These slides are based in part on materials provided by IBM’s Academic Initiative.
Today

- z/OS: Introduction to the most widely used mainframe OS
- Interacting with z/OS (TSO, ISPF, UNIX)
z/OS Fundamentals

- Multiprogramming (many programs) and Multiprocessing (many processors) capable
- OS 360 / MVS heritage
- UNIX support (POSIX 1003.2)
- 64-bit operating system
z/OS overview

- Applications
- Shell and Utilities
- DFSMS
  - HFS
  - NFS
- Language Environment for z/OS
- z/OS UNIX Kernel
  - Process Management
  - File Systems
  - Communications Daemons
  - z/OS Base
- C / C++ for z/OS Compiler
- DBX Debugger
- zFS
- Assembler and REXX Interface
# z/OS vs. UNIX

Quite a few concepts are common to both, but have different names:

<table>
<thead>
<tr>
<th>UNIX</th>
<th>z/OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>boot</td>
<td>IPL</td>
</tr>
<tr>
<td>Files</td>
<td>data sets</td>
</tr>
<tr>
<td>vi, ed, sed</td>
<td>ISPF/oedit</td>
</tr>
<tr>
<td>telnet login</td>
<td>TSO logon</td>
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</table>
## z/OS vs. UNIX

Quite a few execution-related concepts have close relatives:

<table>
<thead>
<tr>
<th>UNIX</th>
<th>z/OS</th>
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<tbody>
<tr>
<td>Process</td>
<td>Address Space</td>
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<tr>
<td>PID</td>
<td>ASID</td>
</tr>
<tr>
<td>Thread</td>
<td>Task</td>
</tr>
<tr>
<td>pthread_t</td>
<td>TCB/SRB</td>
</tr>
</tbody>
</table>
LOGON

• Use x3270 with zos.kctr.marist.edu:1023
• Specify “L TSO” (for now)
• Then use your username and password
• ISPF will automatically start (exit using F3)
• Use LOGOFF to log off (from TSO)
TSO Logon Procedures

On the LOGON screen, you can select a logon procedure.

**IKJACCNT** Minimal initialization; Marist default (only one for us)

**ISPFPROC** z/OS default providing ISPF panels for RACF, SDSF, SMP/E, HCD and ISMF

**OMVSPROC** Starts OMVS Shell directly

**DBSPROC** ISPFPROC plus DB2 and QMF panels
Interacting with z/OS

- Time Sharing Option/Extensions (TSO/E): allows users to logon and use a limited set of basic commands; this is sometimes called using TSO in its *native mode*

- Interactive System Productivity Facility (ISPF): menu-driven interface for TSO used by most users

- UNIX shell: omvs is the z/OS UNIX shell
TSO in native mode

- TSO prompts the user with the string “READY”
- You can start EXEC scripts using “EXEC”
- You can start ISPF using “ispf”
- You can start OMVS using “omvs”
- You can LOGOFF using “logoff”
- More on TSO and ISPF later!
Starting a UNIX shell

- From TSO: type “omvs”
- From ISPF: select option “6”, then enter “omvs”
- Directly: telnet zos.kctr.marist.edu (use your usual username and password)

⇒ Welcome back to the world of COMP 2400...

- Return to ISPF/TSO using “exit”
z/OS Design Goals

- Serving 1000s of users concurrently
- I/O intensive computing
- Processing very large workloads
- Running mission critical applications securely
Key z/OS features

- Can process a large number of concurrent batch jobs, with automatic workload balancing.
- Can manage mixed workloads.
- Provides extensive recovery facilities, making unplanned system restarts very rare.
- Can manage large I/O configurations of 1000s of disk drives, automated tape libraries, large printers, networks of terminals, etc.
Hardware resources managed by z/OS

Mainframe computer
(CPU, processor storage)

z/OS running here...

... Director links mainframes with DASD controllers

Disk storage
(DASD volumes)

DASD controller

Tape drive
Tape cartridges

System Console
(hardware)

Master Console
(z/OS)

Operator Console
(z/OS)
Virtual storage

- z/OS knows three kinds of storage (memory!): real storage, auxiliary storage and virtual storage
- Virtual storage is created through z/OS management of real storage and auxiliary storage through tables
- The running portions of a program are kept in real storage; the rest is kept in auxiliary storage
Address spaces

• An *address space* is the range of addressable virtual storage to a user or program or operating system.

• Each user (or separately running program) is represented by an address space; each user gets a limited amount of “private” storage.

• There is at least one address space per job.

• There can be multiple tasks (TCBs & SRBs) per AS.
Historical Artefacts

- 64-bit addressing (z/OS) – 16 EB
- 31-bit addressing (MVS/XA) – 2 GB
- 24-bit addressing (MVS) – 16 MB

The “Bar”

The “Line”
More Terms

- Virtual storage is divided into 1 MB segments, composed of 4 KB pages; z/OS uses segment and page tables to track these.

- Transfer of pages between auxiliary storage and real storage is called paging (and can be triggered by page fault interrupts).

- A frame is a 4K piece of real storage.

- A slot is a 4K record in a page data set.

- Translation of virtual addresses to actual physical addresses is called dynamic address translation (DAT).
Pages, Frames and Slots illustrated
Page Stealing

z/OS tries to always have some real storage frames on hand; pages that have not been accessed for a relatively long time are good candidates for page stealing.

z/OS uses various storage managers to track storage:

- Auxiliary Storage Manager (ASM)
- Real Storage Manager (RSM)
- Virtual Storage Manager (VSM)
Swapping

- *page stealing* is moving a single page into auxiliary storage

- The RSM can be used for *page fixing* which makes frames **unavailable** for stealing.

- *swapping* is moving an entire address space into auxiliary storage (preventing its processes from executing!)

- A *logically-swapped out* address space is inactive; its pages are ready to be swapped out but have not yet been swapped out
Translation Lookaside Buffer (TLB)

- When resolving a virtual address, the memory management hardware must consult the page tables to translate it to a physical address

⇒ This is a costly and frequent operation

- TLBs are used to cache the results of recent address translations

⇒ Faster translation!
What is in an address space?

- Each user has a unique address space and z/OS 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.

⇒ Not all of the mapped addresses are available for user code and data!
64-bit address space map

- User Private Area
- Common Area
- User Extended Private Area
- Shared Area
- User Extended Private Area
- The “Bar”
- The “Line”
- 0
- 16 megabyte
- 2 gigabytes
- 2 terabytes
- 512 terabytes
- 16 exabytes
- 16 exabytes
Detailed 64-bit address space map
Address Space Sizes

24 bit 16 MegaByte
31 bit 2 GigaByte
32 bit 4 GigaByte
64 bit 16 ExaByte
**z/OS address spaces**

z/OS and its related subsystems require address spaces of their own to provide a functioning operating system:

- 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 address spaces for major system functions and middleware products such as DB2, CICS, and IMS.

- TSO/E address spaces are created for every user who logs on to z/OS.

- Address spaces for every batch job that runs on z/OS.
Storage Management

Storage management functions include:

- Allocation
- Placement
- Monitoring
- Migration (& Recall)
- Backup & Recovery
- Deletion
Storage Management in z/OS

• Typical production systems use combination of manual and automated processes for managing storage

• Users/programs can directly control many aspects of z/OS storage use

• The primary means of managing storage in z/OS is through DFSMS
Data Facility Subsystem Managed Storage (DFSMS)
Disk Space Allocation

Various units are used for disk space allocation:

- Cylinders (1 CYL ≈ 0.85 MB) contain tracks
- Tracks (usually 15 per CYL ≈ 56 KB) contain blocks
- Blocks (size depends on data set) contain records
- Records (size depends on data set) contain bytes
- Bytes
Data Sets

z/OS files are called data sets; you need to allocate space for them before you can write to them. Allocation functions require:

- Volume serial – six character name of disk volume
- Device type – type of disk (usually 3390)
- Organization – method of processing the data set (sequential)
- Record format – data is stored in records of fixed or variable length
- Block size – records are combined into blocks of a certain length
- Extent – allocation of space; when the primary extent is filled, z/OS will automatically allocate more extents, called secondaries
Example: Data Set Allocation from TSO

READY
alloc dataset(USERID.test.test) volume(MARFOD) unit(3390)
  recfm(f) lrecl(80) dsorg(ps)
READY
listds
ENTER DATA SET NAME -
USERID.test.text
USERID.TEST.TEXT
  --RECFM-LRECL-BLKSIZ-D-SORG
     F   80   80   PS
  --VOLUMES
     MARFOD
Example: Sorting Data with TSO

ALLOCATE DATASET(AREA.CODES) FILE(SORTIN) SHR
ALLOCATE DATASET(*) FILE(SORTOUT) SHR
ALLOCATE DATASET(*) FILE(SYSOUT) SHR
ALLOCATE DATASET(*) FILE(SYSPRINT) SHR
ALLOCATE DATASET(SORT.CNTL) FILE(SYSIN) SHR
CALL 'SYS1.SLICELINK(SORT)'
ICE143I 0 BLOCKSET SORT TECHNIQUE SELECTED
ICE000I 1 - CONTROL STATEMENTS FOR Z/OS DFSORT V1R5
   SORT FIELDS=(1,3,CH,A)
201 NJ
202 DC
***
The structure of the Common Business Oriented Language explains some of the TSO call:

- A COBOL program consists of four *Divisions*, the identification division, environment division, data division and procedure division

- The *environment division* describes all of the external dependencies of a COBOL program, in particular files (or data sets) accessed
COBOL Input-Output Section Example

ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE CONTROL.
   SELECT MyFileName ASSIGN TO "EXT.DATASET.NAME"
   ORGANIZATION IS LINE SEQUENTIAL.
FILE SECTION.
   FD MyFileName.
   01 FileRecord.
      02 FirstName PIC X(10).
      02 MiddleInitial PIC X.
      02 LastName PIC X(15).
Programming TSO

TSO supports two scripting languages:

- **CLIST (Command List)** – like a UNIX shell script, interpreted; includes arithmetics and logical operations, string handling and of course routine tasks like dataset allocation

- **REXX** – more general, more portable, can be compiled
ISPF Features

ISPF includes:

- An online help system (press the PF1 key)
- A text editor / text viewer
- Functions for allocating and locating files
- Functions for calling various utilities
ISPF Default Menu Structure

Primary option menu
0 Settings
1 Browse
2 Edit
3 Utilities
4 DS List
5 ...

Settings
/ Cursor at ..
... ...
...
...

View
Proj ...
Group ...
Type ...
Other Dsn ...

Edit
Proj ...
Group ...
Type ...
Other Dsn ...

Utilities
1 Dataset
2 Library
3 CopyMove
4 DS List

Dialog Test
1 ....
2 ....
3 ....
4 ....

CopyMove

Library

Dataset
b Display
D Delete
Proj ...
Group ...
Type ...

***************
ISPF Panel Structure

0  Settings       Terminal and user parameters
1  View          Display source data or listings
2  Edit          Create or change source data
3  Utilities     Perform utility functions
4  Foreground    Interactive language processing
5  Batch         Submit job for language processing
6  Command       Enter TSO or Workstation commands
7  Dialog Test   Perform dialog testing
8  LM Facility   Library administrator functions
9  IBM Products  IBM program development products
10 SCLM          SW Configuration Library Manager
11 Workplace     ISPF Object/Action Workplace
5  SDSF          System Display and Search Facility

Enter X to Terminate using log/list defaults

Option ===> 

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

- Action Bar
- Point-and-Shoot
- Option Number
- Function Keys
# Keyboard mapping

<table>
<thead>
<tr>
<th>Function</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter</td>
<td>CTRL (right side)</td>
</tr>
<tr>
<td>Exit, end, return</td>
<td>PF3</td>
</tr>
<tr>
<td>Help</td>
<td>PF1</td>
</tr>
<tr>
<td>PA1/Attention</td>
<td>Alt-Ins or ESCape</td>
</tr>
<tr>
<td>PA2</td>
<td>Alt-Home</td>
</tr>
<tr>
<td>Cursor movement</td>
<td>Tab or Enter</td>
</tr>
<tr>
<td>Clear</td>
<td>Pause</td>
</tr>
</tbody>
</table>
## Keyboard mapping

<table>
<thead>
<tr>
<th>Function</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page up</td>
<td>PF7</td>
</tr>
<tr>
<td>Page down</td>
<td>PF8</td>
</tr>
<tr>
<td>Scroll left</td>
<td>PF10</td>
</tr>
<tr>
<td>Scroll right</td>
<td>PF11</td>
</tr>
<tr>
<td>Reset locked keyboard</td>
<td>CTRL (left side)</td>
</tr>
</tbody>
</table>
Example: Data Set Allocation from ISPF

Allocate New Data Set

Command ===>

Data Set Name . . . : USERID.TEST2.TEXT

Management class . . . (Blank for default management class)
Storage class . . . . (Blank for default storage class)
  Volume serial . . . (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 . . . FB
    Record length . . . 80
    Block size . . . .
    Data set name type : (LIBRARY, HFS, PDS, or blank) *
ISPF Editor

- Select “Utilities–Dslist–TEST2.TEXT” and use the prefix command “e”; confirm the next dialog by pressing “ENTER”

- Essentially like xedit (minor differences)

- Can be invoked from omvs using oedit
ISHELL

- ISHELL is the ISPF SHELL
- Provides panels for working with UNIX files, file systems and UNIX administration
- Essentially, ISPF-like menu-driven replacement for omvs

⇒ For users more familiar with TSO/ISPF than UNIX, not for you!
UNIX File Systems on z/OS
UNIX File System Organization

Key:
- Directory
- Symbolic link
UNIX Processes on z/OS
“Priced” features

A z/OS system usually requires additional licensed programs:

- Security manager
- Database manager
- Compilers
- Utility programs
- ...

We will discuss some of these in the 2nd half of the course!
Questions