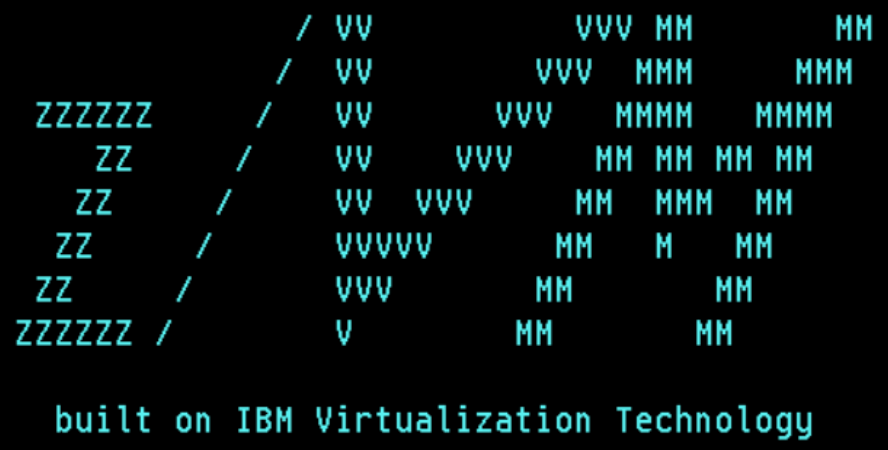
Intro to Virtualization

Presented by Montana Lee



What does Virtualization mean to you?

- "***I don't want to be limited by a single operating system***"

- "I bought the whole computer, I want to use the whole the computer"

- "I want to pool and overcommit resources to enable things to run 'faster'"

- "I want to compartmentalize things for ease or security"

- "I need to be able to support many users of a system"

What does Virtualization mean to you?

"Virtualization is a technology that enables the creation of *virtual environments from a single physical machine*, allowing for more *efficient use of resources* by distributing them across computing environments."

- We create an abstraction layer over our computer hardware, such that resources can be divided amongst instances of virtual machines (VMs)

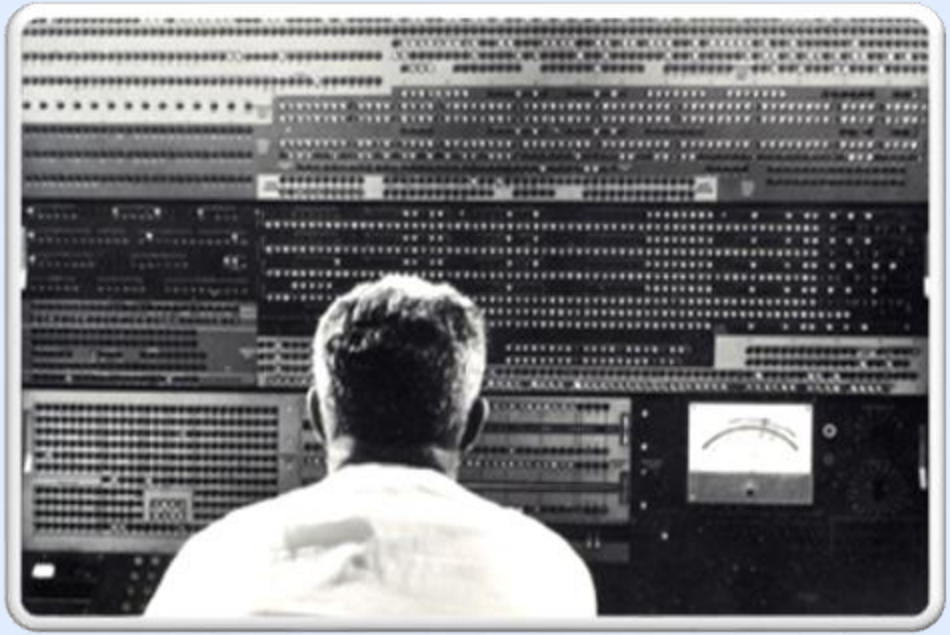
- Enables cloud (distributed) computing and complex, secure IT infrastructures

https://www.ibm.com/think/topics/virtualization

Let’s talk history for a few minutes and discuss just how we got here.

Courtesy of the Computer History Museum
https://www.computerhistory.org/timeline/computers/#169ebbe2ad45559efbc6eb35720c2b08

1961 – IBM 7030 ("Stretch") completed



IBM´s 7000 series of mainframe computers are the company´s first to use transistors. At the top of the line was the Model 7030, also known as "Stretch." Nine of the computers, which featured dozens of advanced design innovations, were sold, mainly to national laboratories and major scientific users. A special version, known as HARVEST, was developed for the US National Security Agency (NSA). **The knowledge and technologies developed for the Stretch project played a major role in the design, management, and manufacture of the later IBM System/360**--the most successful computer family in IBM history.

1964 – IBM announces System/360

System/360 is a major event in the history of computing. On April 7, IBM announced five models of System/360, spanning a 50-to-1 performance range. At the same press conference, IBM also announced 40 completely new peripherals for the new family. System/360 was aimed at both business and scientific customers and all models could run the same software, largely without modification. IBM's initial investment of $5 billion was quickly returned as orders for the system climbed to 1,000 per month within two years. At the time IBM released the System/360, the company had just made the transition from discrete transistors to integrated circuits, and its major source of revenue began to move from punched card equipment to electronic computer systems.

1971 – First Kenbak-1 is sold

One of the earliest personal computers, the Kenbak-1 is advertised for $750 (~$6200 in 2026) in Scientific American magazine. Designed by John V. Blankenbaker using standard medium-- and small-scale integrated circuits, the Kenbak-1 relied on switches for input and lights for output from its 256-byte memory. In 1973, after selling only 40 machines, Kenbak Corporation closed its doors.

1981 – IBM Introduces its Personal Computer (PC)

IBM's brand recognition, along with a massive marketing campaign, ignites the fast growth of the personal computer market with the announcement of its own personal computer (PC). The first IBM PC, formally known as the IBM Model 5150, was based on a 4.77 MHz Intel 8088 microprocessor and used Microsoft´s MS-DOS operating system. The IBM PC revolutionized business computing by becoming the **first PC to gain widespread adoption** by industry. The IBM PC was widely copied ("cloned") and led to the creation of a vast "ecosystem" of software, peripherals, and other commodities for use with the platform.

This along with several others incited the 'PC' world as often taught as computer science fundamentals today.

1985 – IBM Introduces the PR/SM hypervisor

Enables creation of logical partitions (LPARs). In practice, **each LPAR is equivalent to having a 'separate mainframe'**, as the resources are logically blocked off to anything outside of the LPAR. Only PR/SM can communicate with the separate LPARs and the OS running within each is unaware of any other.

https://www.ibm.com/docs/en/zos-basic-skills?topic=design-mainframe-hardware-logical-partitions-lpars

Computing's Beginnings – Main(frame) Takeaways

- Computers that do big, important work are both huge and expensive

- Nobody uses *all* of this computer at one time all the time

- The nature of the invention and current state of technology (pre-microprocessor) forced a *specific approach to writing software that ran on it – birth of CP and then z/VM*

Okay...

Why z/VM?

What Exactly Makes z/VM Special?

- Virtualization implementations (hypervisors) are not all created equal

- The amount of abstraction possible depends on how both the hardware and software has been designed

- ***z/VM has evolved directly alongside the IBM (Z) hardware such that it is a 'native hypervisor, also known as bare-metal***

Thus making z/VM an operating system with 'architectural fidelity'!

What Exactly Makes z/VM Special?

- Besides z/VM, other hypervisors such as Broadcom's VMware ESX are also bare metal, but for x86 hardware

- Every other hypervisor that cannot natively run on 'bare metal' hardware are 'hosted hypervisors'- examples are VMware Workstation and VirtualBox

- There are some special hypervisors that blur the line, such as our own KVM (not discussed at length here)

More 'Modern' Instances of Virtualization...

***Disclaimer: Containerization is not the same as a hypervisor's virtualization, but shares similar ideas of consolidating resources, computing more efficiently, and providing security on a system through compartmentalization.

Citrix
Workspace

VMware
vSphere®

PowerVM™

docker

kubernetes

vmware®
ESXi

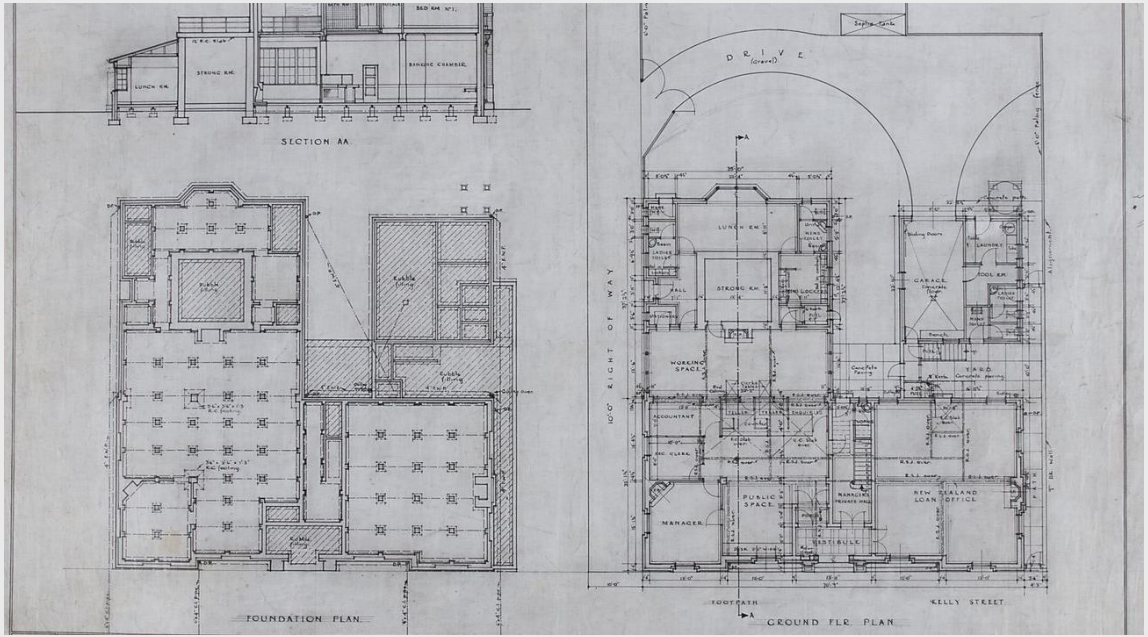
Residual IBM Z-Specific Nomenclature

Level Set 

Intel, System p, etc.	IBM Z
Memory	Storage (central storage)
Disk Storage	DASD (Direct Access Storage Device) FCP (Fibre Channel Protocol)
Computer Host System	CEC (Central Electronics Complex) CPC (Central Processor Complex) Server
Socket Slot	Book, drawer or node
Chip (e.g., multiple cores on a chip)	Core (e.g., multiple processors on a core)
CPU GPU Processor Core HT Core	Processor or Engine CPU or PU CP (Central Processor) IFL (Integrated Facility for Linux) zIIP (zSeries Integrated Information Processor) ICF (Integrated Coupling Feature) SAP (System Assist Processor) IOP (I/O Processor)
Boot	IPL (initial program load)

What are we virtualizing? z/Architecture

- Every computer system has an **architecture**
  - It's the specs for how to build software on the system
  - Defined in z/Architecture Principles of Operation
  - z/VM must both **follow** and **implement** z/Architecture



What does virtualization mean on IBM Z?

z/VM allows the **sharing** of the mainframe's physical resources such as

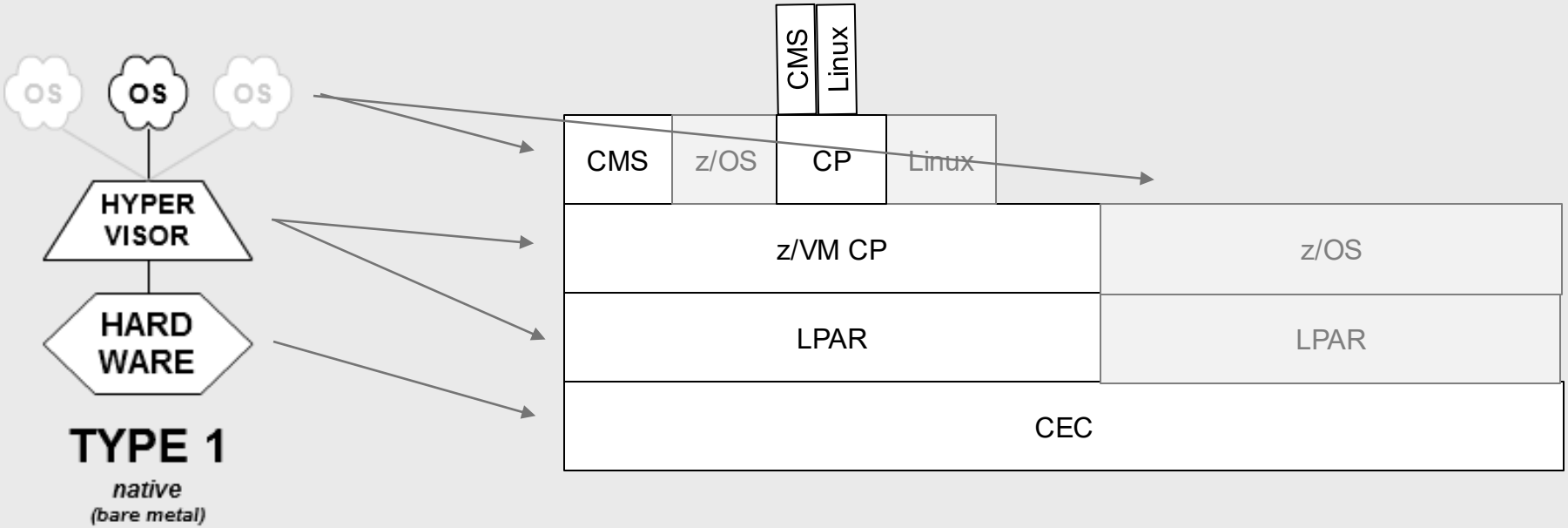
- Disk
- Memory
- Network adapters
- CPUs

These resources are managed by a **hypervisor**.

Virtualization enables four fundamental capabilities:

- resource sharing
- resource aggregation
- emulation of function
- insulation

What does Virtualization look like on IBM Z?



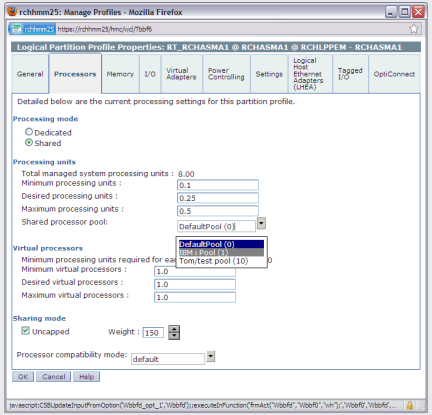
Real, Logical, & Virtual

Level Set

It's important that everyone understands which view YOU are talking about!

What the accounting team sees
(REAL)

What the system programmer sees
(LOGICAL)



What the application developer sees
(VIRTUAL)

CP/CMS: A Symbiotic Relationship

CP (Control Program)

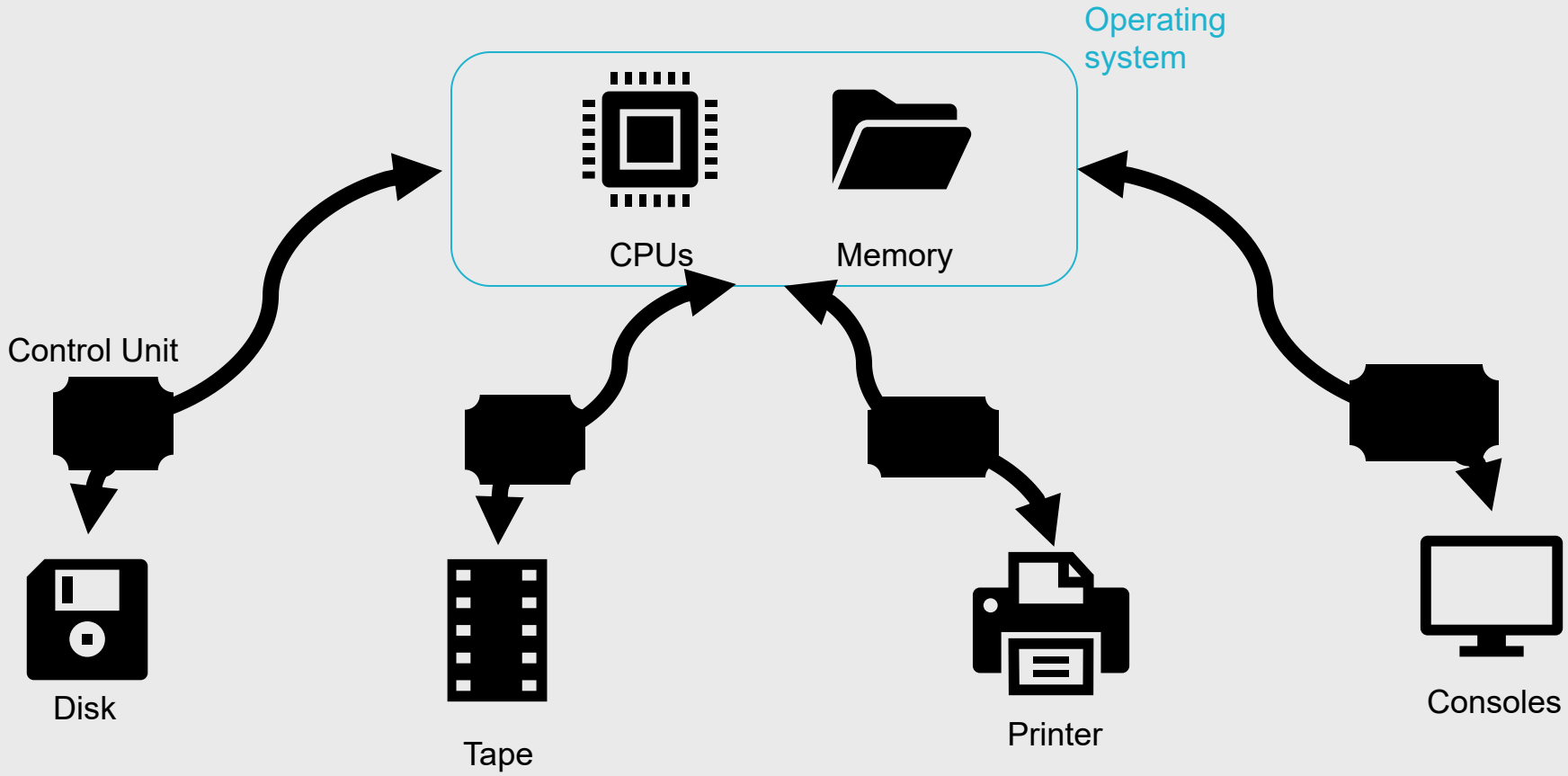
CP solved the problem of multiple use by providing separate computing environments at the machine instruction level for each user (virtual machines).

CMS (Conversational Monitoring System)

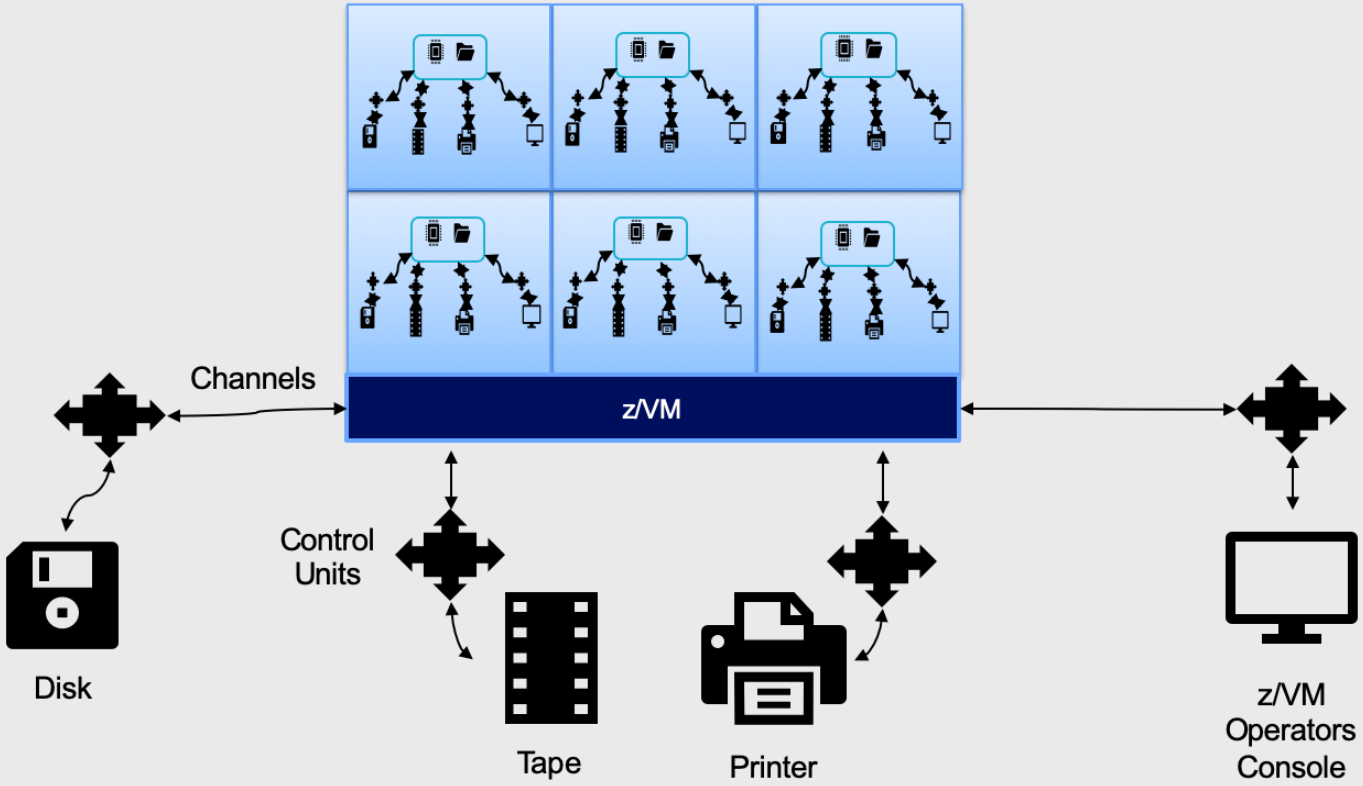
CMS then provided a single user service that did not have to worry about the problems of sharing, allocation, and protections of resources such as memory and disk storage.

Virtual Machines in z/VM

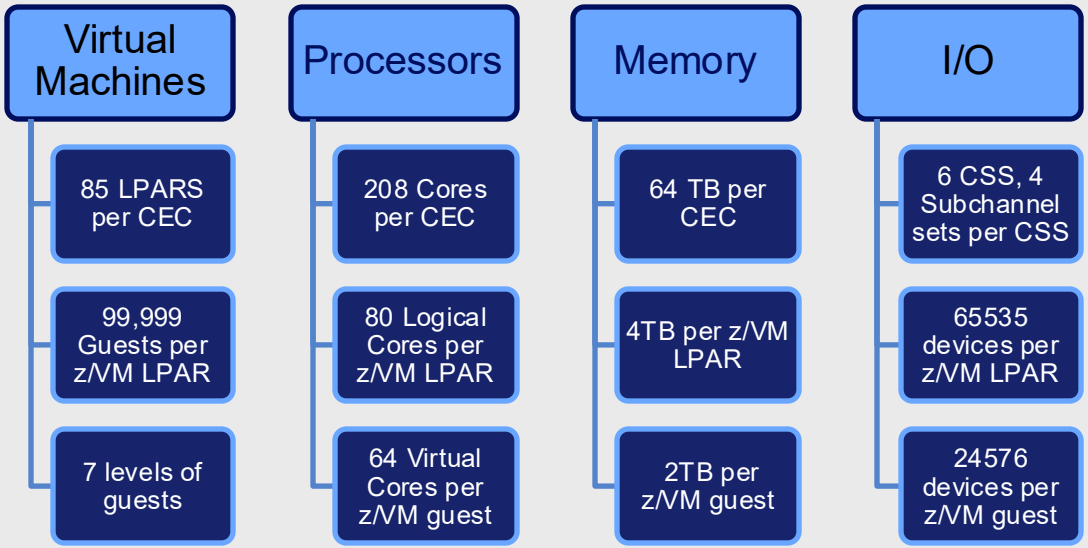
Just like the real thing, we have



Just lots of them!



Testing the Limits (z17)



Intro to Processors and z/VM

Running CPUs 90% busy doesn't scare us.
We want you to get what you pay for!

z/VM supports **logical** processors

z/VM as a Hypervisor

Z/VM faithfully replicates **virtual** processors

z/VM as a guest

Intro to Memory and z/VM

Fully utilizing your memory is not a bad thing - z/VM expects to have to move some memory to paging media.

Flexibility to grow or shrink your memory

Strength to handle many VMs

Intro to I/O and z/VM

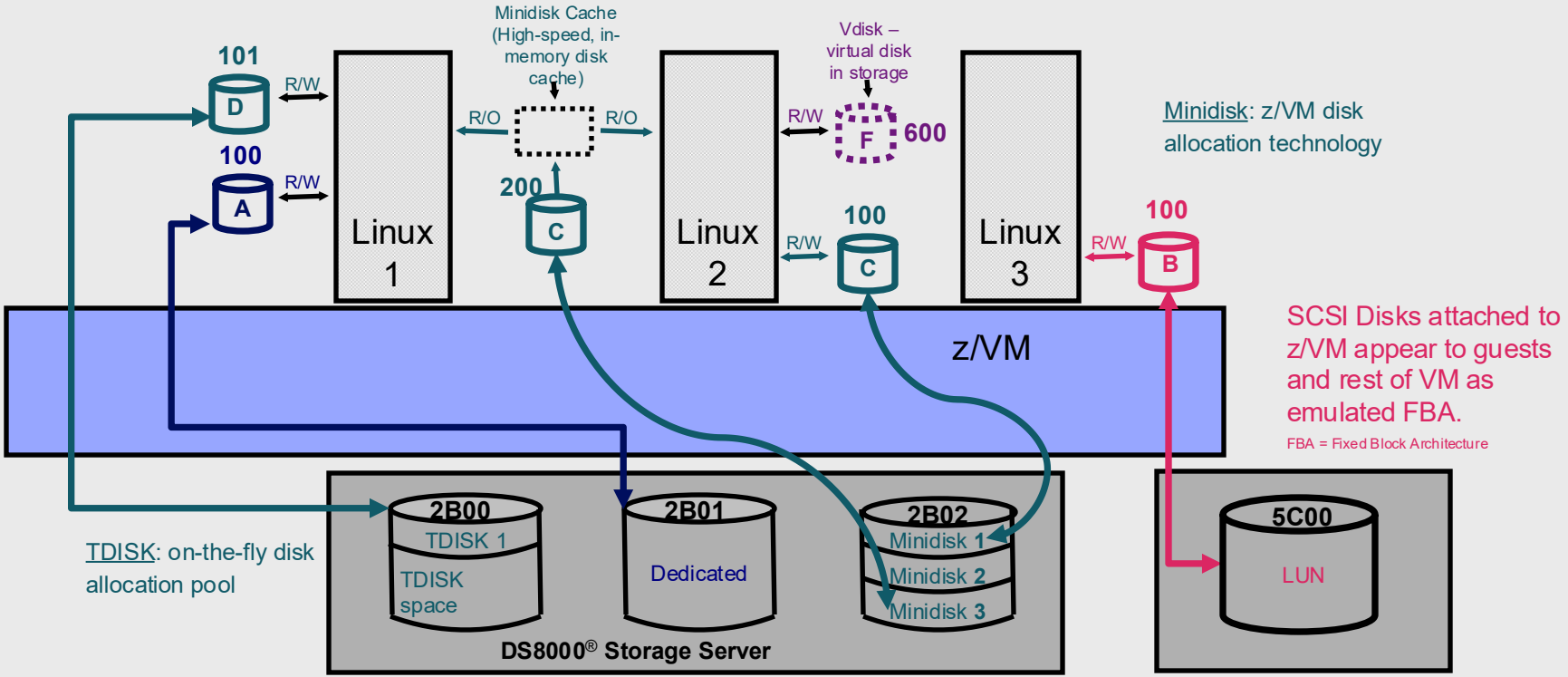
z/VM can accommodate an extremely large variety of I/O devices, allowing for incredible flexibility

Device Management Concepts

How can I get from my house to the post office?

- Dedicated or attached
  - My parents give me my own car to go to the post office
- Virtualized
  - I have to share the car keys with my whole family, so I can go to the PO sometimes
- Simulated
  - I shop online so I don't have to go anywhere physically
- Emulated
  - I take the bus to the post office

Device Management Concepts



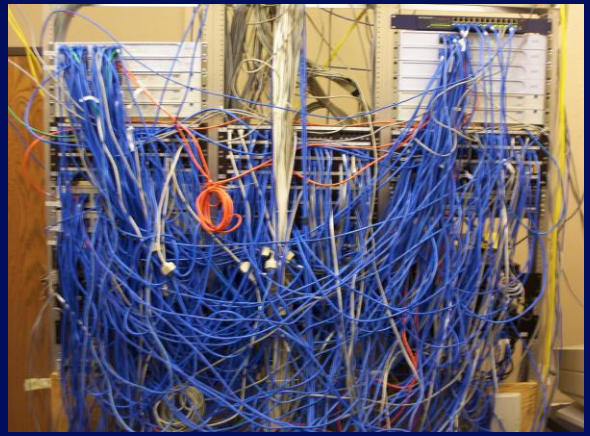
Intro to Networking and z/VM

Users have many options for networking connections on z/VM

Virtualizing network infrastructure saves complexity and time

Configure this functionality with a VSwitch!

From this



To virtual!

Intro to SPOOL in z/VM

- z/VM simulates unit-record devices for virtual machines
  - Simulated reader, punch, printer, console for every virtual machine

- Simulated UR devices are still widely used on z/VM; upcycled to
  - Exchange application data
  - Share data files among multiple virtual machines
  - Collect console output
  - Store data collected by various system functions

- "Intermediary" between information in memory and information that you might devote long term storage to

Card Reader

Card Punch

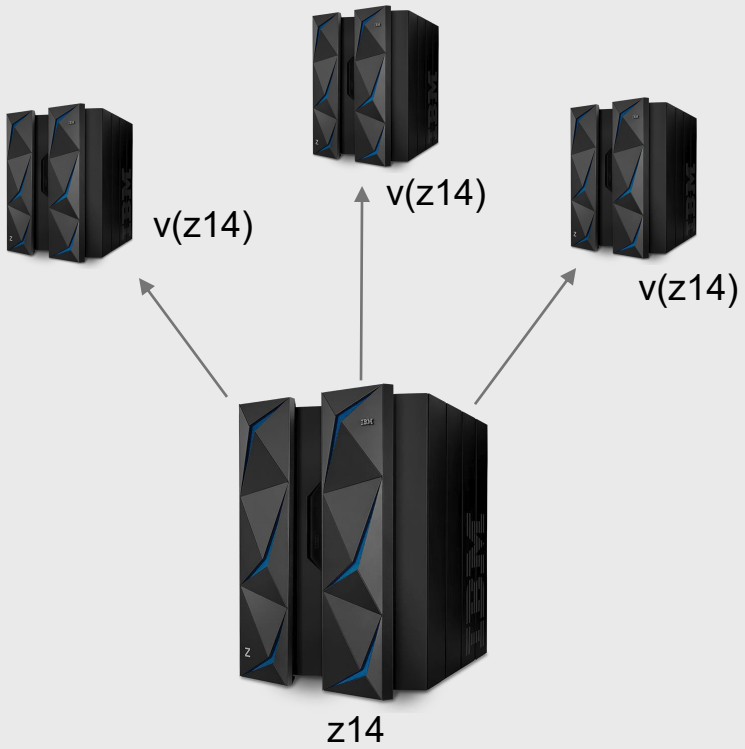
Printer

Console

Overcommitment

Doing more with less
(Heavier content)

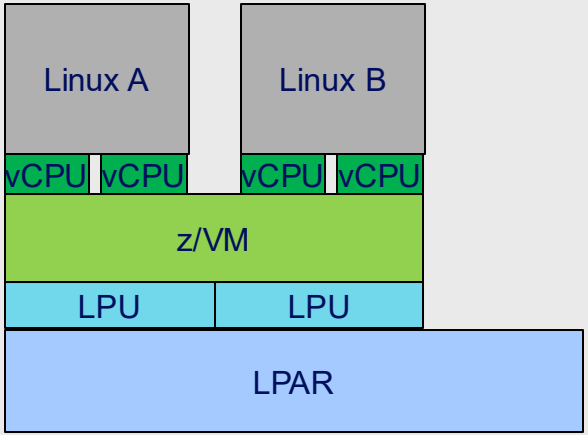
Resource Overcommitment



What is it?

- When the virtual resources defined to an OS (Or multiple OS's) exceed the physical resources of the machine
- **Fundamental** to the idea of virtualization
- Possible because a virtual resource will not need 100% of the physical resource 100% of the time
- What things can be overcommitted? CPU, Memory, I/O, Networking, Crypto

Overcommitting CPU



How's it work?

- When vCPUs need to run they must be **dispatched** onto the logical processor
- Hypervisor must manage vCPU access to the LPU

Tools of CPU management

- Entitlement – The amount of real CPU time a logical partition is entitled based on LPAR configuration.

- Processor Topology – The amount of real CPU a logical processor is entitled
  - Vertical High – entitled to 100% of a real CPU
  - Vertical Medium – entitled to 50-100% of a real CPU
  - Vertical Low – entitled to 0% of a real CPU

- Consumption/Utilization - How much of a real CPU is being used (for LPAR or for entire CEC)

- Share Setting – How much entitlement is due after comparison to other users

- Processor Affinity – A vCPU that must run on a logical processor of the same type

Determining "Who's on first?!"

Gather Partition Information:

- Processor **Topology**
- LPAR weights
- Processor Utilization

Gather Hypervisor Information:

- Share Settings
  - Absolute/Relative
  - Hard/Soft
- Resource Pool Information
- Processor Affinity

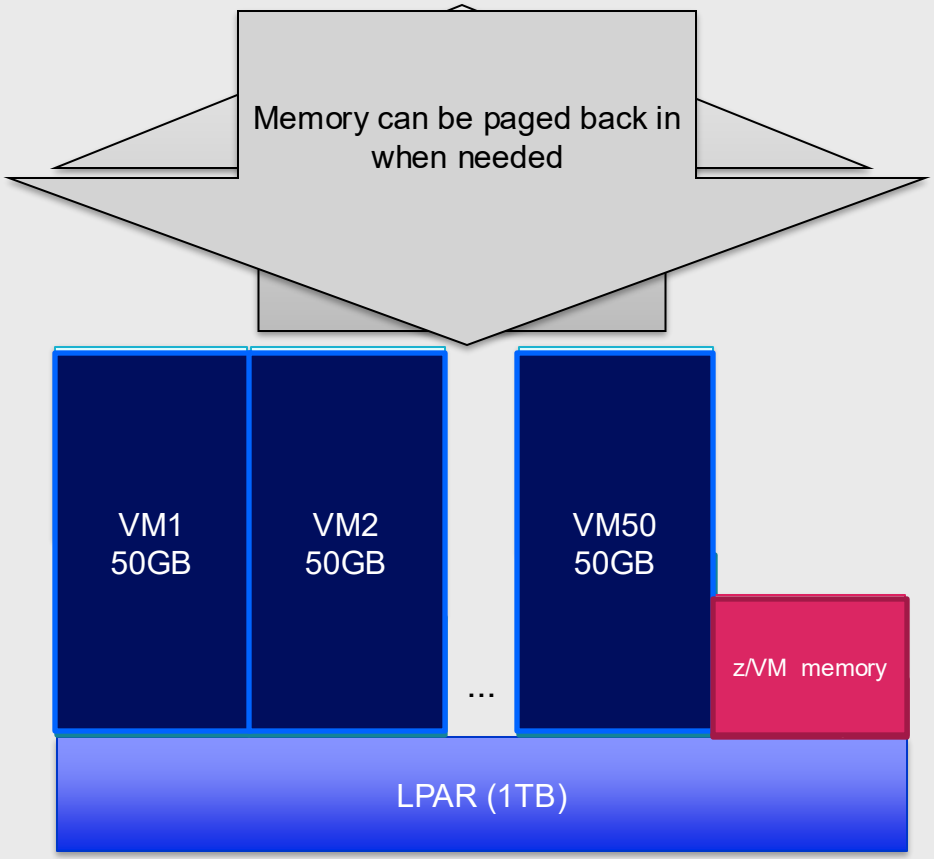
Schedule vCPU based on relative priority:

- Use partition and Hypervisor information to choose the best logical processor to run on.

Dispatch vCPU onto Logical Processor:

- Run CPU under **SIE**
- Let vCPU run for AT LEAST a **Minor Time Slice.**
- Compete with other vCPUs for unused or **until Elapsed Time Slice.**

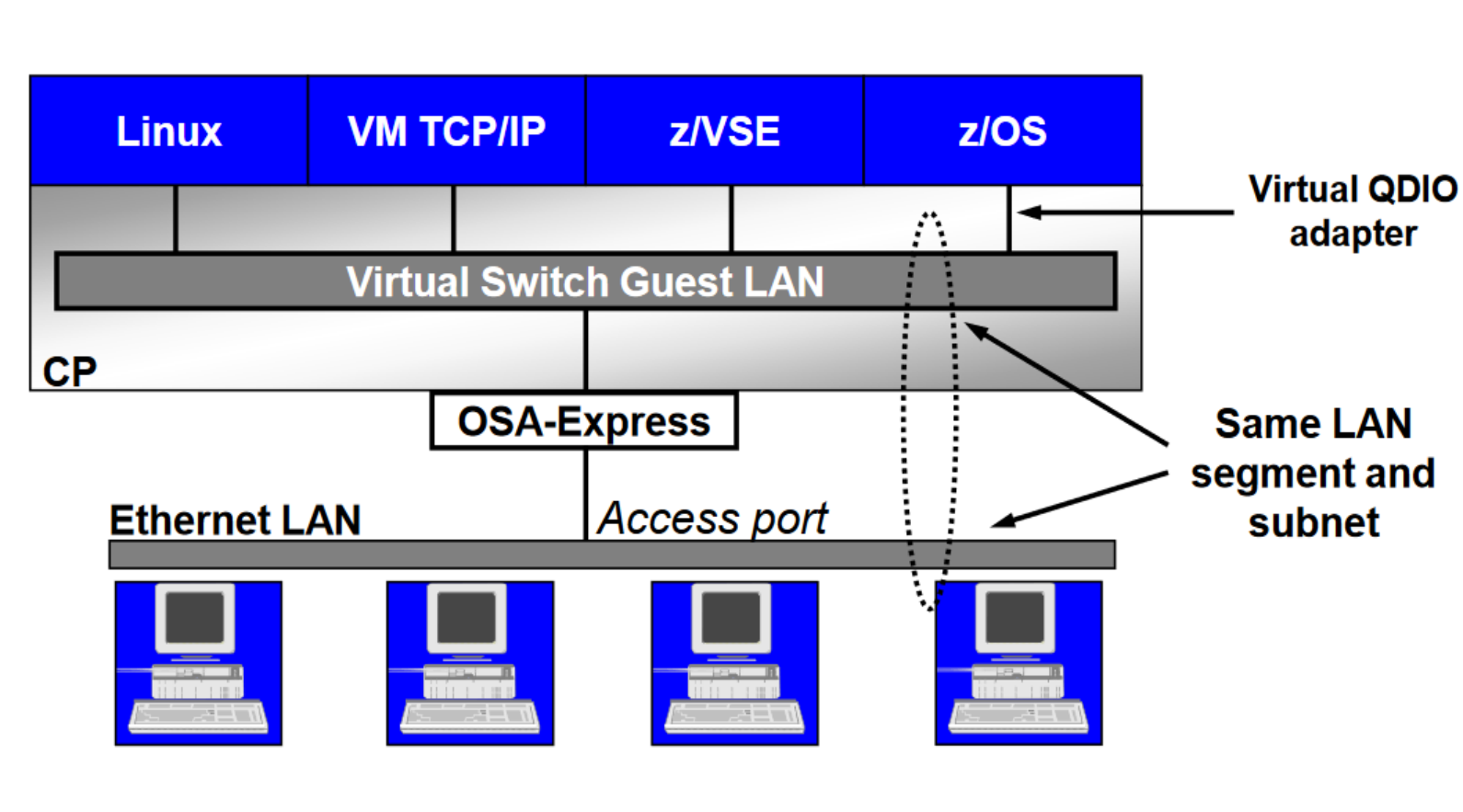
Overcommitting Memory



How's it work?

- We can only keep so much in memory
  - The 1TB must have z/VM's own structures and memory as well as guest memory
- So we choose some memory to page out to disk

Overcommitting network with a VSWITCH



Conclusion


Flexibility
Community
Overcommittment
Testing and Debugging
Hardware Integration

Backup Slides (DVD extras)

How do you Build z/VM?

What do you need?

- LPAR definition - HMC/SE, what PR/SM controls
- IOCDS - I/O definition – or use DPM to give you both IOCDS & PR/SM
- System Config – What's defined to the z/VM system
- User Directory – What's defined to the z/VM users

System Config: What makes up my system?

What is defined in the system configuration file?

- Operator_Consoles statement to find a console
- vSWITCH statements to define our virtual network
- CP_Owned statements to define the residence volume
- And so much more!!!

```
/*********************************************/
/* Set up Console                            */
/*********************************************/

operator_consoles  01F 009  3E0  500

 /*********************************************/
/* Set up VSWITCHES                          */
/*********************************************/

DEFINE  VSWITCH VSWITCH1 RDEV  7080  CONNECT CONTR DTCVSW1 ETH
MODIFY VSWITCH VSWITCH1 GRANT TCPIP
MODIFY VSWITCH VSWITCH1 GRANT LINUX01
DEFINE VSWITCH VSWITCH2 RDEV  6240  CONNECT CONTR DTCVSW1 ETH

/*********************************************/
/* Set up CP Volumes                         */
/*********************************************/

CP_owned slot  001  2ND600
CP_owned slot  002  2ND601
CP_owned slot  003  2ND603
CP_owned slot  004  2ND604
```

User Directory: What Does a Virtual Machine Definition Look Like?

What is defined in a directory entry?

- Login credentials
- Authorizations
  - Access to system resources
  - Command privileges
- Virtual machine characteristics

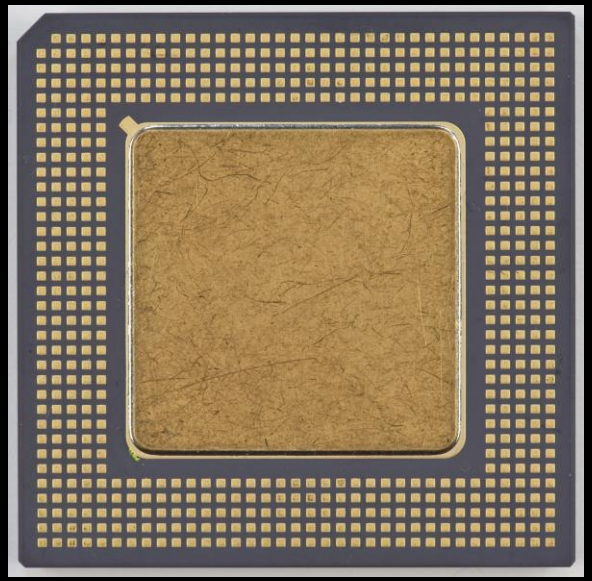
Tools to help you

- DIRECTXA – creates and compiles your user directory
- Directory manager – Does this work for you!

```
USER LINUX01 MYPASS 512M 1024M     G
MACHINE  ESA 2
IPL  190  PARM AUTOCR
CONSOLE 01F  3270   A
SPOOL   00C  2540   READER *
SPOOL   00D  2540   PUNCH  A
SPOOL   00E  1403   A
SPECIAL  500  QDIO  3 SYSTEM MYLAN
LINK     MAINT 190  190  RR
LINK     MAINT 19D  19D  RR
LINK     MAINT 19E  19E  RR
MDISK    191 3390 012  001   ONEBIT  MW
MDISK    200 3390 050  100   TSOBIT  MR
```

Dynamic Resource Management

Dynamic **Processor** Management



VARY PROC/CORE

SMT Enabled – CORE
SMT Disabled – PROC

DYNAMIC SMT

HIPERDISPATCH (Park/Unpark)

Adjustable via:
CP SET SRM UNPARKING

Dynamic **Memory** Management

DEFINE STORAGE

Used to change the memory on a guest.

chmem

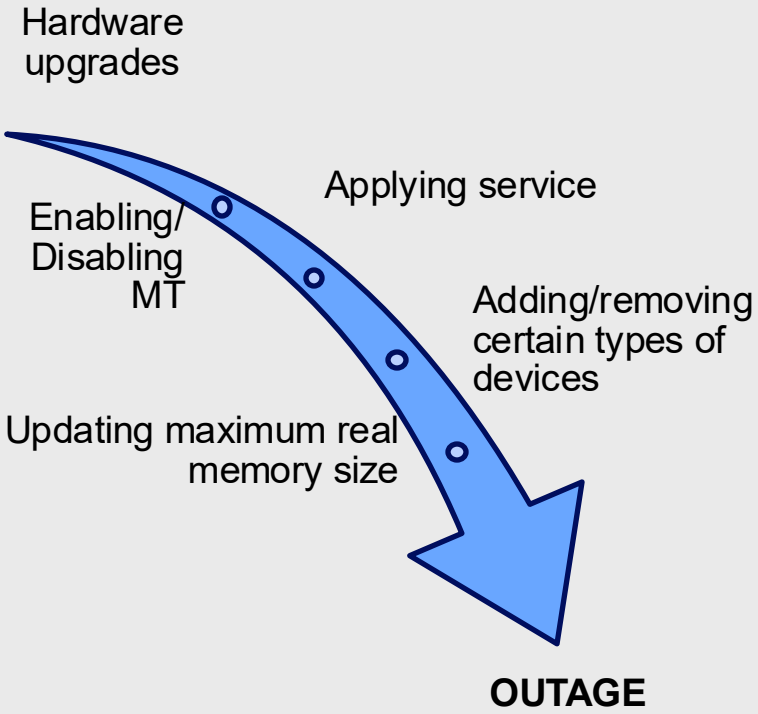
Linux commands are provided to bring more memory online, or take memory offline to the Linux OS.

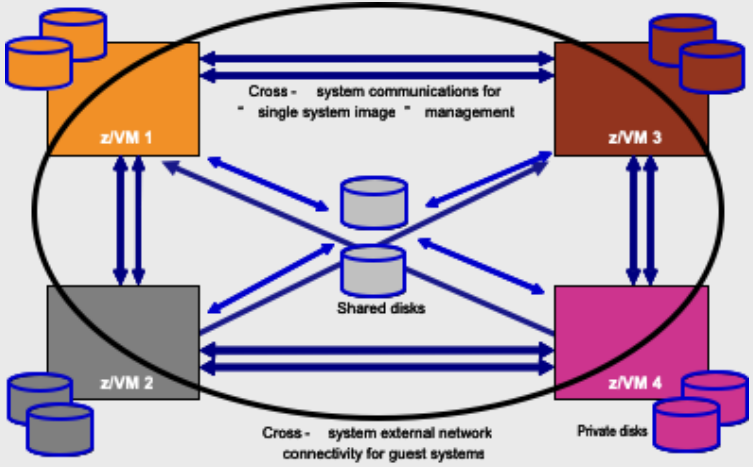
SET STORAGE

Use to add more memory to your z/VM system.

On the z14 and later machines, use this command to remove memory.

What needs a planned outage?





z/VM SSI

z/OS Parallel Sysplex

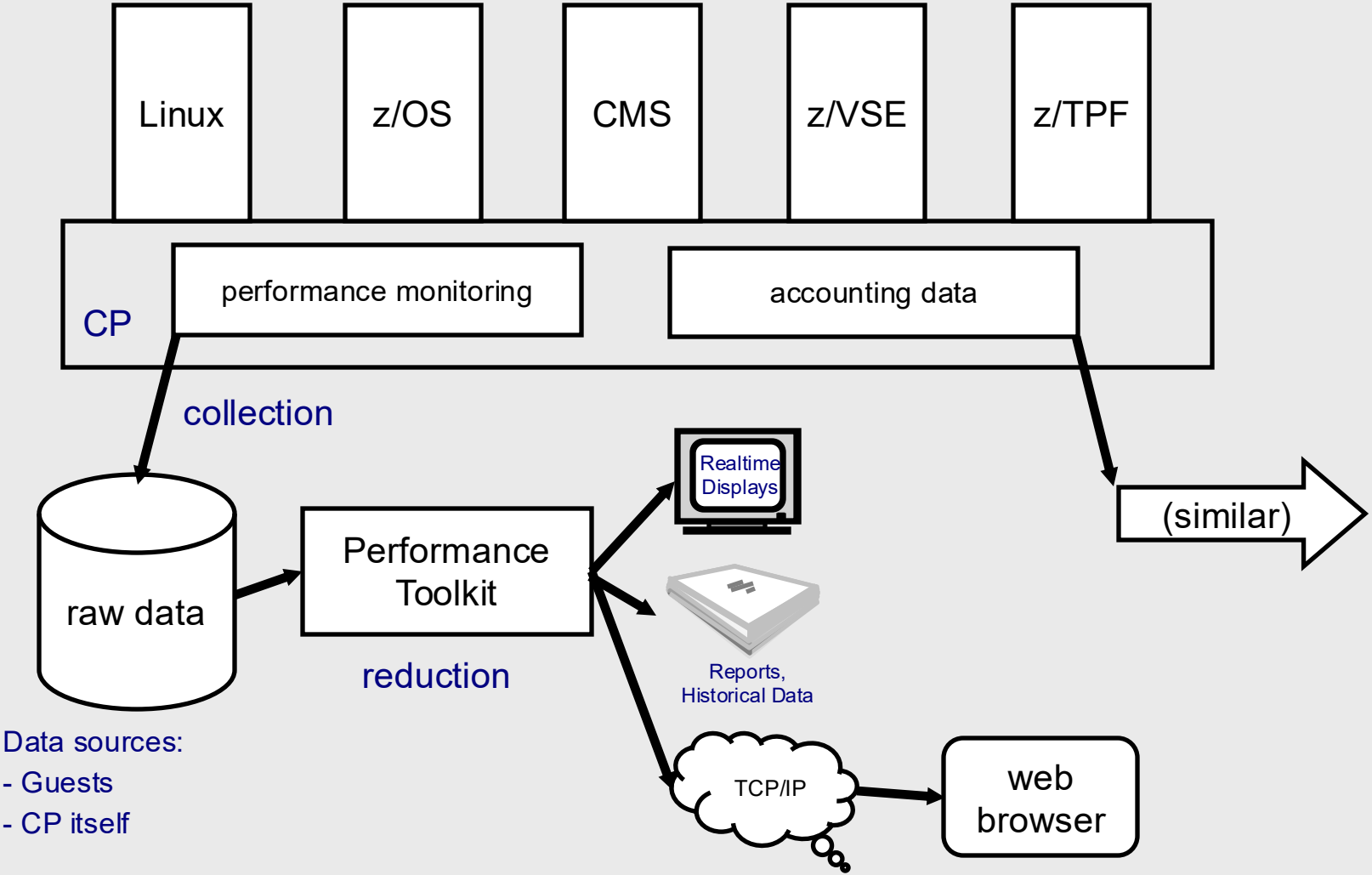
Single Systems Image (SSI) Feature

1. Manage a **single** user directory
2. Cluster management from any member
   - Apply maintenance to **all members** in the cluster from **one location**!
   - Issue commands from one member to operate another!
3. Built-in **cross-member capabilities**
4. Resource coordination and protection of network and disks
5. Relocate a **running** Linux guest from one system to another

FREE in z/VM 7.1+

System services

There are ways to connect into the system to monitor what's going on at a deeper level, or to issue commands to the hardware.


Linux
z/OS
CMS
z/VSE
z/TPF
CP
performance monitoring
accounting data
collection
raw data
Performance Toolkit
reduction
Realtime Displays
Reports, Historical Data
(similar)
TCP/IP
web browser
Data sources:
- Guests
- CP itself

Houston...we have a problem

What happened?

Soft ABEND

- Something went wrong in the program, but CP is ok.

- System stays up, Virtual Machine may terminate.

Hard ABEND

- Something went wrong with the control program.

- The entire system terminates.

Hung User

- A specific user is stuck in CP and cannot continue.

- The rest of the system continues operation.

Hung System

- The entire system is stuck in CP and cannot continue.

Determining Why

CP will dump system storage to aid debug for a hard or soft abend.

SNAPDUMP or **RESTART** dumps help gather information for system or user hangs.

IMPORTANT: configuring your system with adequate dump space will reduce headaches should you need to use it!

Dumping z/VM is not instantaneous and can take on the order of minutes depending on the size of your system. The longer you wait, the more information you'll have.

Where to go when you're stuck

Community Forums

- IBMVM Listserv (z/VM community) http://listserv.uark.edu/cgi-bin/wa?A0=IBMVM
- LINUX 390 Listserv (Linux on Z) http://www.cavmen.org/list390.html
- Additional Listserv can be found here https://www.vm.ibm.com/techinfo/listserv.html

Technical Publications

- VM Library https://www.vm.ibm.com/library/
- IBM Knowledge Center https://www.ibm.com/support/knowledgecenter/en/

Redbooks

- IBM Z Redbooks http://www.redbooks.ibm.com/redbooks.nsf/domains/zsystems

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- Contact the z/VM experts! https://www.vm.ibm.com/forms/