------------------------------------------------------------------------
SDSF HELD OUTPUT DISPLAY ALL CLASSES  LINES 44         LINE 1-1 (1)
COMMAND INPUT ===>                                            SCROLL ===> PAGE
PREFIX=*  DEST=(ALL)  OWNER=*  SYSNAME=
NP    JOBNAME  JobID     Owner     Prty C ODisp Dest               Tot-Rec  Tot-
?_    MIRIAM2  JOB26044 MIRIAM      144 T HOLD  LOCAL                   44
```

Screen 2

```
  Display  Filter  View  Print  Options  Help
-------------------------------------------------------------------------------
SDSF JOB DATA SET DISPLAY - JOB MIRIAM2  (JOB26044)    LINE 1-3 (3)
COMMAND INPUT ===> _                                          SCROLL ===> PAGE
PREFIX=*  DEST=(ALL)  OWNER=*  SYSNAME=
NP    DDNAME   StepName ProcStep DSID Owner     C Dest               Rec-Cnt Page
      JESMSGLG JES2                 2 MIRIAM    T LOCAL                   20
      JESJCL   JES2                 3 MIRIAM    T LOCAL                   12
      JESYSMSG JES2                 4 MIRIAM    T LOCAL                   12
```

Figure 6-3 SDSF viewing the JES2 Output files

The first screen shown in Figure 6-3 displays a list of the jobs we submitted and whose output we directed to the HELD (Class T) queue, as identified in the `MSGCLASS=T` parameter on the job card. In our case only one job has been submitted and executed. Therefore, we only have one job on the Held queue.

Issuing a ? command in the NP column displays the output files generated by job 7359. The second screen, shown in Figure 6-3, displays three ddnames: the JES2 messages log file, the JES2 JCL file, and the JES2 system messages file. This option is useful when you are seeing jobs with many files directed to SYSOUT and you want to display one associated with a specific step. You issue an S in the NP column to select a file you want.

To see all files, instead of a ?, type S in the NP column; the result is presented in Figure 6-5 on page 6-14.

JES2 job log

The following is an example of a JES2 job log.

Example 6-5 JES2 job log

```
J E S 2  J O B  L O G  --  S Y S T E M  S C 6 4  --  N O D E

13.19.24 JOB26044 ---- WEDNESDAY, 27 AUG 2003 ----
13.19.24 JOB26044  IRR010I  USERID MIRIAM   IS ASSIGNED TO THIS JOB.
13.19.24 JOB26044  ICH70001I MIRIAM   LAST ACCESS AT 13:18:53 ON WEDNESDAY,
AUGU
13.19.24 JOB26044  $HASP373 MIRIAM2  STARTED - INIT 1    - CLASS A - SYS SC64
13.19.24 JOB26044  IEF403I MIRIAM2 - STARTED - ASID=0027 - SC64
13.19.24 JOB26044  -                                         --TIMINGS
(MINS.)--
13.19.24 JOB26044  -JOBNAME  STEPNAME PROCSTEP    RC   EXCP    CPU    SRB
CLOCK
13.19.24 JOB26044  -MIRIAM2           STEP1       00      9    .00    .00
.00
13.19.24 JOB26044  IEF404I MIRIAM2 - ENDED - ASID=0027 - SC64
13.19.24 JOB26044  -MIRIAM2  ENDED.  NAME-MIRIAM              TOTAL CPU TIME=
13.19.24 JOB26044  $HASP395 MIRIAM2  ENDED
------ JES2 JOB STATISTICS ------
  27 AUG 2003 JOB EXECUTION DATE
           11 CARDS READ
           44 SYSOUT PRINT RECORDS
            0 SYSOUT PUNCH RECORDS
            3 SYSOUT SPOOL KBYTES
         0.00 MINUTES EXECUTION TIME
        1 //MIRIAM2 JOB 19,MIRIAM,NOTIFY=&SYSUID,MSGCLASS=T,
          // MSGLEVEL=(1,1),CLASS=A
          IEFC653I SUBSTITUTION JCL -
19,MIRIAM,NOTIFY=MIRIAM,MSGCLASS=T,MSGLEVE
        2 //STEP1 EXEC PGM=IEFBR14
          //*-----------------------------------------------------*
//* THIS IS AN EXAMPLE OF A NEW DATA SET ALLOCATION
          //*-----------------------------------------------------*
        3 //NEWDD DD   DSN=MIRIAM.IEFBR14.TEST1.NEWDD,
          //           DISP=(NEW,CATLG,DELETE),UNIT=SYSDA,
          //           SPACE=(CYL,(10,10,45)),LRECL=80,BLKSIZE=3120
        4 //SYSPRINT  DD  SYSOUT=T
          /*
```

```
ICH70001I MIRIAM   LAST ACCESS AT 13:18:53 ON WEDNESDAY, AUGUST 27, 2003
IEF236I ALLOC. FOR MIRIAM2 STEP1
IGD100I 390D ALLOCATED TO DDNAME NEWDD    DATACLAS (        )
IEF237I JES2 ALLOCATED TO SYSPRINT
IEF142I MIRIAM2 STEP1 - STEP WAS EXECUTED - COND CODE 0000
IEF285I   MIRIAM.IEFBR14.TEST1.NEWDD                  CATALOGED
IEF285I   VOL SER NOS= SBOX38.
IEF285I   MIRIAM.MIRIAM2.JOB26044.D0000101.?          SYSOUT
IEF373I STEP/STEP1   /START 2003239.1319
IEF374I STEP/STEP1   /STOP  2003239.1319 CPU    0MIN 00.00SEC SRB    0MIN
00.00S
IEF375I  JOB/MIRIAM2 /START 2003239.1319
IEF376I  JOB/MIRIAM2 /STOP  2003239.1319 CPU    0MIN 00.00SEC SRB    0MIN
00.00S
```

6.8 Utilities

z/OS includes a number of programs useful in batch processing called *utilities*. These program provide many small, obvious, and useful functions. A basic set of system-provided utilities is described in Appendix C, “Utility programs”.

Customer sites often add their own customer-written utility programs (although most users refrain from naming them *utilities*) and many of these are widely shared by the user community. Independent software vendors also provide many similar products (for a fee).

6.9 System libraries

z/OS has many standard system libraries. A brief description of several libraries is appropriate here. The traditional libraries include:

- SYS1.PROCLIB. This library contains JCL procedures distributed with z/OS. In practice, there are many other JCL procedure libraries (supplied with various program products) concatenated with it.
- SYS1.PARMLIB. This library contains control parameters for z/OS and for some program products. In practice, there may be other libraries concatenated with it.
- SYS1.LINKLIB. This library contains many of the basic execution modules of the system. In practice, it is one of a large number of execution libraries that are concatenated together.
- SYS1.LPALIB. This library contains system execution modules that are loaded into the link pack area when the system is initialized. There may be several other libraries concatenated with it.

- SYS1.NUCLEUS. This library contains the basic supervisor ("kernel") modules of z/OS.

These libraries are standard PDS data sets and are found on the system disk volumes. They are discussed in more detail in Section 16.2, "z/OS system libraries" on page 16-13.

6.10 Summary

Basic JCL contains three types of statements: JOB, EXEC, and DD. A job can contain several EXEC statements (*steps*) and each step might have several DD statements. JCL provides a wide range of parameters and controls; only a basic subset is described here.

A batch job uses artificial names (DD names) internally to access data sets. A JCL DD statement connects the DD name to a specific data set (DS name) for one execution of the program. A program can access different groups of data sets (in different jobs) by changing the JCL for each job.

The DISP parameters of DD statements help to prevent unwanted simultaneous access to data sets. This is very important for general system operation. The DISP parameter is not a security control, rather it helps manage the integrity of data sets. New data sets can be created through JCL by using the DISP=NEW parameter and specifying the desired amount of space and the desired volume.

System users are expected to write simple JCL, but normally use JCL procedures for more complex jobs. A cataloged procedure is written once and can then be used by many users. z/OS supplies many JCL procedures, and locally-written ones can be added easily. A user must understand how to override or extend statements in a JCL procedure in order to supply the parameters (usually DD statements) needed for a specific job.

Key terms in this chapter		
concatenation	DD statement	JCL
JOB statement	EXEC statement	jobname
PROC	SDSF	stepname
system catalog	system library	utility

6.11 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. In the procedure fragment and job in 6.6, "JCL procedures (PROCs)" on page 6-9, where is the COBOL source code? What is the likely output data set for the application? What is the likely input data set? How would we code the JCL for a SYSOUT data set for the application?
2. We have three DD statements:

```
//DD1  DD  UNIT=3480,...
//DD2  DD  UNIT=0560,...
//DD3  DD  UNIT=560,...
```

   What do these numbers mean? How do we know this?

3. JCL can be submitted or started. What is the difference?
4. Explain the relationship between a data set name, a DD name, and the file name within a program.
5. Which JCL statement (JOB, EXEC, or DD) has the most operands? Why?
6. What is the difference between JCL and a JCL PROC? What is the benefit of using a JCL PROC?
7. To override a JCL PROC statement in the JCL stream executing the PROC, what PROC names must be known? What is the order of the names on the JCL override statement?
8. When a JCL job has multiple EXEC statements, what is the type of name associated with each EXEC statement?
9. What information about a data set is stored in a catalog? What DD operands would be required if a data set were not in the catalog?

6.12 Topics for further discussion

This material is intended to be discussed in class, and these discussions should be regarded as part of the basic course text.

1. Why has the advent of database systems potentially changed the need for large numbers of DD statements?
2. The first positional parameter of a JOB statement is an accounting field. How important is accounting for mainframe usage? Why?

6.13 Exercises

The lab exercises in this chapter help you develop skills in creating batch jobs and submitting them for execution on z/OS. These skills are required for performing lab exercises in the remainder of this text.

To perform the lab exercises, you or your team require a TSO user ID and password (for assistance, see the instructor).

The exercises teach the following:

6.13.1 Creating a simple job

1. From ISPF, navigate to the Data Set List Utility panel and enter *yourid*.JCL in the Dsname Level field (described in an earlier exercise).
2. Enter `e` (edit) to the left (in the command column) of *yourid*.JCL. Enter `s` (select) to the left of member `JCLTEST`. Enter `RESet` on the editor command line.
3. Notice that only a single JCL line is in the data set, `EXEC PGM=IEFBR14`. This is a system utility that does not request any input or output and is designed to complete with a successful return code (0). Enter `SUBMIT` or `SUB` on the command line. Enter `1` to the message

   `IKJ56700A ENTER JOBNAME CHARACTER(S) -`

   The result will be the message

   `IKJ56250I JOB` *yourid*`1(JOB00037) SUBMITTED`

   And if the job is finished, you may see the message

   `$HASP165  `*yourid*`1 ENDED AT SYS1  MAXCC=0 CN(INTERNAL)`
4. Replicate (`r`) the single line and overtype the first JCL statement to read:

   `//`*yourid*`A JOB 1 ....`

Then submit this JCL and press PF3 to save and exit the editor.

5. From the ISPF Primary Option Menu, find SDSF (described in 3.7.4, "Using SDSF" on page 3-34). You can use the SPLIT screen function for a new Screen Session, so you have one session for the Dslist and the other for SDSF.

6. In the SDSF menu enter `PREFIX yourid*`, then enter `ST` (Status Panel). Both jobs submitted should be listed. Place `S` (select) to the left of either job, then page up and down to view the messages produced from the execution. PF3 will exit.

7. Edit `JCLTEST` again; insert the following line at the bottom:

```
//CREATE DD DSN=yourid.MYTEST,DISP=(NEW,CATLG),
//          UNIT=SYSDA,SPACE=(TRK,1)
```

8. Submit the content of `JCLTEST` created above, press PF3 (save and exit edit), then view the output of this job using SDSF. Notice you have two jobs with the same jobname. The jobname with the highest JOBID number is the last one.

   a. What was the condition code? If it was greater than 0, then page down to the bottom of the output listing to locate the JCL error message. Correct the `JCLTEST` and resubmit until `cond code=0000` is received.
   b. Navigate to the Data Set List Utility panel (`=3.4`) and enter *yourid*.MYTEST in the Dsname Level field. What volume was used to store the data set?
   c. Enter `DEL /` to the left (command column) of the data set to delete the data set. A confirmation message may appear asking you to confirm that you want to delete the data set.
   d. We just learned that JCL execution of program IEFBR14, which requires no inputs or outputs, returns a condition code 0 (success), provided no JCL errors. Although IEFBR14 does no I/O, JCL instructions are read and executed by the system. This program is useful for creating and deleting data sets by specifying DSN and `DISP=(OLD,DELETE)` on a DD statement.

9. From any ISPF panel, enter in the Command Field ==>

```
TSO SUBMIT JCL(JCLERROR)
```

   Your user ID is the assumed prefix of data set JCL containing member `JCLERROR`.

   a. You will be prompted to enter a suffix character for a generated job card. Take note of the jobname and job number from the submit messages.
   b. Use SDSF and select the job output. Page down to the bottom. Do you see the JCL error? What are the incorrect and correct JCL DD operands? Correct the JCL error located in *yourid*.JCL(JCLERROR). Resubmit JCLERROR to validate your correction.

10. From any ISPF panel, enter `TSO SUBMIT JCL(SORT)`. Your user ID is the assumed prefix of data set JCL containing member SORT.

    a. You will be prompted to enter a suffix character for a generated job card. Take note of the jobname and job number from the submit messages.

   b. Use SDSF and place a `?` to the left of the job name. The individual listing from the job will be displayed. Place `s` (select) to the left of `SORTOUT` to view the sort output, then press `PF3` to return. Select `JESJCL`. Notice the "job statement generated message" and the "substitution JCL" messages.

11. Let's purge some (if not all) unnecessary job output. From SDSF, place a `p` (purge) to the left of any job that you would like to purge from the JES output queue.
12. From the ISPF panel, enter `TSO SUBMIT JCL(SORT)`, then review the output.
13. From the ISPF panel, enter `TSO SUBMIT JCL(SORTPROC)`, then review the output.

    You may not see the output in the SDSF ST panel. This is because the jobname is not starting with *yourid*. To see all output, enter `PRE *`, then enter `OWNER` *`yourid`* to see only the jobs that are owned by you.

14. What JCL differences exist between `SORT` and `SORTPROC`? In both JCL streams, the SYSIN DD statement references the sort control statement. Where is the sort control statement located?

> **Tip:** All JCL references to &SYSUID are replaced with the user ID that submitted the job.

15. Edit the partitioned data set member containing the SORT control statement. Change `FIELD=(1,3,CH,A)` to `FIELD=(6,20,CH,A)`. Press PF3 and then from the ISPF panel enter `TSO SUBMIT JCL(SORT)`. Review the job's output using SDSF. Was this sorted by code or area?
16. From the ISPF panel, enter `TSO LISTC ALL`. By default, this will list all catalog entries for data sets beginning with *yourid***.** The system catalog will return the data set names, the name of the catalog storing the detailed information, the volume location, and a devtype number that equates to specific values for JCL UNIT= operand. LISTC is an abbreviation for LISTCAT.

6.13.2 Using ISPF in split screen mode

As discussed earlier, most ISPF users favor a split screen. This is easily done:

1. Move the cursor to the bottom (or top) line.
2. Press PF2 to split the screen.
3. Press PF9 to switch between the two screens.
4. Use PF3 (perhaps several times) to exit from one of the splits.

The screen need not be split at the top or bottom. The split line can be positioned on any line by using PF2.

More than two screens can be used. Try to use the ISPF commands:

```
START
SWAP LIST
SWAP <screen number.>
```

6.13.3 Submitting a job and checking the results

Edit member COBOL1 in *yourid*.LIB.SOURCE library and inspect the COBOL program. Notice that there is no JCL with it. Now edit member COBOL1 in *yourid*.JCL.[3] Inspect the JCL carefully. It uses a JCL procedure to compile and run a COBOL program.[4]

Take these steps:

1. Change the job name to *yourid* plus additional characters.
2. Change the NOTIFY parameter to your user ID.
3. Type `SUB` on the ISPF command line to submit the job.
4. Split your ISPF screen and go to SDSF on the new screen (if not already available from a earlier exercise).
5. In SDSF go to the ST (Status) display and look for your job name.

   You may need to enter a PRE or OWNER command on the SDSF command line to see any job names. (An earlier user may have set a prefix parameter to see only certain job names.)
6. Type `S` beside your job name to see all of the printed output:
   - Messages from JES2
   - Messages from the initiator
   - Messages from the COBOL compiler
   - Messages from the binder
   - Output from the COBOL program
7. Use PF3 to “move up” a level and type `?` beside your job name to display another output format.

The instructor will briefly describe the purposes of the various JES2 and initiator messages.

- Resubmit the job with `MSGLEVEL=(1,1)` on the JOB statement.
- Resubmit the job with `MSGLEVEL=(0,0)` on the JOB statement.

The MSGLEVEL parameter controls the number of initiator messages that are produced.

[3] The matching member names (COBOL1) are not required; however, they are convenient.
[4] This is not exactly the COBOL procedure we discussed earlier. Details of these procedures sometimes change from release to release of the operating system.

6.13.4 Creating a PDS member

There are several ways to create a new PDS member. Try each of the following, using your own user ID. In the following steps, TEST3, TEST4, TEST5, and TEST6 represent new member names. Enter a few lines of text in each case.

Use the ISPF edit panel:

- Go to the ISPF primary menu.
- Go to option 2 (Edit).
- In the Data Set Name line, enter `JCL(TEST3)` (no quotes!)
- Enter a few text lines and use PF3 to save the new member.

A new member can be created while viewing the member list in edit mode:

- Use option 3.4 (or option 2) to edit *yourid*.JCL.
- While viewing the member list, enter `S TEST4` in the command line.
- Enter a few text lines and use PF3 to save the new member.

A new member can be created while editing an existing member:

- Edit *yourid*.JCL(TEST1) or any other existing member.
- Select a block of lines be entering `cc` (in the line command area) in the first and last lines of the block.
- Enter `CREATE TEST5` on the command line. This will create member TEST5 in the current library.

A new member can be created with JCL. Enter the following JCL in *yourid*.JCL(TEST5) or any other convenient location:

```
//yourid1 JOB 1,JOE,MSGCLASS=X
//STEP1    EXEC PGM=IEBGENER
//SYSIN    DD DUMMY
//SYSPRINT DD SYSOUT=*
//SYSUT2   DD DISP=OLD,DSN=yourid.JCL(TEST6)
//SYSUT1   DD *
This is some text to put in the member
More text
/*
```

Save the member with this JCL. It will be used later.

6.13.5 Copying a PDS member

There are many ways to copy a library member. An earlier exercise used the ISPF 3.3 function to copy all the members of a library. The same function can be used to copy one or more members.

While editing a library member, we can copy another member into the member being edited:

- Edit a library member.
- Mark a line in this member with `a` (after) or `b` (before) to indicate where the other member should be copied.
- Enter COPY xxx on the command line, where `xxx` is the name of another member in the current data set.

We can copy a member from another data set (or a sequential data set) as follows:

- Edit a member or sequential data set.
- Mark a line with `a` (after) or `b` (before) to indicate where to insert the new material.
- Enter `COPY` on the command line. This will produce an Edit/View-Copy panel.
- Enter the full sequential data set name (with single quotes, if necessary) or a full library+member name in the Data Set Name field.

6.13.6 Learning about system volumes

The instructor (or each student) can use the ISPF functions to explore several system volumes. The following are of interest:

- Examine the naming of VSAM data sets. Note the names DATA and INDEX as the last qualifier.
- Find the spool area. This may involve a guess based on the data set name. How large is it?
- Find the basic system libraries, such as SYS1.PROCLIB and so forth. Look at the member names.
- Consider the ISPF statistics field that is displayed in a member list. How does it differ for source libraries and execution libraries?

6.13.7 Using the PA1 key

The “real” 3270 terminals had keys labeled PA1, PA2, and PA3. These were *Program Action* keys. In practice, only PA1 is widely used and it functions as a break key for TSO. In TSO terminology, this is an *attention interrupt*. That is, it will terminate a current task. Finding the PA1 key on the keyboard of a TN3270 emulator may be a challenge. It can be customized to many different key combinations. (On an unmodified x3270 session, it is Left Alt-1.)

This is a very important key for TSO users and every user should know how to find it on his/her keyboard.

As an example, try the following:

- Go to ISPF option 6. This panel accepts TSO commands.
- Enter `LISTC LEVEL(SYS1) ALL` on the command line (and press Enter).
- This should produce a screen of output with *** in the last line on the screen.
- The *** indicates that there is more output waiting and the user must press Enter to see the next screen. (This meaning is consistent in almost all TSO usage.)
- Press Enter for the next screen, and press Enter for the next screen, and so forth. This command produces lots of output, although it is not an endless loop.
- Press the PA1 key, using whatever key combination is appropriate for your TN3270 emulator. This should terminate the output.

6.13.8 Using a utility program in a job

We have a utility program named IEBGENER. It uses four DD statements:

- SYSIN for control statements. We can use a DD DUMMY for this statement.
- SYSPRINT for messages from the program. Use SYSOUT=X for this.
- SYSUT1 for input data.
- SYSUT2 for output data.

The basic function of the program is to copy the data set pointed to by SYSUT1 to the data set pointed to by SYSUT2. Both must be sequential data sets or members of a library.

The program automatically obtains the DCB attributes from the input data set and applies them to the output data set. Write the JCL for a job to list the *yourid*.JCL`(TEST1)` member on SYSOUT=X.

6.13.9 Examining the TSO logon JCL

The password panel of the TSO logon process contains the name of the JCL procedure used to create a TSO session. There are several procedures with different characteristics. Look at the ISPFPROC procedure. The instructor can help find the correct library for ISPFPROC.

- What is the name of the basic TSO program that is executed?
- Why are there so many DD statements? Notice the concatenation.

Look for procedure IKJACCNT. This is a minimal TSO logon procedure.

6.13.10 Exploring the master catalog

Go to ISPF option 6 and do the following:

- Use a `LISTC LEVEL(SYS1)` command for a basic listing of all the SYS1 data sets in the master catalog.

- Notice that they are either NONVASM or CLUSTER (and associated DATA and INDEX entries). The CLUSTERs are for VSAM data sets.
- Use PA1 to end the listing.
- Use a `LISTC LEVEL(SYS1) ALL` command for a more extended listing.

  Note the volser and device type data for the NONVSAM data sets. This is the basic information in the catalog.

Use LISTC LEVEL(xxx) to view one of the ALIAS levels and note that it comes from a user catalog.

6.13.11 Using SDSF

From the ISPF Primary Option Menu, locate and select System Display and Search Facility (SDSF). This utility allows you to display output data sets. The ISPF Primary Option Menu typically includes more selections than those listed on first panel, with instructions about how to display the additional selections.

1. Enter LOG, then shift left (PF10), shift right (PF11), page up (PF7) and page down (PF8). Enter TOP, then BOTTOM on the command line. Enter DOWN 500 and UP 500 on the command input line (you will learn how to read this system log later).
2. Note the 'SCROLL' value to the far left on the command input line.

   ```
   Scroll ===> PAGE
   ```

   Tab to the 'SCROLL' value. The values for SCROLL can be:

C - CSR	cursor
P - PAGE	page
H - HALF	half-page

   SCROLL appears on many ISPF panels, including the editor. You can change its value by entering the first letter of the scroll mode over the first letter of the current value. Change the value to CSR, place the cursor on another line in the body of the system log, and press PF7. Did it place the line with the cursor at the top?
3. Enter ST (status) on the SDSF command input line, then enter SET DISPLAY ON. Observe the values for Prefix, Dest, Owner, and Sysname. To display the current values for each, enter '*' as a filter, as shown:

   ```
   PREFIX *
   OWNER *
   DEST
   ```

   The result should be:

   ```
   PREFIX=*  DEST=(ALL)  OWNER=*
   ```

4. Enter DA to display all active. Enter ST to retrieve the status of jobs in input, active and output queues. Again enter PF7 (page up), PF8 (page down), PF10 (shift left) and PF11 (shift right.)

> **Advanced tip:** If you would like to enter commands to display system information from SDSF and you know the format, simply prefix each command with a slash (/).

If you plan to continue with to the next exercise, skip the following logoff step.

5. Enter '=X' to exit the ISPF environment. From TSO READY, enter LOGOFF to exit. The sign-on screen is shown. You can close your 3270 session emulator now.

6.13.12 Checking job status with SDSF

- Using the ISPF panel, SUBMIT the Job HELLO in *yourid*.LIB.SOURCE.
- Split your ISPF screen and go to SDSF on the new screen.
- Check SDSF for the job status

6.14 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. In the procedure fragment and job in 6.6, "JCL procedures (PROCs)" on page 6-9, where is the source code for program SORT? What is the likely output data set for the sort? What is the likely input data set?
2. How would we code the JCL for a SYSOUT data set for the job in 6.6, "JCL procedures (PROCs)" on page 6-9?
3. We have three DD statements:

   ```
   //DD1  DD  UNIT=3480,...
   //DD2  DD  UNIT=0560,...
   //DD3  DD  UNIT=560,...
   ```

   What do these numbers mean?
4. JCL can be submitted or started. What is the difference?
5. Explain the relationship between a data set name, a DD name, and the file name within a program.
6. Which JCL statement (JOB, EXEC, or DD) has the most operands? Why?
7. What is the difference between JCL and a JCL PROC? What is the benefit of using a JCL PROC?

8. To override a JCL PROC statement in the JCL stream executing the PROC, what PROC names must be known? What is the order of the names on the JCL override statement?
9. When a JCL job has multiple EXEC statements, what is the type of name associated with each EXEC statement?
10. What information about a data set is stored in a catalog? What DD operands would be required if a data set were not in the catalog?

6.15 Topics for further discussion

This material is intended to be discussed in class, and these discussions should be regarded as part of the basic course text.

1. Why has the advent of database systems potentially changed the need for large numbers of DD statements? All of the data for a job could potentially be stored in one database rather than in multiple files of other types.
2. The first positional parameter of a JOB statement is an accounting field. How important is accounting for mainframe usage? Why? It is important mainframes are shared by many users. Most shops keep track of who uses resources so they can fund their share of the costs.

Part 2

Application programming on z/OS

In this part, we introduce the tools and utilities for developing a simple program to run on z/OS. The chapters that follow guide the student through the process of application design, choosing a programming language, and using a runtime environment.

7

Designing and developing applications for z/OS

Objective: As your company's newest z/OS application designer/programmer, you will be asked to design and write new programs or modify existing programs to meet the company's business goals. Such an undertaking will require that you fully understand the various user requirements for your application and know which z/OS system services to exploit.

After completing this chapter, you will be able to:

- Describe the roles of the application designer and application programmer
- List the major considerations for designing an application for z/OS
- Describe the advantages and disadvantages of using batch versus online for an application.
- Briefly describe the process for testing a new application on z/OS
- List three advantages for using z/OS as the host for a new application.

7.1 Application designers and programmers

The tasks of *designing* an application and *developing* one are distinct enough to treat each in a separate textbook. In larger z/OS sites, separate departments might be used to carry out each task. This chapter provides an overview of these job roles and shows how each skill fits into the overall view of a typical application development life cycle on z/OS.

The application designer is responsible for determining the best programming solution for an important business requirement. The success of any design will depend in part on the designer's knowledge of the business itself, awareness of other roles in the mainframe organization such as programming and database design, and understanding of the business's hardware and software. In short, the designer must have a global view of the entire project.

As part of the design process, the designer gathers requirements from business analysts and end users and determines which IT resources will be available to support the application. Depending on the complexity of the project, the designer might involve other specialists to assist in the design process.

The application programmer is responsible for developing and maintaining application programs. That is, the programmer builds, tests, and delivers the application programs that run on the mainframe for the end users. Based on the application designer's specifications, the programmer constructs an application program using a variety of tools. The build process includes many iterations of code changes and compiles, application builds, and unit testing.

During the development process, the designer and programmer must interact with other roles in the enterprise. The programmer, for example, often works on a team of other programmers who are building code for related application modules.

When the application modules are completed, they are passed through a testing process that can include functional, integration, and system tests. Following this testing process, the application programs must be acceptance-tested by the user community to determine whether the code actually accomplishes what the users desire.

Besides creating new application code, the programmer is responsible for maintaining and enhancing the company's existing mainframe applications. In fact, this is frequently the primary job for many application programmers on the mainframe today. While many mainframe installations still create new programs with COBOL or PL/I, languages such as Java have become popular for building new applications on the mainframe, just as on distributed platforms.

7.2 Designing an application for z/OS

During the early design phases, the application designer makes decisions regarding the characteristics of the application. These decisions are based on many criteria, which must be gathered and examined in detail to arrive at a solution that is acceptable to the user. The decisions are not independent of each other, in that one decision will have an impact on others and all decisions must be made taking into account the scope of the project and its constraints.

Designing application to run on z/OS shares many of the steps followed for designing an application to run on other platforms, including the distributed environment. z/OS, however, introduces some special considerations. This chapter provides some examples of the decisions that the z/OS application designer makes during the design process for a given application. The list is not meant to be exhaustive, but rather to give you an idea of the process involved:

- "Designing for z/OS: Batch or online?" on page 7-3
- "Designing for z/OS: Data sources and access methods" on page 7-4
- "Designing for z/OS: Integrating a multi-tiered application" on page 7-4
- "Designing for z/OS: Exception handling" on page 7-4
- "Designing for z/OS: Availability and workload requirements" on page 7-5

Beyond these decisions, other factors that might influence the design of a z/OS application might include the choice of one or more programming languages and development environments. We discuss the use of an interactive development environment (IDE) in "Using application development tools" on page 7-11, and we discuss differences between the various programming languages in Chapter 8, "Using programming languages on z/OS" .

Keep in mind that the best systems are those that start with the end result in mind. We must know what it is that we are striving for before we start to design.

7.2.1 Designing for z/OS: Batch or online?

Comment: Add more information on batch vs. online applications. In some ways, the decision is quite obvious. However, as I've seen in a customer environment, one can often make an application fit into either paradigm. The question - how do you make that decision? That is what should be reflected in the material. Batch is not unique to z/OS, but it is far more common there than any other platform. This "batch vs. online" is a key point of discussion.

When designing an application for z/OS and the mainframe, a key consideration is whether the application will run as a batch program or an on-line program. In some cases, the decision is obvious, but most applications can be designed to fit either paradigm. How, then, does the designer decide which approach to use?

7.2.2 Designing for z/OS: Data sources and access methods

- What data must be stored?
- How will the data be accessed? This includes a choice of access method.
- Are the requests ad hoc or predictable?
- Will we choose PDS, VSAM, or a database management system (DBMS) such as DB2?

7.2.3 Designing for z/OS: Integrating a multi-tiered application

Comment: For multi-tier applications - how does zSeries fit? Why do you design multi-tier? How much can you "fit" on zSeries (i.e. web server/web app server/database/transaction manager)? How do you select the proper subsystem? This is another key point that deserves a bit more attention. The design of the application topology, and in particular - how to integrate with zSeries transaction managers - is what I spend most of my time on with z/OS customers. In fact, I had an extensive conversation with one yesterday regarding how to design an integration infrastructure for developing apps that talk to CICS transactions.

–

–

How is an application integrated into the larger zSeries scheme?

What subsystems might be used in a z/OS-based multi-tiered application? Which z/OS subsystems might be relevant to the application?

Example of a typical application topology on zSeries

- Design considerations for integrating a z/OS application with a zSeries transaction manager
- Design considerations for integrating a z/OS application with a zSeries transaction manager

7.2.4 Designing for z/OS: Exception handling

Are there any unusual conditions that might occur? If so, we need to incorporate these in our design in order to prevent failures in the final application. We cannot always assume, for example, that input will always be entered as expected.

7.2.5 Designing for z/OS: Availability and workload requirements

For an application that will run on z/OS, the designer must be able to answer the following questions:

- What is the quantity of data to store and access?
- Is there a need to share the data?
- What are the response time requirements?
- What are the cost constraints of the project?
- How many users will access the application at once?
- What is the availability requirement of the application (24 hours a day, 7 days a week, 8:00a.m - 5:00 p.m., and so on)?

7.3 Application development life cycle: An overview

An application is a collection of programs that satisfies certain specific requirements (resolves certain problems). The solution could reside on any platform or combination of platforms, from a hardware or operating system point of view.

As with other operating systems, application development on z/OS is usually composed of the following phases:

- Design phase
  - Gather requirements.
    - User, hardware and software requirements
  - Perform analysis.
  - Perform design.
    - High-level design
    - Detailed design
  - Hand over to application programmers.
- Code and test application.
- Perform user tests.
  - User tests application for functionality and usability
- Perform system tests.
  - Perform integration test (test application with other programs to verify that all programs continue to function as expected).
  - Perform performance (volume) test using production data.
- Go production—hand off to operations.
  - Ensure that all documentation is in place (user training, operation procedures).
- Maintenance phase—ongoing day-to-day changes and enhancements to application.

Figure 7-1 shows the process flow during the various phases of the application development life cycle.

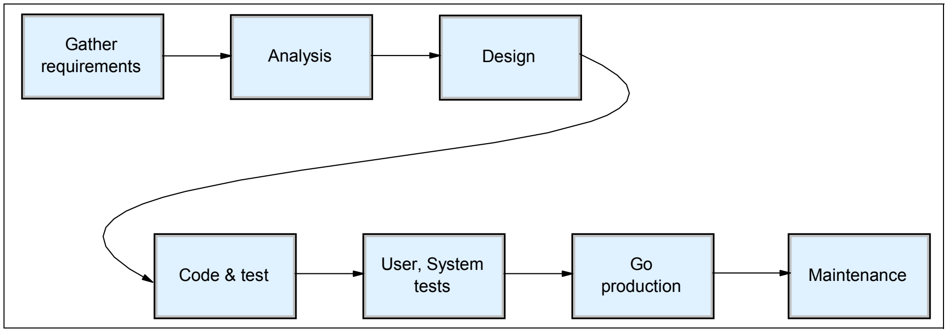


Figure 7-1 Application development life cycle

Figure 7-2 depicts the design phase up to the point of starting development. Once all of the requirements have been gathered, analyzed, verified, and a design has been produced, we are ready to pass on the programming requirements to the application programmers.

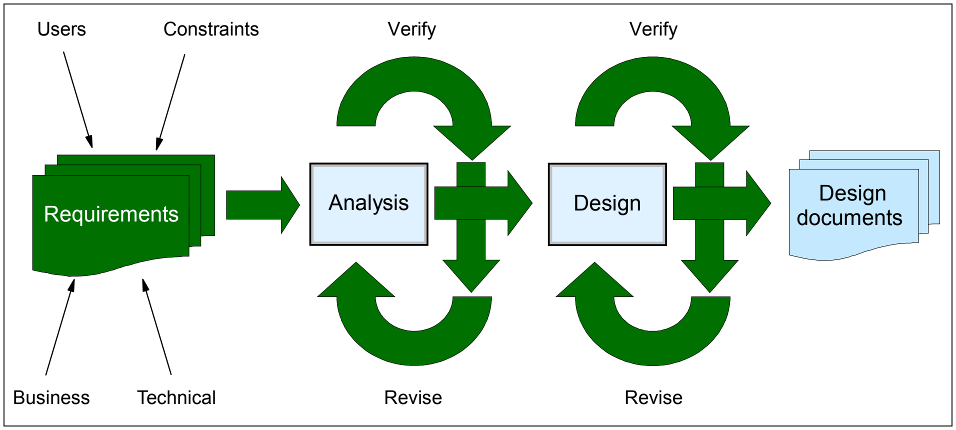


Figure 7-2 Design phase

The programmers take the design documents (programming requirements) and then proceed with the iterative process of coding, testing, revising, and testing again, as we see in Figure 7-3.

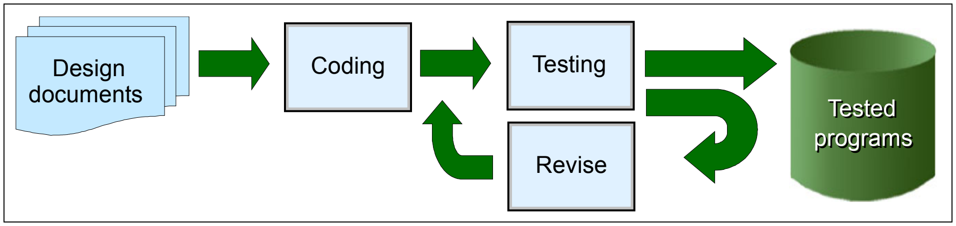


Figure 7-3 Development phase

After the programs have been tested by the programmers, they will be part of a series of formal user and system tests. These are used to verify usability and functionality from a user point of view, as well as to verify the functions of the application within a larger framework (Figure 7-4).

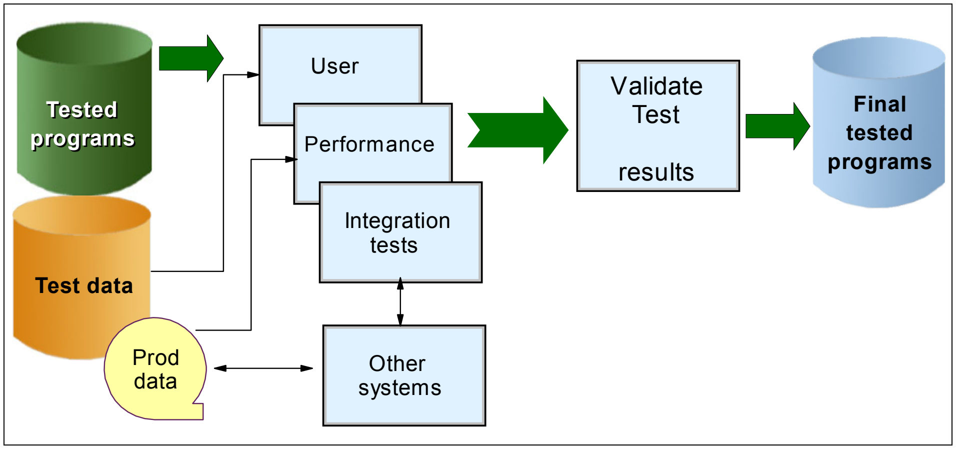


Figure 7-4 Testing

The final phase in the development life cycle is to go to production and become steady state. As a prerequisite to going to production, the development team needs to provide documentation. This usually consists of user training and operational procedures. The user training familiarizes the users with the new application. The operational procedures documentation enables Operations to take over responsibility for running the application on an ongoing basis.

Once in production, the changes and enhancements are handled by a group (possibly the same programming group) that performs this maintenance. At this point in the life cycle of the application, changes are tightly controlled and must be rigorously tested before being implemented into production (Figure 7-5).

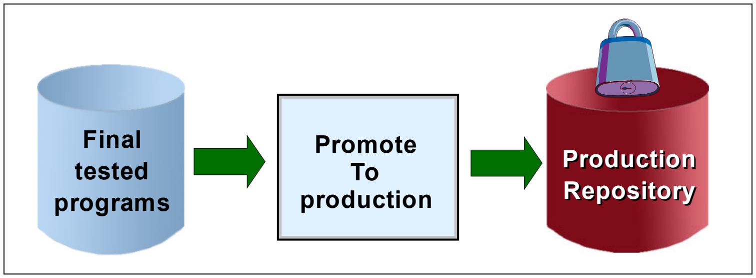


Figure 7-5 Production

As mentioned before, to meet user requirements or solve problems, an application solution might be designed to reside on any platform or a combination of platforms. As shown in Figure 7-6, our specific application can be located in any of the three environments: Internet, enterprise network, or central site. The operating system must provide access to any of these environments.

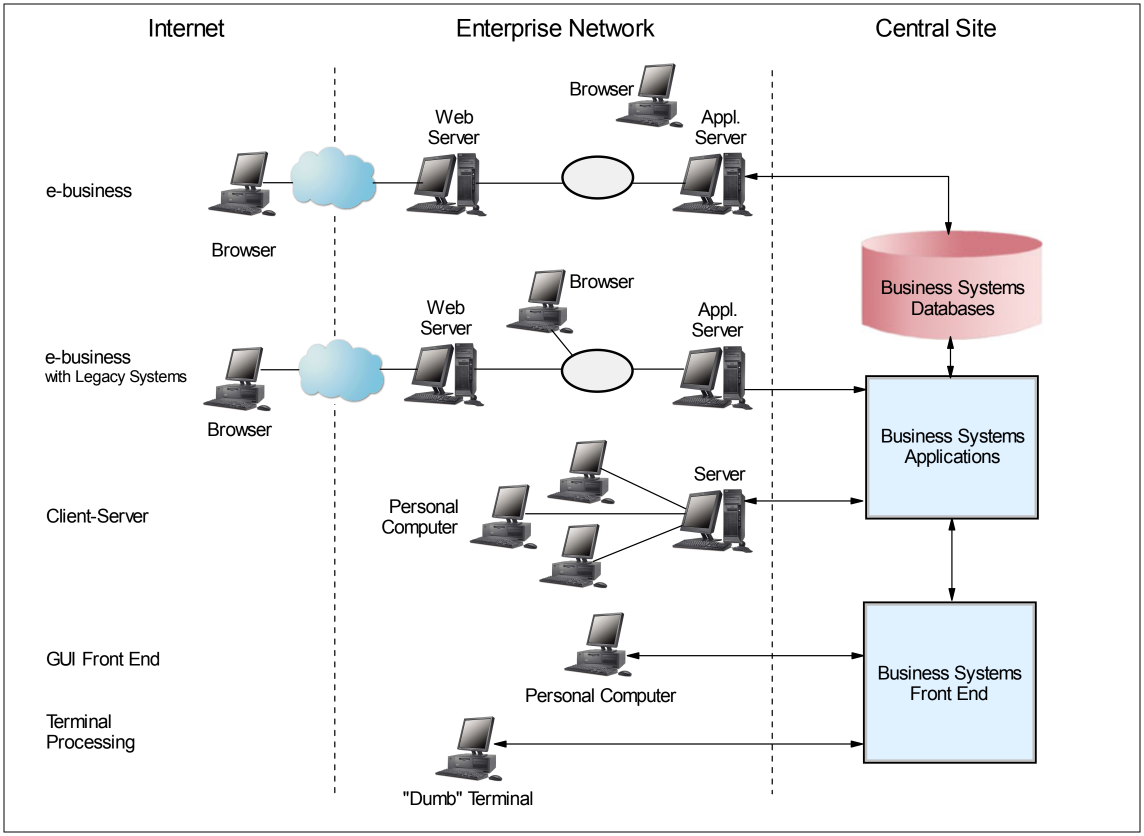


Figure 7-6 Growing infrastructure complexity

To begin the design process, we must first assess what we need to accomplish. Based on the constraints of the project, we determine how and with what we will accomplish the goals of the project. To do so, we conduct interviews with the users (those requesting the solution to a problem) as well as the other stakeholders.

The results of these interviews should inform every subsequent stage of the life cycle of the application project. At many stages of the project, we again call upon the users to verify that we have understood their requirements and that our solution meets their requirements. At these milestones of the project, we also ask the users to sign off on what we have done, so that we can proceed on to the next step of the project.

7.3.1 Gathering requirements for the design

When designing applications, there are many ways to classify the requirements: Functional requirements, non-functional requirements, emerging requirements, system requirements, process requirements, constraints on the development and in the operation—to name a few.

Computer applications operate on data, which resides somewhere and which needs to be accessed from either a local or remote location. The applications manipulate the data, performing some kind of processing on it, and then present the results to whomever was asking for in the first place.

This simple description involves many processes and many operations that have many different requirements, from computers to software products.

Although each application design is a separate case and can have many unique requirements, some of these are common to all applications that are part of the same system. Not only because they are part of the same set of applications that comprise a given information system, but also because they are part of the same installation, which is connected to the same external systems.

One of the problems faced by systems as a whole is that components are spread across different machines, different platforms, and so forth, each one performing its work in a *server farm* environment.

An important advantage to the zSeries approach is that applications can be maintained using tools that reside on the mainframe. Some of these mainframe tools make it possible to have different platforms sharing resources and data in a coordinated and secure way according to workload or priority.

The following is a list of the various types of requirements for an application. The list is not exclusive; some items already include others.

Accessibility	Client	Interoperability

Recoverability	Serviceability	Availability
Connectivity	Performance	Resource can be monitored, controlled, managed, and administered
Usability	Frequency of data backup	Distributed
Portability	Secure centralized controllable capacity	Web services
Changeability	Inter-communicable	Preventing failure and fault analysis

7.4 Developing an application on the mainframe

After the analysis has been completed and the decisions have been made, the process passes on to the application programmer. The programmer is not given free rein, but rather must adhere to the specifications of the designer. However, given that the designer is probably not a programmer, there may be changes required because of programming limitations. But at this point in the project, we are not talking about design changes, merely changes in the way the program does what the designer specified it should do.

The development process is iterative, usually working at the module level. A programmer will usually follow this process:

1. Code a module.
2. Test a module for functionality.
3. Make corrections to the module.
4. Repeat from step 2 until successful.

Once testing has been completed on a module, it is signed off and effectively frozen to ensure that if changes are made to it later, it will be tested again. When sufficient modules have been coded and tested, they can be tested together in tests of ever-increasing complexity.

This whole process repeats itself until all of the modules have been coded and tested. Although the process diagram shows testing only after development has been completed, testing is continuously occurring during the development phase.

7.4.1 Using application development tools

Comment: Add more information about the use of an IDE, such as WebSphere Developer for zSeries.

Producing well-tested code requires the use of tools on the mainframe. The primary tool for the programmer is the ISPF editor.

When developing traditional, procedural programs in languages such as COBOL and PL/I, the programmer often logs on to the mainframe and uses an IDE or the ISPF editor to modify the code, compile it, and run it. The programmer uses a common repository (such as the IBM Software Configuration Library Manager or SCLM) to store code that is under development. The repository allows the programmer check code in or out, and ensures that programmers do not interfere with each others' work.

Note: For purposes of simplicity, the source code could be stored and maintained in a partitioned data set (PDS). However, using a PDS would neither provide change control nor prevent multiple updates to the same version of code in the way that SCLM would. So, wherever we have written "checking out" or "saving" to SCLM, assume that you could substitute this with "edit a PDS member" or "save a PDS member."

When the programmer completes source code changes, a JCL file is submitted to compile the source code, bind the application modules, and create an executable for testing.

When the source code changes are complete, the programmer conducts "unit tests" of the functionality of the program. The programmer uses job monitoring and viewing tools to track the running programs, view the output, and make appropriate corrections to source code or other objects. Sometimes, a program will create a "dump" of memory when a failure occurs. The programmer can also use tools to interrogate the dump output and to trace through executing code to identify the failure points.

Some mainframe application programmers have now switched to the use of Interactive Development Environment (IDE) tools to accelerate the edit/compile/test process. IDEs such as the WebSphere Studio Enterprise Developer allow application programmers to edit, test, and debug source code on a workstation instead of directly on the mainframe system. The use of the IDE is particularly useful for building "hybrid" applications that employ host-based programs or transactional systems, but also contain a Web browser-like user interface.

After the components are developed and tested, the application programmer packages them into the appropriate deployment format and passes them to the team that coordinates production code deployments.

Some of the application enablement services that are available on z/OS include the following:

IBM WebSphere Studio Enterprise Developer	Language Environment®	C/C++ IBM Open Class® Library
DCE Application Support1	Encina® Toolkit Executive2	C/C++ with Debug Tool
DFSORT™	GDDM®-PGF	GDDM-REXX
HLASM Toolkit	Traditional languages such as COBOL, PL/I, and Fortran	

More information about the use of software products and middleware for application development is provided in later chapters of this text.

7.4.2 Conducting a debugging session

The application programmer conducts a “unit test” to test the functionality of a particular module being developed. The programmer uses job monitoring and viewing software such as SDSF (described in 6.7, “Using SDSF” on page 6-12) to track the running compile jobs, view the compiler output, and verify the results of the unit tests. If necessary, the programmer makes the appropriate corrections to source code or other objects.

Sometimes, a program will create a “dump” of memory when a failure occurs. When this happens, a z/OS application programmer might use tools such as IBM Debug Tool and IBM Fault Analyzer to interrogate the dump output and to trace through executing code to find the failure or misbehaving code.

A typical development session follows these steps:

1. Log on to z/OS
2. Enter ISPF and open/check out source code from the SCLM repository (or PDS)
3. Edit the source code to make necessary modifications
4. Submit JCL to build the application and do a test run
5. Switch to SDSF to view the running job status
6. View the job output in SDSF to check for errors
7. View the dump output to find bugs[1]
8. Re-run the compile/link/go job and view the status
9. Check the validity of the job output

10. Save the source code in SCLM (or PDS)

Some mainframe application programmers have now switched to the use of Interactive Development Environment (IDE) tools to accelerate the edit/compile/test process. IDEs such as the WebSphere Studio Enterprise Developer are used to edit source code on a workstation instead of directly on the host system, to run compiles "off-platform," and to perform remote debugging.

The use of the IDE is particularly useful if hybrid applications are being built that employ host-based programs in COBOL or transaction systems such as CICS and IMS, but also contain a Web browser-like user interface. The IDE provides a unified development environment to build both the on-line transaction processing (OLTP) components in a high-level language and the HTML front-end user interface components. Once the components are developed and tested, they are packaged into the appropriate deployment format and passed to the team that coordinates production code deployments.

Besides new application code, the application programmer is responsible for the maintenance and enhancement of existing mainframe applications. In fact, this is the primary job for many high-level language programmers on the mainframe today. While most customers do still create new programs with COBOL, PL/I, etc., languages such as Java have become popular for building new applications on the mainframe, just as on distributed platforms.

However, for those of us interested in the traditional languages, there is still widespread development of programs on the mainframe in high-level languages such as COBOL and PL/I. There are many thousands of programs in production on mainframe systems around the world, and these programs are critical to the day-to-day business of the corporations that use them. COBOL and other high-level language programmers are needed to maintain existing code and make updates and modifications to those programs.

Also, many corporations continue to build new application logic in COBOL and other traditional languages, and IBM continues to enhance the high-level language compilers to include new functions and features that allow these languages to continue to exploit newer technologies and data formats.

7.4.3 Performing a system test

The difference between the testing done at this stage and the testing done during the development phase is that we are now testing the application as a whole, as well as in conjunction with other applications. We also carry out tests that can only be done once

[1] The origin of the term "programming bug" is often attributed to US Navy Lieutenant Grace Murray Hopper in 1945. As the story goes, Lt. Hopper was testing the Mark II Aiken Relay Calculator at Harvard University. One day, a program that worked previously mysteriously failed. Upon inspection, the operator found that a moth was trapped between the circuit relay points and had created a short-circuit (early calculators occupied many square feet, and consisted of tens of thousands of vacuum tubes). The September 9, 1945 log included both the moth and the entry: "First actual case of a bug being found", and that they had "debugged the machine".

the application coding has been completed because we need to know how the whole application performs, and not just a portion of it.

The tests performed during this phase are:

- User testing - The user tests the application for functionality and usability.
- Integration testing - The new application is tested together with other applications to see if they interface as expected.
- Performance or stress testing - The application is tested using real production data or at least real production data volume to see how well the application performs when there is high demand.

The results of the user and integration tests need to be verified to ensure that they are satisfactory. In addition, the performance of the application must match the requirements. Any issues coming out of these tests need to be addressed before going into production. The number of issues encountered during the testing phase are a good indication of how well we did our design work.

7.5 Going into production on the mainframe

The act of "going into production" is not simply turning on a switch that says now the application is production-ready. It is much more complicated than that. And from one project to the next, the way in which a program goes into production can change.

In some cases, where we have an existing system that we are replacing, we might decide to run in parallel for a period of time prior to switching over to the new application. In this case, we run both the old and the new systems against the same data and then compare the results. If after a certain period of time we are satisfied with the results, we switch to the new application. If we discover problems, we can correct them and continue the parallel run until there aren't any new problems.

In other cases, we are dealing with a new system, and we might just have a cut-over day when we start using it. Even in the case of a new system, we are usually replacing some form of system, even if it's a manual system, so we could still do a parallel test if we wanted to.

Whichever method is used to go into production, there are still all of the loose ends that need to be taken care of before we hand the system over to Operations. One of the tasks is to provide documentation for the system, as well as procedures for running and using it. We need to train anyone who interacts with the system.

When all of the documentation and training has been done, then we can hand over responsibility for the running of the application to Operations and responsibility for maintaining the application to the Maintenance group. In some cases, the Development group also maintains applications.

At this point, the application development life cycle reaches a steady state and we enter the maintenance phase of the application. From this point onward, we only apply enhancements and day-to-day changes to the application. Because the application now falls under a change control process, all changes require testing according to the process for change control, before they are accepted into production. In this way, a stable, running application is ensured for end users.

7.6 Summary

This chapter describes the roles of the application designer and application programmer. The discussion is intended to highlight the types of decisions that are involved in designing and developing an application to run in the mainframe environment. This is not to say that the process is much different on other platforms, but some of the questions and conclusions can be different.

This chapter then describes the life cycle of designing and developing an application to run on z/OS. The process begins with the requirement gathering phase, in which the application designer attempts to identify the relevant parts of the problem to be solved. The designer analyzes user requirements to see how best to satisfy them. There may be many ways to arrive at the same solution; the object of the analysis and design phases is to ensure that the optimal solution is chosen. Here, “optimal” does not mean “quickest,” although time is an issue in any project. Instead, optimal refers to the best overall solution, with regard to user requirements and problem analysis.

At the end of the design phase, the programmer’s role takes over. The programmer must now translate the application design into error-free program code. Throughout the development phase, the programmer tests the code as each module is added to the whole. The programmer must correct any logic problems that are detected and add the updated modules to the completed suite of tested programs.

An application rarely exists in isolation. Rather, an application is usually part of a larger set of applications, where the output from one application is the input to the next application. To verify that a new application does not cause problems when incorporated into the larger set of applications, the application programmer conducts a system test or integration test. These tests are themselves designed, and many test results are verified by the actual application users.

If there are problems with the system test, the problems will need to be resolved and the test repeated before the process can proceed to the next step.

Following a successful system test, the application is ready to go into production. This phase is sometimes referred to as promoting an application. Once promoted, the application code is now more closely controlled. A business would not want to introduce a change into a working system without being sure of its reliability. At most z/OS sites, strict rules govern the promotion of applications (or modules within an application) to prevent untested code from contaminating a “pure” system.

At this point in the life cycle of an application, it has reached a steady state. The only changes that will be made to a production application are enhancements, functional changes (for example, tax laws change, so payroll programs need to change), or corrections.

Key terms in this chapter		
application	architecture	database
design	develop	enablement
executable	infrastructure	platform
requirement	transaction	unit test

7.7 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What are the differences between an application designer and an application programmer? Which role must have a global view of the entire project?
2. In which phase of the application development life cycle does the designer conduct interviews?
3. What is the purpose for using a repository to manage source code?
4. What are the phases in an application development life cycle? State briefly what happens in each phase.
5. If you were a designer on a specific project and the time line for getting the new application into production was very short, what decisions might you make to reduce the overall time line of the project?
6. As part of your system testing phase, you do a performance test on the application. Why would you use production data to do this test?
7. Give some possible reasons for deciding to use batch for an application versus online

8

Using programming languages on z/OS

Objective: As your company's newest z/OS application programmer, you will need to know which programming languages are supported on z/OS, and how to determine which is best for a given set of requirements.

After completing this chapter, you will be able to:

- List several common programming languages for the mainframe
- Explain the differences between a compiled language and an interpreted language
- Create a simple CLIST or REXX program
- Choose an appropriate data file organization for an online applications
- Compare the advantages of a high level language to those of Assembler language
- Explain the relationship between a data set name, a DD name, and the file name within a program
- Explain how the use of z/OS Language Environment affects the decisions made by the application designer

8.1 Overview of programming languages

A computer language is the way that a human communicates with a computer. It is needed because a computer works only with its machine language (bits and bytes). This is slow and cumbersome for humans to use. Therefore, we write programs in a computer language, which then gets converted into machine language for the computer to process.

There are many computer languages, and they have been evolving from machine language into a more natural way of writing. Some languages have been adapted to the kind of application that they intended to solve and to the kind of approach used in the design. The word *generation* has been used to indicate this evolution.

A classification of computer languages follows.

1. Machine language, the 1st generation, direct machine code.
2. Assembler, 2nd generation, using mnemonics to present the instructions to be translated later into machine language by an assembly program, such as Assembler language.
3. Procedural languages, 3rd generation, also known as high level languages (HLL), such as Pascal, FORTRAN, Algol, COBOL, PL/I, Basic, and C. The coded program, called a source program, has to be translated via a compilation step.
4. Non-procedural languages, 4th generation, also known as 4GL, used for predefined functions in applications for databases, report generators, queries, such as RPG, CSP, QMF™.
5. Visual Programming languages that use a mouse and icons, such as VisualBasic and VisualC++.
6. HyperText Markup Language, used for writing of World Wide Web documents.
7. Object-Oriented language, OO technology, such as Smalltalk, Java, and C++.
8. Other languages, for example 3D applications.

Each computer language evolved separately, driven by the creation of and adaptation to new standards. In the following sections we describe several of the most widely used computer languages supported by z/OS:

- Assembler - “Using Assembler language on z/OS” on page 8-4
- COBOL - “Using COBOL on z/OS” on page 8-6
- PL/I - “Using PL/I on z/OS” on page 8-12
- C/C++ - “Using C/C++ on z/OS” on page 8-15
- Java - “Using Java on z/OS” on page 8-16
- CLIST - “Using CLISTs on z/OS” on page 8-17
- REXX - “Using REXX on z/OS” on page 8-19

For the computer languages just discussed, we have listed their evolution and classified them. There are procedural and non-procedural, compiled and interpretive, and machine-dependent and non-machine-dependent languages.

Assembler language programs are *machine-dependen*t, because the language is a symbolic version of the machine's language on which the program is running. Assembler language instructions can differ from one machine to another, so an Assembler language program written for one machine might not be portable to another. Rather, it would most likely need to be rewritten to use the instruction set of the other machine. A program written in a high-level language (HLL) would run on other platforms, but it would need to be recompiled into the machine language of the target platform.

Most of the HLLs that we touch upon in this chapter are *procedural languages*. This type is well-suited to writing structured programs. The *non-procedural languages*, such as SQL and RPG, are more suited for special purposes, such as report generation.

Most HLLs are compiled into machine language, but some are interpreted. Those that are compiled result in machine code which is very efficient for repeated executions. Interpreted languages must be parsed, interpreted, and executed each time that the program is run. The trade-off for using interpreted languages is a decrease in programmer time, but an increase in machine resources.

The advantages of compiled and interpreted languages are further explored in 8.10, "Compiled versus interpreted languages" on page 8-20.

8.2 Choosing a programming language for z/OS

In developing a program to run on z/OS, your choice of a programming language might be determined by the following considerations:

- What type of application?
- What are the response time requirements?
- What are the budget constraints for development and ongoing support?
- What are the time constraints of the project?
- Do we need to write some of the subroutines in different languages because of the strengths of a particular language versus the overall language of choice?
- Do we use a compiled or an interpreted language?

8.3 Using Assembler language on z/OS

Assembler language is a symbolic programming language that can be used to code instructions instead of coding in machine language. It is the symbolic programming language that is closest to the machine language in form and content. Therefore, Assembler language is an excellent candidate for writing programs in which:

- You need control of your program, down to the byte or bit level.
- You must write subroutines[1] for functions that are not provided by other symbolic programming languages, such as COBOL, FORTRAN, or PL/I.

Assembler language is made up of statements that represent either instructions or comments. The instruction statements are the working part of the language, and they are divided into the following three groups:

- A *machine instruction* is the symbolic representation of a machine language instruction of the following instruction sets:
  - IBM System/360
  - IBM System/370
  - IBM System/370 Extended Architecture (370-XA)
  - IBM Enterprise Systems Architecture/370™ (ESA/370)
  - IBM Enterprise Systems Architecture/390 (ESA/390)
  - IBM z/Architecture

  It is called a machine instruction because the assembler translates it into the machine language code that the computer can execute.
- An *assembler instruction* is a request to the assembler to do certain operations during the assembly of a source module; for example, defining data constants, reserving storage areas, and defining the end of the source module.
- A *macro instruction* is a request to the assembler program to process a predefined sequence of instructions called a *macro definition*. From this definition, the assembler generates machine and assembler instructions, which it then processes as if they were part of the original input in the source module.

The assembler produces a program listing containing information that was generated during the various phases of the assembly process[2]. It is really a compiler for Assembler language programs.

---

[1] Subroutines are programs that are invoked frequently by other programs and by definition should be written with performance in mind. Assembler language is a good choice for a subroutine.

[2] A program listing does not contain *all* of the information that is generated during the assembly process. To capture all of the information that could possibly be in the listing (and more), the z/OS programmer can specify an assembler option called ADATA to have the assembler produce a SYSADATA file as output. The SYSADATA file is not human-readable -- its contents are in a form that is designed for a tool to process. The use of a SYSADATA file is simpler for tools to process than the older custom of extracting similar data through "listing scrapers".

The assembler also produces information for other processors, such as a *binder* (or *linker*, for earlier releases of the operating system). Before the computer can execute your program, the object code has to be run through another process to resolve the addresses where instructions and data will be located. This process is called *linkage-editing* (or *link-editing*, for short) and is performed by the binder.

The binder or linkage editor (for more details, see 9.3.7, “How is a linkage editor used?” on page 9-15) uses information in the object modules to combine them into load modules. At program fetch time, the load module produced by the binder is loaded into virtual storage. After the program is loaded, it can be run.

Figure 8-1 on page 8-5 shows these steps.

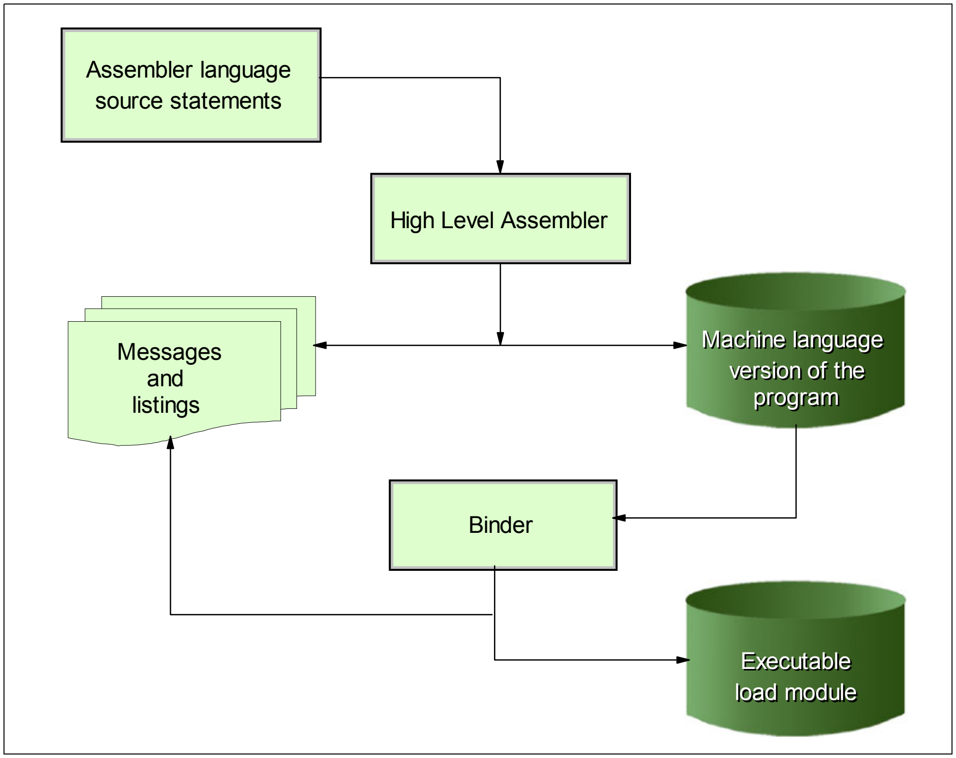


Figure 8-1 Assembler source to executable module

For more information, see the following publications:

- *HLASM General Information*, GC26-4943
- *HLASM Installation and Customization Guide*, SC26-3494
- *HLASM Language Reference*, SC26-4940

You can find them at the following Web site:

http://www.ibm.com/servers/eserver/zseries/zos/bkserv/find_shelves.html

8.4 Using COBOL on z/OS

Common Business-Oriented Language (COBOL) is a programming language similar to English that is widely used to develop business-oriented applications in the area of commercial data processing. COBOL has been almost a generic term for computer programming in this kind of computer language. However, as used in this chapter, COBOL refers to the product IBM Enterprise COBOL for z/OS and OS/390®.

In addition to the traditional characteristics provided by the COBOL language, this version of COBOL is capable, through COBOL functions, of integrating COBOL applications into Web-oriented business processes. With the capabilities of this release, applications developers can do the following:

- Utilize new debugging functions in Debug Tool
- Enable interoperability with Java when an application runs in an IMS Java dependent region
- Simplify the componentization of COBOL programs and enable interoperability with Java components across distributed applications
- Promote the exchange and usage of data in standardized formats including XML and Unicode

With Enterprise COBOL for z/OS and OS/390, COBOL and Java applications can interoperate in the e-business world.

The COBOL compiler produces a program listing containing all the information that it generated during the compilation. The compiler also produces information for other processors, such as the binder.

Before the computer can execute your program, the object code has to be run through another process in order to resolve the addresses where instructions and data will be located. This process is called *linkage edition* and is performed by the binder.

The binder uses information in the object modules to combine them into load modules (these are further discussed in 9.3.7, "How is a linkage editor used?" on page 9-15). At program fetch time, the load module produced by the binder is loaded into virtual storage. When the program is loaded, it can then be run. Figure 8-2 on page 8-7 illustrates the process of translating the COBOL source language statements into an executable load module.

This process is similar to that of Assembler language programs. In fact, this same process is used for all of the HLLs that are compiled.

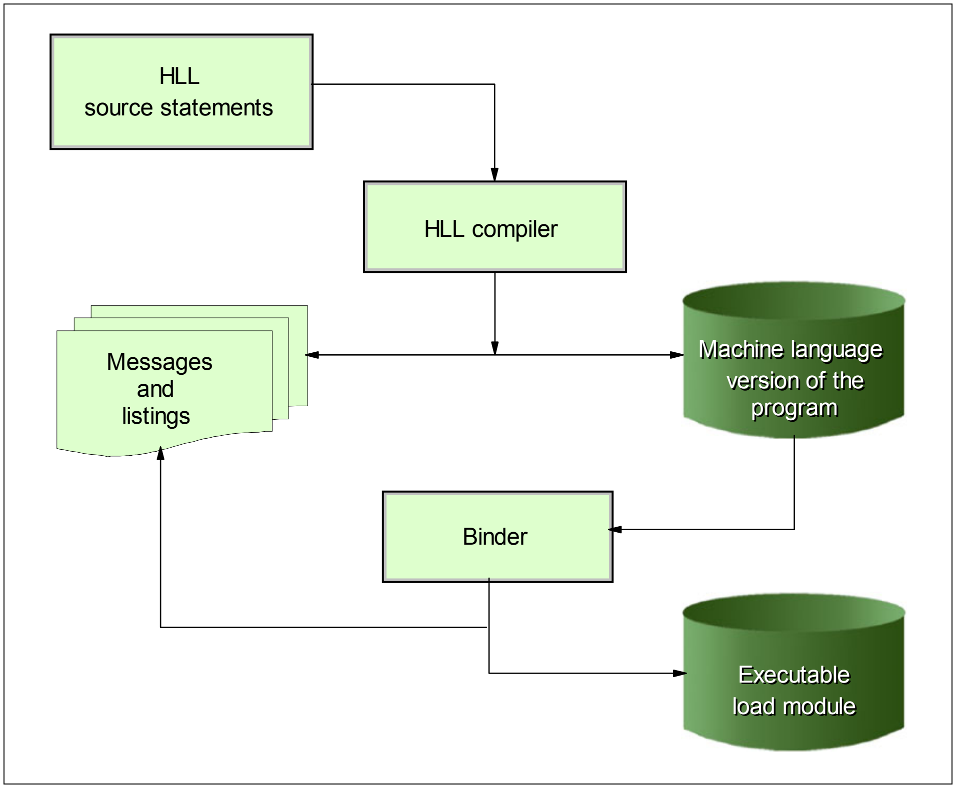


Figure 8-2 HLL source to executable module

COBOL program format

With the exception of the COPY and REPLACE statements and the end program marker, the statements, entries, paragraphs, and sections of a COBOL source program are grouped into the following four divisions:

- **IDENTIFICATION DIVISION**, which identifies the program with a name and, if you want, gives other identifying information.
- **ENVIRONMENT DIVISION**, where you describe the aspects of your program that depend on the computing environment.
- **DATA DIVISION**, where the characteristics of your data are defined. These are defined in one of the following sections in the DATA DIVISION:
  - FILE SECTION, to define data used in input-output operations
  - LINKAGE SECTION, to describe data from another program.

  When defining data developed for internal processing:

- WORKING-STORAGE SECTION, to have storage statically allocated and remain for the life of the run unit.
- LOCAL-STORAGE SECTION, to have storage allocated each time a program is called and de-allocated when the program ends.
- LINKAGE SECTION, to describe data from another program.

- **PROCEDURE DIVISION**, where the instructions related to the manipulation of data and interfaces with other procedures are specified.

  The **PROCEDURE DIVISION** of a program is divided into sections and paragraphs, which contain sentences and statements, as described here:

  - **Section** - a logical subdivision of your processing logic. A section has a section header and is optionally followed by one or more paragraphs. A section can be the subject of a PERFORM statement. One type of section is for declaratives.

    Declaratives are a set of one or more special purpose sections, written at the beginning of the Procedure Division, the first of which is preceded by the key word DECLARATIVES and the last of which is followed by the key word END DECLARATIVES.
  - **Paragraph** - a subdivision of a section, procedure, or program. A paragraph can be the subject of a statement.
  - **Sentence** - is a series of one or more COBOL statements ending with a period.
  - **Statement** - performs a defined step of COBOL processing, such as adding two numbers.
  - **Phrase** - a subdivision of a statement.

Examples of COBOL divisions

Example 8-1 IDENTIFICATION DIVISION

```
 IDENTIFICATION DIVISION.
Program-ID. Helloprog.
Author. A. Programmer.
Installation.  Computing Laboratories.
Date-Written.  08/21/2002.
```

*ENVIRONMENT DIVISION*Example of input-output coding

Explanations of the user-supplied information follow Example 8-2.

Example 8-2 Input and output files in FILE-CONTROL

```
 IDENTIFICATION DIVISION.
. . .
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
```

```
FILE-CONTROL.
    SELECT filename ASSIGN TO assignment-name
    ORGANIZATION IS org ACCESS MODE IS access
    FILE STATUS IS file-status
. . .
DATA DIVISION.
FILE SECTION.
FD  filename
01  recordname
    nn . . . fieldlength & type
    nn . . . fieldlength & type
. . .
WORKING-STORAGE SECTION
01 file-status  PICTURE 99.
. . .
PROCEDURE DIVISION.
    . . .
    OPEN iomode filename
    . . .
    READ filename
    . . .
    WRITE recordname
    . . .
    CLOSE filename
    . . .
    STOP RUN.
```

- `org` indicates the organization, which can be SEQUENTIAL, LINE SEQUENTIAL, INDEXED, or RELATIVE.
- `access` indicates the access mode, which can be SEQUENTIAL, RANDOM, or DYNAMIC.
- `iomode` is for INPUT or OUTPUT mode. If you are only reading from a file, code INPUT. If you are only writing to it, code OUTPUT or EXTEND. If you are both reading and writing, code I-O, except for organization LINE SEQUENTIAL.
- Others like `filename, recordname, fieldname` (nn in the example), `fieldlength` and `type` are also specified.

8.4.1 COBOL relationship between JCL and program files

Example 8-3 depicts the relationship between JCL statements and the files in a COBOL program. By not referring to physical locations of data files in a program, we achieve device independence. That is, we can change where the data resides and what it is called without having to change the program. We would only need to change the JCL.

Example 8-3 COBOL relationship between JCL and program files

```
//MYJOB    JOB
```

```
//STEP1    EXEC IGYWCLG
...
   INPUT-OUTPUT SECTION.
   FILE-CONTROL.
     SELECT INPUT ASSIGN TO INPUT1 .....
     SELECT DISKOUT ASSIGN TO OUTPUT1 ...
   FILE SECTION.
     FD INPUT1
        BLOCK CONTAINS...
        DATA RECORD IS RECORD-IN
     01 INPUT-RECORD
...
     FD OUTPUT1
        DATA RECORD IS RECOUT
     01 OUTPUT-RECORD
...
/*
//GO.INPUT1  DD DSN=MY.INPUT,DISP=SHR
//GO.OUTPUT1 DD DSN=MY.OUTPUT,DISP=OLD
```

Example 8-3 shows a COBOL compile, link, and go job stream, listing the file program statements and the JCL statements to which they refer.

The COBOL SELECT statements make the links between the DDNAMEs INPUT1 and OUTPUT1, and the COBOL FDs INPUT1 and OUTPUT1, respectively. The COBOL FDs are associated with group items INPUT-RECORD and OUTPUT-RECORD.

The DD cards INPUT1 and OUTPUT1 are related to the data sets MY.INPUT and MY.OUTPUT, respectively. The end result of this linkage in our example is that records read from the file INPUT1 will be read from the physical data set MY.INPUT and records written to the file OUTPUT1 will be written to the physical data set MY.OUTPUT. The program is completely independent of the location of the data and the name of the data sets.

Figure 8-3 shows the relationship between the physical data set, the JCL, and the program for Example 8-3. Once again, since the program does not make any reference to the physical data set, we would not need to recompile the program if the name of the data set or its location were to change.

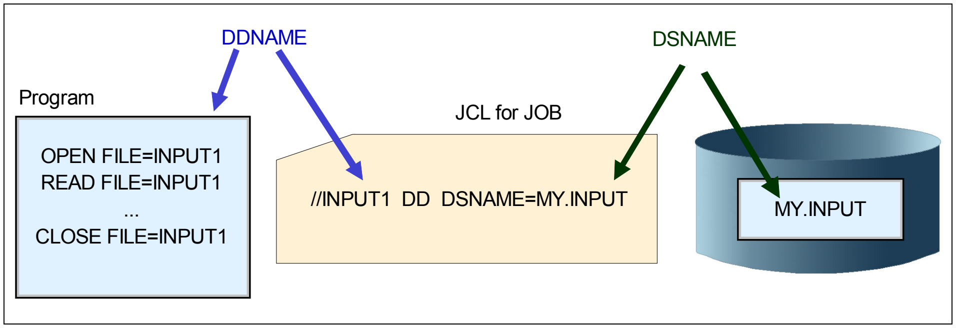


Figure 8-3 Relationship between JCL, program, and data set

8.4.2 HLL relationship between JCL and program files

In 8.4.1, "COBOL relationship between JCL and program files" on page 8-9, we learned how to isolate a COBOL program from changes in data set name and data set location. The technique of referring to physical files by a symbolic file name is not restricted to COBOL; it is used by all HLLs and even in Assembler language. See Example 8-4 for a generic HLL example of a program that references data sets through symbolic file names.

Isolating your program from changes to data set name and location is the normal objective. However, there could be cases when a program needs to access a specific data set at a specific location on a direct access storage device (DASD). This can be accomplished in Assembler language and even in some HLLs.

The practice of "hard-coding" data set names or other such information in a program is not usually considered a good programming practice. Values that are hard-coded in a program are subject to change and would therefore require that the program be recompiled each time a value changed. Externalizing these values from programs, as with the case of referring to data sets within a program by a symbolic name, is a more effective practice that allows the program to continue working even if the data set name changes.

Example 8-4 HLL Relationship between JCL and program files

```
//MYJOB    JOB
//STEP1    EXEC CLG
...
   OPEN FILE=INPUT1
   OPEN FILE=OUTPUT1
   READ FILE=INPUT1
...
   WRITE FILE=OUTPUT1
...
   CLOSE FILE=INPUT1
```

```
   CLOSE FILE=OUTPUT1
/*
//GO.INPUT1  DD DSN=MY.INPUT,DISP=SHR
//GO.OUTPUT1 DD DSN=MY.OUTPUT,DISP=OLD
```

For a more detailed explanation of using a symbolic name to refer to a file, see 5.4, "Why z/OS uses symbolic file references" on page 5-5.

For more information, see the following publications:

- *Enterprise COBOL for z/OS and OS/390 V3R2 Language Reference*, SC27-1408
- *Enterprise COBOL for z/OS and OS/390 V3R2 Programming Guide*, SC27-1412

You can find them on the Web at:

```
http://www.ibm.com/servers/eserver/zseries/zos/bkserv/find_shelves.html
```

8.5 Using PL/I on z/OS

Programming Language/I (PL/I, pronounced "P-L one"), is a full function, general-purpose, high-level programming language suitable for the development of:

- Operating systems
- Commercial applications
- Engineering/scientific applications
- Many other applications

PL/I programs are made up of blocks. A block can be either a subroutine or just a group of statements. A PL/I block allows you to produce highly-modular applications.

The process of compiling a PL/I source program and then link-editing the object code into a load module is basically the same as it is for COBOL. Refer to Example 8-2 on page 8-7, 9.3.7, "How is a linkage editor used?" on page 9-15and Figure 8-3 on page 8-11.

The relationship between JCL and program files is the same for PL/I as it is for COBOL and other HLLs. Refer to Figure 8-3 on page 8-11 and to Example 8-4 on page 8-11.

PL/I program structure

PL/I is a block-structured language, consisting of packages, procedures, *begin blocks*, statements, expressions, and built-in functions as it is shown in Figure 8-4.

PL/I programs are made up of blocks. A *block* can be either a subroutine, or just a group of statements. A PL/I block allows you to produce highly-modular applications, because blocks can contain declarations that define variable names and storage class. Thus, you can restrict the scope of a variable to a single block or a group of blocks, or you can make it known throughout the compilation unit or a load module.

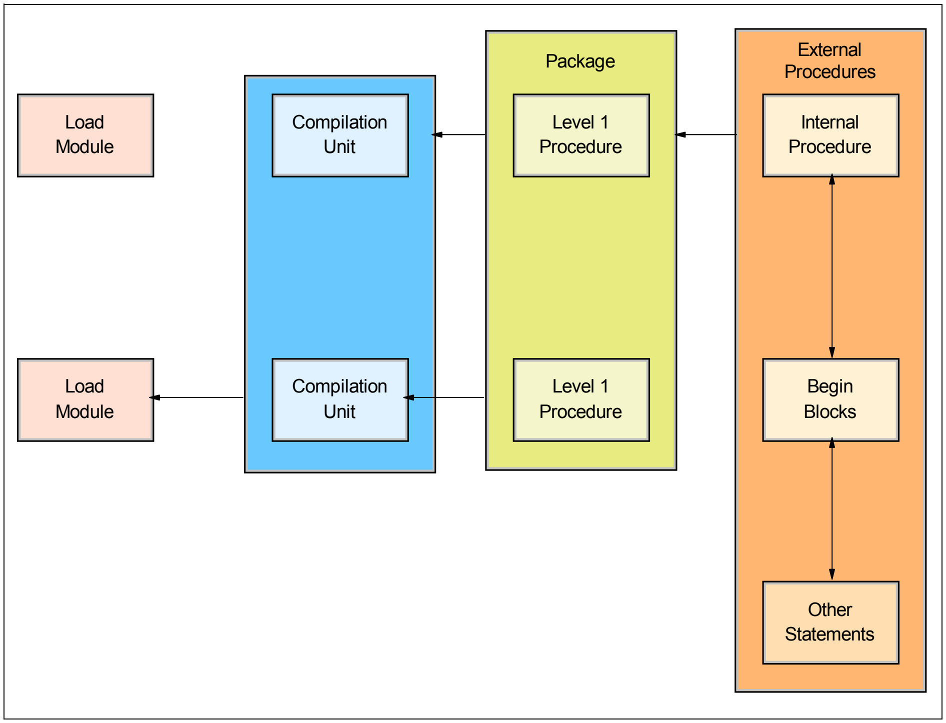


Figure 8-4 PL/I application structure

A PL/I application consists of one or more separately loadable entities, known as a *load module*. Each load module can consist of one or more separately compiled entities, known as a *compilation unit*. Unless otherwise stated, a *program* refers to a PL/I application or a compilation unit.

A compilation unit is a PL/I PACKAGE or an external PROCEDURE. Each package can contain zero or more procedures, some or all of which can be exported. A PL/I external or internal procedure contains zero or more blocks.

A PL/I block is either a PROCEDURE or a BEGIN block, any of which contains zero or more statements and/or zero or more blocks.

A procedure is a sequence of statements delimited by a PROCEDURE statement and a corresponding END statement, as shown in Example 8-5. A procedure can be a main procedure, a subroutine, or a function. An application must have exactly one external procedure that has OPTIONS(MAIN).

Example 8-5 A PROCEDURE block

```
A: procedure;
      statement-1
      statement-2

     .

     .

     .
      statement-n
      end Name;
```

A *BEGIN block* is a sequence of statements delimited by a BEGIN statement and a corresponding END statement, as shown in Example 8-6.

A program is terminated when the main procedure is terminated.

Example 8-6 BEGIN block

```
B:  begin;
     statement-1
     statement-2

     .

     .

     statement-n
     end B;
```

Preprocessors

The PL/I compiler allows you to select one or more of the integrated preprocessors as required for use in your program. You can select the include preprocessor, the macro preprocessor, the SQL preprocessor, or the CICS preprocessor—and you can select the order in which you would like them to be called.

Each preprocessor supports a number of options to allow you to tailor the processing to your needs.

- ***Include preprocessor.*** This allows you to incorporate external source files into your programs by using include directives other than the PL/I directive %INCLUDE (the %INCLUDE directive is used to incorporate external text into the source program).
- ***Macro preprocessor.*** Macros allow you to write commonly used PL/I code in a way that hides implementation details and the data that is manipulated, and exposes only

the operations. In contrast with a generalized subroutine, macros allow generation of only the code that is needed for each individual use.

- ***SQL preprocessor.*** In general, the coding for your PL/I program will be the same whether or not you want it to access a DB2 database. However, to retrieve, update, insert, and delete DB2 data and use other DB2 services, you must use SQL statements. You can use dynamic and static EXEC SQL statements in PL/I applications.

  To communicate with DB2, you need to do the following:

  – Code any SQL statements you need, delimiting them with EXEC SQL.

  – Use the DB2 precompiler or, if using DB2 for OS/390 Version 7 Release 1 or later compile with the PL/I PP(SQL()) compiler option.

  Before you can take advantage of EXEC SQL support, you must have authority to access a DB2 system.

  Note: The PL/I SQL Preprocessor currently does not support DBCS.

  CICS preprocessor. You can use EXEC CICS statements in PL/I applications that run as transactions under CICS.

  For more information, see the following publications:

- *Enterprise PL/I for z/OS V3R3 Language Reference*, SC27-1460
- *Enterprise PL/I for z/OS V3R3 Programming Guide*, SC27-1457

You can find them on the Web at:

```
http://www.ibm.com/servers/eserver/zseries/zos/bkserv/find_shelves.html
```

8.6 Using C/C++ on z/OS

C is a programming language designed for a wide variety of programming tasks. It is used for:

- System-level code
- Text processing
- Graphics
- Many other application areas

The C language contains a concise set of statements with functionality added through its library. This division enables C to be both flexible and efficient. An additional benefit is that the language is highly consistent across different systems.

The process of compiling a C source program and then link-editing the object code into a load module is basically the same as it is for COBOL. Refer to Example 8-2 on page 8-7, 9.3.7, “How is a linkage editor used?” on page 9-15, and Figure 8-3 on page 8-11 to see this process.

The relationship between JCL and program files is the same for PL/I as it is for COBOL and other HLLs. Refer to Figure 8-3 on page 8-11 and to Example 8-4 on page 8-11.

For more information, see the following publications:

- *C/C++ Language Reference*, SC09-4764
- *C/C++ Programming Guide*, SC09-4765

You can find them on the Web at:

`http://www.ibm.com/servers/eserver/zseries/zos/bkserv/find_shelves.html`

8.7 Using Java on z/OS

Java is an object-oriented programming language developed by Sun Microsystems Inc. Programming languages such as Enterprise COBOL and Enterprise PL/I in z/OS provide interfaces to programs written in Java Language. Java can be used for developing traditional zSeries commercial applications as well as Internet and intranet applications that use standard interfaces.

The 64-Bit SDK package for z/OS, Java 2 Technology Edition V1.4, benefits application developers who want to take advantage of the Java APIs for z/OS, write or run applications across multiple platforms, or use Java to access zSeries data. Pure Java applications that were previously storage constrained by 31-bit addressing should be able to execute in a 64-bit environment. In addition, some zSeries servers support a type of Java processor called the zSeries Application Assist Processor (zAAP). Programs can be run interactively through z/OS UNIX or in batch. z/OS supports the Java 2 Platform, Enterprise Edition (J2EE) environment through the WebSphere Application Server, allowing multitier applications to be developed relatively easily.

8.7.1 Interfacing with Java

Here is a brief description of the Java Native Interface (JNI), and it explains why you might be interested in using it with PL/I. Instructions on how to build and run the Java - PL/I sample applications assume the work is being done in the UNIX System Services environment of z/OS. Before you can communicate with Java from PL/I, you need to have Java installed on your system.

The Java Native Interface (JNI)

The Java Native Interface (JNI) is the Java interface to native programming languages and is part of the Java Development Kits. If the standard Java APIs do not have the function you need, the JNI allows Java code that runs within a Java Virtual Machine (JVM) to operate with applications and libraries written in other languages, such as PL/I. In addition, the Invocation API allows you to embed a Java Virtual Machine into your native PL/I applications.

Java is a fairly complete programming language; however, there are situations in which you want to call a program written in another programming language. You would do this from Java with a method call to a native language, known as a *native method*. Programming through the JNI lets you use native methods to do many different operations. A native method can:

- Utilize Java objects in the same way that a Java method uses these objects
- Create Java objects, including arrays and strings, and then inspect and use these objects to perform its tasks
- Inspect and use objects created by Java application code
- Update Java objects that it created or were passed to it; these updated objects can then be made available to the Java application

Lastly, native methods can also easily call already-existing Java methods, capitalizing on the functionality already incorporated in the Java programming framework. In these ways, both the native language side and the Java side of an application can create, update, and access Java objects, and then share these objects between them.

8.8 Using CLISTs on z/OS

The CLIST language is an interpreted language. Like programs in other high-level interpreted languages, CLISTs are easy to write and test. You do not compile or link-edit them. To test a CLIST, you simply run it and correct any errors that might occur until the program runs without error.

The CLIST and REXX languages are the two command languages available from TSO/E. The CLIST language enables you to work more efficiently with TSO/E.

The term CLIST (pronounced "see list") stands for *command list*; it is called this because the most basic CLISTs are lists of TSO/E commands. When you invoke such a CLIST, it issues the TSO/E commands in sequence.

The CLIST programming language is used for:

- Performing routine tasks (such as entering TSO/E commands)
- Invoking other CLISTs
- Invoking applications written in other languages
- ISPF applications (such as displaying panels and controlling application flow)
- One-time quick solutions to problems

Categories of CLISTs

A CLIST can perform a wide range of tasks. Three general categories of CLISTs are:

- CLISTs that perform routine tasks
- CLISTs that are structured applications

- CLISTs that manage applications written in other languages

CLISTs that perform routine tasks

As a user of TSO/E, you will probably perform certain tasks on a regular basis. These tasks may involve entering TSO/E commands to check on the status of data sets, to allocate data sets for particular programs, and to print files.

You can write CLISTs that significantly reduce the amount of time that you have to spend on these routine tasks. By grouping together in a CLIST the instructions required to complete a task, you reduce the time, number of keystrokes, and errors involved in performing the task; thus, you increase your productivity. Such a CLIST can consist of TSO/E commands only, or a combination of TSO/E commands, JCL statements, or CLIST statements.

CLISTs that are structured applications

The CLIST language includes the basic tools you need to write complete, structured applications. Any CLIST can invoke another CLIST, which is referred to as a *nested* CLIST. CLISTs can also contain separate routines called *sub-procedures*. Nested CLISTs and sub-procedures let you separate your CLISTs into logical units and put common functions in a single location. Specific CLIST statements let you:

- Define common data for sub-procedures and nested CLISTs
- Restrict data to certain sub-procedures and CLISTs
- Pass specific data to a sub-procedure or nested CLIST

For interactive applications, CLISTs can issue commands of the Interactive System Productivity Facility (ISPF) to display full-screen panels. Conversely, ISPF panels can invoke CLISTs, based on input that a user types on the panel.

CLISTs that manage applications written in other languages

You might have access to applications that are written in other programming languages. However, the interfaces to these applications might not be easy to use or remember. Rather than write new applications, you can write CLISTs that provide easy-to-use interfaces between the user and such applications.

A CLIST can send messages to, and receive messages from, the terminal to determine what the user wants to do. Then, based on this information, the CLIST can set up the environment and issue the commands required to invoke the program that performs the requested tasks.

Executing CLISTs

To execute a CLIST, use the EXEC command. From an ISPF command line, type `TSO` in front of the command. In TSO/E EDIT or TEST mode, use the EXEC subcommand as you would use the EXEC command. (CLISTs executed under EDIT or TEST can issue only EDIT or TEST sub-commands and CLIST statements, but you can use the END sub-command in a CLIST to end EDIT or TEST mode and allow the CLIST to issue TSO/E commands.)

8.9 Using REXX on z/OS

The Restructured Extended Executor (REXX) language is a procedural language that allows programs and algorithms to be written in a clear and structural way. It is an interpreted and compiled language. An interpreted language is different from other programming languages, such as COBOL, because it is not necessary to compile a REXX command list before executing it. However, you can choose to compile a REXX command list before executing it to reduce processing time.

The REXX programming language can be used for:

- Performing routine tasks (such as entering TSO/E commands)
- Invoking other REXXs
- Invoking applications written in other languages
- ISPF applications (displaying panels and controlling application flow)
- One-time quick solutions to problems
- System programming
- Wherever we can use another HLL compiled language

REXX is also used in the Java environment. A new dialect of REXX called NetRexx™ works seamlessly with Java. NetRexx programs can use any Java classes directly, and can be used for writing any Java class. This brings Java security and performance to REXX programs, and REXX arithmetic and simplicity to Java. A single language, NetRexx, may be used for both scripting and application development.

The structure of a REXX program is simple. It provides a conventional selection of control constructs. For example, these include IF... THEN... ELSE... for simple conditional processing, SELECT... WHEN... OTHERWISE... END for selecting from a number of alternatives, and several varieties of DO... END for grouping and repetitions. No GOTO instruction is included, but a SIGNAL instruction is provided for abnormal transfer of control such as error exits and computed branching.

The process of compiling a REXX source program and then link-editing the object code into a load module is basically the same as it is for COBOL. Refer to Example 8-2 on page 8-7, 9.3.7, "How is a linkage editor used?" on page 9-15and Figure 8-3 on page 8-11 to see this process.

The relationship between JCL and program files is the same for REXX as it is for COBOL and other HLLs. Refer to Figure 8-3 on page 8-11 and to Example 8-4 on page 8-11.

A REXX program compiled under z/OS can run under z/VM. Similarly, a REXX program compiled under z/VM can run under z/OS. A REXX program compiled under z/OS or z/VM can run under VSE/ESA if REXX/VSE is installed.

For more information, see the following publications:

- *The REXX Language*, 2nd Ed., Cowlishaw, ZB35-5100
- *Procedures Language Reference (Level 1)*, C26-4358 SAA® CPI
- *REXX on zSeries V1R4.0 User's Guide and Reference*, SH19-8160
- *Creating Java Applications Using NetRexx* , SG24-2216

Also, visit the following Web site:

`http://www.ibm.com/software/awdtools/REXX/language/REXXlinks.html`

8.10 Compiled versus interpreted languages

During the design of an application, you might need to decide between using an compiled language or an interpreted language for the application source code. Both types of languages have their strengths and weaknesses. Usually, the decision to use an interpreted language is based on time restrictions on development or for ease of future changes to the program. A trade-off is made when using an interpreted language. You trade speed of development for higher execution costs. Because each line of an interpreted program must be translated each time it is executed, there is a higher overhead. Thus, an interpreted language is generally more suited to ad hoc requests versus non-ad hoc.

8.10.1 Advantages of compiled languages

Assembler, COBOL, PL/I, C/C++ are all translated by running the source code through a compiler. This results in very efficient code that can be executed any number of times. The overhead for the translation is incurred just once, when the source is compiled; thereafter, it need only be loaded and executed.

Interpreted languages, in contrast, must be parsed, interpreted, and executed each time the program is run, thereby greatly adding to the cost of running the program. For this reason, interpreted programs are usually less efficient than compiled programs.

Some programming languages, such as REXX and Java, can be either interpreted or compiled.

8.10.2 Advantages of interpreted languages

In "Advantages of compiled languages" we discussed the reasons for using languages that are compiled. In "Using CLISTs on z/OS" and "Using REXX on z/OS" we discussed the strong points of interpreted languages. There is no simple answer as to which language is “better”—it depends on the application. Even within an application we could end up using many different languages. For example, one of the strengths of a language like CLIST is that it is easy to code, test, and change. However, it is not very efficient. The trade-off is machine resources for programmer time.

Keeping this in mind, we can see that it would make sense to use a compiled language for the intensive parts of an application (heavy resource usage), whereas interfaces (invoking the application) and less-intensive parts could be written in an interpreted language. An interpreted language might also be suited for ad hoc requests or even for prototyping an application.

One of the jobs of a designer is to weigh the strengths and weaknesses of each language and then decide which part of an application is best suited for a particular language.

8.11 Overview of Language Environment

As mentioned in Chapter 7, “Designing and developing applications for z/OS” an application is a collection of one or more programs cooperating to achieve particular objectives, such as inventory control or payroll. The goals of application development include modularizing and sharing code, and developing applications on a workstation-based front end.

On z/OS, the Language Environment product provides a common environment for all conforming high-level language (HLL) products. An HLL is a programming language above the level of assembler language and below that of program generators and query languages. z/OS Language Environment establishes a common language development and execution environment for application programmers on z/OS. Whereas functions were previously provided in individual language products, Language Environment eliminates the need to maintain separate language libraries.

In the past, programming languages had limited ability to call each other and behave consistently across different operating systems. This characteristic constrained programs that wanted to use several languages in an application. Programming languages had different rules for implementing data structures and condition handling, and for interfacing with system services and library routines.

With Language Environment, and its ability to call one language from another, z/OS application programmers can exploit the functions and features in each language.

8.11.1 How is Language Environment used?

Language Environment establishes a common run-time environment for all participating HLLs. It combines essential run-time services, such as routines for run-time message handling, condition handling, and storage management. These services are available through a set of interfaces that are consistent across programming languages. The application program can either call these interfaces directly, or use language-specific services that call the interfaces.

With Language Environment, you can use one run-time environment for your applications, regardless of the application's programming language or system resource needs.

Figure 8-5 shows the components in the Language Environment, including:

- Basic routines that support starting and stopping programs, allocating storage, communicating with programs written in different languages, and indicating and handling conditions.
- Common library services, such as math or date and time services, that are commonly needed by programs running on the system. These functions are supported through a library of callable services.
- Language-specific portions of the run-time library.

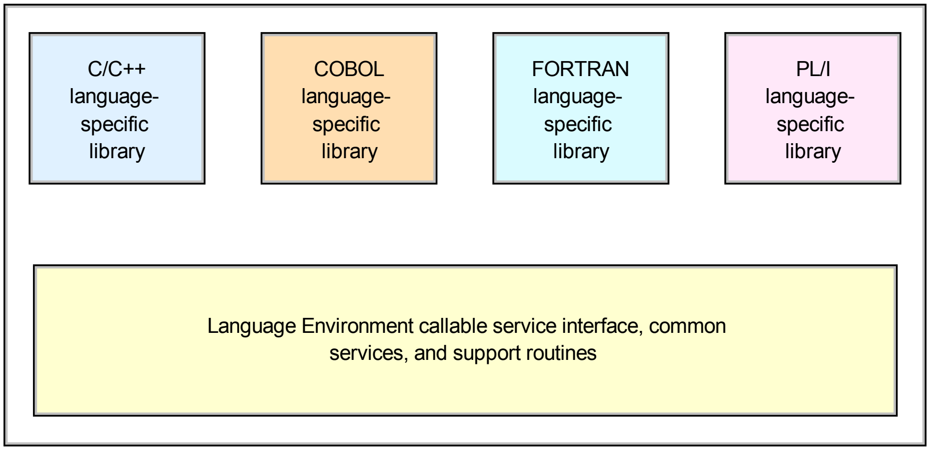


Figure 8-5 z/OS Language Environment components

Language Environment is the prerequisite run-time environment for applications generated with the following IBM compiler products:

- z/OS C/C++
- C/C++ Compiler for z/OS
- AD/Cycle® C/370™ Compiler
- VisualAge® for Java, Enterprise Edition for OS/390
- Enterprise COBOL for z/OS and OS/390
- COBOL for z/OS
- Enterprise PL/I for z/OS and OS/390

- PL/I for MVS & VM (formerly AD/Cycle PL/I for MVS & VM)
- VS FORTRAN and FORTRAN IV (in compatibility mode)

In many cases, you can run compiled code generated from the previous versions of the above compilers. A set of assembler macros is also provided to allow assembler routines to run with Language Environment.

8.12 Summary

This chapter outlines the many decisions you might need to make when you design and develop an application to run on z/OS. Selecting a programming language to use is one important step in the design phase of an application. The application designer must be aware of the strengths as well as the weaknesses of each language to make the best choice, based on the particular requirements of the application.

A critical factor in choosing a language is determining which one is most used at a given installation. If COBOL is used for most of the applications in an installation, it will likely be the language of choice for the installation's new applications as well.

Understand that even when a choice for the primary language is made, however, it does not mean that you are locked into that choice for all programs within the application. There might be a case for using multiple languages, to take advantage of the strengths of a particular language for only certain parts of the application. Here, it might be best to write frequently invoked subroutines in Assembler language to make the application as efficient as possible, even when the rest of the application is written in COBOL or another high level language.

Many z/OS sites maintain a library of subroutines that are shared across the business. The library might include, for example, date conversion routines. As long as these subroutines are written using standard linkage conventions, they can be called from other languages, regardless of the language in which the subroutines are written.

Each language has its inherent strengths, and designers should exploit these strengths. If a given application merits the added complication of writing it in multiple languages, the designer should take advantage of the particular features of each language. Keep in mind, however, that when it is time to update the application, other people must be able to program these languages as well. This is a cardinal rule of programming. The original programmer might be long gone, but the application will live on and on.

Thus, complexity in design must always be weighed against ease of maintenance.

Key terms in this chapter		
assembler	binder	compiler

debugging	dynamic link library	generation
I/O (input/output)	interpreter	load modules
pre-processor	programming language	variable

8.13 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. Why might a program be written in Assembler language?
2. Do companies continue to enhance the compilers for COBOL and PL/I?
3. Why are CLIST and REXX called interpreted languages?
4. What are the main areas of suitability for CLISTs and REXX?
5. Which interpreted language can also be compiled?
6. Is the use of Language Environment mandatory in z/OS application development?
7. Which of the data file organizations are appropriate for online applications? Which are appropriate for batch applications?
8. What is an HLL? What are some of the advantages of writing in an HLL versus Assembler language?
9. Assume that program PROG1 is run using the JCL below:

```
//job  JOB
//STEP010  EXEC PGM=PROG1
//STEPLIB  DD DSN=MY.PROGLIB,DISP=SHR
//INPUT1   DD DSN=A.B.C,DISP=SHR
//OUTPUT1  DD DSN=X.Y.Z,DISP=SHR
```

   If the INPUT1 DD card were changed to use the data set A1.B1.C1, would we be able to use the same program to process it? Assume that the new data set has the same characteristics as the old data set.

8.14 Topics for further discussion

1. If performance is a consideration, should you write a program in a compiled language or an interpreted language?
2. If you have to develop a transaction system, which of the following is your best choice?
   a. COBOL or PL/I on CICS
   b. C/C++ on CICS

   c. A combination of the above?

3. Which language would you use to write an application that calculated premiums on an insurance policy? Assume that this application will be invoked by many other applications.
4. Can a COBOL program call an Assembler language program? Why would you want to have this capability?

9

Compiling and link-editing a program on z/OS

Objective: As your company's newest z/OS application programmer, you will be asked to create new programs to run on z/OS. Doing so will require you to know how to compile, link, and execute a program.

After completing this chapter, you will be able to:

- Explain the purpose of a compiler
- Compile a source program
- Explain the difference between the linkage editor and the binder
- Link-edit an object module to create a load module
- Explain the difference between an object module and a load module
- Execute a load module

9.1 Source, object, and load modules

A program can be divided into logical units that perform specific functions. A logical unit of code that performs a function or several related functions is a *module*. Separate functions should be programmed into separate modules, a process called modular programming. Each module can be written in the symbolic language that best suits the function to be performed.

Each module is assembled or compiled by one of the language translators. The input to a language translator is a *source module*; the output from a language translator is an *object module*. Before an object module can be executed, it must be processed by the linkage editor. The output of the linkage editor is a *load module; see* Figure 9-1.

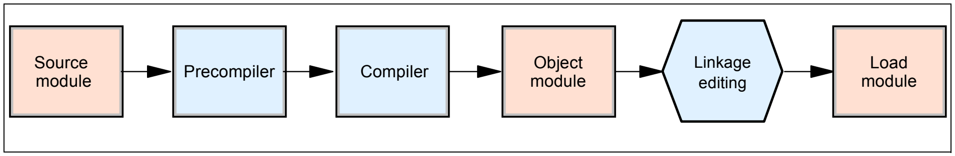


Figure 9-1 Source, object, and load modules

Depending on the status of the module, whatever it is—source, object or load—it can be stored in a library. A library is a partitioned data set (PDS) or a partitioned data set extended (PDSE) on direct access storage. PDSs and PDSEs are divided into partitions called members. In a library, each member contains a program or part of a program.

9.2 What are source libraries?

Source programs (or *source code*) is a set of statements written in an computer language, as discussed in Chapter 8, "Using programming languages on z/OS" . Source programs, once they are error-free, are stored in a partitioned data set known as a *source library.* Source libraries contain the source code to be submitted for a compilation process, or to be retrieved for modification by an application programmer.

A *copybook* is a source library containing pre-written text. It is used to copy text into a source program, at compile time, as a shortcut to avoid having to code the same set of statements over and over again. It is usually a shared library where programmers can store commonly-used program segments to be later included into their source programs. It should not be confused with a subroutine or a program. A copybook member is just text; it might not be actual programming language statements.

A *subroutine* is a commonly-called routine that performs a predefined function. The purpose behind a copybook member and a subroutine are essentially the same, to avoid having to code something that has previously been done. However, a subroutine is a small program (compiled, link-edited and executable) that is called and returns a result, based on the information that it was passed. A copybook member is just text that will be included in a source program on its way to becoming an executable program. The term copybook is a COBOL term, but the same concept is used in most programming languages.

If you use copybooks in the program that you are compiling, you can retrieve them from the source library by supplying a DD statement for SYSLIB or other libraries that you specify in COPY statements. In Example 9-1 on page 9-3, we insert the text in member INPUTRCD from the library DEPT88.BOBS.COBLIB into the source program that is to be compiled.

Example 9-1 Copybook in COBOL source code

```
//COBOL.SYSLIB  DD  DISP=SHR,DSN=DEPT88.BOBS.COBLIB
//SYSIN    DD  *
      IDENTIFICATION DIVISION.
     . . .
      COPY INPUTRCD
      . . .
```

Libraries must reside on direct access storage devices (DASDs). They cannot be in a hierarchical file system (HFS) when you compile using JCL or under TSO.

9.3 Compiling programs on z/OS

The function of a compiler is to translate source code into object code. The object code must then be processed by a linkage editor, a binder or a loader before it is executed. During the compilation of a source module, the compiler assigns relative addresses to all instructions, data elements, and labels, starting from zero.

The addresses are in the form of a base address plus a displacement. This allows programs to be relocated, that is, they do not have to be loaded into the same location in storage each time that they are executed. See 9.4, “Creating load modules for executable programs” on page 9-20 for more information on relocatable programs. Any references to external programs or subroutines are left as unresolved. These references will either be resolved when the object module is linked, or dynamically resolved when the program is executed.

To compile programs on z/OS, you can use a batch job, or you can compile under TSO/E through commands, CLISTs, or ISPF panels. Also, for COBOL programs, you can compile programs in a z/OS UNIX shell by using the **cob2** command.

For compiling through a batch job, z/OS includes a set of cataloged procedures that can help you avoid some of the JCL coding you would otherwise need to do. If none of the cataloged procedures meet your needs, you will need to write all of the JCL for the compilation.

As part of the compilation step, you need to define the data sets needed for the compilation and specify any compiler options necessary for your program and the desired output.

The data set (library) that contains your source code is specified on the SYSIN DD statement, as shown in Example 9-2.

Example 9-2 SYSIN DD statement for the source code

```
//SYSIN   DD  DSNAME=dsname,
//            DISP=SHR
```

You can place your source code directly in the input stream. If you do so, use this SYSIN DD statement:

```
//SYSIN    DD  *
```

When you use the DD * convention, the source code must follow the statement. If another job step follows the compilation, the EXEC statement for that step follows the /* statement or the last source statement.

9.3.1 What is a pre-compiler?

Some compilers have a precompile or preprocessor to process statements that are not part of the computer programming language. If your source program contains EXEC CICS statements or EXEC SQL statements, then it must first be pre-processed to convert these statements into COBOL, PL/I or Assembler language statements, depending on the language in which your program is written.

9.3.2 Compiling with cataloged procedures

The simplest way to compile your program under z/OS is by using a batch job with a *cataloged procedure.* A cataloged procedure is a set of job control statements placed in a partitioned data set (PDS) called the procedure library (PROCLIB). z/OS comes with a procedure library called SYS1.PROCLIB. This system library is discussed more thoroughly in 16.2.6, "SYS1.PROCLIB" on page 16-17. A simple way to look at the use of cataloged procedures is to think of them as copybooks. Instead of source statements, however, cataloged procedures contain JCL statements. You do not need to code a JCL statement to tell the system where to find them because they are located in a system library which automatically gets searched when you execute JCL that references a procedure.

You need to include the following information in the JCL for compilation:

- Job description
- Execution statement to invoke the compiler
- Definitions for the data sets needed but not supplied by the procedure

COBOL compile procedure

The JCL in Example 9-3 executes the IGYWC procedure, which is a single-step procedure for compiling a source program. It produces an object module that will be stored in the SYSLIN data set, as we can see in Example 9-4.

Example 9-3 Basic JCL for compiling a COBOL source program inline

```
//COMP     JOB
//COMPILE EXEC IGYWC
//SYSIN     DD   *
     IDENTIFICATION DIVISION (source program)
.
.
.
/*
//
```

The SYSIN DD statement indicates the location of the source program. In this case, the asterisk (*) indicates that it is in the same input stream.

For PL/I programs, in addition to the replacement of the source program, the compile EXEC statement should be replaced by:

```
//compile EXEC IBMZC
```

The statements shown in Example 9-4 make up the IGYWC cataloged procedure used in Example 9-3. As mentioned previously, the result of the compilation process, the compiled program, is placed in the data set identified on the SYSLIN DD statement.

Example 9-4 Procedure IGYWC - COBOL compile

```
//IGYWC  PROC  LNGPRFX='IGY.V3R2M0',SYSLBLK=3200
//*
//*  COMPILE A COBOL PROGRAM
//*
//*  PARAMETER  DEFAULT VALUE
//*   SYSLBLK   3200
//*   LNGPRFX   IGY.V3R2M0
//*
//*  CALLER MUST SUPPLY //COBOL.SYSIN DD . . .
//*
//COBOL  EXEC PGM=IGYCRCTL,REGION=2048K
//STEPLIB  DD  DSNAME=&LNGPRFX..SIGYCOMP,
//             DISP=SHR
```

```
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,UNIT=SYSDA,
//             DISP=(MOD,PASS),SPACE=(TRK,(3,3)),
//             DCB=(BLKSIZE=&SYSLBLK)
//SYSUT1   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT2   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT3   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT4   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT5   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT6   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
//SYSUT7   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))
```

COBOL pre-processor and compile and link procedure

The JCL in Example 9-5 executes the DFHEITVL procedure, which is a three-step procedure for pre-processing a COBOL source program, compiling the output from the pre-processing step, and then linking it into a load library. The first step produces pre-processed source code in the SYSPUNCH temporary data sets, with any CICS calls expanded into COBOL language statements. The second step takes this temporary data set as input and produces an object module that is stored in the SYSLIN temporary data set, as shown in Example 9-6 on page 9-7. The third step takes the SYSLIN temporary data set as input, as well as any other modules that might need to be included, and creates a load module in the data set referenced by the SYSLMOD DD statement.

In Example 9-5, you can see that the JCL is a bit more complicated than in the simple compile job (Example 9-3 on page 9-5). Once we go from one step to multiple steps, we must tell the system which step we are referring to when we supply JCL overrides.

Looking at the JCL in Example 9-6 on page 9-7, we see that the first step (each step is an EXEC statement, and the step name is the name on the same line as the EXEC statement) is named TRN, so we must qualify the SYSIN DD statement with TRN to ensure that it will be used in the TRN step.

Similarly, the fourth step is called LKED, so we must qualify the SYSIN DD statement with LKED in order for it to apply to the LKED step. See 6.6.1, “JCL PROC statement override” on page 6-10 for more information on overriding a cataloged procedure.

The end result of running the JCL in Example 9-5 (assuming that there are no errors) should be to pre-process and compile our inline source program, link-edit the object code, and then store the load module called PROG1 in the data set MY.LOADLIB.

Example 9-5 Basic JCL for pre-processing, compiling, and linking a COBOL source program inline

```
//PPCOMLNK   JOB
//PPCL      EXEC DFHEITVL,PROGLIB='MY.LOADLIB'
//TRN.SYSIN    DD *
  IDENTIFICATION DIVISION (source program)
    EXEC CICS ...
...
    EXEC CICS ...
...
//LKED.SYSIN DD *
   NAME PROG1(R)
/*
```

The statements shown in Example 9-6 make up the DFHEITVL cataloged procedure used in Example 9-5 on page 9-7. As with the other compile and link procedures, the result of the preprocessor, compile, and link steps, which is the load module, is placed in the data set identified on the SYSLMOD DD statement.

Example 9-6 Procedure DFHEITVL - COBOL preprocessor, compile, and link

```
//DFHEITVL PROC SUFFIX=1$,          Suffix for translator module
//*
//* This procedure has been changed since CICS/ESA Version 3
//*
//* Parameter INDEX2 has been removed
//*
//       INDEX='CICSTS12.CICS', Qualifier(s) for CICS libraries
//       PROGLIB=&INDEX..SDFHLOAD,   Name of output library
//       DSCTLIB=&INDEX..SDFHCOB,    Name of private macro/DSECT lib
//       COMPHLQ='SYS1',             Qualifier(s) for COBOL compiler
//       OUTC=A,                     Class for print output
//       REG=2M,                     Region size for all steps
//       LNKPARM='LIST,XREF',        Link edit parameters
//       STUB='DFHEILIC',            Link edit INCLUDE for DFHECI
//       LIB='SDFHCOB',              Library
//       WORK=SYSDA                  Unit for work data sets
//*      This procedure contains 4 steps
//*      1.   Exec the COBOL translator
//*           (using the supplied suffix 1$)
//*      2.   Exec the vs COBOL II compiler
//*      3.   Reblock &LIB(&STUB) for use by the linkedit step
//*      4.   Linkedit the output into data set &PROGLIB
//*
//*      The following JCL should be used
//*      to execute this procedure
//*
//*      //APPLPROG EXEC DFHEITVL
```

```
//*      //TRN.SYSIN  DD *
//*         .
//*         . Application program
//*         .
//*      /*
//*      //LKED.SYSIN DD *
//*         NAME anyname(R)
//*      /*
//*
//* Where   anyname   is the name of your application program.
//*      (Refer to the system definition guide for full details,
//*      including what to do if your program contains calls to
//*      the common programming interface.)
//*
//TRN    EXEC PGM=DFHECP&SUFFIX,
//            PARM='COBOL2',
//            REGION=&REG
//STEPLIB  DD DSN=&INDEX..SDFHLOAD,DISP=SHR
//SYSPRINT DD SYSOUT=&OUTC
//SYSPUNCH DD DSN=&&SYSCIN,
//            DISP=(,PASS),UNIT=&WORK,
//            DCB=BLKSIZE=400,
//            SPACE=(400,(400,100))
//*
//COB    EXEC PGM=IGYCRCTL,REGION=&REG,
//       PARM='NODYNAM,LIB,OBJECT,RENT,RES,APOST,MAP,XREF'
//STEPLIB  DD DSN=&COMPHLQ..COB2COMP,DISP=SHR
//SYSLIB   DD DSN=&DSCTLIB,DISP=SHR
//         DD DSN=&INDEX..SDFHCOB,DISP=SHR
//         DD DSN=&INDEX..SDFHMAC,DISP=SHR
//         DD DSN=&INDEX..SDFHSAMP,DISP=SHR
//SYSPRINT DD SYSOUT=&OUTC
//SYSIN    DD DSN=&&SYSCIN,DISP=(OLD,DELETE)
//SYSLIN   DD DSN=&&LOADSET,DISP=(MOD,PASS),
//            UNIT=&WORK,SPACE=(80,(250,100))
//SYSUT1   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT2   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT3   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT4   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT5   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT6   DD UNIT=&WORK,SPACE=(460,(350,100))
//SYSUT7   DD UNIT=&WORK,SPACE=(460,(350,100))
//*
//COPYLINK EXEC PGM=IEBGENER,COND=(7,LT,COB)
//SYSUT1   DD DSN=&INDEX..&LIB(&STUB),DISP=SHR
//SYSUT2   DD DSN=&&COPYLINK,DISP=(NEW,PASS),
//            DCB=(LRECL=80,BLKSIZE=400,RECFM=FB),
//            UNIT=&WORK,SPACE=(400,(20,20))
//SYSPRINT DD SYSOUT=&OUTC
```

```
//SYSIN    DD DUMMY
//*
//LKED   EXEC PGM=IEWL,REGION=&REG,
//            PARM='&LNKPARM',COND=(5,LT,COB)
//SYSLIB   DD DSN=&INDEX..SDFHLOAD,DISP=SHR
//         DD DSN=&COMPHLQ..COB2CICS,DISP=SHR
//         DD DSN=&COMPHLQ..COB2LIB,DISP=SHR
//SYSLMOD  DD DSN=&PROGLIB,DISP=SHR
//SYSUT1   DD UNIT=&WORK,DCB=BLKSIZE=1024,
//            SPACE=(1024,(200,20))
//SYSPRINT DD SYSOUT=&OUTC
//SYSLIN   DD DSN=&&COPYLINK,DISP=(OLD,DELETE)
//         DD DSN=&&LOADSET,DISP=(OLD,DELETE)
//         DD DDNAME=SYSIN
```

COBOL compile and link procedure

The JCL in Example 9-7 executes the IGYWCL procedure, which is a two-step procedure for compiling a source program and linking it into a load library. The first step produces an object module that is stored in the SYSLIN temporary data set, as shown in Example 9-8. The second step takes the SYSLIN temporary data set as input, as well as any other modules that might need to be included, and creates a load modules in the data set referenced by the SYSLMOD DD statement.

The end result of running the JCL in Example 9-7 (assuming that there are no errors) should be to compile our inline source program, link-edit the object code and then store the load module called PROG1 in the data set MY.LOADLIB.

Example 9-7   Basic JCL for compiling and linking a COBOL source program inline

```
//COMLNK   JOB
//CL       EXEC IGYWCL
//COBOL.SYSIN    DD *
  IDENTIFICATION DIVISION (source program)
.
.
.
/*
//LKED.SYSLMOD DD DSN=MY.LOADLIB(PROG1),DISP=OLD
```

The statements shown in Example 9-8 make up the IGYWCL cataloged procedure used in Example 9-7. As mentioned previously, the result of the compile and link steps, which is the load module, is placed in the data set identified on the SYSLMOD DD statement.

Example 9-8 Procedure IGYWCL - COBOL compile and link

```
//IGYWCL PROC  LNGPRFX='IGY.V2R1M0',SYSLBLK=3200,
//             LIBPRFX='CEE',
//             PGMLIB='&&GOSET',GOPGM=GO
//*
//*  COMPILE AND LINK EDIT A COBOL PROGRAM
//*
//*  PARAMETER  DEFAULT VALUE
//*   LNGPRFX   IGY.V2R1M0
//*   SYSLBLK   3200
//*   LIBPRFX   CEE
//*   PGMLIB    &&GOSET          DATA SET NAME FOR LOAD MODULE
//*   GOPGM     GO               MEMBER NAME FOR LOAD MODULE
//*
//*  CALLER MUST SUPPLY //COBOL.SYSIN DD ...
//*
//COBOL  EXEC PGM=IGYCRCTL,REGION=2048K
//STEPLIB  DD  DSNAME=&LNGPRFX..SIGYCOMP,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,UNIT=VIO,
//             DISP=(MOD,PASS),SPACE=(TRK,(3,3)),
//             DCB=(BLKSIZE=&SYSLBLK)
//SYSUT1   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT2   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT3   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT4   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT5   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT6   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT7   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//LKED   EXEC PGM=HEWL,COND=(8,LT,COBOL),REGION=1024K
//SYSLIB   DD  DSNAME=&LIBPRFX..SCEELKED,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,DISP=(OLD,DELETE)
//         DD  DDNAME=SYSIN
//SYSLMOD  DD  DSNAME=&PGMLIB(&GOPGM),
//             SPACE=(TRK,(10,10,1)),
//             UNIT=VIO,DISP=(MOD,PASS)
//SYSUT1   DD  UNIT=VIO,SPACE=(TRK,(10,10))
```

COBOL compile, link and go procedure

The JCL in Example 9-9 executes the IGYWCLG procedure, which is a three-step procedure for compiling a source program, linking it into a load library, and then executing the load module. The first two steps are the same as those in the compile and link example (Example 9-7 on page 9-9). However, whereas in Example 9-7 on page 9-9 we override the SYSLMOD DD statement in order to permanently save the load module, in Example 9-9, we do not need to save it in order to execute it. That is why the override to the SYSLMOD DD statement in Example 9-9 is enclosed in square brackets, to indicate that it is optional.

If it is coded, then the load module PROG1 will be permanently saved in MY.LOADLIB. If it is not coded, then the load module will be saved in a temporary data set and deleted after the GO step.

In Example 9-9, you can see that the JCL is very similar to the JCL used in the simple compile job (Example 9-3 on page 9-5). Looking at the JCL in Example 9-10 on page 9-11, the only difference between it and the JCL in Example 9-8 on page 9-10 is that we have added the GO step. The end result of running the JCL in Example 9-9 (assuming that there are no errors) should be to compile our inline source program, link-edit the object code, store the load module (either temporarily or permanently), and then execute the load module.

Example 9-9 Basic JCL for compiling, linking and executing a COBOL source program inline

```
//CLGO    JOB
//CLG     EXEC IGYWCLG
//COBOL.SYSIN    DD *
  IDENTIFICATION DIVISION (source program)
.
.
.
/*
[//LKED.SYSLMOD DD DSN=MY.LOADLIB(PROG1),DISP=OLD]
```

The statements shown in Example 9-10 make up the IGYWCLG cataloged procedure used in Example 9-9 on page 9-11.

Example 9-10 Procedure IGYWCLG - COBOL compile, link, and go

```
//IGYWCLG PROC LNGPRFX='IGY.V2R1M0',SYSLBLK=3200,
//             LIBPRFX='CEE',GOPGM=GO
//*
//*  COMPILE, LINK EDIT AND RUN A COBOL PROGRAM
//*
//*  PARAMETER  DEFAULT VALUE    USAGE
//*   LNGPRFX   IGY.V2R1M0
//*   SYSLBLK   3200
//*   LIBPRFX   CEE
//*   GOPGM     GO
//*
//*  CALLER MUST SUPPLY //COBOL.SYSIN DD ...
//*
```

```
//COBOL  EXEC PGM=IGYCRCTL,REGION=2048K
//STEPLIB  DD  DSNAME=&LNGPRFX..SIGYCOMP,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,UNIT=VIO,
//             DISP=(MOD,PASS),SPACE=(TRK,(3,3)),
//             DCB=(BLKSIZE=&SYSLBLK)
//SYSUT1   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT2   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT3   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT4   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT5   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT6   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//SYSUT7   DD  UNIT=VIO,SPACE=(CYL,(1,1))
//LKED   EXEC PGM=HEWL,COND=(8,LT,COBOL),REGION=1024K
//SYSLIB   DD  DSNAME=&LIBPRFX..SCEELKED,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSLIN   DD  DSNAME=&&LOADSET,DISP=(OLD,DELETE)
//         DD  DDNAME=SYSIN
//SYSLMOD  DD  DSNAME=&&GOSET(&GOPGM),SPACE=(TRK,(10,10,1)),
//             UNIT=VIO,DISP=(MOD,PASS)
//SYSUT1   DD  UNIT=VIO,SPACE=(TRK,(10,10))
//GO     EXEC PGM=*.LKED.SYSLMOD,COND=((8,LT,COBOL),(4,LT,LKED)),
//             REGION=2048K
//STEPLIB  DD  DSNAME=&LIBPRFX..SCEERUN,
//             DISP=SHR
//SYSPRINT DD  SYSOUT=*
//CEEDUMP  DD  SYSOUT=*
//SYSUDUMP DD  SYSOUT=*
```

9.3.3 Compiling object-oriented (OO) applications

If you use a batch job or TSO/E to compile an OO COBOL program or class definition, the generated object code is written, as usual, to the data set that you identify with the SYSLIN or SYSPUNCH ddname.

If the COBOL program or class definition uses the JNI[1] environment structure to access JNI callable services, copy the file JNI.cpy from the HFS to a PDS or PDSE member called JNI, identify that library with a SYSLIB DD statement, and use a COPY statement of the form COPY JNI in the COBOL source program.

[1] The Java Native Interface (JNI) is the Java interface to native programming languages and is part of the Java Development Kits. By writing programs that use the JNI, you ensure that your code is portable across many platforms.

As shown in Example 9-11, use the SYSJAVA ddname to write the generated Java source file to a file in the HFS. For example:

Example 9-11 SYSJAVA ddname for a Java source file

```
//SYSJAVA DD PATH='/u/userid/java/Classname.java',
//           PATHOPTS=(OWRONLY,OCREAT,OTRUNC),
//           PATHMODE=SIRWXU,
//           FILEDATA=TEXT
```

9.3.4 What are object modules?

An *object module* is a collection of one or more compilation units produced by an assembler, compiler, or other language translator, and used as input to the binder or linkage editor.

An object module is in relocatable format with machine code that is not executable. A load module is also relocatable, but with executable machine code. A load module is in a format that can be loaded into virtual storage and relocated by program fetch, a program that prepares load modules for execution by loading them at specific storage locations.

Object modules and load modules share the same logical structure consisting of:

- Control dictionaries, containing information to resolve symbolic cross-references between control sections of different modules, and to relocate address constants.
- Text, containing the instructions and data of the program.
- An end-of-module indication, which is an END statement in an object module, or an end-of-module indicator in a load module.

Object modules are stored in a partitioned data set identified by the SYSLIN or SYSPUNCH DD statement, which is input to the next linkage edition process.

9.3.5 What is an object library?

You can use an *object library* to store object modules. The object modules to be link-edited are retrieved from the object library and transformed into an executable or loadable program.

When using the OBJECT compiler option, you can store the object code on disk as a traditional data set or as an HFS file or on tape. The DISP parameter of the SYSLIN DD statement indicates whether the object code data set is to be:

- Passed to the linkage editor or binder after compile (DISP=PASS)
- Cataloged in an existent object library (DISP=OLD)
- Kept (DISP=KEEP)

- Added to a new object library, which is cataloged at the end of the step (DISP=CATLG)

An object module can be the primary input to the binder by specifying its data set name and member name on the SYSLIN DD statement. In the following example, the member named TAXCOMP in the object library USER.LIBROUT is the primary input. USER.LIBROUT is a cataloged partitioned data set:

```
//SYSLIN    DD    DSNAME=USER.LIBROUT(TAXCOMP),DISP=SHR
```

The library member is processed as if it were a sequential data set.

9.3.6 How does program management work?

Although program management components provide many services, they are used primarily to convert object modules into executable programs, store them in program libraries, and load them into virtual storage for execution.

You can use the program management binder and loader to perform these tasks. These components can also be used in conjunction with the linkage editor. A load module produced by the linkage editor can be accepted as input by the binder or can be loaded into storage for execution by the program management loader. The linkage editor can also process load modules produced by the binder.

Figure 9-2 shows how the program management components work together, and how each one is used to prepare an executable program. We have already discussed some of these components (source and object modules), so now we take a look at the rest of them.

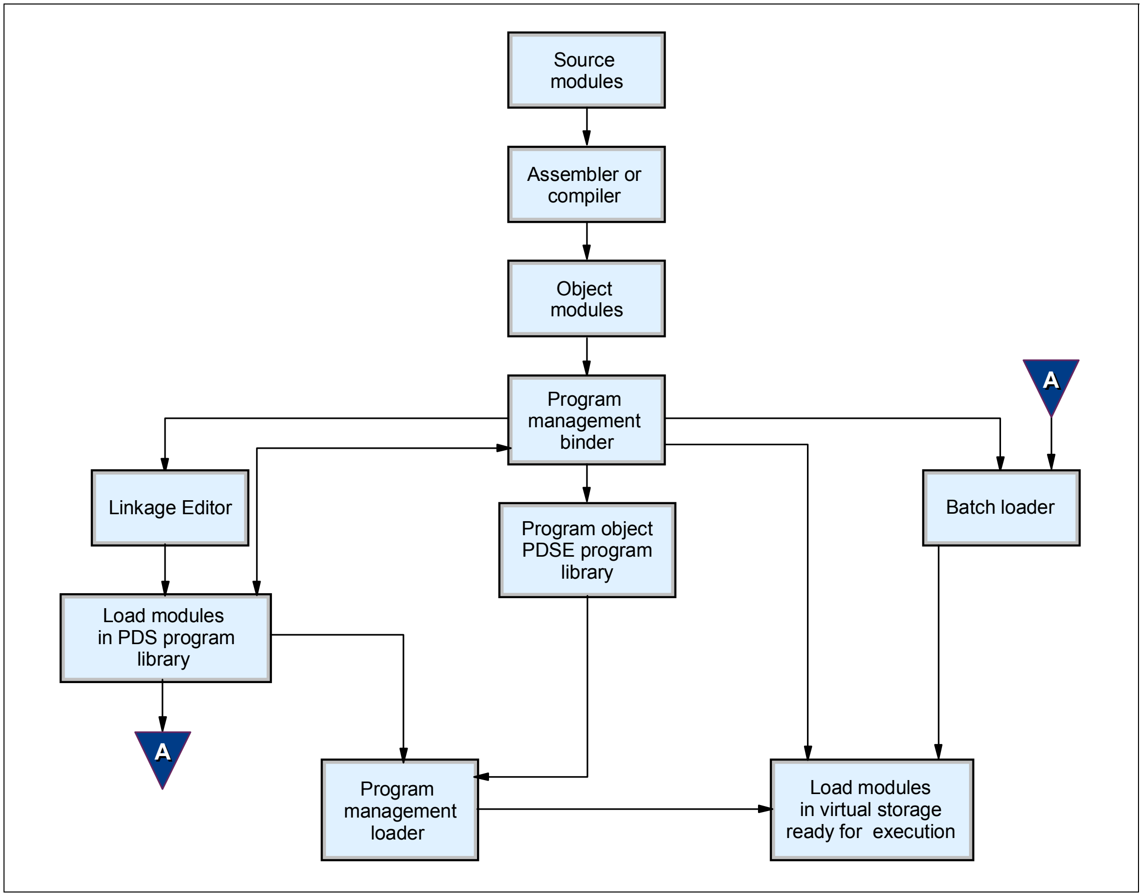


Figure 9-2 Using Program Management components to create and load programs

9.3.7 How is a linkage editor used?

Linkage editor processing follows the source program assembly or compilation of any problem program. The *linkage editor* is both a processing program and a service program used in association with the language translators.

Linkage editor and loader processing programs prepare the output of language translators for execution. The linkage editor prepares a load module that is to be brought into storage for execution by program fetch.

The linkage editor accepts two major types of input:

- Primary input, consisting of object modules and linkage editor control statements.

- Additional user-specified input, which can contain either object modules and control statements, or load modules. This input is either specified by you as input, or is incorporated automatically by the linkage editor from a call library.

Output of the linkage editor is of two types:

- A load module placed in a library (a partitioned data set) as a named member.
- Diagnostic output produced as a sequential data set.

The loader prepares the executable program in storage and passes control to it directly.

9.3.8 How a load module is created

In processing object and load modules, the linkage editor assigns consecutive relative virtual storage addresses to control sections, and resolves references between control sections. Object modules produced by several different language translators can be used to form one load module.

An output load module is composed of all input object modules and input load modules processed by the linkage editor. The control dictionaries of an output module are, therefore, a composite of all the control dictionaries in the linkage editor input. The control dictionaries of a load module are called the composite external symbol dictionary (CESD) and the relocation dictionary (RLD). The load module also contains the text from each input module, and an end-of-module indicator.

Figure 9-3 on page 9-17 shows the process of compiling two source programs: PROGA and PROGB. PROGA is a COBOL program and PROGB is an Assembler language program. PROGA calls PROGB. In this figure we see that after compilation, the reference to PROGB in PROGA is an unresolved reference. The process of link-editing the two object modules resolves the reference so that when PROGA is executed, the call to PROGB will work correctly. PROGB will be transferred to, it will execute, and control will return to PROGA, after the point where PROGB was called.

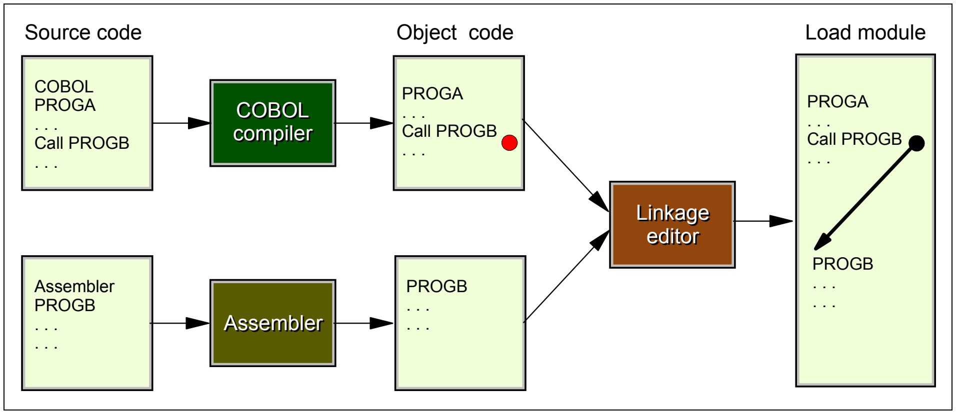


Figure 9-3 Resolving references during load module creation

Using the binder

The *binder* performs all of the functions of the linkage editor. It link-edits, or combines and edits individual object modules or load modules to produce a single load module that is stored in a PDS program library until it is needed. Additionally, the binder can link-edit or bind modules into a program object that can be stored in a PDSE program library. When a member of a program library is needed, the loader brings it into virtual storage and prepares it for execution.You can use the binder to:

- Convert object or load modules, or program objects, into a program object and store the program object in a partitioned data set extended (PDSE) program library or in an z/OS UNIX file.
- Convert object or load modules, or program objects, into a load module and store the load module in a partitioned data set (PDS) program library. This is equivalent to what the linkage editor can do with object and load modules.
- Convert object or load modules, or program objects, into an executable program in virtual storage and execute the program. This is equivalent to what the batch loader can do with object and load modules.

The binder processes object modules, load modules and program objects, link-editing or binding multiple modules into a single load module or program object. Control statements specify how to combine the input into one or more load modules or program objects with contiguous virtual storage addresses. Each object module can be processed separately by the binder, so that only the modules that have been modified need to be recompiled or reassembled. The binder can create programs in 24-bit, 31-bit and 64-bit addressing ranges.

You assign an addressing mode (AMODE) to indicate which hardware addressing mode is active when the program executes. Addressing modes are:

- 24, which indicates that 24-bit addressing must be in effect.
- 31, which indicates that 31-bit addressing must be in effect.
- 64, which indicates that 64-bit addressing must be in effect.
- ANY, which indicates that 24-bit, 31-bit, or 64-bit addressing can be in effect.
- MIN, which requests that the binder assign an AMODE value to the program module.

The binder selects the most restrictive AMODE of all control sections in the input to the program module. An AMODE value of 24 is the *most* restrictive; an AMODE value of ANY is the *least* restrictive.

All of the services of the linkage editor can be performed by the binder.

Refer to 2.4.8, "A brief history of virtual storage and 64-bit addressability" on page 2-15 for more information on the layout of an address and which areas of the address space are addressable by 24 bits, 31 bits and 64 bits.

Binder and linkage editor

The binder relaxes or eliminates many restrictions of the linkage editor. The binder removes the linkage editor's limit of 64 aliases, allowing a load module or program object to have as many aliases as desired. The binder accepts any system-supported block size for the primary (SYSLIN) input data set, eliminating the linkage editor's maximum block size limit of 3200 bytes. The binder also does not restrict the number of external names, whereas the linkage editor sets a limit of 32767 names.

With the binder, you no longer need to pre-link, because the binder handles all of the functionality of the pre-linker. Whether you use the binder or linkage editor is a matter of preference. The binder is the newest and most up-to-date way to create your load module.

The primary input, required for every binder job step, is defined on a DD statement with the ddname SYSLIN. Primary input can be:

- A sequential data set
- A member of a partitioned data set (PDS)
- A member of a partitioned data set extended (PDSE)
- Concatenated sequential data sets, or members of partitioned data sets or PDSEs, or a combination
- A z/OS UNIX file

The primary data set can contain object modules, control statements, load modules and program objects. All modules and control statements are processed sequentially, and their order determines the order of binder processing. The order of the sections after processing, however, might not match the input sequence.

Binder example

Example 9-12 shows a job that can be used to link-edit an object module. The output from the LKED step will be placed in a private library identified by the SYSLMOD DD. The input is passed from a previous job step to a binder job step in the same job (for example, the output from the compiler is direct input to the binder).

Example 9-12 Binder JCL example

```
//LKED     EXEC PGM=IEWL,PARM='XREF,LIST', IEWL is IEWBLINK alias
//              REGION=2M,COND=(5,LT,prior-step)
//*
//*        Define secondary input
//*
//SYSLIB   DD  DSN=language.library,DISP=SHR          optional
//PRIVLIB  DD  DSN=private.include.library,DISP=SHR optional
//SYSUT1   DD  UNIT=SYSDA,SPACE=(CYL,(1,1))           ignored
//*
//*        Define output module library
//*
//SYSLMOD  DD  DSN=program.library,DISP=SHR           required
//SYSPRINT DD  SYSOUT=*                               required
//SYSTERM  DD  SYSOUT=*                               optional
//*
//*        Define primary input
//*
//SYSLIN   DD  DSN=&&OBJECT,DISP=(MOD,PASS)           required
//         DD  * inline control statements
         INCLUDE  PRIVLIB(membername)
         NAME     modname(R)
/*
```

An explanation of the JCL statements follows:

EXEC
: Binds a program module and stores it in a program library. Alternative names for IEWBLINK are IEWL, LINKEDIT, EWL, and HEWLH096.
The PARM field option requests a cross-reference table and a module map to be produced on the diagnostic output data set.

SYSUT1
: Defines a temporary direct access data set to be used as the intermediate data set.

SYSLMOD
: Defines a temporary data set to be used as the output module library.

SYSPRINT
: Defines the diagnostic output data set, which is assigned to output class A.

SYSLIN	Defines the primary input data set, &&OBJECT, which contains the input object module; this data set was passed from a previous job step and is to be passed at the end of this job step.
INCLUDE	Specifies sequential data sets, library members, or z/OS UNIX files that are to be sources of additional input for the binder (in this case, a member of the private library PRIVLIB).
NAME	Specifies the name of the program module created from the preceding input modules, and serves as a delimiter for input to the program module. (R) indicates that this program module replaces an identically named module in the output module library.

9.4 Creating load modules for executable programs

A *load module* is an executable program stored in a partitioned data set program library. Creating a load module to execute only, will require that you use a batch loader or program management loader. Creating a load module that can be stored in a program library requires that you use the binder or linkage editor. In all cases, the load module is relocatable, which means that it can be located at any address in virtual storage within the confines of the residency mode (RMODE).

Once a program is loaded, control is passed to it, with a value in the base register. This gives the program its starting address, where it was loaded, so that all addresses can be resolved as the sum of the base plus the offset. Relocatable programs allow an identical copy of a program to be loaded in many different address spaces, each being loaded at a different starting address. See 9.3, "Compiling programs on z/OS" on page 9-3 for more discussion on relocatable programs.

9.4.1 Batch loader

The *batch loader* combines the basic editing and loading services (which can also be provided by the linkage editor and program fetch) into one job step. The batch loader accepts object modules and load modules, and loads them into virtual storage for execution. Unlike the binder and linkage editor, the batch loader does not produce load modules that can be stored in program libraries. The batch loader prepares the executable program in storage and passes control to it directly.

Batch loader processing is performed in a load step, which is equivalent to the link-edit and go steps of the binder or linkage editor. The batch loader can be used for both compile-load and load jobs. It can include modules from a call library (SYSLIB), the link pack area (LPA), or both. Like the other program management components, the batch loader supports addressing and residence mode attributes in the 24-bit, 31-bit, and 64-bit addressing ranges. The batch loader program is reentrant and therefore can reside in the resident link pack area.

Note: In more recent releases of z/OS, the binder replaces the batch loader.

9.4.2 Program management loader

The program management loader increases the services of the program fetch component by adding support for loading program objects. The loader reads both program objects and load modules into virtual storage and prepares them for execution. It resolves any address constants in the program to point to the appropriate areas in virtual storage and supports the 24-bit, 31-bit and 64-bit addressing ranges.

In processing object and load modules, the linkage editor assigns consecutive relative virtual storage addresses to control sections and resolves references between control sections. Object modules produced by several different language translators can be used to form one load module.

In Example 9-13 we have a compile, link-edit, and execute job, in this case for an assembler program.

Example 9-13 Compile, link-edit, and execute JCL

```
//USUAL     JOB   A2317P,'COMPLGO'
//ASM       EXEC  PGM=IEV90,REGION=256K,  EXECUTES ASSEMBLER
//           PARM=(OBJECT,NODECK,'LINECOUNT=50')
//SYSPRINT  DD    SYSOUT=*,DCB=BLKSIZE=3509  PRINT THE ASSEMBLY LISTING
//SYSPUNCH  DD    SYSOUT=B PUNCH THE ASSEMBLY LISTING
//SYSLIB    DD    DSNAME=SYS1.MACLIB,DISP=SHR THE MACRO LIBRARY
//SYSUT1    DD    DSNAME=&&SYSUT1,UNIT=SYSDA,    A WORK DATA SET
//           SPACE=(CYL,(10,1))
//SYSLIN    DD    DSNAME=&&OBJECT,UNIT=SYSDA, THE OUTPUT OBJECT MODULE
//           SPACE=(TRK,(10,2)),DCB=BLKSIZE=3120,DISP=(,PASS)
//SYSIN     DD    *                              inline SOURCE CODE
                   .
                   .
                   code
                   .
/*
//LKED      EXEC  PGM=HEWL,                     EXECUTES LINKAGE EDITOR
//           PARM='XREF,LIST,LET',COND=(8,LE,ASM)
//SYSPRINT  DD    SYSOUT=*                       LINKEDIT MAP PRINTOUT
//SYSLIN    DD    DSNAME=&&OBJECT,DISP=(OLD,DELETE) INPUT OBJECT MODULE
//SYSUT1    DD    DSNAME=&&SYSUT1,UNIT=SYSDA,    A WORK DATA SET
//           SPACE=(CYL,(10,1))
//SYSLMOD   DD    DSNAME=&&LOADMOD,UNIT=SYSDA,   THE OUTPUT LOAD MODULE
//           DISP=(MOD,PASS),SPACE=(1024,(50,20,1))
//GO        EXEC  PGM=*.LKED.SYSLMOD,TIME=(,30), EXECUTES THE PROGRAM
```

```
//          COND=((8,LE,ASM),(8,LE,LKED))
//SYSUDUMP  DD    SYSOUT*                        IF FAILS, DUMP LISTING
//SYSPRINT  DD    SYSOUT=*,                      OUTPUT LISTING
//          DCB=(RECFM=FBA,LRECL=121)
//OUTPUT    DD    SYSOUT=A,                     PROGRAM DATA OUTPUT
//          DCB=(LRECL=100,BLKSIZE=3000,RECFM=FBA)
//INPUT     DD    *                             PROGRAM DATA INPUT
                 .
                 .
                 data
                 .
/*
//
```

Notes:

- In the step ASM (compile), SYSIN DD is for the inline source code and SYSLIN DD is for the output object module.
- In the step LKED (linkage-edition), the SYSLIN DD is for the input object module and the SYSLMOD DD is for the output load module.
- In the step GO (execute the program), the EXEC JCL statement states that it will execute a program identified in the SYSLMOD DD statement of the previous step.
- This example does not use a cataloged procedure, as the COBOL examples did; instead, all of the JCL has been coded inline. We could have used an existing JCL procedure, or coded one and then only supplied the overrides, such as the INPUT DD statement.

9.4.3 What is a load library?

A *load library* is a library that contains programs ready to be executed. A load library can be any of the following:

- System library
- Private library
- Temporary library

System Library

Unless a job or step specifies a private library, the system searches for a program in the system libraries when you code:

//stepname EXEC PGM=program-name

The system looks in the libraries for a member with a name or alias that is the same as the specified program-name. The most-used system library is SYS1.LINKLIB, which contains executable programs that have been processed by the linkage editor. Refer to 16.2, "z/OS system libraries" on page 16-13for more information on system libraries.

Private Library

Each executable, user-written program is a member of a private library. To tell the system that a program is in a private library, the DD statement defining that library can be coded in one of the following ways:

- With a DD statement with the ddname JOBLIB after the JOB statement, and before the first EXEC statement in the job
- If the library is going to be used in only one step, with a DD statement with the ddname STEPLIB in the step

To execute a program from a private library, code:

```
//stepname  EXEC  PGM=program-name
```

When you code JOBLIB or STEPLIB, the system searches for the program to be executed in the library defined by the JOBLIB or STEPLIB DD statement before searching in the system libraries.

If an earlier DD statement in the job defines the program as a member of a private library, refer to that DD statement to execute the program:

```
//stepname  EXEC  PGM=*.stepname.ddname
```

Private libraries are particularly useful for programs used too seldom to be needed in a system library. For example, programs that prepare quarterly sales tax reports are good candidates for a private library.

Temporary library

Temporary libraries are partitioned data sets created to store a program until it is used in a later step *of the same job*. A temporary library is created and deleted within a job.

When testing a newly written program, a temporary library is particularly useful for storing the load module from the linkage editor until it is executed by a later job step. Because the module will not be needed by other jobs until it is fully tested, it should not be stored in a private library or a system library. In Example 9-13 on page 9-21, the LKED step creates a temporary library called &&LOADMOD on the SYSLMOD DD statement. In the GO step, we refer back to the same temporary data set by coding:

```
//GO        EXEC  PGM=*.LKED.SYSLMOD,....
```

9.5 Overview of compilation to execution

In Figure 9-4, we can see the relationship between the object modules and the load module stored in a load library and then loaded into central memory for execution.

We start with two programs, A and B, which are compiled into two object modules. Then the two object modules are linked into one load module call MYPROG, which is stored in a load library on direct access storage. The load module MYPROG is then loaded into central storage by the program management loader, and control is transferred to it to for execution.

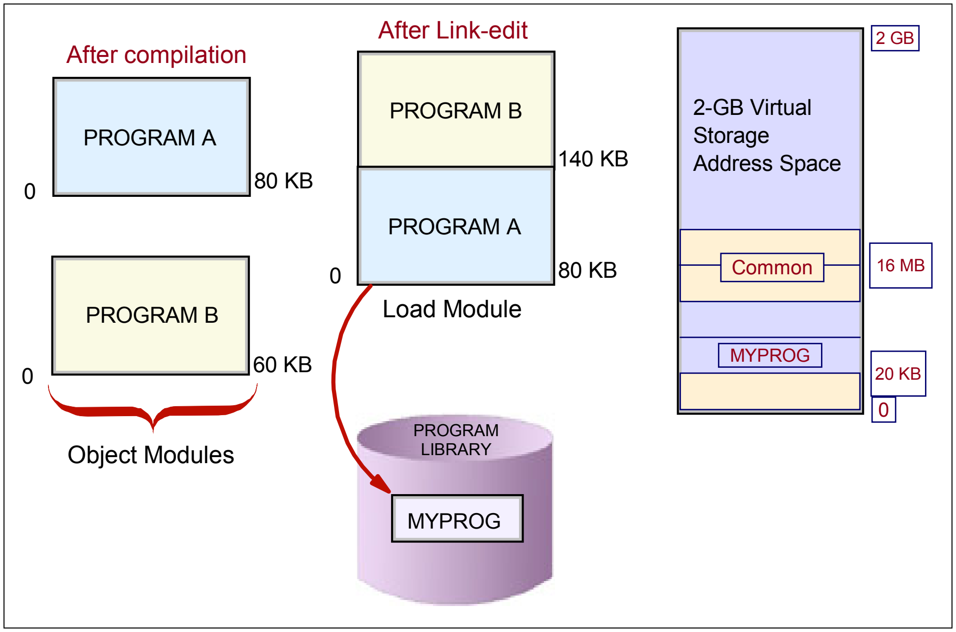


Figure 9-4 Program compile, link-edit, and execution

9.6 Using procedures

To save time and prevent errors, you can prepare sets of job control statements and place them in a partitioned data set (PDS) or partitioned data set extended (PDSE), known as a *procedure library*. This can be used, for example, to compile, assemble, link-edit, and execute a program, as we have seen in Example 9-13 on page 9-21. For a more in-depth discussion on JCL procedures, see 6.6, "JCL procedures (PROCs)" on page 6-9.

A procedure library is a library that contains procedures. A set of job control statements in the system procedure library, SYS1.PROCLIB (or an installation-defined procedure library), is called a *cataloged procedure*. (SYS1.PROCLIB is shown in 6.9, "System libraries" on page 6-15.)

To test a procedure before storing it in a procedure library, add the procedure to the input stream and execute it; a procedure in the input stream is called an *inline procedure*. The maximum number of inline procedures you can code in any job is 15. In order to test a procedure in the input stream, it must end with a procedure end (PEND) statement. The PEND statement signals the end of the PROC. This is only required when the procedure is coded inline. In a procedure library, we do not require a PEND statement.

An inline procedure must appear in the same job before the EXEC statement that calls it.

Example 9-14 Sample definition of a procedure

```
//DEF      PROC  STATUS=OLD,LIBRARY=SYSLIB,NUMBER=777777
//NOTIFY   EXEC  PGM=ACCUM
//DD1      DD    DSNAME=MGMT,DISP=(&STATUS,KEEP),UNIT=3400-6,
//             VOLUME=SER=888888
//DD2      DD    DSNAME=&LIBRARY,DISP=(OLD,KEEP),UNIT=3350,
//             VOLUME=SER=&NUMBER
```

Three symbolic parameters are defined in the cataloged procedure shown in Example 9-14: &STATUS, &LIBRARY, and &NUMBER. Values are assigned to the symbolic parameters on the PROC statement. These values are used if the procedure is called and no values are assigned to the symbolic parameters on the calling EXEC statement.

In Example 9-15 we are testing the procedure called DEF. Note that the procedure is delineated by the PROC and PEND statements. The EXEC statement that follows the procedure DEF references the procedure to be invoked. In this case, since the name DEF matches a procedure that was previously coded inline, the system will use the procedure inline and will not search any further.

Example 9-15 Testing a procedure inline

```
//TESTJOB  JOB ....
//DEF      PROC  STATUS=OLD,LIBRARY=SYSLIB,NUMBER=777777
//NOTIFY   EXEC  PGM=ACCUM
//DD1      DD    DSNAME=MGMT,DISP=(&STATUS,KEEP),UNIT=3400-6,
//            VOLUME=SER=888888
//DD2      DD    DSNAME=&LIBRARY,DISP=(OLD,KEEP),UNIT=3350,
//            VOLUME=SER=&NUMBER
//         PEND
//*
//TESTPROC EXEC DEF
//
```

9.7 Summary

This chapter described the process for translating a source program into an executable load module, and executing the load module. The basic steps for this translation are to compile and link-edit, although there might be a third step to pre-process the source prior to compiling it. The pre-processing step would be required if your source program issues CICS command language calls or SQL calls. The output of the pre-processing step is then fed into the compile step.

The purpose of the compile step is to validate and translate source code into relocatable machine language, in the form of object code. Although the object code is machine language, it is not yet executable. It must first be processed by a linkage-editor, binder, or loader before it can be executed.

The linkage-editor, binder, and loader take as input object code and other load modules, and then produce an executable load module and, in the case of the loader, to execute it. This process resolves any unresolved references within the object code and ensures that everything that is required for this program to execute is included within the final load module. The load module is now ready for execution.

To execute a load module, it must be loaded into central storage. The binder or program fetch service will load a module into storage and then transfer control to it to begin execution. Part of transferring control to the module is to supply it with the address of the start of the program in storage. Because the program's instructions and data are addressed using a base address and a displacement from the base, this starting address gives addressability to the instructions and data within the limits of the range of displacement[2].

Key terms in this chapter		
binder	copybook	linkage-editor
load module	object module	object-oriented code
procedure	procedure library	program library
relocatable	source module	

9.8 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What steps are needed to be able to execute a source program?
2. How can I modify an object module? A load module?
3. How many different types of load libraries can the system have?
4. What is a procedure library, and what is it used for?

[2] The maximum displacement for each base register is 4096 (4K). Any program bigger than 4K must have more than one base register in order to have addressability to the entire program.

5. What is the difference between the linkage editor and the binder?
6. How are copybooks and cataloged procedure libraries similar?
7. What is the purpose of a compiler? What are the inputs and outputs?
8. What does relocatable mean?
9. What is the difference between an object module and a load module?
10. What is the SYSLMOD DD statement used for?
11. Why is a PEND statement required in an inline PROC and not in a cataloged PROC?

9.9 Exercises

The lab exercises in this chapter help you develop skills in preparing programs to run on z/OS. These skills are required for performing lab exercises in the remainder of this text.

To perform the lab exercises, you or your team require a TSO user ID and password (for assistance, see the instructor).

The exercises teach the following:

- "Exercise: compiling and linking a program" on page 9-27
- "Exercise: executing a program" on page 9-29

9.9.1 Exercise: compiling and linking a program

In this section, use at least two programming languages to compile and link; see the JCL in:

```
yourid.LANG.CNTL(language)
where "language" is one of ASM, ASMLE, C, C2, COBOL, COBOL2, PL1, PL12.
```

Do this exercise before attempting the exercise in 9.9.2, "Exercise: executing a program" on page 9-29. The results of successfully running each job in this exercise will be to create the load modules which will be executed in the next exercise.

> **Note:** The JCL will need to be modified to specify the high-level qualifier (HLQ) of the student submitting the jobs. In addition, any jobs referring to Language Environment data sets might also need to be modified. See the comment boxes for more information.
>
> To submit the jobs, enter SUBMIT on the ISPF command line. Once the job completes, you will need to use SDSF to view the output of the job.

1. Submit the following data set to compile and link a complex Assembler language program:

   yourid.LANG.CNTL(ASMLE)

   > **Note:** The student might need to modify the JCL for data sets beginning with CEE. Ask your system programmer what the high-level qualifier (HLQ) is for the Language Environment data sets. The JCL that might need to be changed is highlighted here:
   >
   > ```
   > //C.SYSLIB     DD DSN=SYS1.MACLIB,DISP=SHR
   > //             DD DSN=CEE.SCEEMAC,DISP=SHR
   > //C.SYSIN      DD DSN=ZUSER##.LANG.SOURCE(ASMLE),DISP=SHR
   > //L.SYSLMOD    DD DSN=ZUSER##.LANG.LOAD(ASMLE),DISP=SHR
   > //L.SYSLIB     DD DSN=CEE.SCEELKED,DISP=SHR
   > //             DD DSN=CEE.SCEELKEX,DISP=SHR
   > ```

2. Submit the following data set to compile and link a simple Assembler language program:

   yourid.LANG.CNTL(ASM)

3. Submit the following data set to compile and link a complex C language program:

   yourid.LANG.CNTL(C)

   > **Note:** The student might need to modify the JCL for data sets beginning with CEE and CBC. Ask your system programmer what the high-level qualifiers (HLQs) are for the Language Environment and C language data sets. The JCL that might need to be changed is highlighted here:
   >
   > ```
   > //STEP1 EXEC PROC=EDCCB,LIBPRFX=CEE,LNGPRFX=CBC,
   > //    INFILE='ZUSER##.LANG.SOURCE(C)',
   > //    OUTFILE='ZUSER##.LANG.LOAD(C),DISP=SHR'
   > ```

4. Submit the following data set to compile and link a simple C language program:

   yourid.LANG.CNTL(C2)

   > **Note:** The student might need to modify the JCL for data sets beginning with CEE and CBC. Ask your system programmer what the high-level qualifiers (HLQs) are for the Language Environment and C language data sets. The JCL that might need to be changed is highlighted here:
   >
   > ```
   > //STEP1 EXEC PROC=EDCCB,LIBPRFX=CEE,LNGPRFX=CBC,
   > //    INFILE='ZUSER##.LANG.SOURCE(C2)',
   > //    OUTFILE='ZUSER##.LANG.LOAD(C2),DISP=SHR'
   > ```

5. Submit the following data set to compile and link a complex COBOL language program:

yourid.LANG.CNTL(COBOL)

Note: The student might need to modify the JCL for data sets beginning with CEE. Ask your system programmer what the high-level qualifier (HLQ) is for the Language Environment data sets. The JCL that might need to be changed is highlighted here:

```
//SYSIN        DD DSN=ZUSER##.LANG.SOURCE(COBOL),DISP=SHR
//COBOL.SYSLIB DD DSN=CEE.SCEESAMP,DISP=SHR
//LKED.SYSLMOD DD DSN=ZUSER##.LANG.LOAD(COBOL),DISP=SHR
```

6. Submit the following data set to compile and link a simple COBOL language program:

   yourid.LANG.CNTL(COBOL2)

7. Submit the following data set to compile and link a complex PL/I language program:

   yourid.LANG.CNTL(PL1)

Note: The student might need to modify the JCL for data sets beginning with CEE. Ask your system programmer what the high-level qualifier (HLQ) is for the Language Environment data sets. The JCL that might need to be changed is highlighted here:

```
//SYSIN        DD DSN=ZUSER##.LANG.SOURCE(PL1),DISP=SHR
//PLI.SYSLIB   DD DSN=CEE.SCEESAMP,DISP=SHR
//BIND.SYSLMOD DD DSN=ZUSER##.LANG.LOAD(PL1),DISP=SHR
```

8. Submit the following data set to compile and link a simple PL/I language program:

   yourid.LANG.CNTL(PL12)

9.9.2 Exercise: executing a program

In this section, language examples you selected were compiled and linked in exercise “Exercise: compiling and linking a program” on page 9-27. Do not attempt to run any of the following jobs if you have not successfully completed the previous exercise, because they will end in errors.

The following exercise contains actions to perform for each language sample to execute the load module that was previously stored when a compile and link job was run. For the interpreted languages, you will execute the source members directly from:

yourid.LANG.SOURCE(language)
where “language” is one of CLIST, REXX.

Note: The JCL will need to be modified to specify the HLQ of the student submitting the jobs. To submit the jobs, enter SUBMIT on the ISPF command line. Once the job completes, you will need to use SDSF to view the output of the job.

In order for these jobs to run successfully, the student will have had to complete the compile and link jobs in exercise 9.9.1, "Exercise: compiling and linking a program" on page 9-27 in order to create the load modules in:

```
ZPROF.LANG.LOAD
```

If these jobs did not run successfully, then the student could receive errors in the job log in SDSF similar to:

```
CSV003I REQUESTED MODULE ASM      NOT FOUND
CSV028I ABEND806-04  JOBNAME=ZPROF2    STEPNAME=STEP1
IEA995I SYMPTOM DUMP OUTPUT  238
SYSTEM COMPLETION CODE=806  REASON CODE=00000004
```

The module name, JOBNAME and STEPNAME vary, according to which job had been submitted.

1. Submit the following data set to execute a complex Assembler language program:

   ```
   yourid.LANG.CNTL(USEASMLE)
   This example establishes an LE environment and prints out the message:
   "IN THE MAIN ROUTINE".
   ```

2. Submit the following data set to execute a simple Assembler language program:

   ```
   yourid.LANG.CNTL(USEASM)
   This example sets the return code to 15 and exits.
   ```

3. Submit the following data set to execute a complex C language program:

   ```
   yourid.LANG.CNTL(USEC)
   This example prints out the local date and time.
   ```

4. Submit the following data set to execute a simple C language program:

   ```
   yourid.LANG.CNTL(USEC2)
   This example prints out the message "Hello World".
   ```

5. Submit the following data set to execute a complex COBOL language program:

   ```
   yourid.LANG.CNTL(USECOBOL)
   This example prints out the local date and time.
   ```

6. Submit the following data set to execute a simple COBOL language program:

   ```
   yourid.LANG.CNTL(USECOBO2)
   This example prints out the message "HELLO WORLD".
   ```

7. Submit the following data set to execute a complex PL/I language program:

yourid.LANG.CNTL(USEPL1)
This example prints out the local date and time.

8. Submit the following data set to execute a simple PL/I language program:

   yourid.LANG.CNTL(USEPL12)
   This example prints out the message "HELLO WORLD".

9. Execute the following complex CLIST language program:

   yourid.LANG.SOURCE(CLIST)
   This example prompts the user for a high-level qualifier (HLQ) and then produces a formatted catalog listing for that HLQ.

   On the ISPF command line type:
   TSO EX '*yourid*.LANG.SOURCE(CLIST)'
   When prompted, enter the HLQ *yourid*

10. Execute the following simple CLIST language program:

    yourid.LANG.SOURCE(CLIST2)
    This example prints out the message "HELLO WORLD".

    On the ISPF command line type:
    TSO EX '*yourid.*LANG.SOURCE(CLIST2)'

11. Execute the following complex REXX language program:

    yourid.LANG.SOURCE(REXX)
    This example prompts the user for a high-level qualifier (HLQ) and then produces a formatted catalog listing for that HLQ.

    On the ISPF command line type:
    TSO EX '*yourid*.LANG.SOURCE(REXX)'
    When prompted, enter the HLQ *yourid*

12. Execute the following simple REXX language program:

    yourid.LANG.SOURCE(REXX2)
    This example prints out the message "HELLO WORLD".

    On the ISPF command line type:
    TSO EX '*yourid*.LANG.SOURCE(REXX2)'

Part 3

Online workloads for z/OS

In this part, we examine the major categories of online or *real time* workloads performed on z/OS, such as transaction processing, database management, and Web-serving. The chapters that follow guide the student through discussions of network communications and several popular middleware products, including DB2, CICS, and WebSphere.

10

Overview of z/OS online workloads

Objective: To expand your knowledge of mainframe workloads, you must understand the role of mainframes in today's online world. This chapter introduces concepts and terminology for transactional processing, database management systems, and network communications.

After completing this chapter, you will be able to:

- Describe the role of large systems in a typical online business.
- List the attributes common to most transactional systems.
- Explain how databases are used in a typical online business.
- Describe two models for network connectivity for large systems.

10.1 Online processing on the mainframe

In earlier chapters, we discussed the possibilities of batch processing—but those are not the only applications running on z/OS and the mainframe. Online applications also run on z/OS, as we show in this chapter. We also describe what online, or real time, applications are and discuss their common elements in the mainframe environment.

Also, we examine databases, which are a common way of storing application data. Databases make development easier—especially in the case of a relational database management system (RDBMS). Later, in Chapter 11, "Understanding CICS and DB2" , we discuss several widely used transaction management systems for mainframe-based enterprises.

We begin with the example of a travel agency with a requirement common to many mainframe customers: Provide customers with more immediate access to services and exploit the benefits of Internet-based commerce.

10.2 Example of global online processing--the *new* big picture

A big travel agency has relied on a mainframe-based batch system for many years. Over the years, the agency's customers have enjoyed excellent service, and the agency has continuously improved its systems.

When the business was begun, their IT staff designed some applications to support the agency's internal and external processes: Employee information, customer information, contacts with car rental companies, hotels all over the world, scheduled flights of airlines, and so on. At first these application were handled through periodic batch updates.

This kind of data is not static, however, and has become increasingly prone to frequent change. Because prices, for example, change frequently, it became more difficult over time to maintain current information. The agency's customers wanted their information *now* and that was not always possible through fixed intervals of batch updates (consider the time difference between Asia, Europe, and America).

If these workloads were to be done through traditional mainframe batch jobs, it would mean a certain time lapse between the reception of the change and the actual update. The agency needed a way to update small amounts of data provided in bits and pieces—by phone, fax, or e-mail— the instant that changes occur (Figure 10-1 on page 10-3).

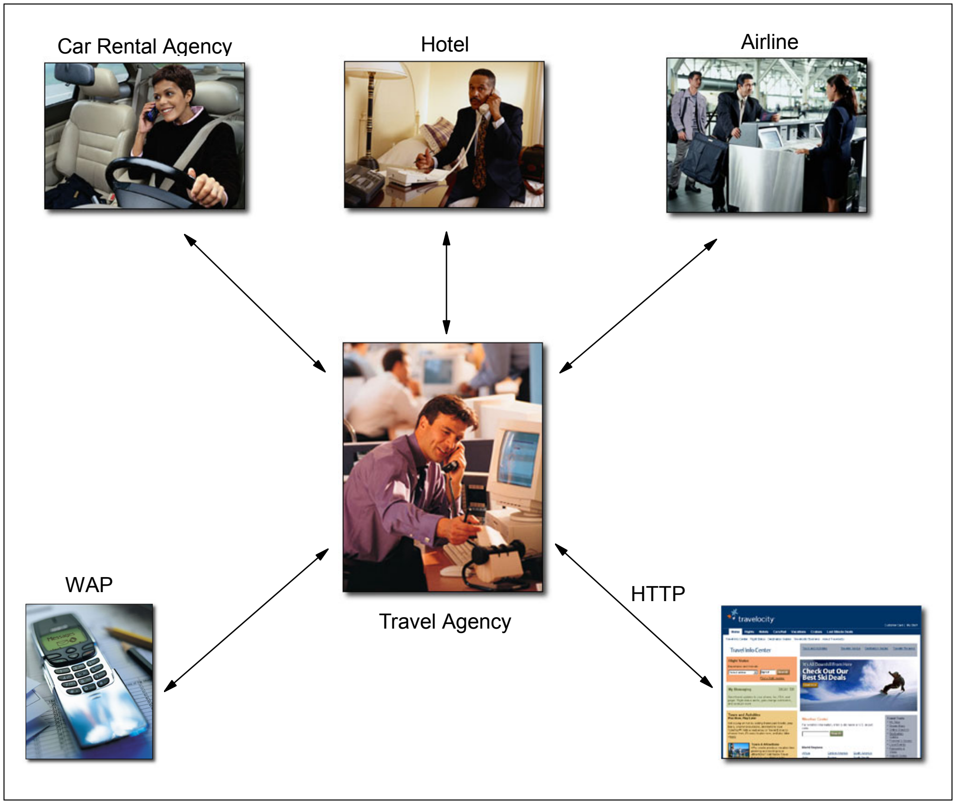


Figure 10-1 A practical example

Therefore, the agency IT staff created some new applications. The new applications are transactional in nature. Changes need to be immediately reflected to the applications's end-users. The applications are called transactional or real time applications because changes in the system data are effective immediately.

The travel agency contacted its suppliers to see what could be done. They needed a way to let the computers talk to each other. Some of the airlines were also working on mainframes, others were not, and everybody wanted to keep their own applications.

They found a solution! It made communicating easy: you could just ask a question and some seconds later get the result—great stuff.

More innovations were required because the customers also evolved. The personal computer got into their homes, so they wanted to see travel possibilities through the Internet. Some customers used their mobile computers as a wireless access point (WAP).

10.3 Transactional systems for the mainframe

Transactions occur in everyday life: When you exchange money for goods and services or when you do a search on the Internet. A transaction is a routine event, usually a request, in running the day-to-day operations of an organization.

Transactions have the following characteristics:

- Small amount of data is processed and transferred per transaction
- Large numbers of users
- Large numbers of transactions

10.3.1 What are transaction programs?

A business transaction is a self-contained business deal. Some transactions involve a short conversation (for example, an address change). Others involve multiple actions that take place over an extended period (for example, the booking of a trip, including car, hotel, and airline tickets).

A single transaction might consist of many application programs that carry out the processing needed. Large-scale transactional systems (such as IBM's CICS product) rely on the *multitasking* and *multithreading* capabilities of z/OS to allow more than one task to be processed at the same time, each task saving its specific variable data and keeping track of the instructions each user is executing.

Multitasking is essential in any environment in which thousands of users can be logged on at the same time. When a multitasking transactional system receives a request to run a transaction, it can start a new task that is associated with *one instance* of the execution of the transaction. That is, one execution of a transaction, with a particular set of data, usually on behalf of a particular user at a particular terminal. You might also consider a task to be analogous to a *thread*. When the transaction completes, the task is ended.

Multithreading allows a single copy of an application program to be processed by several transactions concurrently. Multithreading requires that all transactional application programs be reentrant; that is, they must be serially reusable between entry and exit points. Among programming languages, reentrance is ensured by a *fresh* copy of working storage section being obtained each time the program is invoked.

10.3.2 What is a transactional system?

Figure 10-2 on page 10-5 shows the main characteristics of a transactional system. Before the advent of the Internet, a transactional system served hundreds or thousands of *terminals* with dozens or hundreds of transactions per second. This workload was rather predictable both in transaction rate and mix of transactions.

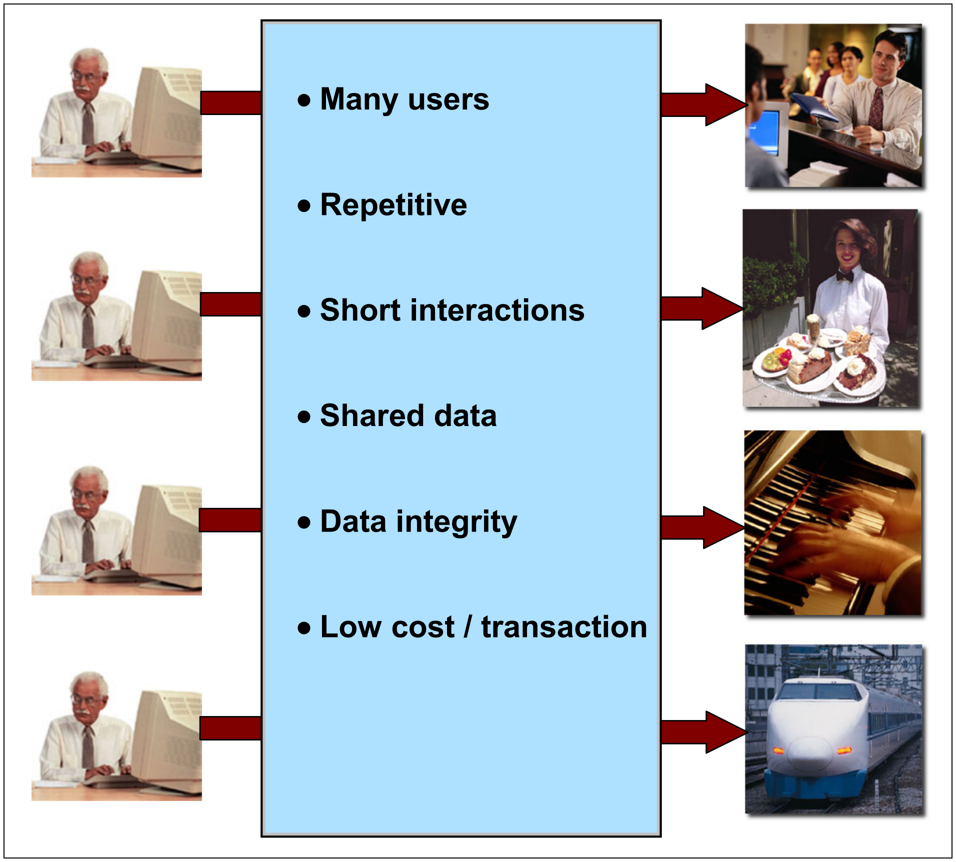


Figure 10-2 Characteristics of a transactional system

Transactional systems must be able to support an unpredictable number of concurrent users and transaction types. Most transactions are executed in short time periods—fractions of a second in some cases.

One of the main characteristics of a transactional or online system is that the interactions between the user and the system are very short. The user will perform a complete business transaction through short interactions, with a good response time required for each interaction. These systems are currently supporting mission-critical applications; therefore, so continuous availability, high performance, and data protection and integrity are required.

Online transaction processing (OLTP) is transactional processing that occurs in real time and requires:

- Quick response time
- Continuous availability of the transactional interface to the end user

- Security
- Data integrity

Online transactions are familiar to many people. Some examples include:

- ATM transactions such as deposits, withdrawals, inquiries, and transfers
- Supermarket payments with debit or credit cards
- Buying merchandise over the Internet

For example, inside a bank branch office or using the Internet bank, customers are using online services when checking an account balance or directing fund balances.

In fact, an online system has many of the characteristics of an operating system:

- Managing and dispatching tasks
- Controlling user access authority to system resources
- Managing the use of real memory
- Managing and controlling simultaneous access to data files
- Providing device independence

10.3.3 What are the typical requirements of a transactional system?

In a transactional system, transactions must comply with four primary requirements known jointly by the mnemonic A-C-I-D or ACID:

- **A**tomicity. The processes performed by the transaction are done as a whole or not at all.
- **C**onsistency. The transaction must work only with consistent information.
- **I**solation. The processes coming from two or more transactions must be isolated from one another.
- **D**urability. The changes made by the transaction must be permanent.

Usually, transactions are initiated by an end user who interacts with the transactional system through a terminal. In the past, transactional systems supported only terminals and devices connected through a teleprocessing network. Today, transactional systems can serve requests submitted in any of the following ways:

- Web page
- Remote workstation program
- Application in another transactional system
- Triggered automatically at a predefined time

10.3.4 What is commit and roll back?

In transactional systems, commit and roll back refers to the set of actions used to ensure sure that an application program either makes *all* changes to the resources represented by a single unit of recovery (UR) or makes *no* changes at all. The protocol verifies that either all changes or no changes are applied even if one of the elements, like the application, the system, or the resource manager fails. The protocol allows for restart and recovery processing to take place after system or subsystem failure.

The two-phase commit protocol is initiated when the application is ready to commit or back out its changes. At this point, the coordinating recovery manager, also called the *syncpoint manager,* gives each resource manager participating in the unit of recovery an opportunity to vote on whether its part of the UR is in a consistent state and can be committed. If all participants vote YES, the recovery manager instructs all the resource managers to commit the changes. If any of the participants vote NO, the recovery manager instructs them to back out the changes. This process is usually represented as two phases.

In phase 1, the application program issues the syncpoint or rollback request to the syncpoint coordinator. The coordinator issues a PREPARE command to send the initial syncpoint flow to all the UR agent resource managers. In response to the PREPARE command, each resource manager involved in the transaction replies to the syncpoint coordinator stating whether it is ready to commit or not.

When the syncpoint coordinator receives all the responses back from all its agents, phase 2 is initiated. In this phase the syncpoint coordinator issues the commit or rollback command based on the previous responses. If any of the agents responded with a negative response, the syncpoint initiator causes *all* of the syncpoint agents to roll back their changes.

The instant when the coordinator records the fact that it is going to tell all the resource managers to either commit or roll back is known as the atomic instant. Regardless of any failures after that time, the coordinator assumes that all changes will either be committed or rolled back. A syncpoint coordinator usually logs the decision at this point. If any of the participants abnormally end (or *abend*) after the atomic instant, the abending resource manager must work with the syncpoint coordinator when it restarts to complete any commits or rollbacks that were in process at the time of the abend.

During the first phase of the protocol, the agents do not know whether the syncpoint coordinator will commit or roll back the changes until the syncpoint coordinator has collected all responses. This time is known as the *indoubt* period. The UR is described as having a particular state depending on what stage it is at in the two-phase commit process:

- Before a UR makes any changes to a resource, it is described as being *In-reset*.
- While the UR is requesting changes to resources, it is described as being *In-flight*.
- Once a commit request has been made (Phase 1), it is described as being *In-prepare*.
- Once the syncpoint manager has made a decision to commit (phase 2 of the two-phase commit process), it is *In-commit*.
- If the syncpoint manager decides to back out, it is *In-backout.*

Figure 10-3 illustrates the two-phase commit.

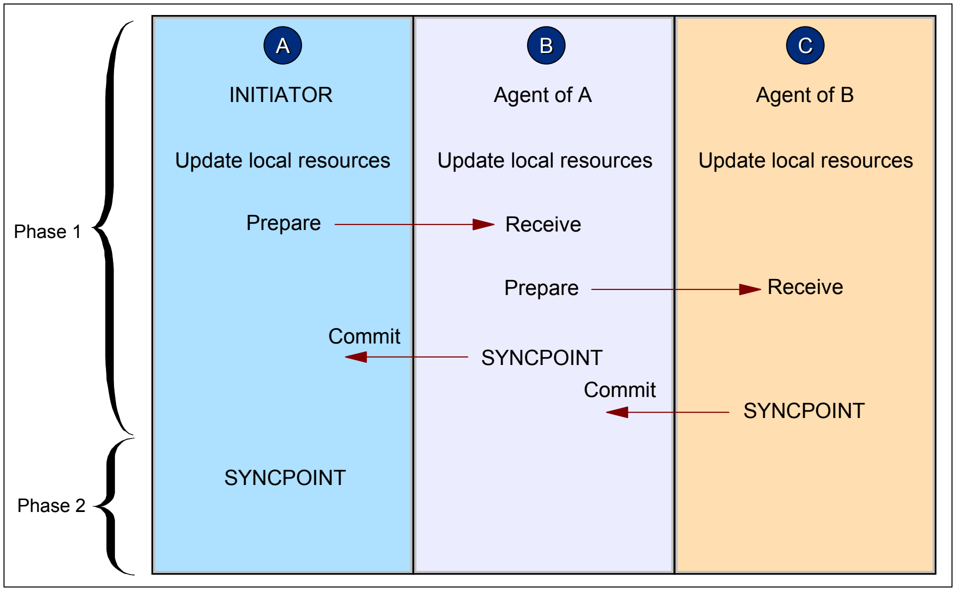


Figure 10-3 Two-phase commit

Most widely-used transaction management systems on z/OS, such as CICS or IMS, support two-phase commit protocols. CICS, for example, supports full two-phase commit in transactions with IMS and the DB2 database management system, and supports two-phase commit across distributed CICS systems.

Why, you might ask, do we need a syncpoint manager on z/OS? The problem is that there are many restrictions imposed on application developers attempting to develop new applications that require updates in many different resource managers, perhaps across a number of systems. Many of these new applications use technologies like DB2 stored procedures and Enterprise Java Beans, and use client attachment facilities of CICS or IMS that do not support two-phase commit. If any of these resource managers are used by an application to update resources, it is not possible to have a global coordinator for the syncpoint.

The lack of a global syncpoint coordinator might have influenced some application design for the following reasons:

- The application would not have been capable of having complex and distributed transactions if not all of the resource managers were participating in the two-phase commit protocol.
- The application could not have been designed as a single application (or unit of recovery) across multiple systems (except for CICS).

The application programmer had to program around these limitations. For example, the programmer could have limited the choice of where to put the business data to ensure that all the data could be committed in a single unit of recovery.

Also, these limitations could have affected the recoverability of the protected resources or their integrity in case of a failure of one of the components because resource managers have no way to either commit or roll back the updates.

10.4 Database management systems for the mainframe

This section gives an overview of basic database (DB) concepts, what they are used for, what the advantages are. There are a lot of databases, but we limit the scope to the two types that are used most on mainframes: hierarchical and relational databases.

10.4.1 What is a database?

A database provides for the storing and control of business data, independent from (but not separate from the processing requirements of) one or more applications. If properly designed and implemented, the database should provide a single consistent view of the business data, so that it can be centrally controlled and managed.

One way of describing a logical view of this collection of data is to use an entity relationship model. The database records details (attributes) of particular items (entities) and the relationships between the different types of entities. For example, for the stock control area of an application, you would have Parts, Purchase Orders, Customers, and Customer Orders (entities). Each entity would have attributes—the Part would have a Part No, Name, Unit Price, Unit Quantity, etc. These entities would also have relationships between them, for example a Customer would be related to orders placed, which would be related to the part that had been ordered, and so on. Figure 10-4 on page 10-10 illustrates an entity relationship mode.

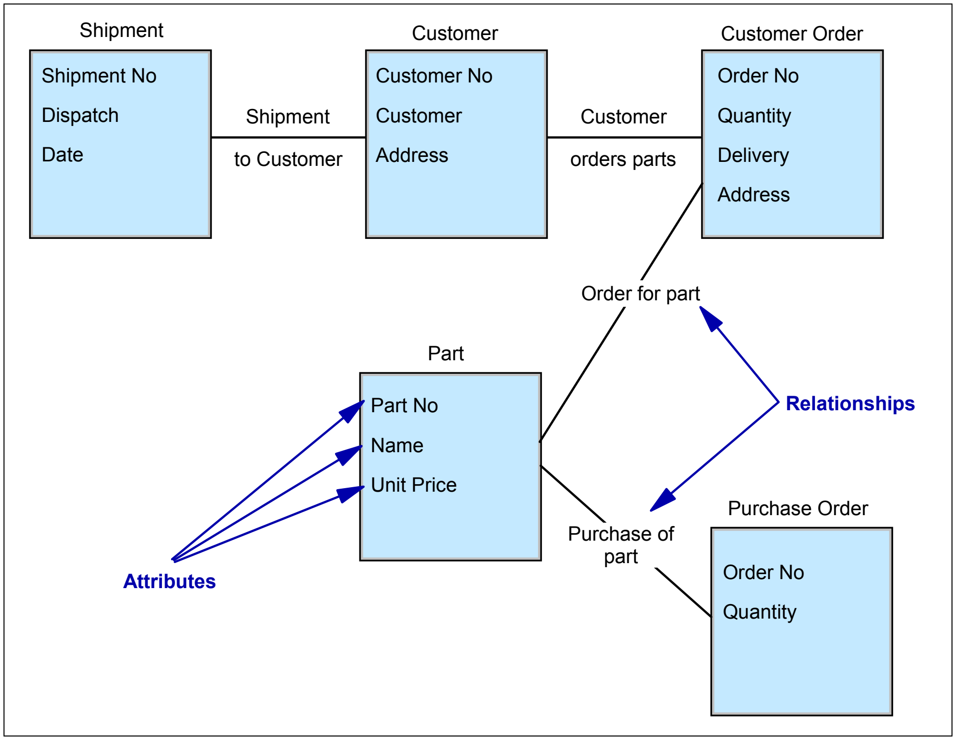


Figure 10-4 Entities, attributes, and relationships

A database management system (DBMS), such as the IMS Database Manager component, or the DB2 product, provide a method of storing and using the business data in the database.

10.4.2 Why use a database?

When computer systems were first developed, the data was stored on individual files, unique to an application or even a small part of an individual application. But a properly designed and implemented DBMS provides many advantages over a flat file PDS system:

- It reduces the application programming effort.
- It manages more efficiently the creation and modification of, and access to, data than a non-DBMS system. As you know, if new data elements need to be added to a file, then all applications that use that file must be rewritten, even those that do not use the new data element.This needs not happen when using a DBMS. Although many programmers have resorted to “tricks” to minimize this application programming rewrite task, it still requires effort.

- It provides a greater level of security and confidentiality of the data than a flat file system. Specifically, when accessing a logical record in a flat file, the application can see *all* data elements—including any confidential or privileged data. To minimize this, many customers have resorted to putting sensitive data into a separately managed file, and linking the two as necessary. This may cause data consistency issues.

  With a DBMS, the sensitive data can be isolated in a separate segment (in IMS/DB) of View (in DB2) that prevents unauthorized applications from seeing it. But these data elements are an integral part of the logical record!

The same details might be stored in several different places, for example the details of a customer might be in both the ordering and invoicing application. This caused a number of problems:

- As the details were stored and processed independently, details that were supposed to be the same, for example a customer's name and address, might be inconsistent in the various applications.
- When common data had to be changed, it had to be changed in several places, causing a high workload. If any copies of the data were missed, it resulted in the problems detailed in the previous point.
- There was no central point of control for the data, to ensure it that was secure, both from loss and from unauthorized access.
- The duplication of the data wasted space on storage media.

The use of a database management system such as IMS Database Manager component or DB2 to implement the database also provides additional advantages. The DBMS:

- Allows multiple tasks to access and update the data simultaneously while preserving database integrity. This is particularly important where large numbers of users are accessing the data via an online application.
- Provides facilities for the application to update multiple database records and ensures that the application data in the various records remains consistent even if an application failure occurs.
- Is able to put confidential or sensitive data in a separate segment (in IMS) or table (in DB2), while in a PDS or VSAM flat file the application program gets access to every data element in the logical record. Some of these elements might contain data that should be restricted.
- Provides utilities that control and implement backup and recovery of the data, preventing loss of vital business data.
- Provides utilities to monitor and tune access to the data.
- Is able to change the structure of the logical record (by adding or moving data fields). Such changes usually require that every application that accesses the VSAM or PDS file must be reassembled or recompiled, even if it does not need the added or changed

fields. A properly designed data base insulates the application programmer from such changes.

The use of a database and database management system will not, in itself, produce the advantages detailed above. It also requires the proper design and administration of the databases, and development of the applications.

10.4.3 What is the role of the database administrator?

The centralization of data and control of access to this data is inherent to a database management system. One of the advantages of this centralization is the availability of consistent data to more than one application. As a consequence, this dictates tighter control of that data and its usage.

Responsibility for an accurate implementation of control lies with the database administrator (DBA) function. Indeed, to gain the full benefits of using a centralized database, you must have a central point of control for it. Because the actual implementation of the DBA function is dependent on a company's organization, we limit ourselves to a discussion of the roles and responsibilities of a DBA. The group fulfilling the DBA role will need experience in both application and systems programming.

DBA roles and responsibilities in a typical installation might be as follows:

- The DBA provides standards for, and controls the administration of, the databases and their use.
- The DBA provides guidance, review, and approval of database design.
- The DBA determines the rules of access to the data and monitors its security.
- The DBA controls the database integrity and availability, monitoring the necessary activities for reorganization backup and recovery.
- The DBA is not responsible for the actual content of databases. This is the responsibility of the user. Rather, the DBA enforces procedures for accurate, complete, and timely update of the databases.
- The DBA approves the operation of new programs with existing production databases, based on results of testing with test data.

In general, the DBA is responsible for the maintenance of current information about the data in the database. Initially, this responsibility might be carried out using a manual approach. But it can be expected to grow to a scope and complexity sufficient to justify, or necessitate, the use of a data dictionary program.

10.4.4 How is a database designed?

The process of database design, in its simplest form, can be described as the structuring of the data elements for the various applications, in such an order that:

- Each data element is readily available by the various applications, now and in the foreseeable future.
- The data elements are efficiently stored.
- Controlled access is enforced for those data elements with specific security requirements.

A number of different models for databases have been developed over the years (such as hierarchical, relational, or object) so that there is no consistent vocabulary for describing the concepts involved.

Entities

A database contains information about entities. An entity is something that:

- Can be uniquely defined.
- We may collect substantial information about, now or in the future.

In practice, this definition is limited to the context of the applications and/or business under consideration. Examples of entities are: parts, projects, orders, customers, trucks, etc. It should be clear that defining entities is a major step in the database design process. The information we store in databases about entities is described by data attributes.

Data attributes

A data attribute is a unit of information that specifies a fact about an entity. For example, suppose the entity is a part. Name=Washer, Color=Green and Weight=143 are three facts about that part. Thus these are three data attributes. A data attribute has a name and a value. A data attribute name tells the kind of fact being recorded; the value is the fact itself. In the above example, Name, Color, and Weight are data attribute names; while Washer, Green and 143 are values. A value must be associated with a name to have a meaning.

An occurrence is the value of a data attribute for a particular entity. An attribute is always dependent on an entity. It has no meaning by itself. Depending on its usage, an entity can be described by one single data attribute, or more. Ideally, an entity should be uniquely defined by one single data attribute, for example, the order number of an order. Such a data attribute is called the key of the entity. The key serves as the identification of a particular entity occurrence, and is a special attribute of the entity. Keys are not always unique. Entities with equal key values are called *synonyms*.

For instance, the full name of a person is generally not a unique identification. In such cases we have to rely on other attributes such as full address, birthday, or an arbitrary sequence number. A more common method is to define a new attribute that serves as the unique key, for example, employee number.

Entity relationships

The entities identified will also have connections between them, called relationships. For example, an order might be for a number of parts. Again these relationships only have meaning within the context of the application and business. These relationships can be one-to-one (that is, one occurrence of an entity relates to a single occurrence of another entity), one-to-many (one occurrence of an entity relates to many occurrences of another entity) or many-to-many (many occurrences of one entity have a relationship with many occurrences of another entity).

Relationships can also be recursive, that is, an entity can have a relationship with other occurrences of the same entity. For example a part, say a fastener, may consist of several other parts, bolt, nut, and washer.

Application functions

Data itself is not the ultimate goal of a database management system. It is the application processing performed on the data that is important. The best way to represent that processing is to take the smallest application unit representing a user interacting with the database. For example, one single order, one part's inventory status. In the following sections we call this an *application function*.

Functions are processed by application programs. In a batch system, large numbers of functions are accumulated into a single program (that is, all orders of a day), then processed against the database with a single scheduling of the desired application program. In the online system, just one or two functions may be grouped together into a single program to provide one iteration with a user.

Although functions are always distinguishable, even in batch, some people prefer to talk about programs rather than functions. But a clear understanding of functions is mandatory for good design, especially in a DB environment. Once you have identified the functional requirements of the application, you can decide how to best implement them as programs using CICS or IMS. The function is, in some way, the individual use of the application by a particular user. As such, it is the focal point of the DB system.

Access paths

Each function bears in its input some kind of identification with respect to the entities used (for example, the part number when accessing a Parts database). These are referred to as the access paths of that function. In general, functions require random access, although for performance reasons sequential access is sometimes used. This is particularly true if the functions are batched, and if they are numerous relative to the database size, or if information is needed from most database records. For efficient random access, each access path should utilize the entities key.

10.4.5 What is a database management system?

A database management system (or DBMS) is essentially nothing more than a computerized data-keeping system. Users of the system are given facilities to perform several kinds of operations on such a system for either manipulation of the data in the database or the management of the database structure itself. Database Management Systems (DBMSs) are categorized according to their data structures or types.

There are several types of databases that can be used on a mainframe to exploit z/OS: inverted list, hierarchic, network, or relational.

Mainframe sites tend to use hierarchical model when the data *structure* (not data values) of the data needed for an application is relatively static. For example, a Bill of Material (BOM) database structure always has a high level assembly part number, and several levels of components with subcomponents. The structure usually has a component forecast, cost, and pricing data, etc. The structure of the data for a BOM application rarely changes, and new data elements (not values) are rarely identified. An application normally starts at the top with the assembly part number, and goes down to the detail components.

Both database systems we have discussed have the above-mentioned benefits (see 10.4.2, "Why use a database?" on page 10-10). RDBMS has the additional, significant advantage over the hierarchical DB of being non-navigational. By *navigational*, we mean that in a hierarchical database, the application programmer must know the structure of the database. The program must contain specific logic to navigate from the root segment to the desired child segments containing the desired attributes or elements. The program must still access the intervening segments, even though they are not needed.

The remainder of this section discusses the hierarchical database structure.

What structures exist in a relational database?

Relational databases include the following structures:

- Database

  A database is a logical grouping of data. It contains a set of related table spaces and index spaces. Typically, a database contains all the data that is associated with one application or with a group of related applications. You could have a payroll database or an inventory database, for example.

- Table

  A tables is a logical structure made up of rows and columns. Rows have no fixed order, so if you retrieve data you might need to sort the data. The order of the columns is the order specified when the table was created by the database administrator. At the intersection of every column and row is a specific data item called a value, or, more precisely, an atomic value. A table is named with a high-level qualifier of the owner's user ID followed by the table name, for example TEST.DEPT or PROD.DEPT. There are three types of tables:

– A base table that is created and holds persistent data
– A temporary table that stores intermediate SQL results
– A results table that is returned when you use an SQL statement to query tables

DEPTNO	DEPTNAME	MGRNO	ADMRDEPT
A00	SPIFFY COMPUTER SERVICE DIV.	000010	A00
B01	PLANNING	000020	A00
C01	INFORMATION CENTER	000030	A00
D01	DEVELOPMENT CENTER		A00
E01	SUPPORT SERVICES	000050	A00
D11	MANUFACTURING SYSTEMS	000060	D01
D21	ADMINISTRATION SYSTEMS	000070	D01
E11	OPERATIONS	000090	E01
E21	SOFTWARE SUPPORT	000100	E01

Figure 10-5 Example of a DB2 table (Department table)

In this table we use:

- Columns - The ordered set of columns are DEPTNO, DEPTNAME, MGRNO, and ADMRDEPT. All the data in a given column must be of the same data type.
- Rows - Each row contains data for a single department.
- Values - At the intersection of a column and row is a *value*. For example, PLANNING is the value of the DEPTNAME column in the row for department B01.

► Indexes

An index is an ordered set of pointers to rows of a table. Unlike the rows of a table that are not in a specific order, an index must always be maintained in order by DB2. An index is used for two purposes:

a. For performance to retrieve data values more quickly

b. For uniqueness

By creating an index on an employee's name, you can retrieve data more quickly for that employee than by scanning the entire table. Also, by creating a unique index on an employee number, DB2 will enforce the uniqueness of each value. A unique index is the only way DB2 can enforce uniqueness.

Creating an index automatically creates the *index space*, the data set that contains the index.

► Keys

A key is one or more columns that are identified as such in the creation of a table or index, or in the definition of referential integrity.

– Primary key

A table can only have one primary key because it defines the entity. There are two requirements for a primary key:

i. It must have a value, that is, it cannot be null.

ii. It must be unique, that is, it must have a unique index defined on it.

– Unique key

We already know that a primary key must be unique, but it is possible to have more than one unique key in a table. For our EMP table, the employee number is defined as the primary key and is therefore unique. If we also had a social security value in our table, hopefully that value would be unique. To guarantee this, you could create a unique index on the social security column.

– Foreign key

A foreign key is a key that is specified in a referential integrity constraint to make its existence dependent on a primary or unique key (parent key) in another table.

The example given is that of an employee's work department number relating to the primary key defined on the department number in the DEPT table. This constraint is part of the definition of the table.

SQL

Structured Query Language (SQL) is a high-level language that is used to specify what information a user needs without having to know how to retrieve it. The database is responsible for developing the access path needed to retrieve the data. SQL works at a set level, meaning that it is designed to retrieve one or more rows. Essentially, it is used on one or more tables and returns the result as a result table.

SQL has three categories based on the functionality involved:

1. DML - Data manipulation language used to read and modify data. There are four SQL statements to do so: SELECT, UPDATE, INSERT, and DELETE.
2. DDL - Data definition language used to define, change, or drop objects. You have three statements for this: CREATE, ALTER and DROP.
3. DCL - Data control language used to grant and revoke authorizations, which has two statements: GRANT and REVOKE. You can specify very granular authorities on your objects, or there is syntax to provide all the appropriate authorities.

If you don’t know any SQL, you may want to look at *DB2 UDB for z/OS: SQL Reference*.

10.5 Summary

In this chapter we have seen how applications keep changing, depending on the needs of the organization, its customers, and suppliers. Often those changes are implemented through new technologies, but the dependable, solid application remains unchanged.

Interaction with the computer happens online through the help of a transaction manager. Many transaction managers and database managers exist (one called CICS is discussed in the next chapter), but their principles are the same.

Data can be stored in a flat file, but this usually results in lots of duplication, which may result in inconsistent data. Therefore, it is better to create central databases, which can be accessed (reading and changing) from different places. The handling of consistency, security, etc. is done by the database management system; the user/developer does not need to worry about it.

Key terms in this chapter		
transactional	segment	DBMS
multitasking	SQL	multithreading
root	WAP	2-phase commit
database	VTAM	thread

10.6 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What might be some typical online transactions that you perform frequently?
2. Why are multitasking and multithreading important to online transaction processing?
3. What are some common characteristics of an online transactional system?
4. Explain two-phase commit.
5. What are some of the responsibilities of a database administrator (DBA)?

10.7 Exercises

11

Understanding Transaction Managers on z/OS

Objective: You will need a good working understanding of the major types of system software used to process online workloads on the mainframe. In this chapter, we focus on two of the most widely used transaction management products for z/OS: CICS and IMS.

After completing this chapter, you will be able to:

- Explain the role of CICS in online transaction processing
- Describe CICS programs, CICS transactions, and CICS tasks
- Explain what conversational and pseudo-conversational programming is
- Explain CICS and Web-enabling
- Discuss the IMS components

11.1 What is CICS?

CICS stands for *Customer Information Control System.* It is a general-purpose transaction processing subsystem for the z/OS operating system. CICS provides services for running an application online, by request, at the same time as many other users are submitting requests to run the same applications, using the same files and programs.

CICS manages the sharing of resources, the integrity of data and prioritization of execution, with fast response. CICS authorizes users, allocates resources (real storage and cycles), and passes on database requests by the application to the appropriate database manager (such as DB2). We could say that CICS acts like, and performs many of the same functions as the z/OS operating system.

A CICS application is a collection of related programs that together perform a business operation, such as processing a travel request or preparing a company payroll. CICS applications execute under CICS control, using CICS services and interfaces to access programs and files.

CICS applications are traditionally run by submitting a transaction request. Execution of the transaction consists of running one or more application programs that implement the required function. In CICS documentation you may find CICS application programs sometimes simply called programs, and sometimes the term transaction is used to imply the processing done by the application programs.

CICS applications can also take the form of Enterprise Java Beans. You can find out more about this form of programming in Java Applications in CICS in the CICS Information Center.

11.1.1 CICS in a z/OS system

In a z/OS system, CICS provides a layer of function for managing transactions, while the operating system remains the final interface with the computer hardware. CICS essentially separates a particular kind of application program (namely, online applications) from others in the system, and handles these programs itself.

When an application program accesses a terminal or any device, for example, it doesn't communicate directly with it. The program issues commands to communicate with CICS, which communicates with the needed access methods of the operating system. Finally, the access method communicates with the terminal or device.

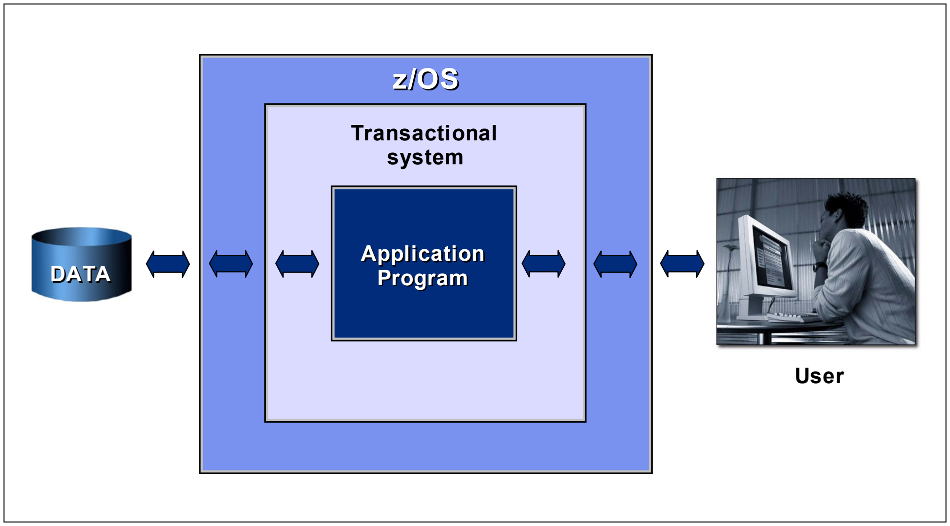


Figure 11-1 Transactional system and the operating system

A z/OS system might have multiple copies of CICS running at one time. Each CICS starts as a separate z/OS address space. CICS provides an option called multi-region operation (MRO), which enables the separation of different CICS functions into different CICS regions (address spaces); so a specific CICS address space (or more) might do the terminal control and will be named terminal owning region (TOR). Other possibilities include application-owning regions (AORs) for applications and file-owning regions (FORs) for files.

11.1.2 CICS programs, transactions and tasks

To develop and run CICS applications, you need to understand the relationship between CICS programs, transactions, and tasks. These terms are used throughout CICS publications and appear in many commands:

- Transaction

  A transaction is a piece of processing initiated by a single request. This is usually from an end user at a terminal, but might also be made from a Web page, from a remote workstation program, from an application in another CICS system, or triggered automatically at a predefined time. The CICS Internet Guide and the CICS External Interfaces Guide describe different ways of running CICS transactions.

- Application program

  A single transaction consists of one or more *application programs* that, when run, carry out the processing needed.

However, the term transaction is used in CICS to mean both a single event and all other transactions of the same type. You describe each transaction type to CICS with a *transaction resource definition*. This definition gives the transaction type a name (the transaction identifier or TRANSID) and tells CICS several things about the work to be done, such as what program to invoke first and what kind of authentication is required throughout the execution of the transaction.

You run a transaction by submitting its TRANSID to CICS. CICS uses the information recorded in the TRANSACTION definition to establish the correct execution environment, and starts the first program.

- Unit of work

  The term transaction is now used extensively in the IT industry to describe a unit of recovery or what CICS calls a *unit of work*. This is typically a complete operation that is recoverable; it can be committed or backed out as an entirety as a result of a programmed command or system failure. In many cases, the scope of a CICS transaction is also a single unit of work, but you should be aware of the difference in meaning when reading non-CICS publications.

- Task

  You will also see the word *task* used extensively in CICS publications. This word also has a specific meaning in CICS. When CICS receives a request to run a transaction, it starts a new task that is associated with this one instance of the execution of the transaction—that is, one execution of a transaction, with a particular set of data, usually on behalf of a particular user at a particular terminal. You can also consider it analogous to a *thread*. When the transaction completes, the task is terminated.

11.1.3 Using programming languages

You can use COBOL, OO COBOL, C, C++, Java, PL/I, or assembler language to write CICS application programs to run on z/OS. Most of the processing logic is expressed in standard language statements, but you use CICS commands, or the Java and C++ class libraries to request CICS services.

Most of the time, you use the CICS command level programming interface, “EXEC CICS”. This is the case for COBOL, OO COBOL, C, C++, PL/I and assembler programs. These commands are defined in detail in the CICS Application Programming Reference.

Programming in Java with the JCICS class library is described in the Java Applications in CICS component of the CICS Information Center.

Programming in C++ with the CICS C++ classes is described in the CICS C++ OO Class Libraries documentation.

11.1.4 CICS programming roadmap

Follow these steps to develop a CICS application that uses the EXEC CICS command level programming interface:

1. Design the application, identifying the CICS resources and services you will use. See the chapter on Application Design of the *CICS Application Programming Guide*.
2. Write the program in the language of your choice, including EXEC CICS commands to request CICS services. See the *CICS Application Programming Reference* for a list of CICS commands.

   One of the needed components for online transactions is the screen definition, that is, the layout of what is displayed on the screen (such as a Web page); in CICS we call this a *map*.
3. Depending on the compiler, you might only need to compile the program and install it in CICS, or you might need to define translator options for the program and then translate and compile your program. See the *CICS Application Programming Guide* for more details.
4. Define your program and related transactions to CICS with PROGRAM resource definitions and TRANSACTION resource definitions, as described in the *CICS Resource Definition Guide*.
5. Define any CICS resources that your program uses, such as files, queues, or terminals.
6. Make the resources known to CICS using the CEDA INSTALL command described in the *CICS Resource Definition Guide*.

11.1.5 Conversational and pseudo-conversational programming

In CICS, when the programs being executed enter into a conversation with the user, it is called a conversational transaction (also see Figure 11-2 on page 11-6). A non-conversational transaction (also see Figure 11-3 on page 11-7), by contrast, processes one input, responds, and ends (disappears). It never pauses to read a second input from the terminal, so there is no real conversation. There is a technique in CICS called pseudo-conversational processing, in which a series of non-conversational transactions gives the appearance (to the user) of a single conversational transaction. No transaction exists while the user waits for input; CICS takes care of reading the input when the user gets around to sending it. The following two figures show different types of conversation in an example of a record update in a banking account.

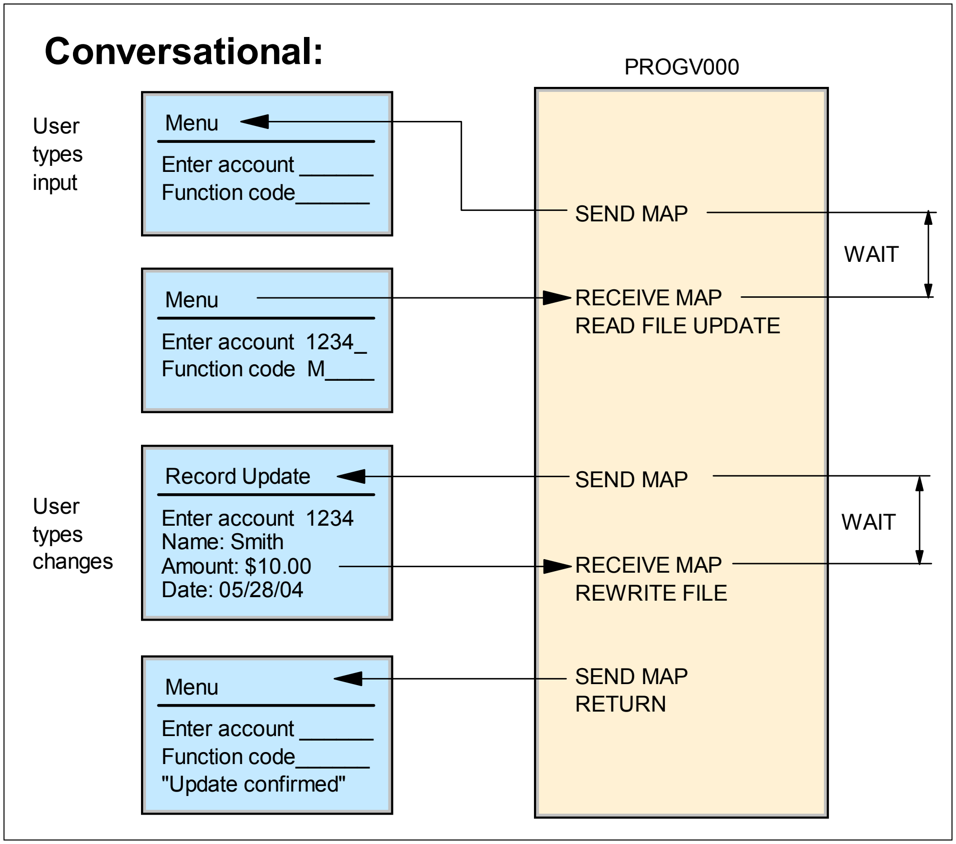


Figure 11-2 Example of a conversational transaction

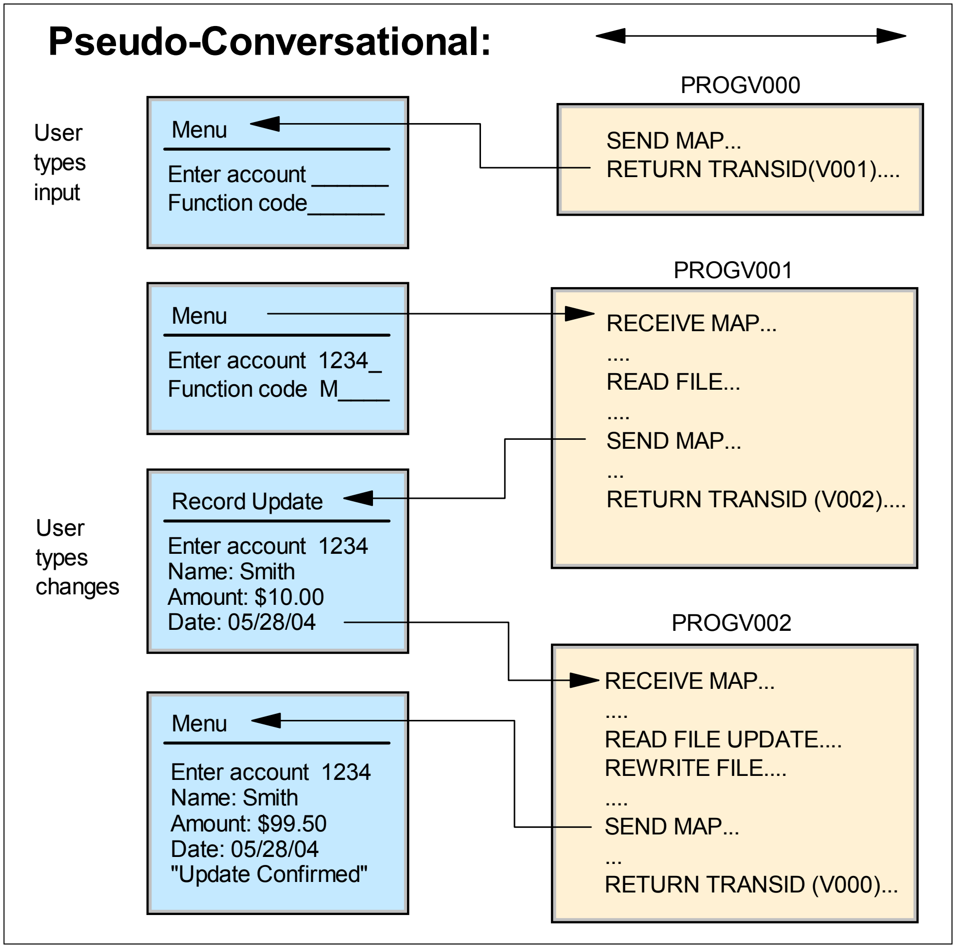


Figure 11-3 Example of a pseudo-conversational transaction

More information can be found in the *CICS Application Programming Guide.*

11.1.6 CICS programming commands

The general format of a CICS command is EXECUTE CICS (or EXEC CICS) followed by the name of the command and possibly one or more options.

You can write many application programs using the CICS command-level interface without any knowledge of, or reference to, the fields in the CICS control blocks and storage areas. However, you might need to get information that is valid outside the local environment of your application program.

When you need a CICS system service, for example when reading a record from a file, you just include a CICS command in your code. In COBOL, for example, CICS commands look like this:

```
EXEC CICS function option option ... END-EXEC.
```

The “`function`” is the thing you want to do. Reading a file is READ, writing to a terminal is SEND, and so on.

An “`option`” is some specification that’s associated with the function. Options are expressed as keyboards. For example, the options for the READ command include FILE, RIDFLD, UPDATE and others. FILE tells CICS which file you want to read, and is always followed by a value indicating or pointing to the file name. RIDFLD (record identification field, that is, the key) tells CICS which record and likewise needs a value. The UPDATE option, on the other hand, simply means that you intend to change the record and doesn’t take any value. So, to read with intent to modify, a record from a file known to CICS as ACCTFIL, using a key that we stored in working storage as ACCTC, we issued the command shown in Example 11-1.

Example 11-1 CICS command example

```
EXEC CICS
   READ FILE(‘ACCTFIL’)
         RIDFLD(ACCTC) UPDATE ...
END-EXEC.
```

You can use the ADDRESS and ASSIGN commands to access such information. For programming information about these commands, see the *CICS Application Programming Reference* manual. When using the ADDRESS and ASSIGN commands, various fields can be read but should not be set or used in any other way. This means that you should not use any of the CICS fields as arguments in CICS commands, because these fields may be altered by the EXEC interface modules.

11.1.7 How a CICS transaction flows

To begin an online session with CICS, users usually begin by signing on, the process which identifies them to CICS. Signing on to CICS gives users the authority to invoke certain transactions. When signed on, users invoke the particular transaction they intend to use. A CICS transaction is usually identified by a 1-to-4 character transaction identifier or TRANSID, which is defined in a table that names the initial program to be used for processing the transaction.

Application programs are stored in a library on a direct access storage device (DASD) attached to the processor. They can be loaded when the system is started, or simply loaded as required. If a program is in storage and isn’t being used, CICS can release the space for other purposes. When the program is next needed, CICS loads a fresh copy of it from the library.

In the time it takes to process one transaction, the system may receive messages from several terminals. For each message, CICS loads the application program (if it isn't already loaded), and starts a task to execute it. Thus, multiple CICS tasks can be running concurrently.

Multithreading is a technique that allows a single copy of an application program to be processed by several transactions concurrently. For example, one transaction may begin to execute an application program (a traveller requests information). While this happens, another transaction may then execute the same copy of the application program (another traveller requests information). Compare this with single-threading, which is the execution of a program to completion: processing of the program by one transaction is completed before another transaction can use it. Multithreading requires that all CICS application programs be quasi-reentrant; that is, they must be serially reusable between entry and exit points. CICS application programs using the CICS commands obey this rule automatically.

CICS maintains a separate thread of control for each task. When, for example, one task is waiting to read a disk file, or to get a response from a terminal, CICS is able to give control to another task. Tasks are managed by the CICS *task control* program.

CICS manages both multitasking and requests from the tasks themselves for services (of the operating system or of CICS itself). This allows CICS processing to continue while a task is waiting for the operating system to complete a request on its behalf. Each transaction that is being managed by CICS is given control of the processor when that transaction has the highest priority of those that are ready to run.

While it runs, your application program requests various CICS facilities to handle message transmissions between it and the terminal, and to handle any necessary file or database accesses. When the application is complete, CICS returns the terminal to a standby state. Figure 11-4, Figure 11-5, and Figure 11-6 should help you understand what goes on.

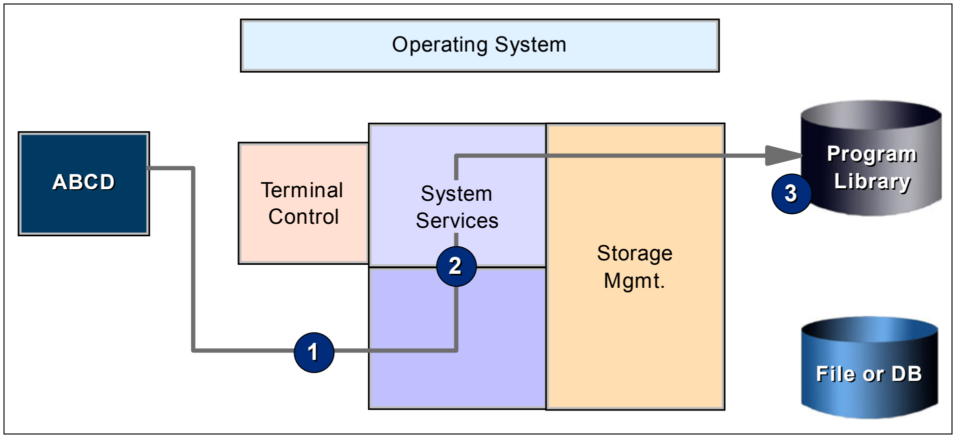


Figure 11-4 CICS transaction flow (part 1)

The flow of control during a transaction (code ABCD) is shown by the sequence of numbers 1 to 8. (We're only using this transaction to show some of the stages than can be involved.) The meanings of the eight stages are as follows:

1. *Terminal control* accepts characters ABCD, typed at the terminal, and puts them in working storage.
2. *System services* interpret the transaction code ABCD as a call for an application program called ABCD00. If the terminal operator has authority to invoke this program, it is either found already in storage or loaded into storage.
3. Modules are brought from the *program library* into working storage.

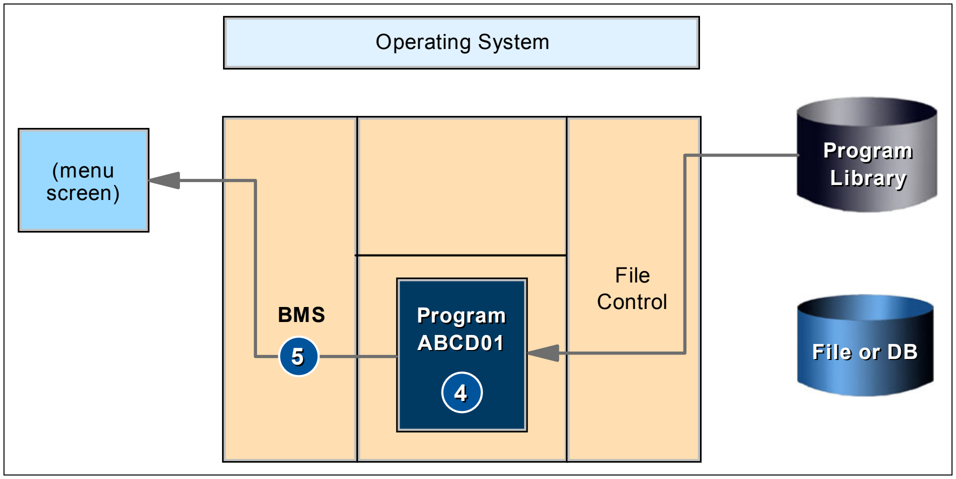


Figure 11-5 CICS transaction flow (part 2)

4. *A task is created*. Program ABCD00 is given control on its behalf.
5. ABCD00 invokes *Basic mapping support (BMS)* and terminal control to send a menu to the terminal, allowing the user to specify precisely what information is needed.

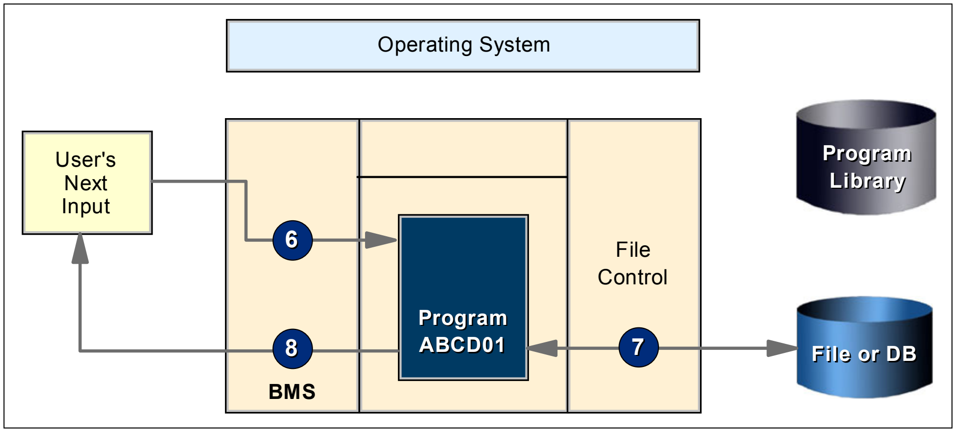


Figure 11-6 CICS transaction flow (part3)

6. BMS and terminal control also handle the user's next input, returning it to ABCD01 (the program designated by ABDC00 to handle the next response from the terminal) which then invokes file control.
7. *File control* reads the appropriate file for the invocation the terminal user has requested.
8. Finally, ABCD01 invokes BMS and terminal control to format the retrieved data and present it on the terminal.

11.1.8 CICS services for application programs

CICS applications execute under CICS control, using CICS services and interfaces to access programs and files.

Application Programming Interface

You use the *Application Programming Interface*, or API to access CICS services from the application program. You write a CICS program in much the same way as you write any other program. Most of the processed logic is expressed in standard language elements, but you can use CICS commands to request CICS services.

Terminal control services

These services allow a CICS application program to communicate with terminal devices. Through these services, information may be sent to a terminal screen and the user input may be retrieved from it. It's not easy to deal with *terminal control services* in a direct way. *Basic Mapping Support*, or BMS, lets you communicate with a terminal with a higher language level. It formats your data, and you do not need to know the details of the data stream.

File and database control services

We may differentiate the following two different CICS data management services:

1. *CICS file control* offers you access to data sets that are managed by either the virtual storage access method (VSAM) or the basic direct access method (BDAM). CICS file control lets you read, update, add, and browse data in VSAM and BDAM data sets and delete data from VSAM data sets.
2. *Database control* lets you access DL/I and DB2 databases. Although CICS has two programming interfaces to DL/I, we recommend that you use the higher-level EXEC DL/I interface. CICS has one interface to DB2: the EXEC SQL interface, which offers powerful statements for manipulating sets of tables, thus relieving the application program of record-by-record (or segment-by-segment, in the case of DL/I) processing.

Other CICS services

- *Task control* can be used to control the execution of a task. You may suspend a task or schedule the use of a resource by a task by making it serially reusable. Also, the priority assigned to a task may be changed.
- *Program control* governs the flow of control between application programs in a CICS system. The name of the application referred to in a program control command must have been defined as a program to CICS. You can use program control commands to link one of your application programs to another, transfer control from one application program to another, with no return to the requesting program.
- *Temporary Storage (TS) and Transient Data (TD) control*. The *CICS* temporary storage control facility provides the application programmer with the ability to store data in temporary storage queues, either in main storage or in auxiliary storage on a direct-access storage device. The CICS transient data control facility provides a generalized queuing facility to queue (or store) data for subsequent or external processing.
- *Interval control* services provide functions that are related to time. Using interval control commands, you can start a task at a specified time or after a specified interval, delay the processing of a task, request notification when a specified time has expired, among others.
- *Storage control* facility controls requests for main storage to provide intermediate work areas and other main storage needed to process a transaction. CICS makes working storage available with each program automatically, without any request from the application program, and provides other facilities for intermediate storage both within and among tasks. In addition to the working storage provided automatically by CICS, however, you can use other CICS commands to get and release main storage.

- *Dump and trace control*. The dump control provides a transaction dump when an abnormal termination occurs during the execution of an application program. CICS trace is a debugging aid for application programmers that produces trace entries of the sequence of CICS operations.

11.1.9 Program control

A transaction (task) may execute several programs in the course of completing its work.

The program definition contains one entry for every program used by any application in the CICS system. Each entry holds, among other things, the language in which the program is written. The transaction definition has an entry for every transaction identifier in the system, and the important information kept about each transaction is the identifier and the name of the first program to be executed on behalf of the transaction.

You can see how these two sets of definitions, transaction and program, work in concert:

- The user types in a transaction identifier at the terminal (or the previous transaction determined it).
- CICS looks up this identifier in the list of installed transaction definitions.
- This tells CICS which program to invoke first.
- CICS looks up this program in the list of installed transaction definitions, finds out where its is, and loads it if it isn’t already in the main storage.
- CICS builds the control blocks necessary for this particular combination of transaction and terminal, using information from both sets of definitions. For programs in command-level COBOL, this includes making a private copy of working storage for this particular execution of the program.
- CICS passes control to the program, which begins running using the control blocks for this terminal. This program may pass control to any other program in the list of installed program definitions, if necessary, in the course of completing the transaction.

There are two CICS commands for passing control from one program to another. One is the LINK command, which is similar to a CALL statement in COBOL. The other is the XCTL (transfer control) command, which has no COBOL counterpart. When one program links another, the first program stays in main storage. When the second (linked-to) program finishes and gives up control, the first program resumes at the point after the LINK. The linked-to program is considered to be operating at one logical level lower than the program that does the linking.

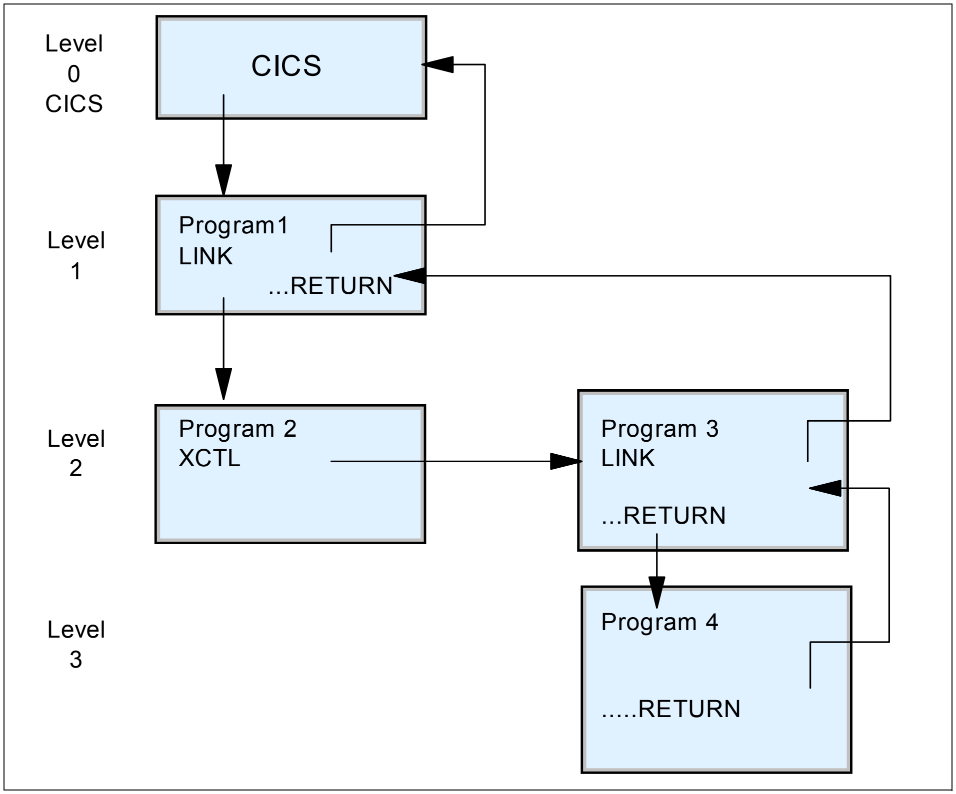


Figure 11-7 Transferring control between programs (normal returns)

In contrast, when one program transfers control to another, the first program is considered terminated, and the second operates at the same level as the first. When the second program finishes, control is returned not to the first program, but to whatever program last issued a LINK command.

Some people like to think of CICS itself as the highest program level in this process, with the first program in the transaction as the next level down, and so on. Figure 11-7 may help.

The LINK command looks like this:

```
EXEC CICS LINK PROGRAM(pgmname)
      COMMAREA(commarea) LENGTH(length) END-EXEC.
```

where `pgmname` is the name of the program to which you wish to link. `Commarea` is the name of the area containing the data to be passed and/or the area to which results are to be returned. The COMMAREA interface is also an option to invoke CICS programs.

A sound principle of CICS application design is to separate the presentation logic from the business logic; communication between the programs is achieved by using the LINK command and data is passed between such programs in the COMMAREA. Such a modular design provides not only a separation of functions, but also provides for much greater flexibility for the Web-enablement of existing applications using new presentation methods.

11.1.10 Our online example

When we look back to our travel agency example of Chapter 10, “Overview of z/OS online workloads” , examples of CICS transactions might be:

- Adding, updating and/or deleting employee information
- Adding, updating and/or deleting available cars by rental company
- Getting the number of available cars by rental company
- Updating prices of rental cars
- Adding, updating and/or deleting regular flights by airline
- Getting the number of sold tickets by airline or by destination

Figure 11-8 shows the possibility to calculate the average salary by department. The department is entered by the user and the transaction calculates the average salary.

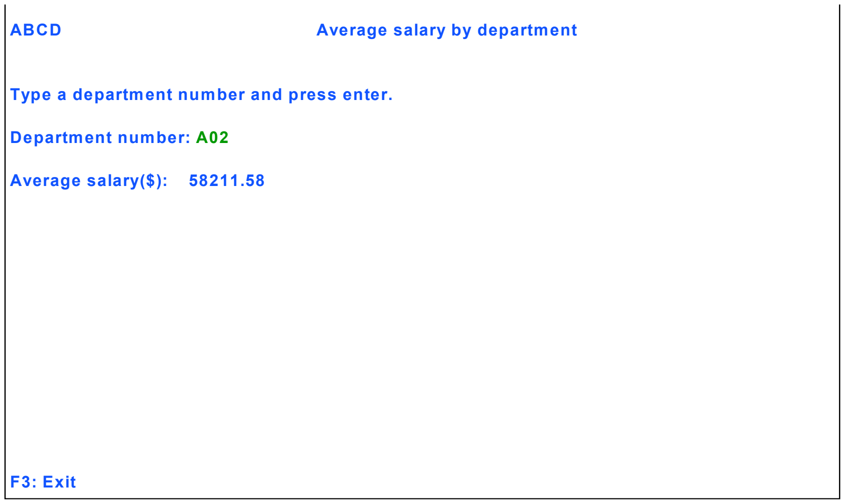


Figure 11-8 CICS application user screen

11.2 What is IMS?

Information Management System (IMS) consists of three components: the Transaction Manager (TM), the Database Manager (DB), and a set of system services that provide common services to the other two components.

As IMS has developed, new interfaces have been added to meet new business requirements. It is now possible to access IMS resources using a number of interfaces to the IMS components.

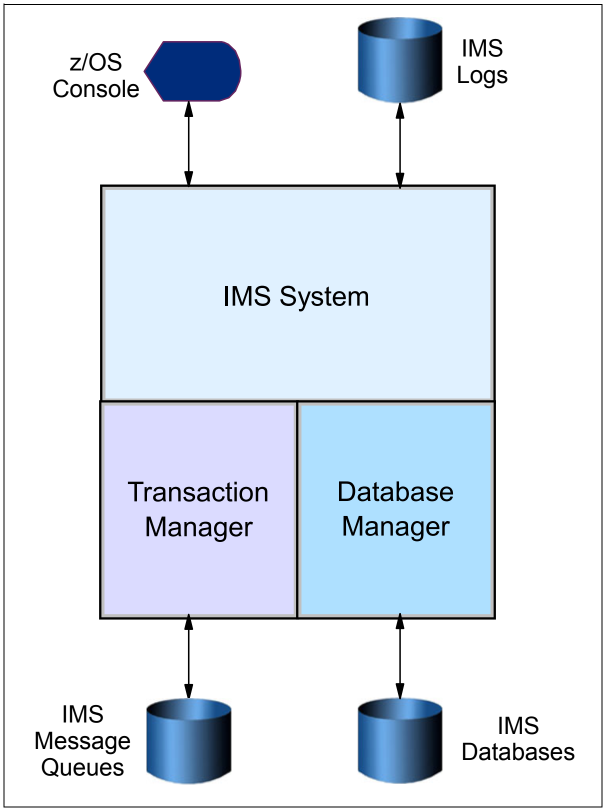


Figure 11-9 Overview of the IMS product

You write an IMS program in much the same way you write any other program. You can use COBOL, OO COBOL, C, C++, Java, PL/I, or assembler language to write IMS application programs. Further information on programming in Java can be found in the *IMS Java Guide and Reference.*

IMS Transaction Manager

The IMS Transaction Manager provides users of a network with access to applications running under IMS. The users can be people at terminals or workstations, or other application programs, either on the same z/OS system, on other z/OS systems, or on other non-z/OS platforms.

A transaction is a setup of input data that triggers the execution of a specific business application program. The message is destined for an application program, and the return of any results is considered one transaction.

IMS Database Manager

The IMS Database Manager provides a central point of control and access for the data that is processed by IMS applications. The Database Manager component of IMS supports databases using the IMS hierarchical database model. It provides access to these databases from applications running under the IMS Transaction Manager, the CICS transaction monitor (now known as Transaction Server for z/OS), and z/OS batch jobs.

It provides facilities for securing (backup/recovery) and maintaining the databases. It allows multiple tasks (batch and/or online) to access and update the data, while retaining the integrity of that data. It also provides facilities for tuning the databases by reorganizing and restructuring them.

The IMS databases are organized internally using a number of IMS database organization access methods. The database data is stored on disk storage using the normal operating system access methods.

IMS System Services

There are a number of functions that are common to both the Database Manager and Transaction Manager:

- Restart and recovery of the IMS subsystems following failures
- Security: controlling access to IMS resources
- Managing the application programs: dispatching work, loading application programs, providing locking services
- Providing diagnostic and performance information
- Providing facilities for the operation of the IMS subsystems
- Providing an interface to other OS/390 subsystems that the IMS applications interface with

11.2.1 IMS in a z/OS system

IMS runs on zSeries and earlier forms of the S/390 architecture or compatible mainframes, and on z/OS and earlier forms of the operating system.

An IMS subsystem runs in several address spaces in a z/OS system. There is one controlling address space and several dependent address spaces providing IMS services and running IMS application programs.

For historical reasons, some documents describing IMS use the term *region* to describe a z/OS address space, for example, IMS Control Region. In this book we use the term region wherever this is in common usage. You can take the term region as being the same as a z/OS address space.

IMS is designed to make the best use of the features of the OS/390 operating system. This includes:

- Runs in multiple address spaces - IMS subsystems (except for IMS/DB batch applications and utilities) normally consist of a control region address space, dependent address spaces providing system services, and dependent address spaces for application programs.
- Runs multiple tasks in each address space - IMS, particularly in the control regions, creates multiple z/OS subtasks for the various functions to be performed. This allows other IMS subtasks to be dispatched by z/OS while one IMS subtask is waiting for system services.
- Uses OS/390 cross memory services to communicate between the various address spaces making up an IMS subsystem. It also uses the z/OS Common System Area (CSA) to store IMS control blocks that are frequently accessed by the address spaces making up the IMS subsystem. This minimizes the overhead of running in multiple address spaces.
- Uses the z/OS subsystem feature - IMS dynamically registers itself as a z/OS subsystem. It uses this facility to detect when dependent address spaces fail, and prevent cancellation of dependent address spaces (and to interact with other subsystems like DB2 and MQ).
- Can make use of a z/OS sysplex - Multiple IMS subsystems can run on the z/OS systems making up the sysplex and access the same IMS databases.

11.2.2 IMS Transaction Manager messages

The network inputs and outputs to IMS Transaction Manager take the form of messages that are input/output to/from IMS and the physical terminals or application programs on the network. These messages are processed asynchronously (that is, IMS will not always send a reply immediately, or indeed ever, when it receives a message, and unsolicited messages may also be sent from IMS).

The messages can be of four types:

- Transactions - Data in these messages is passed to IMS application programs for processing.

- Messages to go to other logical destinations, such as network terminals.
- Commands for IMS to process.
- Messages for the IMS APPC feature to process. Since IMS uses an asynchronous protocol for messages, but APPC uses synchronous protocols (that is, it always expects a reply when a message is sent), the IMS TM interface for APPC has to perform special processing to accommodate this.

If IMS is not able to process an input message immediately, or cannot send an output message immediately, the message is stored on a message queue external to the IMS system. IMS will not normally delete the message from the message queue until it has received confirmation that an application has processed the message, or it has reached its destination.

11.3 Summary

CICS is a transactional processing subsystem. That means that it runs applications on your behalf online, by request, at the same time as many other users may be submitting requests to run the same applications, using the same files and programs.

CICS manages the sharing of resources, integrity of data, and prioritization of execution, with fast response. CICS applications are traditionally run by submitting a *transaction* request. Execution of the transaction consists of running one or more *application programs* that implement the required function.

You write a CICS program in much the same way you write any other program. You can use COBOL, C, C++, Java, PL/I, or assembler language to write CICS application programs. Most of the processing logic is expressed in standard language statements, but you use *CICS commands*. The CICS commands are grouped according to their function, terminal interaction, access to files, or program linking.

Most of the CICS resources may be defined and altered online through CICS-supplied transactions. Other supplied transactions allow us to monitor the CICS system.

The continued growth of the Internet has caused many corporations to consider the best ways to make their legacy systems available to users on the Internet. A small overview of the different technologies available for *Web-enablement* of CICS applications has been shown.

Information Management System (IMS) consists of three components: the Transaction Manager (TM), the Database Manager (DB), and a set of system services that provide common services to the other two components.

You write an IMS program in much the same way you write any other program. You can use COBOL, OO COBOL, C, C++, Java, PL/I, or assembler language to write IMS application programs.

Key terms in this chapter		
bind	transaction	conversational
unit of work	DBMS	CICS TS
BSM	CICS command	task/thread
region	PSB	IRLM
BMP	IMS TM	

11.4 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. Describe the main phases in the CICS programming roadmap.
2. How might the meaning of "business transaction" differ from "CICS transaction"?
3. How do you define resources in CICS?
4. What are the major components of IMS, and what are their tasks?
5. What is IRLM and what uses it?
6. What is a region in IMS? Explain some of them.

11.5 Exercise 1: Create a CICS program

During this exercise, you might find it helpful to consult the *CICS Application Programming Guide* or other manuals.

Analyze and update the class program

- Think of a possible use of the COMMAREA.
- Several simple updates to the class program transaction may be easily done:
  - Include one additional output field in the screen. The maximum value of employee commissions could be an example.
  - Create a previous transaction that could be like a main menu; one of the options would start the current program.

– Learn about the CICS HANDLE CONDITION statement and find out where it may be used.

Business transaction

Analyze a typical business transaction. Think of different CICS programs and transactions that could be needed to accomplish it. Draw a diagram to show the flow of the process.

12

Understanding Database Managers on z/OS

Objective: You will need a good working understanding of the major types of system software used to process online workloads on the mainframe. In this chapter, we focus on two of the most widely used database products for z/OS: DB2 and IMS.

After completing this chapter, you will be able to:

- Explain the role of DB2 in online transaction processing.
- List common DB2 data structures.
- Compose simple SQL queries to run on z/OS.
- Give an overview of application programming with DB2.
- What the IMS components are
- The structure of the IMS DB subsystem

As explained in Chapter 10, “Overview of z/OS online workloads” , there are several types of database managers supported by z/OS. We will discuss the two most widely-used products, DB2, a relational DBMS, and IMS-DB, a hierachical DBMS.

12.1 What is DB2?

The general concepts of a relational database management system (RDBMS) was discussed in Chapter 10, “Overview of z/OS online workloads” . Most table examples in this chapter can be found in Appendix B, “DB2 sample tables”. These tables, such as EMP and DEPT, are part of the Sample Database that comes with the DB2 product on all platforms. We are using Version 8 in the screen captures. Therefore, the owner of our tables is DSN8810.

The elements that DB2 manages can be divided into two categories: Data structures that are used to organize user data, and system structures that are controlled by DB2. Data structures can be further broken down into *basic structures* and *schema structures*. Schema structures are fairly new objects that were introduced on the mainframe for compatibility within the DB2 family. A schema is a logical grouping of these new objects.

12.1.1 Data structures

Basic structures

Most of the basic structures used in all DBRMs are discussed in Chapter 10, “Overview of z/OS online workloads” . Here we describe several structures that are specific to DB2.

Views

A *view* is an alternative way of looking at the data in one or more tables. It is like an overlay that you would put over a transparency to only allow people to see certain aspects of the base transparency. For example, you can create a view on the department table to only let users have access to one particular department in order to update salary information. You don't want them to see the salaries in other departments. You create a view of the table that only lets the users see one department, and they use the view like a table. Thus, a view is used for security reasons. Most companies will not allow users to access their tables directly, using the creation of a view to accomplish this. The users get access via the view. A view can also be used to simplify a complex query for naïve users.

Table spaces

A table is just a logical construct. It is kept in an actual physical data set called a *table space*. Table spaces are storage structures and can contain one or more tables. A table space is named using the database name followed by the table space name: PAYROLL.ACCNT_RECV. There are three types of table spaces: Simple, Segmented, and Partitioned. For more detailed information, see *DB2 UDB for z/OS: SQL Reference.*

Index spaces

An *index space* is another storage structure that contains a single index. In fact, when you create an index, DB2 automatically defines an index space for you.

Storage groups

These consist of a set of volumes on disks (DASD) that hold the data sets in which tables and indexes are actually stored.

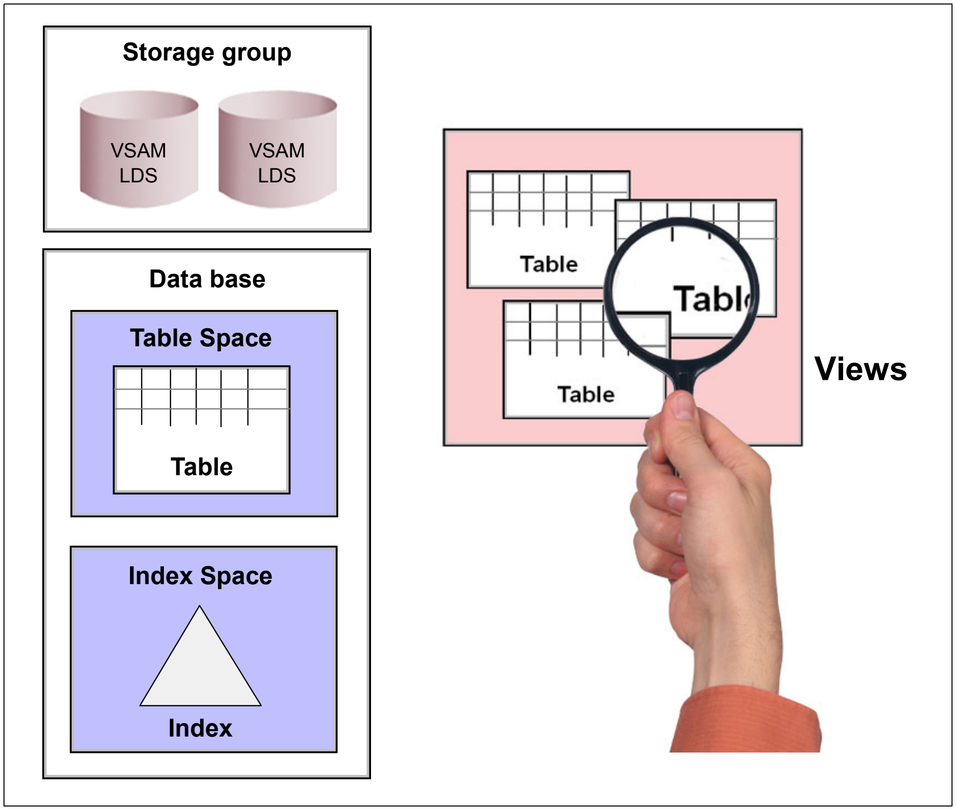


Figure 12-1 There is a hierarchy to the objects in a DB2 subsystem

12.1.2 Schema structures

User-defined Data Type (UDT)

A UDT is a way for the user to define his own data types above and beyond the usual character and numeric data types. However, UDTs are based upon the already existing DB2 data types. If you dealt in international currencies, you would most likely want to differentiate the various types of monies. With a UDT definition, you could define the EURO, based on the decimal data type, as a distinct data type in addition to YEN or US_DOLLAR. As a result, you could not add a YEN to a EURO since they are distinct data types.

User-Defined Function (UDF)

A UDF can be simply defined on an already existing DB2 function, such as rounding or averaging, or can be more complex and written as an application program that could be accessed by an SQL statement. In our international currency example, we could use a UDF to convert one currency value to another in order to do arithmetic functions.

Trigger

A *trigger* defines a set of actions that are executed when an insert, update, or delete operation occurs on a specific table. For example, let's say that every time you insert an employee into your EMP table, you also want to add one to an employee count that you keep in a company statistics table. You can define a trigger that will get "fired" when you do an insert into EMP. This firing will automatically add one to the appropriate column in the COMPANY_STATS table.

Large Object (LOB)

An LOB is a data type used by DB2 to manage unstructured data. There are three types of LOBs:

- Binary Large Objects (BLOBs) - These are used for photographs and pictures, audio and sound clips, and video clips.
- Character Large Objects (CLOBs) - These are used for large text documents.
- Double Byte Character Large Objects (DBCLOBs) - These are used for storing large text documents written in languages that require double-byte characters, such as Kanji.

LOBs are stored in special auxiliary tables that use a special LOB table space. In your EMP base table, text material such as a resume can be included for employees. Since this is a large amount of data, it is contained in its own table. A column in the EMP table, defined as a CLOB, would have a pointer to this special LOB auxiliary table that is stored in an LOB table space. Each column defined as an LOB would have its own associative auxiliary table and LOB table space.

Stored procedure

A *stored procedure* is a user-written application program that typically is stored and run on the server (but it can be run for local purposes as well). Stored procedures were specifically designed for the client/server environment where the client would only have to make one call to the server, which would then run the stored procedure to access DB2 data and return the results. This eliminated having to make several network calls to run several individual queries against the database, which can be expensive. You can think of a stored procedure as being somewhat like a subroutine that can be called to perform a set of related functions. It is an application program, but it is defined to DB2 and managed by the DB2 subsystem.

System structures

Catalog and directory

DB2 itself maintains a set of tables that contain metadata or data about all the DB2 objects in the subsystem. The *catalog* keeps information about all the objects, such as the tables, views, indexes, table spaces, etc., while the *directory* keeps information about the application programs. The catalog can be queried to see the object information; the directory cannot.

When you create a user table, DB2 automatically records the table name, creator, its table space, and database in the catalog and puts this information in the catalog table called SYSIBM.SYSTABLES. All the columns defined in the table are automatically recorded in the SYSIBM.SYSCOLUMNS table. In addition, to record that the owner of the table has authorization on the table, a row is automatically inserted into SYSIBM.SYSTABAUTH. Any indexes created on the table would be recorded in the SYSIBM.SYSINDEXES table.

Buffer pools

Buffer pools are areas of virtual storage in which DB2 temporarily stores pages of table spaces or indexes. They act as a cache area between DB2 and the physical disk storage device where the data resides. A data page is retrieved from disk and placed in a buffer pool page. If the needed data is already in a buffer, expensive I/O access to the disk can be avoided.

Active and archive logs

DB2 records all data changes and other significant events in a *log*. This information is used to recover data in the event of a failure, or DB2 can roll the changes back to a previous point in time. DB2 writes each log record to a data set called the *active log*.

When this is full, DB2 copies the contents of the active log to a disk or tape data set called the *archive log*.

In conjunction with the active and archive log data sets, a *bootstrap* data set keeps track of these active and archive logs. DB2 uses this information in recovery scenarios, for system restarts, or for any activity that requires reading the log.

12.1.3 Using SQL on z/OS

Structured Query Language, better known as SQL, is a high-level language that is used to specify what information a user needs without having to know how to retrieve it. DB2 is responsible for developing the access path needed to retrieve the data. SQL works at a set level, meaning that it is designed to retrieve one or more rows. Essentially, it is used on one or more tables and returns the result as a result table.

SQL has three categories based on the functionality involved:

- DML - Data manipulation language used to read and modify data
- DDL - Data definition language used to define, change, or drop DB2 objects
- DCL - Data control language used to grant and revoke authorizations

Several tools can be used to enter and execute SQL statements. The one that we will focus on here is SPUFI, which stands for SQL Processing Using File Input. SPUFI is part of the DB2 Interactive (DB2I) menu panel, which is a selection from your ISPF panel when DB2 is installed. (This, of course, depends on how your system people set up your system's menu panels.)

SPUFI is most commonly used by database administrators. It allows you to write and save one or more SQL statements at a time. DBAs use it to grant or revoke authorizations; sometimes even to create objects, when that needs to be done urgently. SPUFI is also often used by developers to test their queries. This way they are sure that the query returns exactly what they want.

Another tool that you might encounter on the mainframe is the Query Management Facility (QMF), which allows you to enter and save just one SQL statement at a time. QMF's main strength is its reporting facility. It enables you to design flexible and reusable report formats, including graphs. In addition, it provides a Prompted Query capability that helps users unfamiliar with SQL to build simple SQL statements. Another tool is the Administration Tool, which has SPUFI capabilities as well as a query building facility.

SPUFI

Figure 12-2 shows how SQL is entered using SPUFI. It is the very first selection on the DB2I panel. Note that the name of this DB2 subsystem is DB8H.

```
                              DB2I PRIMARY OPTION MENU          SSID: DB8H
COMMAND ===> 1_

Select one of the following DB2 functions and press ENTER.

 1  SPUFI                    (Process SQL statements)
 2  DCLGEN                   (Generate SQL and source language declarations)
 3  PROGRAM PREPARATION      (Prepare a DB2 application program to run)
 4  PRECOMPILE               (Invoke DB2 precompiler)
 5  BIND/REBIND/FREE         (BIND, REBIND, or FREE plans or packages)
 6  RUN                      (RUN an SQL program)
 7  DB2 COMMANDS             (Issue DB2 commands)
 8  UTILITIES                (Invoke DB2 utilities)
 D  DB2I DEFAULTS            (Set global parameters)
 X  EXIT                     (Leave DB2I)






 F1=HELP      F2=SPLIT     F3=END       F4=RETURN    F5=RFIND     F6=RCHANGE
 F7=UP        F8=DOWN      F9=SWAP     F10=LEFT     F11=RIGHT    F12=RETRIEVE
```

Figure 12-2 Entering SQL using SPUFI

SPUFI uses file input and output, so it is necessary to have two data sets pre-allocated:

- The first, which can be named ZPROF.SPUFI.CNTL, is typically a partitioned data set in order to keep or save your queries as members. A sequential data set would write over your SQL.
- The output file, which can be named ZPROF.SPUFI.OUTPUT, must be sequential, which means your output is written over for the next query. If you want to save it, you must rename the file, using the ISPF menu edit facilities.

In Figure 12-3 on page 12-8 you can see how that fits in.

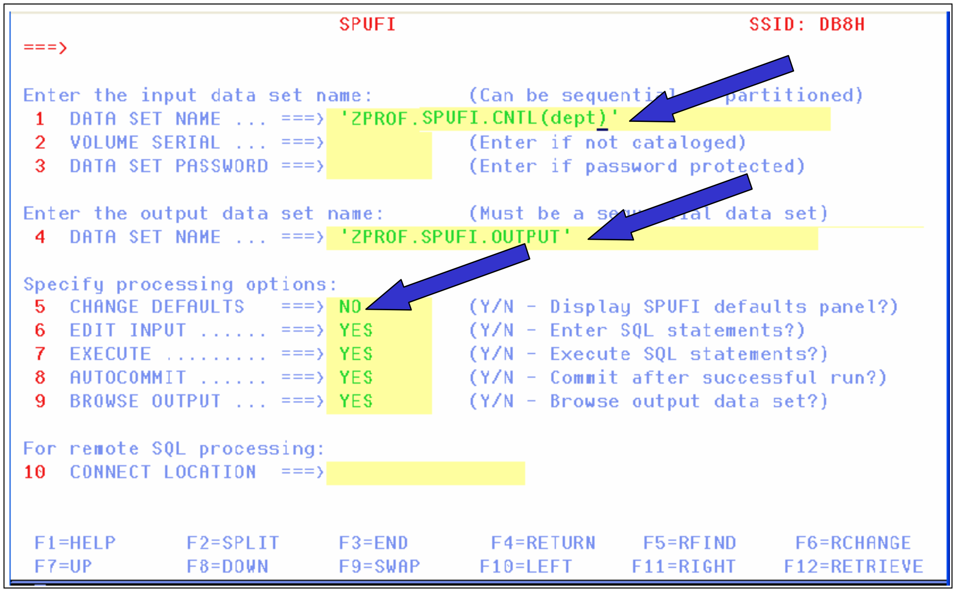


Figure 12-3 Assigning SPUFI data sets

Notice option 5, which you can change to YES temporarily to see the default values. One value you might want to change is the maximum number of rows retrieved.

With option 5 at NO, if you press the Enter key, SPUFI will put you in the input file, ZPROF.SPUFI.CNTL(DEPT), in order to enter or edit an SQL statement. By entering `recov on` in the command and pressing Enter, the warning on top of the screen will disappear. This option is part of the profile, mentioned earlier in this book. The screen is shown in Figure 12-4 on page 12-9.

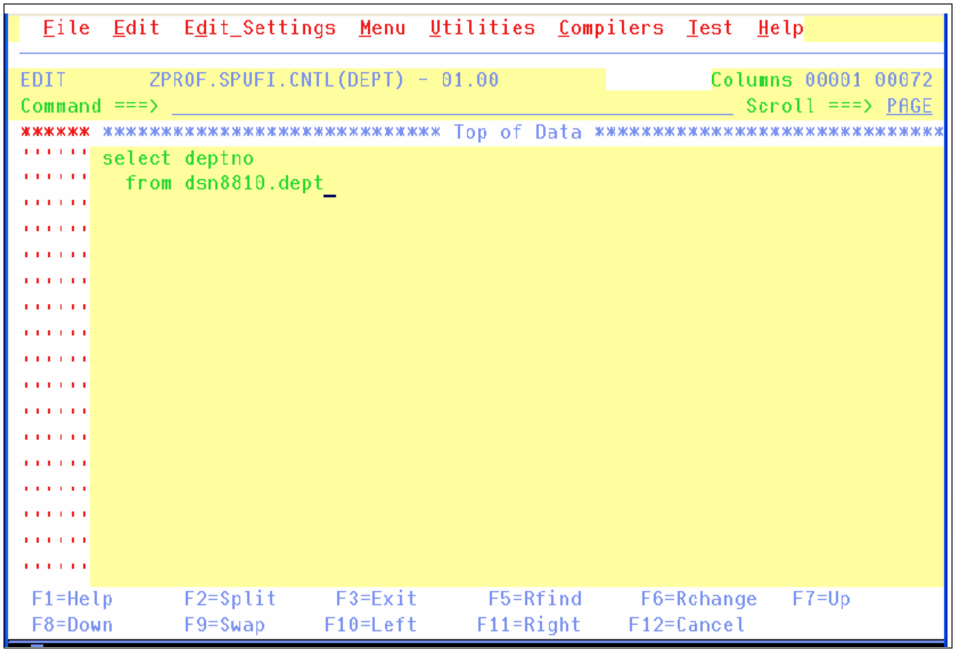


Figure 12-4   Editing the input file

If your profile is set to CAPS ON, the SQL statement you have just typed will normally change to capital letters at the Enter. But this is not needed.

Notice that we have mentioned DSN8810.DEPT as table name. This is the qualified name of the table, since we want to use the sample tables, which are created by user DSN8810.

If you enter just one SQL statement, you do not need to use the SQL terminator (;) since this is specified in the defaults (but you can change this; remember option 5 of the previous screen). However, if you enter more than one SQL statement, you need to use a semicolon at the end of each statement to indicate that you have more than one.

At this point, you need to go back to the first panel of SPUFI by pressing the F3 key. You will then see Figure 12-5 on page 12-10.

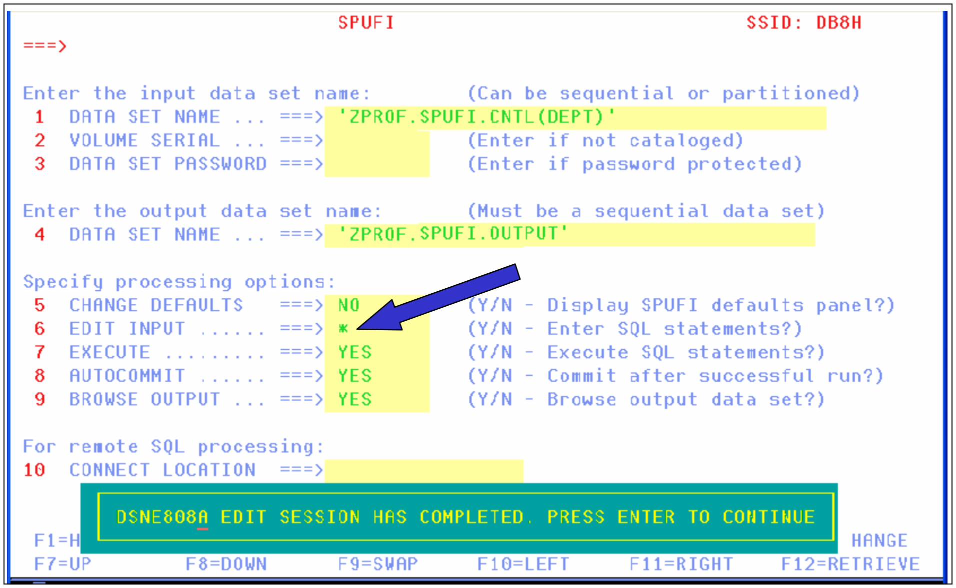


Figure 12-5 Returning to the first SPUFI panel

Notice that there is an asterisk for option 6 since you just finished editing your SQL. At this point, if you press Enter, you will execute your SQL statement and you will automatically be put into your output file, since BROWSE OUTPUT is set to YES. The first part of the output is shown in Figure 12-6 on page 12-11. To get the second (and in this case final) result screen, press F8; see Figure 12-7 on page 12-11.

```
  Menu  Utilities  Compilers  Help
 ────────────────────────────────────────────────────────────────────────────────
 BROWSE    ZPROF.SPUFI.OUTPUT                        Line 00000000 Col 001 080
 Command ===> _                                               Scroll ===> PAGE
********************************* Top of Data **********************************
---------+---------+---------+---------+---------+---------+---------+---------+
select deptno                                                           00010000
  from dsn8810.dept                                                     00020000
---------+---------+---------+---------+---------+---------+---------+---------+
DEPTNO
---------+---------+---------+---------+---------+---------+---------+---------+
A00
B01
C01
D01
D11
D21
E01
E11
E21
F22
G22
  F1=Help    F2=Split   F3=Exit    F5=Rfind   F7=Up      F8=Down    F9=Swap
 F10=Left   F11=Right  F12=Cancel
```

Figure 12-6   First part of the SPUFI query results

```
  Menu  Utilities  Compilers  Help
 ────────────────────────────────────────────────────────────────────────────────
 BROWSE    ZPROF.SPUFI.OUTPUT                        Line 00000018 Col 001 080
 Command ===> _                                               Scroll ===> PAGE
H22
I22
J22
DSNE610I NUMBER OF ROWS DISPLAYED IS 14
DSNE616I STATEMENT EXECUTION WAS SUCCESSFUL, SQLCODE IS 100
---------+---------+---------+---------+---------+---------+---------+---------+
DSNE617I COMMIT PERFORMED, SQLCODE IS 0
DSNE616I STATEMENT EXECUTION WAS SUCCESSFUL, SQLCODE IS 0
---------+---------+---------+---------+---------+---------+---------+---------+
DSNE601I SQL STATEMENTS ASSUMED TO BE BETWEEN COLUMNS 1 AND 72
DSNE620I NUMBER OF SQL STATEMENTS PROCESSED IS 1
DSNE621I NUMBER OF INPUT RECORDS READ IS 2
DSNE622I NUMBER OF OUTPUT RECORDS WRITTEN IS 30
******************************** Bottom of Data ********************************



  F1=Help    F2=Split   F3=Exit    F5=Rfind   F7=Up      F8=Down    F9=Swap
 F10=Left   F11=Right  F12=Cancel
```

Figure 12-7   Second result screen

Notice that you have a result table with just one column. This is what was specified in SELECT, just DEPTNO. We have retrieved the DEPTNO from all the (14) rows in the table. There are a few messages. One gives the number of rows retrieved. Another indicates that SQLCODE, an SQL return code indicating success or not, is 100, which means end of file, no more results to show.

12.1.4 Application programming

Structured Query Language (SQL) is not a full programming language, but it is necessary to access and manipulate data in a DB2 database. SQL is a 4GL non-procedural language that was developed in the mid 1970s to use with DB2. SQL can either be used dynamically with an interpretive program like SPUFI, or it can be imbedded and compiled or assembled in a host language (such COBOL, PL/1, or Assembler).

So how do you write an application program that accesses DB2 data?

To do this, SQL is embedded in the source code of a programming language. SQL can be used with the following programming languages: Java, Smalltalk, REXX, C, C++, COBOL, Fortran, PL/I, and high-level Assembler. There are two categories of SQL statements that can be used in a program: static and dynamic.

- Static

  SQL refers to complete SQL statements that are written in the source code. In the program preparation process, DB2 develops access paths for the statements, and these are recorded in DB2. The SQL never changes from one run to another, and the same determined access paths are used without DB2 having to create them again, a process that can add overhead. (**Note**: All SQL statements must have an access path.)

- Dynamic

  SQL refers to SQL statements that are only partially or totally unknown when the program is written. Only when the program runs does DB2 know what the statements are and is able to determine the appropriate access paths. These do not get recorded since the statements can change from one run to another. An example of this is SPUFI. SPUFI is actually an application program that accepts dynamic SQL statements. These are the SQL statements that you enter in the input file. Each time you use SPUFI, the SQL can change, so special SQL preparation statements are embedded in the application to handle this.

We are concentrating now on Static SQL, to get an idea of the processes involved when using DB2. We also want to add that it may seem complex, but each action has a good reason for being there.

DB2 program preparation: the flow

The traditional program preparation process, compile and linkedit, must have some additional steps to prepare SQL because compilers do not recognize SQL. These steps, including compile/linkedit, can be done with the DB2I panel, although the whole process is usually done in one JCL jobstream except for the DCLGEN. Use Figure 12-8 on page 12-14 in following the explanations.

DCLGEN

DCLGEN is a way to automatically generate your source definitions for the DB2 objects that will be used in your program. This is set up in a member of a DCLGEN library that can optionally be included in your source program. If you do not include it, you must manually code the definitions. The DB2 database administrator usually creates these, based on the company's rules. During this phase, you need a running DB2 system, because the definitions are taken from the DB2 catalog.

PRECOMPILE

Because compilers can not handle SQL, the precompile step comments out the SQL statements and leaves behind a CALL statement to DB2. This passes some parameters such as host variable addresses (to retrieve data into), statement numbers, and (very importantly!) a modified timestamp called a *consistency token* (but often referred to as the timestamp). During this phase, you do not need a running DB2 system—everything is done without accessing DB2.

The precompiler identifies the SQL by special beginning and ending flags that must be included for each SQL statement. The beginning flag, EXEC SQL, is the same for all programming languages. The ending flag differs. COBOL uses END-EXEC. (period), while C and other languages use a semi-colon. Here is a COBOL example:

```
EXEC SQL
     SELECT EMPNO, LASTNAME
      INTO :EMPNO, :LASTNAME
      FROM EMP
END-EXEC.
```

In this example, EMPNO and LASTNAME are retrieved into host variables, which are preceded by a colon. Host variables (HVs) are variables defined in the "host" language (COBOL, PL/1, etc.), the language that embeds the SQL. During the DCLGEN phase, a set of those variables are also defined. The HV name is here the same as the column name, which is not a requirement—it can be any name with a datatype compatible with the columns datatype.

After the precompile, our program is divided into two parts:

- The modified source code; this is the original source code, were the SQL is commented out and replaced by Calls.
- The database request module (DBRM), which is usually a member of a PDS library and contains the SQL statements of the program.

The modified source code is passed on to the compiler to be compiled and link-edited to create an executable load module, just like any program which does not contain SQL.

By the way, you can embed any type of SQL into your program: DML, DDL, and DCL, as long as the authorization rules are respected.

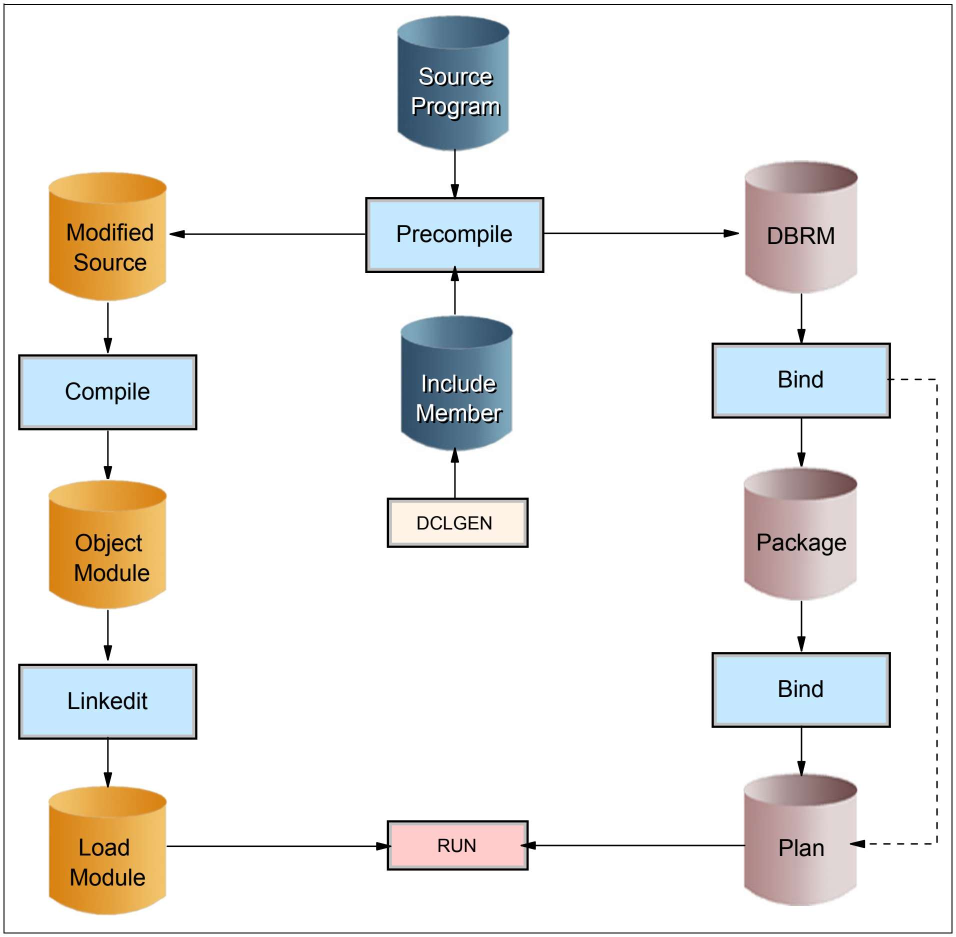


Figure 12-8 Program preparation flow

BIND

BIND can be thought of as the DB2 equivalent compile process for the DBRM. Bind does three things:

- Checks your syntax for errors.
- Checks authorization.

- Most importantly, it determines the access paths for your statements. DB2 has a component called the *optimizer*, which assesses all the different ways that your data can be accessed, such as scanning an entire table, using an index, what index, etc. It weighs the costs of each and picks the least. It is referred to as a cost-based optimizer (as opposed to a rule-based optimizer).

The SQL with its access path (and the consistency token/timestamp) is stored as a package in a DB2 directory. Other information, such as package information and the actual SQL, is stored in the catalog. The bind creates the executable SQL code for one application in a package. Now DB2 has all the information it needs to get to the requested data for this program.

Often programs are calling subroutines, which also contain SQL calls. Each of these subroutines then also has a package. You need to group all of the DB2 information together. Therefore, we need another step: another bind, but this time to create a plan.

Even if you are not using a subroutine, you still need to create a *plan*. The plan may contain more information than just your program info. This is common practice: The plan contains all packages of one project and every run uses the same plan.

To be complete, we need to add that originally the DBRMs were bound straight into the plan (they are called instream DBRMs). However, if there is one small change to one of the programs, you need to rebind the whole plan. The same when an index is added.

During this binding process, as you know, DB2 updates its directory and catalog. Updating means preventing other people from updating (data is locked from them), so most other actions against DB2 were nearly impossible. To avoid this constraint, packages were introduced. Now you only need to rebind the one package, so the duration of the update is very short, and impact on other users is almost zero. There are still plans around with instream DBRMs, although most companies choose to convert them into packages.

Plans are unique to the mainframe environment. Other platforms do not use them.

RUN

When you execute your application program, the load module is loaded into main storage. When an SQL statement is encountered, the CALL to DB2, which replaced the SQL statement, passes its parameters to DB2. One of those is the consistency token. This token, or timestamp, is also in the package. The packages in the specified plan of DB2 are then searched for the corresponding timestamp, and the appropriate package is loaded and executed. So, for the run, you need to specify the plan name as a parameter.

One last note: The result of an SQL statement is usually a result set (more than one row). An application program can only deal with one record, or row, at a time. There is a special construction added to DB2, called a *cursor* (essentially a pointer), which allows you, in your embedded SQL, to fetch, update, or delete one row at a time, from your result set.

To learn more, see *DB2 UDB for z/OS: Application Programming and SQL Guide.*

12.1.5 Database administration

Database administrators are primarily responsible for specific databases in the subsystem.

In some companies, DBAs are given the special group authorization, SYSADM, which gives them the ability to do almost everything in the DB2 subsystem, and gives them jurisdiction over all the databases in the subsystem. In other shops, a DBA's authority is limited to individual databases.

Creation and management of DB2 objects

The DBA creates the hierarchy of DB2 objects, beginning with the database, then table spaces, tables, and any indexes or views that are required. This person also sets up the referential integrity definitions and any necessary constraints.

The DBA essentially implements the physical database design. Part of this involves having to do space calculations and determining how large to make the physical data sets for the table spaces and index spaces, and assigning storage groups (also called storgroups).

There are many tools that can assist the DBA in these tasks, such as the Administration Tool and DB2 Estimator. If objects increase in size, the DBA is able to alter certain objects to make changes.

The DBA can be responsible for granting authorizations to the database objects, although sometimes there is a special security administration group that does this.

Utilities

The DBA maintains the database objects by using a set of utilities and programs, which are submitted using JCL jobs. Usually a company will have a data set library for these jobs that DBAs copy and use. However, there are tools that will generate the JCL, such as the Administration Tool and the Utility option on the DB2I panel.

The utilities help the DBAs do their jobs. You could divide the utilities into categories:

- Data Organization utilities

  Once tables are created, the DBA uses the LOAD utility to populate them, with the ability to compress large amounts of data. There is the UNLOAD utility or the DSNTIAUL assembler program that can let the DBA move or copy data from one subsystem to another. It is possible to keep the data in a certain order with the

REORG utility. Subsequent insertions and loads can disturb this order, and the DBA must schedule subsequent REORGs based on reports from the RUNSTATS utility, which provides statistics and performance information.

- Backup and Recovery utilities

  It is vital that a DBA take image copies of the data and the indexes with the COPY utility in order to recover data. A DBA can make a full copy or an incremental copy (only for data). Since recovery can only be done to a full copy, the MERGECOPY utility is used to merge incremental copies with a full one. The RECOVER utility can recover back to an image copy for a point-in-time recovery. More often, it is used to recover to an image copy, and then information from the logs, which record all data changes, is applied in order to recover forward to a current time. Without an image copy, an index can be recreated with REBUILD INDEX.

- Data Consistency utilities

  One of the important data consistency utilities is the CHECK utility which can be used to check and help correct referential integrity and constraint inconsistencies, especially after an additional population or after a recovery.

Commands

Both the system administrator and the DBA use DB2 commands to monitor the subsystem. The DB2I panel and the Administration Tool provide you with a means to easily enter these commands. The -DISPLAY DATABASE command displays the status of all table spaces and index spaces within a database. For example, without an image copy, your table can be put in a *copy pending* status, requiring that you run the COPY utility. There are several other display commands, such as DISPLAY UTILITY for the status of a utility job, or you can display buffer pool, thread, and log information.

There are also DSN commands that you can issue from a TSO session or batch job. However, these can be more simply entered using the options from the DB2I panel: BIND, DCLGEN, RUN, etc. (In some shops, DBAs are responsible for binds, although these are usually done by programmers as part of the compile job.)

12.2 Functions of the IMS Database Manager

A database management system (DBMS) provides facilities for business application transactions or processes to access stored information. The role of a DBMS is to provide the following functions:

- Allow access to the data for multiple users from a single copy of the data.
- Control concurrent access to the data so as to maintain integrity for all updates.
- Minimize hardware device and operating system access method dependencies.
- Reduce data redundancy by maintaining only one copy of the data.

12.3 Structure of the IMS Database subsystem

The IMS Database Manager provides a central point for the control and access to application data. IMS provides a full set of utility programs to provide all these functions within the IMS product. This section describes the various types of z/OS address spaces and their relationships with each other. The core of an IMS subsystem is the control region, running in one z/OS address space. This has a number of dependent address spaces running in other regions that provide additional services to the control region, or in which the IMS application programs run.

In addition to the control region, some applications and utilities used with IMS run in separate batch address spaces. These are separate from an IMS subsystem and its control region, and have no connection with it.

For historical reasons, some documents describing IMS use the term region to describe a z/OS address space, for example, IMS Control Region. In this course we use the term region wherever this is in common usage. You can take the term region as being the same as a z/OS address space.

Figure 12-9 illustrates the IMS DB/DC subsystem. If you want more details, we refer you to the *IMS Primer*.

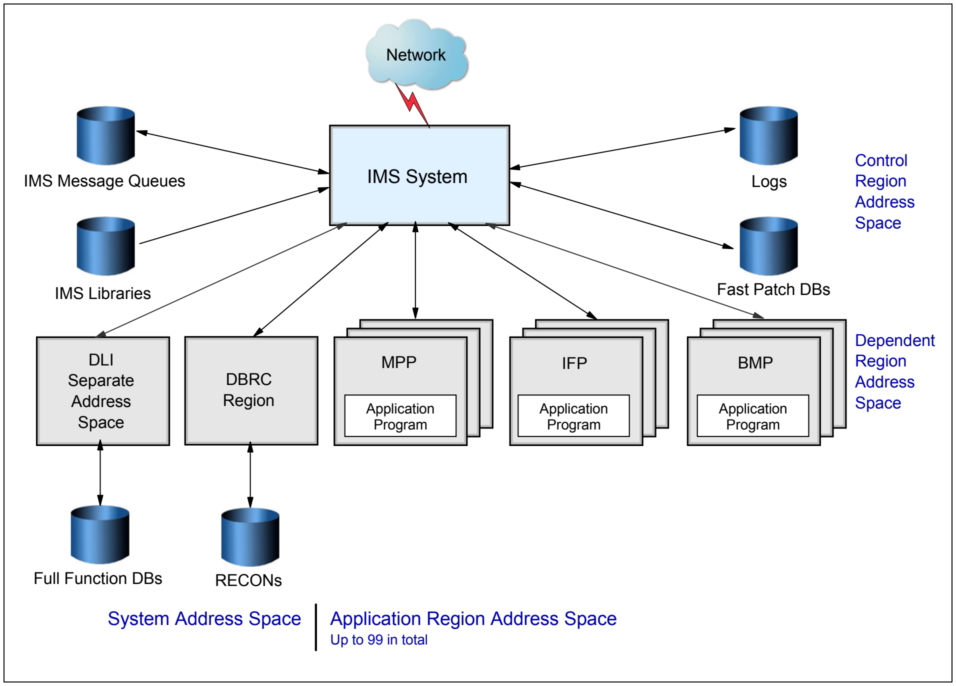


Figure 12-9 Structure of the IMS DB/DC subsystem

12.3.1 The IMS hierarchical database model

IMS uses a hierarchical model as the basic method for storing data, which is a pragmatic way of storing the data and implementing the relationships between the various types of entities.

In this model, the individual entity types are implemented as segments in a hierarchical structure. The hierarchical structure is determined by the designer of the database, based on the relationships between the entities and the access paths required by the applications.

Note that in the IMS program product itself, the term database is used slightly differently from its use in other DBMSs. In IMS, a database is commonly used to describe the implementation of one hierarchy, so that an application would normally access a large number of IMS databases. Compared to the relational model, an IMS database is approximately equivalent to a table.

DL/I allows a wide variety of data structures. The maximum number of segment types is 255 per hierarchical data structure. A maximum of 15 segment levels can be defined in a hierarchical data structure. There is no restriction on the number of occurrences of each segment type, except as imposed by physical access method limits.

Sequence to access the segments

The sequence of traversing the hierarchy is top to bottom, left to right, front to back (for twins).

Segment code numbers do not take twins into account and sequential processing of a database record is in hierarchic sequence. All segments of a database record are included so twins do have a place in hierarchic sequences. Segments may contain sequence fields that determine the order in which they are stored and processed.

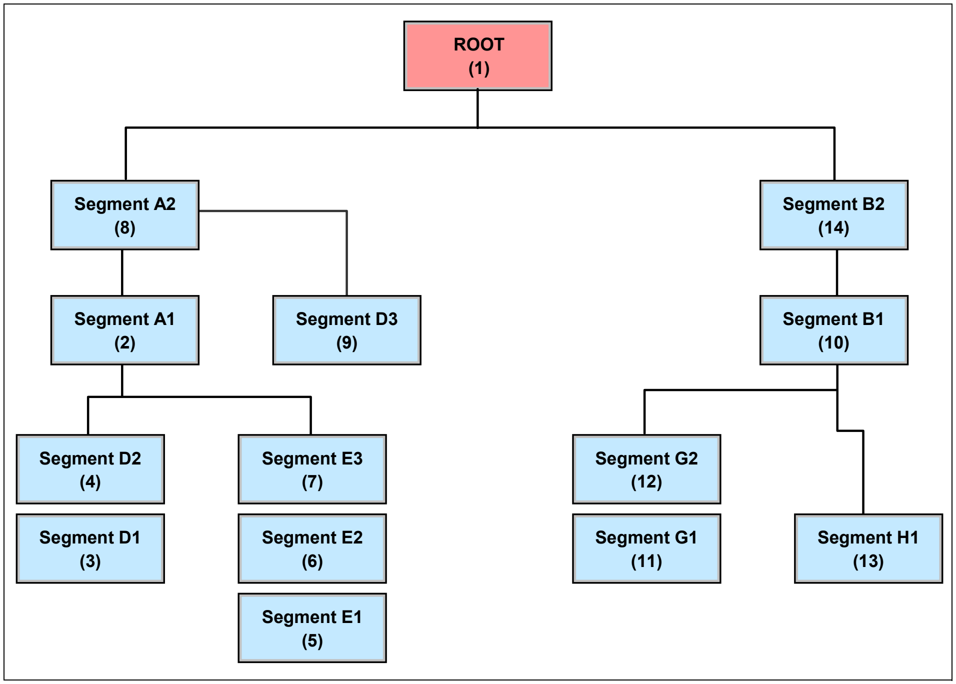


Figure 12-10 The sequence

The hierarchical data structure in Figure 12-10 describes the data of one database record as seen by the application program. It does not represent the physical storage of the data. The physical storage is of no concern to the application program.

The basic building element of a hierarchical data structure is the parent/child relationship between segments of data, also illustrated in Figure 12-10.

12.3.2 IMS use of z/OS services

IMS is designed to make the best use of the features of the z/OS operating system. This includes:

- It runs in multiple address spaces

  IMS subsystems (except for IMS/DB batch applications and utilities) normally consist of a control region address space, dependent address spaces providing system services, and dependent address spaces for application programs. Running in multiple address spaces gives the following advantages:

  – Maximizes use of CPUs when running on a multiple-processor CPC.

  – Address spaces can be dispatched in parallel on different CPUs.

  - Isolates the application programs from the IMS systems code. Reduces outages from application failures.
- It runs multiple tasks in each address space

  IMS, particularly in the control regions, creates multiple z/OS subtasks for the various functions to be performed. This allows other IMS subtasks to be dispatched by z/OS while one IMS subtask is waiting for system services.
- It uses z/OS cross-memory services to communicate between the various address spaces making up an IMS subsystem. It also uses the z/OS Common System Area (CSA) to store IMS control blocks that are frequently accessed by the address spaces making up the IMS subsystem. This minimizes the overhead of running in multiple address spaces.
- It uses the z/OS subsystem feature to detect when dependent address spaces fail, to prevent cancellation of dependent address spaces, and to interact with other subsystems such as DB2 and WebSphere MQ.
- It can make use of a z/OS sysplex (see later in this book). Multiple IMS subsystems can run on the z/OS systems making up the sysplex and access the same IMS databases. This provides:
  - Increased availability - z/OS systems and IMS subsystems can be switched in and out without interrupting the service.
  - Increased capacity - The multiple IMS subsystems can process far greater volumes.

12.3.3 Evolution of IMS

Initially, all IMS/DB online applications used IMS/TM as the interface to the database. However, with the growing popularity of DB2, many customers began to develop online applications using DB2 as a database, next to their existing good applications. That is why you see a lot of mixed environments in the real world.

12.3.4 Our online example

When we look back to our travel agent example of Chapter 11, "Overview of online applications and databases on z/OS" , examples of IMS transactions could be in the part of the airline company:

- Some of the batch may be to update daily, such as the payments done by travel agents and other customers.
- Another batch part may be the reminders to send out to the travel agents and other customers to make some payment.
- Checking whether reservations are made (and paid) can be an online application.

Checking whether there are available seats may be an IMS transaction.

12.4 Summary

The relational database is the predominant approach to data organization in today's business world. IBM's DB2 implements such relational principles as primary keys, referential integrity, a language to access the database (SQL), nulls, and normalized design. In a relational database, the most fundamental structure is the table with columns and rows.

There is a hierarchical dependency to the basic objects in DB2. The table structure can have indexes and views created on it. If a table is removed, these objects also get removed. Tables are contained in a physical data set called the table space, and the table space is associated with a database that is a logical grouping of table spaces. Newer schema objects in DB2 include UDTs, UDFs, LOBs, triggers, and stored procedures.

DB2 also has system structures that help manage the subsystem. The catalog and directory keep metadata about all the objects in the RDBMS. Buffer pools are used to hold pages of data from disk storage for faster retrieval; the active or archive logs and the BSDS are a way for DB2 to record all the changes made to the data for recovery purposes.

The only way to access the data in DB2 databases is with SQL. It is not a full programming language, and it works at the set level, using a result table when it manipulates data. SQL has three categories based on functionality: DML, DDL, and DCL. On the mainframe, SPUFI is a tool used to enter SQL statements.

Some special steps are needed to use SQL in application programs because traditional 3GL compilers do not recognize SQL. The precompiler comments out SQL statements in a program, copies them to a DBRM with a consistency token, and replaces them with calls to DB2. The modified source code is then compiled and link-edited. The DBRM performs a bind process that determines the access path and stores this executable SQL code in a package. Packages are then logically associated with a plan. When run, the call to DB2 in the load module passes its consistency token to DB2 to be matched to its twin in the appropriate plan in order to execute the SQL.

SQL can handle both static and dynamic statements, and EXPLAIN can be used to find out what access path the optimizer chose for the SQL.

Key terms in this chapter		
unit of work	DBMS	
SPUFI	SQLJ	SYSADM
EXPLAIN	view	modified source

DL/I	full-function database	

12.5 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. What DB2 objects define a physical storage area? Does a table?
2. What are some of the problems with the following SQL statement?

```
SELECT *
FROM PAYROLL;
```

3. What category of SQL would you use to define objects to DB2?
4. How does the precompiler find an SQL statement in a program?
5. How does a load module get put back together with the SQL statements?
6. How could you find out what access path the optimizer chose? What process creates this path?
7. What is a stored procedure?
8. What are some of the responsibilities of a system administrator?
9. What are some of the responsibilities of a database administrator (DBA)?
10. What are some of the ways that security is handled by DB2?
11. What is the database structure of IMS-DB? Describe it.

12.6 Exercise 1 -- Use SPUFI in a COBOL program

12.6.1 Step 1: Create files

Before you start with the DB2 exercise, you need to create two more PDSs:

- ZUSER##.DB2.INCLUDE: to store your DCLGENs
- ZUSER##.DB2.DBRM: to store your DBRMs

You can use ZUSER##.LANG.CNTL as base.

Furthermore, you also need a ZUSER##.SPUFI.OUTPUT file, which should be a flat file of record format VB, with a record length of 4092 and block length of 4096.

12.6.2 Step 2: DCLGEN

A DCLGEN is an easy way to generate COBOL definition statements for the DB2 information that you use in an application program. These statements can then be included in the source program.

First, from the DB2I (DB2 Interactive) menu, choose D for DB2I Defaults (Figure 12-11) and press Enter.

```
                            DB2I PRIMARY OPTION MENU          SSID: DB8H
COMMAND ===> D_

Select one of the following DB2 functions and press ENTER.

 1  SPUFI                    (Process SQL statements)
 2  DCLGEN                   (Generate SQL and source language declarations)
 3  PROGRAM PREPARATION      (Prepare a DB2 application program to run)
 4  PRECOMPILE               (Invoke DB2 precompiler)
 5  BIND/REBIND/FREE         (BIND, REBIND, or FREE plans or packages)
 6  RUN                      (RUN an SQL program)
 7  DB2 COMMANDS             (Issue DB2 commands)
 8  UTILITIES                (Invoke DB2 utilities)
 D  DB2I DEFAULTS            (Set global parameters)
 X  EXIT                     (Leave DB2I)





 F1=HELP      F2=SPLIT     F3=END       F4=RETURN    F5=RFIND     F6=RCHANGE
 F7=UP        F8=DOWN      F9=SWAP     F10=LEFT     F11=RIGHT    F12=RETRIEVE
```

Figure 12-11 DB2I menu

On the DB2I Defaults Panel 1, specify IBMCOB for option 3 Application Language (Figure 12-12 on page 12-25).

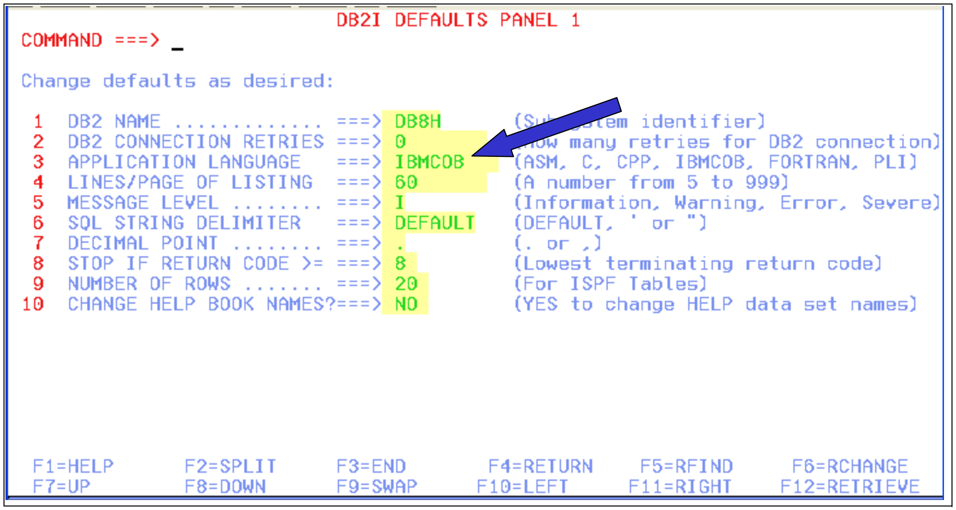


Figure 12-12 DB2I default panel 1

Press Enter, and on DB2I Defaults Panel 2, specify DEFAULT for the COBOL string delimiter under option 2 and G for the DBCS symbol for DCLGEN for option 3. Press Enter (Figure 12-13).

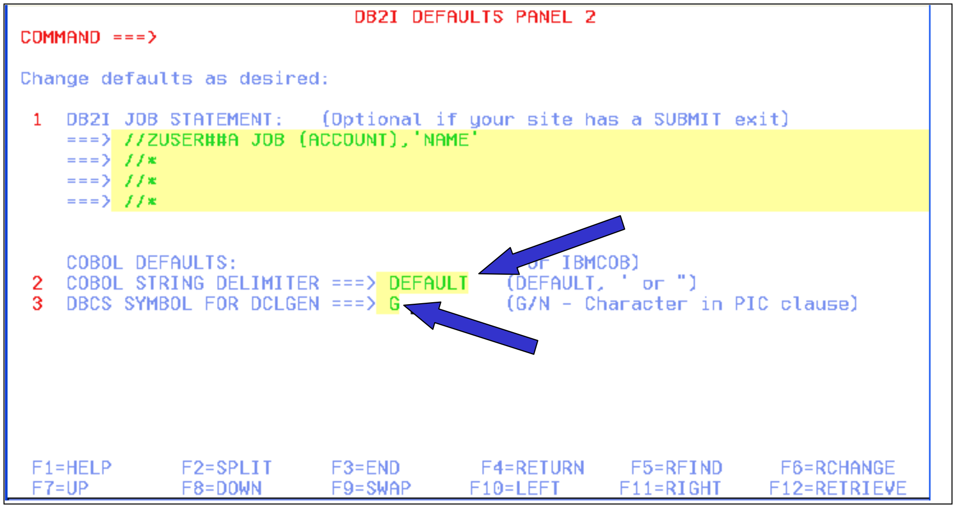


Figure 12-13 DB2I Default panel 2

This is just to make sure that you have the correct language.

After Enter, you are back on the main DB2I panel (Figure 12-11 on page 12-24); now select option 2, DCLGEN.

You will need to have a destination data set already allocated to hold your DCLGEN definition (ZUSER##.DB2.INCLUDE); it should be created for you. If you do not have one, go to the ISPF menu and create a PDS file.

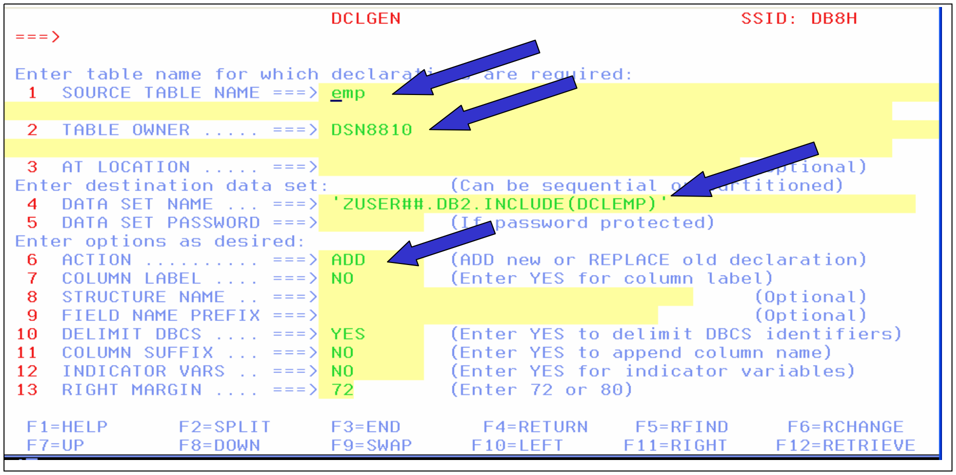


Figure 12-14 DCLGEN

As Figure 12-14 shows, you need to specify the table, the table owner, your PDS file, and the action ADD. The resulting message should be:

If the definition of the table changes, you must also change DCLGEN and use REPLACE.

12.6.3 Step 3: Test your SQL

Go to SPUFI; use your SPUFI.CNTL PDS. In that PDS you find the member SELECT. This is the SQL statement you will use in your program. The where-clause is not there, so that you can see all the results you can get. It also gives you the opportunity to know what departments are available in the table.

Surely, for more complex queries, this is common practice. As an application developer you are sure to execute the right SQL.

12.6.4 Step 4: Create the program

Here, you can create a program, or use the program that is supplied for you in LANG.SOURCE(COBDB2). This sample program calculates the average salary for one department. You specify the department and get the result. To end the program, enter 999.

To modify this program, add the following:

- Your variables (include the member you have created in step 1).
- Specify the SQL delimiters for COBOL.

If you search for "???" you will find the locations to do this.

12.6.5 Step 5: Complete the program

Edit the LANG.CNTL(COBDB2) job and make the changes stated at the top of the job.

You find the following steps in this job:

- Step PC: this is the DB2 precompile; it splits your source into two parts: the DBRM and the modified source.
- Steps COB, PLKED and LKED: these do the compile and linking of your modified source.
- Step BIND: this does the bind of the package and the plan.

  Question: If you needed to change your program, which bind could be left out? Feel free to change the program. Instead of the average, you can ask the minimum or maximum salary within a department (then you just need to change the SQL).
- Step Run: this runs the program in batch for two departments: A00 and D21.

12.6.6 Step 6: Run the program from TSO

Instead of running your program in batch, try running it from the TSO READY prompt. To do so, you must allocate both files to your session (this must be executed before you run the job).

Enter the following and press Enter after each line:

```
TSO alloc da(*) f(sysprint) reuse
tso alloc da(*) f(sysin) reuse
```

Then return to your DB2I screen.

Select option 6 RUN. Here, you enter the file name and the plan name (Figure 12-15 on page 12-28).

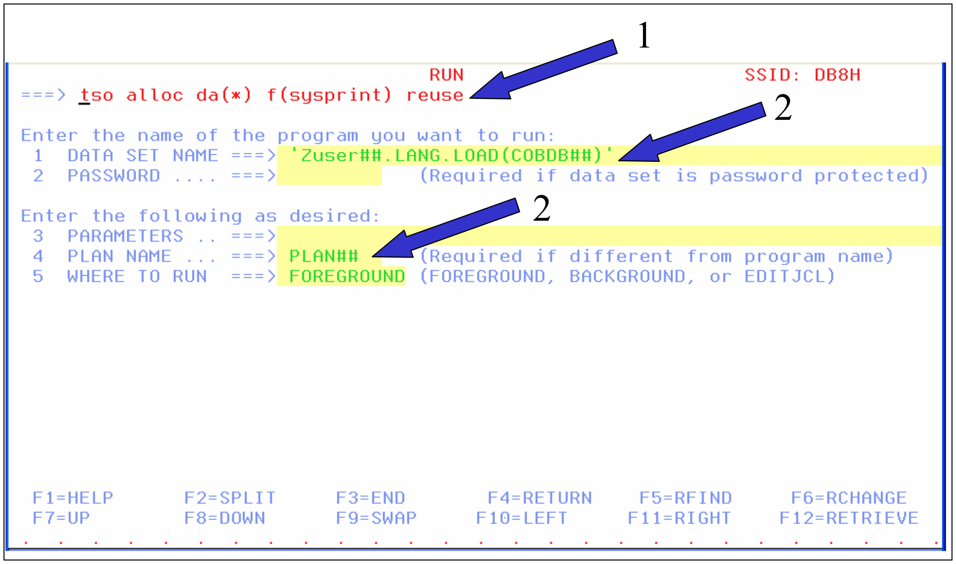


Figure 12-15 Ready to execute

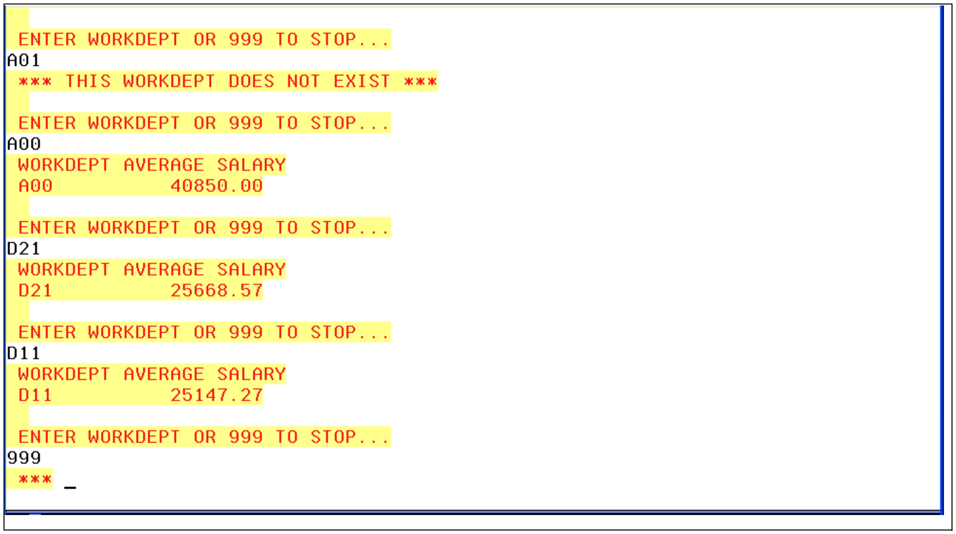


Figure 12-16 The execution of the program

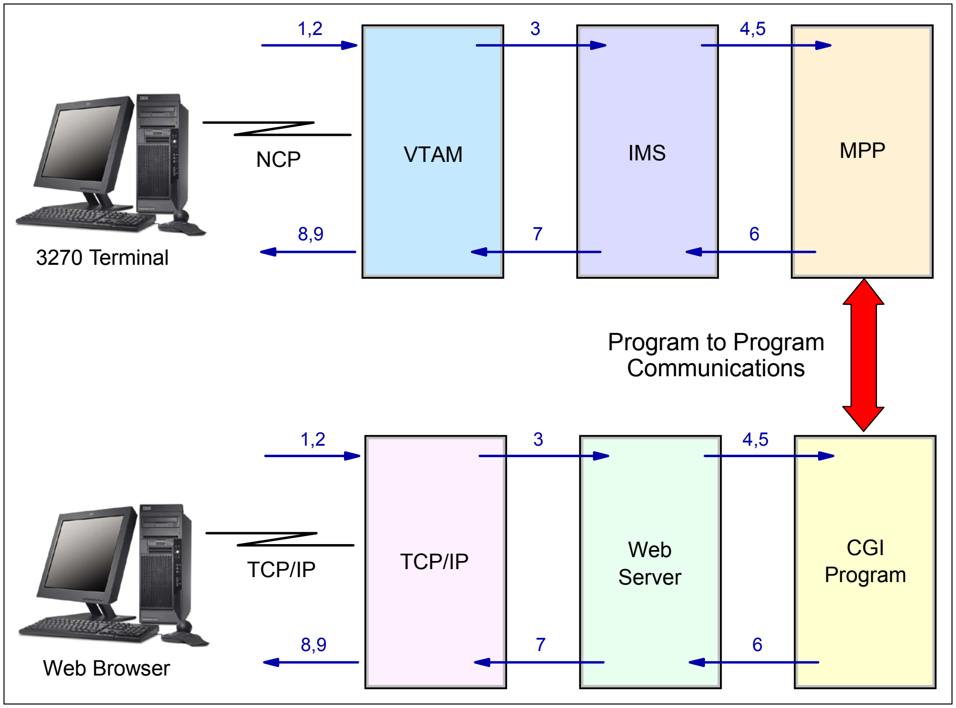


Figure 12-17 Message flow IMS transaction and Web server CGI programs

We have now reached the crux of the problem. The initial question, "How can I make my core business applications available to the Internet?" can now be answered. All it takes is to extend the CGI program that receives the data from a Web browser, and pass this data along to IMS as a transaction. The question now becomes one of getting the Web program to communicate with IMS.

- Over the past few years, IMS has greatly increased the number of options available for communication with the outside world. Many of these options are described in a redbook, *Connecting IMS to the World Wide Web, A Practical Guide to IMS Connectivity*.

13

z/OS HTTP Server

Objective: As a mainframe professional, you will need to know how to deploy a Web application on z/OS and how to enable z/OS for serving Web-based workloads.

After completing this chapter, you will be able to:

- List the three server modes
- Explain static and dynamic Web pages
- List at least two functions from each of the groups: basic, security, and caching

13.1 Introduction to Web-based workloads on z/OS

As enterprises move many of their applications to the Web, mainframe organizations face the complexity of enabling and managing new Web-based workloads in addition to more traditional workloads, such as batch processing. The next three chapters show how middleware products are used to supply the key functions needed to enable z/OS for processing Web-based workloads. Many such products exist in the marketplace today. We cover the following widely used middleware products in the next few chapters:

- Chapter 13, "z/OS HTTP Server"
- Chapter 14, "WebSphere Application Server on z/OS"
- Chapter 15, "WebSphere MQ"

13.2 What is z/OS HTTP Server?

z/OS HTTP Server serves static and dynamic Web pages. HTTP Server has the same capabilities as any other Web server, but it also has some features that are z/OS-specific. You can run HTTP Server in any of three modes, with each offering advantages for handling Web-based workloads:

Stand-alone server This mode is typically used for HTTP Server-only implementations (simple Web sites). Its main role is to provide a limited exposure to the Internet.

Scalable server This mode is typically used for interactive Web sites, where the traffic volume increases or decline dynamically. It is intended for a more sophisticated environment, in which servlets and JSPs are invoked.

Multiple servers This mode uses a combination of stand-alone and scalable servers to improve scalability and security throughout the system. For example, a stand-alone server could be used as a gateway to scalable servers, and the gateway could verify the user authentication of all requests, and reroute requests to the other servers.

13.2.1 Serving static Web pages on z/OS

With a Web server on z/OS, such as HTTP Server, the serving of static Web pages is similar to Web servers on other platforms. The user sends an HTTP request to HTTP Server to obtain a specific file. HTTP Server retrieves the file from its file repository and sends it to the user, along with information about the file (such as mime type and size) in the HTTP header.

Unlike other Web servers, however, HTTP Server has a major difference. Because z/OS systems encode files in EBCDIC, the documents on z/OS must first be converted to the ASCII format typically used on the Internet (binary documents such as pictures need not be converted).

HTTP Server performs these conversions, thus saving the programmer from performing this step. However, the programmer must use FTP to load documents on the server. That is, the programmer specifies ASCII as the FTP transport format to have the file converted from EBCDIC. For binary transfers, the file is not converted.

13.2.2 Serving dynamic Web pages on z/OS

Dynamic Web pages are an essential part of Web-based commerce. Every kind of interaction and personalization requires dynamic content. When a user fills out a form on a Web site, for example, the data in the form must be processed, and feedback must be sent to the user.

Two approaches for serving dynamic Web pages on z/OS are:

- “Using CGI for dynamic Web pages” on page 13-3
- “Using the plug-in interface” on page 13-4

Using CGI for dynamic Web pages

One way to provide dynamic Web pages is through the Common Gateway Interface (CGI), which is part of the HTTP protocol. CGI is a standard way for a Web server to pass a Web user’s HTTP request to an application. GCI generates the output and passes it back to HTTP Server, which sends it back to the user in an HTTP response (Figure 13-1).

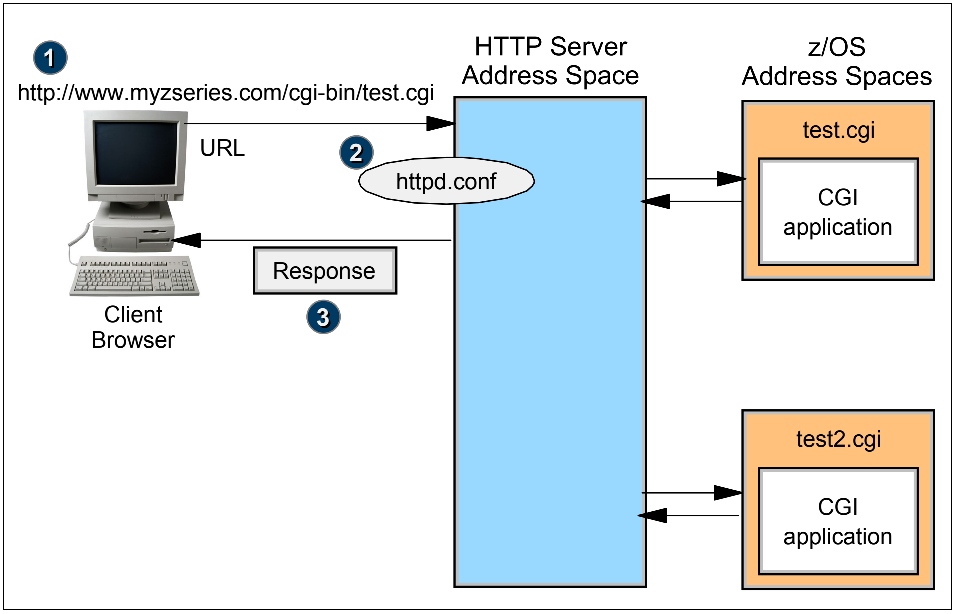


Figure 13-1 How the CGI works

CGI is not limited to returning only HTML pages; the application can also create plain text documents, XML documents, pictures, PDF documents, and so on. The mime type must reflect the content of the HTTP response.

CGI has one major disadvantage, which is that each HTTP request requires a separate address space. This causes a lack of efficiency when there are many requests at a time.

To avoid this problem, FastCGI was created. Basically, HTTP Server FastCGI plug-in is a program that manages multiple CGI requests in a single address space, which saves many program instructions for each request. More information about HTTP Server plug-ins in provided in “Using the plug-in interface” on page 13-4.

Using the plug-in interface

Another way of providing dynamic content is by using the plug-in interface of HTTP Server, which allows one of several products to interface with HTTP Server. Here, for example, are some ways in which HTTP Server can pass control to WebSphere;

- WebSphere plug-in, same address space. Figure 13-2 shows a simple configuration in which no J2EE server is needed. This servlet can connect to CICS or IMS, or to DB2 through JDBC. However, coding business logic inside servlets is not recommended.

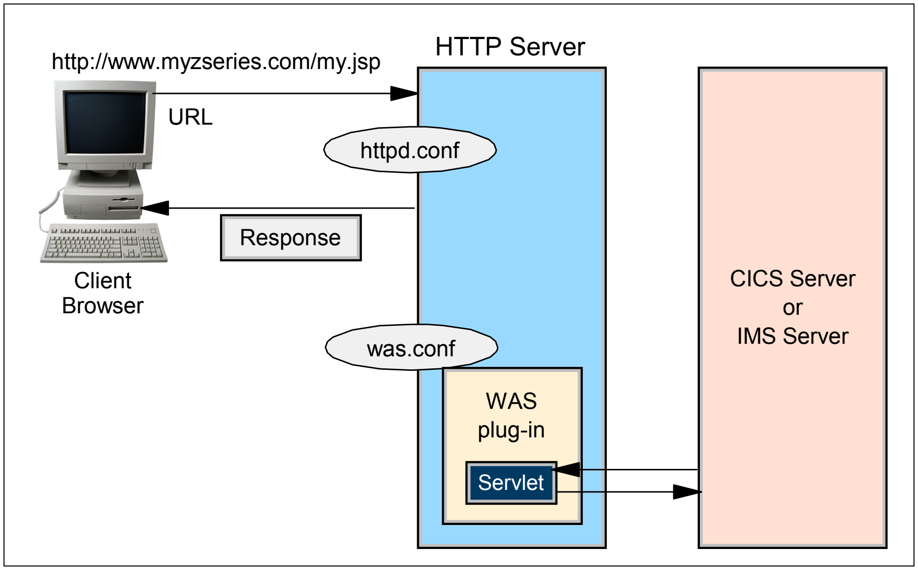


Figure 13-2 Accessing servlets using the WebSphere plug-in

– Web container inside HTTP Server, separate EJB container. Figure 13-3 shows a more usable configuration in which the servlets run in a different address space than the EJBs, so the EJBs are invoked from remote calls. The EJBs then get information from other servers.

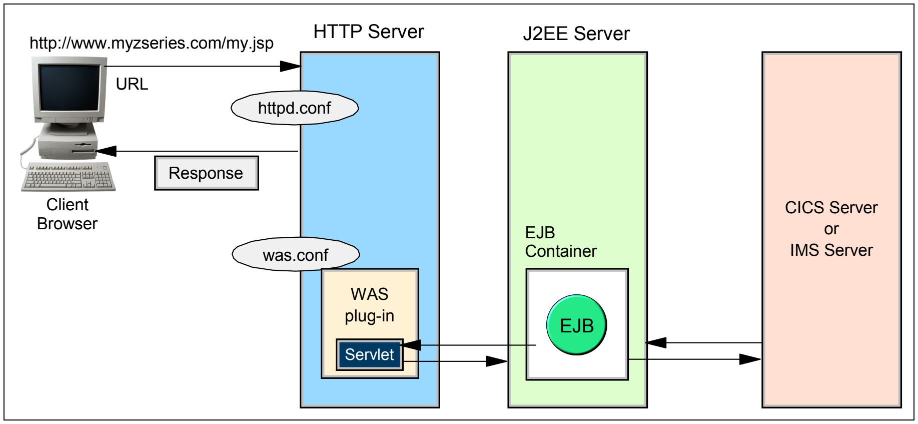


Figure 13-3 Accessing EJBs from a WebSphere plug-in

– Separate J2EE server with both Web container and EJB container. In addition to running your servlets locally within the WebSphere Plug-in, you can also use the WebSphere plug-in to run servlets remotely in a Web container, as shown in

Figure 13-4. This allows you to localize your servlets and EJBs to the same z/OS address space, so that no remote EJB calls are required.

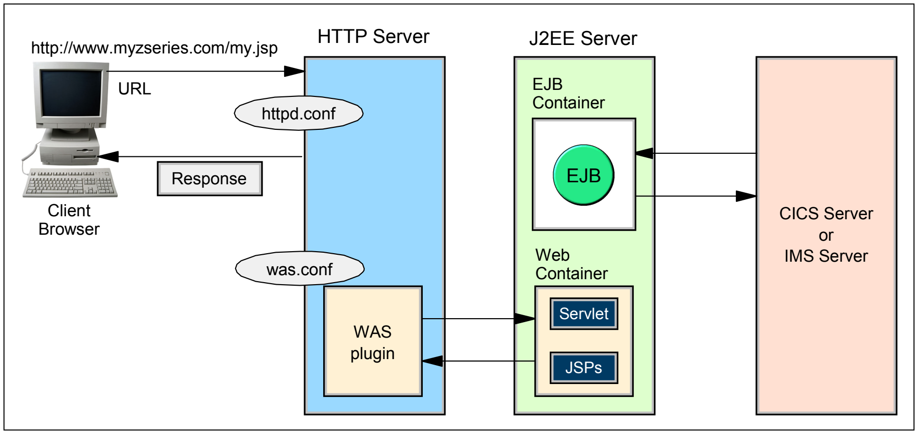


Figure 13-4 Accessing servlets in a Web Container using the WebSphere plug-in

If you are using WebSphere Application Server, HTTP Server might not be needed, yet there are several ways in which HTTP Server can interact with WebSphere Application Server. These possibilities are mentioned here.

13.3 HTTP Server capabilities

HTTP Server provides capabilities similar to other Web servers, but with some functions specific to z/OS as well. The z/OS-specific functions can be grouped as follows:

- Basic functions
- Security functions
- File caching

13.3.1 Basic functions

- EBCDIC/ASCII file access

  The server accesses files and converts them, if needed, from EBCDIC to ASCII encoding.

- Performance and usage monitoring

  As part of the z/OS features, HTTP Server can produce system management facilities (SMF[1]) records that the system programmer can retrieve later to do performance and usage analysis.

- Tracing and logging

HTTP Server comes with a complete set of logging, tracing, and reporting capabilities that allow you to keep track of every HTTP request.

- Server side includes (SSI)

  Server side includes allows you to insert information into documents (static or dynamic) that the server sends to the clients. This could be a variable (like the “Last modified” date), the output of a program, or the content of another file. Enabling this function, but not using it, can have a serious performance impact.

- Simple Network Management Protocol (SNMP) Management Information Base (MIB)

  HTTP Server provides an SNMP MIB and SNMP subagent, so you can use any SNMP-capable network management system to monitor your server’s health, throughput, and activity. It can then notify you if specified threshold values are exceeded.

- Cookies support

  Because HTTP is a stateless protocol, a state can be added with the help of cookies, which store information on the client’s side. This support is useful for multiple Web pages, for example to achieve customized documents or for banner rotation.

- Multi-Format Processing

  This feature is used for personalization of Web pages. The browser sends header information along with the request, including the *accept header*. This information includes the language of the user. HTTP Server can make use of the contents of the accept header to select the appropriate document to return to the client.

- Persistent connections

  With the help of this HTTP/1.1-specific feature, not every request has to establish a new connection. Persistent connections stay “alive” for a certain amount of time to enable the use of a given connection to another request.

- Virtual hosts

  Virtual hosts allow you to run one Web server while making it appear to clients as if you are running several. This is achieved by the use of different DNS names for the same IP and/or different IP addresses bound to the same HTTP Server.

13.3.2 Security functions

- Thread level security

  An independent security environment can be set for each thread running under HTTP Server, which basically means that every client connecting to the server will have its own security environment.

[1] SMF is an optional feature of z/OS that provides customers with the means for gathering and recording information that can be used to evaluate system usage for accounting, charge-back, and performance tuning.

- HTTPS/SSL support

  HTTP Server has full support for the Secure Socket Layer (SSL) protocol. HTTPS uses SSL as a sub-layer under the regular HTTP layer to encrypt and decrypt HTTP requests and HTTP responses. HTTPS uses port 443 for serving instead of HTTP port 80.

- LDAP support

  The Lightweight Data Access Protocol (LDAP) specifies a simplified way to retrieve information from an X.500-compliant directory in an asynchronous, client/server type of protocol

- Certificate authentication

  As part of the SSL support, HTTP Server can use certificate authentication and act as a certificate authority.

- Proxy support

  HTTP Server can act as a proxy server. You cannot, however, use the Fast Response Cache Accelerator (FRCA).

13.3.3 File caching

Performance can be significantly increased by using any of the following file caching (buffering) possibilities:

- HTTP Server caching HFS files
- HTTP Server caching z/OS data sets
- z/OS UNIX caching HFS files
- Fast Response Cache Accelerator (FRCA)

13.4 Summary

z/OS provides an HTTP server for both static and dynamic Web pages. HTTP Server supports the WebSphere plug-in (which handles EJB containers and J2EE), and security and file caching. These features make it easier to work with dynamic Web pages.

Key terms in this chapter		
CGI	dynamic	FRCA
HTTP	J2EE	LDAP
SSL	static	

13.5 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. List the three server modes
2. Explain static and dynamic Web pages
3. List at least two functions from each of the three groups: basic, security, and caching
4. When should connectors not be used?
5. Why not store all documents in ASCII format, so they would not have to be converted from EBCDIC?

13.6 Exercises

Work with the ISHELL or OMVS shell for this exercise (see the instructor for assistance). Also, you will need to know:

- Location of the HTTP Server configuration file, `httpd.conf`
- IP address or name of HTTP Server

Do each of the following steps and answer the questions:

1. Browse the httpd.conf file of the HTTP Server product installed on z/OS. In which directory are the Web documents stored (F “URL translation rules”)? Also, which port should be used? (F “Port directive”)?
2. From a Web browser window, display the class HTTP Server. How is WebSphere plugged into this HTTP Server? (F “Websphere”)?
3. Use OEDIT to create an HTML document in the Web documents folder. Name it *yourid*`test.html`. Here is an example:

```
<!doctype html public "//W3//Comment//EN">
<html>
<head>
<META content="text/html; charset=iso-8859-1">
<title> This is a simple HTML Exercise</title>
</head>
<body bgcolor="#FFFFFF">
<p>Hello World
</body>
</html>
```

4. Open a Web browser to your HTML document, for example:

```
www.yourserver.com/youridtest.html
```

   What needs to be done to install your own CGI?

5. Examine the httpd.conf file. Is the HTCounter CGI option “Date and Time” enabled? If so, change *yourid*`text.html` and add the following line to the body section:

```
<img src="/cgi-bin/datetime?Timebase=Local">
```

Save the file. What has changed?

14

WebSphere Application Server on z/OS

Objective: As a mainframe professional, you will need to know how to deploy a Web application on z/OS and how to enable z/OS for processing Web-based workloads.

After completing this chapter, you will be able to:

- List the six qualities of the J2EE Application model
- Give three reasons for running WebSphere Application Server under z/OS
- Name three connectors to CICS, DB2, and IMS

14.1 Introduction to Web-based workloads on z/OS

As enterprises move many of their applications to the Web, mainframe organizations face the complexity of enabling and managing new Web-based workloads in addition to more traditional workloads, such as batch processing.

14.2 What is WebSphere Application Server for z/OS?

WebSphere Application Server is a comprehensive, sophisticated, Java 2 Enterprise Edition (J2EE) and Web services technology-based application system. WebSphere Application Server on the mainframe is the J2EE implementation conforming to the current Software Development Kit (SDK) specification supporting applications at an API level. As mentioned, it is a Java Application deployment and runtime environment built on open standards-based technology supporting all major functions such as servlets, Java server pages (JSPs), and Enterprise Java Beans (EJBs) including the latest technology integration of services and interfaces.

The application server runtime is highly integrated with all inherent features and services offered on z/OS. The application server inter-operates with all major subsystems on the operating system including DB2, CICS, and IMS. It has extensive attributes for security, performance, scalability and recovery. The application server also uses sophisticated administration and tooling functions, thus providing seamless integration into any data center or server environment.

WebSphere Application Server is an e-business application deployment environment. It is built on open standards-based technology such as CORBA, HTML, HTTP, IIOP, and J2EE-compliant Java technology standards for servlets, Java Server Pages (JSP) technology, and Enterprise Java Beans (EJB), and it supports all Java APIs needed for J2EE compliance.

The Controller Address Space will automatically start a servant region as work arrives. As shown in Figure 14-1, an application server instance is composed of a controller region (CR) and one or more servant regions (SRs).

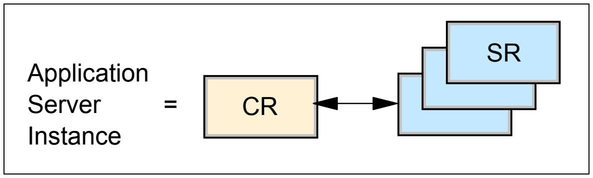


Figure 14-1 An application server instance

The application server on z/OS provides for two configurations and uses essentially the same architectural hierarchy regardless of the implementation. The application server is organized based on the concepts of *servers*, *nodes* and *cells*. While all these elements are present in each configuration, cells and nodes do not play an important role until you implement the Network Deployment configuration.

Now let’s take a closer look at these three elements:

Servers

These perform the code execution for your application. There are several types of servers, depending on the configuration. Each server runs in its own Java Virtual Machine (JVM).

The application server is the primary runtime component in all configurations. This is where the application actually executes. It provides containers and services that specialize in enabling the execution of specific Java application components. Each application server runs in its own JVM. All WebSphere Application Server configurations can have one or more application servers.

Within this runtime you have a Base configuration which each application server functions as a separate entity. There is no workload distribution or common administration among the application servers.

The other runtime is called the Network Deployment configuration, in which multiple application servers are maintained from a central administration point.

In addition, application servers can be clustered for workload distribution.

Note: Another type of application server is a JMS Server, which is not covered in this book.

Nodes (and node agents)

A node is a logical grouping of WebSphere-managed server processes that share common configuration and operational control. A node is generally associated with one physical installation of the application server.

As you move up to the more advanced application server configurations, the concepts of configuring multiple nodes from one common administration server and workload distribution among nodes are introduced. In these centralized management configurations, each node has a node agent that works with a Deployment Manager to manage administration processes.

Cells

A cell is a grouping of nodes into a single administrative domain. In the Base configuration, a cell contains one node. That node may have multiple servers, but the configuration files for each server are stored and maintained individually (XML-based).

With the Network Deployment configuration, a cell can consist of multiple nodes, all administered from a single point. The configuration and application files for all nodes in the cell are centralized into a cell master configuration repository. This centralized repository is managed by the Deployment manager process and synchronized out to local copies held on each of the nodes.

Within the address spaces used for the application server there is a concept of *containers,* which provide runtime separation between the various artifacts that execute. A single container, known as an EJB container, is used to run Enterprise Java Beans. Another container, known as the Web container, is used to execute Web-related elements such as HTML, GIF files, servlets, and Java server pages (JSPs). Together they make up the application server's runtime within the Java Virtual Machine (JVM).

14.3 J2EE application model on z/OS

The J2EE Application Model on z/OS is exactly the same as on other platforms, and it follows the SDK specification, exhibiting the following qualities:

- Functional - satisfies user requirements
- Reliable - performs under changing conditions
- Usable - enables easy access to application functions
- Efficient - uses system resources wisely
- Maintainable - can be modified easily
- Portable - can be moved from one environment to another

WebSphere Application Server on z/OS supports four major models of application design: Web-based computing, integrated enterprise computing, multithreading distributed business computing, and service-oriented computing. All these design models focus on separating the application logic from the underlying infrastructure; that is, the physical topology and explicit access to the information system is distinct from the programming model for the application.

The J2EE programming model supported by WebSphere Application Server for z/OS makes it much easier to build applications for new business requirements because it separates the details from the underlying infrastructure. It provides for the deployment of the component and service-oriented programming model offered by J2EE.

14.4 Running WebSphere Application Server on z/OS

WebSphere Application Server runs as a standard subsystem on z/OS. Therefore, it inherits all the characteristics of mainframe qualities and functionality that accompany that platform, such as its unique capacity for running hundreds of heterogeneous workloads concurrently, and meeting service level objectives as defined by the user.

14.4.1 Consolidation of workloads

The mainframe can be used to consolidate workloads from many individual servers. Therefore, if there is a large administration overhead or a physical capacity concern of many individual servers, the mainframe can take on the role of a single server environment managing those workloads. It can present a single view of administration, performance and recovery for applications that harness the mainframe's services during execution.

Several application servers can easily be migrated into one logical partition of a mainframe's resources (logical partitions, or *LPARs* are discussed in "Hardware systems and LPARs" on page 19-1), thus providing ease of management and monitoring. Consolidation also allows for instrumentation and metric gathering, resulting in easier capacity analysis.

14.4.2 WebSphere for z/OS security

The combination of zSeries hardware- and software-based security, along with incorporated J2EE security, offers significant defense against possible intrusions. The product security is a layered architecture built on top of the operating system platform, the Java Virtual Machine (JVM), and Java2 security.

WebSphere Application Server for z/OS integrates infrastructure and mechanisms to protect sensitive J2EE resources and administrative resources addressing the enterprise from an end-to-end security perspective based on industry standards.

The open architecture possesses secure connectivity and inter-operability with all mainframe Enterprise Information Systems, which includes:

- CICS Transaction Server (TS)
- DB2
- Lotus® Domino®
- IBM Directory

WebSphere Application Server integrates with RACF and WebSEAL Secure Proxy (Trusted Association Interceptor), providing a unified, policy-based and permission-based model for securing all Web resources and Enterprise Java Bean components, as defined in the J2EE specification.

14.4.3 Continuous availability

WebSphere for z/OS uses the zSeries platform's error detection and correction internal capabilities, which implement hardware component redundancy. WebSphere for z/OS has recovery termination management that detects, isolates, corrects and recovers from software errors. WebSphere for z/OS can differentiate and prioritize work based on service level agreements. It offers clustering capability as well as the ability to make non-disruptive changes to software components, such as resource managers.

In a critical application, WebSphere for z/OS can implement a failure management facility of z/OS called a*utomatic restart manager* or *ARM*. This facility can detect application failures, and restart servers when failures occur. WebSphere uses ARM to recover application servers (servants). Each application server running on a z/OS system is registered with an ARM restart group.

WebSphere for z/OS can implement a feature called *clustering*. Clustering technology is used extensively in high availability solutions involving WebSphere, as shown in Figure 14-2 on page 14-6.

A cluster consists of multiple copies of the same component with the expectation that at least one of the copies will be available to service a request. In general, the cluster works as a unit where there is some collaboration among the individual copies to ensure that the request can be directed toward a copy that is capable of servicing the request.

Designers of a high availability solution participate in establishing a service level as they determine the number and placement of individual members of clusters. WebSphere for z/OS provides management for some of the clusters needed to create the desired service level. Greater service levels of availability can be obtained as WebSphere clusters are supplemented with additional cluster technologies.

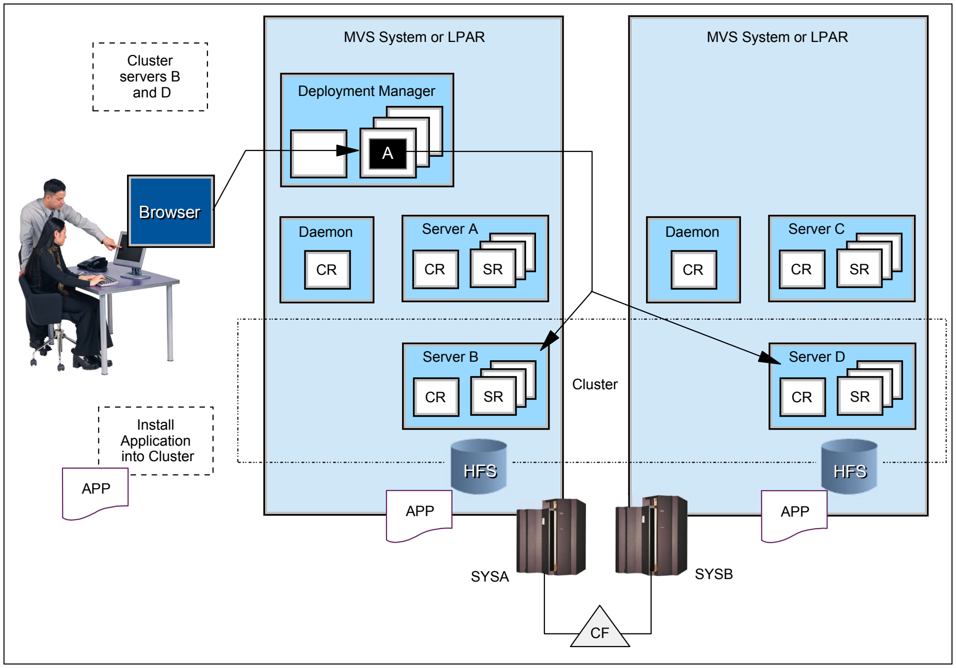


Figure 14-2 Clustering of servers in a cell

A WebSphere Application Server cluster is composed of individual cluster members, with each member containing the same set of applications. In front of a WebSphere Application Server cluster is a workload distributor, which routes the work to individual members.

Clusters can be vertical within an LPAR (that is, two or more members residing in a z/OS system image) or they can be placed horizontally across LPARs (where you obtain the highest in availability in the event an LPAR containing a member has an outage).

Workload in this case can still be taken on from the remaining cluster members. Also within these two configurations, it is possible to have a hybrid in which the cluster is composed of vertical and horizontal members (see Figure 14-3 on page 14-7).

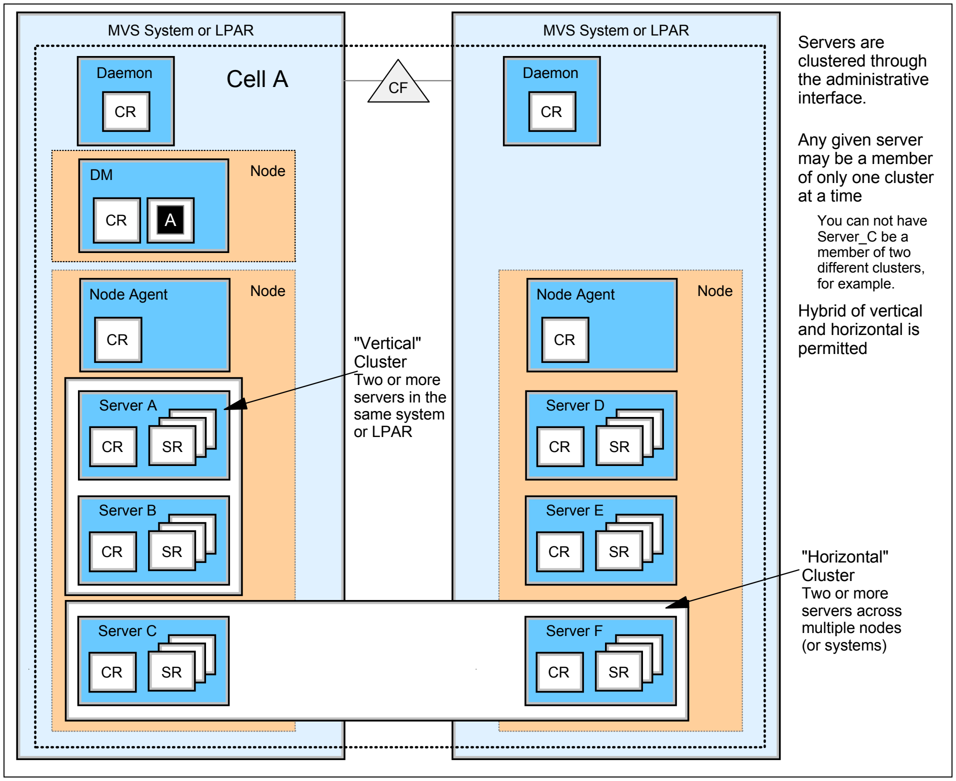


Figure 14-3 Vertical and horizontal clusters

14.4.4 Performance

Performance is highly dependent on application design and coding, regardless of the power of the runtime platform—a defectively written application will perform just as poorly on z/OS as on another machine's architecture.

WebSphere Application Server for z/OS uses the mainframe qualities in hardware, and software characteristics incorporating Workload Management schemes, dynamic LPAR configuration, and Parallel Sysplex functionality.

WebSphere Application Server for z/OS uses the three distinct functions of the mainframe's workload manager (WLM):

- Routing - WLM routing services are used to direct clients to servers on a specific system based on measuring current system utilization, known as the Performance Index (PI).
- Queuing - The WLM queuing service is used to dispatch work requests from a Controller Region to one or more Server Regions. It is possible for a Work Manager to register with WLM as a Queuing Manager. This tells WLM that this server would like to use WLM-managed queues to direct work to other servers. This allows WLM to manage server spaces to achieve the specified performance goals established for the work.
- Prioritize - The application server provides for starting and stopping Server Regions to set work precedence. This allows WLM to manage application server instances in order to achieve goals specified by the business.

WLM maintains a performance index (PI) for each service class period to measure how actual performance varies from the goal. Because there are several types of goals, WLM needs some way of comparing how well or poorly work in one service class is doing compared to other work. A service class (SC) is used to describe a group of work within a workload with equivalent performance characteristics

14.5 Application server configuration on z/OS

An application server configuration on z/OS includes the following:

- Base server node
- Network deployment manager

14.5.1 Base server node

The base application server node is the simplest operating structure in the Application Server for z/OS. It consist of an application server and a daemon server (one node and one cell), as shown in Figure 14-4 on page 14-9. All of the configuration files and definitions are kept in the HFS directory structure created for this base application server. The daemon server is a special server with one controller region. The system architecture of WebSphere for z/OS calls for one Daemon server per cell per system or LPAR.

Each base application server node contains administration for its own cell domain and a separate repository for its configuration. Therefore, you can have many base application servers, each isolated from the others, having its own administration policy for its specific business needs.

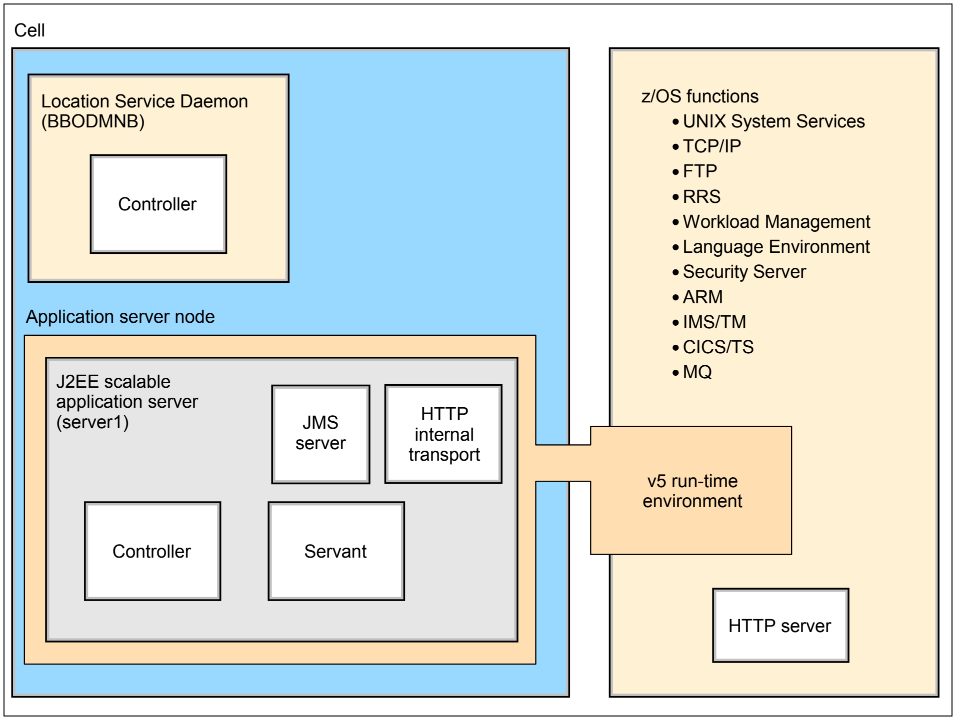


Figure 14-4 Base server node

14.5.2 Network Deployment Manager

Network Deployment Manager (see Figure 14-5 on page 14-10) is an extension to the base application server, having a deployment manager packaged within this configuration. Unlike the base application server, the Deployment Manager allows the system to administer multiple application servers from one centralized location. With the Deployment Manager, horizontally and vertically scaled systems, as well as distributed applications, can be easily administered.

In this topology application servers are attached to nodes, and multiple nodes belong to a cell.

The Network Deployment Manager also manages the repositories on each node, performing such tasks as creating, maintaining, and removing the repositories. The system uses an extract/modify method to update the configuration.

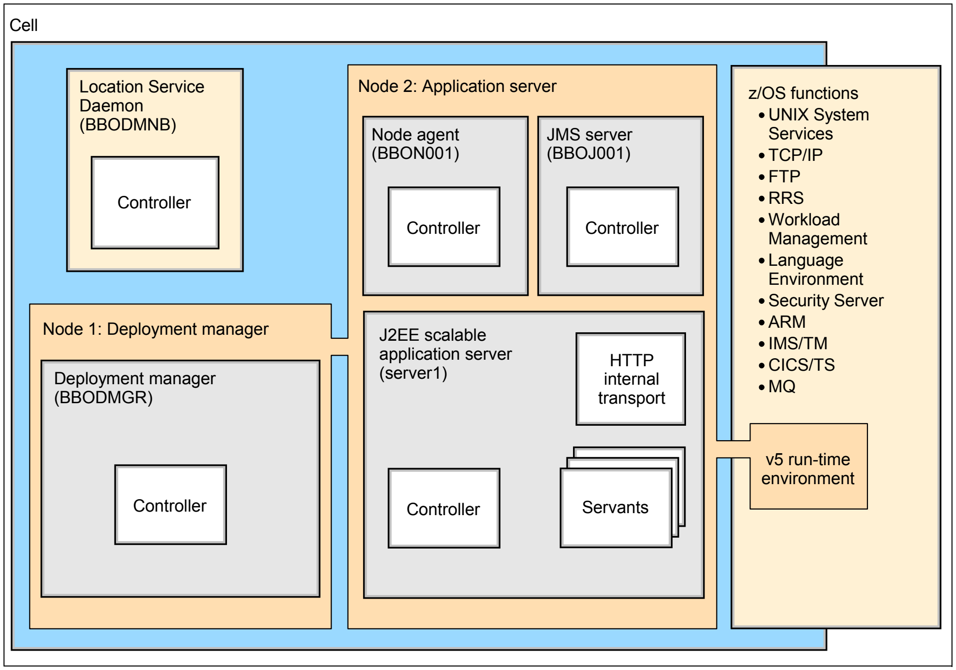


Figure 14-5 Network Deployment Manager

14.6 Connectors for Enterprise Information Systems (EIS)

The ability of applications to interface with resources outside of the application server process and to use those resources efficiently has always been an important requirement. Equally important is the ability for vendors to plug in their own solutions for connecting to and using their resources.

An application might require access to many types of resources, which may or may not be located in the same machine as the application. Therefore, access to a resource begins with a connection that is a pathway from an application to a resource requiring use. That resource might be another transaction manager or database manager.

Java Program access to a broad range of back-end resources is performed through a resource adapter. This is a system-level software driver that plugs into an application server and enables a Java application to connect to various back-end resources. The specification provides the necessary interfaces for supporting these resource types, as well as the interface for use by application programmers.

The following considerations are common to all connections:

- Creating a connection can be expensive - setting up a connection can take a long time when compared to the amount of time the connection is actually used.
- Connections need to be secured - this is often a joint effort between the application and the server working with the resource.
- Connections need to perform well - connection performance can be critical to the success of an application, and it is a function of the application's overall performance.
- Connections need to be monitorable and have good diagnostics - the quality of the diagnostics for a connection depends on the information regarding the server and resource status.
- Methods for connecting to and working with a resource - different database architectures require different means for access from an application server.
- Quality of Service comes into play when accessing resources outside of the application server - the application may require the ACID (Atomicity, Consistency, Isolation, and Durability) properties that can be obtained when using data in managing a transaction.

Enterprise resources are often legacy resources that were developed over time by a business and are external to the application server process. Each type of resource has its own connection protocol and proprietary set of interfaces to the resource, meaning that the resource has to be adapted to be accessible from a JVM process as contained in an application server.

WebSphere Application Server has facilities to interface with other mainframe subsystems such as CICS, DB2 and IMS. This is performed through a resource adapter and a connector. Accessing back-end Enterprise Information Systems (EIS) extends the functionality of the application server into existing business functions, providing enhanced capabilities reaching all corporate needs of deployment.

The Java Cryptography Architecture (JCA) defines the contracts between the application, the connector and the application server where the application is deployed. The application has a component called the *resource adapter*. This is contained within the application code handling the interface to the connector which the application developer creates.

From a programming perspective, this means that programmers only have to use a single unified interface with which they can obtain data from the EIS. The resource adapter will take care of abstracting out the different elements and provide the programming model that is independent of the actual EIS behavior and communication requirements.

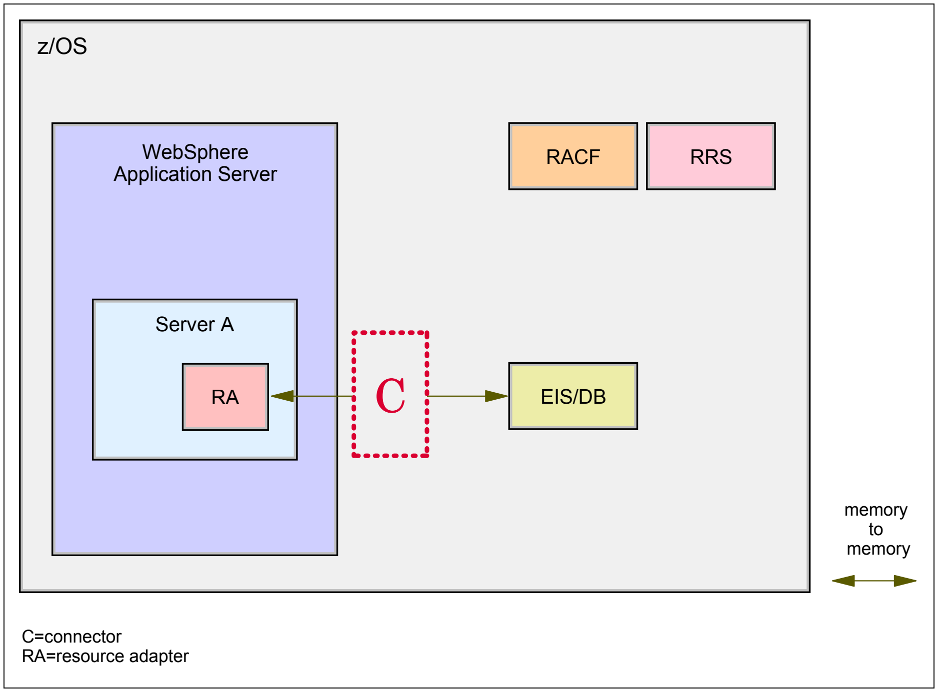


Figure 14-6 Basic architecture of a connector to an EIS

14.6.1 Three major mainframe connectors

WebSphere for z/OS provides *connectors* that allow z/OS applications to interface with mainframe middleware products CICS, IMS, and DB2, as described in the following sections:

- CICS Transaction Gateway
- IMS Connect
- DB2 JDBC

CICS Transaction Gateway

Customer Information Control System (CICS) has the CICS Transaction Gateway (CTG) to connect from the application server to CICS. CTG provides the interface between Java and CICS application transactions. It is a set of client and server software components incorporating the services and facilities to access CICS from the application server.

CTG uses special APIs and protocols in servlets or EJBs to request services and functions of the CICS Transaction Manager.

IMS Connect

IMS Connect is the connector TCP/IP server that enables an application server client to exchange messages with IMS Open Transaction Manager Access (OTMA). This server provides communication links between TCP/IP clients and IMS (datastores). It supports multiple TCP/IP clients accessing multiple datastore resources. To protect information that is transferred through TCP/IP, IMS Connect provides Secure Sockets Layer (SSL) support to protect and secure the information.

IMS Connect can also perform router functions between application server clients and local option clients with datastores and IMSplex resources. Request messages received from TCP/IP clients using TCP/IP connections, or local option clients using the z/OS Program Call (PC), are passed to a datastore through cross-system Coupling Facility (XCF) sessions. IMS Connect receives response messages from the datastore and then passes them back to the originating TCP/IP or local option clients.

IMS Connect supports TCP/IP clients communicating with socket calls, but it can also support any TCP/IP client that communicates with a different input data stream format. User-written message exits can execute in the IMS Connect address space to convert customer message format to OTMA message format before IMS Connect sends the message to IMS. The user-written message exits also convert OTMA message format to customer message format before sending a message back to IMS Connect. IMS Connect then sends output to the client.

DB2 JDBC

The Java Database Connectivity (JDBC) is an application programming interface (API) that the Java programming language uses to access different forms of tabular data, as well as some hierarchical systems such as IMS. JDBC specifications were developed by Sun Microsystems together with relational database providers such as Oracle and IBM to ensure portability of Java applications across database platforms.

This interface does not necessarily fall into the category of "connector" because there is no separate address space required for its implementation. The interface is a Java construct that looks like a Java class but does not provide an implementation of its methods. For JDBC, the actual implementation of the JDBC interface is provided by the database vendor as a "driver". This provides portability in that all access using the JDBC is through standard calls with standard parameters. Thus an application can be coded with little regard to the database being used, because all of the platform-dependent code is stored in the JDBC drivers.

As a result, JDBC must be flexible with regard to what functionality it does and does not provide, solely based on the fact that different database systems have different levels of functionality.

JDBC drivers provide the physical code that implements the objects, methods, and data types defined in the specification. JDBC standards define four types of drivers, numbered

1 through 4. The distinction between them is based on how the driver is physically implemented and how it communicates with the database.

The mainframe supports only type 2 and type 4 drivers:

- Type 2

  The JDBC API calls platform- and database-specific code to access the database. This is the most common driver type used, and offers the best performance. However, because the driver code is platform-specific, a different version has to be coded (by the database vendor) for each platform.

- Type 4

  A Type 4 driver is fully written in Java, and accesses the target database directly using the protocol of the database itself. (In the case of DB2, this is DRDA®.) Because the driver is fully written in Java, it can be ported to any platform that supports that DBMS protocol without change, thus allowing applications to also use it across platforms without change.

  A Java application, running under WebSphere Application Server, talks to the (Universal) Type 4 JDBC driver that supports two-phase commit, and the driver talks directly to the remote database server through DRDA. The Universal Type 4 driver implements DRDA Application Requester functionality.

To access DB2 on z/OS, IBM provides a type 2 driver and a driver that combines type 2 and type 4 JDBC implementations.

In general, JDBC type 2 connectivity is used for Java programs that run on the same z/OS system with the target DB2 subsystem. JDBC type 4 connectivity is used for Java programs that run on a z/OS system other than that of the target DB2 subsystem.

Key terms in this chapter		
cell	CS	CGI
EIS	JMX	J2EE
SR	cluster	node

14.7 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. List the six qualities of the J2EE Application model.
2. List three reasons for running WebSphere Application Server under z/OS.
3. Name three connectors to CICS, DB2, and IMS.

4. What is a major difference between HTTP Server and WebSphere Application Server for z/OS?
5. When should connectors not be used?
6. Why not store all documents in ASCII format, so they would not have to be converted from EBCDIC?

14.8 Exercises

15

WebSphere MQ

Objective: As a mainframe professional, you will need to understand messaging and queuing. These functions are needed for communication between heterogeneous applications and platforms.

After completing this chapter, you will be able to:

- Explain why messaging and queuing is used
- Describe the asynchronous flow of messages
- Explain the function of a queue manager
- List three zSeries-related adapters

Most large organizations today have an inheritance of IT systems from various manufacturers, which often makes it difficult to share communications and data across systems. Many of these organizations also need to communicate and share data electronically with suppliers and customers--who might have other disparate systems. It would be handy to have a message handling tool that could receive from one type of system and send to another type.

IBM WebSphere MQ facilitates application integration by passing messages between applications and Web services. It is used on more than 35 hardware platforms and for point-to-point messaging from Java, C, C++ and COBOL applications. Three-quarters of enterprises that buy inter-application messaging systems buy WebSphere MQ. In the largest installation, over 250 million messages a day are transmitted.

15.1 Components and terminology

Let's take a look at the definitions and building blocks in WebSphere MQ.

15.1.1 What is messaging and queuing?

Where data held on different databases on different systems must be kept synchronized, little is available in the way of protocols to coordinate updates and deletions and so on. Mixed environments are difficult to keep aligned; complex programming is often required to integrate them.

Message queues, and the software that manages them, such as IBM WebSphere MQ for z/OS, enable program-to-program communication. In the context of online applications, *messaging and queuing* can be understood as follows:

- *Messaging* means that programs communicate by sending each other messages (data), rather than by calling each other directly.
- *Queuing* means that the messages are placed on queues in storage, so that programs can run independently of each other, at different speeds and times, in different locations, and without having a logical connection between them.

15.1.2 Synchronous communication

Figure 16-1 shows the basic mechanism of program-to-program communication using a synchronous communication model.

Program A prepares a message and puts it on Queue 1. Program B gets the message from Queue 1 and processes it. Both Program A and Program B use an application programming interface (API) to put messages on a queue and get messages from a queue. The WebSphere MQ API is called the Message Queue Interface (MQI).

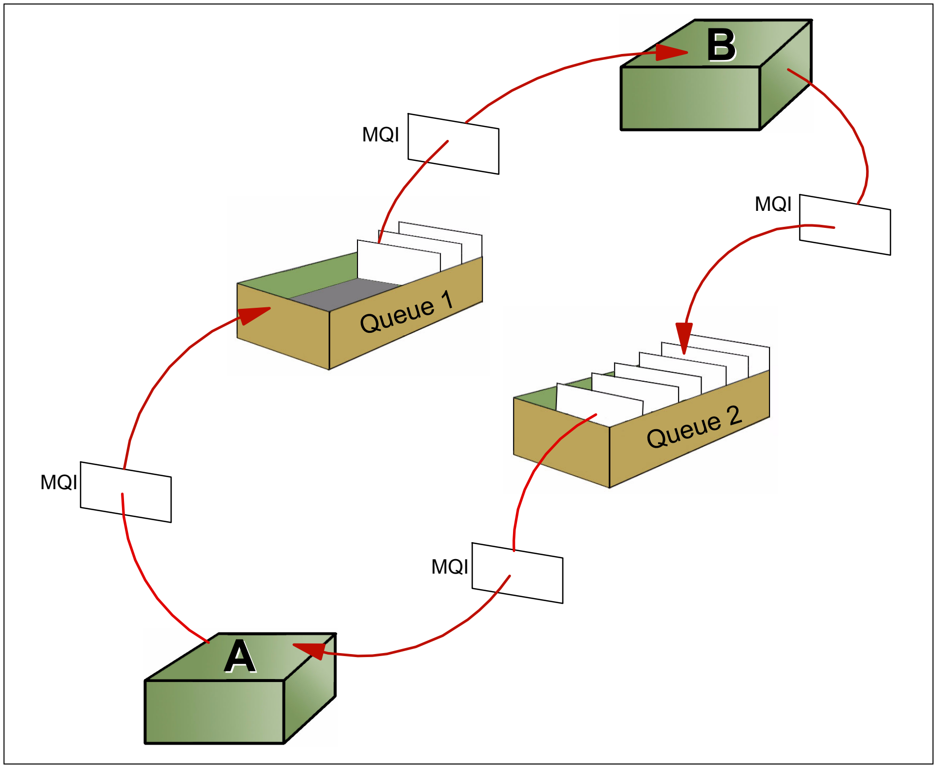


Figure 15-1 Synchronous application design model

When Program A puts a message on Queue 1, Program B might not be running. The queue stores the message safely until Program B starts and is ready to get the message. Likewise, at the time Program B gets the message from Queue 1, Program A might no longer be running. Using this model, there is no requirement for two programs communicating with each other to be executing at the same time.

There is clearly a design issue, however, about how long Program A should wait before continuing with other processing. This design might be desirable in some situations, but when the wait is too long, it is not so desirable any more. Asynchronous communication is designed to handle those situations.

15.1.3 Asynchronous processing

Using the asynchronous model, Program A puts messages on Queue 1 for Program B to process, but it is Program C, acting asynchronously to Program A, which gets the replies from Queue 2 and processes them. Typically, Program A and Program C would be part of the same application. You can see the flow of this activity in Figure 15-2.

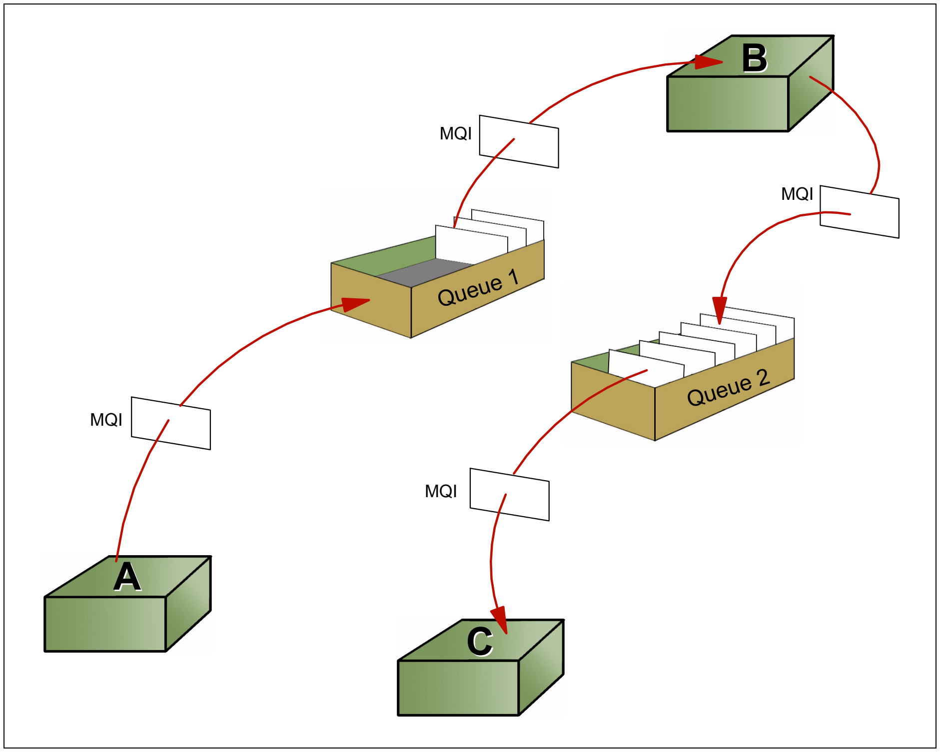


Figure 15-2 Asynchronous application design model

The asynchronous model is natural for WebSphere MQ. Program A can continue to put messages on Queue 1 and is not blocked by having to wait for a reply to each message. It can continue to put messages on Queue 1 even if Program B fails. If so, Queue 1 stores the messages safely until Program B is restarted.

In a variation of the asynchronous model, Program A could put a sequence of messages on Queue 1, optionally continue with some other processing, and then return to get and process the replies itself. This property of WebSphere MQ, in which communicating applications do not have to be active at the same time, is known as *time independence*.

15.1.4 Message types

WebSphere MQ uses four types of messages:

Datagram A message for which no response is expected.

Request A message for which a reply is requested.

Reply A reply to a request message.

Report A message that describes an event such as the occurrence of an error or a confirmation on arrival or delivery.

15.1.5 Message queues

Message queues are used to store messages sent by programs. They are defined as objects belonging to the queue manager.

When an application puts a message on a queue, the queue manager ensures that the message is:

- Stored safely
- Is recoverable
- Is delivered once, and once only, to the receiving application

This is true even if a message has to be delivered to a queue owned by another queue manager, and is known as the assured delivery property of WebSphere MQ.

15.1.6 What is a queue manager?

The component of software that owns and manages queues is called a queue manager (QM). The heart of WebSphere MQ is the message queue manager (MQM). The MQM provides messaging services for an application, ensures that messages are put in the correct queue, routes messages to other queue managers, and processes messages through a common programming interface called the Message Queue Interface (MQI).

The queue manager can retain messages for future processing in the event of application or system outages. Messages are retained in a queue until a successful completion response is received through the MQI.

There are similarities between queue managers and database managers. Queue managers own and control queues similar to the way that database managers own and control their data storage objects. They provide a programming interface to access data, and also provide security, authorization, recovery and administrative facilities.

There are also important differences, however. Databases are designed to provide long-time data storage with sophisticated search mechanisms, whereas queues are not designed for this. A message on a queue generally indicates that a business process is incomplete; it might represent an unsatisfied request, an unprocessed reply, or an unread report. Figure 15-4 on page 15-9 shows the flow of activity in queue managers and database managers.

15.1.7 Types of message queues

Several types of message queues exist. In this text, the most relevant are the following:

- Local queue

  A queue is local if it is owned by the queue manager to which the application program is connected. It is used to store messages for programs that use the same queue manager. The application program doesn't have to run on the same machine as the queue manager.

- Remote queue

  A queue is remote if it is owned by a different queue manager. A remote queue is not a real queue; it is only the *definition* of a remote queue to the local queue manager. Programs cannot read messages from remote queues. Remote queues are associated with a transmission queue.

- Transmission queue

  This local queue has a special purpose; it is used as an intermediate step when sending messages to queues that are owned by a different queue manager. Transmission queues are transparent to the application; that is, they are used internally by the queue manager initiation queue.

  This is a local queue to which the queue manager writes (transparently to the programmer) a trigger message when certain conditions are met on another local queue, for example, when a message is put into an empty message queue or in a transmission queue. Two WebSphere MQ applications monitor initiation queues and read trigger messages, the trigger monitor and the channel initiator. The *trigger manager* can start applications, depending on the message. The *channel initiator* starts the transmission between queue managers.

- Dead-letter queue

  A queue manager (QM) must be able to handle situations when it cannot deliver a message, for example:

  - Destination queue is full.
  - Destination queue does not exist.
  - Message puts have been inhibited on the destination queue.
  - Sender is not authorized to use the destination queue.
  - Message is too large.
  - Message contains a duplicate message sequence number.

  When one of these conditions occurs, the message is written to the dead-letter queue. This queue is defined when the queue manager is created, and each QM should have one. It is used as a repository for all messages that cannot be delivered.

15.1.8 What is a channel?

A *channel* is a logical communication link. The conversational style of program-to-program communication requires the existence of a communications connection between each pair of communicating applications. Channels shield applications from the underlying communications protocols.

WebSphere MQ uses two kinds of channels:

- Message channel

A message channel connects two queue managers through message channel agents (MCAs). A message channel is unidirectional, comprised of two message channel agents (a sender and a receiver) and a communication protocol. An MCA transfers messages from a transmission queue to a communication link, and from a communication link to a target queue. For bidirectional communication, it is necessary to define a *pair* of channels, consisting of a sender and a receiver.

- MQI channel

  An MQI channel connects a WebSphere MQ client to a queue manager. Clients do not have a queue manager of their own. An MQI channel is bidirectional.

15.1.9 Data integrity

A business might require two or more distributed databases to be maintained in step. WebSphere MQ offers a solution involving multiple units of work acting asynchronously, as shown in Figure 15-3.

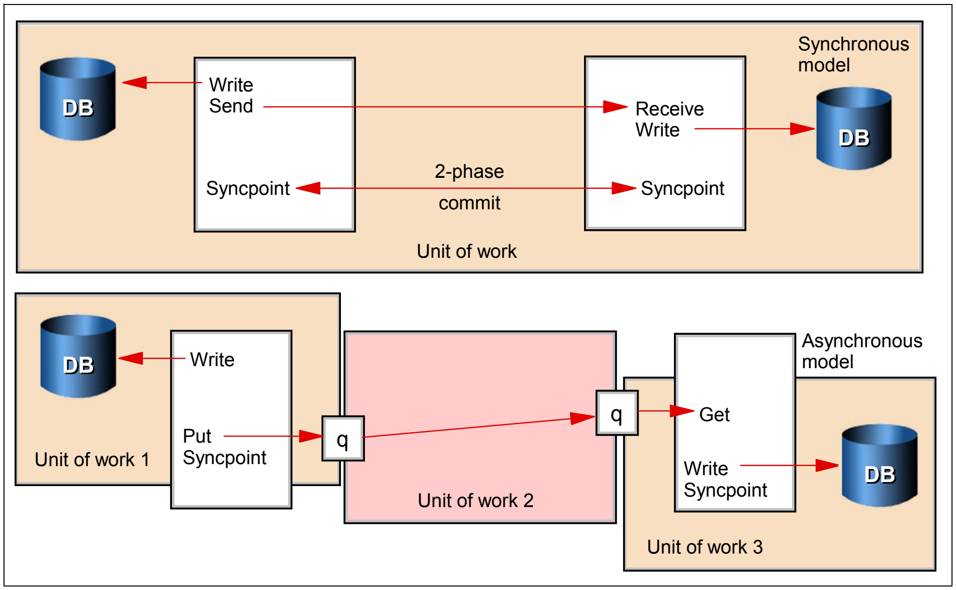


Figure 15-3 Data integrity

The top half of Figure 15-3 shows a two-phase commit structure, while the WebSphere MQ solution is shown in the lower half, as follows:

- The first application writes to a database, places a message on a queue, and issues a syncpoint to commit the changes to the two resources. The message contains data which is to be used to update a second database on a separate system. Because the queue is a remote queue, the message gets no further than the transmission queue within this unit of work. When the unit of work is committed, the message becomes available for retrieval by the sending MCA.

- In the second unit of work, the sending MCA gets the message from the transmission queue and sends it to the receiving MCA on the system with the second database, and the receiving MCA places the message on the destination queue. This is performed reliably because of the assured delivery property of WebSphere MQ. When this unit of work is committed, the message becomes available for retrieval by the second application.
- In the third unit of work, the second application gets the message from the destination queue and updates the database using the data contained in the message.

It is the transactional integrity of units of work 1 and 3, and the once and once only, assured delivery property of WebSphere MQ used in unit of work 2, which ensures the integrity of the complete business transaction.

If the business transaction is a more complex one, many units of work may be involved.

15.2 Online example

Now let's return to the earlier example of a travel agency to see how messaging facilities play a role in booking a vacation. Assume that the travel agent must reserve a flight, a hotel room, and a rental car. All of these reservations must succeed before the overall business transaction can be considered complete (Figure 15-4).

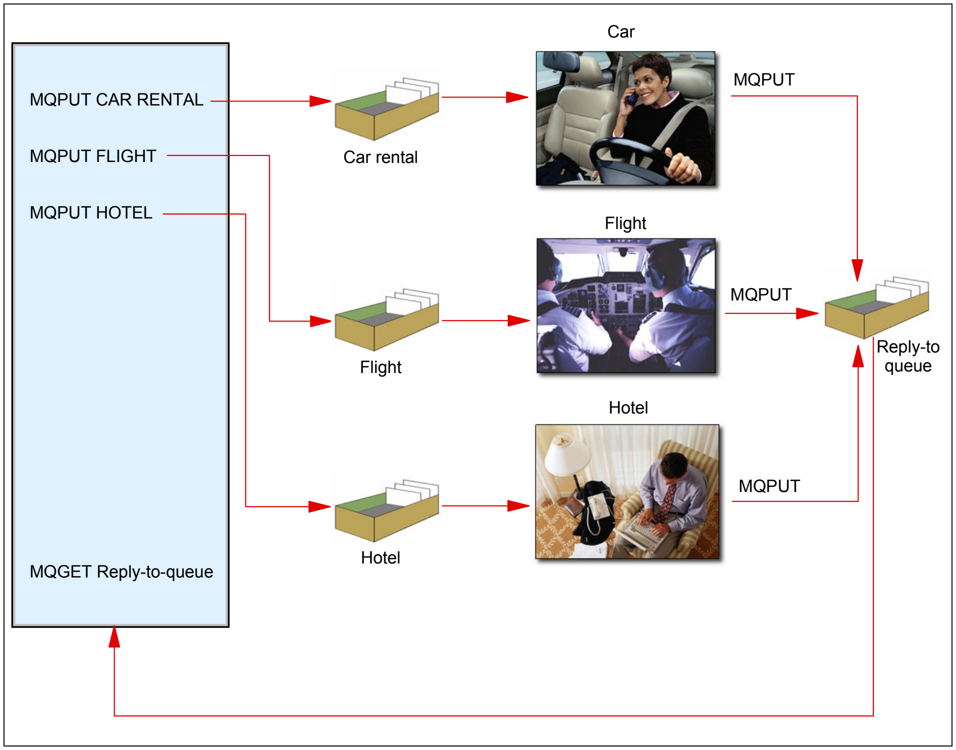


Figure 15-4 Parallel processing

With a message queue manager such as WebSphere MQ, the application can send several requests at once; it need not wait for a reply to one request before sending the next. A message is placed on each of three queues, serving the flight reservations application, the hotel reservations application, and the car rental application. Each application can then perform its respective task in parallel with the other two and place a reply message on the reply-to queue. The agent's application waits for these replies and produces a consolidated answer for the travel agent.

Designing the system in this way can improve the overall response time. Although the application might normally process the replies only when they have all been received, the program logic may also specify what to do when only a partial set of replies is received within a given period of time.

15.3 Interfacing with CICS, IMS, batch, or TSO/E

WebSphere MQ is available for a variety of platforms. WebSphere MQ for z/OS includes several adapters to provide messaging and queuing support for:

- CICS: the WebSphere MQ-CICS bridge
- IMS: the WebSphere MQ-IMS bridge
- Batch or TSO/E

15.4 Summary

In an online application environment, messaging and queueing enables communication between applications on different platforms. IBM WebSphere MQ for z/OS is an example of software that manages messaging and queuing in the mainframe and other environments. With messaging, programs communicate by through messages, rather than by calling each other directly. With queuing, messages are retained on queues in storage, so that programs can run independently of each other (asynchronously).

Here are some of the functional benefits of WebSphere MQ:

1. A common application programming interface, the MQI, which is consistent across the supported platforms.
2. Data transfer data with assured delivery. Messages are not lost, even if a system fails. Nor is there duplicate delivery of messages.
3. Asynchronous communication. That is, communicating applications need not be active at the same time.
4. Message-driven processing as a style of application design. An application is divided into discrete functional modules that can run on different systems, be scheduled at different times, or act in parallel.
5. Application programming is made faster when the programmer is shielded from the complexities of the network.

Key terms in this chapter		
local queue	channel	message-driven
MQI	asynchronous application	dead-letter queue
QM	remote queue	syncpoint

15.5 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. List the reason to use messaging and queuing
2. Describe the asynchronous flow of messages

3. Explain the function of a queue manager
4. List three zSeries-related adapters
5. Why is messaging and queuing needed for communication between heterogeneous applications and platforms?
6. Why would you use asynchronous processing?

15.6 Exercises

System programming on z/OS

In this part we reveal the inner workings of z/OS with discussions of system libraries, security, and procedures for starting (IPLing) and stopping a z/OS system. This part also includes chapters on hardware details and virtualization, and the clustering of multiple z/OS systems in a *sysplex*.

16

Topics in z/OS system programming

Objective: As a z/OS system programmer, you need to know how z/OS works.

After completing this chapter, you will be able to:

- Discuss the responsibilities of a z/OS system programmer.
- Explain system libraries, their use, and methods for managing their content.
- Configure consoles.
- IPL a system.

16.1 The role of the system programmer

When a new application is to be added to a system, a number of tasks need to be performed before the application can be used by end users. For example, a production control analyst is needed to add batch applications into the batch scheduling package, add the new procedures to a procedure library, and set up the operational procedures.

A system programmer is needed to perform tasks concerned with the system itself, such as setting up security privileges and adding programs to system libraries. The programmer is also involved with setting up any automation for the new application.

In a large installation there may be a division of duties. The system programmer may be responsible for a number of these. The following roles (and more) exist:

- z/OS system programmer
- CICS system programmer
- Database system programmer
- Database administrator
- Network system programmer
- Automation specialist
- Security manager
- Hardware management
- Production control analyst
- System operator
- Network operator
- Security administrator
- Service manager

The role of the system programmer is to install, customize, and maintain the operating system. The z/OS operating system runs on various hardware configurations. The system programmer must define the hardware I/O configuration resources that are to be available to the operating system. The hardware can be used in two modes:

- Basic mode

  This refers to a central processor mode that does not use logical partitioning. With one central processor, one copy of the z/OS operating system runs in the machine.

- LPAR mode

  This refers to logically partitioned (LPAR) mode, which is a central processor complex (CPC) Power-on Reset mode that enables use of the PR/SM™ feature and allows an operator to allocate CPC hardware resources (including central processor central storage, expanded storage, and channel paths) to logical partitions. A z/Series operating system runs in each LPAR in the machine, but does not necessarily run z/OS in each one.

Hardware is discussed further in Chapter 19, “Hardware systems and LPARs” .

There is often a "separation of duties" in system programming. This is usually an audit requirement—ensuring that one person does not have too much power on a system. On a test system, however, a single person may have to perform all the roles, including being the operator, and this is often the best way to learn how everything works.

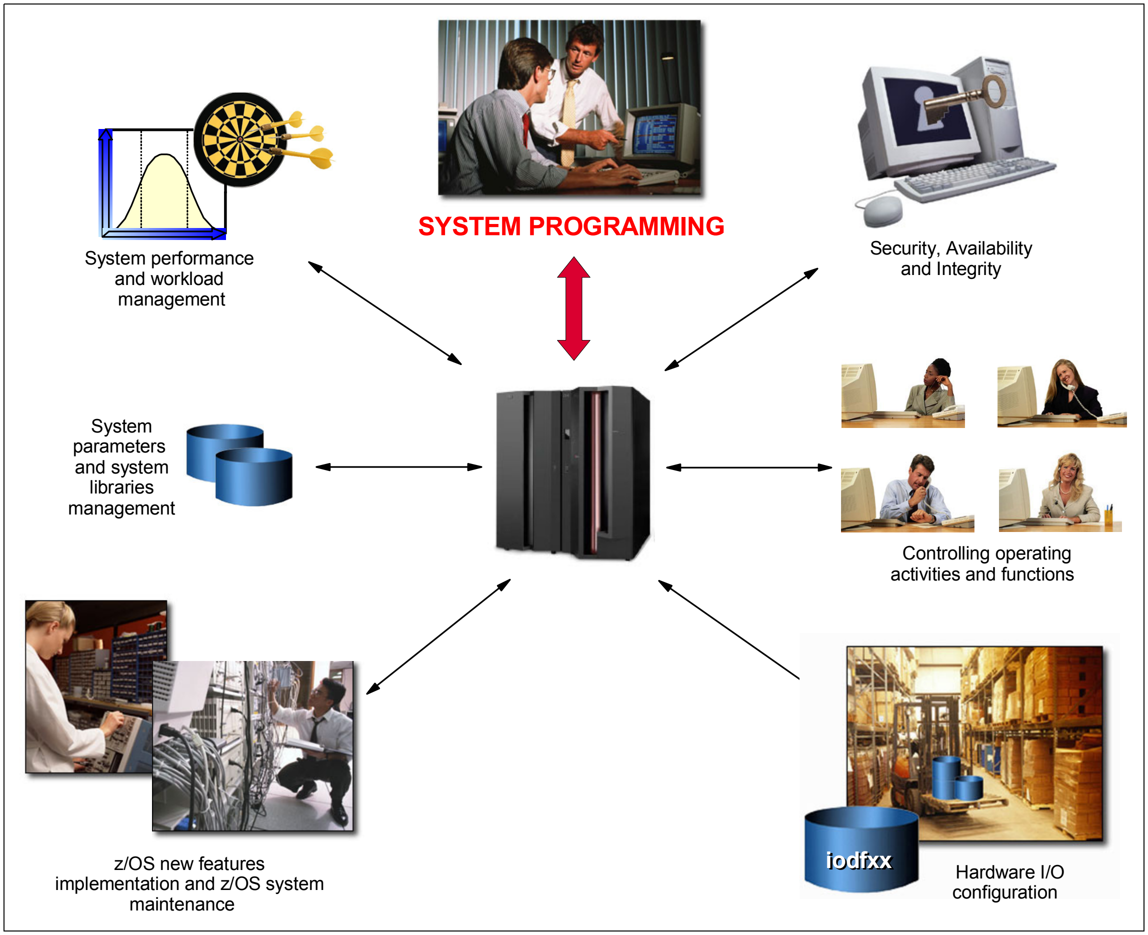


Figure 16-1 Systems programming overview

z/OS system programming covers the following areas:

- z/OS operational system administration
- Workload management
- System performance
- Job flow
- I/O device management
- Security

- Integrity
- Availability
- Change control
- z/OS operation
- z/OS production control

In the following sections, we discuss these areas in greater detail and discuss how they relate to the responsibilities of the system programmer.

It is clear that the job of a z/OS system programmer is very complex and requires skills in many aspects of the system, such as:

- Device I/O configurations
- Processor configurations
- Console definitions
- System libraries where the software is placed
- System data sets and their placement
- Customization parameters that are used to define your z/OS configuration
- Security administration

16.1.1 z/OS operational system administration

This administration includes the following topics:

- Customization parameters that are used to define the z/OS configuration
- z/OS implementation and maintenance
- System libraries where the software is located, and system data sets and their placement
- z/OS system address spaces and control of subsystems (*MASTER*, JES2, CATALOG, etc.)
- Real and virtual storage considerations when installing and customizing a z/OS operating system environment

16.1.2 Workload management

Workload management is the combined cooperation of various subsystems (CICS, IMS/ESA®, JES, APPC, TSO/E, z/OS UNIX System Services, DDF, DB2, SOM®, LSFM, and Internet Connection Server) with the Workload Manager z/OS component. Workload Manager (WLM) provides a solution for managing workload distribution, workload balancing, and distributing resources to competing workloads. WLM is a policy-driven task, and there are often different policies in effect at various times of the day. For example, there may be a daytime policy where online tasks have priority, and a nighttime policy where batch jobs are more important.

16.1.3 System performance

The task of "tuning" a system is an iterative and continuous process, and it is the discipline that most directly impacts all users of system resources in an enterprise. The controls offered by WLM are only one aspect of this process. Initial tuning consists of selecting appropriate parameters for various system components and subsystems. Once the system is operational and criteria have been established for the selection of jobs for execution via job classes and priorities, WLM controls the distribution of available resources according to the parameters specified by the installation.

WLM, however, can only deal with available resources. If these are inadequate to meet the needs of the installation, even optimal distribution may not be the answer; other areas of the system should be examined to determine the possibility of increasing available resources.

When requirements for the system increase and it becomes necessary to shift priorities or acquire additional resources (such as a larger processor, more storage, or more terminals), the WLM parameters might have to be adjusted to reflect changed conditions.

16.1.4 Job flow

z/OS uses a job entry subsystem (JES) to receive jobs into the operating system, to schedule them for processing by z/OS, and to control their output processing. JES is the component of the operating system that provides supplementary job management, data management, and task management functions such as scheduling, control of job flow, and spooling.

16.1.5 I/O device management

The I/O configuration to the operating system (software) and the channel subsystem (hardware) must be defined. The Hardware Configuration Definition (HCD) component of z/OS consolidates the hardware and software I/O configuration processes under a single interactive end-user interface. The output of HCD is an I/O definition file (IODF), which contains I/O configuration data. An IODF is used to define multiple hardware and software configurations to the z/OS operating system.

When a new IODF is activated, HCD defines the I/O configuration to the channel subsystem and/or the operating system. With the HCD activate function or the z/OS ACTIVATE operator command, changes can be made in the current configuration without having to initial program load (IPL) the software or power-on reset (POR) the hardware. Making changes while the system is running is known as *dynamic configuration* or *dynamic reconfiguration*.

16.1.6 Security

Data security is the protection of data against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. A security system must be installed in the operating system by a system programmer to maintain the resources necessary to meet the security objectives. The system programmer has the overall responsibility, using the technology available, of transforming the objectives of the security policy into a usable plan. (See Chapter 17., “Security on z/OS” on page 17-1.)

16.1.7 Integrity

An operating system is said to have *system integrity* when it is designed, implemented and maintained to protect itself against unauthorized access, and does so to the extent that security controls specified for that system cannot be compromised. Specifically for z/OS, this means that there must be no way for any unauthorized program, using any system interface, defined or undefined, to do the following:

- Obtain control in an authorized state
- Bypass store or fetch protection
- Bypass OS password, VSAM password, or RACF security checking

16.1.8 Availability

The software products supporting system programmers and operators in managing their systems heavily influence the complexity of their job and their ability to keep system availability at a high level.

Installations need to ensure that their system and its services are available and operating to meet service level agreements. Installations with 24-hour, 7-day operations need to plan for minimal disruption of their operation activities. In terms of z/OS operations, how the installation establishes console recovery or whether an operator must re-IPL a system to change processing options are important planning considerations.

16.1.9 Change control

Data center management is typically held accountable for Service Level Agreements (SLAs), often through a specialist team of service managers. Change control mechanics and practices in a data center are implemented to ensure that SLAs are met.

Implementation of change

The implementation of any change must be under the control of the Operations staff. When a change is introduced into a production environment that results in problems or instability, Operations staff are responsible for observing, reporting, and then managing the activities required to correct the problem or back out the change.

Although system programmers will normally raise and implement their own changes, sometimes changes are based on a request via the change management system. Any instructions for Operations or other groups would be in the change record, and the approval of each group is required.

Implementing business application changes would normally be handled by a production control analyst. Application changes will normally reside in test libraries, and an official request (with audit trail) would result in the programs in the test libraries being promoted to the production environment.

Procedures involved in the change must be circulated to all interested parties. When all parties consider the change description to be complete, then it is considered for implementation and either scheduled, deferred, or possibly rejected.

The factors that need to be considered when planning a change are:

- The benefits that will result from the change
- What will happen if the change is not done
- The resources required to implement the change
- The relative importance of the change request compared to others
- Any interdependency of change requests

All change involves risk. One of the advantages of the mainframe is the very high availability that it offers. All change must therefore be carefully controlled and managed. A high proportion of any system programmer's time is involved in the planning and risk assessment of change. One of the most important aspects of change is how to reverse it and go back to the previous state.

Risk assessment

It is common practice for data center management to have a weekly change control meeting to discuss, approve, or reject changes. These changes might be for applications, a system, a network, hardware, or power.

An important part of any change is *risk assessment,* in which the change is considered and evaluated from the point of view of risk to the system. Low risk changes may be permitted during the day, while higher risk changes would be scheduled for an outage slot.

It is also common practice for a data center to have periods of low and high risk, which will influence decisions. For example, if the system runs credit authorizations, then the periods around major public holidays are usually extremely busy and may cause a change freeze. Also, annual sales are extremely busy periods in retailing and may cause changes to be rejected.

IT organizations achieve their goals through disciplined change management processes and policy enforcement. These goals include:

- High service availability
- Increased security
- Audit readiness
- Cost savings

Change control record system

A *change control record system* is typically in place to allow for the requesting, tracking, and approval of changes. This is usually the partner of a *problem management system*. For example, if a production system has a serious problem on a Monday™ morning, then one of the first actions will be to examine the changes that were implemented over the weekend to determine if these have any bearing on the problem.

These records also show that the system is under control, which is often necessary to prove to auditors, especially in the heavily regulated financial services sector. The Sarbanes-Oxley Act of 2002 in the United States, which addresses corporate governance, has established the need for an effective internal control system. Demonstrating strong change management and problem management in IT services is part of compliance with this measure. Additionally, the 8th Directive on Company Law in the European Union, which is under discussion at the time of writing, will address similar areas to Sarbanes-Oxley.

For these reasons, and at a bare minimum, before any change is implemented there should be a set of controlled documents defined, which are known as *change request forms.* These should include the following:

- Who - that is, the department, group or person that requires the change, who is responsible for implementing the change, completing the successful test and responsible for backout if required. Also who will "sign off" the change as successful.
- What - that is, the affected systems or services (for example e-mail, file service, domain, etc.). Include as much detail as possible. Ideally, complete instructions should be included so that the change could be performed by someone else in an emergency.
- Where - that is, scope of change, the business units, buildings, departments or groups affected or required to assist with the change.
- When - that is, start date and time and estimated duration of the change. There are often three dates: requested, scheduled. and actual.
- Priority - that is, high, medium, low, business as usual, emergency, dated (for example clock change).
- Risk - that is, high, medium, low
- Impact - that is, what will happen if the change is implemented; what will happen if it is not; what other systems may be affected; what will happen if something unexpected occurs.

16.1.10 z/OS operation

Operating z/OS involves managing hardware such as processors and peripheral devices (including the consoles where your operators do their work); and software such as the z/OS operating control system, the job entry subsystem, subsystems (such as NetView®) that can control automated operations, and all the applications that run on z/OS.

The operation of a z/OS system involves the following:

- Message and command processing that forms the basis of operator interaction with z/OS and the basis of z/OS automation
- Console operations, or how operators interact with z/OS to monitor or control the hardware and software

Planning z/OS operations for a system must take into account how operators use consoles to do their work and how to manage messages and commands. The system programmer needs to ensure that operators receive the necessary messages at their consoles to perform their tasks, and select the proper messages for suppression, automation, or other kinds of message processing.

Because messages are also the basis for automated operations, the system programmer needs to understand message processing to plan z/OS automation.

As more installations make use of multisystem environments, the need to coordinate the operating activities of those systems becomes crucial. Even for single z/OS systems, an installation needs to think about controlling communication between functional areas (such as a tape-pool library and the master console area, for example). In both single and multisystem environments, the commands that operators can enter from consoles can be a security concern that requires careful coordination. As a planner, the system programmer needs to make sure that the right people are doing the right tasks when they interact with z/OS.

Configuring consoles

A *console configuration* consists of the various consoles that operators use to communicate with z/OS. Your installation first defines the I/O devices it can use as consoles with the hardware configuration definition (HCD). HCD manages the I/O configuration for the z/OS system. Once the devices have been defined, z/OS is told which devices to use as consoles by specifying the appropriate device numbers in the CONSOLxx PARMLIB member.

Generally, operators on a z/OS system receive messages and enter commands on MCS and SMCS consoles. They can use other consoles (such as NetView consoles) to interact with z/OS, but here we describe MCS and SMCS consoles and how to plan for their use.

MCS consoles are devices that are locally attached to a z/OS system and provide the basic communication between operators and z/OS. (MCS consoles are attached to control devices that do *not* support systems network architecture (SNA) protocols.)

SMCS consoles are devices that do not have to be locally attached to a z/OS system and provide the basic communication between operators and z/OS. SMCS consoles use z/OS Communications Server to provide communication between operators and z/OS, instead of direct I/O to the console device.

The system programmer defines MCS and SMCS consoles in a console configuration according to their functions. For example, one console can function as a master console for the system. Important messages that require action can be directed to the operator, who can act by entering commands on the console. Another console can act as a monitor to display messages to an operator working in a functional area like a tape pool library, or to display messages about printers at your installation.

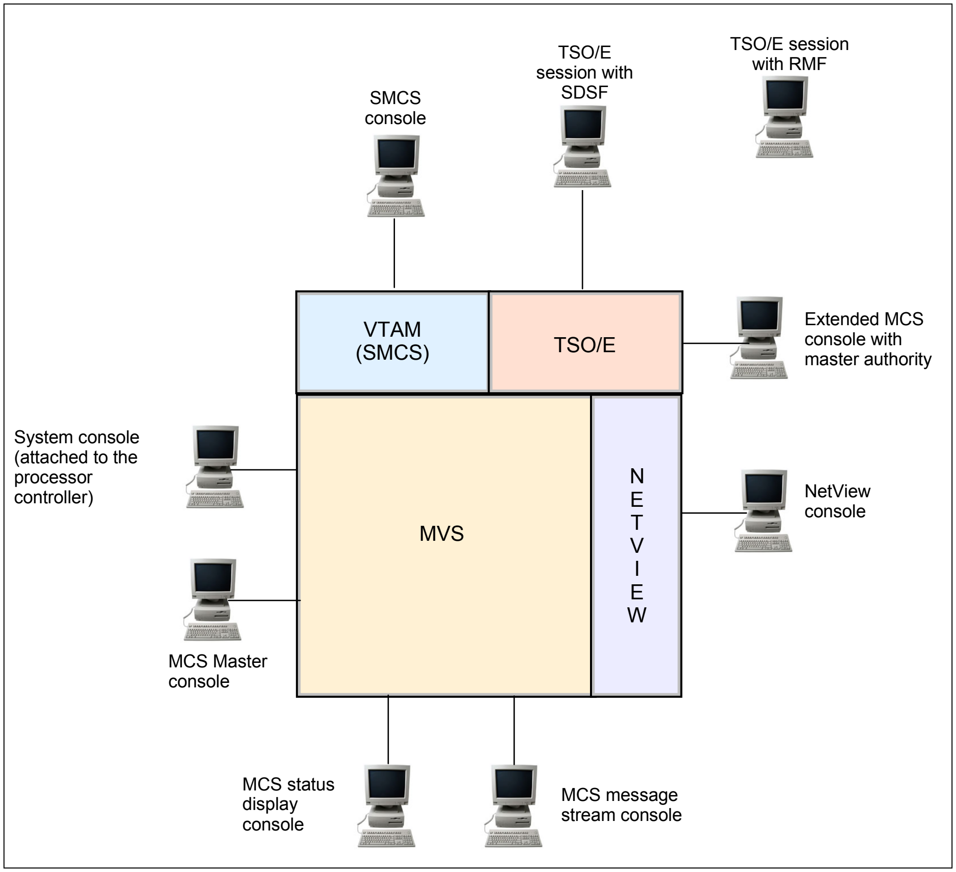


Figure 16-2 Sample console configuration for a z/OS system

Figure 16-2 shows a console configuration for a z/OS system that also includes the system console, an SMCS console, NetView, and TSO/E.

The *system console* function is provided as part of the Hardware Management Console (HMC). An operator can use the system console to initialize z/OS and other system software, and during recovery situations when other consoles are unavailable.

In addition to MCS and SMCS consoles, the z/OS system shown in Figure 16-2 has a NetView console defined to it. NetView works with system messages and command lists to help automate z/OS operator tasks. Many system operations can be controlled from a NetView console.

Users can monitor many z/OS system functions from TSO/E terminals. Using the System Display and Search Facility (SDSF) and the Resource Measurement Facility (RMF™), TSO/E users can monitor z/OS and respond to workload balancing and performance problems. An authorized TSO/E user can also initiate an extended MCS console session to interact with z/OS.

The MCS consoles shown in Figure 16-2 are:

- An MCS master console from which an operator can view messages and enter all z/OS commands

  This console is in full capability mode because it can receive messages and accept commands. An operator can control the operations for the z/OS system from an MCS or SMCS master console.

- An MCS status display console

  An operator can view system status information from DEVSERV, DISPLAY, TRACK, or CONFIG commands. However, because this is a status display console, an operator cannot enter commands from the console. An operator on a full capability console can enter these commands and route the output to a status display console for viewing.
  Note: an SMCS console cannot be a status display console.

- An MCS message-stream console

  A message-stream console can display system messages. An operator can view messages routed to this console. However, because this is a message-stream console, an operator cannot enter commands from here. Routing codes and message level information for the console are defined so that the system can direct relevant messages to the console screen for display. Thus, an operator who is responsible for a functional area like a tape pool library, for example, can view MOUNT messages. An SMCS console cannot be a message stream console.

In many installations, this proliferation of screens has been replaced by operator workstations that combine many of these screens onto one windowed display. Generally, the hardware console is separate, but most other terminals are combined. The systems are managed by alerts for exception conditions from the automation product.

The 2074 Console Support controller is the modern way of connecting consoles. It can replace several older control units, connecting to several images to provide consoles via a TN3270 connection (telnet).

16.1.11 z/OS production control

Production control usually involves a specialized staff to manage batch scheduling, using a tool such as Tivoli® Workload Scheduler to build and manage a complex batch schedule. This work might involve daily and weekly backups running at particular points within a complex sequence of application suites. Databases and online services might also be taken down and brought back up as part of the schedule. While making such changes, production conrol often needs to accommodate public holidays and other special events such as (in the case of a retail sales business) a winter sale.

Production control is also responsible for taking a programmer's latest program and releasing it to production. This task typically involves moving the source code to a secure production library, recompiling the code to produce a production load module, and placing that module in a production load library. JCL is copied and updated to production standards and placed in appropriate procedure libraries, and application suites added to the job scheduler.

There may also be an interaction with the system programmer if a new library needs to be added to the linklist, or authorized.

16.2 z/OS system libraries

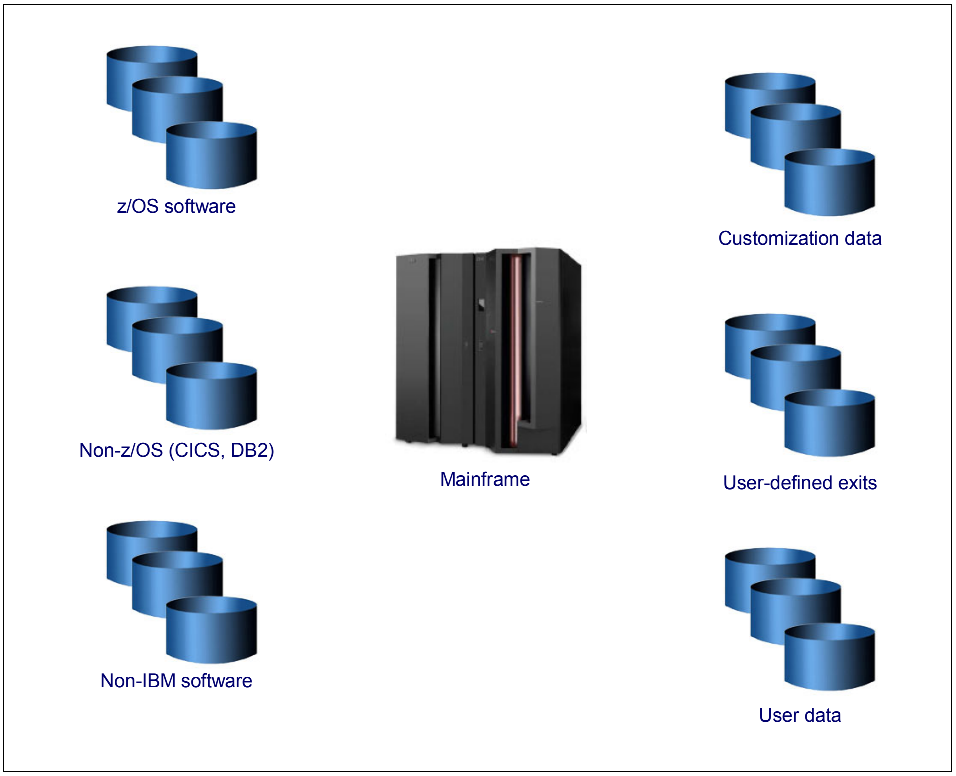


Figure 16-3 Types of data

As can be seen in Figure 16-3, different types of data exist in a system.

First there is the z/OS software as supplied by IBM. This is usually installed to a series of disk volumes known as the system residence volumes (SYSRES).

Much of the flexibility of z/OS is built on these SYSRES sets. They make it possible to apply maintenance to a new set that is cloned from the production set while the current set is running production work. A short outage can then be taken to IPL from the new set—and the maintenance has been implemented! Also, the change can be backed out by IPLing from the old set.

Fixes to z/OS are managed with a product called System Management Program/Extended (SMP/E). Indirect cataloging using system symbols is used so that a particular library is cataloged as being on, for example, SYSRES volume 2, and the name of that volume is resolved by the system at IPL time from the system symbols. Symbols are discussed in 16.3, “System symbols” on page 16-20.

Another group of volumes are the non-z/OS and non-IBM software volumes. These may be combined into one group. The majority of non-z/OS software is not usually on the SYSRES volumes, as the SYSRES sets are usually managed as one entity by SMP/E. The other software is usually managed separately. These volumes do not form part of the SYSRES sets, and therefore there is only one copy of each library. As many volumes as required can be added to this group, each with an individual disk name.

Customization data refers to items such as SYS1.PARMLIB, SYS1.PROCLIB, the master catalog, the IODF, page data sets, JES spools, and other items essential to the running of the system. It is also where SMP/E data is stored to manage the software.

These data sets are not always located on separate DASD volumes from IBM-supplied z/OS software; some installations place the PARMLIB and PROCLIB on the first SYSRES pack, others place them on the master catalog pack. This is a matter of choice and is dependent on how the SYSRES volumes are managed. Each installation will have a preferred method.

On many systems, some of the IBM-supplied defaults are not appropriate so they need to be modified. User exits and user modifications (usermods) are made to IBM code so that it will behave as the installation requires. The modifications are usually managed using SMP/E.

Finally, there is *user data*, which is usually the largest pool of disk volumes. This is not part of the system libraries, but is presented here for completeness. It contains production, test and user data. It is often split into pools and managed by System Managed Storage (SMS), which can target data to appropriately managed volumes. For example, production data can be placed on volumes which are backed up daily, whereas user data may only be captured weekly and may be migrated to tape after a short period of inactivity to free up the disk volumes for further data.

z/OS has many standard system libraries, such as: SYS1.PARMLIB, SYS1.LINKLIB, SYS1.LPALIB, SYS1.PROCLIB, and SYS1.NUCLEUS. Some of these are related to IPL processing, while others are related to the search order of invoked programs or to system security, as described here:

- SYS1.PARMLIB contains control parameters for the whole system.
- SYS1.LINKLIB has many execution modules of the system.
- SYS1.LPALIB contains the system execution modules that are loaded into the link pack area when the system initializes.
- SYS1.PROCLIB contains JCL procedures distributed with z/OS.
- SYS1.NUCLEUS has the basic supervisor modules of the system.

16.2.1 SYS1.PARMLIB

SYS1.PARMLIB is a required partitioned data set that contains IBM-supplied and installation-created members. It must reside on a direct access volume, which can be the system residence volume. It is the most important data set in a z/OS operating system, and may be viewed as performing a function similar to /etc on a UNIX system.

The purpose of the PARMLIB is to provide many initialization parameters in a prespecified form in a single data set, and thus minimize the need for the operator to enter parameters.

All parameters and members of the SYS1.PARMLIB data set are described in *z/OS MVS Initialization and Tuning Reference,* SA22-7592. Some of the most important PARMLIB members are discussed in this section.

16.2.2 SYS1.LPALIB

The link pack area (LPA) is a section of the common area of an address space. It exists below the system queue area (SQA) and consists of the pageable link pack area (PLPA), then the fixed link pack area (FLPA), if one exists, and finally the modified link pack area (MLPA).

Link pack area (LPA) modules are loaded in common storage, shared by all address spaces in the system. Because these modules are reentrant and are not self-modifying, each can be used by a number of tasks in any number of address spaces at the same time. Modules found in LPA do not need to be brought into virtual storage because they are already in virtual storage.

Modules placed anywhere in the LPA are always in virtual storage, and modules placed in FLPA are also always in central storage. LPA modules must be referenced very often in order to prevent their pages from being stolen. When a page in LPA (other than in FLPA) is not continually referenced by multiple address spaces, it tends to be stolen.

16.2.3 Pageable link pack area (PLPA)

The PLPA is an area of common storage that is loaded at IPL time (when a cold start is done and the CLPA option is specified). This area contains read-only system programs, along with any read-only reenterable user programs selected by an installation that can be shared among users of the system. The PLPA and extended PLPA contain all members of SYS1.LPALIB and other libraries that are specified in the active LPALSTxx through the LPA parameter in IEASYSxx or from the operator’s console at system initialization (this would override the PARMLIB specification).

You may use one or more LPALSTxx members in SYS1.PARMLIB to concatenate your installation’s program library data sets to SYS1.LPALIB. You can also use the

LPALSTxx member to add your installation's read-only reenterable user programs to the pageable link pack area (PLPA). The system uses this concatenation, which is referred to as the *LPALST concatenation*, to build the PLPA during the nucleus initializing process. SYS1.LPALIB must reside in a direct access volume, which can be the system residence volume. Figure 16-4 shows an example of the LPALSTxx member.

```
 File  Edit  Edit_Settings  Menu  Utilities  Compilers  Test  Help
-------------------------------------------------------------------------------
EDIT      SYS1.PARMLIB(LPALST5B) - 01.01              Columns 00001 00072
Command ===>________________________________________  Scroll ===> CSR
******** ***************************** Top of Data ******************************
000001 SYS2.LPALIB,
000002 SYS1.LPALIB,
000003 SYS1.SERBLPA,
000004 SDF2.V1R4M0.SDGILPA,
000005 SYS1.SIATLPA,
000006 ING.SINGMOD3,
000007 NETVIEW.SCNMLPA1,
000008 REXX.V1R3M0.SEAGLPA,
000009 ISF.SISFLPA,
000010 EOY.SEOYLPA,
000011 SYS1.SBDTLPA,
000012 CEE.SCEELPA,
****** **************************** Bottom of Data ******************************
```

Figure 16-4 Example of LPALST PARMLIB member

16.2.4 Fixed link pack area (FLPA)

The FLPA is loaded at IPL time, with those modules listed in the active IEAFIXxx member of SYS1.PARMLIB. This area should be used only for modules that significantly increase performance when they are fixed rather than pageable. The best candidates for the FLPA are modules that are infrequently used, but needed for fast response.

Modules from the LPALST concatenation, the LNKLST concatenation, SYS1.MIGLIB, and SYS1.SVCLIB can be included in the FLPA. FLPA is selected through specification of the FIX parameter in IEASYSxx, which is appended to IEAFIX to form the IEAFIXxx PARMLIB member, or from the operator's console at system initialization.

Figure 16-5 shows an IEAFIX PARMLIB member; part of the modules for FLPA belong to the SYS1.LPALIB library.

```
 File  Edit  Edit_Settings  Menu  Utilities  Compilers  Test  Help
-------------------------------------------------------------------------------------------------------
EDIT      SYS1.PARMLIB(IEAFIX01) - 01.01                    Columns 00001 00072
Command ===>____________________________________________  Scroll ===> CSR
******** ***************************** Top of Data ****************************************
000001 INCLUDE LIBRARY(SYS1.LPALIB)
000002               MODULES (IEAVAR00,      /*  7K RCT INIT/TERM       */
000003                          IEAVAR06,    /*  RCT INIT/TERM ALIAS  */
000004                          IGC001G,     /*  456 RESTORE(SVC17)  */
000005                          ICHRFC00,    /*  RACF IMS/CICS          */
000006                          ICHRFR00)    /*  RACF IMS/CICS          */
000007 INCLUDE LIBRARY(SYS1.SVCLIB) MODULES(IGC09302)
********************************** Bottom of Data ***************************************
```

Figure 16-5 The IEAFIX PARMLIB member

16.2.5 Modified link pack area (MLPA)

The MLPA may be used to contain reenterable routines from APF-authorized libraries (see 17.7.1, "Authorized programs" on page 17-9) that are to be part of the pageable extension to the link pack area during the current IPL. Note that the MLPA exists only for the duration of an IPL. Therefore, if an MLPA is desired, the modules in the MLPA must be specified for each IPL (including quick start and warm start IPLs). When the system searches for a routine, the MLPA is searched before the PLPA. The MLPA can be used at IPL time to temporarily modify or update the PLPA with new or replacement modules.

16.2.6 SYS1.PROCLIB

SYS1.PROCLIB is a library that participates both in system initialization and in normal operations.

16.2.7 The master scheduler subsystem

The *master scheduler subsystem* is used to establish communication between the operating system and the primary job entry subsystem, which can be JES2 or JES3. When you start z/OS, master initialization routines initialize system services, such as the system log and communication task, and start the master scheduler address space, which becomes address space number one (ASID=1).

Then, the master scheduler may start the job entry subsystem (JES2 or JES3). JES is the primary job entry subsystem. On many production systems JES is not started immediately; instead, the automation package starts all tasks in a controlled sequence. Then other defined subsystems are started. All subsystems are defined in the PARMLIB library, member IEFSSNxx. These subsystems are *secondary subsystems*.

An initial MSTJCL00 load module can be found in SYS1.LINKLIB library. If modifications are required, the recommended procedure is to create a MSTJCLxx PARMLIB member. The suffix is specified by the MSTRJCL parameter in the IEASYSxx PARMLIB member. The MSTJCLxx member is commonly called *master JCL*. It contains data definition (DD) statements for all system input and output data sets that are needed to do the communication between the operating system and JES.

Example 16-1 shows a sample MSTJCLxx PARMLIB member.

Example 16-1 Sample master JCL

```
//MSTJCL05 JOB MSGLEVEL=(1,1),TIME=1440
//EXEC PGM=IEEMB860
//STCINRDR DD SYSOUT=(A,INTRDR)
//TSOINRDR DD SYSOUT=(A,INTRDR)
//IEFPDSI DD DSN=SYS1.PROCLIB,DISP=SHR
//IEFPARM DD DSN=SYS1.PARMLIB,DISP=SHR
//SYSUADS DD DSN=SYS1.UADS,DISP=SHR
//SYSLBC DD DSN=SYS1.BRODCAST,DISP=SHR
```

When the master scheduler has to process the start of a started task, the system determines whether the START command refers to a procedure or to a job. If the IEFJOBS DD exists in the MSTJCLxx member, the system searches the IEFJOBS DD concatenation for the member requested in the START command.

If there is no member by that name in the IEFJOBS concatenation, or if the IEFJOBS concatenation does not exist, the system searches the IEFPDSI DD for the member requested in the START command. If a member is found, the system examines the first record for a valid JOB statement and, if one exists, uses the member as the JCL source for the started task. If the member does not have a valid JOB statement in its first record, the system assumes that the source JCL is a procedure and creates JCL to invoke the procedure.

After the JCL source has been created (or found), the system processes the JCL. As shipped, MSTJCL00 contains an IEFPDSI DD statement that defines the data set that contains procedure source JCL for started tasks. Normally this data set is SYS1.PROCLIB; it may be a concatenation. For useful work to be performed, SYS1.PROCLIB must at least contain the procedure for the primary JES, as shown in next section.

16.2.8 A job procedure library

SYS1.PROCLIB contains the JES2 cataloged procedure. This procedure defines the job-related procedure libraries, as shown in Example 16-2.

Example 16-2 How to specify procedure libraries in the JES2 procedure

```
//PROC00 DD  DSN=SYS1.PROCLIB,DISP=SHR
//         DD  DSN=SYS3.PROD.PROCLIB,DISP=SHR
//PROC01 DD  DSN=SYS1.PROC2,DISP=SHR
...
//PROCNN DD  DSN=SYS1.LASTPROC,DISP=SHR
...
```

Many installations have very long lists of procedure libraries in the JES procedure. This is because JCLLIB is a relatively recent innovation.

Note: Care should be taken as to the number of users who can delete these libraries, because JES will not start if one is missing. Normally a library that is in use cannot be deleted, but JES does not hold these libraries although it uses them all the time.

Programmers can override the default specification by specifying a `/*JOBPARM PROCLIB=` statement; then, in the name of the procedure library, they must code the name of the DD statement in the JES2 procedure that points to the library they want to use. For example, let's assume that you run a job in class A. That class has a default PROCLIB of SYS1.PROCLIB. If you want to use a procedure that resides in SYS1.LASTPROC, you'll need to include a `/*JOBPARM PROCLIB=PROCnn` in the JCL (see Example 16-2).

There is another way to specify a procedure library, which is to use the JCLLIB JCL statement. This statement allows you to code and use procedures without using system procedure libraries. The system searches the libraries in the order in which you specify them on the JCLLIB statement, prior to searching any unspecified default system procedure libraries.

Example 16-3 shows the use of the JCLLIB statement.

Example 16-3 Sample JCLLIB statement

```
//MYJOB   JOB
//MYLIBS  JCLLIB   ORDER=(MY.PROCLIB.JCL,SECOND.PROCLIB.JCL)
//S1      EXEC PROC=MYPROC1
...
```

Assuming that the system default procedure library includes SYS1.PROCLIB only, the system searches the libraries for procedure `MYPROC1` in the following order:

1. MY.PROCLIB.JCL
2. SECOND.PROCLIB.JCL
3. SYS1.PROCLIB

16.3 System symbols

System symbols are elements that allow different z/OS systems to share PARMLIB definitions while retaining unique values in those definitions. System symbols act like variables in a program; they can take on different values, based on the input to the program. When you specify a system symbol in a shared PARMLIB definition, the system symbol acts as a “placeholder”. Each system that shares the definition replaces the system symbol with a unique value during initialization.

Each system symbol has a name (which begins with an ampersand (&) and optionally ends with a period (.)) and a substitution text, which is the character string that the system substitutes for a symbol each time it appears.

There are two types of system symbols:

dynamic The substitution text can change at any point in an IPL.

static The substitution text is defined at system initialization and remains fixed for the life of an IPL.

There are symbols that are reserved for system use. You can display the symbols in your system by issuing the **D SYMBOLS** command, as Example 16-4 shows:

Example 16-4 Partial output of the D SYMBOLS command

```
HQX7708 -----------------  SDSF PRIMARY OPTION MENU  --
COMMAND INPUT ===> /D SYMBOLS
 RESPONSE=SC67
  IEA007I STATIC SYSTEM SYMBOL VALUES 378
          &SYSALVL.  = "2"
          &SYSCLONE. = "67"
          &SYSNAME.  = "SC67"
          &SYSPLEX.  = "WTSCPLX1"
          &SYSR1.    = "Z05RD1"
          &ALLCLST1. = "CANCEL"
          &CIC13SET. = "A"
          &CIC22SET. = "A"
          &CIC22VOL. = "TOTCIC"
          &CIC23SET. = "B"
          &CIC23VOL. = "TOTCID"
          &CIC31SET. = "A"
          &CIC31VOL. = "TOTCIJ"
          &CMDLIST1. = "67,00"
          &COMMDSN1. = "COMMON"
          &CPCNAME.  = "P801"
          &CPENABLE. = "(0,0)"
          &DB2LINKL. = "DB2V8"
```

The IEASYMxx PARMLIB member provides a single place to specify system parameters for each system in a multisystem environment. IEASYMxx contains statements that define static system symbols and specify IEASYSxx PARMLIB members that contain system parameters (the SYSPARM statement). Example 16-5 shows an IEASYMxx PARMLIB member.

Example 16-5 IEASYMxx PARMLIB member

```
SYSDEF HWNAME(SCZP801)
LPARNAME(A08)
SYSNAME(SC04)
SYSPARM(R3,04)
SYMDEF(&CPCNAME='P801')
SYMDEF(&DFHSMHST='ON')
SYMDEF(&SYSR2='ZXYSY2')
SYMDEF(&SYSR3='&SYSR1(1:5).3')
```

Here, &SYSNAME is replaced by the value of the name of the current system, so this single statement works for all the systems in the sysplex. &SYSR2 is used to define the name second system residence volume and &SYSR3 is used to define a third system residence volume. As you can see, the variables can be used to construct one another. &SYSR1 is system-defined as the first system residence volume.

System symbols are used in cases where multiple z/OS systems will share a single PARMLIB. Here the use of symbols allows individual members to be used with symbolic substitution, as opposed to having each system require a unique member. The LOADxx PARMLIB member specifies the IEASYMxx member that the system is to use.

16.4 Loading the system

An initial program load (IPL) is the act of loading a copy of the operating system from disk into the CPU's central storage and executing it.

z/OS systems are designed to run continuously with many months between reloads, allowing important production workloads to be continuously available. Change is the usual reason for a reload, and the level of change on a system dictates the reload schedule. For example:

- A test system may be IPLed daily or even more often.
- A high-availability banking system may only be reloaded once a year, or even less frequently, to refresh the software levels.
- Outside influences may often be the cause of IPLs, such as the need to test and maintain the power systems in the machine room.

- Sometimes badly behaved software uses up system resources that can only be replenished by an IPL, but this sort of behavior is normally the subject of investigation and correction.

Many of the changes that required an IPL in the past can now be done dynamically. Examples of these tasks are:

- Adding a library to the linklist for a subsystem such as CICS
- Adding modules to LPA

16.4.1 Initialization functions

System initialization process

The system initialization process (Figure 16-6 on page 16-23) prepares the system control program and its environment to do work for the installation. This process essentially consists of:

- System and storage initialization, including the creation of system component address spaces
- Master scheduler initialization and subsystem initialization

When the system is initialized and the job entry subsystem is active, the installation can submit jobs for processing by using the START, LOGON, or MOUNT command.

The initialization process begins when the system operator selects the LOAD function at the system console. z/OS locates all usable central storage that is online and available, and creates a virtual environment for the building of various system areas.

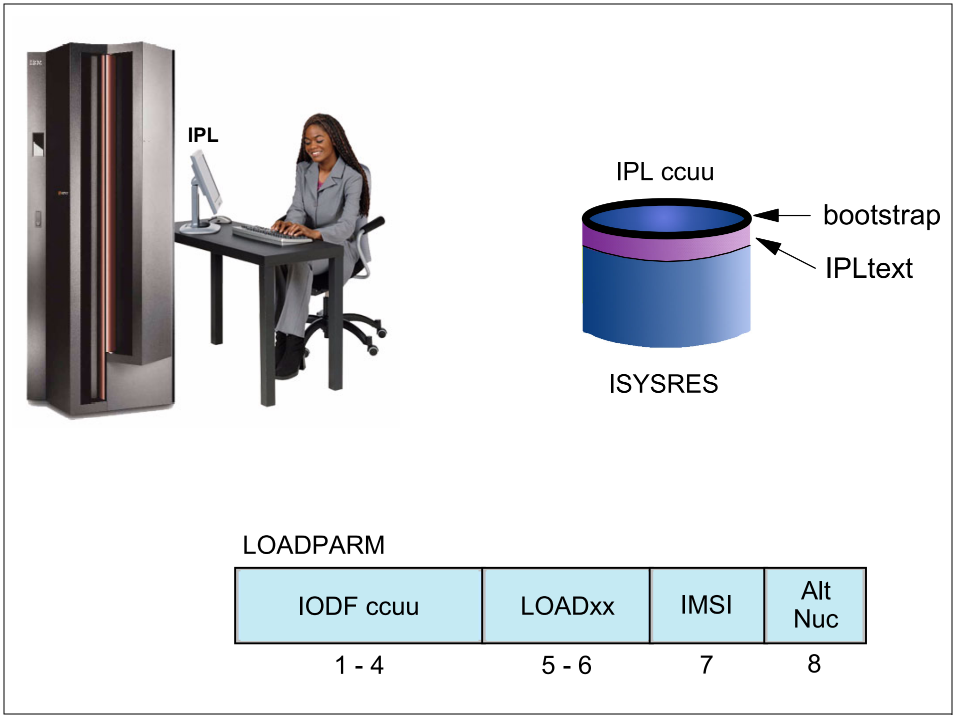


Figure 16-6 IPLing the machine

Not all disks attached to a CPU have loadable code on them. A disk that does is generally referred to as an “IPLable” disk, and more specifically as the SYSRES volume.

IPLable disks contain a bootstrap module at cylinder 0 track 0. At IPL, this bootstrap is loaded into storage at real address zero and control is passed to it. The bootstrap then reads the IPL control program IEAIPL00 (also known as IPL text) and passes control to it. This in turn starts the more complex task of loading the operating system and executing it.

After the bootstrap is loaded and control is passed to IEAIPL00, IEAIPL00 prepares an environment suitable for starting the programs and modules that make up the operating system, as follows:

1. It clears central storage to zeros before defining storage areas for the master scheduler.
2. It locates the SYS1.NUCLEUS data set on the SYSRES volume and loads a series of programs from it known as IPL Resource Initialization Modules (IRIMs).
3. These IRIMs begin creating the normal operating system environment of control blocks and subsystems.

Some of the more significant tasks performed by the IRIMs are as follows:

- Read the LOADPARM information entered on the hardware console at the time the IPL command was executed.
- Search the volume specified in the LOADPARM as containing the IODF data set for the LOADxx member–the value of *xx* is also taken from the LOADPARM. IRIM will first attempt to locate LOADxx in SYS0.IPLPARM. If this is unsuccessful, it will look for SYS1.IPLPARM, and so on, up to and including SYS9.IPLPARM. If at this point it still has not been located, the search continues in SYS1.PARMLIB.
- When a LOADxx member has been successfully located, it is opened and information including the nucleus suffix (unless overridden in LOADPARM), the master catalog name, and the suffix of the IEASYSxx member to be used, is read from it.
- Load the MVS nucleus.
- Initialize virtual storage in the master scheduler address space for the System Queue Area (SQA), the Extended SQA (ESQA), the Local SQA (LSQA), and the Prefixed Save Area (PSA). At the end of the IPL sequence, the PSA will replace IEAIPL00 at real storage location zero, where it will then stay.
- Initialize real storage management, including the segment table for the master scheduler, segment table entries for common storage areas, and the page frame table.

The last of the IRIMs then loads the first part of the Nucleus Initialization Program (NIP), which invokes the Resource Initialization Modules (RIMs), one of the earliest of which starts up communications with the NIP console defined in SYS1.NUCLEUS.

The system continues the initialization process, interpreting and acting on the system parameters that were specified. NIP carries out the following major initialization functions:

- Expands the SQA and the extended SQA by the amounts specified on the SQA system parameter.
- Creates the pageable link pack area (PLPA) and the extended PLPA for a cold start IPL; resets tables to match an existing PLPA and extended PLPA for a quick start or a warm start IPL. For more information about quick starts and warm starts, see *z/OS MVS Initialization and Tuning Reference.*
- Loads modules into the fixed link pack area (FLPA) or the extended FLPA. Note that NIP carries out this function only if the FIX system parameter is specified.
- Loads modules into the modified link pack area (MLPA) and the extended MLPA. Note that NIP carries out this function only if the MLPA system parameter is specified.
- Allocates virtual storage for the common service area (CSA) and the extended CSA. The amount of storage allocated depends on the values specified on the CSA system parameter at IPL.

- Page-protects the NUCMAP, PLPA and extended PLPA, MLPA and extended MLPA, FLPA and extended FLPA, and portions of the nucleus.

Note: An installation can override page protection of the MLPA and FLPA by specifying NOPROT on the MLPA and FIX system parameters.

IEASYSnn, a member of PARMLIB, contains parameters and pointers that control the direction that the IPL takes. See Example 16-6:

Example 16-6 Partial listing of IEASYS00 member

```
Menu  Utilities  Compilers  Help
BROWSE    SYS1.PARMLIB(IEASYS00) - 02.99            Line 00000000 Col 001 080
 Command ===>                                                 Scroll ===> PAGE
********************************* Top of Data **********************************
ALLOC=00,                                                              00010000
CLOCK=00,                    TOD CLOCK INITIALIZATION                  00020000
CLPA,                                                                  00030099
CMB=(UNITR,COMM,GRAPH,CHRDR), ADDITIONAL CMB ENTRIES                   00040000
CON=(00),                    CONSOLE DEFINITIONS                       00050000
COUPLE=00,                   COUPLE  DEFINITIONS                       00060048
CSA=(2048,128M),             CSA BELOW,ABOVE                           00070037
DEVSUP=00,                   DEVICE SUPPORT                            00080000
DIAG=01,                     CSA/SQA TRACING                           00090000
DUMP=NO,                     DYNAMIC ALLOCATION ACTIVE (COMMND00)      00100000
FIX=00,                      FIX MODULES SPECIFIED              /*J3*/ 00110000
GRS=STAR,                    LETS GET THIS BABY GOING                  00120063
GRSCNF=00,                   GRS CONFIG DEFINITIONS                    00130000
GRSRNL=03,                   GRS RNLS DEFINITIONS                      00140067
ICS=00,                      SELECT IEAICS00 INSTALL CNTL SPECS FOR SRM 00150000
IOS=00,                      USE IECIOS00 FOR MIH VALUES               00160000
LNKAUTH=LNKLST,              LINKLIST APF AUTHORIZATION                00170000
LPA=00,                      SELECT LPALST00 CONCATENATED LPA LIBRARY  00180000
LOGCLS=Y,                    WILL NOT BE PRINTED BY DEFAULT            00190000
LOGLMT=999999,               MUST BE 6 DIGITS, MAX WTL MESSAGES QUEUED 00200000
LOGREC=LOGSTREAM,            LOGREC GOES TO LOGR LOGSTREAM             00210000
MAXCAD=35,                   CICSPLEX CMAS NUMBER OF COMMON DSPACES    00220044
MAXUSER=1000,                (SYS TASKS + INITS + TSOUSERS)            00230053
MLPA=00,                     SELECT IEALPA00 MODULES LOADED INTO PLPA  00240000
MSTRJCL=01,                  MSTJCL WITHOUT UADS & WITH IEFJOBS        00250000
```

To see information on how your system was IPLed, you can issue the **D IPLINFO** command, as Example 16-7 shows:

Example 16-7 Output of D IPLINFO command

```
Display  Filter  View  Print  Options  Help
HQX7708 -----------------  SDSF PRIMARY OPTION MENU  -- COMMAND ISSUED
 COMMAND INPUT ===> /D IPLINFO
```

```
RESPONSE=SC67
  IEE254I  16.30.46 IPLINFO DISPLAY 380
   SYSTEM IPLED AT 16.17.14 ON 04/22/2005
   RELEASE z/OS 01.05.00    LICENSE = z/OS
   USED LOADR2 IN SYS0.IPLPARM ON 3800
   ARCHLVL = 2   MTLSHARE = N
   IEASYM LIST = XX
   IEASYS LIST = (R3,67) (OP)
   IODF DEVICE 3800
   IPL DEVICE A831 VOLUME Z05RD1
```

System address space creation

In addition to initializing system areas, z/OS establishes system component address spaces. It establishes an address space for the master scheduler and other system address spaces for various subsystems and system components. Some of the component address spaces are: *MASTER*, ALLOCAS, APPC, CATALOG, and so on.

Master scheduler initialization

Master scheduler initialization routines initialize system services such as the system log and communications task, and start the master scheduler itself. They also cause creation of the system address space for the job entry subsystem (JES2 or JES3), and then start the job entry subsystem.

Subsystem initialization

Subsystem initialization is the process of readying a subsystem for use in the system. IEFSSNxx members of SYS1.PARMLIB contain the definitions for the primary subsystems such as JES2 or JES3, and the secondary subsystems such as NetView and DB2. For detailed information about the data contained in IEFSSNxx members for secondary systems, refer to the installation manual for the specific system.

During system initialization, the defined subsystems are initialized. You should define the primary subsystem (JES) first because other subsystems, such as DB2, require the services of the primary subsystem in their initialization routines. Problems can occur if subsystems that use the subsystem affinity service in their initialization routines are initialized before the primary subsystem. After the primary JES is initialized, then the subsystems are initialized in the order in which the IEFSSNxx PARMLIB members are specified by the SSN parameter. For example, for SSN=(aa,bb), PARMLIB member IEFSSNaa would be processed before IEFSSNbb.

START/LOGON/MOUNT processing

After the system is initialized and the job entry subsystem is active, jobs can be submitted for processing. When a job is activated through START (for batch jobs), LOGON (for time-sharing jobs), or MOUNT, a new address space is allocated. Note that before

LOGON, the operator must have started VTAM/TCAS, which have their own address spaces.

Figure 16-7 shows some of the important system address spaces and VTAM, CICS, TSO, a TSO user and a batch initiator. Each address space has 2 GB of virtual storage by default, whether the system is running in 31-bit or 64-bit mode.

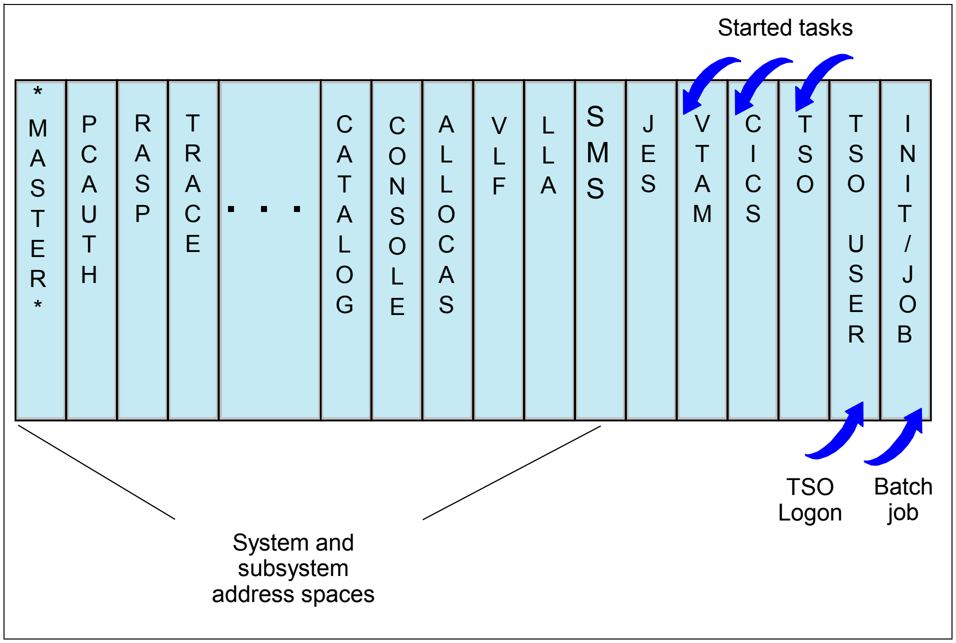


Figure 16-7 Virtual storage layout for multiple address spaces

Each address space is mapped as shown in Figure 16-8. Note that the private areas are available only to that address space, but common areas are available to all.

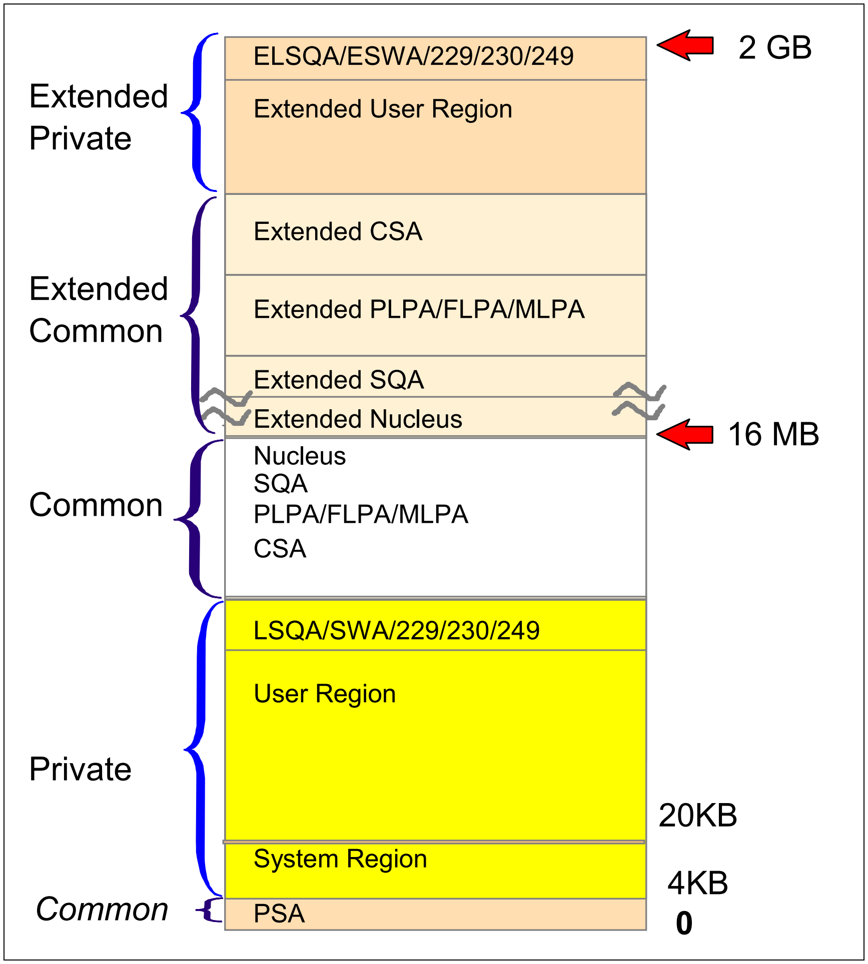


Figure 16-8 The 31-bit address space

16.4.2 Initializing the system

During initialization of a z/OS system, the operator uses the system console or hardware management console, which is connected to the support element. From the system console, the operator initializes the system control program during the Nucleus Initialization Program (NIP) stage.

During the NIP stage, the system might prompt the operator to provide system parameters that control the operation of z/OS. The system also issues informational messages that inform the operator about the stages of the initialization process.

IPL types

Several types of IPL exist; these are described as follows:

- Cold start

  An IPL that loads (or reloads) the PLPA, but does not preserve VIO data set pages. The first IPL after system installation is always a cold start because the PLPA is initially loaded. Subsequent IPLs are cold starts when the PLPA is reloaded, either to alter its contents or to restore its contents if they were lost. This is usually done when changes have been made to the LPA (for example, when a new SYSRES containing maintenance is being loaded).

- Quick start

  An IPL that does not reload the PLPA, but does not preserve VIO data set pages. (The system resets the page and segment tables to match the last-created PLPA.) This is usually done when there have been no changes to LPA, but VIO must be refreshed. This prevents the warm start of jobs that were using VIO data sets.

- Warm start

  An IPL that does not reload the PLPA, but preserves journaled VIO data set pages. This will allow jobs that were running at the time of the IPL to restart with their journaled VIO data sets.

> **Note:** VIO is a method of using memory to store small temporary data sets for rapid access. However, unlike a RAM disk on a PC, these are actually backed up to disk and so can be used as a restart point. Obviously there should not be too much data stored in this way, so the size is restricted.

Often, the preferred approach is to do a cold start IPL (specifying CLPA). The other options can be used, but extreme care must be taken to avoid unexpected change or backout of change. A warm start could be used when you have long-running jobs which you want to restart after IPL, but an alternative approach is to break down those jobs into smaller pieces which pass real data sets rather than use VIO. Modern disk controllers with large cache memory have reduced the need for VIO data to be kept for long periods.

Also, do not confuse a cold start IPL (CLPA would normally be used rather than the term “cold start”) with a JES cold start. Cold starting JES is something that is done extremely rarely, if ever, on a production system, and totally destroys the existing data in JES.

16.4.3 Shutting down the system

To shut down the system each task must be closed in turn, in the correct order. On modern systems, this is the task of the automation package. Shutting down the system usually requires a single command. This will remove most tasks except Automation itself. The Automation task is closed manually, and then any commands needed to remove the system from a sysplex or serialization ring are issued.

16.5 Summary

The role of the z/OS system programmer is to install, customize, and maintain the operating system.

The system programmer must understand the following areas (and more):

- z/OS operational system administration
- Workload management
- System performance
- Job flow
- I/O device management
- Security
- Integrity
- Availability
- z/OS operation

To maximize the performance of the task of retrieving modules, the z/OS operating system has been designed to maintain in memory those modules that are needed for fast response to the operating system, as well as for critical applications. Link pack area (LPA), LNKLST, and authorized libraries are the cornerstones of the fetching process.

Also discussed was the system programmer's role in configuring consoles and setting up message-based automation.

System start-up or IPL was introduced with the following topics.

- IPL and the initialization process
- Types of IPLs: cold start, quick start, and warm start
- Reasons for IPLing

Key terms in this section		
HCD	IODF	SYSRES
SMP/E	LNKLST	IPL
WTOR	PARMLIB	PROCLIB
system symbols	PSA	LPA
nucleus	LOADPARM	SQA

16.6 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. Look at the following system specifications, and indicate what the final LNKLST concatenation will be.

   ```
   IEASYSxx: ...,LNK=(00,02,03,05)
   LNKLST00: SYS1.CMDLIB,SYS1.BTAMLIB
   LNKLST02: SYS1.LINKLIB,LUISM.MYLIB(DSD001),SYS2.MIRLIB
   LNKLST03: SYS1.AUXLIB,SYS1.JES3
   LNKLST05: SYS1.TEST01, SYS1.TESTLIB
   ```

   What happens with the SYS1.LINKLIB specification in LNKLST02?
2. Take Example 16-2 on page 16-18 and assume that the class assigned to a certain job has a default PROCLIB concatenation of PROC00. The job needs a procedure that resides in SYS1.OTHERPRO. What can be done to accomplish this? Which procedure libraries would be searched if nothing were done?
3. Why are console operations often automated?
4. Why does a message and command structure lend itself to automation?
5. Why are system reloads necessary?

16.7 Topics for further discussion

1. The mainframe is considered secure because it does not permit "plug-in" devices; only devices defined by the system programmer can be connected and used. In your opinion is this correct?
2. Compare the scope the "program search order" to the search paths used in other operating systems.
3. Discuss the following statement in relation to z/OS and other operating systems you are familiar with: The main goal of a system programmer is to avoid system reloads.

16.8 Exercises

1. **Laboratory:** Find out which IEASYSxx members were used in the current IPL. Did the operator specify the suffix of an alternate IEASYSxx?
2. **Laboratory:** Did the operator specify any parameter in response to the message `SPECIFY SYSTEM PARAMETERS`? If the answer is Y, find the related PARMLIB members for that parameter and obtain the parameter value that would be active if that operator response hadn't occurred.

z/OS is IPLed using the system console or the Hardware Master Console (HMC). You need to supply the following information to IPL z/OS:

- The device address of the IPL volume
- The LOADxx member that contains pointers to system parameters
- The IODF data set that contains the configuration information
- The device address of the IODF volume

1. On your system, find out the IPL device address and the IPL Volume: Go to SDSF, enter ULOG, and then /D IPLINFO.
2. What is the IODF device address?
3. What is the LOADxx member that was used for IPL? What is the data set that contains this LOADxx member?
4. Browse this member; what is the name of the system catalog used by the system?
5. What is the name of the IODF data set currently used? Enter /D IOS,CONFIG.
6. The system parameters can come from a number of PARMLIB data sets. Enter /D PARMLIB. What are the PARMLIB data sets used by your system?

17

Security on z/OS

Objective: In working with z/OS, you need to understand the importance of security and the facilities utilized by z/OS to implement it.

After completing this chapter, you will be able to:

- Explain security and integrity concepts.
- Explain RACF and its interface with the operating system.
- Authorize a program.
- Discuss integrity concepts.
- Explain the importance of change control.
- Explain the concept of risk assessment.

17.1 Why security?

An installation's data and application programs are among its most valuable resources. They must be protected from unauthorized access both internally (employees) and externally (customers, business partners, and hackers).

Over time, it has become much easier to create and access computerized information. No longer is system access limited to a handful of highly skilled programmers. Information can now be created and accessed by almost anyone who takes a little time to become familiar with the newer, easier-to-use, high-level inquiry languages.

More and more people are becoming increasingly dependent on computer systems and the information they store in these systems. As general computer literacy and the number of people using computers has increased, the need for data security has taken on a new measure of importance. No longer can the installation depend on keeping data secure simply because no one knows how to access the data.

Further, making data secure not only means making confidential information inaccessible to those who should not see it. It also means preventing the inadvertent destruction of files by people who may not even know that they are improperly manipulating data.

An operating system is said to have system integrity when it is designed, implemented, and maintained to protect itself against unauthorized access, and does so to the extent that security controls specified for that system cannot be compromised. Specifically for z/OS, this means that there must be no way for any unauthorized program, using any system interface, defined or undefined, to do the following:

- Obtain control in an authorized state
- Bypass store or fetch protection
- Bypass password checking

17.2 Security facilities of z/OS

In the following sections, we cover the facilities of z/OS that provide its high level of security and integrity.

Data about customers is a valuable resource that could be sold to competitors; or the threat of a sale could lead to blackmail. So the aim of any security policy is to provide users with only their required level of access and to deny nonauthorized users access. This is one reason why auditors prefer that users or groups are granted specific access, rather than using universal access facilities. The traditional focus of mainframe security was to focus on stopping unauthorized people from logging on to the system, and then ensuring that users were only allowed access to data on a need-to-know basis. As mainframes have become Internet servers, however, additional security has been required. There are outside threats such as hackers, viruses, and trojan horses; the security server includes tools to deal with these.

However, the main threat to company data has always been from within. An employee within a company has a much better chance of obtaining data than someone outside. A well-thought-out security policy is always the first line of defense. In addition to that, z/OS provides a number of integrity features to minimize intentional or accidental damage from other programs.

17.3 Security roles

Usually it is the system programmer who, working with management, decides the overall security policy and procedures.

The system administrator assigns user IDs and initial passwords and ensures that the passwords are non-trivial, random, and frequently changed. Because the user IDs and passwords are so critically important, special care must be taken to protect the files that contain them.

There may even be a separate security manager who sets the policies. If so, the system programmer may not have direct responsibility for security, other than advising the security manager about new products. Separation of duties is necessary to prevent any one individual from having uncontrolled access to the system.

Many installations run several copies of z/OS and often do not permit general TSO/ISPF users to access the production systems. z/OS security controls can protect the production environment if they are properly configured. Even with proper security controls, a TSO/ISPF user (either maliciously or accidentally) can impact important production work.

17.4 The IBM Security Server

Many installations use a package called the IBM Security Server, which is commonly referred to by the name of its most well-known component, RACF.

z/OS security provisions include:

- Controlling the access of users (user ID and password) to the system
- Restricting the functions that an authorized user can perform on the systems' data files and programs

For students who would like to learn more about the tools available to a z/OS security administrator, here is a list of the security components of z/OS that are collectively known as the Security Server:

- DCE Security Server

  This server provides a fully functional OSF DCE 1.1 level security server that runs on z/OS.

- Lightweight Directory Access Protocol (LDAP) Server

  This server is based on a client/server model that provides client access to an LDAP server. An LDAP directory provides an easy way to maintain directory information in a central location for storage, update, retrieval, and exchange.

- z/OS Firewall Technologies

  This is an IPV4 network security firewall program for z/OS. In essence, the z/OS firewall consists of traditional firewall functions as well as support for virtual private networks.

  The inclusion of a firewall means that the mainframe can be connected directly to the Internet if required without any intervening hardware and can provide the required levels of security to protect vital company data. With the VPN technology, securely encrypted tunnels can be established through the Internet from a client to the mainframe.

- Network Authentication Service for z/OS

  This provides Kerberos security services without requiring that you purchase or use a middleware product such as Distributed Computing Environment (DCE).

- Enterprise Identity Mapping (EIM)

  This offers a new approach to enable inexpensive solutions to easily manage multiple user registries and user identities in an enterprise.

- PKI Services

  This allows you to establish a public key infrastructure and serve as a certificate authority for your internal and external users, issuing and administering digital certificates in accordance with your own organization's policies.

- Resource Access Control Facility (RACF)

  This is the primary component of the z/OS Security Server; it works closely with z/OS to protect its vital resources.

The topic of security can be a whole course by itself. In this textbook, we introduce you to the RACF component and show how its features are used to implement z/OS security.

17.4.1 RACF

Access, in a computer-based environment, means the ability to do something with a computer resource (for example, use, change, or view something). Access control is the method by which this ability is explicitly enabled or restricted. Computer-based access controls are called *logical access controls*. These are protection mechanisms that limit users' access to information to only what is appropriate for them.

Logical access controls are often built into the operating system, or may be part of the logic of application programs or major utilities, such as database management systems. They may also be implemented in add-on security packages that are installed into an operating system; such packages are available for a variety of systems, including PCs and mainframes. Additionally, logical access controls may be present in specialized components that regulate communications between computers and networks.

The Resource Access Control Facility (RACF) is an add-on software product that provides basic security for a mainframe system. There are other security software packages, such as ACF2 or Top Secret, both from Computer Associates.

RACF protects resources by granting access only to authorized users of the protected resources. RACF retains information about users, resources, and access authorities in special structures called *profiles* in its database, and it refers to these profiles when deciding which users should be permitted access to protected system resources.

To accomplish its goals, RACF gives you the ability to:

- Identify and authenticate users
- Authorize users to access protected resources
- Log and report various attempts of unauthorized access to protected resources
- Control the means of access to resources
- Allow applications to use the RACF macros

Figure 17-1 on page 17-6 shows a simple view of RACF functions.

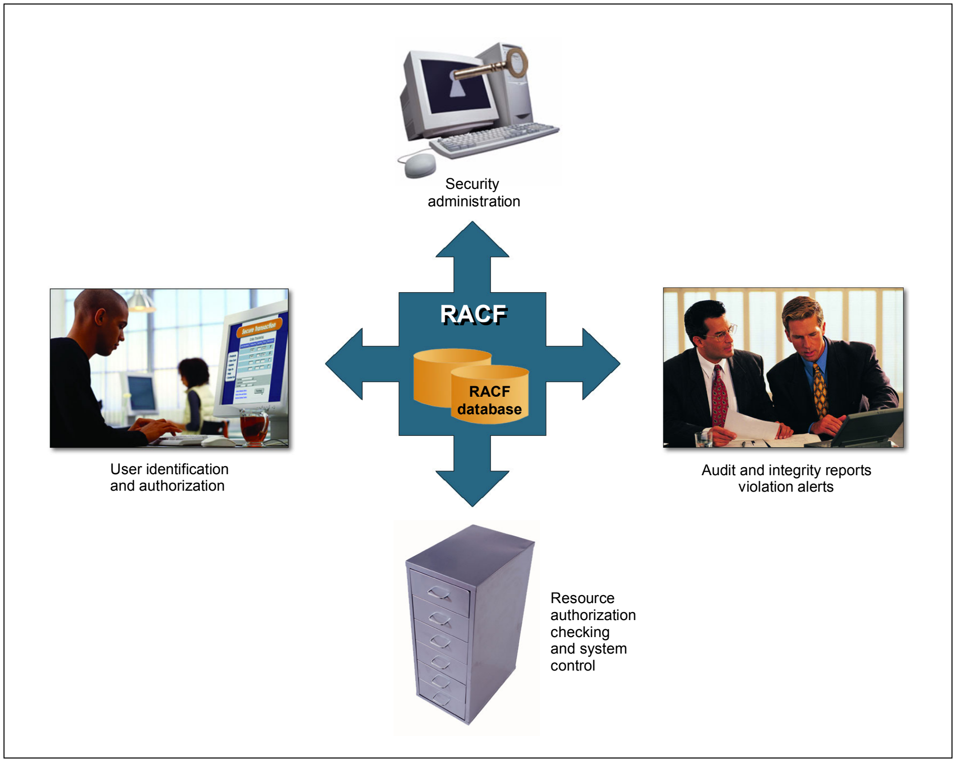


Figure 17-1 Overview of RACF functions

RACF uses a user ID and a system-encrypted password to perform its user identification and verification. The user ID identifies the person to the system as a RACF user. The password verifies the user's identity. Often exits are used to enforce a password policy such as a minimum length, lack of repeating characters or adjacent keyboard letters, and also the use of numerics as well as letters. Popular words such as "password" or the use of the user ID are often banned.

The other important policy is the frequency of password change. If a user ID has not been used for a long time, it may be revoked and special action is needed to use it again. When someone leaves a company, there should be a special procedure that ensures that the user IDs are deleted from the system.

17.4.2 System authorization facility (SAF)

The system authorization facility (SAF) is part of the z/OS operating system and provides the interfaces to the callable services provided to perform authentication, authorization, and logging.

SAF does not require any other product as a prerequisite, but overall system security functions are greatly enhanced and complemented if it is used concurrently with RACF. The key element in SAF is the SAF router. This router is always present, even when RACF is not present.

The SAF router provides a common focal point for all products providing resource control. This focal point encourages the use of common control functions shared across products and across systems. The resource managing components and subsystems call the z/OS router as part of certain decision-making functions in their processing, such as access-control checking and authorization-related checking. These functions are called *control points*.

The system authorization facility (SAF) conditionally directs control to RACF (if RACF is present), or to a user-supplied processing routine, or both, when receiving a request from a resource manager.

17.5 Security administration

Data security is the protection of data from accidental or deliberate unauthorized disclosure, modification, or destruction. Based on this definition, it is apparent that all data-processing installations have at least potential security or control problems. Users have found, from past experience, that data security measures can have a significant impact on operations in terms of both administrative tasks and demands made on the end user.

RACF gives the user defined with the SPECIAL attribute (the security administrator) many responsibilities both at the system level and at the group level. The security administrator is the focal point for planning security in the installation and needs to:

- Determine which RACF functions to use
- Identify the level of RACF protection
- Identify which data RACF is to protect
- Identify administrative structures and users

17.5.1 RACF Remote Sharing Facility (RRSF)

The RACF Remote Sharing Facility (RRSF) allows you to administer and maintain RACF databases that are distributed throughout the enterprise. It provides improvements in system performance, system management, system availability, and usability. RRSF helps to ensure that data integrity is kept across system or network failures and delays. It lets you know when key events have occurred and returns output to view at your convenience.

17.5.2 RACF with middleware

Major subsystems such as CICS and DB2 use the facilities of RACF to protect transactions and files. Much of the work to configure RACF profiles for these subsystems is done by the CICS and DB2 system programmers. So there is a need for people in these roles to have a useful understanding of RACF and how it relates to the software they manage.

17.6 Operator console security

We can look at one example of how z/OS security affects system functions by discussing the operator consoles. Console security means controlling which commands operators can enter on their consoles to monitor and control z/OS. How you define command authorities for your consoles, or control logon for operators, enables you to plan the operations security of your z/OS system or sysplex. In a sysplex, because an operator on one system can enter commands that affect the processing on another system, your security measures become more complicated and you need to plan accordingly.

If your installation plans to use extended multiple console support (MCS), you should consider ways to control what an authorized TSO/E user can do during a console session. Because an extended MCS console can be associated with a TSO/E user ID and not a physical console, you might want to use RACF to limit not only the z/OS commands a user can enter, but from which TSO/E terminals the user can enter the commands.

You can control whether an operator can enter commands from a console via the following:

- The AUTH keyword on the CONSOLE statement of CONSOLxx
- The LOGON keyword of the DEFAULT statement and RACF commands and profiles.

17.7 Integrity

There are many features and facilities in z/OS specifically designed to protect one program from affecting another, either intentionally or accidentally. This is why z/OS is known for program integrity as well as security.

This section discusses:

- The authorized program facility (APF)
- Storage protection
- Cross-memory communication

17.7.1 Authorized programs

z/OS contains a feature called the authorized program facility (APF) to allow selected programs to access sensitive system functions. APF was designed to avoid integrity exposures. The installation identifies which libraries contain those special functions or programs. Those libraries are then called APF libraries.

An APF-authorized program can do virtually anything that it wants. It is essentially an extension of the operating system. It can put itself into supervisor state or a system key. It can modify system control blocks. It can execute privileged instructions (while in supervisor state). It can turn off logging to cover its tracks. Clearly, this authorization must be given out sparingly and monitored carefully.

You can use APF to identify system or user programs that can use sensitive system functions. For example, APF:

- Restricts the use of sensitive system supervisor call (SVC) routines (and sensitive user SVC routines, if you need them) to APF-authorized programs.
- Allows the system to fetch all modules in an authorized job step task only from authorized libraries, to prevent programs from counterfeiting a module in the module flow of an authorized job step task.

Many system functions, such as supervisor calls (SVCs) or special paths through SVCs, are sensitive. Access to these functions must be restricted to only authorized programs to avoid compromising the security and integrity of the system.

The system considers a task authorized when the executing program has the following characteristics:

- It runs in supervisor state (bit 15 of the program status word (PSW) is zero). For a brief look at a PSW, see Chapter 2, "z/OS overview" .
- It runs with PSW key 0 to 7 (bits 8 through 11 of the PSW contain a value in the range 0 to 7).
- All previous programs executed in the same task were APF programs.

Authorized libraries

Libraries that contain authorized programs are known as authorized libraries. APF-authorized programs must reside in one of the following authorized libraries:

- SYS1.LINKLIB
- SYS1.SVCLIB
- SYS1.LPALIB
- Authorized libraries specified by your installation

17.7.2 Storage protection

The zSeries hardware has a *storage protection* function. It is normally used to prevent unauthorized alteration of storage. It can also be used to prevent unauthorized reading of storage areas, although z/OS protects only small areas of storage this way. Storage protection works on 4K pages. It deals only with real memory, not virtual memory. When a page of virtual memory is copied from disk to a free page in main storage, z/OS also sets an appropriate storage protection key in that page of main storage.

Storage protection was much more significant before multiple address spaces came into use. When multiple users and jobs were in a single address space (or in real memory in the days before virtual memory), protecting a user's memory from corruption (or inappropriate data peeking) was critical. With z/OS, the primary protection for each user's memory is the isolation provided by multiple address spaces.

Storage protection keys cannot be altered by application programs. There is no way, using the storage protection function, for a normal application program (that is, not an *authorized program*) to protect part of its virtual memory from other parts of the application in the same address space.

An additional storage protection bit (for each 4K page of real memory) is the *page protection* bit. This prevents even system routines (running in key 0, which can normally store anywhere) from storing in the page. This bit is typically used to protect LPA pages from accidental damage by system routines.

17.7.3 Cross-memory communication

With proper page table management by the operating system, users and applications in different address spaces are completely isolated from each other. One exception to this isolation is the common area. Another exception is *cross-memory communication*.

With proper setup by the operating system, it is possible for a program in one standard address space to communicate with programs in other address spaces. A number of cross-memory capabilities are possible, but two are commonly used:

- The ability to call a program that resides in a different address space
- The ability to access (fetch, store) virtual memory in another address space

The first case uses the *program call* (PC) instruction. Once the proper setup has been completed by z/OS, only a single hardware instruction is needed to call a program in another address space. A common example of this involves DB2, the major IBM database product. Various parts of DB2 occupy up to four address spaces. Users of DB2 may be TSO users, batch jobs, and other middleware (such as a Web server). When these users issue SQL instructions for DB2, the SQL interface in the application uses a program call to obtain services from the DB2 address spaces.

Cross-memory programming can be rather complex and must be coordinated with z/OS security controls. In practice, almost all cross-memory usage is in major middleware products and is rarely directly used by typical application programs.

Routine application programming seldom ventures into this area. Both the zSeries hardware architecture and internal z/OS design protect these functions from improper use and there have been no significant security or integrity concerns related to the cross-memory capabilities.

17.7.4 z/OS firewall technologies

The traditional firewall functions act as a blockade between your intranet (a secure, internal private network) and another (nonsecure) network or the Internet. The purpose of a firewall is to prevent unwanted or unauthorized communication into or out of the secure network. The firewall has two jobs:

- It lets users in your own network use authorized resources from the outside network without compromising your network’s data and other resources.
- It keeps users who are outside your network from coming in to compromise or attack your network.

There are several ways a firewall can protect your network. A firewall can provide screening services that deny or grant access based on such things as user name, host name, and TCP/IP protocol. A firewall can also provide a variety of services that let authorized users through while keeping unauthorized users out, and at the same time ensure that all communications between your network and the Internet appear to end at the firewall, denying the outside world to see the structure of your network.

To control access between your intranet and the Internet, and at the same time permit authorized transactions, z/OS Firewall Technologies provides three key technologies: network servers, filters and address translation, and virtual private network.[1]

17.8 Summary

Making data secure does not mean just making confidential information inaccessible to those who should not see it; it means preventing the inadvertent destruction of files by people who may not even know that they are improperly manipulating data. Without better awareness of good data security practices, technology evolution could result in a higher likelihood of unauthorized persons accessing, modifying, or destroying data, either inadvertently or deliberately. The Security Server is a set of features in z/OS that provides security implementation.

[1] *z/OS V1R4.0 Security Server Firewall Technologies*, SC24-5922-04, http://publibz.boulder.ibm.com/cgi-bin/bookmgr_OS390/BOOKS/ICAA1A21/CCONTENTS

The system authorization facility (SAF) is part of the z/OS operating system and provides the interfaces to the callable services provided to perform authentication, authorization, and logging.

The Resource Access Control Facility (RACF) is a component of the Security Server for z/OS and controls access to all protected z/OS resources. RACF protects resources by granting access only to authorized users of the protected resources and retains information about the users, resources, and access authorities in specific profiles.

RACF provides the tools and databases to allow program products such as TSO, CICS, and DB2 to check and verify a user's access level and thus permit or deny the use of data sets, transactions, or database views.

RACF enables the organization to define individuals and groups who use the system RACF protects. For example, for a secretary in the organization, a security administrator uses RACF to define a user profile that defines the secretary's user ID, initial password, and other information.

To accomplish its goals, RACF gives you the ability to:

- Identify and authenticate users
- Authorize users to access the protected resources
- Log and report attempts of unauthorized access to protected resources
- Control the means of access to resources

The operation of a z/OS system involves the following:

- Console operations, or how operators interact with z/OS to monitor or control the hardware and software
- Message and command processing that forms the basis of operator interaction with z/OS and the basis of z/OS automation

Operating z/OS involves managing hardware such as processors and peripheral devices and software such as the z/OS operating control system, the job entry subsystem, and all the applications that run on z/OS.

When implementing console security, the installation can control which commands operators can enter on their consoles to monitor and control z/OS. Basically, the customization is made in RACF and in the CONSOLxx member in PARMLIB.

Key terms in this section		
authorized libraries	authorized program facility (APF)	encryption

firewall	hacker	page protection bit
password	Resource Access Control Facility (RACF)	security policy
separation of duties	system integrity	user ID

17.9 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. Is the following statement true or false?

   Access information in the resource profiles can be set only at group level. This means that it is impossible for a single user to have the update attribute to a specific data set if the RACF group to which the user is connected has only the read attribute.

2. In the following situation, what will occur with the program if no authorized SVC or special functions are invoked?

   a. One program link-edited with AC=0
   b. Running from an APF-authorized library

3. In the following example, what are the possible problems in a program executing from a library called SYS1.LINKLIB located in the volume MPRES2?

```
D PROG,APF,ENTRY=1
CSV450I 05.24.55 PROG,APF DISPLAY 979
FORMAT=DYNAMIC
ENTRY VOLUME DSNAME
   1  MPRES1 SYS1.LINKLIB?
```

17.10 Topics for further discussion

1. On other platforms, how do you protect data sets or files? Is there a way to prevent the execution of a specific application?
2. RACF enables you to assign the group administrator attribute to users. With this, it is possible to implement a decentralized administration. Discuss the pros and cons.

17.11 Exercises

1. Try to log on to TSO after changing the initial logon procedure IKJACCNT to IKJACCN1. The expected message is:

   ```
   IKJ56483I THE PROCEDURE NAME IKJACCN1 HAS NOT BEEN AUTHORIZED FOR THIS
   USERID
   ```

2. Using your TSO user (now with your default logon procedure IKJACCNT), try to delete the data set *ZPROF*.JCL.NOT.DELETE, which is set up by the standard jobs in the supplied JCL. This is a protected data set and you can only read its content.

3. Execute the next sample JCL to obtain a DSMON utility report with the current RACF group tree structure (available in the sample JCL as member DSMON):

   ```
   //DSMONRPT JOB
   (POK,999),'DSMONREPORT',MSGLEVEL=(1,1),MSGCLASS=X,
   //  CLASS=A,NOTIFY=&SYSUID
   /*JOBPARM SYSAFF=*
   //*
   //* NOTE:
   //* REMEMBER THAT ICHDSM00 MUST BE RUN BY A USER WITH
   AUDITOR ATTRIBUTE
   //*
   //STEPNAME EXEC PGM=ICHDSM00
   //SYSPRINT DD SYSOUT=A
   //SYSUT2   DD SYSOUT=A
   //SYSIN    DD  *
    FUNCTION RACGRP
   /*
   ```

4. Verify that the SYS1.LINKLIB library is an APF-authorized library.
   - Using the DISPLAY APF command to display the entire APF list.
   - Using the ENTRY= operand in the DISPLAY APF command.
   - Using the DSNAME= operand in the DISPLAY APF command. Verify the entry number in the command display result in the syslog.

5. The following JCL example can be used to invoke the ADRDSSU utility and issue a WTOR message in the console. The WTOR command lets you write an ADR112A message to the system console. The ADR112A message requests that the operator perform some action, and then issue a reply. You can use WTOR, for example, to request that the operator mount a required volume or quiesce a database before your DFSMSdss job continues to process (available in the sample JCL as member ADRDSSU).

   ```
   //WTORTEST JOB (POK,999),'USER',MSGLEVEL=(1,1),MSGCLASS=X,
   //  CLASS=A,NOTIFY=&SYSUID
   //        EXEC PGM=ADRDSSU
   //SYSPRINT DD   SYSOUT=*
   ```

```
//SYSIN    DD   *
 WTOR 'TEST'
/*
```

DFSMSdss assigns the following routing code to the WTOR message:

1 Master console action

DFSMSdss assigns the following descriptor code to the WTOR message:

2 Action that is required

In the SDSF main screen, choose the SR option (system requests) and reply with any response you want.

18

Overview of network communications on z/OS

Objective: To expand your knowledge of mainframe workloads, you must understand the role of mainframes in today's online world. This chapter introduces concepts and terminology for transactional processing, database management systems, and network communications.

After completing this chapter, you will be able to:

- Describe the role of large systems in a typical online business.
- Describe two models for network connectivity for large systems.

18.1 Online processing on the mainframe

18.2 Network communications for the mainframe

Network communications has both a software and a hardware aspect, and a separation of software and hardware communications duties is common in large enterprises. A skilled software data communication expert, however, needs to understand both aspects.

The z/OS system programmer must bring a thorough understanding of z/OS communications software to any project that involves working with the company's network. While network hardware technicians have specific skills and tools for supporting the physical network, their expertise often does not extend to the z/OS communications software. When a nationwide retail chain opens a new store, the z/OS system programmers and network hardware technicians must coordinate their efforts to open the new store.

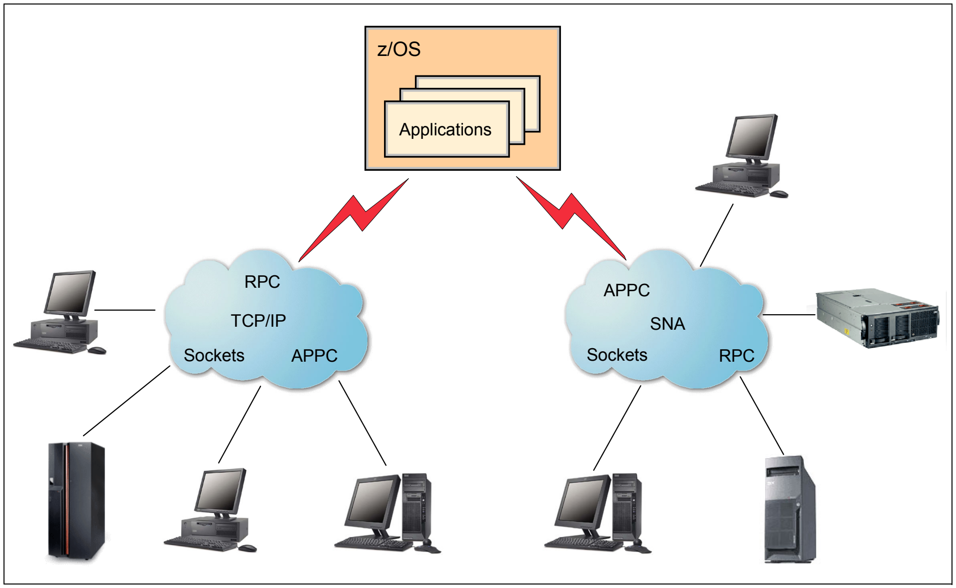


Figure 18-1 IBM communications server

z/OS includes a fully featured communications server with multiprotocol networking. This chapter begins with an overview of the available networking technologies on z/OS and then discusses the main operational aspects of the operating system's communications server in 18.6, "z/OS Communications Server" on page 18-6.

18.3 SNA and TCP/IP on z/OS

System Network Architecture (SNA) was developed by IBM. SNA provided industry with a technology that permitted unparalleled business opportunities. SNA included products such as *Virtual Telecommunication Access Method* (VTAM®), *Network Control Program* (NCP) and terminal controllers to expand the reach of the mainframe's hosted data and processing capability using the *synchronous data link control* (SDLC) protocol. What TCP/IP and the Internet were to the public in the 1990s, SNA was to large enterprises in the 1980s.

Transmission Control Protocol/Internet Protocol (TCP/IP) is an industry-standard, nonproprietary set of communications protocols that provide reliable end-to-end connections between applications over interconnected networks of different types. TCP/IP was widely embraced when the Internet came of age because it permitted access to remote data and processing for a relatively small cost. TCP/IP and the Internet resulted in a proliferation of small computers and communications equipment for chat, e-mail, conducting business, and downloading and uploading data.

Large SNA enterprises have recognized the increased business potential of expanding the reach of SNA-hosted data and applications to this proliferation of small computers and communications equipment in the customers' homes, small offices, and so on.

18.4 Brief history of data networks

Established in 1969, TCP/IP is actually five years older than SNA. Differences in the introduction of each technology stem mainly from the factors of commercial availability and technical maturity. SNA was immediately available to the public, while TCP/IP was limited at first to military and research institutions, for use in the interconnected networks that formed the precursors to the Internet.

SNA was designed to include network management controls through Synchronous Data Link Control (SDLC) protocol. SNA also supported non-SDLC protocols, such as start-stop (SS) and bisynchronous (BSC) protocol. In the 1980s, SNA was widely implemented by large corporations because it allowed their IT organizations to extend central computing capability worldwide with reasonable response times and reliability. For example, widespread use of SNA allowed the retail industry to offer new company credit card accounts to customers at the point-of-sale.

In 1983, TCP/IP entered the public domain in Berkeley BSD UNIX. TCP/IP maturity, applications and acceptance advanced through an open standards committee using the Request-For-Comment (RFC) mechanism. TCP/IP contains data flow control and assigns class of service to specific workloads.

TCP/IP was designed for interconnected networks (an internet), while SNA design was hierarchical with the "centralized" mainframe being at the top of the hierarchy. The SNA design included network management, data flow control, and the ability to assign "class of service" priorities to specific data workloads.

Communication between autonomous SNA networks became available in 1983. Before than, SNA networks were not automatically compatible. The ability of independent SNA networks to share business application and network resources is called SNA Network Interconnect (SNI).

18.5 Layered network models

TCP/IP and SNA are both layered network models. Each can indirectly map to the international *Open Systems Interconnect* (OSI) network model (Figure 18-2).

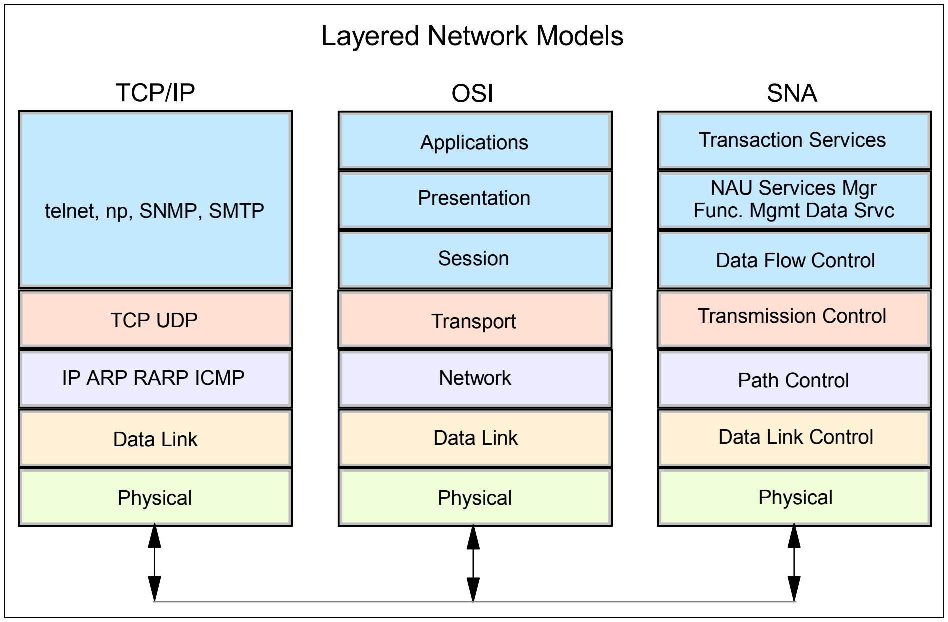


Figure 18-2 Open Systems Interconnect (OSI) network model

The OSI network model depicts the organization of the individual elements of technology involved with end-to-end data communication. As shown in Figure 18-2, the OSI network model provides some common ground for both SNA and TCP/IP. While neither technology maps directly into the OSI network model (TCP/IP and SNA existed before the OSI network model was formalized), common ground still exists due to the defined model layers.

The OSI network model is divided into seven layers. OSI layer 7 (Application) indirectly maps into the top layers of the SNA and TCP/IP stacks. OSI layer 1 (Physical) and layer 2 (Data Link) map into the bottom layers of SNA and TCP/IP stacks.

In one typical scenario, two geographically separated end-point software applications are connected at each end by a layered network model. Data is sent by one end-point application and received by the other end-point application. The applications can reside on large mainframes, PCs, point-of-sale (POS) devices, ATMs, terminals, or printer controllers.

Consider how this model might be used in the network communications between a large chain of grocery stores. Each time a customer pays for groceries at one of the many point-of-sale (POS) locations in a grocery store, the layered network model is used twice:

- The POS application resides at the top of the local layered network stack.
- The application that records details of the sale and authorizes completion resides at the top of a remote layer network stack.

The local network stack might run on an AIX system with attached POS devices, while the remote network stack would quite often run on a mainframe, to handle transactions received from all of the store locations. Method of payment, purchases, store location, and time are recorded by mainframe applications, and authorization to print a sales receipt is returned back through both layered network stacks to complete the sale.

This transactional model is commonly known as a request/server or client/server relationship.

18.5.1 Network reliability, availability, and serviceability

What if the network or attached mainframe for our example grocery store chain were to somehow become unavailable? Most POS systems in use today include the ability to accumulate transactions in an intelligent store POS controller or small store processor. When the outage is corrected, the accumulated transactions can then be sent in bulk to the mainframe.

In the previous example, the recovery of transactions would be essential to preventing bookkeeping and inventory problems at the store and in the chain's central office. The cumulative effect of unaddressed, inaccurate records could easily destroy a business. Therefore, reliability, availability and serviceability (RAS) are just as important in the design of a network as they are in the mainframe itself.

18.5.2 Factors contributing to the continued use of SNA

SNA has been stable, trusted and relied upon for mission-critical business applications worldwide. A majority of the world's corporate data is handled by z/OS-resident SNA applications[1]. A distinctive strength of SNA has been that it is connection-oriented with many timers and control mechanisms to ensure reliable delivery of data.

Mainframe IT organizations are often reluctant to move away from SNA, despite the allure of TCP/IP and Web-based commerce. This reluctance is often justified. Rewriting stable, well-tuned business applications to change from SNA program interfaces to TCP/IP sockets is costly, time consuming, and risks negatively impacting response time performance.

Many businesses choose to use Web-enabling technologies to make the vast amount of centralized data available to the TCP/IP-based Web environment, while maintaining the SNA APIs. So SNA as a networking protocol has been migrated to TCP/IP, while the SNA application interfaces are still around to provide reliability and flow control. This "best of both worlds" approach ensures that SNA and VTAM will be around well into the foreseeable future.

18.6 z/OS Communications Server

z/OS includes the Communications Server, which is an integrated set of software components that enable network communications for applications running on z/OS. Communications Server provides the data transportation corridor between the external network and the business applications running on z/OS. It contains an extensive suite of commonly used TCP/IP applications.

z/OS Communications Server provides a set of communications protocols that support peer-to-peer connectivity functions for both local and wide-area networks, including the most popular wide-area network, the Internet. z/OS Communications Server also provides performance enhancements that can benefit a variety of TCP/IP applications.

Communications Server includes a number of sophisticated products and functions. The three major components are:

- Transmission Control Protocol/Internet Protocol or TCP/IP
- Virtual Telecommunication Access Method or VTAM, which provides the capabilities of the IBM System Network Architecture (SNA) in z/OS
- Communications Storage Manager or CSM, which provides a shared I/O buffer area for both TCP/IP and VTAM data flow

Communications Server, with its combination of TCP/IP and SNA functions, is implemented on a number of platforms besides z/OS, for example AIX, Microsoft® Windows, and Linux. As a result, z/OS application programmers can exploit technological advancements in communications (information access, electronic commerce, and collaboration) across distinctly different operating systems.

[1] SNA applications running on z/OS are also known as VTAM applications.

The CSM function allows authorized host applications to share data without having to physically move the data.

18.7 TCP/IP overview

TCP/IP is the general term used to describe the suite of protocols that form the basis for the Internet. It was first included in the UNIX system offered by the University of California at Berkeley, and is now delivered with essentially all network-capable computers in the world..

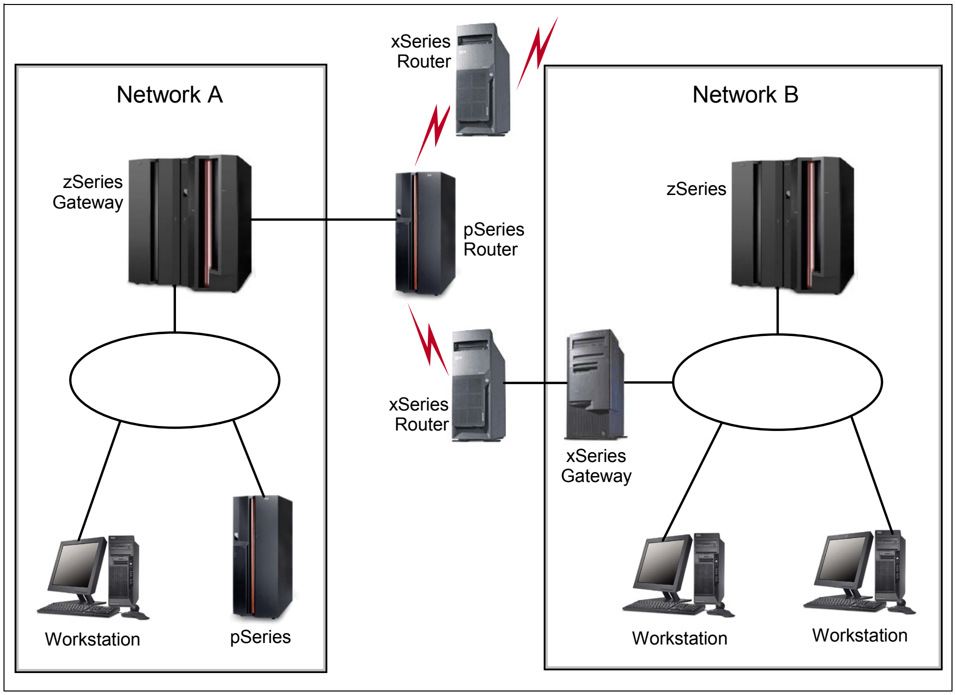


Figure 18-3 TCP/IP introduction

All systems, regardless of size, appear the same to all other systems in the network. TCP/IP can be used over Local Area Network (LAN) hardware using most common protocols, and over Wide Area Networks (WANs).

In a TCP/IP network environment, a machine which is running TCP/IP is called a *host*. A TCP/IP network consists of one or more hosts linked together via various communication links. Any host can address all the other hosts directly to establish communication. The links between networks are invisible to an application communicating with a host in a different network.

18.7.1 Interconnecting TCP/IP networks

An internet is a collection of networks, interconnected through TCP/IP to provide communication services.

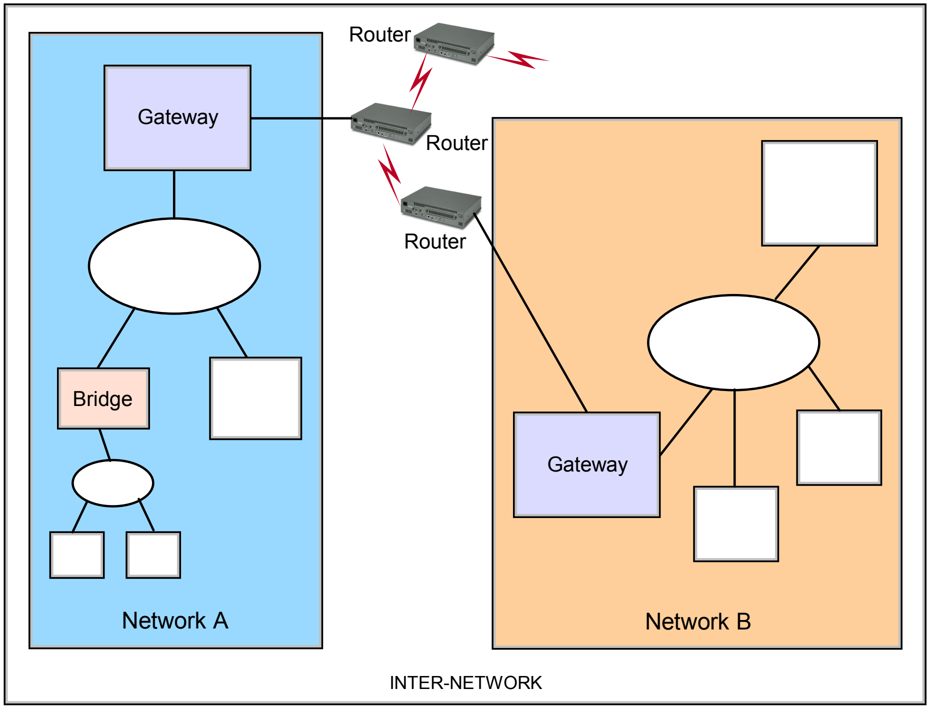


Figure 18-4 Interconnection TCP/IP networks

To interconnect two networks, you need a device attached to both that can forward information from one network to the other. These devices are referred to as gateways or routers. All hosts on all networks within an internet communicate with one another as if all other hosts were on the same network. This allows you to communicate with any of the other systems in an internet.

Bridge A node that connects two LANs within one network.

Router An intermediate node that receives IP packets from hosts and other routers on the network. It forwards packets on to host or other routers, and may contain some intelligence with respect to routing and data flow control. (Sometimes the term *gateway* is used.)

Firewall A host application or router that protects networks and/or hosts from unwanted IP traffic. Contains considerable configurability and intelligence.

The term internet is used as a generic term for a TCP/IP network and should not be confused with the Internet, which consists of the large international backbone networks connecting all TCP/IP hosts that have links to the Internet backbone.

18.8 Network topologies supported by VTAM

The hierarchical design of SNA serves the centralized data processing needs of large enterprises. At the top of this hierarchy is VTAM.

VTAM serves the following types of network topologies:

- Subarea
- Advanced Peer-to-Peer Network (APPN)
- Subarea/APPN mixed

The part of VTAM that manages a subarea topology is called System Services Control Point (SSCP). The part of VTAM that manages APPN topology is called Control Point (CP).

VTAM subarea networks predate APPN. In many large enterprises, migration of subarea networks to an APPN topology is a desired technical objective. The migration allows the business to exploit APPN capabilities such as TCP/IP packet enveloping of SNA application data. Doing so permits elimination of older SNA-specific communication equipment by redirecting SNA data flows through existing TCP/IP communication networks. Also, VTAM administration and required coordination between communication hardware and software personnel can be significantly reduced with a pure APPN topology as a result of its increased flexibility over subarea networks.

All three VTAM configuration types (subarea, APPN, and mixed subarea/APPN) exist throughout the world's large enterprises.

18.8.1 What is a subarea network topology?

The distinguishing characteristics of a VTAM subarea network include the ownership and sharing of SNA resources. A subarea is a collection of SNA resources controlled by a single VTAM address space or a Network Control Program (NCP).

A single VTAM and the SNA resources it owns is called a *domain.* A cross-domain resource manager (CDRM), allows for communication between VTAM instances in the SNA network. When an LU requests a session to be established with an LU in a separate VTAM domain, the VTAM instances cooperate to establish a *cross-domain session.*

Figure 18-5 on page 18-11 shows a pure VTAM subarea network. This diagram might, for example, be representative of a business that is based in New York City with a large presence in Los Angeles, and a later expansion into Chicago.

In Figure 18-5, the network communication between cities is made possible through the use of SNA wide-area communication controllers (3725s or 3745s), loaded with a network control program (NCP). The NCP provides data flow control between PUs and LUs located in three the cities.

NCP, like VTAM, is a subarea. NCP, however, does not start or own SNA resources. Rather, NCP is part of a VTAM domain. The first VTAM to activate NCP would own it and the NCP-attached PUs and LUs when no owner is explicitly coded on the PU or LU definitions.

Figure 18-5 includes three VTAM domains and six subareas. The Chicago subarea could be controlled and managed by any of the three VTAM domains. The first VTAM to activate the Chicago NCP will own the PUs and LUs located in the Chicago subarea.

In general, full migration from the older subarea topology to an APPN topology is a desired technical objective due to opportunities to leverage a newer IP network infrastructure and the cost reduction associated with elimination of older SNA network equipment.

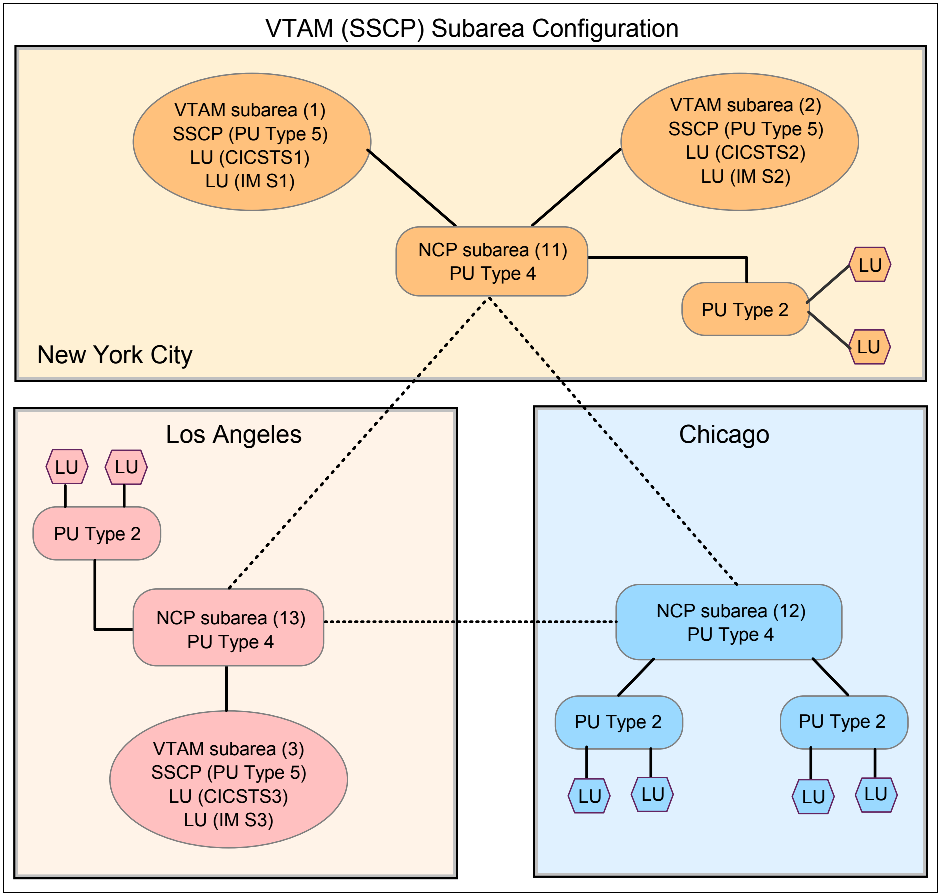


Figure 18-5 A pure VTAM subarea network

18.8.2 What is an APPN network topology?

Advanced Peer-to-Peer Networking® (APPN) is a kind of data communications support that routes data in a network between two or more systems that do not need to be directly connected.

APPN topology does not have a subarea number, nor does it have exclusive ownership of the SNA resources. Each APPN-participating VTAM is included in a geographically dispersed collection of shared SNA resources, eliminating the need for a cross-domain resource manager to establish sessions.

APPN includes a high-performance routing (HPR) method of sending SNA application data through existing TCP/IP network equipment. APPN includes a function called

Enterprise Extender (EE), sometimes referred to as HPR/IP. EE ensures that SNA applications can be served by state-of-the-art IP networking technology.

Assume that the company shown in Figure 18-5 on page 18-11 later migrates from subarea network topology to APPN topology. Figure 18-6 on page 18-12 shows the same company after migration.

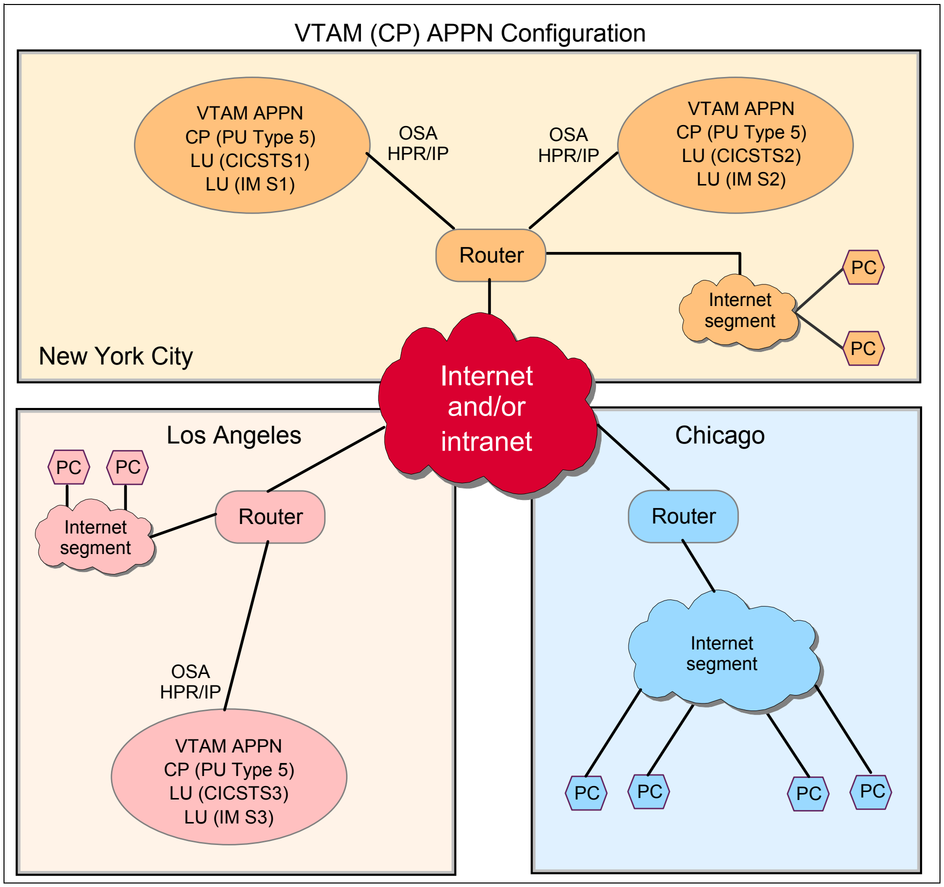


Figure 18-6 APPN topology

18.8.3 Summary of VTAM topologies

VTAM can be a subarea SSCP, an APPN CP, or both SSCP and CP serving a mixed network. The newer APPN topology is a desired architecture because of its ability to directly participate with existing IP infrastructures.

The original subarea SSCP VTAM instances will naturally evolve into a mixed subarea SSCP and APPN CP to take advantage of EE HPR/IP function and reduce costs of network-attached SNA communication equipment. This will most likely lead to subsequent decisions to migrate all remaining subareas to APPN topology to reduce network complexity.

18.9 Summary

In this chapter we have seen how applications keep changing, depending on the needs of the organization, its customers, and suppliers. Often those changes are implemented through new technologies, but the dependable, solid application remains unchanged.

Interaction with the computer happens online through the help of a transaction manager. Many transaction managers and database managers exist (one called CICS is discussed in the next chapter), but their principles are the same.

Data can be stored in a flat file, but this usually results in lots of duplication, which may result in inconsistent data. Therefore, it is better to create central databases, which can be accessed (reading and changing) from different places. The handling of consistency, security, etc. is done by the database management system; the user/developer does not need to worry about it.

To support the changing requirements of online transactions, enterprise networks can be designed, customized, operated, and supported using combined features and functions of both SNA and TCP/IP network layers using Communications Server on z/OS, AIX, Windows, Linux, and Linux on zSeries.

Key terms in this chapter		
APPN	communications server	Internet
LU-to-LU	NCP	OSI
SDLC	SNA	TCP/IP

18.10 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

18.11 Exercises

Find out the system's IP address, as follows:

1. From SDSF, enter the TCP/IP command /D TCPIP,,NETSTAT,HOME and from ISPF enter TSO NETSTAT HOME.
   - Is the output from each command the same? What is the home IP address or addresses of this z/OS system?
2. From SDSF, enter the VTAM command /D NET,CSM.
   - How much space TOTAL ALL SOURCES is INUSE?
   - How much space TOTAL ALL SOURCES is FREE?
   - How much space TOTAL ALL SOURCES is AVAILABLE?
3. From SDSF, enter the following VTAM commands:

   ```
   /D NET
   /D NET,APPLS
   /D NET,MAJNODES
   /D NET,TOPO,LIST=SUMMARY
   /D NET,CPCP
   /D NET,SESSIONS
   /D NET,SESSIONS,LIST=ALL
   /D NET,TSOUSER,ID=yourid
   ```

   Write down your IP address ___.___.___.___

   Briefly describe how the output of this command could be useful.
4. From ISPF start the z/OS UNIX shell with TSO OMVS.
   - Enter `onetstat -h`.
     Same information as in Exercise 1?
   - Note that you can use the TCP/IP commands from the z/OS UNIX shell as well (prefix `o`).
   - Enter `ping your.ip.addr.ess`.
   - Enter `traceroute your.ip.addr.ess`.

     Maybe the **`traceroute`** command is called **`tracert`**.
   - Enter `nslookup`.
     - Enter a WWW address, like `www.ibm.com`.
     - Exit the nslookup (Nameserver Lookup) (**`exit`**).
5. Exit the z/OS UNIX shell (**`exit`**).

19

Hardware systems and LPARs

Objective: As a new z/OS system programmer, you will need to develop a thorough understanding of the hardware that runs the z/OS operating system. z/OS is designed to make full use of IBM zSeries mainframe hardware and its many sophisticated peripheral devices.

After completing this chapter, you will be able to:

- Discuss the S/360 and zSeries hardware design.
- Explain processing units and disk hardware.
- Explain how mainframes differ from PC systems in data encoding.
- List some typical hardware configurations.

19.1 Hardware terminology

This chapter looks at the hardware in a complete system, although most of the emphasis is on the processor "box." In the early S/360 days a system had a single processor, which was also known as the central processing unit (CPU). The terms *system*, *processor*, and *CPU* were used interchangeably. However, these terms became confusing when systems became available with more than one processor. This is illustrated in Figure 19-1.

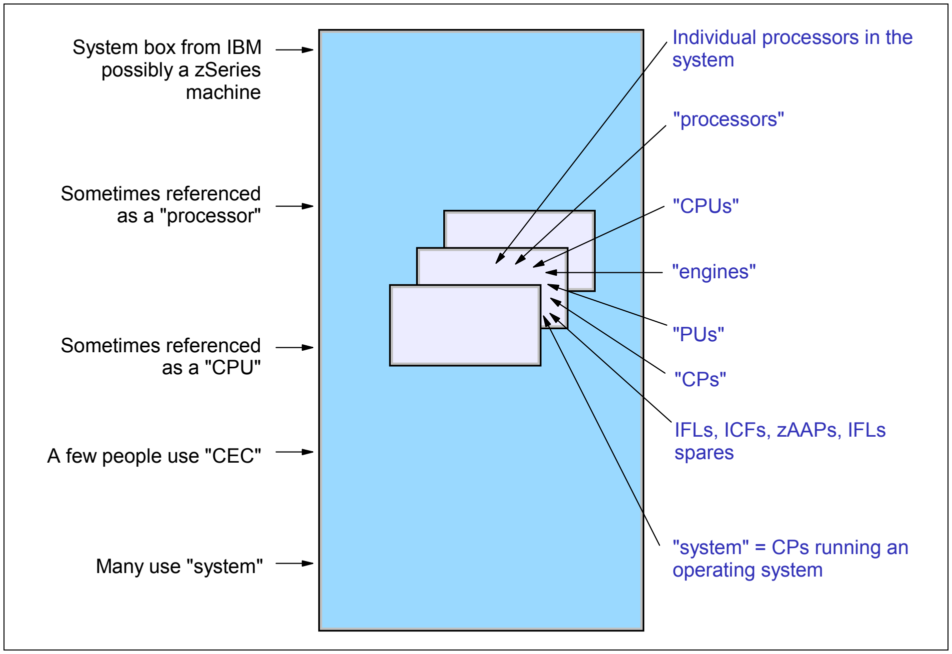


Figure 19-1 Terminology overlap

Processor and CPU can refer to either the complete system box, or to one of the processors (CPUs) within the system box. Although the meaning may be clear from the context of a discussion, even mainframe professionals must clarify which *processor* or *CPU* meaning they are using in a discussion. IBM introduced the term CEC (central electronic complex) to unambiguously refer to the "box." However, this term is not widely used.

Partitioning and some of the terms in Figure 19-1 are discussed later in this chapter. Briefly, all the S/390 or z/Architecture processors within a CEC are *processing units* (PUs). When IBM delivers the CEC, the PUs are characterized as CPs (for normal work), Integrated Facility for Linux (IFL), Integrated Coupling Facility (ICF) for Parallel Sysplex configurations, and so forth.

In this text, we hope the meanings of *system* and *processor* are clear from the context. We normally use *system* to indicate the hardware box, a complete hardware environment (with I/O devices), or an operating environment (with software), depending on the context. We normally use *processor* to mean a single processor (CP) within the CEC.

19.2 Early system design

Figure 19-2 presents a conceptual diagram of a S/360 system.

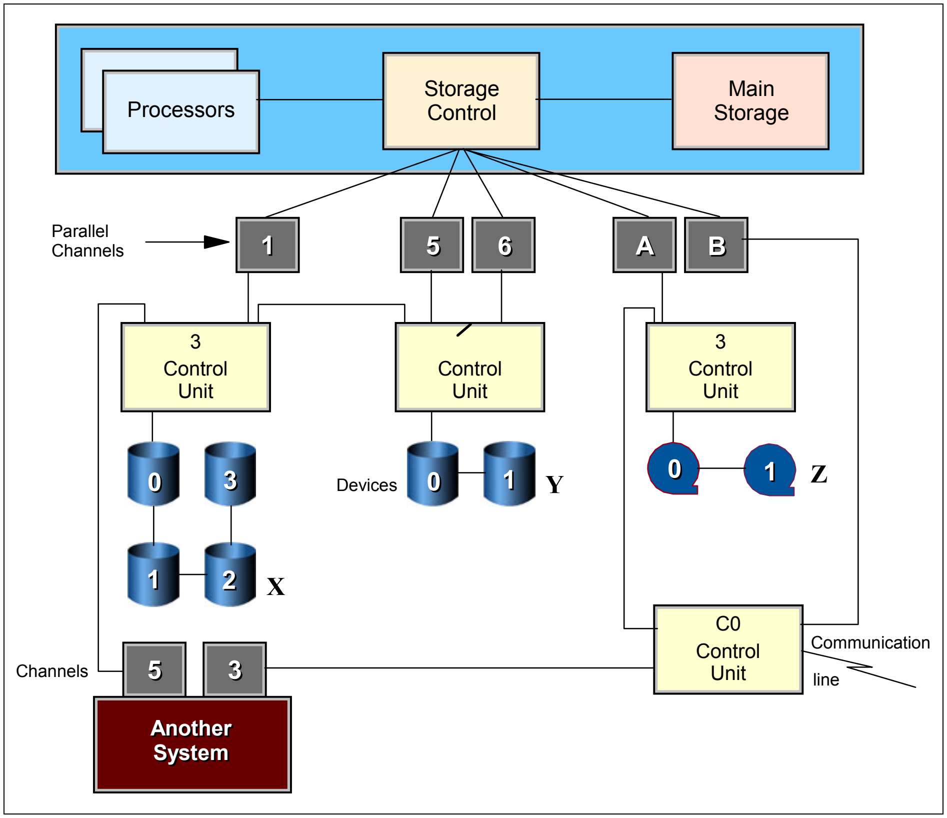


Figure 19-2 Conceptual S/360

Current systems are not connected as shown in Figure 19-2. However, this figure helps explain the background terminology that permeates mainframe discussions.

The central processor box contains the processors, memory,[1] control circuits, and interfaces for *channels*. A channel provides an independent data and control path between I/O devices and memory. Early systems had up to 16 channels; the largest zSeries machines at the time of writing can have over 1000 channels.

Channels connect to *control units*. A control unit contains logic to work with a particular type of I/O device. A control unit for a printer would have much different internal circuitry and logic than a control unit for a tape drive, for example. Some control units can have multiple channel connections providing *multiple paths* to the control unit and its devices.

Control units connect to *devices*, such as disk drives, tape drives, communication interfaces, and so forth. The division of circuitry and logic between a control unit and its devices is not defined, but it is usually more economical to place most of the circuitry in the control unit.

The channels in Figure 19-2 are *parallel channels* (also known as *bus and tag channels*, named for the two heavy copper cables they use). A parallel channel can be connected to a maximum of eight control units. Most control units can be connected to multiple devices; the maximum depends on the particular control unit, but 16 is a typical number.

Each channel, control unit, and device has an address, expressed as a hexadecimal number. The disk drive marked with an X in Figure 19-2 has address 132, derived as shown in Figure 19-3.

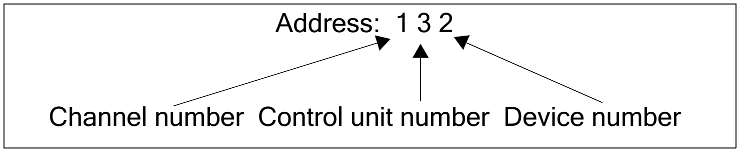


Figure 19-3 Device address

The disk drive marked with a Y in the figure can be addressed as 171, 571, or 671 because it is connected through three channels. By convention the device is known by its lowest address (171), but all three addresses could be used by the operating system to access the disk drive. Multiple paths to a device are useful for performance and for availability. When an application wants to access disk 171, the operating system will first try channel 1. If it is busy (or not available), it will try channel 5, and so forth.

Figure 19-2 contains another S/360 system with two channels connected to control units used by the first system. This sharing of I/O devices is common in all mainframe installations. Tape drive Z is address A31 for the first system, but is address 331 for the second system. Sharing devices, especially disk drives, is not a simple topic and there are hardware and software techniques used by the operating system to control exposures such as updating the same disk data at the same time from two independent systems.

As mentioned, current mainframes are not used exactly as shown in Figure 19-2 on page 19-3. Differences include:

[1] Some S/360s had separate boxes for memory. However, this is a conceptual discussion and we ignore such details.

- Parallel channels are not available on the newest mainframes and are slowly being displaced on older systems.
- Parallel channels have been replaced with ESCON® (Enterprise Systems CONnection) and FICON® (FIber CONnection) channels. These channels connect to only one control unit or, more likely, are connected to a *director* (switch) and are optical fibers.
- Current mainframes have more than 16 channels and use two hexadecimal digits as the channel portion of an address.
- Channels are generally known as CHPIDs (Channel Path Identifiers) or PCHIDs (Physical Channel IDs) on later systems, although the term *channel* is also correct. The channels are all integrated in the main processor box.

The device address seen by software is more correctly known as a device number (although the term *address* is still widely used) and is indirectly related to the control unit and device addresses.

For more information on the development of the IBM mainframe since 1964, see Appendix A, "A brief look at IBM mainframe history".

19.3 Current design

Current CEC designs are considerably more complex than the early S/360 design. This complexity includes many areas:

- I/O connectivity and configuration
- I/O operation
- Partitioning of the system

19.3.1 I/O connectivity

Figure 19-4 on page 19-6 illustrates a recent configuration. (A real system would have more channels and I/O devices, but this figure illustrates key concepts.) Partitions, ESCON channels, and FICON channels are described later.

Briefly, partitions create separate logical machines in the CEC. ESCON and FICON channels are logically similar to parallel channels but they use fiber connections and operate much faster. A modern system might have 100-200 channels or CHPIDs.[2] Key concepts partly illustrated here include the following:

- ESCON and FICON channels connect to only one device or one port on a switch.

[2] The more recent zSeries machines can have more than 256 channels, but an additional setup is needed for this. The channels are assigned in a way that only two hexadecimal digits are needed for CHPID addresses.

- Most modern mainframes use switches between the channels and the control units. The switches may be connected to several systems, sharing the control units and some or all of its I/O devices across all the systems.
- CHPID addresses are two hexadecimal digits.
- Multiple partitions can sometimes share CHPIDs. Whether this is possible depends on the nature of the control units used through the CHPIDs. In general, CHPIDs used for disks can be shared.
- An I/O subsystem layer exists between the operating systems in partitions (or in the basic machine if partitions are not used) and the CHPIDs.

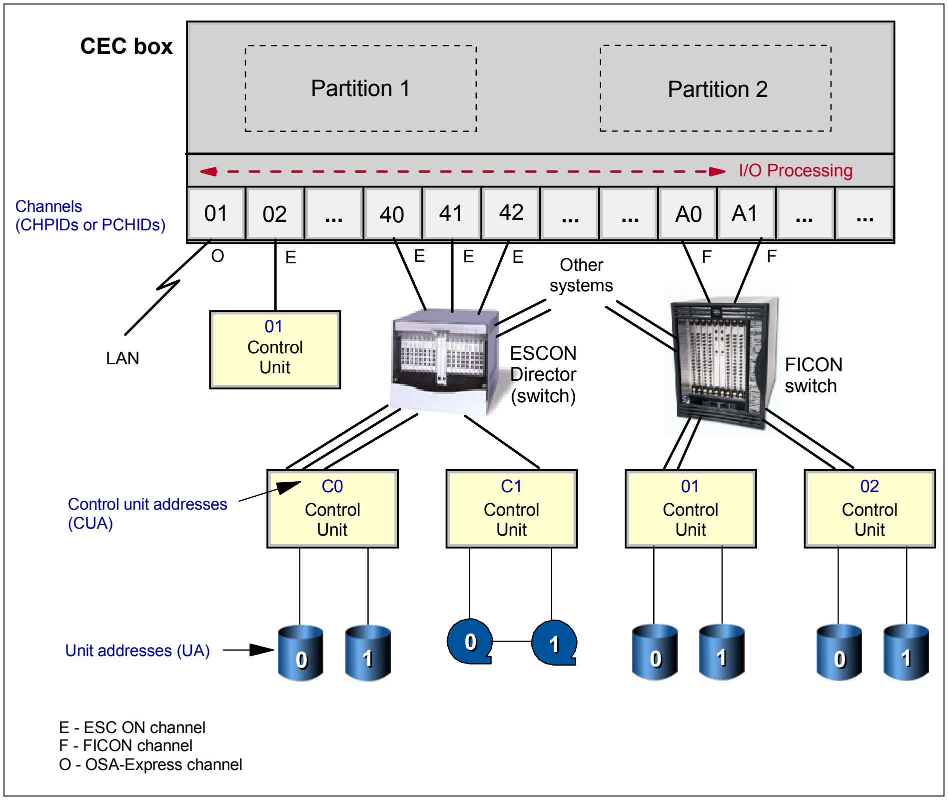


Figure 19-4 Recent system configuration

An ESCON director or FICON switch is a sophisticated device that can sustain high data rates through many connections. (A large director might have 200 connections, for example, and all of these can be passing data at the same time.) The director or switch must keep track of which CHPID (and partition) initiated which I/O operation so that data and status information is returned to the right place. Multiple I/O requests, from multiple CHPIDs attached to multiple partitions on multiple systems, can be in progress through a single control unit.

The I/O control layer uses a control file known as an IOCDS (I/O Control Data Set) that translates physical I/O addresses (composed of CHPID numbers, switch port numbers, control unit addresses, and unit addresses) into *device numbers* that are used by the operating system software to access devices. This is loaded into the Hardware Save Area (HSA) at power-on and can be modified dynamically. A device number looks like the addresses we described for early S/360 machines except that it can contain three or four hexadecimal digits.

Many users still refer to these as “addresses” although the device numbers are arbitrary numbers between x'0000' and x’FFFF’. The newest zSeries machines, at the time of writing, have two layers of I/O address translations between the real I/O elements and the operating system software. The second layer was added to make migration to newer systems easier.

Modern control units, especially for disks, often have multiple channel (or switch) connections and multiple connections to their devices. They can handle multiple data transfers at the same time on the multiple channels. Each device will have a Unit Control Block (UCB) in each MVS image.

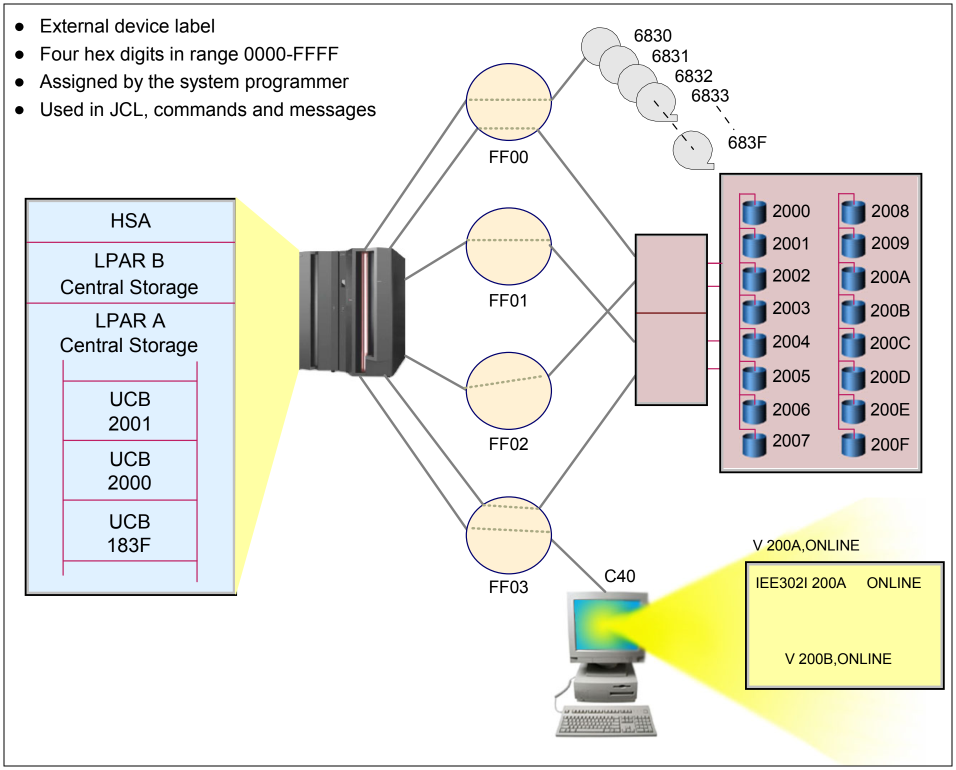


Figure 19-5 Device addressing

19.3.2 System control and partitioning

There are many ways to illustrate a zSeries mainframe's internal structure, depending on what we wish to emphasize. Figure 19-6 on page 19-9, while highly conceptual, shows several of the functions of the internal system controls on current mainframes. The internal controllers are microprocessors but use a much simpler organization and instruction set than zSeries processors. They are usually known as *controllers* to avoid confusion with zSeries *processors*.

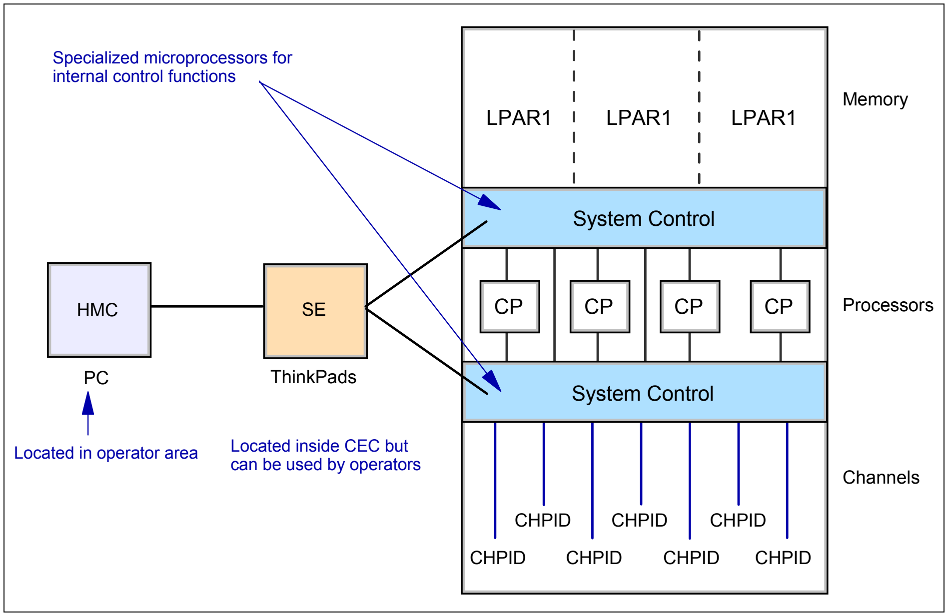


Figure 19-6 System control and partitioning

Among the system control functions is the capability to partition the system into several *logical partitions* (LPARs). An LPAR is a subset of the processor hardware that is defined to support an operating system. An LPAR contains resources (processors, memory, and input/output devices) and operates as an independent system. Multiple logical partitions can exist within a mainframe hardware system.

For many years there was a limit of 15 LPARs in a mainframe; more recent machines have a limit of 30 (and potentially more). Practical limitations of memory size, I/O availability, and available processing power usually limit the number of LPARs to less than these maximums.

Note: The hardware and firmware that provides partitioning is known as PR/SM (Processor Resource/System Manager). It is the PR/SM functions that are used to create and run LPARs. This difference between PR/SM (a built-in facility) and LPARs (the result of using PR/SM) is often ignored and the term LPAR is used collectively for the facility and its results.

System administrators assign portions of memory to each LPAR; memory cannot be shared among LPARs. The administrators can assign processors (noted as CPs in Figure 19-6) to specific LPARs or they can allow the system controllers to dispatch any or all the processors to all the LPARs using an internal load-balancing algorithm.

Channels (CHPIDs) can be assigned to specific LPARs or can be shared by multiple LPARs, depending on the nature of the devices on each channel.

A system with a single processor (CP processor) can have multiple LPARs. PR/SM has an internal dispatcher that can allocate a portion of the processor to each LPAR, much as an operating system dispatcher allocates a portion of its processor time to each process, thread, or task.

Partitioning control specifications are partly contained in the IOCDS and are partly contained in a system *profile*. The IOCDS and profile both reside in the *Support Element* (SE) which is simply a ThinkPad® (IBM laptop) inside the system. The SE can be connected to one or more Hardware Management Consoles (HMCs), which are desktop personal computers. An HMC is more convenient to use than an SE and can control several different mainframes.

Working from an HMC (or from an SE, in unusual circumstances), an operator prepares a mainframe for use by selecting and loading a profile and an IOCDS. These create LPARs and configure the channels with device numbers, LPAR assignments, multiple path information, and so forth. This is known as a Power-on Reset (POR). By loading a different profile and IOCDS, the operator can completely change the number and nature of LPARs and the appearance of the I/O configuration. However, doing this is usually disruptive to any running operating systems and applications and is therefore seldom done without advance planning.

19.3.3 Characteristics of LPARs

LPARs are, in practice, equivalent to separate mainframes. Each LPAR runs its own operating system. This can be any mainframe operating system; there is no need to run z/OS, for example, in each LPAR. The installation planners may elect to share I/O devices across several LPARs, but this is a local decision.

The system administrator can assign one or more system processors for the exclusive use of an LPAR. Alternately, the administrator can allow all processors to be used on some or all LPARs. Here, the system control functions (often known as microcode or firmware) provide a dispatcher to share the processors among the selected LPARs. The administrator can specify a maximum number of concurrent processors executing in each LPAR. The administrator can also provide weightings for different LPARs; for example, specifying that LPAR1 should receive twice as much processor time as LPAR2.

The operating system in each LPAR is IPLed separately, has its own copy[3] of its operating system, has its own operator console (if needed), and so forth. If the system in one LPAR crashes, there is no effect on the other LPARs.

[3] Most, but not all, of the z/OS system libraries can be shared.

In Figure 19-6 on page 19-9, for example, we might have a production z/OS in LPAR1, a test version of z/OS in LPAR2, and Linux for S/390 in LPAR3. If our total system has 8 GB of memory, we might have assigned 4 GB to LPAR1, 1 GB to LPAR2, 1 GB to LPAR3, and have kept 2 GB in reserve for some reason. The operating system consoles for the two z/OS LPARs might be in completely different locations.[4]

For most practical purposes there is no difference between, for example, three separate mainframes running z/OS (and sharing most of their I/O configuration) and three LPARs on the same mainframe doing the same thing. With minor exceptions z/OS, the operators, and applications cannot detect the difference.

The minor differences include the ability of z/OS (if permitted when the LPARs were defined) to obtain performance and utilization information across the complete mainframe system and to dynamically shift resources (processors and channels) among LPARs to improve performance.

19.3.4 Consolidation of mainframes

There are fewer mainframes in use today than there were 15 or 20 years ago. In some cases, all the applications were moved to other types of systems. However, in most cases the reduced number is due to consolidation. That is, several smaller mainframes have been replaced with a smaller number of larger systems.

There is a compelling reason for consolidation. Mainframe software (from many vendors) can be expensive and typically costs more than the mainframe hardware. It is usually less expensive (and sometimes *much* less expensive) to replace multiple software licenses (for smaller machines) with one or two licenses (for larger machines). Software license costs are often linked to the power of the system but the pricing curves favor a small number of large machines.

Software license costs for mainframes have become a dominant factor in the growth and direction of the mainframe industry. There are several nonlinear factors that make software pricing very difficult. We must remember that mainframe software is not a mass market situation like PC software. The growth of mainframe processing power in recent years has been nonlinear.

The relative power needed to run a traditional mainframe application (a batch job written in COBOL, for example) does not have a linear relation to the power needed for a new application (with a GUI interface, written in C and Java). The consolidation effect has produced very powerful mainframes. These might need 1% of their power to run an application, but the application vendor often sets a price based on the total power of the machine.

[4] Linux does not have an operator console in the sense of the z/OS consoles.

This results in the odd situation where customers want the latest mainframe (to obtain new functions or to reduce maintenance costs associated with older machines) but they want the *slowest* mainframe that will run their applications (to reduce software costs based on total system processor power).

19.4 Processing units

Figure 19-1 on page 19-2 lists several different types of processors in a system. These are all z/Architecture processors that can be used for slightly different purposes.[5] Several of these purposes are related to software cost control, while others are more fundamental.

All these start as equivalent processor units[6] (PUs) or engines. A PU is a processor that has not been *characterized* for use. Each of the processors begins as a PU and is characterized by IBM during installation or at a later time. The potential characterizations are:

- Central Processor (CP)

  This is a processor available to normal operating system and application software.

- System Assistance Processor (SAP)

  Every modern mainframe has at least one SAP; larger systems may have several. The SAPs execute internal code[7] to provide the I/O subsystem. An SAP, for example, translates device numbers and real addresses of CHPIDs, control unit addresses, and device numbers. It manages multiple paths to control units and performs error recovery for temporary errors. Operating systems and applications cannot detect SAPs, and SAPs do not use any “normal” memory.

- Integrated Facility for Linux (IFL)

  This is a normal processor with one or two instructions disabled that are used only by z/OS. Linux does not use these instructions and can be executed by an IFL. Linux can be executed by a CP as well. The difference is that an IFL is not counted when specifying the model number[8] of the system. This can make a substantial difference in software costs.

- zAAP

  This is a processor with a number of functions disabled (interrupt handling, some instructions) such that no full operating system can be executed on the processor. However, z/OS can detect the presence of zAAP processors and will use them to

---

[5] Do not confuse these with the controller microprocessors. The processors discussed in this section are full, standard mainframe processors.

[6] This discussion applies to the current zSeries machines at the time of writing. Earlier systems had fewer processor characterizations, and even earlier systems did not use these techniques.

[7] IBM refers to this as Licensed Internal Code (LIC). It is often known as microcode (which is not technically correct) or as firmware. It is definitely not user code.

[8] Some systems do not have different models; in this case a *capacity model number* is used.

execute Java code (and possibly other similar code in the future). The same Java code can be executed on a standard CP. Again, zAAP engines are not counted when specifying the model number of the system. Like IFLs, they exist only to control software costs.

- Integrated Coupling Facility (ICF)

  These processors run only Licensed Internal Code. They are not visible to normal operating systems or applications. A Coupling Facility is, in effect, a large memory scratch pad used by multiple systems to coordinate work. ICFs must be assigned to LPARs that then become coupling facilities. These topics are discussed in more detail in Chapter 20, "Parallel Sysplex" .

- Spare

  An uncharacterized PU functions as a "spare." If the system controllers detect a failing CP or SAP, it can be replaced with a spare PU. In most cases this can be done without any system interruption, even for the application running on the failing processor.

- Various forms of Capacity on Demand and similar arrangements exist whereby a customer can enable additional CPs at certain times (for unexpected peak loads, for example).

In addition to these characterizations of processors, some mainframes have models or versions that are configured to operate slower than the potential speed of their CPs. This is widely known as *kneecapping*, although IBM prefers the term *capacity setting,* or something similar. It is done by using microcode to insert null cycles into the processor instruction stream. The purpose, again, is to control software costs by having the minimum mainframe model or version that meets the application requirements. IFLs, SAPs, zAAPs, and ICFs always function at the full speed of the processor since these processors "do not count" in software pricing calculations.[9]

19.5 Multiprocessors

All the earlier discussions and examples assume that more than one processor (CP) is present in a system (and perhaps in an LPAR). It is possible to purchase a current mainframe with a single processor (CP), but this is not a typical system.[10] The term *multiprocessor* means several processors (CP processors) and implies that several processors are used by a copy of z/OS.

All operating systems today, from PCs to mainframes, can work in a multiprocessor environment. However, the degree of integration of the multiple processors varies

[9] This is true for IBM software but may not be true for all software vendors.

[10] All current IBM zSeries systems also require at least one SAP, so the minimum system has two processors: one CP and one SAP. However, the use of "processor" in the text usually means a CP processor usable for applications. Whenever discussing a processor other than a CP, we always make this clear.

considerably. For example, pending interrupts in a system (or in an LPAR) can be accepted by any processor in the system (or working in the LPAR). Any processor can initiate and manage I/O operations to any channel or device available to the system or LPAR. Channels, I/O devices, interrupts, and memory are owned by the system (or by the LPAR) and not by any specific processor.

This multiprocessor integration appears simple on the surface, but its implementation is complex. It is also important for maximum performance; the ability of any processor to accept any interrupt sent to the system (or to the LPAR) is especially important.

Each processor in a system (or in an LPAR) has a small private area of memory (8 KB starting at real address 0 and always mapped to virtual address 0) that is unique to that processor. This is the Prefix Storage Area (PSA) and is used for interrupt handling and for error handling. A processor can access another processor's PSA through special programming, although this is normally done only for error recovery purposes. A processor can interrupt other processors by using a special instruction (SIGP, for Signal Processor). Again, this is typically used only for error recovery.

19.6 Disk devices

IBM 3390 disk drives are commonly used on current mainframes. Conceptually, this is a simple arrangement, as shown in Figure 19-7.

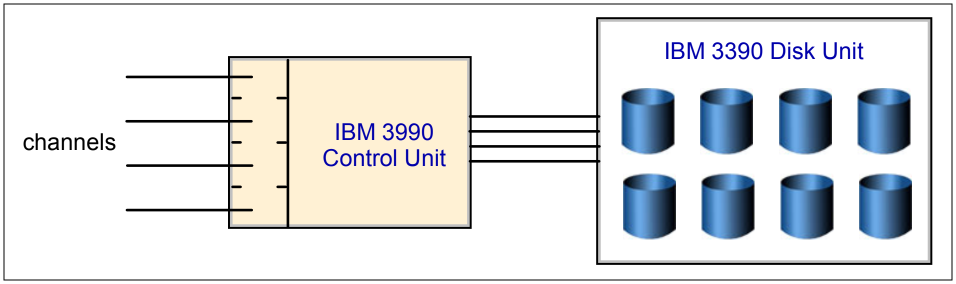


Figure 19-7 Initial IBM 3390 disk implementation

The associated control unit (3990) typically has four channels connected to one or more processors (probably with a switch), and the 3390 unit typically has eight or more disk drives. Each disk drive has the characteristics explained earlier. This illustration shows 3990 and 3390 units, and it also represents the concept or architecture of current devices.

The current equivalent device is an IBM 2105 Enterprise Storage Server®, simplistically illustrated in Figure 19-8.

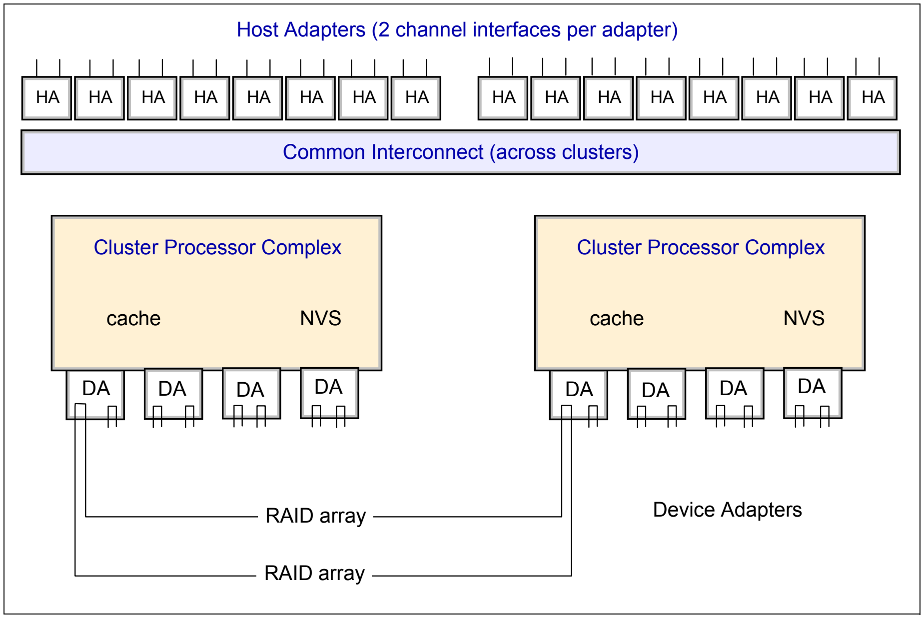


Figure 19-8 Current 3390 implementation

The 2105 unit is a very sophisticated device. It emulates a large number of control units and 3390 disk drives. It contains up to 11 TB of disk space, has up to 32 channel interfaces, 16 GB cache, and 284 MB of non-volatile memory (used for write queueing). The Host Adapters appear as control unit interfaces and can connect up to 32 channels (ESCON or FICON).

The physical disk drives are commodity SCSI-type units (although a serial interface, known as SSA, is used to provide faster and redundant access to the disks). A number of internal arrangements are possible, but the most common involves many RAID 5 arrays with hot spares. Practically everything in the unit has a spare or fallback unit. The internal processing (to emulate 3990 control units and 3390 disks) is provided by four high-end RISC processors in two processor complexes; each complex can operate the total system. Internal batteries preserve transient data during short power failures. A separate console is used to configure and manage the unit.

The 2105 offers many functions not available in real 3390 units, including FlashCopy®, Extended Remote Copy, Concurrent Copy, Parallel Access Volumes, Multiple Allegiance, a huge cache, and so forth.

A simple 3390 disk drive (with control unit) has different technology from the 2105 just described. However, the basic architectural appearance to software is the same. This allows applications and system software written for 3390 disk drives to use the newer technology with no revisions.[11]

There have been several stages of new technology implementing 3390 disk drives; the 2105 is the most recent of these. The process of implementing an architectural standard (in this case the 3390 disk drive and associated control unit) with newer and different technology while maintaining software compatibility is characteristic of mainframe development. As has been mentioned several times, maintaining application compatibility over long periods of technology change is an important characteristic of mainframes.

19.7 EBCDIC

The IBM S/360 zSeries machines use the Extended Binary Coded Decimal Interchange (EBCDIC) character set for most purposes. This is an 8-bit character set that was developed before 8-bit ASCII (American Standard Code for Information Interchange) became commonly used. Most systems that you are familiar with use ASCII. You need to be aware of the difference in encoding when moving data from ASCII-based systems to EBCDIC-encoded systems. Generally the conversion is handled under the covers, for example when text is sent from a 3270 emulator running on a PC to a TSO session. However, when transferring programs these must not normally be translated and a binary transfer must be specified. Occasionally, even when transferring text there are problems with certain characters such as the OR sign (|) or the logical *not*, and the programmer must look at the actual value of the translated character.

The EBCDIC character set is an extension of the 6-bit BCD character set that was widely used before the S/360 machines were developed. The BCD bit assignments for characters were partly related to the holes used in a punched card for the character. This appears to have been carried forward into EBCDIC bit assignments. The “gaps” in the character sequences in EBCDIC occur at the same places certain card row punches changed. In the early implementation of S/360 hardware this may have saved circuitry.

The original S/360 machines offered an ASCII option (a bit in a key control register) to shift from EBCDIC to the then-current 7-bit ASCII character set. It was used so little that the bit was later reassigned for other purposes.

A listing of EBCDIC and ASCII bit assignments is presented in Appendix D, “EBCDIC - ASCII table” and may be useful for this discussion. ASCII and EBCDIC are both 8-bit character sets. The difference is the way they assign bits for specific characters. The following are a few examples:

Character	EBCDIC	ASCII
A	11000001 (x'C1')	01000001 (x'41')
B	11000010 (x'C2')	01000010 (x'42')
a	10000001 (x'81')	01100001 (x'61')
1	11110001 (x'F1')	00110001 (x'31')

[11] Some software enhancements are needed to use some of the new functions, but these are compatible extensions at the operating system level and do not affect application programs.

```
space       01000000 (x'40')   00100000 (x'20')
```

The ASCII arrangement is more logical. However, the huge amount of existing data in EBCDIC and the large number of programs that are sensitive to the character set make it impractical to convert all existing data and programs to ASCII.

A character set has a collating sequence, corresponding to the binary value of the character bits. For example, A has a lower value than B in both ASCII and EBCDIC. The collating sequence is important for sorting and for almost any program that scans and manipulates character strings. The general collating sequence for common characters in the two character sets is as follows:

```
                      EBCDIC          ASCII
Lowest value:         space           space
                      punctuation     punctuation
                      lower case      numbers
                      upper case      upper case
Highest value:        numbers         lower case
```

For example, “a” is less than “A” in EBCDIC, but “a” is greater than “A” in ASCII. Numeric characters are less than any alphabetic letter in ASCII but are greater than any letter in EBCDIC. A-Z and a-z are two contiguous sequences in ASCII. In EBCDIC there are gaps between some letters. If we subtract A from Z in ASCII we have 25. If we subtract A from Z in EBCDIC we have 40 (due to the gaps in binary values between some letters).

Converting simple character strings between ASCII and EBCDIC is trivial. The situation is more difficult if the character being converted is not present in the standard character set of the target code. A good example is a logical *not* symbol that is used in a major mainframe programming language (PL/I); there is no corresponding character in the ASCII set. Likewise, some ASCII characters used for C programming were not present in the original EBCDIC character set, although these were later added to EBCDIC. There is still some confusion about the cent sign (¢) and the hat symbol (^), and a few more obscure symbols.

Mainframes also use several versions of Double Byte Character Sets (DBCS), mostly for Asian languages. The same character sets are used by some PC programs. Both mainframes (using EBCDIC for single-byte characters), PCs, and various RISC systems use the same Unicode assignments. (Unicode provides 16-bit characters, intending to include all modern languages on Earth.)

Traditional mainframe programming does not use special characters to terminate fields. In particular, nulls and new line characters (or CL/LF character pairs) are not used. There is no concept of a *binary* versus a *text* file. Bytes can be interpreted as EBCDIC or ASCII or something else if programmed properly. If such files are sent to a mainframe printer, it will attempt to interpret them as EBCDIC characters because the printer is sensitive to the character set. The z/OS Web server routinely stores ASCII files since the data will be interpreted by a PC browser program that expects ASCII data. Providing that no one attempts to print the ASCII files on a mainframe printer (or display them on a 3270), the system does not care what character set is being used.

19.7.1 Unicode

The use of Unicode is slowly growing. The latest zSeries mainframes have a number of unique hardware instructions for Unicode. At the time of writing, Unicode usage on mainframes is primarily in Java. However, other middleware is also beginning to use Unicode, and this is certainly an area of change for the near future.

19.8 Clustering

Clustering has been done on mainframes since the early S/360 days, although the term *cluster* is seldom used there. A clustering technique can be as simple as a shared DASD configuration where manual control or planning is needed to prevent unwanted data overlap.

Additional clustering techniques have been added over the years. In the following paragraphs we discuss three levels of clustering: Basic Shared DASD, CTC Rings, and Parallel Sysplex. Most z/OS installations today use one or more of these levels; a single z/OS installation is relatively rare.

In this discussion we use the term “image.” A z/OS system (with one or more processors) is a *z/OS image*. A z/OS image might exist on a S/390 or zSeries server (with LPARs), or it might exist in an LPAR, or it might run under z/VM (a hypervisor operating system mentioned in 1.9, “z/OS and other mainframe operating systems” on page 1-23). A system with six LPARs—each a separate z/OS system—has six z/OS images. We use the term image to indicate that we do not care where (basic system, LPAR, z/VM) a z/OS system is running.

19.8.1 Basic shared DASD

A basic shared DASD environment is illustrated in Figure 19-9. The figure shows z/OS images, but these could be any earlier version of the operating system. This could be two LPARs in the same system or two separate systems; there is absolutely no difference in the concept or operation.

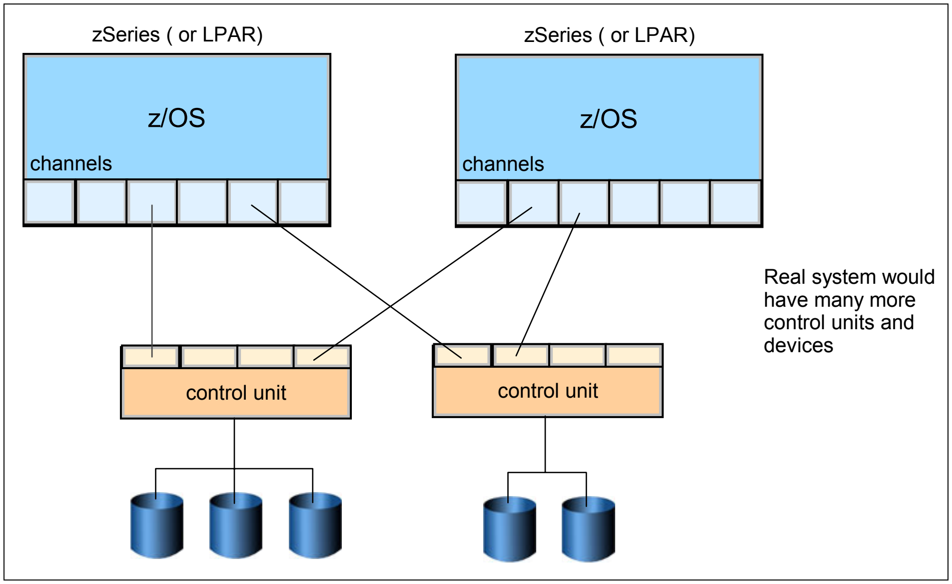


Figure 19-9 Basic shared DASD

The capabilities of a basic shared DASD system are limited. The operating systems automatically issue RESERVE and RELEASE commands to a disk drive before updating the VTOC or catalog on a drive. (These contain metadata for the disk drive indicating where various data sets reside on the drive.) A disk RESERVE command limits access to the complete disk drive to the system issuing the command, and this lasts until a RELEASE command is issued. These commands work well for limited periods (such as updating metadata). Applications can also issue RESERVE/RELEASE disk commands to protect their data sets for the duration of the application. This is not automatically done in this environment and is seldom done in practice because it would lock out other systems' access to the drive for too long.

A basic shared DASD system is typically used where the Operations staff controls which jobs go to which system and ensures that there is no conflict such as both systems trying to update the same data at the same time. Despite this limitation, a basic shared DASD environment is very useful for testing, recovery, and careful load balancing.

Other types of devices or control units can be attached to both systems. For example, a tape control unit, with multiple tape drives, can be attached to both systems. In this configuration the operators can then allocate individual tape drives to the systems as needed.

19.8.2 CTC rings

Figure 19-10 illustrates the next level of clustering. This has the same shared DASD as discussed previously, but also has two *channel-to-channel* (CTC) connections between the systems. This is known as a *CTC ring*. (The ring aspect is more obvious when more than two systems are involved.)

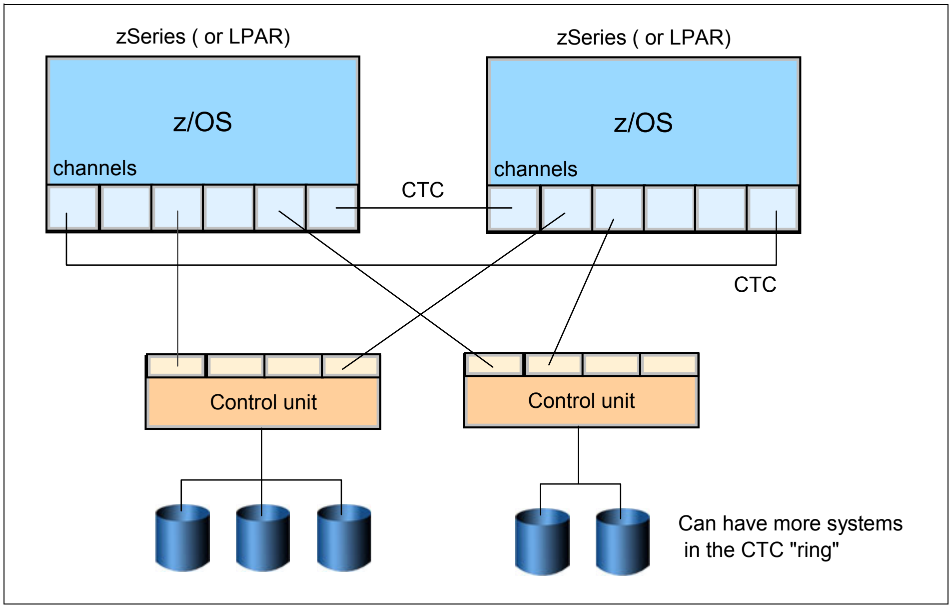


Figure 19-10 Basic sysplex

z/OS can use the CTC ring to pass control information among all systems in the ring. The information that can be passed this way includes:

- Usage and locking information for data sets on disks. This allows the system to automatically prevent unwanted duplicate access to data sets. (This locking is based on JCL specifications provided for jobs sent to the system, as explained in Chapter 6, “Using JCL and SDSF” .)
- Job queue information such that all the systems in the ring can accept jobs from a single input queue. Likewise, all systems can send printed output to a single output queue.
- Security controls that allow uniform security decisions across all systems.
- Disk metadata controls so that RESERVE and RELEASE disk commands are not necessary.

To a large extent, batch jobs and interactive users can run on any system in this configuration because all disk data sets can be accessed from any z/OS image. Jobs (and interactive users) can be assigned to whichever system is most lightly loaded at the time.

When the CTC configurations were first used, the basic control information shared was locking information. The internal z/OS component doing this is a General Resource Sharing (GRS) function, and the configuration became known as a GRS ring. The primary limitation of the ring is the latency involved in sending messages around the ring.

A different CTC configuration was used before the ring technique was developed. This required two CTC connections from every system to every other system in the configuration. When more than two or three systems were involved, this became complex and required a considerable number of channels.

The earlier CTC configurations (every-system-to-every-system or a ring configuration) were later developed into a basic *sysplex* configuration. This includes control data sets on the shared DASD. These are used for consistent operational specifications for all systems and to retain information over system restarts.

Configurations with shared DASD, CTC connections, and shared job queues are known as *loosely coupled systems*. (Multiprocessors, where several processors are used by the operating system, are sometimes contrasted as *tightly coupled systems* but this terminology is seldom used. These are also known as Symmetrical MultiProcessors (SMPs); the SMP terminology is common with RISC systems, but is not normally used for mainframes.)

19.8.3 Parallel sysplex

The most recent cluster configuration is a Parallel Sysplex. This involves one or more Coupling Facilities (CFs). A Coupling Facility is a zSeries processor, with memory and special channels, and a built-in operating system. It has no I/O devices, other than the special channels, and the operating system is very small.[12]

A CF functions largely as a fast scratch pad. It is used for three purposes:

- Locking information that is shared among all attached systems
- Cache information (such as for a data base) that is shared among all attached systems
- Data list information that are shared among all attached systems

The information in the CF resides in memory and a CF typically has a large memory. A CF can be a separate system or an LPAR can be used as a CF. Figure 19-11 illustrates a small Parallel Sysplex with two z/OS images. Again, this whole configuration could be in three LPARs of a single system, in three separate systems, or in a mixed combination.

[12] The CF operating system is nothing like z/OS and has no direct user interfaces.

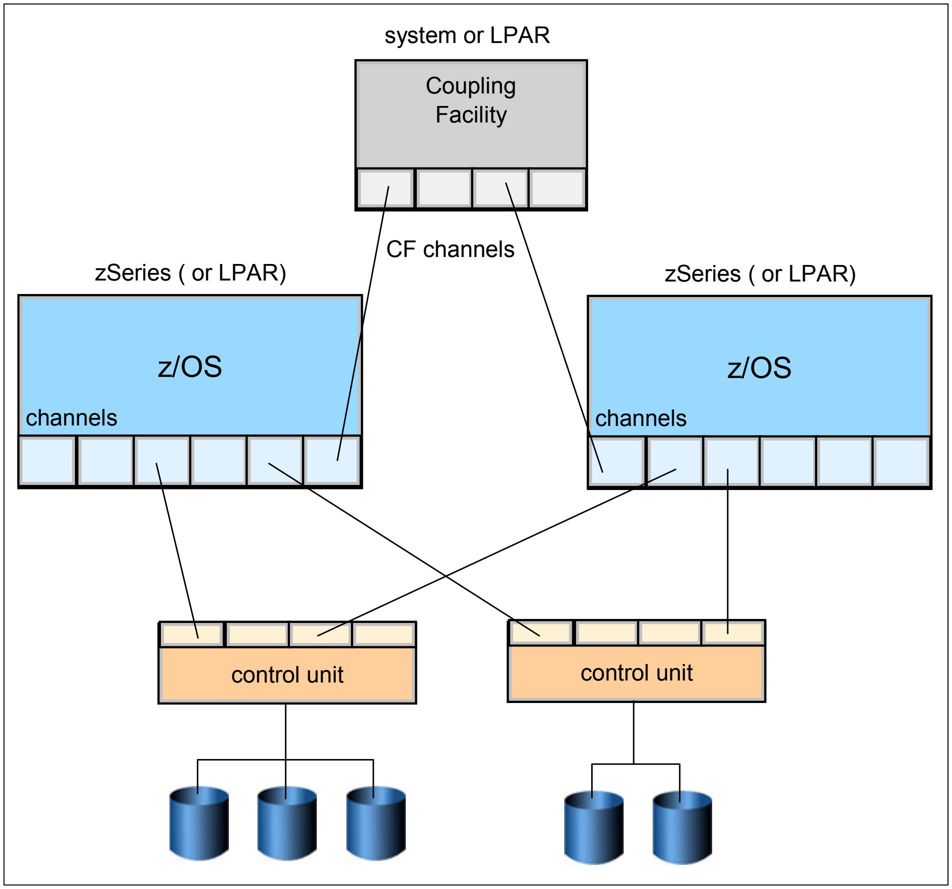


Figure 19-11 Parallel Sysplex

In many ways a Parallel Sysplex system appears as a single large system. It has a single operator interface (which controls all systems). With proper planning and operation (neither of which is trivial), complex workloads can be shared by any or all systems in the Parallel Sysplex, and recovery (by another system in the Parallel Sysplex) can be automatic for many workloads.

Parallel Sysplex systems are described in more detail in Chapter 20, “Parallel Sysplex” . The purpose of this brief introduction is to introduce additional terminology.

19.9 Typical mainframe systems

We outline the general configurations of three different levels of configuration in this section. These are not intended to be detailed descriptions, but are simply overviews.

19.9.1 Very small systems

The first two examples, in Figure 19-12 on page 19-23, show that *mainframe* refers more to a *style* of computing rather than to unique hardware. Two different systems are illustrated and neither uses mainframe hardware in the generally accepted sense of the term.

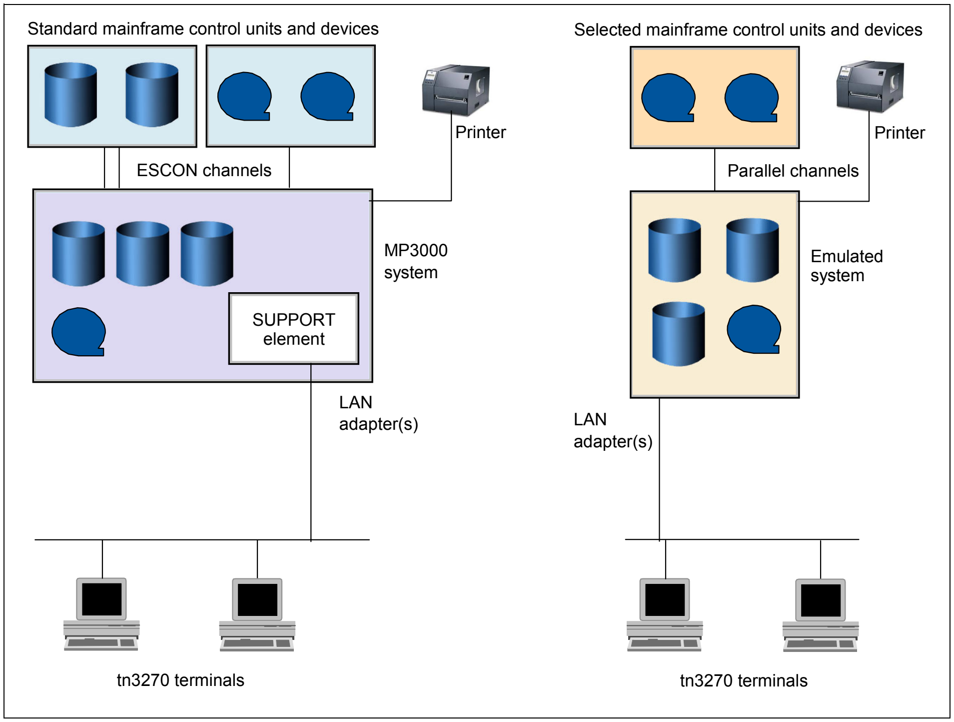


Figure 19-12 Very small mainframe configurations

The first system illustrated is an IBM Multiprise® 3000 system (MP3000). which IBM withdrew from marketing as this book was written. It was the smallest S/390 system produced in recent years. The MP3000 has one or two S/390 processors plus a SAP processor. It also has internal disk drives that can be configured to operate as normal IBM 3390 disk drives. A minimal internal tape drive is normally used for software installation. The MP3000 can have a substantial number of ESCON or parallel channels for connection to traditional external I/O devices.

The MP3000 is completely compatible with S/390 mainframes, but lacks later zSeries features. It can run early versions of z/OS and all prior versions of the operating system. It is typically used with z/VM or VSE operating systems (which were briefly described in 1.9, "z/OS and other mainframe operating systems" on page 1-23.)

The second system shown, the emulated zSeries system, has no mainframe hardware. It is based on a personal computer (running Linux or UNIX) and uses software to emulate z/OS[13]. Special PCI channel adapters can be used to connect to selected mainframe I/O devices. The personal computer running the emulated z/OS can have substantial internal disks (typically in a RAID array) for emulating IBM 3390 disk drives.

Both of these systems lack some features found in “real” mainframes. Nevertheless, both are capable of doing quality work. Typical application software cannot distinguish these systems from real mainframes. In fact, these are considered mainframes because their operating systems, their middleware, their applications, and their style of usage are the same as for larger mainframes. The MP3000 can be configured with LPARs and might run both test and production systems. The emulated system does not provide LPARs, but can accomplish much the same thing by running multiple copies of the emulator softare.

A key attraction of these systems is that they can be a “mainframe in a box.” In many cases no external traditional I/O devices are needed. This greatly reduces the entry-level price for a mainframe system.

19.9.2 Medium single systems

Figure 19-13 on page 19-25 shows a modest mainframe system and shows the typical external elements needed. The particular system shown is an IBM z890 system with two recent external disk controllers, a number of tape drives, printers, LAN attachments, and consoles.

This is a somewhat idealized configuration in that no older devices are involved. The systems outlined here might have a number of LPARs active, for example:

- A production z/OS system running interactive applications.
- A second production z/OS devoted to major batch applications. (These could also be run in the first LPAR, but some installations prefer a separate LPAR for management purposes.)
- A test z/OS version for testing new software releases, new applications, and so forth.
- One or several Linux partitions, perhaps running Web-related applications.

---

[13] One such product for emulating z/OS is called FLEX-ES, which is offered by Fundamental Software, Incorporated, of Fremont, California. FLEX-ES supports the same instruction set as a real zSeries mainframe and runs the same operating systems and applications.

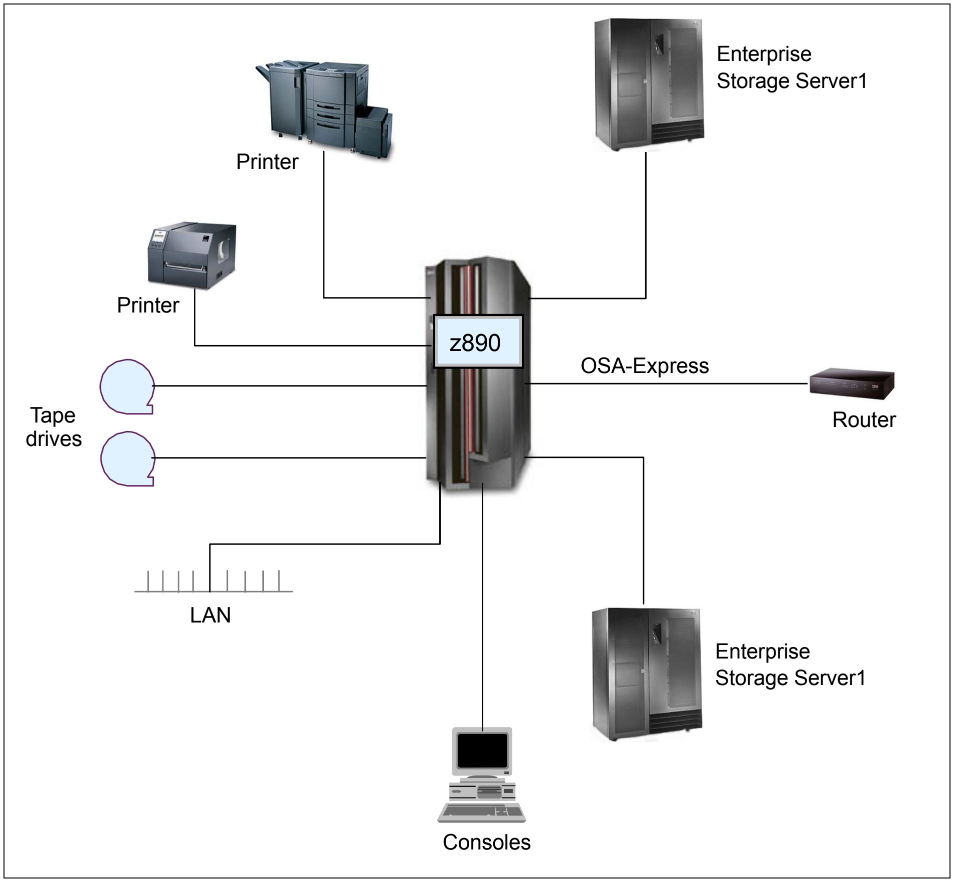


Figure 19-13 Medium mainframe configuration

The disk controllers in Figure 19-13 contain a large number of commodity drives running in multiple RAID configurations. The control unit transforms their interfaces to appear as standard IBM 3390 disk drives, which is the most common disk appearance for mainframes. These disk control units have multiple channel interfaces and can all operate in parallel.

19.9.3 Larger systems

Figure 19-14 shows a larger mainframe, although this is still a modest configuration when compared to a *large* mainframe installation. This example is typical in that both older and newer mainframes are present, along with channel switches allowing all systems to access most I/O devices. Likewise, new and older disk controllers (and devices) and tape controllers (and devices) are present. The total system is in a modest Parallel Sysplex configuration.

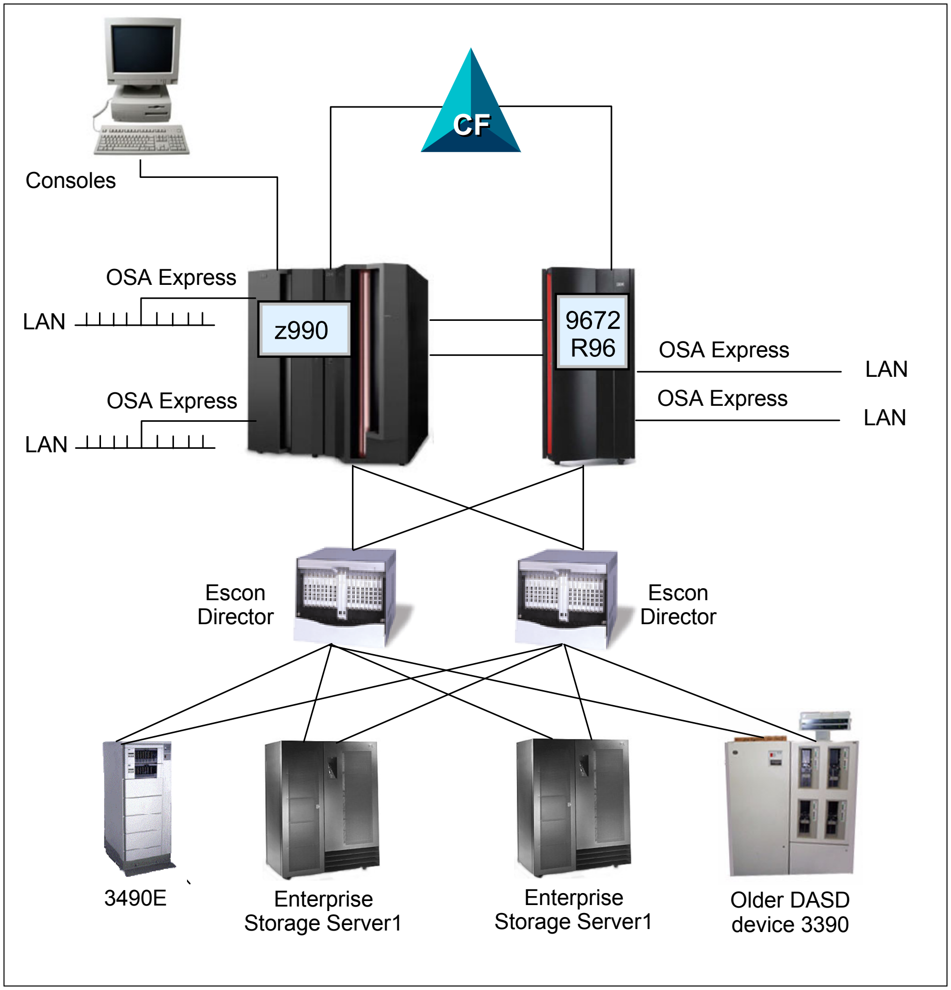


Figure 19-14 Moderately large mainframe configuration

Briefly, the devices in Figure 19-14 include:

- An IBM 3745, which is a communications controller optimized for connection to remote terminals and controllers, and LANs. A 3745 appears as a control unit to the mainframe.
- IBM 3490E tape drives, which, though somewhat outdated, handle the most widely-used mainframe-compatible tape cartridges.
- A sixth-generation mainframe design (G6).
- A newer z990 mainframe.
- An Enterprise Storage Server (ESS).

- ESCON directors.
- OSA Express connections to several LANs.
- CF (shown as a separate box, but it might be an LPAR in the z990).

19.10 Summary

Being aware of various meanings of the terms *systems*, *processors*, *CP*s, and so forth is important for your understanding of mainframe computers.

The original S/360 architecture, based on CPUs, memory, channels, control units, and devices, and the way these are addressed, is fundamental to understanding mainframe hardware—even though almost every detail of the original design has been changed in various ways. The concepts and terminology of the original design still permeate mainframe descriptions and designs.

The ability to partition a large system into multiple smaller systems (LPARs) is now a core requirement in practically all mainframe installations. The flexibility of the hardware design, allowing any processor (CP) to access and accept interrupts for any channel, control unit, and device connected to a given LPAR, contributes to the flexibility, reliability, and performance of the complete system. The availability of a pool of processors (PUs) that can be configured (by IBM) as customer processors (CPs), I/O processors (SAPs), dedicated Linux processors (IFLs), dedicated Java-type processors (zAAPs), and spare processors is unique to mainframes and, again, provides great flexibility in meeting customer requirements. Some of these requirements are based on the cost structures of some mainframe software.

In addition to the primary processors just mentioned (the PUs, and all their characterizations), mainframes have a network of controllers (special microprocessors) that control the system as a whole. These controllers are not visible to the operating system or application programs.

Since the early 1970s mainframes have been designed as multiprocessor systems, even when only a single processor is installed. All operating system software is designed for multiple processors; a system with a single processor is considered a special case of a general multiprocessor design.

The EBCDIC character set is different from the ASCII character set. On a character-by-character basis, translation between these two character sets is trivial. When collating sequences are considered, the differences are more significant and converting programs from one character set to the other can be trivial or it can be quite complex. The EBCDIC character set, based on an earlier 6-bit BCD character set, became an established standard before the current 8-bit ASCII character set had significant use.

All but the smallest mainframe installations typically use clustering techniques, although they do not normally use the terms *cluster* or *clustering*. As stated previously, a clustering technique can be as simple as a shared DASD configuration where manual control or planning is needed to prevent unwanted data overlap.

More common today are configurations that allow sharing of locking and enqueueing controls among all systems. Among other benefits, this automatically manages access to data sets so that unwanted concurrent usage does not occur.

The most sophisticated of the clustering techniques is a Parallel Sysplex, which is discussed in Chapter 20, "Parallel Sysplex" .

Key terms in this chapter		
central electronic complex (CEC)	central processing unit (CPU)	Channel Path Identifier (CHPID)
channel-to-channel (CTC)	ESCON channel	FICON channel
hardware management console (HMC)	I/O connectivity	Integrated Facility for Linux (IFL)
logical partition (LPAR)	multiprocessor	power-on reset (POR)
Support Element (SE)	unicode	zAAP processor

19.11 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1. Why does software pricing for mainframes seem so complex?
2. Why does IBM have so many models (or "capacity settings") in recent mainframe machines?
3. Why doesn't the power needed for a traditional COBOL application have a linear relationship with the power needed for a new Java application?
4. *Multiprocessor* means several processors (and that these processors are used by the operating system and applications). What does *multiprogramming* mean?
5. How integrated is the multiprocessing hardware on a RISC machine?
6. Why is converting a program from EBCDIC to ASCII not just a simple recompile?
7. What are the differences between loosely coupled systems and tightly coupled systems?
8. What z/OS application changes are needed to work in an LPAR?

19.12 Topics for further discussion

Visit a mainframe installation if this can be arranged. The range of new, older, and much older systems and devices found in a typical installation is usually interesting and helps to illustrate the sense of continuity that is so important to mainframe customers.

19.13 Exercises

1. To display the CPU configuration:
   a. Access SDSF from the ISPF primary option menu.
   b. In the command input field, enter `/D M=CPU` and press Enter.
   c. Use the ULOG option in SDSF to view the command display result.
2. To display the page data set usage:
   a. In the command input field, enter `/D ASM` and press Enter.
   b. Press PF3 to return to the previous screens.

20

Parallel Sysplex

Objective: In working with the z/OS operating system, you need to understand how it achieves near-continuous availability through technologies such as "no single points of failure."

After completing this chapter, you will be able to:

- Discuss Parallel Sysplex.
- Explain how Parallel Sysplex can achieve continuous availability.
- Explain dynamic workload balancing.
- Explain the single system image.

20.1 Sysplex overview

A *sysplex* is a collection of z/OS systems that cooperate, using certain hardware and software products, to process work. It is a clustering technology that can provide near-continuous availability.

A conventional large computer system also uses hardware and software products that cooperate to process work. A major difference between a sysplex and a conventional large computer system is the improved growth potential and level of availability in a sysplex. The sysplex increases the number of processing units and z/OS operating systems that can cooperate, which in turn increases the amount of work that can be processed. To facilitate this cooperation, new products were developed and old products were enhanced.

20.2 What is Parallel Sysplex?

The zSeries Parallel Sysplex uses multisystem data-sharing technology. It allows direct, concurrent read/write access to shared data from all processing nodes (or servers) in the configuration without impacting performance or data integrity. Each node can concurrently cache shared data in local processor memory through hardware-assisted cluster-wide serialization and coherency controls.

As a result, work requests that are associated with a single workload, such as business transactions or database queries, can be dynamically distributed for parallel execution on nodes in the sysplex cluster based on available processor capacity.

Figure 20-1 shows the visible parts of a Parallel Sysplex, namely the hardware. These are the key components of Parallel Sysplex as implemented in the zSeries architecture.

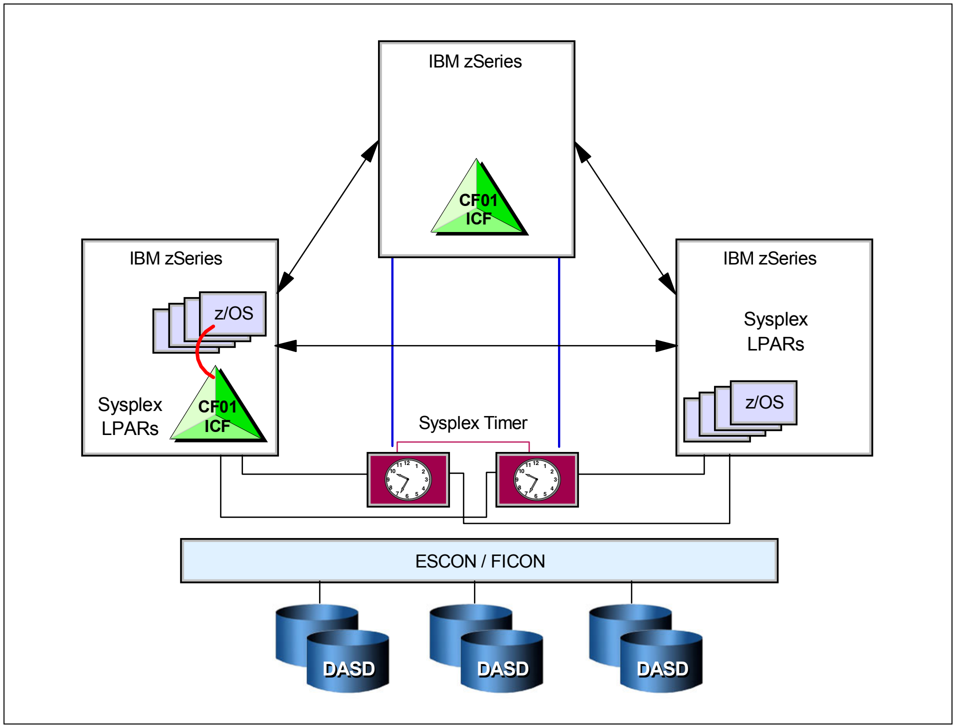


Figure 20-1 Sysplex hardware overview

20.2.1 Shared data clustering

Parallel Sysplex technology builds on and extends the strengths of zSeries servers by linking up to 32 servers with near linear scalability to create a powerful commercial processing clustered system. Every server in a Parallel Sysplex cluster has access to all data resources, and every "cloned" application can run on every server. Using zSeries Coupling Technology, Parallel Sysplex technology provides a "shared data" clustering technique that permits multi-system data sharing with high performance read/write integrity.

This "shared data" (as opposed to "shared nothing") approach enables workloads to be dynamically balanced across all servers in the Parallel Sysplex cluster. It enables critical business applications to take advantage of the aggregate capacity of multiple servers to help ensure maximum system throughput and performance during peak processing periods. In the event of a hardware or software outage, either planned or unplanned, workloads can be dynamically redirected to available servers, thus providing near-continuous application availability.

20.2.2 Non-disruptive maintenance

Another unique advantage of using Parallel Sysplex technology is the ability to perform hardware and software maintenance and installation in a non-disruptive manner.

Through data sharing and dynamic workload management, servers can be dynamically removed from or added to the cluster, allowing installation and maintenance activities to be performed while the remaining systems continue to process work. Furthermore, by adhering to the IBM software and hardware coexistence policy, software and/or hardware upgrades can be introduced one system at a time. This capability allows customers to roll changes through systems at a pace that makes sense for their business.

The ability to perform rolling hardware and software maintenance in a non-disruptive manner allows business to implement critical business function and react to rapid growth without affecting customer availability.

20.2.3 No single points of failure

Parallel Sysplex technology is an enabling technology, allowing highly reliable, redundant, and robust zSeries technologies to achieve near-continuous availability. A properly configured Parallel Sysplex cluster is designed to have no single points of failure, for example:

- Hardware and software components provide for concurrency to facilitate non-disruptive maintenance, like zSeries Capacity Upgrade on Demand that allows processing or coupling capacity to be added, one engine at a time, without disruption to customer workloads.
- DASD subsystems employ disk mirroring or RAID technologies to help protect against data loss, and exploit technologies to enable point-in-time backup, without the need to shut down applications.
- Networking technologies deliver functions such as VTAM Generic Resources, Multi-Node Persistent Sessions, Virtual IP Addressing, and Sysplex Distributor to provide fault-tolerant network connections.
- I/O subsystems support multiple I/O paths and dynamic switching to prevent loss of data access and improved throughput.
- z/OS and OS/390 software components allow new software releases to coexist with lower levels of those software components to facilitate rolling maintenance.
- Business applications are “data sharing-enabled” and cloned across servers to allow workload balancing to prevent loss of application availability in the event of an outage.
- Operational and recovery processes are fully automated and transparent to users, and reduce or eliminate the need for human intervention.

Parallel Sysplex is a way of managing this multi-system environment, providing such benefits as:

- Continuous availability
- Capacity
- Dynamic workload balancing
- Ease of use
- Single system image
- Compatible change and non-disruptive growth
- Application compatibility

In the following sections, we explain these in more detail.

20.2.4 Continuous availability

In a Parallel Sysplex cluster, it is possible to construct a parallel processing environment with no single points of failure. Since all systems in the Parallel Sysplex can have concurrent access to all critical applications and data, the loss of a system due to either hardware or software failure does not necessitate loss of application availability.

Peer instances of a failing subsystem executing on remaining healthy system nodes can take over recovery responsibility for resources held by the failing instance. Alternatively, the failing subsystem can be automatically restarted on still-healthy systems using automatic restart capabilities to perform recovery for work in progress at the time of the failure. While the failing subsystem instance is unavailable, new work requests can be redirected to other data-sharing instances of the subsystem on other cluster nodes to provide continuous application availability across the failure and subsequent recovery. This provides the ability to mask planned as well as unplanned outages to the end user.

Because of the redundancy in the configuration, there is a significant reduction in the number of single points of failure. Without a Parallel Sysplex, the loss of a server could severely impact the performance of an application, as well as introduce system management difficulties in redistributing the workload or reallocating resources until the failure is repaired. In an Parallel Sysplex environment, it is possible that the loss of a server may be transparent to the application, and the server workload can be redistributed automatically within the Parallel Sysplex with little performance degradation. Therefore, events that otherwise would seriously impact application availability, such as failures in CEC hardware elements or critical operating system components, would, in a Parallel Sysplex environment, have reduced impact.

Even though they work together and present a single image, the nodes in a Parallel Sysplex cluster remain individual systems, making installation, operation, and maintenance non-disruptive. You can introduce changes, such as software upgrades, one system at a time, while the remaining systems continue to process work. This allows you to roll changes through your systems on a schedule that is convenient to you.

20.2.5 Capacity

The Parallel Sysplex environment can scale near linearly from 2 to 32 systems. This can be a mix of any servers that support the Parallel Sysplex environment. The aggregate capacity of this configuration meets every processing requirement known today.

20.2.6 Dynamic workload balancing

The entire Parallel Sysplex cluster can be viewed as a single logical resource to end users and business applications. Just as work can be dynamically distributed across the individual processors within a single SMP server, so too can work be directed to any node in a Parallel Sysplex cluster having available capacity. This avoids the need to partition data or applications among individual nodes in the cluster or to replicate databases across multiple servers.

Workload balancing also permits you to run diverse applications across a Parallel Sysplex cluster while maintaining the response levels critical to your business. You select the service level agreements required for each workload, and the z/OS Workload Manager (WLM), along with subsystems such as CP/SM or IMS, automatically balances tasks across all the resources of the Parallel Sysplex cluster to meet your business goals. The work can come from batch, SNA, TCP/IP, DRDA, or WebSphere MQ.

There are several aspects to consider for recovery. First, when a failure occurs, it is important to bypass it by automatically redistributing the workload to utilize the remaining available resources. Secondly, it is necessary to recover the elements of work that were in progress at the time of the failure. Finally, when the failed element is repaired, it should be brought back into the configuration as quickly and transparently as possible to again start processing the workload. Parallel Sysplex technology enables all this to happen.

Workload distribution

Once the failing element has been isolated, it is necessary to non-disruptively redirect the workload to the remaining available resources in the Parallel Sysplex. In the event of failure in the Parallel Sysplex environment, the online transaction workload is automatically redistributed without operator intervention.

Generic Resource Management

Generic Resource Management provides the ability to specify to VTAM a common network interface. This can be used for CICS terminal owning regions (TORs), IMS Transaction Manager, TSO, or DB2 DDF work.

One of the features of this support is that, for example, if one of the CICS TORs fails, only a subset of the network will be affected. The affected terminals will be able to immediately log on again and continue processing after being connected to a different TOR.

20.2.7 Ease of use

The Parallel Sysplex solution satisfies a major customer requirement for continuous 24-hour-a-day, 7-day-a-week availability, while providing techniques for achieving simplified Systems Management consistent with this requirement. Some of the features of the Parallel Sysplex solution that contribute to increased availability also help to eliminate some Systems Management tasks. Examples include:

- z/OS Workload Manager

  The Workload Manager, or WLM, provides sysplex-wide workload management capabilities based on installation-specified performance goals and the business importance of the workloads. The Workload Manager tries to attain the performance goals through dynamic resource distribution. WLM provides the Parallel Sysplex cluster with the intelligence to determine where work needs to be processed and in what priority. The priority is based on the customer's business goals and is managed by sysplex technology.

- Sysplex Failure Manager (SFM)

  The Sysplex Failure Management policy allows the installation to specify failure detection intervals and recovery actions to be initiated in the event of the failure of a system in the sysplex.

  Without SFM, when one of the systems in the Parallel Sysplex fails, the operator is notified and prompted to take some recovery action. The operator may choose to partition the non-responding system from the Parallel Sysplex, or to take some action to try to recover the system. This period of operator intervention might tie up critical system resources required by the remaining active systems. Sysplex Failure Manager allows the installation to code a policy to define the recovery actions to be initiated when specific types of problems are detected, such as fencing off the failed image that prevents access to shared resources, logical partition deactivation, or central storage and expanded storage acquisition, to be automatically initiated following detection of a Parallel Sysplex failure.

- Automatic Restart Manager (ARM)

  The Automatic Restart Manager enables fast recovery of the subsystems that might hold critical resources at the time of failure. If other instances of the subsystem in the Parallel Sysplex need any of these critical resources, fast recovery will make these resources available more quickly. Even though automation packages are used today to restart the subsystem to resolve such deadlocks, ARM can be activated closer to the time of failure.

  The Automatic Restart Manager reduces operator intervention in the following areas:

  - Detection of the failure of a critical job or started task

  - Automatic restart after a started task or job failure

    After an ABEND of a job or started task, the job or started task can be restarted with specific conditions, such as overriding the original JCL or specifying job dependencies, without relying on the operator.

  - Automatic redistribution of work to an appropriate system following a system failure

    This removes the time-consuming step of human evaluation of the most appropriate target system for restarting work

- Cloning and symbolics

  Cloning refers to replicating the hardware and software configurations across the different physical servers in the Parallel Sysplex. That is, an application that is going to take advantage of parallel processing might have identical instances running on all images in the Parallel Sysplex. The hardware and software supporting these applications could also be configured identically on all systems in the Parallel Sysplex to reduce the amount of work required to define and support the environment.

  The concept of *symmetry* allows new systems to be introduced and enables automatic workload distribution in the event of failure or when an individual system is scheduled for maintenance. It also reduces the amount of work required by the system programmer in setting up the environment. Note that symmetry does *not* preclude the need for systems to have unique configuration requirements, such as the asymmetric attachment of printers and communications controllers, or asymmetric workloads that do not lend themselves to the parallel environment.

  System symbolics are used to help manage cloning. z/OS provides support for the substitution values in startup parameters, JCL, system commands, and started tasks. These values can be used in parameter and procedure specifications to allow unique substitution when dynamically forming a resource name.

20.2.8 zSeries Resource Sharing

A number of base z/OS components have discovered that IBM S/390 Coupling Facility shared storage provides a medium for sharing component information for the purpose of multi-system resource management. This exploitation, called IBM zSeries Resource Sharing, enables sharing of physical resources such as files, tape drives, consoles, and catalogs with improvements in cost, performance and simplified systems management. This is *not to be confused* with Parallel Sysplex data sharing by the database subsystems. zSeries Resource Sharing delivers immediate value even for customers who are not leveraging data sharing, through native system exploitation delivered with the base z/OS software stack.

One of the goals of the Parallel Sysplex solution is to provide simplified systems management by reducing complexity in managing, operating, and servicing a Parallel

Sysplex, without requiring an increase in the number of support staff and without reducing availability.

20.2.9 Single system image

Even though there could be multiple servers and z/OS images in the Parallel Sysplex and a mix of different technologies, the collection of systems in the Parallel Sysplex should appear as a single entity to the operator, the end user, the database administrator, and so on. A single system image brings reduced complexity from both operational and definition perspectives.

Regardless of the number of system images and the complexity of the underlying hardware, the Parallel Sysplex solution provides for a single system image from several perspectives:

- Data access, allowing dynamic workload balancing and improved availability
- Dynamic Transaction Routing, providing dynamic workload balancing and improved availability
- End-user interface, allowing logon to a logical network entity
- Operational interfaces, allowing easier Systems Management

Single point of control

It is a requirement that the collection of systems in the Parallel Sysplex can be managed from a logical single point of control. The term “single point of control” means the ability to access whatever interfaces are required for the task in question, without reliance on a physical piece of hardware. For example, in a Parallel Sysplex of many systems, it is necessary to be able to direct commands or operations to any system in the Parallel Sysplex, without the necessity for a console or control point to be physically attached to every system in the Parallel Sysplex.

Persistent single system image across failures

Even though individual hardware elements or entire systems in the Parallel Sysplex fail, a single system image must be maintained. This means that, as with the concept of single point of control, the presentation of the single system image is not dependent on a specific physical element in the configuration. From the end-user point of view, the parallel nature of applications in the Parallel Sysplex environment must be transparent. An application should be accessible regardless of which physical z/OS image supports it.

20.2.10 Compatible change and non-disruptive growth

A primary goal of Parallel Sysplex is continuous availability. Therefore, it is a requirement that changes such as new applications, software, or hardware can be introduced non-disruptively, and that they be able to coexist with current levels. In support of compatible change, the hardware and software components of the Parallel

Sysplex solution will allow the coexistence of two levels, that is, level N and level N+1. This means, for example, that no IBM software product will make a change that cannot be tolerated by the previous release.

20.2.11 Applications in a Parallel Sysplex

A design goal of Parallel Sysplex clustering is that no application changes be required to take advantage of the technology. For the most part, this has held true, although some affinities need to be investigated to get the maximum advantage from the configuration.

From the application architects' point of view, three major points might lead to the decision to run an application in a Parallel Sysplex:

- Technology benefits

  Scalability (even with non-disruptive upgrades), availability, and dynamic workload management are tools that enable an architect to meet customer needs in cases where the application plays a key role in the customer's business process. With the multisystem data sharing technology, all processing nodes in a Parallel Sysplex have full concurrent read/write access to shared data without affecting integrity and performance.

- Integration benefits

  Since many applications are historically S/390- and z/OS-based, new applications on z/OS get performance and maintenance benefits, especially if they are connected to existing applications.

- Infrastructure benefits

  If there is already an existing Parallel Sysplex, it needs very little infrastructure work to integrate a new application. In many cases the installation does not need to integrate new servers. Instead it can leverage the existing infrastructure and make use of the strengths of the existing sysplex. With Geographically Dispersed Parallel Sysplex™ (GDPS®)—connecting sysplexes in different locations—you can design a solution that is enabled for disaster recovery.

20.2.12 Geographically Dispersed Parallel Sysplex

Geographically Dispersed Parallel Sysplex (GDPS) is the primary disaster recovery and continuous availability solution for a zSeries multi-site enterprise. GDPS automatically mirrors critical data and efficiently balances workload between the sites.

GDPS also uses automation and Parallel Sysplex technology to help manage multi-site databases, processors, network resources and storage subsystem mirroring. This technology offers continuous availability, efficient workload management, resource management and prompt data recovery for business-critical zSeries applications and data.

With GDPS, the current maximum distance between the two sites is 100km (about 62 miles) of fiber, although there are some other restrictions. This provides a synchronous solution that helps to ensure no loss of data.

There is also GDPS/XRC, which can be used over extended distances and should provide a recovery point objective of less than two minutes (that is, a maximum of two minutes of data would need to be recovered or is lost).

20.3 Summary

Parallel Sysplex technology allows the linking up to 32 servers with near linear scalability to create a powerful commercial processing clustered system. Every server in a Parallel Sysplex cluster has access to all data resources, and every “cloned” application can run on every server. When used with coupling technology, Parallel Sysplex provides a “shared data” clustering technique that permits multi-system data sharing with high performance read/write integrity.

Sysplex design characteristics help businesses to run continuously, even during periods of dramatic change. Sysplex sites can dynamically add and change systems in a sysplex, and configure the systems for no single points of failure.

Through this state-of-the-art cluster technology, multiple z/OS systems can be made to work in concert to more efficiently process the largest commercial workloads.

Key terms in this chapter		
Automatic Restart Manager (ARM)	cloning	continuous availability
coupling technology	dynamic workload management	Geographically Dispersed Parallel Sysplex (GDPS)
Parallel Sysplex	shared data	single point of control
symbolics	sysplex	Workload Manager (WLM)

20.4 Questions for review

To help test your understanding of the material in this chapter, complete the following review questions:

1.

2.

3.

4.

5.

20.5 Topics for further discussion

1. What are the advantages of a Parallel Sysplex presenting a single image externally? Are there any disadvantages?
2. Why is continuous availability required in today's marketplace?
3. How might someone justify the cost of the "redundant" hardware and the cost of the software licences required to build a Parallel Sysplex?

Part 5

Appendixes

The appendixes that follow contain supplementary materials for the text and hands-on exercises.

A

A brief look at IBM mainframe history

This appendix discusses the development of the IBM mainframe from 1964 to the present, as illustrated in Figure A-1.

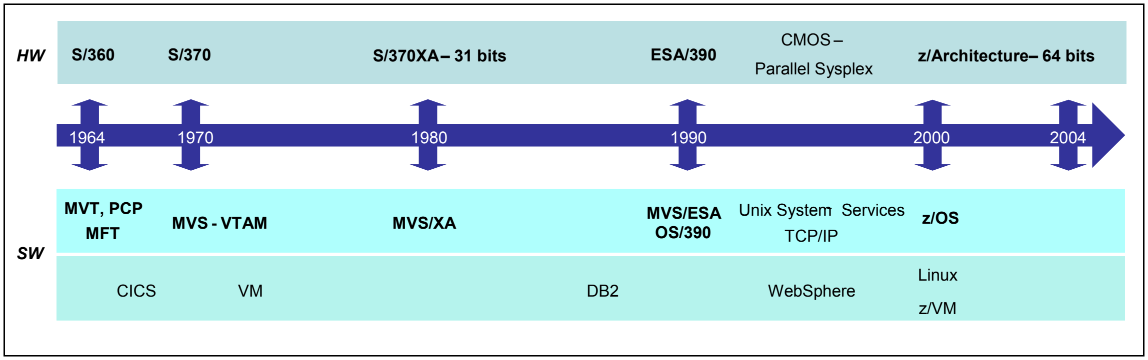


Figure A-1 IBM mainframe timeline

On April 7, 1964 IBM introduced System/360, a family of five increasingly powerful computers that ran the same operating system and could use the same 44 peripheral devices. Along with S/360 were also born the I/O subsystem concept (namely defining processors to transfer data between memory and I/O devices), and parallel channels (channels to transmit data in parallel to I/O devices).

Figure A-2 S/360 Model 40

For the first time, companies could run mission-critical applications for business on a highly secure platform.

In 1968, IBM introduced Customer Information Control System (CICS). It allowed workplace personnel to enter, update, and retrieve data online. To date, CICS remains one of the industry's most popular transaction monitors.

In 1969, Apollo 11's successful landing on the moon was supported by several System 360s, Information Management System (IMS) 360 and IBM software.

In the summer of 1970, IBM announced a family of machines with an enhanced instruction set, called System/370. These machines were capable of using more than one processor in the same system (initially two), sharing the memory. Through the 1970s the machines got bigger and faster, and multiprocessor systems became common. The 370 Model 145 was the first computer with fully integrated monolithic memory (circuits in which all of the same elements—resistors, capacitors, and diodes—are fabricated on a single slice of silicon) and 128-bit bipolar chips. More than 1,400 microscopic circuit elements were etched onto each one-eighth-inch-square chip.

Figure A-3 S/370™ Model 165

Able to run System/360 programs, thus easing the upgrade burden for customers, System/370 was also one of the first lines of computers to include “virtual memory” technology. This is a technique developed to expand the capabilities of the computer by using space on the hard drive to accommodate the memory requirements of software.

1980 saw the introduction of the 3081 processor. The 3081 offered a two-fold increase in internal performance from the previous mainframe processor, the 3033. It also featured Thermal Conduction Modules (TCMs) that significantly reduce space, cooling, and power requirements.

Figure A-4 3081 processor complex

Around 1982, addresses were extended from 24 bits to 31 bits (370XA).

In 1984, IBM announced a 1-megabit Silicon and Aluminum Metal Oxide Semiconductor (SAMOS) chip. Although “mega” means million, the chip actually holds 1,048,576 bits of information in a space smaller than a child's fingernail.

In 1988 extensions were added to support multiple address spaces. Still in 1988, using the mainframe, customers could deploy the DB2 database beyond “decision support systems” and into core transactional processing, driving reductions in CPU costs and dramatic improvements in concurrency.

In this period, IBM introduced the logical partition (LP) concept, which makes it possible to logically partition a mainframe into several independent processors sharing the same hardware.

Some industry pundits, however, didn't think the mainframe would survive the early 1990s. They predicted that the rapid growth in personal computers and small servers would render “big iron” (industry jargon for mainframe) obsolete. But IBM believed that serious, security-rich, industrial-strength computing would always be in demand, hence System/390. IBM stuck with the mainframe, but reinvented it from the inside, infusing it with an entirely new technology core and reducing its price.

Figure A-5 S/390 G5 and G6

IBM introduced the concept of System Clustering and Data Sharing, and announced System/390 Parallel Sysplex, which made possible very high levels of system availability.

Complementary Metal Oxide Semiconductor (CMOS)-based processors were introduced into the mainframe environment, replacing the bipolar technology and setting the new direction for modern mainframe technology. CMOS chips required less power than chips using just one type of transistor.

In the same decade, IBM introduced the parallel channel by Enterprise System Connectivity (ESCON) and began the integration of the network adapter to the mainframe, Open System Adapter (OSA).

In 1998 IBM introduced a new module capable of surpassing the 1,000 MIPS barrier, making it one of the world's most powerful mainframes. Also in this period, the concept of logical partition was extended to support 15 partitions.

Capacity Upgrade on Demand (CUoD) debuted on System/390 in 1999. CUoD provides extra processors as spare capacity that can be “turned on” as dictated by business needs. It provides a critical tool that can help companies better manage spikes in demand and handle unpredictable changes.

Still in 1999, IBM introduced the first enterprise server to use IBM's innovative copper chip technology. The synergy helped extend customers' ability to handle millions of e-business workload transactions and large-scale Enterprise Resource Planning applications. A new concept arose at that time, the possibility to increase the machines’ capacity without stopping them.

FICON, a new fiber optic channel was introduced with up to eight times the capacity of ESCON channels. Also in 1999, Linux appeared on System/390 for the first time.

In October 2000, IBM announced the first generation of IBM's current mainframe family, the z/Series.

The z/Architecture is an extension of ESA/390 and supports 64-bit addressing. Dynamic channel management was also introduced, as well as specialized cryptographic capability. The mainframe became "open" and capable of executing Linux; special processors (IFLs) were developed.

The on demand era plays to the strengths of the IBM eServer™ z/Series. z900 was launched in 2000 and was the first IBM server "designed from the ground up for e-business." The latest member of the family, z990, brings enriched functions that are required for the on demand data center.

Figure A-6 z900

The current generation of mainframes reaches 9000 MIPS; the increased scalability is further supported by the increase in the number of logical partitions available from 15 to 30 LPARs. There is still a 256-channel limit per operating system image, but z990 can have 1024 channels distributed in four Logical Channel SubSystems (LCSSs). The current model also offers IFL, a special processor for Linux to manage clustering, and zAAP to process Java.

Figure A-7 z990

zSeries is based on the 64-bit z/Architecture, which is designed to reduce memory and storage bottlenecks and which can automatically direct resources to priority workloads through Intelligent Resource Director (IRD). IRD is a key feature of the z/Architecture. Together, Parallel Sysplex technology and IRD are designed to provide the flexibility and responsiveness required by on demand business workloads.

The z990 provides a multibook system structure that supports the configuration of one to four *books*. Each book is comprised of a MultiChip Module (MCM) with 12 processors, of which eight can be configured as standard processors; memory cards that can support up to 64 GB of memory per book; and high performance Self-Timed Interconnects. The maximum number of processors available on a z990 is 32.

To support the highly scalable multibook system design, the Channel SubSystem (CSS) has been enhanced with Logical Channel SubSystems (LCSSs), which offers the capability to install up to 1024 ESCON channels across three I/O cages. With Spanned Channel support, HiperSockets™, ICB, ISC-3, OSA-Express and FICON Express can be shared across LCSSs for additional flexibility. High-speed interconnects for TCP/IP communication, known as HiperSockets, allow TCP/IP traffic to travel among partitions and virtual servers at memory speed, rather than network speed.

The mainframe delivers enriched functions for the on demand operating environment. zSeries is the enterprise class e-business server optimized for mixed workload integration, high transaction processing, and data serving for the on demand world.

B

DB2 sample tables

Most of the examples in Chapter 11, “Understanding CICS and DB2” refer to the tables in this appendix. As a group, the tables include information that describes employees and departments and make up a sample application that illustrates most of the features of DB2.

Department table (DEPT)

The department table describes each department in the enterprise, identifies its manager, and shows the department to which it reports. The table resides in table space DSN8D81A.DSN8S81D and is created with the following code:

```
CREATE TABLE DSN8810.DEPT
      (DEPTNO    CHAR(3)          NOT NULL,
       DEPTNAME  VARCHAR(36)      NOT NULL,
       MGRNO     CHAR(6)                  ,
       ADMRDEPT  CHAR(3)          NOT NULL,
       LOCATION  CHAR(16)                 ,
       PRIMARY KEY (DEPTNO)               )
  IN DSN8D81A.DSN8S81D
  CCSID EBCDIC;
```

Because the table is self-referencing, and also is part of a cycle of dependencies, its foreign keys must be added later with these statements:


```
ALTER TABLE DSN8810.DEPT
      FOREIGN KEY RDD (ADMRDEPT) REFERENCES DSN8810.DEPT
              ON DELETE CASCADE;

ALTER TABLE DSN8810.DEPT
      FOREIGN KEY RDE (MGRNO) REFERENCES DSN8810.EMP
              ON DELETE SET NULL;
```

The content of the department table

Column	Column Name	Description
1	DEPTNO	Department ID, the primary key
2	DEPTNAME	A name describing the general activities of the department
3	MGRNO	Employee number (EMPNO) of the department manager
4	ADMRDEPT	ID of the department to which this department reports; the department at the highest level reports to itself
5	LOCATION	The remote location name

Indexes on the department table

Name	On Column	Type of Index
DSN8810.XDEPT1	DEPTNO	Primary, ascending
DSN8810.XDEPT2	MGRNO	Ascending
DSN8810.XDEPT3	ADMRDEPT	Ascending

Content of the department table

DEPTNO	DEPTNAME	MGRNO	ADMRDEPT	LOCATION
A00	SPIFFY COMPUTER SERVICE DIV.	000010	A00	----------------
B01	PLANNING	000020	A00	----------------
C01	INFORMATION CENTER	000030	A00	----------------
D01	DEVELOPMENT CENTER	------	A00	----------------
E01	SUPPORT SERVICES	000050	A00	----------------
D11	MANUFACTURING SYSTEMS	000060	D01	----------------
D21	ADMINISTRATION SYSTEMS	000070	D01	----------------
E11	OPERATIONS	000090	E01	----------------
E21	SOFTWARE SUPPORT	000100	E01	----------------
F22	BRANCH OFFICE F2	------	E01	----------------
G22	BRANCH OFFICE G2	------	E01	----------------
H22	BRANCH OFFICE H2	------	E01	----------------
I22	BRANCH OFFICE I2	------	E01	----------------
J22	BRANCH OFFICE J2	------	E01	----------------

Relationship to other tables

The table is self-referencing: the value of the administering department must be a department ID. The table is a parent table of:

- The employee table, through a foreign key on column WORKDEPT.
- The project table, through a foreign key on column DEPTNO. It is a dependent of the employee table, through its foreign key on column MGRNO.

Employee table (EMP)

The employee table identifies all employees by an employee number and lists basic personnel information. The table resides in the partitioned table space DSN8D81A.DSN8S81E. Because it has a foreign key referencing DEPT, that table and the index on its primary key must be created first. Then EMP is created with the following:

```
CREATE TABLE DSN8810.EMP
      (EMPNO     CHAR(6)                            NOT NULL,
       FIRSTNME  VARCHAR(12)                        NOT NULL,
       MIDINIT   CHAR(1)                            NOT NULL,
       LASTNAME  VARCHAR(15)                        NOT NULL,
       WORKDEPT  CHAR(3)                                    ,
       PHONENO   CHAR(4)          CONSTRAINT NUMBER CHECK
                 (PHONENO >= '0000' AND
                  PHONENO <= '9999')                        ,
       HIREDATE  DATE                                       ,
       JOB       CHAR(8)                                    ,
       EDLEVEL   SMALLINT                                   ,
       SEX       CHAR(1)                                    ,
       BIRTHDATE DATE                                       ,
       SALARY    DECIMAL(9,2)                               ,
       BONUS     DECIMAL(9,2)                               ,
       COMM      DECIMAL(9,2)                               ,
       PRIMARY KEY (EMPNO)                                  ,
       FOREIGN KEY RED (WORKDEPT) REFERENCES DSN8810.DEPT
                 ON DELETE SET NULL                         )
  EDITPROC  DSN8EAE1
  IN DSN8D81A.DSN8S81E
  CCSID EBCDIC;
```

Columns of the employee table

Column	Column Name	Description
1	EMPNO	Employee number (the primary key)
2	FIRSTNME	First name of employee
3	MIDINIT	Middle initial of employee
4	LASTNAME	Last name of employee
5	WORKDEPT	ID of department in which the employee works
6	PHONENO	Employee telephone number
7	HIREDATE	Date of hire
8	JOB	Job held by the employee
9	EDLEVEL	Number of years of formal education
10	SEX	Sex of the employee (M or F)
11	BIRTHDATE	Date of birth
12	SALARY	Yearly salary in dollars
13	BONUS	Yearly bonus in dollars
14	COMM	Yearly commission in dollars

Indexes of the employee table

Name	On Column	Type of Index
DSN8810.XEMP1	EMPNO	Primary, partitioned, ascending
DSN8810.XEMP2	WORKDEPT	Ascending

Relationship to other tables

The table is a parent table of:

- The department table, through a foreign key on column MGRNO.
- The project table, through a foreign key on column RESPEMP. It is a dependent of the department table, through its foreign key on column WORKDEPT.

C

Utility programs

z/OS includes a narrow and somewhat uncertain definition of *utility programs*. Initially, utility programs were those programs documented in the early *OS/360 Utilities* manual. By common acceptance by the MVS user community, a few programs have been added to this set and several have been removed (by becoming obsolete). There is no specific definition of what constitutes a z/OS utility program today, but common usage includes only a few z/OS-provided programs as *utilities*.

The UNIX community, by contrast, considers many of the standard commands as *utilities*. This includes compilers, backup programs, filters, and many other types of programs. To the z/OS community these are *applications* or *programs*, but are not *utilities*.[1] The difference is simply one of terminology, but it can be confusing to new z/OS users.

Considering the wide-ranging functions and abilities of z/OS, there are only a small number of system-provided utilities. This has resulted in a large number of customer-written utility programs (although most users refrain from naming them *utilities*), and many of these are widely shared by the user community. Independent software vendors also provide many similar products (for a fee).

Most of the basic and system utilities described here are documented in *z/OS V1R3.0-V1R6.0 DFSMSdfp Utilities*, SC26-7414. This appendix is intended to provide a flavor of what is available and to provide simple examples of the most basic functions.

---

[1] z/OS UNIX uses the common UNIX terminology for utilities.

Basic utilities

A few utility programs (using the traditional terminology) are widely used in batch jobs. These are described in some detail here.

IEFBR14

The only function of this program is to provide a zero (0) completion code. It is used as a safe vehicle to "execute JCL." The notion of executing JCL is considered incorrect terminology, but it conveys the idea very well. For example, consider the following job:

```
//OGDEN1 JOB 1,BILL,MSGCLASS=X
//  EXEC PGM=IEFBR14
//A DD DSN=OGDEN.LIB.CNTL,DISP=(NEW,CATLG),VOL=SER=WORK02,
//        UNIT=3390,SPACE=(CYL,(3,1,25)
//B DD DSN=OGDEN.OLD.DATA,DISP=(OLD,DELETE)
```

This is a useful job although the program that is executed (IEFBR14) does nothing. While preparing to run the job, the initiator allocates OGDEN.LIB.CNTL and keeps the data set when the job ends. It also deletes OGDEN.OLD.DATA at the end of the job. The DD names A and B have no meaning and are used because the syntax of a DD statement requires a DD name.

The same functions to create one data set and delete another could be done through ISPF, for example, but these actions might be needed as part of a larger sequence of batch jobs.

Note: The name IEFBR14 is interesting. One IBM group writing early OS/360 code used the prefix IEF for all their modules. In assembly language BR means Branch to the address in a Register. Branching to the address in general register 14 is the standard way to end a program. While not an especially clever name, practically all dedicated z/OS users remember IEFBR14 easily.

IEFBR14 is not a utility, in the sense that it is not included in the *Utilities* manual. However, there is no other practical category for this useful program, so we have arbitrarily placed it in the utility category.

IEBGENER

The IEBGENER utility copies one sequential data set to another. (Remember that a member of a partitioned data set can be used as a sequential data set.) It can also do some filtering of the data, change LRECL and BLKSIZE, generate records, and several other functions. However, the most common use is to simply copy data sets. A typical job could be the following:

```
//OGDEN2 JOB 1,BILL,MSGCLASS=X
```

```
//  PGM=IEBGENER
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=X
//SYSUT1 DD DISP=SHR,DSN=BILL.SEQ.DATA
//SYSUT2 DD DISP=(NEW,CATLG),DSN=BILL.COPY.DATA,UNIT=3390,
//  VOL=SER=WORK02,SPACE=(TRK,3,3))
```

IEBGENER requires four DD statements with the DD names indicated in the example. The SYSIN DD statement is used to read control parameters; for simple uses no control parameters are needed and a DD DUMMY can be used. The SYSPRINT statement is for messages from IEBGENER. The SYSUT1 statement is for input and the SYSUT2 statement is for output. This example reads an existing data set and copies it to a new data set.

If the output data set is new and if no DCB parameters are specified, IEBGENER copies the DCB parameters from the input data set. (The DCB parameters include LRECL, RECFM, and BLKSIZE, as described in 4.8, "Data set record formats" on page 4-7.)

Another common example is something like the following:

```
//OGDEN2 JOB 1,BILL,MSGCLASS=X
//  PGM=IEBGENER
//SYSIN DD DUMMY
//SYSPRINT DD SYSOUT=X
//SYSUT2 DD DISP=OLD,DSN=BILL.TEST.DATA
//SYSUT1 DD *
   This is in-stream data. It can be as long
   as you like. It appears to an application as
   LRECL=80, RECFM=F, BLKSIZE=80. You would
   want to have the SYSUT2 data set allocated with
   a better blocksize.
/*
```

This example assumes BILL.TEST.DATA has already been created. This job will overwrite it with the data in the SYSUT1 input stream. Since the output data set already exists, IEBGENER will use its existing DCB attributes.

IEBGENER is the most basic copy or list program supplied with z/OS. It has been present since the first release of OS/360.

IEBCOPY

This utility is commonly used for several purposes:

- To copy selected (or all) members from one partitioned data set to another.
- To copy a partitioned data set into a unique sequential format known as an *unloaded* partitioned data set. As a sequential data set it can be written on tape, sent by FTP,[2] or manipulated as a simple sequential data set.

- To read an unloaded partitioned data set (which is a sequential file) and recreate the original partitioned data set. Optionally, only selected members might be used.
- To *compress* partitioned data sets (in place) to recover lost space.

Most z/OS software products are distributed as unloaded partitioned data sets. The ISPF copy options (option 3.3, among others) uses IEBCOPY "under the covers." Moving a PDS or PDSE from one volume to another is easily done with IEBCOPY. If there is a need to manipulate partitioned data sets in batch jobs, IEBCOPY is probably used. Equivalent manipulation under TSO (using ISPF) uses IEBCOPY indirectly.

A simple IEBCOPY job might be the following:

```
//OGDEN5 JOB 1,BILL,MSGCLASS=X
//  EXEC  PGM=IEBCOPY
//SYSPRINT DD SYSOUT=*
//SYSIN DD DUMMY
//SYSUT1 DD DISP=SHR,DSN=OGDEN.LIB.SOURCE
//SYSUT2 DD DISP=(NEW,KEEP),UNIT=TAPE,DSN=OGDENS.SOURCE,
//          VOL=SER=123456
```

This job will unload OGDEN.LIB.SOURCE (which we assume is a partitioned data set) and write it on tape. (The name TAPE is assumed to be an *esoteric name* that the local installation associates with tape drives.) By default IEBCOPY copies from SYSUT1 to SYSUT2. Notice that the data set name on tape is not the same as the data set name used as input (the same name could be used, but there is no requirement to do so). The following job could be used to restore the PDS on another volume:

```
//JOE6 JOB 1,JOE,MSGCLASS=X
//  EXEC  PGM=IEBCOPY
//SYSPRINT DD SYSOUT=*
//SYSIN DD DUMMY
//SYSUT1 DD DISP=OLD,UNIT=TAPE,DSN=OGDENS.SOURCE,
            VOL=SER=123456
//SYSUT2 DD DISP=(NEW,CATLG),DSN=P390Z.LIB.PGMS,UNIT=3390,
//          SPACE=(TRK,(10,10,20)),VOL=SER=333333
In this example IEBCOPY will detect that the input data set is an unloaded
partitioned data set. We required external knowledge to determine that the
data set would fit in about 10 tracks and should have 20 directory blocks.
Instead of using DD DUMMY for SYSIN we could this:
//SYSIN DD *
 COPY OUTDD=SYSUT2,INDD=SYSUT1
 SELECT MEMBER=(PGM1,PGM2)
/*
```

[2] The output data set is normally V or VB, and there are additional considerations about sending V or VB data sets via FTP.

The OUTDD and INDD parameters specify the DD names to be used. In this case we simply used the default names, but this is not required. The SELECT statement specifies the member names to be processed.

Restoring a partitioned data set from an unloaded copy automatically compresses (recovers lost space) the data set.

IEBDG

The IEBDG utility is used to create records in which fields can be generated with various types of data. IEBDG is typically used to create test data. A variety of fields and data can be generated and the fields can be changed for each record with ripple, wave, shift, roll, and other field permutations. IEBDG can accept input data records and overlay specified fields in the input with generated data.

The following is a simple example of IEGDB use:

```
//OGDEN7 JOB 1,BILL,MSGCLASS=X
//  EXEC PGM=IEBDG
//SYSPRINT DD SYSOUT=*
//OUT DD DISP=(NEW,CATLG),DSN=OGDEN.TEST.DATA,UNIT=3390,
//          VOL=SER=WORK01,SPACE=(CYL,(10,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=8000)
//SYSIN DD *
  DSD OUTPUT=(OUT)
  FD NAME=FIELD1,LENGTH=30,FORMAT=AL,ACTION=RP
  FD NAME=FIELD2,LENGTH=10,PICTURE=10,'TEST DATA '
  FD NAME=FIELD3,LENGTH=10,FORMAT=RA
  CREATE QUANTITY=90000,NAME=(FIELD1,FIELD2,FIELD3)
  END
/*
```

This job creates a new data set, OGDEN.TEST.DATA, with 90,000 records. Each record is 80 bytes, as specified in the DCB parameters in the DD statement. The control statements specify three fields that occupy the first 50 bytes of each record. By default, IEBDG fills the remaining bytes with binary zeros. The three fields are:

- An alphabetic field ('ABCDEF...'), 30 bytes long. It is rippled (rotated left one byte) after each record is generated.
- The second field contains 10 bytes with the fixed constant 'TEST DATA '.
- The third field contains 10 bytes with random binary data.

The utility can generate more complex patterns, but this example is typical of simple usage. It also illustrates an estimate of the amount of disk space needed for data:

- We know that a 3390 track holds about 57 K, less whatever space is lost to inter-record gaps.

- We know the DCB parameters (as specified in the JCL) are LRECL=80, BLKSIZE=8000, and RECFM=FB. We do not know why these DCB parameters were selected, but we assume they relate to the program that will use the test data.
- We can estimate that six blocks of 8000 each will probably fit on one track. This is not an efficient block size because some track space is probably lost, but it is useful enough.
- Each block contains 100 records of 80 bytes each. Each track contains 600 records. (There is no space lost within a block of FB records.)
- A cylinder contains 15 tracks, therefore a cylinder will hold 9000 of these records.
- Based on this, we need 10 cylinders to hold 90,000 records. We specified 10 cylinders as the primary allocation space in the JCL, with one cylinder as the secondary allocation increment. We should not require any secondary allocation, but it provides a safety factor. We could have asked for 150 tracks instead of 10 cylinders; the result would be the same.

IDCAMS

The IDCAMS program is not part of the basic set of z/OS utilities documented in the z/OS *Utilities* manual. The IDCAMS program is primarily used to create and manipulate VSAM data sets. It has other functions (such as catalog updates), but it is most closely associated with VSAM. It provides many complex functions and whole manuals are needed to describe all of them. The basic IBM manual, at the time of writing, is *DFSMS Access Method Services for Catalogs*.

A typical example of a simple use of IDCAMS is as follows:

```
//OGDEN12 JOB 1,BILL,MSGCLASS=X
//DEL  EXEC PGM=IDCAMS
//SYSPRINT DD SYSOUT=*
//SYSIN DD *
  DELETE OGDEN.DATA.VSAM CLUSTER
/*
//LOAD  EXEC PGM=IDCAMS
//SYSPRINT DD *
//DATAIN DD DISP=OLD,DSN=OGDEN.SORTOUT
//SYSIN DD *
  DEFINE CLUSTER (NAME (OGDEN.DATA.VSAM) -
          VOLUMES(WORK02) CYLINDERS(1 1) -
          RECORDSIZE (72 100) KEYS(9 8) INDEXED)
  REPRO INFILE(DATAIN) OUTDATASET(OGDEN.DATA.VSAM) ELIMIT(200)
/*
```

This example illustrates a number of points:

- There are two job steps. The first step deletes the data set that will be created by the second step. This is a clean-up function. The data set might not exist at this point and the first step will have a completion code indicating the action failed. This is ignored.
- Note that there are no DD statements for the VSAM data set. IDCAMS performs dynamic allocation to create the necessary JCL.
- The second step performs two functions. It first creates a VSAM data set (with the DEFINE CLUSTER command), and then loads it from a sequential data set (with the REPRO command). The sequential data set does require a DD statement.
- The DEFINE CLUSTER command is continued over three records. The continuation indicators are the same as used for TSO commands.
- The VSAM data set is on volume WORK02, and uses one cylinder for primary space and one cylinder for secondary allocation. The average record size is 72 bytes and the maximum record size is 100 bytes. (VSAM data sets always use variable length records.) The primary key (for accessing records in the data set) is 8 bytes long and begins at an offset of 9 bytes into each record.
- Records for loading a VSAM data set this way should already be sorted into key order.
- The ELIMIT parameter specifies the number of error records that REPRO will ignore before terminating operation. An error record is usually due to a duplicate key value.

Many of IDCAMS functions can be entered as TSO commands. For example, DEFINE CLUSTER can be used as a TSO command. However, this is generally not recommended because these commands can be complex and the errors encountered can be complex. Entering the IDCAMS commands through a batch job allows the commands and resulting messages to be reviewed as often as necessary by using SDSF to view the output.

> **Note:** Some users pronounce the name of this program as “id cams” (two syllables) while others say “I D cams” (three syllables).

IEBUPDTE

The IEBUPDTE utility is used to create multiple members in a partitioned data set, or to update records within a member. While it can be used for other types of records, its main use is to create or maintain JCL procedure libraries or assembler macro libraries. Today, this utility is used mostly for program product distributions and maintenance. It is seldom used by TSO users.

A basic example involves adding two JCL procedures to MY.PROCLIB. This could easily be accomplished through ISPF, but if we assume the following job was sent on tape, then the usefulness is more apparent:

```
//OGDEN10 JOB 1,BILL,MSGCLASS=X
```

```
//  EXEC PGM=IEBUPDTE
//SYSPRINT DD SYSOUT=*
//SYSUT1 DD DISP=OLD,DSN=MY.PROCLIB
//SYSUT2 DD DISP=OLD,DSN=MY.PROCLIB
//SYSIN DD DATA
./  ADD  LIST=ALL,NAME=MYJOB1
//STEP1 EXEC=BILLX1
//PRINT DD SYSOUT=A
//          (more JCL for MYJOB1)
//SYSUDUMP DD SYSOUT=*   (last JCL for MYJOB1)
./    REPL  LIST=ALL,NAME=LASTJOB
//LIST EXEC PGM=BILLLIST
//          (more JCL for this procedure)
//* LAST JCL STATEMENT FOR LASTJOB
./      ENDUP
/*
```

This example requires a few comments:

- When a library is to be updated, then SYSUT1 and SYSUT2 both point to that library. (If they point to different libraries, the SYSUT1 library is copied to the SYSUT2 library and then updated.)
- The SYSIN DD DATA format indicates that the data in the input stream contains // in columns one and two. It should not be interpreted as JCL. The end of the input stream is indicated by /*.
- The IEBUPDTE utility uses control statements with ./ in the first two columns.
- A member named MYJOB1 is added to MY.PROCLIB; this member should not already exist in the library.
- A member named LASTJOB is replaced with new contents.

The IEBUPDTE utility can also add or replace statements in a member based on the *sequence numbers* in the statements. This is one of the few remaining uses for sequence numbers in JCL or source statements.

Again, we stress that IEBUPDTE is typically used for program distribution and maintenance. For example, if a software vendor's product needs to add 25 JCL procedures to a customer's procedure library, they might package the procedures as an IEBUPDTE job. One advantage is that all the material is in source format and the customer can easily review the contents before running the job.

System-oriented utilities

The programs discussed in this section provide several basic utility functions for system administrators and are only briefly described.

IEHLIST

The IEHLIST utility is used to list a partitioned data set directory or a disk volume VTOC. It is normally used for VTOC listings and provides bit-level information. IEHLIST is not used often in most installations, but is needed in the rare cases where a VTOC is corrupted. It is sometimes used with the SUPERZAP program to patch or fix a broken VTOC.

IEHINITT

The IEHINITT utility is used to write standard labels on tapes. It can be used, as needed, to label a single tape or it can be used to label large batches of tapes. Many larger z/OS installations do not allow unlabeled tapes to be brought into the installation.

IEHPROGM

The IEHPROGM utility is almost obsolete. It is used primarily to manage catalogs, rename data sets, and delete data sets by a program instead of by JCL actions. It was primarily used during system installation or the installation of a major program product. These functions may involve dozens (or hundreds) of such catalog and data set actions. Having commands prepared beforehand (in a batch job with IEHPROGM) is much less error-prone than more dynamic approaches. Most of the IEHPROGM functions are available in IDCAMS and that is now the preferred utility for catalog and data set functions.

ICKDSF

The ICKDSF utility is used primarily to initialize disk volumes. As a minimum, this involves creating the disk label record and the VTOC. ICKDSF can also scan a volume to ensure that it is usable, reformat all the tracks, write home addresses and R0 records, and so forth.

SUPERZAP

The SUPERZAP program is used to patch VTOCs, executable programs, or almost any other disk record. In practice it is mostly used to patch executable programs. It was extensively used in earlier days to install minor fixes in programs.

Consider, for example, a new release of product XXX. The new release may have been sent on tape to hundreds or thousands of customers. After shipping all these tapes the developers may have discovered a minor bug that could be fixed by changing a few instructions. Instead of creating new distribution tapes and shipping them to all the customers (a massive and expensive undertaking for a major software product), the developers could create a SUPERZAP solution and mail/fax/ftp it to their customers.

SUPERZAP is a bit-level tool. Its use is practical where relatively few bits or bytes need to be changed. An example of SUPERZAP is:

```
//OGDEN15 JOB 1,BILL,MSGCLASS=X
//  EXEC PGM=AMASPZAP
//SYSPRINT DD SYSOUT=*
//SYSLIB DD DISP=OLD,DSN=OGDEN.LIB.LOAD
//SYSIN DD *
  NAME QSAM1
  VERIFY 004E 4780
  REP    004E 4700
/*
```

A SYSLIB DD statement must point to the data set containing the load module to be modified. The NAME control statement identifies the executable module (which is the PDS member name) to be altered. The VERIFY statement says to look at offset x'004E' in the module and verify that it contains x'4780'. If the verify is correct then change the module to contain x'4700' at this same offset. This changes a Branch Equal instruction to a No Operation and, we assume, changes the logic of the program.

We can make a SUPERZAP patch like this because we had an assembly listing of the program and could see the exact offset within the module containing the instruction we wanted to change. This would be much more difficult without a listing although it has been done by reading hexadecimal storage dumps and reconstructing machine language operation from the dumps. Note that the format of executable programs on disk is complex and is not a simple image of the program when it is loaded into memory. (Relocation data, external symbols, and an optimized disk loading format form part of the complexity.) SUPERZAP understands this disk format and allows users to zap an executable program as if it were a memory image.

We have discussed SUPERZAP, but the program in the example is AMASPZAP. This is the current name of the program although it is still widely known as SUPERZAP.

Note: There is much folklore associated with SUPERZAP. When it first appeared many years ago (as an undocumented, under-the-table tool by IBM) it had no security controls. (In those days there was not much security anywhere else in the operating system, so this was not unusual.) A clever user could change *anything* in the system with SUPERZAP; payroll records were usually the example cited. This caused much concern for management, auditors, and similar people.

Installations were required to hide SUPERZAP, keep it offline, disable it, and so forth. The status of SUPERZAP was high on the list of security auditors. (This is still true today, although the need has long since disappeared.) It is still regarded as a *magic program* by some traditional users.

It is possible to construct much more sophisticated zaps than the example shown here. These were sometimes regarded almost as an art form. For many years developers (at least, those developers working in assembly language) often left *patch areas* in their programs. These were unused areas where someone could later *zap in* a few instructions if a fix needed more bytes than provided by instructions being replaced.

Application-level utilities

There are many application programs that could be considered as utilities. We briefly describe a few of the very common ones here. These are more complex to use than the basic programs above and we do not include usage examples.

ADRDSSU

This program is the primary *disk dump* and *disk restore* program provided with z/OS. It is capable of filtering and selecting which data sets to dump or restore, but it is used primarily as a full disk dump program. The purpose of dumping a disk is usually to provide a backup of the contents that can be restored, if needed. A common use is to dump complete volumes but restore only a specific data set that was accidentally destroyed.

A backup is usually written to tape, but can be written to a disk data set. A disk can be dumped track-by-track (known as a physical dump) or data set-by-data set (known as a logical dump). When a logical dump is performed, multiple data set extents may be combined into a single extent, partitioned data sets are compressed, and free space is all in a single extent.

SMP/E

This program is used by the system programmers (administrators) to install software products, updates, and fixes. Using SMP/E is one of the most complex functions associated with maintaining z/OS software. Figure C-1 illustrates the general flow when using SMP/E to apply a fix to z/OS. (Such fixes for z/OS software are known as PTFs, for Product Temporary Fix.)

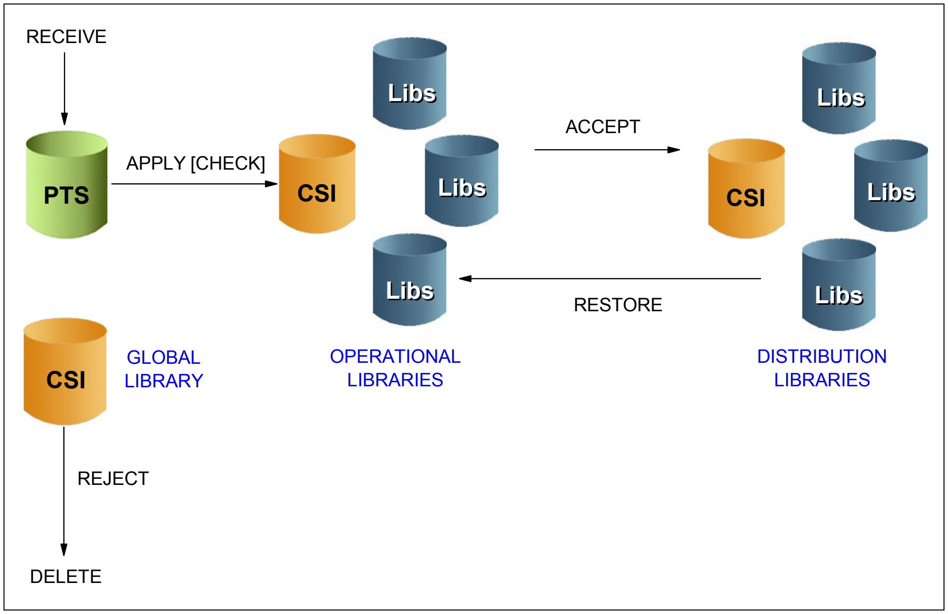


Figure C-1 SMP/E overview for fixes

SMP/E works with three levels of libraries:

- A receive-level library that is a holding area - This library is known as the PTS (PTF Temporary Storage) and is in the *GLOBAL zone*.
- Operational or *target libraries* - These are the working libraries used by z/OS and various software products while they are installed for use.
- Distribution libraries or *DLIBs* - These contain a master copy of all the modules in the operational libraries. The DLIBs are not used for execution.

Each set of libraries has a Consolidated Software Index (CSI), which is a VSAM data set containing data about all the modules in the set. In principle, it is possible to rebuild any operational z/OS module from the DLIBs. The CSI contains all the binder (linkage editor) control statements needed to rebuild an operational module from submodules in the DLIBs. (This is a simplistic description of a complex set of functions and should be regarded as such.)

The SMP/E RECEIVE command is used to accept modules (or submodules of a larger module) that are fixes for distributed products. The RECEIVEed module is placed in the PTS. The APPLY CHECK command is used to determine whether the fix can be cleanly applied to the operational module. (This may involve relinking/rebinding many submodules.) If these checks are positive, the APPLY command is used to install the fix in the operational libraries. The installation would then use the fixed module and determine whether it is acceptable. If it is not acceptable, a RESTORE command can rebuild the original module from material in the DLIBs.

If the fix is acceptable (and it make take months to determine this) an ACCEPT command integrates the fix module into the DLIBs. After this is done, the fix can no longer be *backed out* of the system (except by restoring old backup tapes, perhaps). Future fixes can then be built on top of this fix in the DLIBs. A REJECT command is used to discard a fix from the global area; this might be done if someone decides the fix will never be used.

SMP/E control statements can verify the status of previous and concurrent fixes, the existence of a product and its release level, and many other factors.

z/OS and practically all z/OS software products from IBM are installed using SMP/E. Most independent software vendor products are installed by using SMP/E. Many z/OS installations will not purchase any software that is not installed with SMP/E.

Each product can have its own global, target, and DLIB libraries, or many products can be placed in the same set of global, target, and DLIB libraries. SMP/E is included with all z/OS systems.

SMP/E usage can be quite complex and SMP/E skills are a primary prerequisite for a z/OS system programmer. The DLIBs for a product (including z/OS) tend to be as large as the operational libraries. In a sense, almost all the software for z/OS and most associated software products are present twice on disk, once for the operational libraries and once for the distribution libraries.

In earlier days, when disks were smaller and more expensive, some installations did not keep their DLIBs online. In principle, they are needed only when a fix or new product is installed and they could occupy a number of disk drives. Smaller installations might dump the DLIB volumes onto tape and restore them (to scratch disks) only when needed. In even earlier days the use of SMP/E was considered optional and some installations did not maintain their DLIBs. In today’s systems, however, the DLIBs are required for most practical purposes and are usually available online.

HCD

This program consists of a large set of ISPF panels, using ISPF as a dialog manager, plus several executable modules. HCD is used for several purposes:

- Using input from the ISPF panels, it builds a special VSAM data set that defines the I/O configuration available to z/OS. The data set is known as an IODF. When z/OS is started, an IODF must be specified. Every I/O device used by z/OS must be defined in the IODF.

- Using approximately the same input from the ISPF panels, HCD builds an I/O definition for the complete mainframe machine and sends it to the controller section of the mainframe. This definition also specifies the existence of LPARs and other system-wide parameters. This is known as an I/O Configuration Data Set (IOCDS). The IOCDS is discussed in more detail in Chapter 19, “Hardware systems and LPARs” .
- It can be used to create a new IODF from an existing IODF and dynamically activate the new version.

An IODF and IOCDS may contain definitions for I/O devices that do not exist or are not currently attached. It need not contain definitions for all I/O devices, although the system (for the IOCDS) or z/OS (for an IODF) cannot use a device that is not defined. HCD usage is a specialized skill needed by only a few system programmers. It is included with all z/OS systems.

RMF

Resource Measurement Facility (RMF) is an optional IBM program product used to measure various aspects of system performance. Different RMF modules provide long-term statistical gathering, instantaneous data, long-term reporting, batch-type reports, TSO-oriented reports, and so forth. The hardware I/O system maintains statistical counters about queueing time for each I/O device, amount of activity per device, and other low-level information. RMF accesses these hardware counters and includes them in its reports.

Non-IBM utilities

Many independent software vendors produce programs for z/OS. Some of these can be categorized as utilities; of these, some compete with IBM utilities, while many others provide functions not included with the IBM-provided utilities.

Summary

The notion of what is a utility program is not well defined for z/OS, but the concept is not nearly as wide as for UNIX or Linux.

IBM provides a few very basic utility programs. These are batch programs (although they can be used in the TSO foreground with appropriate ALLOC commands) and they tend to have similar JCL requirements. These include DD statements for SYSPRINT, SYSIN, SYSUT1, SYSUT2. Most z/OS users are familiar with IEFBR14, IEBGENER, and IEBCOPY. VSAM users must be familiar with IDCAMS.

SMP/E, ADRDSSU, HCD, and RMF are typically used only by system programmers and other administrators and are very seldom used by anyone else. SMP/E and HCD are vital for zSeries and z/OS operation. ARDRSSU and RMF are optional and there are non-IBM products that compete with these utilities.

SUPERZAP (whose actual name has changed a number of times) can be used to patch disk records. It understands the format of executable modules in PDS libraries, and this is needed for its most common use in applying patches to such executable modules. SUPERZAP is not often used for system maintenance now, whereas its use was more common in earlier versions of the system.

D

EBCDIC - ASCII table

Hx	Dec	E	A	Hx	Dec	E	A	Hx	Dec	E	A	Hz	Dec	E	A
00	00		NUL	20	32		SP	40	64	SP	@	60	96	-	'
01	01			21	33		!	41	65		A	61	97	/	a
02	02			22	34		“	42	66		B	62	98		b
03	03			23	35		#	43	67		C	63	99		c
04	04			24	36		$	44	68		D	64	100		d
05	05			25	37		%	45	69		E	65	101		e
06	06			26	38		&	46	70		F	66	102		f
07	07			27	39		'	47	71		G	67	103		g
08	08			28	40		(	48	72		H	68	104		h
09	09			29	41		)	49	73		I	69	105		i
0A	10			2A	42		*	4A	74	^	J	6A	106	|	j
0B	11			2B	43		+	4B	75	.	K	6B	107	,	k
0C	12			2C	44		,	4C	76	<	L	6C	108	%	l
0D	13			2D	45		-	4D	77	(	M	6D	109	_	m
0E	14			2E	46		.	4E	78	+	N	6E	110	>	n
0F	15			2F	47		/	4F	79	|	O	6F	111	?	o
10	16			30	48		0	50	80	&	P	70	112		p
11	17			31	49		1	51	81		Q	71	113		q
12	18			32	50		2	52	82		R	72	114		r
13	19			33	51		3	53	83		S	73	115		s
14	20			34	52		4	54	84		T	74	116		t
15	21			35	53		5	55	85		U	75	117		u
16	22			36	54		6	56	86		V	76	118		v

Hx	Dec	E	A	Hx	Dec	E	A	Hx	Dec	E	A	Hz	Dec	E	A
17	23			37	55		7	57	87		W	77	119		w
18	24			38	56		8	58	88		X	78	120		x
19	25			39	57		9	59	89		Y	79	121		y
1A	26			3A	58		:	5A	90	!	Z	7A	122	:	z
1B	27			3B	59		;	5B	91	$	[	7B	123	#	{
1C	28			3C	60		<	5C	92	*	\	7C	124	@	|
1D	29			3D	61		=	5D	93	)	]	7D	125	'	}
1E	30			3E	62		>	5E	94	;	^	7E	126	=	~
1F	31			3F	63		?	5F	95	not	_	7F	127	“	

80	128			A0	160			C0	192	{		E0	224	\	
81	129	a		A1	161			C1	193	A		E1	225		
82	130	b		A2	162	s		C2	194	B		E2	226	S	
83	131	c		A3	163	t		C3	195	C		E3	227	T	
84	132	d		A4	164	u		C4	196	D		E4	228	U	
85	133	e		A5	165	v		C5	197	E		E5	229	V	
86	134	f		A6	166	w		C6	198	F		E6	230	W	
87	135	g		A7	167	x		C7	199	G		E7	231	X	
88	136	h		A8	168	y		C8	200	H		E8	232	Y	
89	137	i		A9	169	z		C9	201	I		E9	233	Z	
8A	138			AA	170			CA	202			EA	234		
8B	139			AB	171			CB	203			EB	235		
8C	140			AC	172			CC	204			EC	236		
8D	141			AD	173	[		CD	205			ED	237		
8E	142			AE	174			CE	206			EE	238		
8F	143			AF	175			CF	207			EF	239		
90	144			B0	176			D0	208	}		F0	240	0	
91	145	j		B1	177			D1	209	J		F1	241	1	
92	146	k		B2	178			D2	210	K		F2	242	2	
93	147	l		B3	179			D3	211	L		F3	243	3	
94	148	m		B4	180			D4	212	M		F4	244	4	
95	149	n		B5	181			D5	213	N		F5	245	5	
96	150	o		B6	182			D6	214	O		F6	246	6	
97	151	p		B7	183			D7	215	P		F7	247	7	
98	152	q		B8	184			D8	216	Q		F8	248	8	
99	153	r		B9	185			D9	217	R		F9	249	9	
9A	154			BA	186			DA	218			FA	250		
9B	155			BB	187			DB	219			FB	251		
9C	156			BC	188			DC	220			FC	252		
9D	157			BD	189	]		DD	221			FD	253		
9E	158			BE	190			DE	222			FE	254		
9F	159			BF	191			DF	223			FF	255		

E

Class Program

All the exercises here work with a employee file (or database); this file identifies all employees by an employee number and lists basic personnel information.

The exercise has the department number as input, selects all records from that department and, then do the sum of the salary fields of those records. Finally the average salary is displayed.

The exercises that follow are written in different languages, executed in different environments and with different data sources, but all covering the functionality above described. The code, preparation jobs and instructions are provided.

We assume students have installed an appropriate 3270 emulator and have the appropriate TSO, CICS, DB2 and WAS authorizations. Pay attention to the system definitions (like HLQs, DB2 database name, etc.) that each exercise may require.

COBOL-CICS-DB2 program

Source code

Map definition

This definition is in member TMAP01 in LUISM.TEST.SAMPLIB library.

```
          PRINT NOGEN
TMAPSET  DFHMSD TYPE=&SYSPARM,                                         x
               LANG=COBOL,                                             x
               MODE=INOUT,                                             x
               TERM=3270-2,                                            x
               CTRL=FREEKB,                                            x
               STORAGE=AUTO,                                           x
               TIOAPFX=YES
TMAP01   DFHMDI SIZE=(24,80),                                          x
               LINE=1,                                                 x
               COLUMN=1,                                               x
               MAPATTS=COLOR
         DFHMDF POS=(1,1),                                             x
               LENGTH=9,                                               x
               ATTRB=(NORM,PROT),                                      x
               COLOR=BLUE,                                             x
               INITIAL='ABCD txid'
         DFHMDF POS=(1,26),                                            x
               LENGTH=28,                                              x
               ATTRB=(NORM,PROT),                                      x
               COLOR=GREEN,                                            x
               INITIAL='Average salary by department'
         DFHMDF POS=(9,1),                                             x
               LENGTH=41,                                              x
                ATTRB=(NORM,PROT),                                     x
               INITIAL='Type a department number and press enter.'
         DFHMDF POS=(11,1),                                            x
               LENGTH=18,                                              x
               ATTRB=(NORM,PROT),                                      x
               COLOR=GREEN,                                            x
               INITIAL='Department number:'
DPTONO   DFHMDF POS=(11,20),                                           x
               LENGTH=3,                                               x
               ATTRB=(NORM,UNPROT,IC),                                 x
               COLOR=TURQUOISE,                                        x
               INITIAL='___'
         DFHMDF POS=(11,24),                                           x
               LENGTH=1,                                               x
               ATTRB=ASKIP
         DFHMDF POS=(13,1),                                            x
               LENGTH=18,                                              x
               ATTRB=(NORM,PROT),                                      x
               COLOR=GREEN,                                            x
               INITIAL='Average salary($):'
AVGSAL   DFHMDF POS=(13,20),                                           x
               LENGTH=11,                                              x
               ATTRB=(NORM,PROT),                                      X
```

```
              COLOR=TURQUOISE
MSGLINE  DFHMDF POS=(23,1),                                          x
               LENGTH=78,                                            x
              ATTRB=(BRT,PROT),                                      x
              COLOR=BLUE
         DFHMDF POS=(23,79),                                         x
              LENGTH=1,                                              x
              ATTRB=(DRK,PROT,FSET),                                 x
              INITIAL=' '
         DFHMDF POS=(24,1),                                          x
              LENGTH=7,                                              x
              ATTRB=(NORM,PROT),                                     x
              COLOR=RED,                                             x
              INITIAL='F3=Exit'
         DFHMSD TYPE=FINAL
         END
```

Program code

This program resides in member XYZ2 in LUISM.TEST.SAMPLIB library.

```
IDENTIFICATION DIVISION.
      *-----------------------------------------------------------
      *    COBOL-CICS-DB2 PROGRAM ZSCHOLAR RESIDENCY
      *    OBTAINS THE AVERAGE SALARY OF EMPLOYEES OF A GIVEN DEPART.
      *----------------------------------------------------------
      *----------------------
       PROGRAM-ID.    XYZ2.
      /
       ENVIRONMENT DIVISION.
      *-------------------
       CONFIGURATION SECTION.
       INPUT-OUTPUT SECTION.
       FILE-CONTROL.
       DATA DIVISION.
      *------------
       FILE SECTION.
      /
      *------------
       WORKING-STORAGE SECTION.
      ***************************************************
      * WORKAREAS                                       *
      ***************************************************
       01 SWITCH.
        05 DATA-IS         PIC X VALUE 'Y'.
           88 DATA-IS-O           VALUE 'Y'.
```

```
 05 SEND-IND        PIC X.
    88 SEND-IND-ERASE     VALUE '1'.
    88 SEND-IND-DATAO     VALUE '2'.
    88 SEND-IND-ALARM     VALUE '3'.
 01 COMMUNICATION-AREA PIC X.
 01 MSGLINET.
   02 MSGSQLC      PIC X(8).
   02 FILLER       PIC X.
   02 MSGREST      PIC X(69).
***************************************************
* DB2 HOST VARIABLES DECLARATION                  *
***************************************************
 01  WORKDEPT-HV   PIC X(3).
 01  SALARY-HV     PIC X(11).
 01  SALARY-IN     PIC S9(4) COMP-5.
***************************************************
* SQLCA DECLARATION                               *
***************************************************
    EXEC SQL INCLUDE SQLCA END-EXEC.
***************************************************
* DFHAID                                          *
***************************************************
   COPY DFHAID.
 ***************************************************
* MAP COPY                                        *
***************************************************
   COPY MAPONL.
***************************************************
* DECLARE OF DB2 TABLE                            *
***************************************************
    EXEC SQL
     DECLARE DSN8810.EMP TABLE
     (EMPNO     CHAR(6)     NOT NULL,
      FIRSTNAME VARCHAR(12) NOT NULL,
      MIDINIT   CHAR(1)     NOT NULL,
      LASTNAME  VARCHAR(15) NOT NULL,
      WORKDEPT  CHAR(3)             ,
      PHONENO   CHAR(4)             ,
      HIREDATE  DATE                ,
      JOB       CHAR(8)             ,
      EDLEVEL   SMALLINT            ,
      SEX       CHAR(1)             ,
      BIRTHDATE DATE                ,
      SALARY    DECIMAL(9,2)        ,
      BONUS     DECIMAL(9,2)        ,
      COMM      DECIMAL(9,2)        )
    END-EXEC.
**************************************************************
 LINKAGE SECTION.
```

```
*************************************************************
 01 DFHCOMMAREA    PIC X.
/
 PROCEDURE DIVISION USING DFHCOMMAREA.
*************************************************************
* MAIN ROGRAM ROUTINE
*************************************************************
 MAINLINE.
*************************************************************
* 2000-PROCESS
*************************************************************
 2000-PROCESS.
     EVALUATE TRUE
      WHEN EIBCALEN = ZERO
         MOVE LOW-VALUE TO TMAP01O
         SET SEND-IND-ERASE TO TRUE
         PERFORM 2000-10-SEND
      WHEN EIBAID = DFHCLEAR
         MOVE LOW-VALUE TO TMAP01O
         SET SEND-IND-ERASE TO TRUE
         PERFORM 2000-10-SEND
      WHEN EIBAID = DFHPA1 OR DFHPA2 OR DFHPA3
         CONTINUE
      WHEN EIBAID = DFHPF3
          EXEC CICS RETURN
         END-EXEC
         GOBACK
      WHEN EIBAID = DFHENTER
         PERFORM 2000-00-PROCESS
      WHEN OTHER
         MOVE LOW-VALUE TO TMAP01O
         MOVE 'WRONG KEY' TO MSGLINEO
         SET SEND-IND-ALARM TO TRUE
         PERFORM 2000-10-SEND
     END-EVALUATE.
*
     EXEC CICS RETURN TRANSID('ABCD')
         COMMAREA(COMMUNICATION-AREA)
     END-EXEC.
     GOBACK.
 2000-00-PROCESS.
     EXEC CICS RECEIVE MAP('TMAP01')
                       MAPSET('TMAPSET')
                       INTO(TMAP01I)
     END-EXEC.
     IF DPTONOL = ZERO OR DPTONOI = SPACE
        MOVE 'N' TO DATA-IS
        MOVE 'ENTER A VALID DEPARTMENT NUMBER' TO MSGLINEO
     END-IF.
```

```
     IF DATA-IS-O
        MOVE DPTONOI TO WORKDEPT-HV
        PERFORM 2000-01-DB2
     END-IF.
     IF DATA-IS-O
        SET SEND-IND-DATAO TO TRUE
        PERFORM 2000-10-SEND
     ELSE
        SET SEND-IND-ALARM TO TRUE
        PERFORM 2000-10-SEND
     END-IF.
*
  2000-01-DB2.
     EXEC SQL SELECT CHAR(DECIMAL(SUM(SALARY),9,2))
         INTO :SALARY-HV :SALARY-IN
         FROM DSN8810.EMP
         WHERE WORKDEPT=:WORKDEPT-HV END-EXEC.
     IF SQLCODE = 0
     THEN
        IF SALARY-IN = -1
        THEN
          MOVE 'N' TO DATA-IS
          MOVE 'NO EMPLOYEES EXIST IN THIS DEPARTMENT' TO MSGLINEO
          MOVE SPACES TO AVGSALO
        ELSE
          MOVE SALARY-HV TO AVGSALO
          MOVE SPACES TO MSGLINEO
        END-IF
     ELSE
        MOVE 'O' TO DATA-IS
        MOVE SPACES TO AVGSALO
        MOVE 'SQLSTATE' TO MSGSQLC
        MOVE SQLSTATE TO MSGREST
        MOVE MSGLINET TO MSGLINEO
     END-IF.
*
 2000-10-SEND.
     EVALUATE TRUE
     WHEN SEND-IND-ERASE
       EXEC CICS SEND MAP('TMAP01')
            MAPSET('TMAPSET')
            FROM (TMAP01O)
            ERASE
       END-EXEC
     WHEN SEND-IND-DATAO
       EXEC CICS SEND MAP('TMAP01')
            MAPSET('TMAPSET')
            FROM (TMAP01O)
            DATAONLY
```

```
  END-EXEC
WHEN SEND-IND-ALARM
  EXEC CICS SEND MAP('TMAP01')
       MAPSET('TMAPSET')
       FROM (TMAP01O)
       DATAONLY
       ALARM
  END-EXEC
END-EVALUATE.
```

Preparation Jobs

Assembling and link-editing the map

This job is in member MAPASSEM, LUISM.TEST.SAMPLIB library. Both invoked procedures are in SYS1.PROCLIB.

```
//LUISM01 JOB (999,POK),'BMS Compilation',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*********************************************************************
//*       ASSEMBLE MAP SET                                            *
//*********************************************************************
//STEP01  EXEC PROC=DFHASMV1,PARM.ASSEM='SYSPARM(MAP)'
//SYSLIN   DD DSN=LUISM.OBJETO,DCB=(LRECL=80),
//         SPACE=(2960,(10,10)),UNIT=SYSDA,DISP=(NEW,PASS)
//SYSIN    DD DSN=LUISM.TEST.SAMPLIB(TMAP01),DISP=SHR
/*
//*********************************************************************
//*       LINK EDIT                                                   *
//*********************************************************************
//STEP02  EXEC PROC=DFHLNKV1,PARM='LIST,LET,XREF'
//SYSLIN  DD DSN=LUISM.OBJETO,DISP=(OLD,DELETE)
//        DD *
          MODE RMODE(ANY)
          NAME TMAPSET(R)
/*
```

Generating the map copy file

This job is in member MAPCOPYGM, LUISM.TEST.SAMPLIB library.

```
//LUISM02 JOB (999,POK),'BMS COPY',
```

```
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//*       MAP COPY GENERATION                                       *
//*******************************************************************
//STEP01  EXEC PROC=DFHASMV1,PARM.ASSEM='SYSPARM(DSECT)'
//SYSLIN   DD DSN=LUISM.TEST.SAMPLIB(MAPCOPY),DISP=OLD
//SYSIN    DD DSN=LUISM.TEST.SAMPLIB(TMAP01),DISP=SHR
/*
```

Preparing the program

This job is in member CICSDB2P, in library LUISM.TEST.SAMPLIB.

```
//LUISM03 JOB (999,POK),'Cobol-CICS-DB2',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//*  DB2 precompile, CICS translation, COBOL compile, pre-link,     *
//*  and link edit. Also DB2 Bind.                                  *
//*******************************************************************
//*******************************************************************
//*       DB2 Precompile                                            *
//*******************************************************************
//PC       EXEC PGM=DSNHPC,PARM='HOST(IBMCOB)'
//SYSIN    DD  DSN=LUISM.TEST.SAMPLIB(XYZ2),DISP=SHR
//DBRMLIB  DD  DISP=SHR,
//             DSN=DB8HU.DBRMLIB.DATA(XYZ2)
//STEPLIB  DD  DISP=SHR,DSN=DB8H8.SDSNEXIT
//         DD  DISP=SHR,DSN=DB8H8.SDSNLOAD
//SYSCIN   DD  DSN=&&DSNHOUT,DISP=(MOD,PASS),UNIT=SYSDA,
//             SPACE=(800,(500,500))
//SYSLIB   DD  DISP=SHR,DSN=DB8HU.SRCLIB.DATA
//SYSPRINT DD  SYSOUT=*
//SYSTERM  DD  SYSOUT=*
//SYSUDUMP DD  SYSOUT=*
//SYSUT1   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT2   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
/*
//*******************************************************************
//*       CICS Translator                                           *
//*******************************************************************
//TRN    EXEC PGM=DFHECP1$,
//            COND=(4,LT,PC)
//STEPLIB  DD DSN=CICSTS23.CICS.SDFHLOAD,DISP=SHR
//SYSPRINT DD SYSOUT=*
//SYSPUNCH DD DSN=&&SYSCIN,
//            DISP=(MOD,PASS),UNIT=SYSDA,
```

```
//            DCB=BLKSIZE=400,
//            SPACE=(400,(400,100))
//SYSUDUMP DD  SYSOUT=*
//SYSIN    DD  DSN=&&DSNHOUT,DISP=(OLD,DELETE)
//*
//*********************************************************************
//*       Compile                                                     *
//*********************************************************************
//COB      EXEC PGM=IGYCRCTL,
//             PARM=(NOSEQUENCE,QUOTE,RENT,'PGMNAME(LONGUPPER)'),
//             COND=(4,LT,TRN)
//SYSPRINT DD  SYSOUT=*
//SYSLIB   DD  DSN=CICSTS23.CICS.SDFHCOB,DISP=SHR
//         DD  DSN=CICSTS23.CICS.SDFHMAC,DISP=SHR
//         DD  DSN=CICSTS23.CICS.SDFHSAMP,DISP=SHR
//         DD  DSN=LUISM.TEST.SAMPLIB,DISP=SHR
//SYSTERM  DD  SYSOUT=*
//SYSLIN   DD  DSN=&&LOADSET,DISP=(MOD,PASS),UNIT=VIO,
//             SPACE=(800,(500,500))
//SYSIN    DD  DSN=&&SYSCIN,DISP=(OLD,DELETE)
//SYSUT1   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT2   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT3   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT4   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT5   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT6   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT7   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//*********************************************************************
//*       Prelink                                                     *
//*********************************************************************
//PLKED   EXEC PGM=EDCPRLK,COND=(4,LT,COB)
//STEPLIB  DD  DISP=SHR,DSN=CEE.SCEERUN
//SYSMSGS  DD  DISP=SHR,
//             DSN=CEE.SCEEMSGP(EDCPMSGE)
//SYSIN    DD  DSN=&&LOADSET,DISP=(OLD,DELETE)
//SYSMOD   DD  DSN=&&PLKSET,UNIT=SYSDA,DISP=(MOD,PASS),
//             SPACE=(32000,(30,30)),
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//SYSDEFSD DD  DUMMY
//SYSOUT   DD  SYSOUT=*
//SYSPRINT DD  SYSOUT=*
//SYSTERM  DD  SYSOUT=*
//*********************************************************************
//*       Linkedit                                                    *
//*********************************************************************
//LKED     EXEC PGM=IEWL,PARM='LIST,XREF',
//         COND=(4,LT,PLKED)
//SYSLIB   DD  DISP=SHR,DSN=CEE.SCEELKED
//         DD  DISP=SHR,DSN=DB8H8.SDSNLOAD
```

```
//          DD  DISP=SHR,DSN=CICSTS23.CICS.SDFHLOAD
//          DD  DISP=SHR,DSN=ISP.SISPLOAD
//          DD  DISP=SHR,DSN=GDDM.SADMMOD
//SYSLMOD   DD  DSN=CICSTS23.CICS.SDFHLOAD(XYZ2),
//              DISP=SHR
//SYSPRINT  DD  SYSOUT=*
//SYSUT1    DD  SPACE=(1024,(50,50)),UNIT=VIO
//SYSLIN    DD  DSN=&&PLKSET,DISP=(OLD,DELETE)
//          DD  DDNAME=SYSIN
//CICSLOAD  DD  DSN=CICSTS23.CICS.SDFHLOAD,
//              DISP=SHR
//SYSIN     DD  *
          INCLUDE CICSLOAD(DSNCLI)
          MODE RMODE(ANY)
          NAME XYZ2(R)
/*
//*********************************************************************
//*        Bind                                                       *
//*********************************************************************
//BIND      EXEC PGM=IKJEFT01,DYNAMNBR=20,COND=(4,LT,LKED)
//STEPLIB   DD DSN=DB8H8.SDSNLOAD,DISP=SHR
//DBRMLIB   DD DSN=DB8HU.DBRMLIB.DATA,DISP=SHR
//SYSUDUMP  DD SYSOUT=*
//SYSTSPRT  DD SYSOUT=*
//SYSPRINT  DD SYSOUT=*
//SYSIN     DD *
   GRANT BIND, EXECUTE ON PLAN XYZP TO PUBLIC;
//SYSTSIN   DD *
DSN SYSTEM(DB8H)
BIND PACKAGE (DSN8CC81) MEMBER(XYZ2) -
     ACT(REP) ISO(CS) ENCODING(EBCDIC)
BIND PLAN(XYZP)  PKLIST(DSN8CC81.*) -
     ACT(REP) ISO(CS) ENCODING(EBCDIC)
RUN  PROGRAM(DSNTIAD) PLAN(DSNTIA81) -
     LIB('DB8HU.RUNLIB.LOAD')
END
/*
```

CICS definitions

All the CICS resources have defined online through CEDA transaction. The group is PAZSGROU.

Resource	**Tipo**
ABCD	Transaction
XYZ2	Program
TMAPSET	Program (map)
TMAPSET	Mapset

XYZE DB2 entry (correlates ABCD transaction and XYZP planname)

Program execution

Type ABCD in a CICS screen and press enter. Then, type a department number and press enter. When finished, press PF3.

```
ABCD txid                Average salary by department



 Type a department number and press enter.

 Department number: ___

 Average salary($):





 F3=Exit
```

COBOL-Batch-VSAM program

Program code

This program is in member XYZ3, in library LUISM.TEST.SAMPLIB

```
      IDENTIFICATION DIVISION.
     *-------------------------------------------------------------
     *    COBOL VSAM PROGRAM ZSCHOLAR RESIDENCY
     *------------------------------------------------------------
     *----------------------
      PROGRAM-ID.    XYZ3.
     /
      ENVIRONMENT DIVISION.
     *-------------------
      CONFIGURATION SECTION.
      SPECIAL-NAMES.
      INPUT-OUTPUT SECTION.
      FILE-CONTROL.
          SELECT I-FILE
           ASSIGN TO KSDATA
           ORGANIZATION IS INDEXED
```

```
          ACCESS IS DYNAMIC
          RECORD KEY IS I-FILE-RECORD-KEY
          ALTERNATE RECORD KEY IS I-FILE-ALTREC-KEY
          FILE STATUS IS FSTAT-CODE VSAM-CODE.
         SELECT DPTONO
          ASSIGN TO SYSIN
          ORGANIZATION IS SEQUENTIAL
          ACCESS IS SEQUENTIAL
           FILE STATUS IS DPTONO-CODE.
     DATA DIVISION.
    *-------------
     FILE SECTION.
     FD I-FILE
         RECORD CONTAINS 101 CHARACTERS.
       01 I-FILE-RECORD.
         05 I-FILE-RECORD-KEY           PIC X(6).
         05 FILLER                      PIC X(32).
         05 I-FILE-ALTREC-KEY           PIC X(3).
         05 FILLER                      PIC X(42).
         05 SALARY                      PIC S9(7)V9(2) COMP-3.
         05 FILLER                      PIC X(13).
     FD DPTONO
         RECORDING MODE F
         BLOCK 0 RECORDS
         RECORD 80 CHARACTERS
         LABEL RECORD STANDARD.
       01 DPTONO-RECORD     PIC X(80).
    /
     WORKING-STORAGE SECTION.
     01 STATUS-AREA.
       05 FSTAT-CODE                   PIC X(2).
         88 I-O-OKAY                   VALUE ZEROES.
       05 VSAM-CODE.
         10 VSAM-R15-RETURN-CODE       PIC 9(2) COMP.
         10 VSAM-FUNCTION-CODE         PIC 9(1) COMP.
         10 VSAM-FEEDBACK-CODE         PIC 9(3) COMP.
     77 DPTONO-CODE                    PIC XX.
     01 WS-DPTONO-RECORD.
       05 DPTONO-KEYED       PIC X(3).
       05 FILLER             PIC X(77).
     01 WS-SALARY            PIC S9(7)V9(2) COMP-3 VALUE 0.
     01 WS-SALARY-EDITED     PIC $ZZ,ZZZ,ZZ9.99.
    /
     PROCEDURE DIVISION.
         OPEN INPUT DPTONO.
         READ DPTONO INTO WS-DPTONO-RECORD.
         DISPLAY DPTONO-KEYED.
         OPEN INPUT I-FILE.
         IF FSTAT-CODE NOT = "00"
```

```
          DISPLAY "OPEN INPUT VSAMFILE FS-CODE: " FSTAT-CODE
          PERFORM VSAM-CODE-DISPLAY
          STOP RUN
        END-IF.
        MOVE DPTONO-KEYED TO I-FILE-ALTREC-KEY.
        PERFORM READ-FIRST.
        IF FSTAT-CODE = "02"
          PERFORM READ-NEXT UNTIL FSTAT-CODE = "00"
        END-IF.
        IF FSTAT-CODE = "23"
          DISPLAY "NO RECORDS EXISTS FOR THIS DEPARTMENT"
        END-IF.
        MOVE WS-SALARY TO WS-SALARY-EDITED.
        DISPLAY WS-SALARY-EDITED.
        CLOSE DPTONO.
        CLOSE I-FILE.
        STOP RUN.

    READ-NEXT.
        READ I-FILE NEXT.
        IF FSTAT-CODE NOT = "00" AND FSTAT-CODE NOT = "02"
           DISPLAY "READ NEXT I-FILE FS-CODE: " FSTAT-CODE
           PERFORM VSAM-CODE-DISPLAY
        ELSE
           ADD SALARY TO WS-SALARY
        END-IF.

    READ-FIRST.
        READ I-FILE RECORD KEY IS I-FILE-ALTREC-KEY.
        IF FSTAT-CODE NOT = "00" AND FSTAT-CODE NOT = "02"
           DISPLAY "READ I-FILE FS-CODE: " FSTAT-CODE
           PERFORM VSAM-CODE-DISPLAY
        ELSE
           ADD SALARY TO WS-SALARY
        END-IF.

    VSAM-CODE-DISPLAY.
          DISPLAY "VSAM CODE -->"
                  " RETURN: " VSAM-R15-RETURN-CODE,
                  " COMPONENT: " VSAM-FUNCTION-CODE,
                  " REASON: " VSAM-FEEDBACK-CODE.
```

Preparation Jobs

Creating the VSAM environment

This job is in VSAMDEF member in LUISM.TEST.SAMPLIB library.

The job performs the following steps:

- Unloads the employee DB2 table into a sequential file
- Deletes/Defines the VSAM KSDS file
- Defines the alternate index (by department number)
- Defines the path
- Does the repro of the VSAM file from the sequential file (step1)
- Does the BLDINDEX

```
//LUISM06 JOB (999,POK),'UNLTAB/DEFVSAM/REPRO',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//*       UNLOAD DB2 TABLE                                          *
//*******************************************************************
//STEP00   EXEC PGM=IKJEFT01,DYNAMNBR=20
//STEPLIB  DD DSN=DB8H8.SDSNLOAD,DISP=SHR
//SYSTSPRT DD SYSOUT=*
//SYSPRINT DD SYSOUT=*
//SYSUDUMP DD SYSOUT=*
//SYSREC00 DD DSN=LUISM.EMP.TABLE.UNLOAD,
//            SPACE=(TRK,(1,1)),DISP=(,CATLG)
//SYSPUNCH DD DSN=LUISM.EMP.TABLE.SYSPUNCH,
//            SPACE=(TRK,(1,1)),DISP=(,CATLG),
//            RECFM=FB,LRECL=120
//SYSIN    DD *
DSN8810.EMP
/*
//SYSTSIN  DD *
DSN SYSTEM(DB8H)
RUN  PROGRAM(DSNTIAUL) PLAN(DSNTIB81) -
     LIB('DB8HU.RUNLIB.LOAD')
END
/*
//*******************************************************************
//*       DELETE THE KSDS FILE                                      *
//*******************************************************************
//STEP01   EXEC PGM=IDCAMS,COND=(4,LT,STEP00)
//SYSPRINT DD  SYSOUT=*
//SYSIN    DD *
 DELETE LUISM.KSDATA
/*
//*******************************************************************
//*       DEFINE A KSDS FILE                                        *
//*******************************************************************
//STEP02   EXEC PGM=IEFBR14,COND=(4,LT,STEP01)
//DEFINE   DD  DSN=LUISM.KSDATA,DISP=(NEW,KEEP),
//             SPACE=(TRK,(1,1)),AVGREC=U,RECORG=KS,
```

```
//             KEYLEN=6,KEYOFF=0,LRECL=101
/*
//*********************************************************************
//*        DEFINE ALTERNATE INDEX                                    *
//*********************************************************************
//STEP03   EXEC PGM=IDCAMS,COND=(4,LT,STEP02)
//SYSPRINT DD  SYSOUT=*
//SYSIN    DD *
 DEFINE ALTERNATEINDEX                      -
       (NAME(LUISM.ALTINDEX)                -
        RELATE(LUISM.KSDATA)                -
       NONUNIQUEKEY                        -
        KEYS(3 38)                          -
        RECORDSIZE(23 150)                  -
        VOLUMES(TOTSSI)                     -
        KILOBYTES(100 100)                  -
        UPGRADE)
/*
//*********************************************************************
//*        DEFINE PATH                                               *
//*********************************************************************
//STEP04   EXEC PGM=IDCAMS,COND=(4,LT,STEP03)
//SYSPRINT DD  SYSOUT=*
//SYSIN    DD *
 DEFINE PATH                                -
       (NAME(LUISM.PATH)                    -
        PATHENTRY(LUISM.ALTINDEX))
/*
//*********************************************************************
//*        REPRO INTO THE KSDS FROM DB2 UNLOAD SEQ FILE              *
//*********************************************************************
//STEP05   EXEC PGM=IDCAMS,COND=(4,LT,STEP04)
//SEQFILE  DD  DSN=LUISM.EMP.TABLE.UNLOAD,DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSIN    DD *
 REPRO INFILE(SEQFILE)                      -
       OUTDATASET(LUISM.KSDATA)             -
       REPLACE
/*
//*********************************************************************
//*        BLDINDEX                                                  *
//*********************************************************************
//STEP06   EXEC PGM=IDCAMS,COND=(4,LT,STEP05)
//BASEDD   DD  DSN=LUISM.KSDATA,DISP=SHR
//AIXDD    DD  DSN=LUISM.ALTINDEX,DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSIN    DD *
 BLDINDEX INFILE(BASEDD)                      -
          OUTFILE(AIXDD)             -
```

```
         SORTCALL
/*
```

Preparing the program

This job is in BATVSAMP member in LUISM.TEST.SAMPLIB library.

```
//LUISM07 JOB (999,POK),'Cobol-VSAM',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//*       Compile the IBM COBOL program                             *
//*******************************************************************
//COB      EXEC PGM=IGYCRCTL,
//             PARM=(NOSEQUENCE,QUOTE,RENT,'PGMNAME(LONGUPPER)')
//SYSPRINT DD  SYSOUT=*
//SYSTERM  DD  SYSOUT=*
//SYSLIN   DD  DSN=&&LOADSET,DISP=(MOD,PASS),UNIT=VIO,
//             SPACE=(800,(500,500))
//SYSIN    DD  DSN=LUISM.TEST.SAMPLIB(XYZ3),DISP=SHR
//SYSUT1   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT2   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT3   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT4   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT5   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT6   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//SYSUT7   DD  SPACE=(800,(500,500),,,ROUND),UNIT=VIO
//*******************************************************************
//*  PRELINK STEP.                                                  *
//*******************************************************************
//PLKED   EXEC PGM=EDCPRLK,COND=(4,LT,COB)
//STEPLIB  DD  DISP=SHR,DSN=CEE.SCEERUN
//SYSMSGS  DD  DISP=SHR,
//             DSN=CEE.SCEEMSGP(EDCPMSGE)
//SYSIN    DD  DSN=&&LOADSET,DISP=(OLD,DELETE)
//SYSMOD   DD  DSN=&&PLKSET,UNIT=SYSDA,DISP=(MOD,PASS),
//             SPACE=(32000,(30,30)),
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//SYSDEFSD DD  DUMMY
//SYSOUT   DD  SYSOUT=*
//SYSPRINT DD  SYSOUT=*
//SYSTERM  DD  SYSOUT=*
//*******************************************************************
//*       Linkedit                                                  *
//*******************************************************************
//LKED     EXEC PGM=IEWL,PARM='LIST,XREF',
//         COND=(4,LT,PLKED)
//SYSLIB   DD  DISP=SHR,DSN=CEE.SCEELKED
//         DD  DISP=SHR,DSN=ISP.SISPLOAD
//         DD  DISP=SHR,DSN=GDDM.SADMMOD
//SYSLMOD  DD  DSN=LUISM.TEST.LOADLIB(XYZ3),
```

```
//              DISP=SHR
//SYSPRINT DD  SYSOUT=*
//SYSUT1   DD  SPACE=(1024,(50,50)),UNIT=VIO
//SYSLIN   DD  DSN=&&PLKSET,DISP=(OLD,DELETE)
//         DD  DDNAME=SYSIN
//SYSIN    DD  *
          MODE RMODE(ANY)
         NAME XYZ3(R)
/*
```

Program execution

The job execution is in RUNXYZ3 member in LUISM.TEST.SAMPLIB library.

```
//LUISM08 JOB (999,POK),'EJEC. COB-VSAM',
//              CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//STEP01   EXEC PGM=XYZ3
//STEPLIB  DD  DSN=LUISM.TEST.LOADLIB,DISP=SHR
//KSDATA   DD  DSN=LUISM.KSDATA,DISP=SHR
//KSDATA1  DD  DSN=LUISM.PATH,DISP=SHR
//OUTPUTFI DD  SYSOUT=*
//SYSIN    DD  *
E01
/*
```

Following is the output for department E01:

```
****************************** TOP OF DATA *********************************
E01
$    40,175.00
***************************** BOTTOM OF DATA *******************************
```

The output for a department that have no employees is like the following:

```
****************************** TOP OF DATA *********************************
A01
READ I-FILE FS-CODE: 23
VSAM CODE --> RETURN: 08 COMPONENT: 2 REASON: 016
NO RECORDS EXISTS FOR THIS DEPARTMENT
$         0.00
***************************** BOTTOM OF DATA *******************************
```

DSNTEP2 utility

This PL/I program dynamically executes SQL statements read in from SYSIN. This application can also execute non-SELECT statements.

Execution job

This execution job can be found in DSNTEP2 member in LUISM.TEST.SAMPLIB library.

```
//LUISM04 JOB (999,POK),'Dsntep2',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
//*******************************************************************
//*       DSNTEP2                                                   *
//*******************************************************************
//DSNTEP2  EXEC PGM=IKJEFT01,DYNAMNBR=20
//STEPLIB  DD DSN=DB8H8.SDSNLOAD,DISP=SHR
//SYSTSPRT DD SYSOUT=*
//SYSTSIN  DD *
DSN SYSTEM(DB8H)
RUN  PROGRAM(DSNTEP2) PLAN(DSNTEP81) -
     LIB('DB8HU.RUNLIB.LOAD')
END
/*
//SYSPRINT DD SYSOUT=*
//SYSUDUMP DD SYSOUT=*
//SYSIN    DD *
    SELECT CHAR(DECIMAL(SUM(SALARY),9,2))
    FROM DSN8810.EMP
    WHERE WORKDEPT='A00'
/*
```

Following is the output:

```
PAGE    1
***INPUT STATEMENT:
     SELECT CHAR(DECIMAL(SUM(SALARY),9,2))
     FROM DSN8810.EMP
     WHERE WORKDEPT='A00'
                                                             +-------------+
                                                             |             |
                                                             +-------------+
                                                           1_|  0204250.00 |
                                                             +-------------+
SUCCESSFUL RETRIEVAL OF        1 ROW(S)
```

QMF batch execution

This exercise shows QMF procedure/query/form executed in batch. The EMPQRY query contains the SQL statement of our class program. The EMPPRO procedure invokes the query execution and the report printing. The job invokes the QMF procedure and passes the department number to it; also the execution mode (batch, M=B) and the DB2 subsystem are specified.

The job is in QMFBATCH member in LUISM.TEST.SAMPLIB library.

QMF is invoked with ISPF option Q7 in SC47TS system with ISPQMF71 in the COMMAND field.

Execution job

```
//LUISM10 JOB (999,POK),'QMF in batch',
//             CLASS=A,MSGCLASS=T,MSGLEVEL=(1,1)
/*JOBPARM SYSAFF=SC47
//*****************************************************************
//QMFBAT   EXEC PGM=DSQQMFE,
//         PARM='M=B,I=LUISM.EMPPRO(&&DEP=''A00''),S=DB7D'
//STEPLIB  DD  DISP=SHR,DSN=DB7DU.SDSQLOAD
//         DD  DISP=SHR,DSN=DB7D7.SDSNLOAD
//         DD  DISP=SHR,DSN=DB7D7.SDSNEXIT
//ADMGGMAP DD  DSN=DB7DU.DSQMAPE,DISP=SHR
//DSQPRINT DD  SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//DSQDEBUG DD  SYSOUT=A,DCB=(RECFM=FBA,LRECL=121,BLKSIZE=1210)
//DSQUDUMP DD  SYSOUT=A,DCB=(RECFM=VBA,LRECL=125,BLKSIZE=1632)
//DSQSPILL DD  DSN=&&SPILL,DISP=(NEW,DELETE),
//     UNIT=VIO,SPACE=(TRK,(100),RLSE),
//     DCB=(RECFM=F,LRECL=4096,BLKSIZE=4096)
//*
```

QMF procedure

```
RUN QUERY EMPQRY (&&D=&DEP FORM=EMPFORM
PRINT REPORT
```

QMF query

```
SELECT CHAR(DECIMAL(SUM(SALARY),9,2))
FROM DSN8710.EMP
WHERE WORKDEPT=&D
```

Batch C program to access DB2

Source code

This program is in member CDB2 in GMULLER.TEST.C library

Example: E-1 C source code for accessing DB2

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

EXEC SQL INCLUDE SQLCA;
EXEC SQL INCLUDE SQLDA;

EXEC SQL
    DECLARE DSN8810.EMP TABLE
    (EMPNO     CHAR(6)     NOT NULL,
    FIRSTNAME VARCHAR(12) NOT NULL,
    MIDINIT   CHAR(1)     NOT NULL,
    LASTNAME  VARCHAR(15) NOT NULL,
    WORKDEPT  CHAR(3)             ,
    PHONENO   CHAR(4)             ,
    HIREDATE  DATE                ,
    JOB       CHAR(8)             ,
    EDLEVEL   SMALLINT            ,
    SEX       CHAR(1)             ,
    BIRTHDATE DATE                ,
    SALARY    DECIMAL(9,2)        ,
    BONUS     DECIMAL(9,2)        ,
    COMM      DECIMAL(9,2)        );

EXEC SQL BEGIN DECLARE SECTION;
  long sum;
  long count;
  char deptno[4];
EXEC SQL END DECLARE SECTION;

int avg_sal(char*);
int record_read(FILE*,char*);

void main()
{
  FILE* cardin; /* for DD card CARDIN */
  int avgsal;
  char dept[4];

  cardin = fopen("DD:CARDIN","rb,recfm=FB,lrecl=80,type=record");
  if(cardin == NULL)
```

```
  {
    printf("Error opening DD CARDIN\n");
    exit(-2);
  }

  while(record_read(cardin, dept) != 0)
  {
    avgsal = avg_sal(dept);
    if(avgsal > 0)
      printf("Average salary of %s is %d\n",dept, avgsal);

  }
  fclose(cardin);
}

int avg_sal(char* dept)
{
  int avgsal;
  count = 0;
  strncpy(deptno, dept, 3);
  deptno[3] = 0;

  EXEC SQL SELECT SUM(SALARY), COUNT(*) INTO :sum, :count
           FROM DSN8810.EMP
           WHERE WORKDEPT = :deptno;

  if(count != 0)
  {
    avgsal = sum/count;
    return avgsal;
  } else
  {
    printf("DEPT %s does not exist\n", deptno);
    return -1;
  }
}

int record_read(FILE* file, char* dept)
{
  int readbytes;
  char linebuf[81], linebuf2[80];
  readbytes = fread(linebuf, 1, 81, file);
  strncpy(dept, linebuf, 3); /* first 3 bytes are dept. number */
  dept[3]=0; /* terminate string */
  return readbytes;
}
```

Preparing the program

This JCL is in member CDB2 in GMULLER.TEST.CNTL library

Example: E-2 GMULLER.TEST.CNTL(CDB2)

```
//GMULLERC JOB 1,GEORG,MSGLEVEL=(1,1),NOTIFY=&SYSUID
//* PRECOMPILE AND COMPILE THE SAMPLE C FILE
//PROCLIB JCLLIB ORDER=DB8HU.PROCLIB
/*JOBPARM SYSAFF=SC04
//STEP1 EXEC PROC=DSNHC,MEM=CDB2,
//      PARM.PC=('HOST(C),CCSID(1047)')
//PC.DBRMLIB DD DSN=DB8HU.DBRMLIB.DATA(CDB2),DISP=SHR
//PC.SYSLIB  DD DSN=GMULLER.TEST.C,DISP=SHR
//PC.SYSIN   DD DSN=GMULLER.TEST.C(&MEM),DISP=SHR
//LKED.SYSLMOD DD DSN=GMULLER.TEST.LOAD(&MEM),DISP=SHR
//LKED.SYSIN DD *
 INCLUDE SYSLIB(DSNELI)
/*
//****************************************************
//* BIND AND RUN THE PROGRAM                          *
//****************************************************
//BIND     EXEC PGM=IKJEFT01,DYNAMNBR=20,COND=(4,LT)
//STEPLIB  DD DSN=DB8H8.SDSNLOAD,DISP=SHR
//DBRMLIB  DD DSN=DB8HU.DBRMLIB.DATA,DISP=SHR
//SYSUDUMP DD SYSOUT=*
//SYSTSPRT DD SYSOUT=*
//SYSPRINT DD SYSOUT=*
//CARDIN   DD *
D11
XYZ
A00
/*
//SYSIN    DD *
   GRANT BIND,EXECUTE ON PLAN CDB2 TO PUBLIC;
//SYSTSIN  DD *
 DSN SYSTEM(DB8H)
 BIND PACKAGE (CDB2PAK) MEMBER(CDB2) -
      ACT(REP) ISO(CS) ENCODING(EBCDIC)
 BIND PLAN(CDB2)  PKLIST(CDB2PAK.*) -
      ACT(REP) ISO(CS) ENCODING(EBCDIC)
 RUN  PROGRAM(CDB2) PLAN(CDB2) LIB('GMULLER.TEST.LOAD')
 END
/*
```

- This Job requires the PDS GMULLER.TEST.LOAD with RECFM=U

- Statement "/*JOBPARM SYSAFF=SC04" points to the system where DB2 is running and has to be modified (or deleted, if not in a sysplex)
- DB8H has to be replaced with the name of the local DB2
- HLQs for DB2 libs may differ

Output:

Example: E-3 Output of CDB2

```
Average salary of D11 is 25147
DEPT XYZ does not exist
Average salary of A00 is 40850
```

Running the program

This JCL is in member RUNJCL in GMULLER.TEST.CNTL library

Example: E-4 GMULLER.TEST.CNTL(RUNJCL)

```
//GMULLERR JOB 1,GEORG,MSGLEVEL=(1,1),NOTIFY=&SYSUID
//* PRECOMPILE AND COMPILE THE SAMPLE C FILE
/*JOBPARM SYSAFF=SC04
//****************************************************
//* RUN THE PROGRAM                                  *
//****************************************************
//BIND     EXEC PGM=IKJEFT01,DYNAMNBR=20,COND=(4,LT)
//STEPLIB  DD DSN=DB8H8.SDSNLOAD,DISP=SHR
//DBRMLIB  DD DSN=DB8HU.DBRMLIB.DATA,DISP=SHR
//SYSUDUMP DD SYSOUT=*
//SYSTSPRT DD SYSOUT=*
//SYSPRINT DD SYSOUT=*
//CARDIN   DD DISP=SHR,DSN=GMULLER.TEST.CNTL(CARDIN)
//SYSTSIN  DD *
 DSN SYSTEM(DB8H)
 RUN  PROGRAM(CDB2) PLAN(CDB2) LIB('GMULLER.TEST.LOAD')
 END
/*
```

- This requires the Member CARDIN in GMULLER.TEST.CNTL library
- HLQ for DB2 libs may differ

Input

Example: E-5   GMULLER.TEST.CNTL(CARDIN)

```
D11
A00
XYZ
C01
ABC
E21
```

Output

Example: E-6   Output of RUNJCL

```
Average salary of D11 is 25147
Average salary of A00 is 40850
DEPT XYZ does not exist
Average salary of C01 is 29722
DEPT ABC does not exist
Average salary of E21 is 24086
```

Java Servlet access to DB2

Servlet source code

Example: E-7   SalaryServlet.java

```
import java.io.IOException;
import java.io.PrintWriter;
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;

import javax.naming.Context;
import javax.naming.InitialContext;
import javax.naming.NamingException;
import javax.servlet.ServletException;
import javax.servlet.http.HttpServlet;
import javax.servlet.http.HttpServletRequest;
import javax.servlet.http.HttpServletResponse;
import javax.sql.DataSource;

public class SalaryServlet extends HttpServlet {

    private DataSource ds;
```

```
    private boolean dbProblem = false;

    public void init() throws ServletException {
        super.init();
        try { // get DataSource from Container
            Context context = new InitialContext();
            ds = (DataSource) context.lookup("jdbc/DB8H");
        } catch (NamingException e) {
            e.printStackTrace();
            this.dbProblem = true;
        }
    }

    protected void doGet(HttpServletRequest req, HttpServletResponse resp)
            throws ServletException, IOException {

        resp.setContentType("text/html");
        String deptno = req.getParameter("deptno"); // get from request string

        PrintWriter out = resp.getWriter();
        out.println("<html>\n<head>\n <title>Average
Salary</title>\n</head>\n<body>");
        out.println("<h1>Average Salary</h1>");
        out.println("<form action=\"salary\" method=\"get\">");
        out.println("Dept. No.: <input type=\"text\" name=\"deptno\" />");
        out.println(" <input type=\"submit\" />\n</form>");

        if (deptno != null) {
            try {
                int avgSal = getAvgSal(deptno);
                out.println("The average salary of <b>" + deptno + "</b> is
<b>$ " + avgSal
                        + "</b><br>");
            } catch (Exception e) {
                out.println("<b>Error: " + e.getMessage() + "</b><br>");
            }
        }
        out.println("</html>");
    }

    private int getAvgSal(String deptno) throws Exception {
        String sqlStatement = "SELECT SUM(salary), COUNT(*) "
                + "FROM DSN8810.EMP WHERE WORKDEPT = '" + deptno + "'";
        // Connect to database
        Connection con = null;
        try {
            con = ds.getConnection();
            Statement stmt = con.createStatement();
            ResultSet rs = stmt.executeQuery(sqlStatement); // Execute SQL
```

```
            // statement

            rs.next(); // get Values from result set
            int sum = rs.getInt(1);
            int count = rs.getInt(2);
            if (count == 0)
                throw new Exception("Department " + deptno
                        + " does not exist");
            return sum / count;

        } catch (SQLException e) {
            throw new Exception(e.getMessage());
        } finally {
            try {
                con.close();
            } catch (SQLException e) {}
        }
    }
}
```

- This servlet requires a data source (here jndi name “jdbc/DB8H”) defined in the web container, which points to the DB2 database

Deployment descriptor

Example: E-8 web.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE web-app PUBLIC "-//Sun Microsystems, Inc.//DTD Web Application
2.3//EN" "http://java.sun.com/dtd/web-app_2_3.dtd">
<web-app id="WebApp_ID">
    <display-name>Salary</display-name>
    <servlet>
        <servlet-name>Salary</servlet-name>
        <servlet-class>SalaryServlet</servlet-class>
    </servlet>
    <servlet-mapping>
        <servlet-name>Salary</servlet-name>
        <url-pattern>/salary</url-pattern>
    </servlet-mapping>
</web-app>
```

C program to access MQ

MQPUT writes a message onto a queue (entered in TSO)

Program is started with TSO CALL ‘ZSCHOLAR.PROGRAM.LOAD(MQPUT)’, then you have to enter a message.

MQGET gets the message back and displays it on the screen.

Program is started with TSO CALL ‘ZSCHOLAR.PROGRAM.LOAD(MQGET)’, then you have to enter a message.

It is also possible to receive the message with the java application in , “Java program to access MQ” on page 38.

MQPUT

Example: E-9 ZSCHOLAR.PROGRAM.SRC(MQPUT)

```
#pragma csect(code,"CSQ4BCK1")
/*                                                                   */
/* Define static CSECT name                                          */
/*                                                                   */
#pragma csect(static,"BCK1WS")

#include <stdlib.h>
#include <string.h>
#include <stdio.h>
#include <cmqc.h>

/*                                                                   */
/* Function prototypes                                               */
/*                                                                   */
void usageError( char* programName );
void errorMessage( char* msgStr, MQLONG CC, MQLONG RC );

int main( int argc, char** argv )
{
   /*                                                                */
   /* API variables                                                  */
   /*                                                                */
   MQHCONN HConn = MQHC_DEF_HCONN;
   MQHOBJ  HObj;
   MQLONG  OpenOptions;
   MQMD    MsgDesc = { MQMD_DEFAULT };
   MQOD    ObjDesc = { MQOD_DEFAULT };
```

```
MQPMO   PutMsgOpts = { MQPMO_DEFAULT };
MQLONG  CompCode;
MQLONG  Reason;

/*                                                                   */
/* Parameter variables                                               */
/*                                                                   */
MQCHAR48 qMgr;
MQCHAR48 qName;
char     msgBuffer[255];
int      msgLength;
char     persistent = 'N';
long     rc = 0;

printf("Please enter message text:\n");
fgets(msgBuffer, 255, stdin);
msgLength = strlen(msgBuffer);

strcpy( qMgr,  "MQ8H\0" );
strcpy( qName, "GMULLER\0" );
/*
memset( qMgr,  '\0', MQ_Q_MGR_NAME_LENGTH );
memset( qName, '\0', MQ_Q_NAME_LENGTH );
*/

/*                                                                   */
/* Connect to Queue Manager (MQCONN)                                 */
/*                                                                   */
MQCONN( qMgr,
        &HConn,
        &CompCode,
        &Reason     );
/*                                                                   */
/* If connect failed then display error message and exit             */
/*                                                                   */
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQCONN", CompCode, Reason );
   return Reason;
   }

printf( "MQCONN SUCCESSFUL\n" );

/*                                                                   */
/* Open Queue for output (MQOPEN). Fail the call if the queue        */
/* manager is quiescing.                                             */
/*                                                                   */
OpenOptions = MQOO_OUTPUT +
              MQOO_FAIL_IF_QUIESCING;
```

```
strncpy( ObjDesc.ObjectName, qName, MQ_Q_NAME_LENGTH );
MQOPEN( HConn,
        &ObjDesc,
        OpenOptions,
        &HObj,
        &CompCode,
        &Reason     );
/*                                                                   */
/* If open failed then display error message,                        */
/* disconnect from the queue manager and exit                        */
/*                                                                   */
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQOPEN", CompCode, Reason );
   rc = Reason;
   MQDISC( &HConn,
           &CompCode,
           &Reason    );
   return rc;
   }

printf( "MQOPEN SUCCESSFUL\n" );

/*                                                                   */
/* Set persistence depending on parameter passed                     */
/*                                                                   */
if( 'P' == persistent )
   MsgDesc.Persistence = MQPER_PERSISTENT;
else
   MsgDesc.Persistence = MQPER_NOT_PERSISTENT;

/*                                                                   */
/* Put String format messages                                        */
/*                                                                   */
strncpy( MsgDesc.Format, MQFMT_STRING, MQ_FORMAT_LENGTH );

/*                                                                   */
/* Set the put message options to fail the call if the queue         */
/* manager is quiescing.                                             */
/*                                                                   */
PutMsgOpts.Options = MQPMO_FAIL_IF_QUIESCING;


strncpy( MsgDesc.MsgId,    MQMI_NONE, MQ_MSG_ID_LENGTH );
strncpy( MsgDesc.CorrelId, MQCI_NONE, MQ_CORREL_ID_LENGTH );

MQPUT( HConn,
       HObj,
```

```
       &MsgDesc,
       &PutMsgOpts,
       msgLength,
       msgBuffer,
       &CompCode,
       &Reason    );
/*
/* If put failed then display error message                    */
/* and break out of loop                                       */
/*                                                             */
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQPUT", CompCode, Reason );
   rc = Reason;
   }

printf("MESSAGE PUT TO QUEUE\n");

free( msgBuffer );

/*                                                               */
/* Close the queue and then disconnect from the queue manager     */
/*                                                               */
MQCLOSE( HConn,
         &HObj,
         MQCO_NONE,
         &CompCode,
         &Reason    );
if( MQCC_OK != CompCode  )
   {
   errorMessage( "MQCLOSE", CompCode, Reason );
   rc = Reason;
   }
else printf( "MQCLOSE SUCCESSFUL\n" );


MQDISC( &HConn,
        &CompCode,
        &Reason    );
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQDISC", CompCode, Reason );
   return Reason;
   }
else
   {
   printf( "MQDISC SUCCESSFUL\n" );
   return rc;
   }
```

```
   return(rc);
} /*end main*/

/********************************************************************/
/* Functions to display error messages                              */
/********************************************************************/
void errorMessage( char* msgStr, MQLONG CC, MQLONG RC )
{
   printf( "***********************************************\n" );
   printf( "* %s\n", msgStr );
   printf( "* COMPLETION CODE : %09ld\n", CC );
   printf( "* REASON CODE     : %09ld\n", RC );
   printf( "***********************************************\n" );
}
```

JCL to compile:

Example: E-10 ZSCHOLAR.PROGRAM.CNTL(MQPUT)

```
//GMULLERT JOB 1,GEORG,MSGCLASS=H,MSGLEVEL=(1,1),NOTIFY=&SYSUID
//* COMPILE MQ PROGRAM
//STEP1    EXEC PROC=EDCCB,
//            INFILE='ZSCHOLAR.PROGRAM.SRC(MQPUT)',
//            OUTFILE='ZSCHOLAR.PROGRAM.LOAD(MQPUT),DISP=SHR'
//SYSLIB   DD DSN=MQ531.SCSQC370,DISP=SHR
//BIND.CSQBSTUB  DD DSN=MQ531.SCSQLOAD(CSQBSTUB),DISP=SHR
//BIND.SYSIN DD *
  INCLUDE CSQBSTUB
/*
```

MQGET

Source code

Example: E-11 ZSCHOLAR.PROGRAM.SRC(MQGET)

```
#pragma csect(code,"CSQ4BCK1")
/*                                                                  */
/* Define static CSECT name                                         */
/*                                                                  */
#pragma csect(static,"BCK1WS")

#include <stdlib.h>
#include <string.h>
#include <stdio.h>
#include <cmqc.h>
```

```
#define maxMessageLength  65536

/*                                                                  */
/* Function prototypes                                              */
/*                                                                  */
void usageError( char* programName );
void errorMessage( char* msgStr, MQLONG CC, MQLONG RC );

int main( int argc, char** argv )
{
   /*                                                               */
   /* API variables                                                 */
   /*                                                               */
   MQHCONN HConn = MQHC_DEF_HCONN;
   MQHOBJ  HObj;
   MQLONG  OpenOptions;
   MQMD    MsgDesc = { MQMD_DEFAULT };
   MQOD    ObjDesc = { MQOD_DEFAULT };
   MQGMO   GetMsgOpts = { MQGMO_DEFAULT };
   MQLONG  CompCode;
   MQLONG  Reason;

   /*                                                               */
   /* Parameter variables                                           */
   /*                                                               */
   MQCHAR48 qMgr;
   MQCHAR48 qName;
   char     msgBuffer[maxMessageLength];
   int      msgLength = maxMessageLength;
   char     persistent = 'N';
   long     rc = 0;
   long     dataLength;
   char     browseGet = 'D'; /* destructive get */
   char     syncpoint = 'N'; /* no Syncpoint */

   memset( msgBuffer, '\0', msgLength );

   strcpy( qMgr,  "MQ8H\0" );
   strcpy( qName, "GMULLER\0" );

   /*                                                               */
   /* Connect to Queue Manager (MQCONN)                             */
   /*                                                               */
   MQCONN( qMgr,
           &HConn,
           &CompCode,
           &Reason     );
   /*                                                               */
   /* If connect failed then display error message and exit         */
```

```
/*                                                                    */
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQCONN", CompCode, Reason );
   return Reason;
   }

printf( "MQCONN SUCCESSFUL\n" );

/*                                                                    */
/* Open Queue for input shared and browse. Fail the call if the      */
/* queue manager is quiescing.                                        */
/*                                                                    */
OpenOptions = MQOO_INPUT_SHARED +
              MQOO_BROWSE +
              MQOO_FAIL_IF_QUIESCING;

strncpy( ObjDesc.ObjectName, qName, MQ_Q_NAME_LENGTH );
MQOPEN( HConn,
        &ObjDesc,
        OpenOptions,
        &HObj,
        &CompCode,
        &Reason     );
/*                                                                    */
/* If open failed then display error message,                         */
/* disconnect from the queue manager and exit                         */
/*                                                                    */
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQOPEN", CompCode, Reason );
   rc = Reason;
   MQDISC( &HConn,
           &CompCode,
           &Reason    );
   return rc;
   }

printf( "MQOPEN SUCCESSFUL\n" );

/*                                                                    */
/* Set persistence depending on parameter passed                      */
/*                                                                    */
if( 'P' == persistent )
   MsgDesc.Persistence = MQPER_PERSISTENT;
else
   MsgDesc.Persistence = MQPER_NOT_PERSISTENT;

/*                                                                    */
```

```
/* Set GetMsgOpts .. don't wait if there are no messages on the   */
/* queue, truncate the message if it does not fit into our        */
/* buffer, perform data conversion on the message if required     */
/* and if possible, and fail the call if the queue manager is     */
/* quiescing.                                                     */
/*                                                                */
GetMsgOpts.Options = MQGMO_NO_WAIT +
                     MQGMO_ACCEPT_TRUNCATED_MSG +
                     MQGMO_CONVERT +
                     MQGMO_FAIL_IF_QUIESCING;

strncpy( MsgDesc.MsgId,    MQMI_NONE, MQ_MSG_ID_LENGTH );
strncpy( MsgDesc.CorrelId, MQCI_NONE, MQ_CORREL_ID_LENGTH );

/*                                                                */
/* Set additional GetMsgOpts depending on parameters passed       */
/* into program.                                                  */
/*                                                                */
if( ('S' == syncpoint) && ('B' != browseGet) )
   GetMsgOpts.Options += MQGMO_SYNCPOINT;
else
   GetMsgOpts.Options += MQGMO_NO_SYNCPOINT;

if( ('B' == browseGet) )
   GetMsgOpts.Options += MQGMO_BROWSE_FIRST;

MsgDesc.Encoding = MQENC_NATIVE;
MsgDesc.CodedCharSetId = MQCCSI_Q_MGR;

/* GET */
MQGET( HConn,
       HObj,
       &MsgDesc,
       &GetMsgOpts,
       msgLength,
       msgBuffer,
       &dataLength,
       &CompCode,
       &Reason    );

if( (MQCC_FAILED == CompCode) )
   {
   errorMessage( "MQGET", CompCode, Reason );
   rc = Reason;
   }
else
   {
   /*                                                          */
   /* Only character data messages are correctly displayed     */
```

```
   /* by this code                                                  */
   /*                                                               */
   if (MQRC_TRUNCATED_MSG_ACCEPTED == Reason)
      {
      msgBuffer??( msgLength - 1 ??) = 0;
      printf( "Message received (truncated):\n%s\n",
             msgBuffer );
      }
   else
      {
      msgBuffer??( dataLength ??) = 0;
      printf( "Message received:\n%s\n",
             msgBuffer );
      }
   }

free( msgBuffer );

/*                                                                  */
/* Close the queue and then disconnect from the queue manager     */
/*                                                                  */
MQCLOSE( HConn,
         &HObj,
         MQCO_NONE,
         &CompCode,
         &Reason    );

if( MQCC_OK != CompCode  )
   {
   errorMessage( "MQCLOSE", CompCode, Reason );
   rc = Reason;
   }
else printf( "MQCLOSE SUCCESSFUL\n" );


MQDISC( &HConn,
        &CompCode,
        &Reason    );
if( MQCC_OK != CompCode )
   {
   errorMessage( "MQDISC", CompCode, Reason );
   return Reason;
   }
else
   {
   printf( "MQDISC SUCCESSFUL\n" );
   return rc;
   }
```

```
   return(rc);
} /*end main*/

/*********************************************************************/
/* Functions to display error messages                               */
/*********************************************************************/
void errorMessage( char* msgStr, MQLONG CC, MQLONG RC )
{
   printf( "************************************************\n" );
   printf( "* %s\n", msgStr );
   printf( "* COMPLETION CODE : %09ld\n", CC );
   printf( "* REASON CODE     : %09ld\n", RC );
   printf( "************************************************\n" );
}
```

JCL to compile

Example: E-12   ZSCHOLAR.PROGRAM.CNTL(MQGET)

```
//GMULLERT JOB 1,GEORG,MSGCLASS=H,MSGLEVEL=(1,1),NOTIFY=&SYSUID
//* COMPILE MQ PROGRAM
//STEP1    EXEC PROC=EDCCB,
//            INFILE='ZSCHOLAR.PROGRAM.SRC(MQGET)',
//            OUTFILE='ZSCHOLAR.PROGRAM.LOAD(MQGET),DISP=SHR'
//SYSLIB   DD DSN=MQ531.SCSQC370,DISP=SHR
//BIND.CSQBSTUB  DD DSN=MQ531.SCSQLOAD(CSQBSTUB),DISP=SHR
//BIND.SYSIN DD *
  INCLUDE CSQBSTUB
/*
```

Java program to access MQ

The java program receives a message from a queue. The MessageHandler class also contains a class to send messages.

You have to add com.ibm.mq.jar and connector.jar to your CLASSPATH.

All files are in “program sample\mq”.

Run the program with java -jar mqconnect.jar

Example: E-13   MQReceiver.java

```
import com.ibm.mq.MQException;
```

```
public class MQReceiver {

    public static void main(String[] args) {

        // Connection settings
        String hostname = "wtsc04.itso.ibm.com";
        String queueName = "GMULLER";
        int port = 1598; // mq port
        String channel = "GMULLER.SERV";

        MessageHandler handler = new MessageHandler(hostname, port, queueName,
                channel);

        String message;
        try {
            System.out.println("Sending message...");
            handler.sendMessage("Hello");
            //System.out.println("Receiving message...");
            //message = handler.receiveMessage();
            //System.out.println("Message: " + message);
            System.out.println("Finished");
        } catch (MQException e) {
            if (e.reasonCode == MQException.MQRC_NO_MSG_AVAILABLE)
                System.out.println("No message in queue");
            else {
                System.out.println("Error getting message");
                e.printStackTrace();
            }
        }
    }
}
```

Example: E-14   MessageHandler.java

```
import java.io.IOException;

import com.ibm.mq.*;

public class MessageHandler {

    private String hostname;
    private String queueName;

    public MessageHandler(String hostname, int port, String queueName, String
channel) {
```

```
        MQEnvironment.hostname = hostname;
        MQEnvironment.port = port;
        MQEnvironment.channel = channel;
        this.queueName = queueName;
    }

    public String receiveMessage() throws MQException {
        try {
            MQQueueManager mqm = new MQQueueManager(hostname);

            int openOptions = MQC.MQOO_INPUT_AS_Q_DEF + MQC.MQOO_OUTPUT;

            MQQueue queue = mqm.accessQueue(queueName, openOptions);
            // create new Message for receiving
            MQMessage message = new MQMessage();

            // get message from queue
            queue.get(message);
            // get the whole message string
            String messageString =
message.readString(message.getMessageLength());
            // close queue;
            queue.close();
            // disconnect from queue manager
            mqm.disconnect();

            return messageString;

        } catch (IOException e) {
            e.printStackTrace();
            return null;
        }
    }

    public void sendMessage(String messageString) throws MQException {
        try {
            MQQueueManager mqm = new MQQueueManager(hostname);

            int openOptions = MQC.MQOO_INPUT_AS_Q_DEF + MQC.MQOO_OUTPUT;



            MQQueue queue = mqm.accessQueue(queueName, openOptions);
            // create new Message for receiving
            MQMessage message = new MQMessage();


            // write message
            message.writeString(messageString);
```

```
            message.encoding = MQC.MQENC_NATIVE;
            message.characterSet = MQC.MQCCSI_INHERIT;

            // put message onto the queue
            queue.put(message);

            // close queue;
            queue.close();
            // disconnect from queue manager
            mqm.disconnect();

        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

F

Backmatter

This appendix contains the following:

Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this textbook.

IBM provides access to z/OS manuals on the Internet. To view, search, and print z/OS manuals, go to the z/OS Internet Library:

`http://www.ibm.com/servers/eserver/zseries/zos/bkserv`

z/OS Data Management references

- *z/OS DFSMS: Using Data Sets,* SC26-7410

z/OS JCL and Utilities references

- *z/OS MVS JCL Reference*, SA22-7597
- *z/OS MVS JCL User's Guide*, SA22-7598
- *z/OS DFSMSdfp Utilities*, SC26-7414

z/OS system programming

- *z/OS MVS System Data Set Definition,* SA22-7629
- *z/OS MVS Initialization and Tuning Reference,* SA22-7592
- *z/OS MVS Initialization and Tuning Guide,* SA22-7591
- *JES2 Initialization and Tuning Guide*, SA22-7532

z/OS UNIX references

- *z/OS UNIX System Services Command Reference*, SA22-7802
- *z/OS UNIX System Services User's Guide*, SA22-7801
- *z/OS UNIX System Services Planning*, GA22-7800

z/OS Communications Server references

- *z/OS Communications Server IP Configuration Guide*, SC31-8775
- *z/OS Communications Server IP Configuration Reference*, SC31-8776

Language references

- *HLASM General Information*, GC26-4943
- *HLASM Installation and Customization Guide*, SC26-3494
- *HLASM Language Reference*, SC26-4940
- *Enterprise COBOL for z/OS and OS/390 V3R2 Language Reference*, SC27-1408

- *Enterprise COBOL for z/OS and OS/390 V3R2 Programming Guide*, SC27-1412
- *Enterprise PL/I Language Reference*, SC27-1460
- *Enterprise PL/I for z/OS V3R3 Programming Guide*, SC27-1457
- *C/C++ Language Reference*, SC09-4764
- *C/C++ Programming Guide*, SC09-4765
- *IBM SDK for z/OS V1.4 Program Directory*, GI11-2822
- *z/OS V1R5.0 Language Environment Concepts Guide,* SA22-7567
- *z/OS V1R5.0 Language Environment Programming Guide*, SA22-7561
- *The REXX Language*, 2nd Ed., Cowlishaw, ZB35-5100
- *Procedures Language Reference (Level 1)*, C26-4358 SAA CPI
- *REXX on zSeries V1R4.0 User's Guide and Reference*, SH19-8160
- *Creating Java Applications Using NetRexx* , SG24-2216

For more information, refer to this Web site:

`http://www-306.ibm.com/software/awdtools/REXX/language/REXXlinks.html`

CICS references

- *CICS Application Programming Primer*, SC33-0674
- *CICS Transaction Server for z/OS - CICS Application Programming Guide,* SC34-6231
- *CICS Transaction Server for z/OS - CICS System Programming Reference,* SC34-6233

IMS references

- *IMS Primer*, SG25-5352
- *IMS Application Programming: Database Manager,* SG27-1286
- *IMS Application Programming: Transaction Manager,* SG27-1289

DB2 references

- *DB2 UDB for z/OS: Administration Guide*, SC18-7413
- *DB2 UDB for z/OS: Application Programming and SQL Guide,* SC18-7415
- *DB2 UDB for z/OS: SQL Reference,* SC18-7426

WebSphere MQ references

- *WebSphere MQ Application Programming Guide*, SC34-6064
- *WebSphere MQ Bibliography and Glossary*, SC34-6113
- *WebSphere MQ System Administration Guide*, SC34-6068

For more information, refer to this Web site:

http://www.ibm.com/software/integration/mqfamily/library/manualsa/

IBM Redbooks

For information on ordering these publications, see "How to get IBM Redbooks" on page FF-5. Note that some of the documents referenced here might be available in softcopy only.

- *ABCs of z/OS System Programming, Volume 1*: Introduction to z/OS and storage concepts, TSO/E, ISPF, JCL, SDSF, MVS delivery and installation
- *ABCs of z/OS System Programming, Volume 2*: z/OS implementation and daily maintenance, defining subsystems, JES2 and JES3, LPA, LNKLST, authorized libraries, catalogs
- *ABCs of z/OS System Programming, Volume 3*: Introduction to DFSMS, storage management
- *ABCs of z/OS System Programming, Volume 4*: Communication Server, TCP/IP, and VTAM
- *ABCs of z/OS System Programming, Volume 5*: Base and Parallel Sysplex, system logger, global resource serialization, z/OS system operations, automatic restart management, hardware management console, performance management
- *ABCs of z/OS System Programming, Volume 6*: RACF, PKI, LDAP, cryptography, Kerberos, and firewall technologies
- *ABCs of z/OS System Programming, Volume 7*: Infoprint® Server, Language Environment, and SMP/E
- *ABCs of z/OS System Programming, Volume 8*: z/OS problem diagnosis
- *ABCs of z/OS System Programming, Volume 9*: z/OS UNIX System Services
- *ABCs of z/OS System Programming, Volume 10*: Introduction to z/Architecture, zSeries processor design, zSeries connectivity, LPAR concepts, and HCD
- *IBM WebSphere Application Server V5.1 System Management and Configuration WebSphere Handbook Series,* SG24-6195 (IBM Redbook)
- *z/OS WebSphere Application Server V5 and J2EE 1.3 Security Handbook,* SG24-6086 (IBM Redbook)

Online resources

These Web sites and URLs are also relevant as further information sources:

- IBM zSeries homepage

  http://www.ibm.com/servers/eserver/zseries

- IBM z/OS homepage

  `http://www.ibm.com/servers/eserver/zseries`
- IBM Internet Library for zSeries and z/OS

  `http://www.ibm.com/servers/eserver/zseries/bkserv`
- IBM z/OS Communications Server homepage

  `http://www.software.ibm.com/network/commserver/support/`
- IBM Terminologies

  `http://www.ibm.com/ibm/terminology/`
- Sysprog Net, independent resource for the z/OS system programmer

  `http://www.sysprog.net`

How to get IBM Redbooks

You can search for, view, or download Redbooks, Redpapers, Hints and Tips, draft publications and Additional materials, as well as order hardcopy Redbooks or CD-ROMs, at this Web site:

`ibm.com/redbooks`

Help from IBM

IBM Support and downloads

ibm.com/support

Glossary

A

abend. Termination of a task before its completion because of an error condition that cannot be resolved by recovery facilities while the task is executing.

access authority. An authority that relates to a request for a type of access to protected resources. In RACF, the access authorities are NONE, READ, UPDATE, ALTER, and EXECUTE.

access list. A list within a profile of all authorized users and their access authorities.

access method. A technique for moving data between main storage and input/output devices.

access. A specific type of interaction between a subject and an object that results in the flow of information from one to the other.

ACID properties. The properties of a transaction: atomicity, consistency, isolation, and durability. In CICS, the ACID properties apply to a unit of work (UOW). See also atomicity, consistency, isolation, durability.

address. The unique code assigned to each device, workstation or system connected to a network.

address space. The area of virtual storage available for a particular job. In z/OS, an address space can range up to 16 exabytes of contiguous virtual storage addresses that the system creates for the user. An address space contains user data and programs, as well as system data and programs, some of which are common to all address spaces.

addressing mode (AMODE). The mode, 24-bit, 31-bit, or 64-bit, in which a program holds and processes addresses on z/OS.

administrator. A person responsible for administrative tasks such as access authorization and content management. Administrators can also grant levels of authority to users.

allocate. To assign a resource for use in performing a specific task.

alphanumeric character. A letter or a number.

amode. Addressing mode. A program attribute that can be specified (or defaulted) for each CSECT, load module, and load module alias. AMODE states the addressing mode that is expected to be in effect when the program is entered.

application. (1) A particular use to which an information processing system is put - for example, a stock control application, an airline reservation application, an order entry application. (2) A program or set of programs that performs a task; some examples are payroll, inventory management, and word processing applications.

ASCII (American Standard Code for Information Interchange). The standard code, using a coded character set consisting of 7-bit coded characters (8-bit including parity check), that is used for information interchange among data processing systems, data communication systems, and associated equipment. The ASCII set consists of control characters and graphic characters.

assembler. A computer program that converts assembler language instructions into object code.

assembler language. A symbolic programming language that comprises instructions for basic computer operations which are structured according to the data formats, storage structures, and registers of the computer.

asynchronous processing. A series of operations that are done separately from the job in which they were requested; for example, submitting a batch job from an interactive job at a work station. See also synchronous processing.

audit. To review and examine the activities of a data processing system mainly to test the adequacy and effectiveness of procedures for data security and data accuracy.

authority. The right to access objects, resources, or functions.

authorization checking. The action of determining whether a user is permitted access to a RACF-protected resource.

authorized program facility (APF). A facility that permits identification of programs authorized to use restricted functions.

automated operations. Automated procedures to replace or simplify actions of operators in both systems and network operations.

auxiliary storage. All addressable storage other than processor storage. See also memory.

B

back-up. The process of creating a copy of data to ensure against accidental loss.

basic mode. A central processor mode that does not use logical partitioning. Contrast with logical partitioned (LPAR) mode.

batch. A group of records or data processing jobs brought together for processing or transmission.

batch job. A predefined group of processing actions submitted to the system to be performed with little or no interaction between the user and the system. See also interactive job.

batch processing. A method of running a program or a series of programs in which one or more records (a batch) are processed with little or no action from the user or operator. See also interactive processing.

batch message processing (BMP) program. An IMS batch processing program that has access to online databases and message queues. BMPs run online, but like programs in a batch environment, they are started with job control language (JCL).

binary data. (1) Any data not intended for direct human reading. Binary data may contain unprintable characters, outside the range of text characters. (2) A type of data consisting of numeric values stored in bit patterns of 0s and 1s. Binary data can cause a large number to be placed in a smaller space of storage.

BIND. In SNA, a request to activate a session between two logical units (LUs).

buffer. A portion of storage used to hold input or output data temporarily.

C

cache structure. A Coupling Facility structure that enables high-performance sharing of cached data by multisystem applications in a sysplex. Applications can use a cache structure to implement several different types of caching systems, including a store-through or a store-in cache.

cache. A random access electronic storage in selected storage controls used to retain frequently used data for faster access by the channel.

carriage control character. An optional character in an input data record that specifies a write, space, or skip operation.

carriage return (CR). (1) A keystroke generally indicating the end of a command line. (2) In text data, the action that indicates to continue printing at the left margin of the next line. (3) A character that will cause printing to start at the beginning of the same physical line in which the carriage return occurred.

case-sensitive. Pertaining to the ability to distinguish between uppercase and lowercase letters.

catalog. (1) A directory of files and libraries, with reference to their locations. (2) To enter information about a file or a library into a catalog. (3) The collection of all data set indexes that are used by the control program to locate a volume containing a specific data set.

CEMT. The CICS-supplied transaction that allows checking of the status of terminals, connections, and other CICS entities from a console or from CICS terminal sessions.

central processor (CP). The part of the computer that contains the sequencing and processing facilities for instruction execution, initial program load, and other machine operations.

central processor complex (CPC). A physical collection of hardware that includes main storage, one or more central processors, timers, and channels.

channel connection address (CCA). The input/output (I/O) address that uniquely identifies an I/O device to the channel during an I/O operation.

channel interface. The circuitry in a storage control that attaches storage paths to a host channel.

channel-to-channel (CTC). The communication (transfer of data) between programs on opposite sides of a channel-to-channel adapter (CTCA).

channel-to-channel adapter (CTCA). An input/output device that is used a program in one system to communicate with a program in another system.

checkpoint. (1) A place in a routine where a check, or a recording of data for restart purposes, is performed. (2) A point at which information about the status of a job and the system can be recorded so that the job step can be restarted later.

checkpoint write. Any write to the checkpoint data set. A general term for the primary, intermediate, and final writes that update any checkpoint data set.

client. A functional unit that receives shared services from a server. See also client-server.

client-server. In TCP/IP, the model of interaction in distributed data processing in which a program at one site sends a request to a program at another site and awaits a response. The requesting program is called a client; the answering program is called a server.

code page. (1) A table showing codes assigned to character sets. (2) An assignment of graphic characters and control function meanings to all code points. (3) Arrays of code points representing characters that establish ordinal sequence (numeric order) of characters. (4) A particular assignment of hexadecimal identifiers to graphic elements.

code point. A 1-byte code representing one of 256 potential characters.

coexistence. Two or more systems at different levels (for example, software, service or operational levels) that share resources. Coexistence includes the ability of a system to respond in the following ways to a new function that was introduced on another system with which it shares resources: ignore a new function; terminate gracefully; support a new function.

command and response token (CART). A parameter on WTO, WTOR, MGCRE, and certain TSO/E commands and REXX execs that allows you to link commands and their associated message responses.

command prefix facility (CPF). A z/OS facility that allows the system programmer to define and control subsystem and other command prefixes for use in a sysplex.

complementary metal-oxide semiconductor (CMOS). A technology that combines the electrical properties of positive and negative voltage requirements to use considerably less power than other types of semiconductors.

connection. In TCP/IP, the path between two protocol applications that provides reliable data stream delivery service. In Internet communications, a connection extends from a TCP application on one system to a TCP application on another system.

consistent copy. A copy of data entity (for example, a logical volume) that contains the contents of the entire data entity from a single instant in time.

console group. In z/OS, a group of consoles defined in CNGRPxx, each of whose members can serve as an alternate console in console or hardcopy recovery or as a console to display synchronous messages.

console. That part of a computer used for communication between the operator or user and the computer.

control unit address. The high order bits of the storage control address, used to identify the storage control to the host system.

control unit. Synonymous with device control unit.

conversation. A logical connection between two programs over an LU type 6.2 session that allows them to communicate with each other while processing a transaction.

conversational. Pertaining to a program or a system that carries on a dialog with a terminal user, alternately accepting input and then responding to the input quickly enough for the user to maintain a train of thought.

copy group. One or more copies of a page of paper. Each copy can have modifications, such as text suppression, page position, forms flash, and overlays.

couple data set. A data set that is created through the XCF couple data set format utility and, depending on its designated type, is shared by some or all of the z/OS systems in a sysplex. See also sysplex couple data set.

Coupling Facility. A special logical partition that provides high-speed caching, list processing, and locking functions in a sysplex.

Coupling Facility channel. A high bandwidth fiber optic channel that provides the high-speed connectivity required for data sharing between a coupling facility and the central processor complexes directly attached to it.

coupling services. In a sysplex, the functions of XCF that transfer data and status between members of a group residing on one or more z/OS systems in the sysplex.

cross-system Coupling Facility (XCF). A component of z/OS that provides functions to support cooperation between authorized programs running within a sysplex.

cryptographic key. A parameter that determines cryptographic transformations between plaintext and ciphertext.

cryptography. The transformation of data to conceal its meaning.

Customer Information Control System (CICS). An IBM licensed program that enables transactions entered at remote terminals to be processed concurrently by user-written application programs. It includes facilities for building, using, and maintaining databases.

D

daemon. A program that runs unattended to perform a standard service.

data definition (DD) statement. A job control statement that describes a data set associated with a particular job step.

data definition name. The name of a data definition (DD) statement, which corresponds to a data control block that contains the same name. Abbreviated as ddname.

data in transit. The update data on application system DASD volumes that is being sent to the recovery system for writing to DASD volumes on the recovery system.

data integrity. The condition that exists as long as accidental or intentional destruction, alteration, or loss of data does not occur.

data set label. (1) A collection of information that describes the attributes of a data set and is normally stored on the same volume as the data set. (2) A general term for data set control blocks and tape data set labels.

data set separator pages. Those pages of printed output that delimit data sets.

data set. The major unit of data storage and retrieval, consisting of a collection of data in one of several prescribed arrangements and described by control information to which the system has access.

data sharing. The ability of concurrent subsystems (such as DB2 or IMS DB) or application programs to directly access and change the same data, while maintaining data integrity.

data stream. (1) All information (data and control commands) sent over a data link usually in a single read or write operation. (2) A continuous stream of data elements being transmitted, or intended for transmission, in character or binary-digit form, using a defined format.

DB2 data sharing group. A collection of one or more concurrent DB2 subsystems that directly access and change the same data while maintaining data integrity.

deallocate. To release a resource that is assigned to a specific task.

default. A value, attribute, or option that is assumed when no alternative is specified by the user.

destination node. The node that provides application services to an authorized external user.

device address. The ESA/390 term for the field of an ESCON device-level frame that selects a specific device on a control unit image. The one or two leftmost digits are the address of the channel to which the device is attached. The two rightmost digits represent the unit address.

device control unit. A hardware device that controls the reading, writing, or displaying of data at one or more input/output devices or terminals.

device number. ESA/390 term for a four-hexadecimal-character identifier, for example 13A0, that you associate with a device to facilitate communication between the program and the host operator. The device number that you associate with a subchannel.

Device Support Facilities program (ICKDSF). A program used to initialize DASD at installation and perform media maintenance.

device type. The general name for a kind of device; for example, 3330.

direct access storage device (DASD). A device in which the access time is effectively independent of the location of the data.

directory. (1) A type of file containing the names and controlling information for other files or other directories. Directories can also contain subdirectories, which can contain subdirectories of their own. (2) A file that contains directory entries. No two directory entries in the same directory can have the same name. (POSIX.1). (3) A file that points to files and to other directories. (4) An index used by a control program to locate blocks of data that are stored in separate areas of a data set in direct access storage.

disaster recovery. Recovery after a disaster, such as a fire, that destroys or otherwise disables a system. Disaster recovery techniques typically involve restoring data to a second (recovery) system, then using the recovery system in place of the destroyed or disabled application system. See also recovery, backup, and recovery system.

display console. In z/OS, an MCS console whose input/output function you can control.

DLL filter. A filter that provides one or more of these functions in a dynamic load library - init(), prolog(), process(), epilog(), and term(). See cfilter.h and cfilter.c in the /usr/lpp/Printsrv/samples/ directory for more information. See also filter.

dotted decimal notation. The syntactical representation for a 32-bit integer that consists of four 8-bit numbers written in base 10 with periods (dots) separating them. It is used to represent IP addresses.

double-byte character set (DBCS). A set of characters in which each character is represented by a two-bytes code. Languages such as Japanese, Chinese, and Korean, which contain more symbols than can be represented by 256 code points, require double-byte character sets. Because each character requires two bytes, the typing, display, and printing of DBCS characters requires hardware and programs that support DBCS. Contrast with single-byte character set.

drain. Allowing a printer to complete its current work before stopping the device.

dual copy. A high availability function made possible by the nonvolatile storage in cached IBM storage controls. Dual copy maintains two functionally identical copies of designated DASD volumes in the logical storage subsystem, and automatically updates both copies every time a write operation is issued to the dual copy logical volume.

duplex pair. A volume comprised of two physical devices within the same or different storage subsystems that are defined as a pair by a dual copy, PPRC, or XRC operation, and are in neither suspended nor pending state. The operation records the same data onto each volume.

E

Enterprise Systems Connection (ESCON). A set of products and services that provides a dynamically connected environment using optical cables as a transmission medium.

entry area. In z/OS, the part of a console screen where operators can enter commands or command responses.

ETR. External Time Reference. See also Sysplex Timer®.

extended MCS console. In z/OS, a console other than an MCS console from which operators or programs can issue system commands and receive messages. An extended MCS console is defined through an OPERPARM segment.

extended remote copy (XRC). A hardware- and software-based remote copy service option that provides an asynchronous volume copy across storage subsystems for disaster recovery, device migration, and workload migration.

F

fixed utility volume. A simplex volume assigned by the storage administrator to a logical storage subsystem to serve as working storage for XRC functions on that storage subsystem.

FlashCopy. A point-in-time copy services function that can quickly copy data from a source location to a target location.

floating utility volume. Any volume of a pool of simplex volumes assigned by the storage administrator to a logical storage subsystem to serve as dynamic storage for XRC functions on that storage subsystem.

frame. For a System/390 microprocessor cluster, a frame contains one or two central processor complexes (CPCs), support elements, and AC power distribution.

G

gateway node. A node that is an interface between networks.

generalized trace facility (GTF). Like system trace, gathers information used to determine and diagnose problems that occur during system operation. Unlike system trace, however, GTF can be tailored to record very specific system and user program events.

global access checking. The ability to allow an installation to establish an in-storage table of default values for authorization levels for selected resources.

global resource serialization complex. One or more z/OS systems that use global resource serialization to serialize access to shared resources (such as data sets on shared DASD volumes).

global resource serialization. A function that provides a z/OS serialization mechanism for resources (typically data sets) across multiple z/OS images.

group. A collection of RACF users who can share access authorities for protected resources.

H

hardcopy log. In systems with multiple console support or a graphic console, a permanent record of system activity.

hardware configuration dialog. In z/OS, a panel program that is part of the hardware configuration definition. The program allows an installation to define devices for z/OS system configurations.

Hardware Management Console (HMC). A console used to monitor and control hardware such as the System/390 microprocessors.

hardware. Physical equipment, as opposed to the computer program or method of use; for example, mechanical, magnetic, electrical, or electronic devices. Contrast with software.

highly parallel. Refers to multiple systems operating in parallel, each of which can have multiple processors. See also n-way.

I

image. A single occurrence of the z/OS operating system that has the ability to process work.

IMS DB data sharing group. A collection of one or more concurrent IMS DB subsystems that directly access and change the same data while maintaining data integrity.

initial program load (IPL). The initialization procedure that causes an operating system to begin operation.

instruction line. In z/OS, the part of the console screen that contains messages about console control and input errors.

internal reader. A facility that transfers jobs to the job entry subsystem (JES2 or JES3).

J

JES common coupling services. A set of macro-driven services that provide the communication interface between JES members of a sysplex. Synonymous with JES XCF.

JES2 multi-access spool configuration. A multiple z/OS system environment that consists of two or more JES2 processors sharing the same job queue and spool.

JES2. A z/OS subsystem that receives jobs into the system, converts them to internal format, selects them for execution, processes their output, and purges them from the system. In an installation with more than one processor, each JES2 processor independently controls its job input, scheduling, and output processing.

JES3 complex. A multiple z/OS system environment that allows JES3 subsystem consoles and MCS consoles with a logical association to JES3 to receive messages and send commands across systems.

JES3. A z/OS subsystem that receives jobs into the system, converts them to internal format, selects them for execution, processes their output, and purges them from the system. In complexes that have several loosely-coupled processing units, the JES3 program manages processors so that the global processor exercises centralized control over the local processors and distributes jobs to them via a common job queue.

JES XCF. JES cross-system coupling services. The z/OS component, common to both JES2 and JES3, that provides the cross-system coupling services to either JES2 multi-access spool members or JES3 complex members, respectively.

job entry subsystem (JES). A system facility for spooling, job queuing, and managing the scheduler work area.

job separator pages. Those pages of printed output that delimit jobs.

journal. A checkpoint data set that contains work to be done. For XRC, the work to be done consists of all changed records from the primary volumes. Changed records are collected and formed into a "consistency group", and then the group of updates is applied to the secondary volumes.

K

keyword. A part of a command operand or SYS1.PARMLIB statement that consists of a specific character string (such as NAME= on the CONSOLE statement of CONSOLxx).

L

Licensed Internal Code (LIC)
Microcode that IBM does not sell as part of a machine, but licenses to the customer. LIC is implemented in a part of storage that is not addressable by user programs. Some IBM products use it to implement functions as an alternative to hard-wired circuitry.

link address. On an ESCON interface, the portion of a source, or destination address in a frame that ESCON uses to route a frame through an ESCON director. ESCON associates the link address with a specific switch port that is on the ESCON director. Equivalently, it associates the link address with the channel subsystem or controller link-level functions that are attached to the switch port.

list structure. A Coupling Facility structure that enables multisystem applications in a sysplex to share information organized as a set of lists or queues. A list structure consists of a set of lists and an optional lock table, which can be used for serializing resources in the list structure. Each list consists of a queue of list entries.

lock structure. A Coupling Facility structure that enables applications in a sysplex to implement customized locking protocols for serialization of application-defined resources. The lock structure supports shared, exclusive, and application-defined lock states, as well as generalized contention management and recovery protocols.

logical partition (LPAR). A subset of the processor hardware that is defined to support an operating system. An LPAR contains resources (processors, memory, and input/output devices) and operates as an independent system. If hardware requirements are met, multiple logical partitions can exist within a system.
See also logical partitioned (LPAR) mode.

logical partitioning. A function of an operating system that enables the creation of logical partitions.

logical partition (LPAR) mode. A central processor complex (CPC) Power-on-Reset mode that enables use of the PR/SM feature and allows an operator to allocate CPC hardware resources (including central processors, central storage, expanded storage, and channel paths) among logical partitions. Contrast with basic mode..

logical subsystem. The logical functions of a storage controller that allow one or more host I/O interfaces to access a set of devices. The controller aggregates the devices according to the addressing mechanisms of the associated I/O interfaces. One or more logical subsystems exist on a storage controller. In general, the controller associates a given set of devices with only one logical subsystem.

logical unit (LU). In SNA, a port through which an end user accesses the SNA network in order to communicate with another end user, and through which the end user accesses the functions provided by system services control points (SSCPs).

logical unit type 6.2. The SNA logical unit type that supports general communication between programs in a cooperative processing environment.

loosely coupled. A multisystem structure that requires a low degree of interaction and cooperation between multiple z/OS images to process a workload. See also tightly coupled.

master console authority. In a system or sysplex, a console defined with AUTH(MASTER) other than the master console from which all z/OS commands can be entered.

master console. In a z/OS system or sysplex, the main console used for communication between the operator and the system from which all z/OS commands can be entered. The first active console with AUTH(MASTER) defined becomes the master console in a system or sysplex.

master trace. A centralized data tracing facility of the master scheduler, used in servicing the message processing portions of z/OS.

MCS console. A non-SNA device defined to z/OS that is locally attached to a z/OS system and is used to enter commands and receive messages.

member. A specific function (one or more modules/routines) of a multisystem application that is defined to XCF and assigned to a group by the multisystem application. A member resides on one system in the sysplex and can use XCF services to communicate (send and receive data) with other members of the same group.

message processing facility (MPF). A facility used to control message retention, suppression, and presentation.

message queue. A queue of messages that are waiting to be processed or waiting to be sent to a terminal.

message text. The part of a message consisting of the actual information that is routed to a user at a terminal or to a program.

microprocessor. A processor implemented on one or a small number of chips.

mixed complex. A global resource serialization complex in which one or more of the systems in the global resource serialization complex are not part of a multisystem sysplex.

multi-access spool (MAS). A complex of multiple processors running z/OS and JES2 that share a common JES2 spool and JES2 checkpoint data set.

multiple console support (MCS). The operator interface in a z/OS system.

multiprocessing. The simultaneous execution of two or more computer programs or sequences of instructions. See also parallel processing.

multiprocessor (MP). A CPC that can be physically partitioned to form two operating processor complexes.

multisystem application. An application program that has various functions distributed across z/OS images in a multisystem environment.

multisystem console support. Multiple console support for more than one system in a sysplex. Multisystem console support allows consoles on different systems in the sysplex to communicate with each other (send messages and receive commands)

multisystem environment. An environment in which two or more z/OS images reside in one or more processors, and programs on one image can communicate with programs on the other images.

multisystem sysplex. A sysplex in which two or more z/OS images are allowed to be initialized as part of the sysplex.

N

Network File System. A component of z/OS that allows remote access to z/OS host processor data from workstations, personal computers, or any other system on a TCP/IP network that is using client software for the Network File System protocol.

nonstandard labels. Labels that do not conform to American National Standard or IBM System/370 standard label conventions.

nucleus initialization program (NIP). The stage of z/OS that initializes the control program; it allows the operator to request last minute changes to certain options specified during initialization.

n-way. The number (n) of CPs in a CPC. For example, a 6-way CPC contains six CPs.

O

offline. Pertaining to equipment or devices not under control of the processor.

online. Pertaining to equipment or devices under control of the processor.

operating system (OS). Software that controls the execution of programs and that may provide services such as resource allocation, scheduling, input/output control, and data management. Although operating systems are predominantly software, partial hardware implementations are possible.

operations log. In z/OS, the operations log is a central record of communications and system problems for each system in a sysplex.

orphan data. Data that occurs between the last, safe backup for a recovery system and the time when the application system experiences a disaster. This data is lost when either the application system becomes available for use, or when the recovery system is used in place of the application system.

P

parallel processing. The simultaneous processing of units of work by many servers. The units of work can be either transactions or subdivisions of large units of work (batch). See also highly parallel.

Parallel Sysplex. A sysplex that uses one or more coupling facilities.

partitionable CPC. A CPC that can be divided into two independent CPCs. See also physical partition, single-image mode, MP, side.

partitioned data set (PDS). A data set on direct access storage that is divided into partitions, called members, each of which can contain a program, part of a program, or data.

partitioned data set extended (PDSE). A system-managed data set that contains an indexed directory and members that are similar to the directory and members of partitioned data sets. A PDSE can be used instead of a partitioned data set.

password. A unique string of characters known to a computer system and to a user, who must specify the character string to gain access to a system and to the information stored within it.

peer-to-peer remote copy. A hardware-based remote copy option that provides a synchronous volume copy across storage subsystems for disaster recovery, device migration, and workload migration.

permanent data set. A user-named data set that is normally retained for longer than the duration of a job or interactive session. Contrast with temporary data set.

PFK capability. On a display console, indicates that program function keys are supported and were specified at system generation.

physical partition. Part of a CPC that operates as a CPC in its own right, with its own copy of the operating system.

physically partitioned (PP) configuration. A system configuration that allows the processor controller to use both central processor complex (CPC) sides as individual CPCs. The A-side of the processor controller controls side 0; the B-side of the processor controller controls side 1. Contrast with single-image (SI) configuration.

primary device. One device of a dual copy or remote copy volume pair. All channel commands to the copy logical volume are directed to the primary device. The data on the primary device is duplicated on the secondary device. See also secondary device.

Print Services Facility™ (PSF). The access method that supports the 3800 Printing Subsystem Models 3 and 8. PSF can interface either directly to a user's application program or indirectly through the job entry subsystem (JES) of z/OS.

printer. A device that writes output data from a system on paper or other media.

processor controller. Hardware that provides support and diagnostic functions for the central processors.

Processor Resource/Systems Manager™ (PR/SM). The feature that allows the processor to use several z/OS images simultaneously and provides logical partitioning capability. See also LPAR.

profile. Data that describes the significant characteristics of a user, a group of users, or one or more computer resources.

program function key (PFK). A key on the keyboard of a display device that passes a signal to a program to call for a particular program operation.

program status word (PSW). A doubleword in main storage used to control the order in which instructions are executed, and to hold and indicate the status of the computing system in relation to a particular program.

R

read access. Permission to read information.

recording format. For a tape volume, the format of the data on the tape, for example, 18, 36, 128, or 256 tracks.

recovery system. A system that is used in place of a primary application system that is no longer available for use. Data from the application system must be available for use on the recovery system. This is usually accomplished through backup and recovery techniques, or through various DASD copying techniques, such as remote copy.

recovery. The process of rebuilding data after it has been damaged or destroyed, often by using a backup copy of the data or by reapplying transactions recorded in a log.

redundant array of independent disk (RAID). A disk subsystem architecture that combines two or more physical disk storage devices into a single logical device to achieve data redundancy.

remote copy. A storage-based disaster recovery and workload migration function that can copy data in real time to a remote location. Two options of remote copy are available. See peer-to-peer remote copy and extended remote copy.

remote operations. Operation of remote sites from a host system.

Resource Access Control Facility (RACF). A security manager for z/OS that provides for access control by identifying and verifying the users to the system, authorizing access to protected resources, logging the detected unauthorized attempts to enter the system and logging the detected accesses to protected resources.

restructured extended executor (REXX). A general-purpose, procedural language for end-user personal programming, designed for ease by both casual general users and computer professionals. It is also useful for application macros. REXX includes the capability of issuing commands to the underlying operating system from these macros and procedures. Features include powerful character-string manipulation, automatic data typing, manipulation of objects familiar to people, such as words, numbers, and names, and built-in interactive debugging.

resynchronization. A track image copy from the primary volume to the secondary volume of only the tracks which have changed since the volume was last in duplex mode.

routing code. A code assigned to an operator message and used to route the message to the proper console.

routing. The assignment of the communications path by which a message will reach its destination.

S

secondary device. One of the devices in a dual copy or remote copy logical volume pair that contains a duplicate of the data on the primary device. Unlike the primary device, the secondary device may only accept a limited subset of channel commands.

shared DASD option. An option that enables independently operating computing systems to jointly use common data residing on shared direct access storage devices.

side. A part of a partitionable CPC that can run as a physical partition and is typically referred to as the A-side or the B-side.

single point of control. The characteristic a sysplex displays when you can accomplish a given set of tasks from a single workstation, even if you need multiple IBM and vendor products to accomplish that particular set of tasks.

single system image. The characteristic a product displays when multiple images of the product can be viewed and managed as one image.

single-image (SI) mode. A mode of operation for a multiprocessor (MP) system that allows it to function as one CPC. By definition, a uniprocessor (UP) operates in single-image mode. Contrast with physically partitioned (PP) configuration.

single-system sysplex. A sysplex in which only one z/OS system is allowed to be initialized as part of the sysplex. In a single-system sysplex, XCF provides XCF services on the system but does not provide signalling services between z/OS systems. See also multisystem sysplex.

small computer system interface (SCSI). A standard hardware interface that enables a variety of peripheral devices to communicate with one another.

software. (1) All or part of the programs, procedures, rules, and associated documentation of a data processing system. (2) A set of programs, procedures, and, possibly, associated documentation concerned with the operation of a data processing system. For example, compilers, library routines, manuals, circuit diagrams. Contrast with hardware.

status-display console. An MCS console that can receive displays of system status but from which an operator cannot enter commands.

storage administrator. A person in the data processing center who is responsible for defining, implementing, and maintaining storage management policies.

storage class. A collection of storage attributes that identify performance goals and availability requirements, defined by the storage administrator, used to select a device that can meet those goals and requirements.

storage group. A collection of storage volumes and attributes, defined the storage administrator. The collections can be a group of DASD volume or tape volumes, or a group of DASD, optical, or tape volumes treated as single object storage hierarchy.

Storage Management Subsystem (SMS). A facility used to automate and centralize the management of storage. Using SMS, a storage administrator describes data allocation characteristics, performance and availability goals, backup and retention requirements, and storage requirements to the system through data class, storage class, management class, storage group, and ACS routine definitions.

storage management. The activities of data set allocation, placement, monitoring, migration, backup, recall, recovery, and deletion. These can be done either manually or by using automated processes. cThe Storage Management Subsystem automates these processes for you, while optimizing storage resources. See also Storage Management Subsystem.

storage subsystem. A storage control and its attached storage devices.

structure. A construct used by z/OS to map and manage storage on a Coupling Facility. See cache structure, list structure, and lock structure.

subsystem interface (SSI). A component that provides communication between z/OS and its job entry subsystem.

supervisor call instruction (SVC). An instruction that interrupts a program being executed and passes control to the supervisor so that it can perform a specific service indicated by the instruction.

support element. A hardware unit that provides communications, monitoring, and diagnostic functions to a central processor complex (CPC).

suspended state. When only one of the devices in a dual copy or remote copy volume pair is being updated because of either a permanent error condition or an authorized user command. All writes to the remaining functional device are logged. This allows for automatic resynchronization of both volumes when the volume pair is reset to the active duplex state.

SVC routine. A control program routine that performs or begins a control program service specified by a supervisor call instruction.

symmetry. The characteristic of a sysplex where all systems, or certain subsets of the systems, have the same hardware and software configurations and share the same resources.

synchronization. An initial volume copy. This is a track image copy of each primary track on the volume to the secondary volume.

synchronous messages. WTO or WTOR messages issued by a z/OS system during certain recovery situations.

synchronous operation. A type of operation in which the remote copy PPRC function copies updates to the secondary volume of a PPRC pair at the same time that the primary volume is updated. Contrast with asynchronous operation.

sysplex couple data set. A couple data set that contains sysplex-wide data about systems, groups, and members that use XCF services. All z/OS systems in a sysplex must have connectivity to the sysplex couple data set. See also couple data set.

Sysplex Timer. An IBM unit that synchronizes the time-of-day (TOD) clocks in multiple processors or processor sides.

sysplex. A set of z/OS systems communicating and cooperating with each other through certain multisystem hardware components and software services to process customer workloads. See also Parallel Sysplex.

system. A z/OS image together with its associated hardware, which collectively are often referred to simply as a system, or z/OS system.

system console. In z/OS, a console attached to the processor controller used to initialize a z/OS system.

system control element (SCE). Hardware that handles the transfer of data and control information associated with storage requests between the elements of the processor.

system management facility (SMF). An optional control program feature of z/OS that provides the means for gathering and recording information that can be used to evaluate system usage.

System Modification Program Extended (SMP/E). In addition to providing the services of SMP, SMP/E consolidates installation data, allows more flexibility in selecting changes to be installed, provides a dialog interface, and supports dynamic allocation of data sets.

Systems Network Architecture (SNA). A description of the logical structure, formats, protocols, and operational sequences for transmitting information units through, and controlling the configuration and operation of networks.

T

temporary data set. A data set that is created and deleted in the same job.

terminal user. In systems with time-sharing, anyone who is eligible to log on.

terminal. A device, usually equipped with a keyboard and some kind of display, capable of sending and receiving information over a link.

tightly coupled multiprocessor. Any CPU with multiple CPs.

tightly coupled. Multiple CPs that share storage and are controlled by a single copy of z/OS. See also loosely coupled, tightly coupled multiprocessor.

Time Sharing Option (TSO). The facility in z/OS that allows interactive time sharing from remote terminals.

timeout. The time in seconds that the storage control remains in a "long busy" condition before physical sessions are ended.

transaction. A unit of work performed by one or more transaction programs, involving a specific set of input data and initiating a specific process or job.

U

uniprocessor (UP). A CPC that contains one CP and is not partitionable.

V

Virtual Storage Access Method (VSAM). An access method for direct or sequential processing of fixed-length and varying-length records on direct access devices. The records in a VSAM data set or file can be organized in logical sequence by a key field (key sequence), in the physical sequence in which they are written on the data set or file (entry-sequence), or by relative-record number.

virtual storage. (1) The storage space that can be regarded as addressable main storage by the user of a computer system in which virtual addresses are mapped into real addresses. The size of virtual storage is limited by the addressing scheme of the computer system and by the amount of auxiliary storage available, not by the actual number of main storage locations. See also storage. (2) An addressing scheme that allows external disk storage to appear as main storage.

virtual telecommunications access method (VTAM). A set of programs that maintain control of the communication between terminals and application programs running under z/OS.

volume serial number. A number in a volume label that is assigned when a volume is prepared for use in the system.

volume table of contents (VTOC). An area on a DASD volume that describes the location, size, and other characteristics of each data set on the volume.

volume. (1) That portion of a single unit of storage which is accessible to a single read/write mechanism, for example, a drum, a disk pack, or part of a disk storage module. (2) A recording medium that is mounted and demounted as a unit, for example, a reel of magnetic tape, a disk pack, a data cell.

W

wait state. Synonymous with waiting time.

waiting time. (1) The condition of a task that depends on one or more events in order to enter the ready condition. (2) The condition of a processing unit when all operations are suspended.

wrap mode. The console display mode that allows a separator line between old and new messages to move down a full screen as new messages are added. When the screen is filled and a new message is added, the separator line overlays the oldest message and the newest message appears immediately before the line.

write-to-operator (WTO) message. A message sent to an operator console informing the operator of errors and system conditions that may need correcting.

write-to-operator-with-reply (WTOR) message. A message sent to an operator console informing the operator of errors and system conditions that may need correcting. The operator must enter a response.

z

z/OS. A widely used operating system for the IBM zSeries mainframe computers that uses 64-bit real storage.

z/OS UNIX System Services (z/OS UNIX). The set of functions provided by the SHELL and UTILITIES, kernel, debugger, file system, C/C++ Run-Time Library, Language Environment, and other elements of the z/OS operating system that allow users to write and run application programs that conform to UNIX standards.

Abbreviations and acronyms

ABEND	abnormal end
ACB	application control block
ACID	atomicity-consistency-isolation -durability
ALU	Arithmetic/Logical Unit
AMI	Application Messaging Interface
AMS	Access Method Services
ANSI	American National Standards Institute
AOR	application-owning region
APF	authorized program facility
API	Application Programming Interface
APPC	Advanced Program-to-Program Communications
APPN	Advanced Peer-to-Peer Network
ARM	Automatic Restart Manager
ASCII	American National Standard Code for Information Interchange
ASID	address space ID
BCD	binary-coded decimal notation
BCP	base control program
BDAM	basic direct access method
BIOS	Basic Input Output System
BIU	Basic Information Unit
BLKSIZE	Block Size
BLOB	Binary Large Object
BLU	Basic Link Unit
BMP	batch message processing
BMS	basic mapping support
BOM	Bill of Material
BPAM	basic partitioned access method
BSAM	basic sequential access method
BSC	bisynchronous control
BSDS	bootstrap data set
BTU	Basic Transmission Unit
CCF	controller configuration facility
CDB	communications database
CDLC	Channel Data Link Control
CDRM	cross-domain resource manager
CDSA	Common Data Security Architecture
CE	Customer Engineer
CEC	Central Electronic Complex
CESD	composite external symbol dictionary
CF	Coupling Facility
CGI	Common Gateway Interface
CHPID	Channel Path Identifier
CI	control interval
CICS	Customer Information Control System
CIDF	control interval definition field
CKD	Count Key Data
CLAW	common link access to workstation
CLIST	command list
CLOB	Character Large Object
CLPA	create link pack area
CMOS	Complementary Metal Oxide Semiconductor
CMS	Conversational Monitor System
COBOL	Common Business Oriented Language

CORBA	Common Object Request Broker Architecture
CP	central processor
CPC	central processor complex
CPI	Common Programming Interface
CPI-C	Common Programming Interface for Communications
CPU	central processing unit
CQSAS	Common Queue Server Address Space
CR	Controller Region
CR+LF	carriage return and line feed
CS	central storage
CSA	common storage area
CSD	CICS system definition
CSI	Consolidated Software Index
CSM	Communication Storage Manager
CSS	Channel SubSystem
CTC	channel-to-channel
CTG	CICS Transaction Gateway
CWS	CICS Web support
CYL	cylinders
DASD	direct access storage device
DAT	dynamic address translation
DB/DC	database/data communication
DBA	database administrator
DBAS	Database Services Address Space
DBCLOB	Double Byte Character Large Object
DBCS	Double Byte Character Set
DBMS	database management system
DBRC	Database Recovery Control
DBRM	database request module
DBT	DBCTL Thread
DCA	Document Content Architecture
DCB	data control block
DCC	data country code
DCCTL	Data Communications Control
DCE	Distributed Computing Environment
DCLGEN	declarations generator
DD	data definition
DDF	distributed data facility
DDL	data definition language
DEDB	data entry database
DFS™	Distributed File Service
DFSMS	Data Facility Storage Management Subsystem
DISP	disposition
DL/I	Data Language/I
DLC	Data Link Control
DLIB	distribution library
DLISAS	DL/I separate address space
DLL	dynamic link library
DLQ	dead-letter queue
DM	database manager
DML	data manipulation language
DNS	Domain Name System
DOS	Disk Operating System
DOS/VS	Disk Operating System / Virtual Storage
DRDA	Distributed Relational Database Architecture
DSECT	dummy control section
DSMON	data security monitor
DSORG	data set organization
DUW	distributed unit of work
EBCDIC	extended binary coded decimal interchange code
EIM	Enterprise Identity Mapping
EIS	Enterprise Information Systems

EJB	Enterprise Java Beans
EMH	Expedited Message Handling
EPI	external presentation interface
ESA	Enterprise Systems Architecture
ESCON	Enterprise Systems CONnection
ESDS	Entry Sequence Data Set
ESQA	Extended System Queue Area
EXCI	external CICS interface
EXCP	Execute Channel Program
FB	Fixed Blocked
FBA	Fixed-block-architecture
FCP	Fibre Channel Protocol
FICON	FIber CONnection
FLPA	fixed link pack area
FPU	Fast Path utility
FRCA	Fast Response Cache Accelerator
FSP	Flexible Support Processor
FTAM	file transfer, access, and management
FTP	File Transfer Protocol
GB	gigabyte
GDG	generation data group
GDPS	Geographically Dispersed Parallel Sysplex
GMT	Greenwich Mean Time
GRS	General Resource Sharing
GSAM	Generalized Sequential Access Method
GSS-API	Generic Security Service Application Programming Interface
GUI	graphical user interface
GWAPI	Go Webserver API
HCD	Hardware Configuration Definition
HDA	Head Disk Assembly
HFS	hierarchical file system
HISAM	Hierarchical Indexed Sequential Access Method
HLL	high-level language
HLQ	high-level qualifier
HMC	Hardware Management Console
HPR	high-performance routing
HSA	Hardware Save Area
HSAM	Hierarchical Sequential Access Method
HSSP	high-speed sequential processing
HTML	HyperText Markup Language
HTTP	hypertext transfer protocol
HTTPS	HyperText Transfer Protocol Secure
HTTPS/SSL	HyperText Transfer Protocol/Secure Sockets Layer
HV	host variable
I/O	Input/Output
ICF	Integrated Coupling Facility
ICKDSF	Device Support Facilities utility
IDE	Interactive Development Environment
IFL	Integrated Facility for Linux
IFP	IMS Fast Path
IIOP	Internet Inter-ORB Protocol
ILC	Inter-Language Communication
IMS	Information Management System
IMSI	initialization message suppression indicator
IOCDS	I/O Configuration Data Set
IODF	I/O definition file
IP	Internet Protocol
IPL	initial program load

IRD	Intelligent Resource Director
IRLM	Internal Resource Lock Manager
ISO	International Standards Organization
ISO/IEC	International Organization for Standardization/International Electrotechnical Commission
ISPF	Interactive System Productivity Facility
ISV	independent software vendor
ITOC	IMS TCP/IP OTMA Connector
JCA	Java Cryptography Architecture
JCK	Java Certification Kit
JCL	job control language
JDBC	Java Database Connectivity
JES	job entry subsystem
JMS	Java Message Service
JMX	Java Machine Extension
JNI	Java Native Interface
JSP	Java Server Page
JVM	Java Virtual Machine
KB	kilobyte
KSDS	Key Sequence Data Set
LAN	local area network
LCS	LAN channel station
LCSS	logical channel subsystem
LDAP	Lightweight Data Access Protocol
LDS	Linear Data Set
LFS	logical file system
LLA	library lookaside
LP	logical partition
LPA	link pack area
LPAR	logical partition
LRECL	logical record length
LSQA	Local SQA
LU	logical unit
LUW	logical unit of work
MB	megabyte
MCA	message channel agent
MCM	Multiple Chip Modules
MCP	Message Channel Protocol
MCS	multiple console support
MFT	Multiprogramming with a Fixed Number of Tasks
MIB	Management Information Base
MLPA	modified link pack area
MPC	multi-path channel
MPP	message processing program
MPR	message processing region
MQ	Message Queue
MQI	Message Queue Interface
MRO	multi-region operation
MSDB	main storage database
MTBF	mean time between failures
MVS	Multiple Virtual Storage
MVT	Multiprogramming with a Variable Number of Tasks
NAU	network addressable unit
NCP	Network Control Program
NFS	net work file system
NIP	nucleus initialization program
NL	new line
OCEP	Open Cryptographic Enhanced Plug-ins
OCSF	Open Cryptographic Services Facility
ODBC	Open Database Connectivity
OEM	original equipment manufacturer
OLTP	online transaction processing
OO	object oriented

OS	operating system
OSA	Open Systems Adapter
OSF	Open Software Foundation
OSI	Open Systems Interconnect
OTMA	Open Transaction Manager Access
PC	program call
PCB	Program Communication Block
PCF	programmable command format
PCHID	Physical Channel ID
PCI	Peripheral Component Interconnect
PCP	program control program
PDF	Portable Document Format
PDS	partitioned data set
PDSE	partitioned data set extended
PF	program function
PFS	physical file system
PGID	process group identifier
PI	Performance Index
PID	process identifier
PIU	Path Information Unit
PK	primary key
PKI	public key infrastructure
PL/I	Programming Language/I
PLPA	pageable link pack area
PMI	Performance Monitoring Infrastructure
POR	power-on reset
PPID	parent process ID
PPRC	peer-to-peer remote copy
PR/SM	Processor Resource/Systems Manager
PSA	Prefixed Save Area
PSB	program specification block
PSW	program status word
PTF	Product Temporary Fix
PTS	PTF Temporary Storage
PU	physical unit
PWS	programmable workstation
QM	queue manager
QMF	Query Management Facility
QSAM	queued sequential access method
RACF	Resource Access Control Facility
RAID	redundant array of independent disks
RAS	reliability, availability, serviceability
RC	return code
RCT	resource control table
RDBMS	relational database management system
RDF	record descriptor fields
RDMS	remote database management system
RDO	resource definition online
RDW	record descriptor word
RECFM	record format
RECON	recovery control data set
REXX	Restructured Extended Executor Lanaguage
RFC	request for comment
RH	response header
RH-RU	response header - response unit
RISC	reduced instruction set computer
RLD	relocation dictionary
RMF	Resource Measurement Facility
RMODE	residency mode
RPC	remote procedure call
RPG	Report Program Generator
RRDS	Relative Record Data Set

RRS	Resource Recovery Services
RRSF	RACF Remote Sharing Facility
RTLS	Run-time Library Services
RTM	recovery termination management
RU	response unit
SAF	security access facility
SAN	Storage Area Network
SAP	System Assistance Processor
SC	Service Class
SCLM	Software Configuration Library Manager
SCP	system control program
SCSI	small computer system interface
SD	Sysplex Distributor
SDK	Software Development Kit
SDLC	synchronous data link control
SDSF	System Display and Search Facility
SE	Support Element
SFM	Sysplex Failure Manager
SHSAM	Simple Hierarchical Sequential Access Method
SIGP	Signal Processor
SLA	service level agreement
SMF	system management facility
SMP	System Modification Program
SMP/E	System Modification Program/Extended
SMS	Storage Management Subsystem
SNA	Systems Network Architecture
SNI	SNA Network Interconnect
SNMP	Simple Network Management Protocol
SP	System Product
SPI	System Product Interpreter
SPUFI	SQL Processing Using File Input
SQA	System Queue Area
SQL	Structured Query Language
SQLJ	Structured Query Language Java
SR	Servant Region
SRB	service request block
SRM	system resource manager
SS	start-stop
SSA	segment search argument
SSAS	System Services Address Space
SSCP	System Services Control Point
SSI	Server Side Includes
SSL	Secure Socket Layer
SVC	supervisor call
SVS	Single Virtual Storage
TCO	total cost of ownership
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TD	Transient Data
TG	Transaction Gateway
TH	transmission header
TLS	thread local storage
TM	transaction manager
TOD	time-of-day
TOR	terminal owning region
TPF	Transaction Processing Facility
TPS	transactions per second
TS	table space
TSO	Time Sharing Option
TSO/E	Time Sharing Option/Extensions
TT	Information Technology
UACC	universal access authority
UCB	Unit Control Block

UDB	universal database
UDF	user-defined function
UDP	User Datagram Protocol
UDT	user-defined data type
UID	user ID
UPS	uninterruptable power system
UR	unit of recovery
URL	Uniform Resource Locator
USD	US dollar
VB	variable blocked
VIO	virtual input output
VLF	virtual lookaside facility
VM	Virtual Machine
VM/ESA®	Virtual Machine/Enterprise Systems Architecture
VM/SP	Virtual Machine/System Product
VM/XA	Virtual Machine/Extended Architecture
VPN	virtual private network
VSAM	Virtual Storage Access Method
VSE	Virtual Storage Extended
VTAM	virtual telecommunications access method
VTOC	volume table of contents
WAP	wireless access point
WLM	Workload Manager
WTOR	write to operator with reply
XA	Extended Architecture
XCF	cross-system coupling facility
XML	Extensible Markup Language
XMLCLOB	XML character large object
XRC	extended remote copy

Index

D

E

T

IBM

An Introduction to the Mainframe: z/OS Basics

(1.0” spine)
0.875”<->1.498”
460 <-> 788 pages

Notices

This information was developed for products and services offered in the U.S.A.

IBM may not offer the products, services, or features discussed in this document in other countries. Consult your local IBM representative for information on the products and services currently available in your area. Any reference to an IBM product, program, or service is not intended to state or imply that only that IBM product, program, or service may be used. Any functionally equivalent product, program, or service that does not infringe any IBM intellectual property right may be used instead. However, it is the user's responsibility to evaluate and verify the operation of any non-IBM product, program, or service.

IBM may have patents or pending patent applications covering subject matter described in this document. The furnishing of this document does not give you any license to these patents. You can send license inquiries, in writing, to:
IBM Director of Licensing, IBM Corporation, North Castle Drive Armonk, NY 10504-1785 U.S.A.

The following paragraph does not apply to the United Kingdom or any other country where such provisions are inconsistent with local law: INTERNATIONAL BUSINESS MACHINES CORPORATION PROVIDES THIS PUBLICATION "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Some states do not allow disclaimer of express or implied warranties in certain transactions, therefore, this statement may not apply to you.

This information could include technical inaccuracies or typographical errors. Changes are periodically made to the information herein; these changes will be incorporated in new editions of the publication. IBM may make improvements and/or changes in the product(s) and/or the program(s) described in this publication at any time without notice.

Any references in this information to non-IBM Web sites are provided for convenience only and do not in any manner serve as an endorsement of those Web sites. The materials at those Web sites are not part of the materials for this IBM product and use of those Web sites is at your own risk.

IBM may use or distribute any of the information you supply in any way it believes appropriate without incurring any obligation to you.

Information concerning non-IBM products was obtained from the suppliers of those products, their published announcements or other publicly available sources. IBM has not tested those products and cannot confirm the accuracy of performance, compatibility or any other claims related to non-IBM products. Questions on the capabilities of non-IBM products should be addressed to the suppliers of those products.

This information contains examples of data and reports used in daily business operations. To illustrate them as completely as possible, the examples include the names of individuals, companies, brands, and products. All of these names are fictitious and any similarity to the names and addresses used by an actual business enterprise is entirely coincidental.

COPYRIGHT LICENSE:
This information contains sample application programs in source language, which illustrates programming techniques on various operating platforms. You may copy, modify, and distribute these sample programs in any form without payment to IBM, for the purposes of developing, using, marketing or distributing application programs conforming to the application programming interface for the operating platform for which the sample programs are written. These examples have not been thoroughly tested under all conditions. IBM, therefore, cannot guarantee or imply reliability, serviceability, or function of these programs. You may copy, modify, and distribute these sample programs in any form without payment to IBM for the purposes of developing, using, marketing, or distributing application programs conforming to IBM's application programming interfaces.

Trademarks

The following terms are trademarks of the International Business Machines Corporation in the United States, other countries, or both:

- Redbooks (logo) ™
- eServer™
- z/Architecture™
- z/OS®
- z/VM®
- zSeries®
- Advanced Peer-to-Peer Networking®
- AD/Cycle®
- AIX®
- C/370™
- CICS®
- Domino®
- DB2®
- DFS™
- DFSMSdfp™
- DFSMSdss™
- DFSMShsm™
- DFSORT™
- DRDA®
- Encina®
- Enterprise Storage Server®
- Enterprise Systems Architecture/370™
- Enterprise Systems Architecture/390®
- ECKD™
- ESCON®
- FlashCopy®
- FICON®
- Geographically Dispersed Parallel Sysplex™
- GDDM®
- GDPS®
- HiperSockets™
- Infoprint®
- IBM®
- IMS™
- IMS/ESA®
- Language Environment®
- Lotus®
- Monday™
- Multiprise®
- MVS™
- MVS/XA™
- NetRexx™
- NetView®
- Open Class®
- OS/390®
- Parallel Sysplex®
- Print Services Facility™
- Processor Resource/Systems Manager™
- PR/SM™
- QMF™
- Redbooks™
- RACF®
- RMF™
- S/360™
- S/370™
- S/390®
- Sysplex Timer®
- System/360™
- System/370™
- System/390®
- SAA®
- SOM®
- ThinkPad®
- Tivoli®
- VisualAge®
- VM/ESA®
- VSE/ESA™
- VTAM®
- WebSphere®

The following terms are trademarks of other companies:

Java and all Java-based trademarks and logos are trademarks or registered trademarks of Sun Microsystems, Inc. in the United States, other countries, or both.

Microsoft, Windows, and the Windows logo are trademarks of Microsoft Corporation in the United States, other countries, or both.

Intel is a trademark of Intel Corporation in the United States, other countries, or both.

UNIX is a registered trademark of The Open Group in the United States and other countries.

Linux is a trademark of Linus Torvalds in the United States, other countries, or both.

Other company, product, and service names may be trademarks or service marks of others.

An Introduction to the Mainframe: z/OS Basics

This text provides technical educational material for zSeries and z/OS, suitable for university, IBM, or other educational environments. Related material includes an instructor guide with additional material, and a set of instructor slides.

INTERNATIONAL TECHNICAL SUPPORT ORGANIZATION

BUILDING TECHNICAL INFORMATION BASED ON PRACTICAL EXPERIENCE

IBM textbooks are developed by the IBM International Technical Support Organization. Experts from IBM, Customers and Partners from around the world create textbooks for college students.

For more information:
ibm.com/redbooks

SG24-6366-00 ISBN