A SHAREd History of the Mainframe – Chronicles, Artifacts, and Stories

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Where we are today...
A smarter operating system with designs for:

**Improving Usability and Skills**
- z/OSMF Software
- Deployment and Storage Management applications, User-level mount command for z/OS UNIX System Services, Automatic F4DSCB updates, SDSF Sysplex functions to work without MQ, Catalog parmlib member, Better O/C/EOV Messages, Health Checks, …

**Integrating new Applications and Supporting Industry and Open Standards**
- Java/COBOL interoperability, Improved Support for unnamed sections, ISPF Edit Macros, Subsystem and Unauthorized XTIOT support, dbx hookless debug, DFSORT improvements, Job level return codes, …

**Scalability & Performance**
- Fully-shared zFS in a sysplex, RMODE 64 extensions, IFASMFDL improvements, 500K+ aliases per user catalog, Larger VVDSs, FREE=EOV, FTP support for large format data sets and EAS,…

**Self Managing Capabilities**
- WLM and RMF to provide response time distribution for all goals, DFSMShsm Journal Backup and space management improvements, …

**Enhancing Security**
- RRSF over TCP/IP, LDAP improvements, SAF security for z/OSMF, NAS address checking and encryption negotiation, New restricted QNAMEs, PKI support for DB2 backstore, ICSF support for new HMACs, FTP & TN3270 password phrase support, …

**Extending the Network**
- IDS IPv6 support, NAT Traversal for IKEV2, NMI extensions, More VLANs per OSA port, more 64-bit TCP/IP, EE improvements, …

**Improving Availability**
- Warn before TIOT exhaustion, CMDS enhancements, Parallel FTP for dump transfers, PFA ENQ tracking, RTD improvements, zFS Refresh, DADSM Dynamic Exits, JES3 dynamic spool addition, Better channel recovery, More ASID reuse, …

*All statements regarding IBM future direction and intent are subject to change or withdrawal without notice, and represent goals and objectives only.*
## z/OS and IBM zEnterprise Functions and Features

<table>
<thead>
<tr>
<th>Five hardware models</th>
<th>Capacity Provisioning enhanced[^1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased capacity processors</td>
<td>Three subchannel sets per LCSS[^3]</td>
</tr>
<tr>
<td>Up to 15 subcapacity CPs at capacity settings 4, 5, or 6</td>
<td>Platform Management from HMC</td>
</tr>
<tr>
<td>6.0 GB/sec InfiniBand® I/O interconnect</td>
<td>Up to 128 Coupling Link CHPIDs</td>
</tr>
<tr>
<td>8 slot, 2 domain I/O drawer</td>
<td>Improved processor cache design</td>
</tr>
<tr>
<td>Concurrent I/O drawer add, remove, replace</td>
<td>Power save functions</td>
</tr>
<tr>
<td>Optional water cooling</td>
<td>Crypto Express3 enhancements[^5]</td>
</tr>
<tr>
<td>Optional High Voltage DC power</td>
<td>Secure key HMAC Support</td>
</tr>
<tr>
<td>Optional overhead I/O cable exit</td>
<td>Elliptic Curve Cryptography (ECC) Digital Signatures[^3]</td>
</tr>
<tr>
<td>Up to 80 processors per server configurable as CPs, zAAPs, zIIPs, IFLs, ICFs, or SAPs (up to 32-way on R7, 64-way on R9, 80-way on R11)</td>
<td>CPACF enhancements[^5]</td>
</tr>
<tr>
<td>New and enhanced instructions</td>
<td>Out of order instruction execution</td>
</tr>
<tr>
<td></td>
<td>z/OS discovery and auto-configuration (zDAC)[^3]</td>
</tr>
<tr>
<td></td>
<td>OSA-Express3 Inbound Workload Queuing (IWQ)[^3]</td>
</tr>
</tbody>
</table>

[^1]: [z/OS R7 and z/OS R8 support require IBM Lifecycle Extension for z/OS (5637-A01 or 5638-A01). PTFs required for z/OS R8-R12; refer to the PSP.](#)
[^2]: Maximum of 1 TB per LPAR. Maximum supported by z/OS R7 is 512 GB. z/OS R8 and later are designed to support up to 4 TB per image.
[^3]: z/OS R12 required
[^4]: z/OS R12, or R10 or later with PTFs required
[^5]: Cryptographic Support for z/OS V1.10 through z/OS V1.12 Web deliverable with the PTF for APAR OA33260 required.

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Where we’ve been...
It all started with…

- Herman Hollerith’s punched cards…
- ...and their influence continues to affect us today!

Ever wonder…

- Why the 3270 default screen size is 24x80?
- Why we have a “block size” concept?
- Why we have data sets with sequence numbers?
• How did you know the holes were in the right places?
• With a card registration plate, of course!
• Still standard issue in the 1970’s
Rear view of card registration plate

THE REGISTRATION OF ALL CARD PUNCHING EQUIPMENT SHOULD BE CHECKED ONCE EACH DAY. THIS GAUGE SHOULD BE USED TO CHECK THE REGISTRATION OF ALL KEY PUNCHES, REPRODUCING PUNCHES, AND CALCULATING PUNCHES.

TO USE THIS GAUGE, PUNCH A TEST CARD WITH 12-9 DIAGONALLY ACROSS 80 COLUMNS AND PLACE THE CARD FACE UP 12 EDGE TO THE TOP FIRMLY AGAINST THE GUIDES AT TOP AND RIGHT HAND END.

ANY MACHINES OUT OF REGISTRATION SHOULD BE REPORTED TO YOUR SUPERVISOR IMMEDIATELY.
Punched Cards, Continued…

- It’s hard to believe this now, but punched cards were pervasive!
- Many bills and warranty cards were printed on punched cards
- “Do not fold, spindle, or mutilate…”
- This card came with my garbage disposal many moons ago:
What’s a Card Jam?

• When two cards tried to fit into the space meant for one, how did you get them out?
• You used a card saw…
• Once standard issue in CE tool bags, the thin (.010” or so), spring-steel card saw was essential if you worked on card readers, punches, or keypunch machines.
• It would clear out the card jam…eventually.

![Card Jam Tool](image)
Punched Cards, Continued…

- Of course, IBM used punched cards, too:

An operator named Carol K. wrote this MTN against a printer I fixed in 1980… and I obviously forgot to return the card because I found it in my old tool bag in 2007!
Punched Cards, Continued…

• An IBM 029 Keypunch, 1964

• Not exactly a laptop!

• It existed only to punch holes in cards

• Blank cards in feeder on top right; punched ones in stacker on left; chad bin underneath

• No error correction, of course; cards with typos went into the trash can (which is conspicuously absent in this photo)

• This is actually a model with an optional drum-mounted “template card” (I can’t recall the actual name) to speed things up
• There were no PDAs, then, but there was…

• The Port-A-Punch!

• “Designed to fit in the pocket”

  • I suppose pockets might have been larger then (some things were even before my time, after all)

• Not exactly a BlackBerry® handheld device!
Punched Cards, Continued...

• An IBM 77 Collator
• A collator is the opposite of a sorter
• For some things, you didn’t need a computer to make punched cards useful
• Today, we use things like SORT/MERGE’s descendant, DFSORT
• The industry did have to invent some things:
  • Parity (IBM uses odd parity)
  • NRZI recording for tape
  • CRC and LRC checking algorithms
  • ECC memory
  • Microcode
  • …the list goes on and on
Printers like this 1403 came with a print train or print chain.

A hydraulic unit—sort of a 2-speed mini-automatic transmission—drove the tractors to move the paper.

Spacing and skips were controlled by a 12-channel carriage tape.

It was just amazing how fast a box of paper could empty when one broke…

Don’t leave a cup of coffee on top!

Some models raised the cover automatically when out of paper to catch an operator’s attention.
Disk drives

• The 2314

• 9 drawers to a “bank” (because they were high maintenance, you could only use up to 8 at a time)

• Hydraulic pistons moved heads in & out of removable disk packs

• Removable disk packs and address plugs moved together to keep the same address for the same volume

• Don’t drop a disk pack! (The bits would fall off.)
Disk drives

- The 3330, 1970
- Much more reliable than the 2914, so 8 drawers to a bank
- Voice coil electromagnet and large static magnet used to replace hydraulic unit to drive access mechanism
- Can still move disk pack and unit address plug together
- 101 MB/volume (3330-1) or 202 MB/volume (3330-11)
Disk drives

- A 3330 disk pack, called a 3336, alongside two Mass Storage Subsystem (3851) cartridges
  - 10 2-sided data platters
  - 19 data tracks per cylinder with 1 servo track
DASD Scale

- **2314:**
  - Average seek time – 75ms
  - Average latency – 12.5ms
  - Data rate – 291 KB/sec

- **3330:**
  - Average seek time – 30ms
  - Average latency – 8.4ms
  - Data rate – 806 KB/sec

- **3330-A:**
  - Average seek time – 223GB*
  - Average latency – 262,668 cyl
  - Data rate – 2-3.7 GB/sec

- **3350:**
  - Average seek time – 25ms
  - Average latency – 8.4ms
  - Data rate – 1.2 MB/sec

- **3380:**
  - Average seek time – 17ms
  - Average latency – 8.3ms
  - Data rate – 3 MB/sec

- **3390:**
  - Average seek time – 12ms
  - Average latency – 7.1ms
  - Data rate – 4.2 MB/sec

- **DS8000™:**
  - Seek time and rotational latency do not apply to SSD-based drives; but for 15K RPM disk:
    - Average seek time – 3.5ms
    - Average latency – 2ms
    - Data rate – 2-3.7 GB/sec

---

**DASD Scale Details**

<table>
<thead>
<tr>
<th>Model</th>
<th>Average Seek Time</th>
<th>Average Latency</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2314</td>
<td>75ms</td>
<td>12.5ms</td>
<td>291 KB/sec</td>
</tr>
<tr>
<td>3330</td>
<td>30ms</td>
<td>8.4ms</td>
<td>806 KB/sec</td>
</tr>
<tr>
<td>3330-A</td>
<td>223GB*</td>
<td>262,668 cyl</td>
<td>2-3.7 GB/sec</td>
</tr>
<tr>
<td>3350</td>
<td>25ms</td>
<td>8.4ms</td>
<td>1.2 MB/sec</td>
</tr>
<tr>
<td>3380</td>
<td>17ms</td>
<td>8.3ms</td>
<td>3 MB/sec</td>
</tr>
<tr>
<td>3390</td>
<td>12ms</td>
<td>7.1ms</td>
<td>4.2 MB/sec</td>
</tr>
<tr>
<td>DS8000</td>
<td>3.5ms</td>
<td>2ms</td>
<td>2-3.7 GB/sec</td>
</tr>
</tbody>
</table>

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**Architectural Limit:** 228 TB
Tape drives

- The IBM 2420
- 1600 bpi!
- “Stubby” triangular vacuum columns at the top helped reduce start/stop inertia
- “Autoloading” tape covers
- Don’t forget the Write Ring! (Ever wonder where “RING” and “NORING” came from in the JES3 mount messages?)

Write Ring
Tape drives

- The IBM 3420, 1970
- Up to 6250 bpi!
- Odd models (3, 5, 7) were 1600 bpi only
- Even models (4, 6, 8) were 1600/6250 “Dual Density”
- Models 7 and 8 moved tape at 800 IPS
- High-speed rewind was fast! Cracked or broken, off-balance tape reels could disintegrate spectacularly, spreading plastic shrapnel throughout much of the machine.
Then, there were the CPUs

The 3168—IBM’s de facto flagship in 1977

• This picture does not convey the sheer scale of this machine:
  • CPU frames ~7’ high
  • Processor alone weighed nearly 3 ½ tons (6,881 lbs)
  • It took time to walk by the CPU, console, CDU, PDU, and channel frames—MPs took more than double the space
  • Channel-to-CPU cables nearly filled the space between 18” high raised floor posts across two floor tiles (4’ wide)
  • 6.3 KVA for the CPU alone

• Could run an MP as two “physically partitioned” UPs
Did I mention the number of cables? Some over 100’ long, and heavy. The rule for which end to plug in where was, “Light grey away.”
3168 Block Diagram

The 168 was the basis for many later designs, and elements of its design still persist in today’s servers.
Hardware Diagnosis Wasn’t Always Easy...

Shooting the bugs...

- Components were discrete before SLT packaging:
  - Transistors
  - Resistors
  - Capacitors
  - Inductors
- CEs used microcode and software diagnostics, printed logic diagrams and oscilloscopes
- Processor diagnosis often involved putting instructions into memory manually from the console using switches and dials...
- …and then following the bug circuit by circuit until the problem was found
- Intermittent problems could be solved over time by using the ‘scope’s “single sweep” mode to monitor events one at a time
The E-Unit could be a bit difficult to diagnose problems in at times…but today’s are all *part* of one chip!
• Cycle time: 80ns
  • About 1/416th the speed of a single z196 CP
• Max storage 8MB (16MB for an MP!)
  • That’s less than 25% of the space needed to store the scans of the cartoons in this presentation…and 1/2000th of my phone’s memory
• Worst-case storage access time: About 480ns (6 machine cycles, for a partial Store; most storage operations took 4 machine cycles, or 320ns)
• Board-to-board and frame-to-frame interconnections were done with “trileads,” a semi-shielded three-part wire with push-on connectors
• Power-on-Reset (POR) set the TOD clock to 0 and loaded the microcode
• Console characters were drawn on the screen with continuous lines (not pixelated)
Some people apparently thought the overall design could stand improvement...
More 3168 Trivia

• Fed by a big, honkin’ 240V 415Hz AC motor generator
• Cooled with (lots of!) chilled water (~30 Gal/m @ 52°F) through a large water-to-water heat exchanger in the Coolant Distribution Unit (CDU) and water-to-air exchangers inside the CPU frames
• HSM (High-Speed Multiply) internals were a trade secret, not disclosed even to CE
• Up to 12 channels in separate frames connected with cables
  • Maximum channel data rate was 1.5 MB/sec
  • Only tape drives and 2305s could get close to that (3420’s could read 6250 BPI at 800 IPS, minus overhead for IBGs, etc.)
Needless to say, 8 MB was a lot of storage back then…
Ever hear a coworker say “Hit Load” and wonder….?
More CPUs

• The 3033’s were almost as big
  • But the new, 3270-based console was a bit smaller
  • No separate channel frames; “directors” were introduced, putting the channel subsystem entirely under the covers of the CPU, which reduced the total system footprint quite a bit
• Maximum channel speed doubled to 3 MB/sec (the new cables were blue instead of grey but still had dark grey and light grey ends)
  • Maximum memory 16MB (32 for an MP!)
• Cycle time: 57ns
• Memory access time: 5 or 8 machine cycles (285 / 456 ns)
Then, there were operating systems

• But…what about the software?

• PCP
• MFT
• MVT
• SVS
• MVS™
• MVS/SP™
• MVS/XA™
• MVS/ESA™
• OS/390®
• z/OS®
In the beginning...there were punched cards...

- ...and Core Storage and PCP
  - No, nothing to do with Phencyclidine
  - PCP was the Primary Control Program
  - 32KB of main storage
  - Available in March 1966
- The life of an operator using PCP:
  - IPL from a card deck
  - Read in a job from another card deck
  - Job starts to process
  - Go hang tapes, feed printer, etc. as needed
  - Job finishes, machine goes into a wait state
  - Repeat
Despite its one-job-at-a-time programming model, PCP was well-designed for its time:

- The machines were incredibly slow by today’s standards, with cycle times in the microsecond range
- Machine utilization was actually pretty good except when the system was doing I/O because:
  - There wasn’t that much data at first
    - A typical YouTube video might have required millions of punched cards…which could be read at the rate of about 300/minute
  - There wasn’t enough memory to do any more, anyway!
- “Job scheduling” had to do only with whose job ran when
• Still on core storage…
• But we learned how to make more of it, faster
• We could multi-task as we waited for I/O…at last!

• OS/MFT was born in 1966
  • Fence off storage areas in real memory, called “partitions”
  • Run a separate job in every partition
  • Re-IPL to change the number of partitions or their sizes
  • 64KB of storage!
• “Job scheduling” took on a whole new meaning; not every job could run in the order it was handed to an operator as it could have been under PCP. IPLs often scheduled at specific times every day.
• MFT was “Multiprogramming (with a) Fixed (number of) Tasks”
• MVT supported Variable tasks
• No IPL to change partition sizes any more!

• OS/MVT, 1967:
  • Still real storage based – 128KB
  • Still ran a separate job in every region
  • Job scheduling became a bit easier since one need not re-IPL to change partition sizes, but still highly limited by the machine’s capacity
  • Online work begins to “interfere with” batch work at about this time
MVT could run up to 15 jobs concurrently.

The initiators selected jobs from the queue, carved out the real memory to satisfy the region requirements, allocated data sets and passed control to the application programs.
The World Goes Virtual with SVS

• SVS (Single Virtual Storage) was introduced in 1972
• Virtual storage! One 16 MB address space
• Partition it however you want
• Back it with enough real storage and paging to make it all work
• The OS didn’t take much storage back then, so most virtual storage was available for programs
Multiple Virtual Worlds with MVS

• MVS, 1974
• Multiple Virtual Storage = Multiple address spaces!
• Memory fragmentation (which forced frequent IPLs of SVS by today’s standards) was much less a problem because initiators could be stopped and restarted to clean up when necessary
• Symmetric Multiprocessing introduced (3158, 3168, perhaps 3165 and 3155)
• JES2 and JES3 introduced
  • JES2 based on HASP
  • JES3 based on ASP
Setting the bar for serious business

The Philosophy of MVS

- Assume the work is mission critical
- Allow no undetected errors
- Isolate all failures to the smallest affected unit of work
- Provide diagnostics from the first failure sufficient to debug the problem
- Allow no program access to data it is not authorized to access
Reliability, Availability, Serviceability

Availability is intrinsic to the design

- System (and subsystem) code is "covered" by a recovery routine.
- Critical code has "nested recovery" to cover the recovery routines.
- Diagnostic data specific to the error is gathered and reported.
- Retry is attempted whenever possible after repairing damage and isolating the failure.
RAS is big business

- MVS RAS Guidelines
  - A lot of the code of any component (or subsystem) is devoted to RAS.
  - Hundreds of thousands of lines of RAS infrastructure code.
  - Tremendous synergy with hardware platform
  - Commitment to first failure data capture
  - Industry-unique commitment to system integrity
The MVS/SP Version 1 Virtual Storage Map

• Hey, back then 16 MB was a lot!
• Nobody had yet imagined GUIs.
• There was a lot to remember.
• So, we had reference cards. Lots of reference cards.
• You’ve probably heard of this one—the “Green Card.”
• But there were cards before the green one

• Like this one, a JCL reference card for PCP and MFT

• It was originally white but has yellowed with age

• (Bob Hout gave me this card when he retired several years ago)
• Here’s an Attached Support Processor (ASP) reference card
• ASP was JES3’s forerunner, and it included Dynamic Support Programs (DSPs)
• As with JES3, commands started with an asterisk (*)
• If you’ve ever heard anyone say (or seen the SHARE button that says) “JES3 is a ‘half-ASP’ system,” now you know what they meant
Reference Cards

- Here are a few more:
Reference Cards

• and some more:
IPL processing got a bit more complicated…

IPL, load the segment table, build the LSQA’s, load the page table, find the external page table, load the page, do the job, do this, do that, ....... whee! what a day!!
As did diagnosis…
• Notwithstanding the prior chart…
• AMDPRDMP was the forerunner to IPCS
• A standalone dump took about half a box of paper on a large, busy system…at least, until XA came along:
  • With MVS/XA, a typical standalone dump was like Midwestern corn by the 4th of July—that is, “knee high.”
  • With MVS/ESA, with dataspace storage, they could be…well…bigger!
• With 64-bit z/OS, it’s a Good Thing we have IPCS.
MVS/XA

- MVS/XA Version 2 was introduced in 1981
- 31-bit addressing hits the streets
- 2 GB of virtual storage per address space looked like infinite space back then (you can trust me on this)
- Required new hardware, 3083, 3081 or 3084 (3084 pictured)
- Introduction of Dynamic Path Selection on DASD controllers
- Hardware and software both incredibly reliable by early 1980’s standards
  - Months between IPLs vs. days or weeks
  - We found out we had been relying on frequent IPLs for some business processes
  - And, we found new problems related to the longer life of an IPL—like initiator fragmentation, now (mostly) a thing of the past
The MVS/XA Version 2 Virtual Storage Map

• After 16 MB…

• …2 GB looked like it would last us a long time…

• …which, of course, it did not.
MVS/ESA

- MVS/ESA Version 3, 1988
- Introduced access registers, linkage stacks, data spaces, and Hiperspace™
- PR/SM introduced on 3090 at about the same time, creating LPAR mode (later the only mode) in addition to Basic Mode
- System-Managed Storage (SMS) introduced, with the Interactive Storage Management Facility (ISMF)
- LLA and VLF introduced, along with what is now z/OS UNIX System Services
MVS/ESA, continued

• MVS/ESA SP Version 4, 1991
• Extended Multi-Image Facility (EMIF) introduced for PR/SM™
• MVS/ESA SP 4.1 introduced:
  • Sysplex
  • HCD
• Available on:
  • 1600 or 6250 bpi open-reel tape
  • 3480 (uncompressed only)
MVS/ESA, continued

- MVS/ESA SP Version 5, 1994
  - Parallel Sysplex® introduced
    - IMS™ data sharing is first exploiter
  - Workload Manager (WLM) is introduced
    - Defined policies for the system’s workloads
    - Goal-based performance management
    - CICSPlex®/SM and VTAM® are first cross-system exploiters
OS/390 – Putting it All Together

• OS/390, 1996

  • 72 products in one*!
    • Former products became “elements” of OS/390, some at no additional charge, some not
  • All tested together, at the same time
    • Intended to improve quality by letting us focus our test efforts
  • Ordering became simpler—checklist was much shorter because there were fewer options
  • New installation vehicle, ServerPac, replaced CBIPO

*OK, so not all of them were separate products.
z/OS – The Next Generation

- z/OS, 2000
  - The beginning of 64-bit addressing
    - First exploiters were access methods, HFS, XRC, and DB2
  - Support for IRD
    - WLM moves work to resources
    - IRD moves resources to work
      - LPAR CPU management
      - I/O priority queueing
      - Dynamic Channel Path Management
  - Workload license charges introduced
  - SNA Master Console Support
  - ServerPac provides a Recommended System Layout function to automatically place data sets on volumes
The z/OS R9 Virtual Storage Map

• We are hopeful that 16 EB will last us at least a few more months…

• …and if it’s not, I’m not sure what we’ll do next…

• One wag noted that 128-bit addressing would require more silicon atoms than we think there might be in the known universe
The z/OS R12 Virtual Storage Map

Note that the area below the Bar is just marked “below 2 GB”!

(No, I don’t know why we didn’t call the area from 2-4 GB “The Dead Zone.”)

2011 update: The 2-4GB area is now used for Java™ processing
Over 40 Years of Innovation

<table>
<thead>
<tr>
<th>S/360</th>
<th>S/370™</th>
<th>S/390®</th>
<th>zSeries</th>
<th>System z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Models 40, 50, 65, 90, 91</td>
<td>3195</td>
<td>3145 3158 3031 3032 3155 3168 3033</td>
<td>3081, 3083, 3090 3084</td>
<td>ES/9000® 64, 65, 66</td>
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<td>MFT</td>
<td>MVT</td>
<td>MVS</td>
<td>MVS/XA</td>
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<td>RTM</td>
<td>TSO</td>
<td>RACF</td>
<td>DFP</td>
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<td>SVS OS/VS1</td>
<td>JES2 JES3</td>
<td>IFO</td>
<td>SMS</td>
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<td>OS/VS2</td>
<td>ISMF</td>
<td>VTAM</td>
<td>PDSE</td>
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<td>AC R</td>
<td>HIPERVF</td>
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<td>Cross-memory</td>
<td>31-bit</td>
<td>Hiperspace</td>
<td>ServerPac</td>
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</table>

- IMS NCP
- CICS
- DB2
- WebSphere
- Assembler
- COBOL
- C
- C++
- JAVA J2EE
- XML
- HTML
- Application investment protection
Speed, speed, and more speed

- Stealing a trick out of Grace Hopper’s book…
  - Here’s a nanosecond’s worth of wire…
  - Here’s the cycle time of a 3168…
  - Here’s the cycle time of a z196

- You can start to see one of the problems facing the industry this way

- n-way scalability seems likely to become the order of the day for a while…
  - When you last shopped for a home computer, how many were single-core?

- …with horizontal scalability becoming necessary at some point

- The NextGen message? Learn to multiprogram and multithread well!
N-way Scale on MVS – z/OS

- MP (2-way) support with OS/VS2 Release 2 in 1974
  - zAAPs and zIIPs didn’t exist then)
- 16-way support with MVS/XA™ in 1983
  - 3084 MP was 4-way
  - 3090-600 was 6-way
  - (No zAAPs or zIIPs then, either!)
- 32-way support with z/OS R6 on z990 servers in 2005
  - Sum of CPs, zIIPs, and zAAPs in one z/OS LPAR
- 54-way support with z/OS R9 on IBM System z9 EC servers in 2007
  - Likewise, the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR
- 64-way support with z/OS R9 on IBM System z10 EC servers in 2008
  - Still the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR
- 80-way support with z/OS R11 on IBM zEnterprise 196 servers in 2010
  - This remains the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR
Other Trivia
Another 168 console pushbutton:

Nothing to do with “fortified” wine: It set a 1-byte data pattern from eight separate console toggle switches into every byte of real memory.

http://en.wikipedia.org/wiki/Thunderbird_(wine)
Thanks for attending
Hope you had fun...I did!
The Future Runs on System z
A SHAREd History of the Mainframe – Chronicles, Artifacts, and Stories

John Eells
IBM Poughkeepsie
SHARE 116, Session 9022
March 2, 2011

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RMF
RPM
Series i
Series Storage
System 2
System z
System z10
SystemPac®
TRAD®
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z/Architecture®
z/OS®
z/VM®

Notes:

PERFORMANCE is in Internal Throughput Rate (ITR) ratio based on measurements and projections using standard IBM benchmarks in a controlled environment. The actual throughput that any user will experience will vary depending upon considerations such as the amount of multiprogramming in the user’s job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput improvements equivalent to the performance ratios stated here.

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Where we are today…
A smarter operating system

**Improving Usability and Skills**
- z/OSMF Software
- Deployment and Storage Management applications,
  User-level mount command for z/OS UNIX System Services,
  Automatic F4DSCB updates, SDSF Sysplex functions to work without
  MQ, Catalog parmilib member, Better O/C/EOV Messages, Health Checks, …

**Self Managing Capabilities**
- WLM and RMF to provide response time distribution for all
  goals, DFSMShsm Journal Backup and space management improvements, …

**Enhancing Security**
- RRSF over TCP/IP, LDAP improvements, SAF security for
  z/OSMF, NAS address checking and encryption negotiation, New restricted
  QNAMEs, PKI support for DB2 backstore, ICSF support for new
  HMACs, FTP & TN3270 password phrase support, …

**Integrating new Applications and Supporting Industry and Open Standards**
- Java/COBOL interoperability, Improved Support for named sections, ISPF Edit Macros,
 Subsystem and Unauthorized XTIOT support, dbx hookless debug, DFSORT improvements,
  Job level return codes, …

**Extending the Network**
- IDS IPv6 support, NAT Traversal for IKEV2, NMI extensions, More VLANs per
  OSA port, more 64-bit TCP/IP, EE improvements, …

**Scalability & Performance**
- Fully-shared zFS in a sysplex, RMODE 64 extensions, IFASMFDL improvements,
  500K+ aliases per user catalog, Larger VVDSs, FREE=EOV, FTP support for large format
  data sets and EAS,…

**Improving Availability**
- Warn before TIOT exhaustion, CMDS enhancements, Parallel
  FTP for dump transfers, PFA ENQ tracking, RTD improvements, zFS Refresh,
  DADSM Dynamic Exits, JES3 dynamic spool addition, Better channel recovery, More ASID
  reuse, …

**Extending the Network**
- IDS IPv6 support, NAT Traversal for IKEV2, NMI extensions, More VLANs per
  OSA port, more 64-bit TCP/IP, EE improvements, …

---

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  change or withdrawal without notice, and represent goals and objectives only.
Integration and exploitation of IBM zEnterprise System

• IBM introduces the IBM zEnterprise System -- a system that combines the gold standard of enterprise computing with built-in function to extend IBM's mainframe-like governance and quality of service to special-purpose workload optimizers and general-purpose application serving. End-to-end management is enabled for this heterogeneous environment by the IBM zEnterprise Unified Resource Manager, which provides energy monitoring and management, goal-oriented policy-based workload monitoring and management, increased security, virtual networking, and data management, consolidated in a single interface that can be tied to business requirements. An IBM zEnterprise System is composed of the IBM zEnterprise 196, the IBM zEnterprise Unified Resource Manager, the IBM zEnterprise BladeCenter Extension (zBX), and optimizers or blades.

• The IBM zEnterprise 196 server adds additional scalability and performance capabilities for your z/OS environment.

  • The new 96-way core design (with 80 cores that are customer configurable) delivers massive scalability for secure data serving and transaction processing for large-scale businesses. The performance of a z196 (2817) processor is expected to be 1.3 to 1.5 times the performance of a z10 EC (2097) based on workload and model. The largest z196 (2817-780) is expected to exceed 1.6 times the capacity of the largest z10 (2097-764). It has up to twice the available real memory, 3 terabytes (TB) per server (with up to 1 TB real memory per LPAR) compared to the z10 EC Model E64. New quad-core 5.2 GHz processor chips, with more than 100 new instructions to enable improved code efficiency, are also designed to help improve the execution of Java and CPU-intensive workloads. For example,
Where we’ve been…
It all started with…

▪ …Herman Hollerith’s punched cards…
▪ …and their influence continues to affect us today!

▪ Ever wonder…
  ➢ Why the 3270 default screen size is 24x80?
  ➢ Why we have a “block size” concept?
  ➢ Why we have data sets with sequence numbers?
Punched Cards, Continued…

• How did you know the holes were in the right places?
• With a card registration plate, of course!
• Still standard issue in the 1970’s
Rear view of card registration plate

THE REGISTRATION OF ALL CARD PUNCHING EQUIPMENT SHOULD BE CHECKED ONCE EACH DAY. THIS GAUGE SHOULD BE USED TO CHECK THE REGISTRATION OF ALL KEY PUNCHES, REPRODUCING PUNCHES, AND CALCULATING PUNCHES.

TO USE THIS GAUGE, PUNCH A TEST CARD WITH 12-9 DIAGONALLY ACROSS 80 COLUMNS AND PLACE THE CARD FACE UP 12 EDGE TO THE TOP FIRMLY AGAINST THE GUIDES AT TOP AND RIGHT HAND END.

ANY MACHINES OUT OF REGISTRATION SHOULD BE REPORTED TO YOUR SUPERVISOR IMMEDIATELY.
Punched Cards, Continued…

- It’s hard to believe this now, but punched cards were pervasive!
- Many bills and warranty cards were printed on punched cards
- “Do not fold, spindle, or mutilate…”
- This card came with my garbage disposal many moons ago:

![Image of a punched card]
What’s a Card Jam?

• When two cards tried to fit into the space meant for one, how did you get them out?

• You used a card saw…

• Once standard issue in CE tool bags, the thin (.010” or so), spring-steel card saw was essential if you worked on card readers, punches, or keypunch machines.

• It would clear out the card jam…eventually.

IBM 129 Card Removal Tool image courtesy of Mike Loewen, Pennsylvania State University (PSU)
Of course, IBM used punched cards, too:

An operator named Carol K. wrote this MTN against a printer I fixed in 1980...and I obviously forgot to return the card because I found it in my old tool bag in 2007!
Punched Cards, Continued…

• An IBM 029 Keypunch, 1964
• Not exactly a laptop!
• It existed only to punch holes in cards
• Blank cards in feeder on top right; punched ones in stacker on left; chad bin underneath
• No error correction, of course; cards with typos went into the trash can (which is conspicuously absent in this photo)
• This is actually a model with an optional drum-mounted “template card” (I can’t recall the actual name) to speed things up
• There were no PDAs, then, but there was…
• The Port-A-Punch!

• “Designed to fit in the pocket”
  • I suppose pockets might have been larger then (some things were even before my time, after all)

• Not exactly a BlackBerry® handheld device!

Port-A-Punch

IBM’s Supplies Division introduced the Port-A-Punch in 1958 as a fast, accurate means of manually punching holes in specially scored IBM punched cards. Designed to fit in the pocket, Port-A-Punch made it possible to create punched card documents anywhere. The product was intended for "on-the-spot" recording operations -- such as physical inventories, job tickets and statistical surveys -- because it eliminated the need for preliminary writing or typing of source documents.
Punched Cards, Continued…

• An IBM 77 Collator
• A collator is the opposite of a sorter
• For some things, you didn’t need a computer to make punched cards useful
• Today, we use things like SORT/MERGE’s descendant, DFSORT
• The industry did have to invent some things:
  • Parity (IBM uses odd parity)
  • NRZI recording for tape
  • CRC and LRC checking algorithms
  • ECC memory
  • Microcode
  • …the list goes on and on
Printers

- Printers like this 1403 came with a print train or print chain
- A hydraulic unit—sort of a 2-speed mini-automatic transmission—drove the tractors to move the paper
- Spacing and skips were controlled by a 12-channel carriage tape
  - It was just *amazing* how fast a box of paper could empty when one broke…
- Don’t leave a cup of coffee on top!
  - Some models raised the cover automatically when out of paper to catch an operator’s attention
Disk drives

- The 2314
- 9 drawers to a “bank” (because they were high maintenance, you could only use up to 8 at a time)
- Hydraulic pistons moved heads in & out of removable disk packs
- Removable disk packs and address plugs moved together to keep the same address for the same volume
- Don’t drop a disk pack! (The bits would fall off.)

Introduced in 1965, the IBM 2314 Direct Access Storage Facility provided eight independently operating disk drives and a spare along with a control unit in one facility. Users of large-scale computer systems could attach enough 2314s to provide nearly 10 billion bytes of data storage.
The IBM 3330 Data Storage (seen here in a design model) was a high-performance, high-capacity direct access storage subsystem for use with all IBM System/370 models as well as the IBM System/360 Model 195. Each 3330 subsystem could have from two to 16 drives, giving users up to 1.6 billion bytes of online storage. Developed and manufactured at IBM's facilities in San Jose, Calif., the 3330 was announced in 1970 and withdrawn from marketing 13 years later.
Disk drives

• A 3330 disk pack, called a 3336, alongside two Mass Storage Subsystem (3851) cartridges
• 10 2-sided data platters
• 19 data tracks per cylinder with 1 servo track
SHARE button image courtesy of Barry Merrill, Merrill Consultants
Tape drives

• The IBM 2420
• 1600 bpi!
• “Stubby” triangular vacuum columns at the top helped reduce start/stop inertia
• “Autoloading” tape covers
• Don’t forget the Write Ring! (Ever wonder where “RING” and “NORING” came from in the JES3 mount messages?)

Write Ring
Tape drives

- The IBM 3420, 1970
- Up to 6250 bpi!
- Odd models (3, 5, 7) were 1600 bpi only
- Even models (4, 6, 8) were 1600/6250 “Dual Density”
- Models 7 and 8 moved tape at 800 IPS
- High-speed rewind was *fast!* Cracked or broken, off-balance tape reels could disintegrate spectacularly, spreading plastic shrapnel throughout much of the machine.
Then, there were the CPUs

The 3168—IBM’s de facto flagship in 1977

• This picture does not convey the sheer scale of this machine:
  • CPU frames ~7’ high
  • Processor alone weighed nearly 3 ½ tons (6,881 lbs)
  • It took time to walk by the CPU, console, CDU, PDU, and channel frames—MPs took more than double the space
  • Channel-to-CPU cables nearly filled the space between 18” high raised floor posts across two floor tiles (4’ wide)
  • 6.3 KVA for the CPU alone

• Could run an MP as two “physically partitioned” UPs

The 3168 is shown with its Power and Cooling Distribution Units (PDU and CDU) behind it to the left and its console ahead of it; a 3803 control unit & 3420 tape drives to the far left; a 3830 control unit & 3330 disk drives on the far right; a 327x terminal, 3505 reader & 3525 punch in the left foreground; and 3211 printers in the right foreground. I can’t identify the box in the far right rear; it might be a 2701 or 2703 communications controller.

The displays on the left showed the state of various bits and pieces of hardware with indicator lights. Rotating knobs changed the labels and meanings of the lights. One light’s label was, simply, “Always On.” When the machine was powered up…it was!
Did I mention the number of cables? Some over 100’ long, and heavy. The rule for which end to plug in where was, “Light grey away.”
The 168 was the basis for many later designs, and elements of its design still persist in today's servers.

Instruction-Unit (I-Unit) → Storage Control (SCU) → Channels

Execution-Unit (E-Unit) → High-Speed Buffer → Main Storage

Translation Lookaside Buffer (TLB)
Hardware Diagnosis Wasn’t Always Easy…

**Shooting the bugs…**

- Components were discrete before SLT packaging:
  - Transistors
  - Resistors
  - Capacitors
  - Inductors
- CE's used microcode and software diagnostics, printed logic diagrams and oscilloscopes
- Processor diagnosis often involved putting instructions into memory manually from the console using switches and dials…
- …and then following the bug circuit by circuit until the problem was found
- Intermittent problems could be solved over time by using the 'scope's "single sweep" mode to monitor events one at a time
The E-Unit could be a bit difficult to diagnose problems in at times…but today's are all *part of one chip!*
## 3168 Trivia

- Cycle time: 80ns
  - About 1/416th the speed of a single z196 CP
- Max storage 8MB (16MB for an MP!)
  - That's less than 25% of the space needed to store the scans of the cartoons in this presentation...and 1/2000th of my phone's memory
- Worst-case storage access time: About 480ns (6 machine cycles, for a partial Store; most storage operations took 4 machine cycles, or 320ns)
- Board-to-board and frame-to-frame interconnections were done with “trileads,” a semi-shielded three-part wire with push-on connectors
- Power-on-Reset (POR) set the TOD clock to 0 and loaded the microcode
- Console characters were **drawn** on the screen with continuous lines (not pixelated)
Some people apparently thought the overall design could stand improvement…
• Fed by a big, honkin’ 240V 415Hz AC motor generator
• Cooled with (lots of!) chilled water (~30 Gal/m @ 52°F) through a large water-to-water heat exchanger in the Coolant Distribution Unit (CDU) and water-to-air exchangers inside the CPU frames
• HSM (High-Speed Multiply) internals were a trade secret, not disclosed even to CEs
• Up to 12 channels in separate frames connected with cables
  • Maximum channel data rate was 1.5 MB/sec
  • Only tape drives and 2305s could get close to that (3420’s could read 6250 BPI at 800 IPS, minus overhead for IBGs, etc.)
Needless to say, 8 MB was a lot of storage back then…
Ever hear a coworker say “Hit Load” and wonder….?
More CPUs

- The 3033’s were almost as big
  - But the new, 3270-based console was a bit smaller
  - No separate channel frames; “directors” were introduced, putting the channel subsystem entirely under the covers of the CPU, which reduced the total system footprint quite a bit
  - Maximum channel speed doubled to 3 MB/sec (the new cables were blue instead of grey but still had dark grey and light grey ends)
- Maximum memory
  16MB (32 for an MP!)
- Cycle time: 57ns
- Memory access time:
  5 or 8 machine cycles
  (285 / 456 ns)

3033 shown with PDU and CDU to the back left and L-shaped 3270-based console in front. 3800 printer on the left has the optional Burster/Trimmer/Stacker feature; it’s next to a 3505 card reader and 3525 punch. The box to the right rear might be a 3851 Mass Storage Subsystem (MSS). 3330s to the far right may have been MSS staging drives; they are flanked by 3350 disk drives.
Then, there were operating systems

• But…what about the software?
  • PCP
  • MFT
  • MVT
  • SVS
  • MVS™
  • MVS/SP™
  • MVS/XA™
  • MVS/ESA™
  • OS/390®
  • z/OS®
In the beginning…there were punched cards…

• ...and Core Storage and PCP
  • No, nothing to do with Phencyclidine
  • PCP was the Primary Control Program
  • 32KB of main storage
  • Available in March 1966

• The life of an operator using PCP:
  • IPL from a card deck
  • Read in a job from another card deck
  • Job starts to process
  • Go hang tapes, feed printer, etc. as needed
  • Job finishes, machine goes into a wait state
  • Repeat

SHARE button image courtesy of Barry Merrill, Merrill Consultants
Despite its one-job-at-a-time programming model, PCP was well-designed for its time:

- The machines were incredibly slow by today’s standards, with cycle times in the microsecond range
- Machine utilization was actually pretty good except when the system was doing I/O because:
  - There wasn’t that much data at first
    - A typical YouTube video might have required millions of punched cards…which could be read at the rate of about 300/minute
  - There wasn’t enough memory to do any more, anyway!
  - “Job scheduling” had to do only with whose job ran when
OS/MFT

• Still on core storage…
• But we learned how to make more of it, faster
• We could multi-task as we waited for I/O…at last!

• OS/MFT was born in 1966
  • Fence off storage areas in real memory, called “partitions”
  • Run a separate job in every partition
  • Re-IPL to change the number of partitions or their sizes
  • 64KB of storage!
  • “Job scheduling” took on a whole new meaning; not every job could run in the order it was handed to an operator as it could have been under PCP. IPLs often scheduled at specific times every day.
OS/MVT

- MFT was “Multiprogramming (with a) Fixed (number of) Tasks”
- MVT supported Variable tasks
- No IPL to change partition sizes any more!

OS/MVT, 1967:
- Still real storage based – 128KB
- Still ran a separate job in every region
- Job scheduling became a bit easier since one need not re-IPL to change partition sizes, but still highly limited by the machine’s capacity
- Online work begins to “interfere with” batch work at about this time

SHARE button image courtesy of Barry Merrill, Merrill Consultants
Layout of real memory under MVT

MVT could run up to 15 jobs concurrently.

The initiators selected jobs from the queue, carved out the real memory to satisfy the region requirements, allocated data sets and passed control to the application programs.
The World Goes Virtual with SVS

- SVS (Single Virtual Storage) was introduced in 1972
- Virtual storage! One 16 MB address space
- Partition it however you want
- Back it with enough real storage and paging to make it all work
- The OS didn’t take much storage back then, so most virtual storage was available for programs

Ribbon image courtesy of Barry Merrill, Merrill Consultants

3155 processor shown, flanked by 3330 disk drives with a 3830 control unit on right, a remote 3215 console and 3420 tape drives on left, a rear view of two 1403-N1 printers in the right foreground with a 2821 control unit to their left. Behind the 2821 is a 2540 card reader/punch; to its right is a 3211 printer.

This note is a formal non-working paper of the Project MAC Computer Systems Research Division. It should be reproduced and distributed wherever levity is lacking, and may be referenced at your own risk in other publications.

The Paging Game
By Jeff Berryman

RULES

1. Each player gets several million things.

2. Things are kept in crates that hold 4096 things each.
   Things in the same crate are called crate-mates.

3. Crates are stored either in the workshop or the warehouse.
   The workshop is almost always too small to hold all the crates.

4. There is only one workshop but there may be several warehouses. Everybody shares them.

5. Each thing has its own thing number.

6. What you do with a thing is to zark it. Everybody takes turns zarking.

7. You can only zark your things, not anybody else's.
Multiple Virtual Worlds with MVS

- MVS, 1974
- Multiple Virtual Storage = Multiple address spaces!
- Memory fragmentation (which forced frequent IPLs of SVS by today’s standards) was much less a problem because initiators could be stopped and restarted to clean up when necessary
- Symmetric Multiprocessing introduced (3158, 3168, perhaps 3165 and 3155)
  - JES2 and JES3 introduced
    - JES2 based on HASP
    - JES3 based on ASP

3032 processor shown without its PDU or CDU, with a 3851 MSS to the far left. 3505 reader and 3525 punch shown left of center, 3211 printer right of center. 3330 disk drives to the right rear. 3420 tape drives shown on the right.
Setting the bar for serious business

➤ The Philosophy of MVS
  ✗ Assume the work is mission critical
  ✗ Allow no undetected errors
  ✗ Isoolate all failures to the smallest affected unit of work
  ✗ Provide diagnostics from the first failure sufficient to debug the problem
  ✗ Allow no program access to data it is not authorized to access
Reliability, Availability, Serviceability

Availability is intrinsic to the design

- System (and subsystem) code is "covered" by a recovery routine.
- Critical code has "nested recovery" to cover the recovery routines.
- Diagnostic data specific to the error is gathered and reported.
- Retry is attempted whenever possible after repairing damage and isolating the failure.
RAS is big business

- MVS RAS Guidelines
  - A lot of the code of any component (or subsystem) is devoted to RAS.
  - Hundreds of thousands of lines of RAS infrastructure code.
  - Tremendous synergy with hardware platform
  - Commitment to first failure data capture
  - Industry-unique commitment to system integrity
The MVS/SP Version 1 Virtual Storage Map

• Hey, back then 16 MB was a lot!
• Nobody had yet imagined GUIs.
• There was a lot to remember.
• So, we had reference cards. Lots of reference cards.
• You’ve probably heard of this one—the “Green Card.”
• But there were cards before the green one

• Like this one, a JCL reference card for PCP and MFT

• It was originally white but has yellowed with age

• (Bob Hout gave me this card when he retired several years ago)
• Here’s an Attached Support Processor (ASP) reference card
• ASP was JES3’s forerunner, and it included Dynamic Support Programs (DSPs)
• As with JES3, commands started with an asterisk (*)
• If you’ve ever heard anyone say (or seen the SHARE button that says) “JES3 is a ‘half-ASP’ system,” now you know what they meant

SHARE button image courtesy of Barry Merrill, Merrill Consultants
Reference Cards

• Here are a few more:

IBM System/360
Reference Data

BALD Capacity and
Transmission Time

<table>
<thead>
<tr>
<th>Models</th>
<th>Average Assemble Time</th>
<th>Average Functional Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25 ms</td>
<td>40 ms</td>
</tr>
<tr>
<td>2</td>
<td>35 ms</td>
<td>50 ms</td>
</tr>
</tbody>
</table>

The formulas used to determine capacity and measured average transmission time are as follows:

- Capacity: Power-on Time = (Power-on Time) / (Power-off Time) in ms
- Average Transmission Time = (Average Transmission Time) / (Average Transmission Time) in ms

For a detailed description of these operations, see IBM System/360 Reference Data and IBM System/360 Reference Data, Vol. 2.

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Reference Cards

• ...and some more:

IBM 3330 Series Disk Storage
3333 Models 1 and 11
3330 Models 1, 2 and 11
Reference Summary

IBM Reference Card
Decimal-Hexadecimal Fraction Conversion Chart

Program Update Tape
with SMP4
Reference Guide
IPL processing got a bit more complicated…

IPL, load the segment table, build the ISQ's, load the page table, find the external page table, load the page, do the IOC, do this, do that, ....... whew! what a day!!
As did diagnosis…
Diagnosis

• Notwithstanding the prior chart...
• AMDPRDMP was the forerunner to IPCS
• A standalone dump took about half a box of paper on a large, busy system…at least, until XA came along:
  • With MVS/XA, a typical standalone dump was like Midwestern corn by the 4th of July—that is, “knee high.”
  • With MVS/ESA, with dataspace storage, they could be…well…bigger!
  • With 64-bit z/OS, it’s a Good Thing we have IPCS.
<table>
<thead>
<tr>
<th>MVS/XA</th>
<th>MVS/XA Version 2 was introduced in 1981</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31-bit addressing hits the streets</td>
</tr>
<tr>
<td></td>
<td>2 GB of virtual storage per address space looked like infinite space back then (you can trust me on this)</td>
</tr>
<tr>
<td></td>
<td>Required new hardware, 3083, 3081 or 3084 (3084 pictured)</td>
</tr>
<tr>
<td></td>
<td>Introduction of Dynamic Path Selection on DASD controllers</td>
</tr>
<tr>
<td></td>
<td>Hardware and software both incredibly reliable by early 1980’s standards</td>
</tr>
<tr>
<td></td>
<td>Months between IPLs vs. days or weeks</td>
</tr>
<tr>
<td></td>
<td>We found out we had been relying on frequent IPLs for some business processes</td>
</tr>
<tr>
<td></td>
<td>And, we found new problems related to the longer life of an IPL—like initiator fragmentation, now (mostly) a thing of the past</td>
</tr>
</tbody>
</table>

SHARE button images courtesy of Barry Merrill, Merrill Consultants
The MVS/XA Version 2 Virtual Storage Map

• After 16 MB...

• ...2 GB looked like it would last us a long time...

• ...which, of course, it did not.
MVS/ESA

- MVS/ESA Version 3, 1988
- Introduced access registers, linkage stacks, data spaces, and Hiperspace™
- PR/SM introduced on 3090 at about the same time, creating LPAR mode (later the only mode) in addition to Basic Mode
- System-Managed Storage (SMS) introduced, with the Interactive Storage Management Facility (ISMF)
- LLA and VLF introduced, along with what is now z/OS UNIX System Services

SHARE button images courtesy of Barry Merrill, Merrill Consultants
• MVS/ESA SP Version 4, 1991
• Extended Multi-Image Facility (EMIF) introduced for PR/SM™
• MVS/ESA SP 4.1 introduced:
  • Sysplex
  • HCD
• Available on:
  • 1600 or 6250 bpi open-reel tape
  • 3480 (uncompressed only)
MVS/ESA, continued

• MVS/ESA SP Version 5, 1994
  • Parallel Sysplex® introduced
    • IMS™ data sharing is first exploiter
  • Workload Manager (WLM) is introduced
    • Defined policies for the system’s workloads
    • Goal-based performance management
    • CICSPlex®/SM and VTAM® are first cross-system exploiters

SHARE button image courtesy of Barry Merrill, Merrill Consultants
• OS/390, 1996
  • 72 products in one*!
    • Former products became “elements” of OS/390, some at no additional charge, some not
  • All tested together, at the same time
    • Intended to improve quality by letting us focus our test efforts
  • Ordering became simpler—checklist was much shorter because there were fewer options
  • New installation vehicle, ServerPac, replaced CBIPO

*OK, so not all of them were separate products
z/OS – The Next Generation

• z/OS, 2000
  • The beginning of 64-bit addressing
    • First exploiters were access methods, HFS, XRC, and DB2
  • Support for IRD
    • WLM moves work to resources
    • IRD moves resources to work
      • LPAR CPU management
      • I/O priority queueing
      • Dynamic Channel Path Management
  • Workload license charges introduced
  • SNA Master Console Support
  • ServerPac provides a Recommended System Layout function to automatically place data sets on volumes
### The z/OS R9 Virtual Storage Map

- We are hopeful that 16 EB will last us *at least* a few more months…
- …and if it’s not, I’m not sure what we’ll do next…
- One wag noted that 128-bit addressing would require more silicon atoms than we think there might be in the known universe

<table>
<thead>
<tr>
<th>Private</th>
<th>16 EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared Area</td>
<td>512 TB</td>
</tr>
<tr>
<td>Low User</td>
<td>2 TB</td>
</tr>
<tr>
<td>Reserved</td>
<td>4 G</td>
</tr>
<tr>
<td>2 G</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Extended Private</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended SQA</td>
<td>16 Mb</td>
</tr>
<tr>
<td>Extended Nucleus</td>
<td></td>
</tr>
<tr>
<td>Nucleus</td>
<td></td>
</tr>
<tr>
<td>SQA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Common</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended LSQA/SWA230</td>
<td></td>
</tr>
<tr>
<td>User Region</td>
<td>24K</td>
</tr>
<tr>
<td>System Region</td>
<td>8 K</td>
</tr>
<tr>
<td>PSA</td>
<td>0</td>
</tr>
</tbody>
</table>
The z/OS R12 Virtual Storage Map

Note that the area below the Bar is just marked “below 2 GB”!

(No, I don’t know why we didn’t call the area from 2-4 GB “The Dead Zone.”)

2011 update: The 2-4GB area is now used for Java™ processing
System/360 was introduced in 1964. System z, its successor, is the result of over 45 years of constant innovation and refinement. From the System/360 Model 40 to the zEnterprise 196, and from the beginnings of OS/360 to z/OS, new capabilities and technologies have been added while protecting your investment in existing applications.
Stealing a trick out of Grace Hopper’s book…
  - Here’s a nanosecond’s worth of wire…
  - Here’s the cycle time of a 3168…
  - Here’s the cycle time of a z196

You can start to see one of the problems facing the industry this way:

n-way scalability seems likely to become the order of the day for a while…
  - When you last shopped for a home computer, how many were single-core?

…with horizontal scalability becoming necessary at some point

The NextGen message? Learn to multiprogram and multithread well!

(All numbers approximate. The velocity factor of wire is variable. However, the ratios should be accurate.)

1’ per nanosecond
80’ for the cycle time of a 3168
2.3” for the cycle time of a z196
N-way Scale on MVS – z/OS

- MP (2-way) support with OS/VS2 Release 2 in 1974
  - zAAPs and zIIPs didn’t exist then.

- 16-way support with MVS/XA™ in 1983
  - 3084 MP was 4-way
  - 3090-600 was 6-way
  - (No zAAPs or zIIPs then, either!)

- 32-way support with z/OS R6 on z990 servers in 2005
  - Sum of CPs, zIIPs, and zAAPs in one z/OS LPAR

- 54-way support with z/OS R9 on IBM System z9 EC servers in 2007
  - Likewise, the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR

- 64-way support with z/OS R9 on IBM System z10 EC servers in 2008
  - Still the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR

- 80-way support with z/OS R11 on IBM zEnterprise 196 servers in 2010
  - This remains the sum of CPs, zIIPs, and zAAPs in one z/OS LPAR
Other Trivia

SONGS of The IBM

SHARES Songbook 1986
Another 168 console pushbutton:

START RIPPLE

Nothing to do with “fortified” wine: It set a 1-byte data pattern from eight separate console toggle switches into every byte of real memory.

http://en.wikipedia.org/wiki/Thunderbird_(wine)
Thanks for Coming

- Thanks for attending
- Hope you had fun…I did!
The Future Runs on System z