GLASSHOUSE SYSTEMS

50 Years of Mainframe Virtualization

VM/370 (and CP/67) to z/VM

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Abstract

- **2022 marks the 55th anniversary of CP/40 going into production and the 50th anniversary of the announcement of VM/370**
- **This presentation will provide an historical view of the evolution of mainframe virtualization over the decades**
- **Workload evolution will also be covered from early time-sharing to DOS/VS guests through to PROFS and now Linux on IBM zSystems**

*The focus of the presentation will be on the evolution of mainframe virtualization through VM/SP R6, but charts on subsequent VM enhancements are included for completeness. This is **NOT** an exhaustive presentation on the history of VM as that would take hours (days?) so I recommend reading the material in the bibliography.*

Speaker

- **Sir Jim the Evangelist is a Knight of VM**
- **Jim spent most of nearly 43 years at IBM working on the various iterations of VM from CP-67/CMS and VM/370 through to today's z/VM**
- **Currently, Jim works at GlassHouse Systems, providing technical support for their mainframe (zSystems and LinuxONE) customers in Canada, Egypt, Jamaica, and the USA**
- **For more information, see my blog at http://jlelliotton.blogspot.ca/**

Note: This presentation is my personal view of highlights of the history of VM and I apologize, in advance, for any errors or omissions. Corrections and/or clarifications are appreciated.

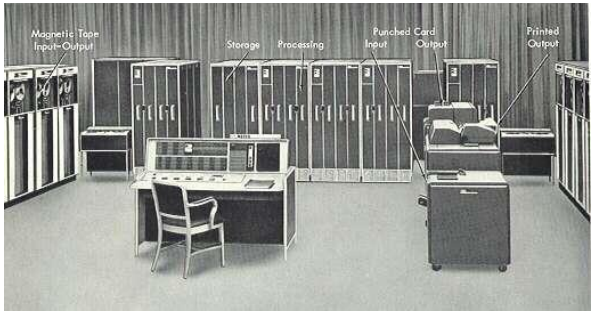
Virtualization leadership born from 50 years of experience

- **Throughout the history of VM, IBM's ground-breaking virtualization software for mainframes, key design principles formed the backbone of the family of VM products**
- **The high-level capabilities of z/VM are grounded in these original key design principles which include:**
  - A virtualization hypervisor, also called the Control Program, that would create virtual machines that replicate the IBM mainframe architecture
  - Interfaces for virtual machines to interact with the hypervisor
  - Comprehensive management of virtual machines through various system services such as accounting, performance monitoring, and security management
  - Ability to run 1000s of virtual machines with diverse or disparate workloads within a single hardware footprint
  - Over commitment of real resources compared to total virtual resources
- **The adaptability of VM ever since the announcement of VM/370 in 1972 has demonstrated IBM's commitment to provide innovative approaches that have in a nutshell, continually helped customers do more with less**

Before CP-67/CMS

Early research projects

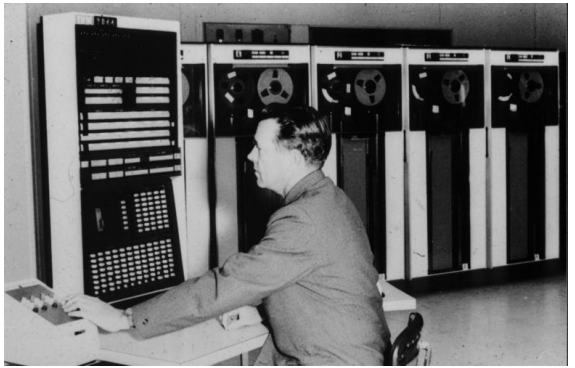
- In 1961 John McCarthy of MIT proposed the idea of a “time-sharing computer system”
- IBM built a 3 terminal system using an IBM 709 (later an IBM 7094) at MIT using IBM 1050 terminals
- In 1961 MIT started development of CTSS (Compatible Time-Sharing System) using the IBM 7094[1]
- Ferranti-Packard (later ICL) in the UK developed OLS (One-Level Store) for their Atlas computer which was the 1st to have a concept of pages (512 words each with a 32 page memory and 200 page drum)[2]



1. Compatible Time-Sharing System (1961-1973) Fiftieth Anniversary Commemorative Overview
2. Features of the Ferranti Atlas Computer May, 1961

Multiple IBM projects

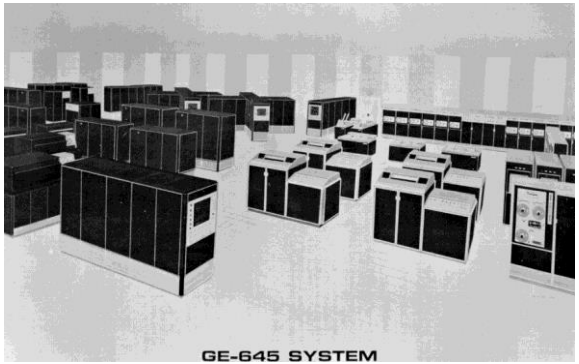
- In 1962 IBM Research modified an IBM 7044 with virtual storage resulting in the M44 which had a control program called the Modular Operating System that created and managed virtual machines
- At the same time, IBM ASDD (Advanced Systems Development Division) modified an IBM 7090 with relocation features and code borrowed from NASA's Project Mercury
- And in 1963, IBM DSD (Data Systems Division) modified an IBM 7040/7044 to run up to 40 "conversational" users in a Fortran environment[1]



1. IBM 7040/7044 QUIKTRAN User's Guide, C28-6800-2

MIT decided not to use any IBM option

- In February 1963 at SHARE, MIT engineers met with Fred Brooks and Gene Amdahl from IBM
- MIT wanted a machine designed to run time-sharing, IBM wanted MIT to use the soon to be announced mainstream system designed for business and scientific purposes
- MIT elected to go with the General Electric 635 (a prototype) later the GE 645
- Bell Telephone Laboratories also decided to go with the GE 645



The IBM response

- **Vin Learson and Dick Watson did not like losing in technology to GE**
- **ASDD and DSD were merged in SDD (Systems Development Division) in January 1965**
- **In August 1965 IBM announced the S/360 Model 67[1], a modified version of the S/360 Model 65 with Dynamic Address Translation, along with the TSS (Time Sharing System[2]) operating system**
  - The S/360-67 was designed to have up to 4 processors!
- **TSS was finally released in October 1967**
  - IBM decided in short order that TSS should be replaced by OS/360's TSO (Time Sharing Option), but TSS still lived on for years

1. IBM System/360 Model 67 Functional Characteristics GA23-2719-2
2. IBM Time-Sharing System/360 Concepts and Facilities Z20-1788-0

MTS – The Michigan Terminal System[1]

- **While IBM was trying to get TSS to work well, other offerings were developed**
- **The University of Michigan initially developed MTS to run on a S/360-50, but later adapted MTS with paging on a 2 processor S/360-67**
- **MTS continued in use for many years**
- **In Vancouver, both the University of British Columbia and Simon Fraser University ran MTS**
  - Initially UBC used a S/360-67 installed at the IBM computing centre in Vancouver before moving “in-house” – this machine became my sandbox to learn CP/67

1. Michigan Terminal System Archive

CP-40 / CP-67 with CMS

CP-40 / CMS

- **CP-40 and CMS were the result of a research effort at IBM Research's Cambridge Scientific Center**
- **Four goals:**
  1. Research into time-sharing techniques and methods
  2. Examine hardware requirements for time-sharing
  3. Development of a time-sharing system for internal use
  4. Development of a method for observing the interaction between operating systems and hardware
- **System/360 Model 40 modified with an address translation mechanism designed by Gerrit Blaauw (known then as the "Blaauw box", later as the "DAT box")**
- **Two independent software components**
  - CP-40 – the Virtual Machine Control Program – supported 12 virtual machines
  - CMS – the Cambridge Monitor System, which could run "bare metal" or under CP-40

The birth of CP-67

- **CP-40 evolved (well, a substantial re-write) into CP-67 (CMS did not have to change)**
  - The CP-67 kernel was 80KB!
  - CP-67 was supported only on the uniprocessor model of the S/360-67
  - Initially up to 24 virtual machines were supported and the guest operating systems included OS/360, DOS/360, RAX, DOS/APL, CMS, and CMS Batch
  - Gained wide-spread adoption (much more than the “official” TSS)

System/360 Model 67

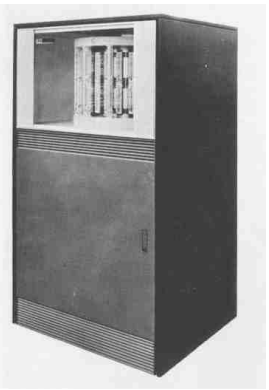
“DAT box”

University of Newcastle Upon Tyne

CP-67 / CMS hardware configuration

- **A virtual machine which is a software replica of a complete computer system, which for CMS was:**
  - Memory and virtual CPU
  - Operator console (1052)
  - Printer (1403)
  - Card reader / punch (2540)
  - Disk for “minidisks” (2311 or 2314)
  - Tape (2401)
- **CP-67 supported the above devices plus:**
  - Paging device (2301)
  - Networking controller (2703)
  - Display console (2250 with the Operator Control Panel feature)

IBM 2250



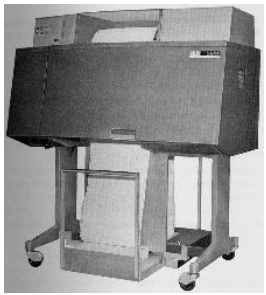
IBM 2301

CMS virtual machines

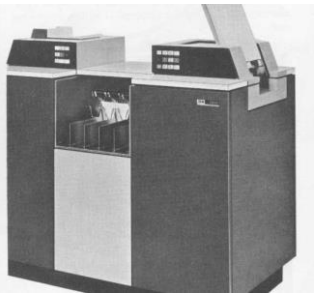
- **Virtual machines, including CMS, always ran in problem state with privileged instruction (“privop”) being intercepted by CP for handling**
- **Memory protection handled by DAT**
- **CMS virtual machine definition:**
  - 256K bytes of memory at a minimum
  - Two minidisks with an optional third (at 190, 191, 192)
  - Operator console (1052 at 009)
  - Card reader (2540 at 00C)
  - Card punch (2540 at 00D)
  - Printer (1403 at 00E)
  - Tape (2401 at 180 …)

IBM 2311

IBM 1052



IBM 1403



IBM 2540

CMS minidisks

- **Three minidisks supported for CMS userids**
  - Shared “S” at 190
  - Private “P” at 191
  - Optional Temporary “T” disk at 192
- **Minidisk physical block size was 892 bytes (¼ of a 2311 track)**
- **Maximum file size of 25.24 Mb (203 cylinders of 2314)**

IBM 2314

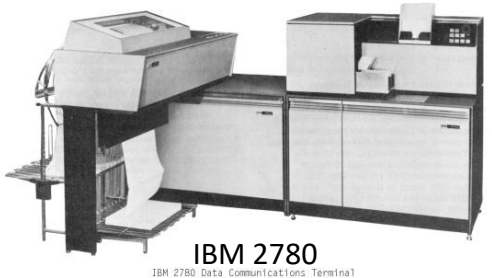
CMS compilers and utilities

- **Several compilers from OS/360 included:**
  - Assembler F
  - Fortran IV G
  - PL/I F
  - Resulting programs could run on CMS or OS/360
- **SNOBOL – string processing**
- **SCRIPT – text processing**
- **BRUIN – Brown University Interactive language (similar to PL/I)**
- **EXEC – command processor**
- **EDIT – line mode editor**
- **Utilities for tape handling, code conversion (BCDIC to EBCDIC), etc.**

Remote access to CP-67

- **Interactive terminal access was via 2741**
  - Selectric typewriter-based workstation connected via leased lines or via an acoustic coupler on a dial-up connection
- **Remove input/output was via the CPREMOTE service machine on CP-67**
  - CP-67 spool was initially between unit record devices and guests; support was added in 1968 for spool interaction between users
  - CPREMOTE supported CP-67 to/from CP-67, CP-67 to/from OS/360, and CP-67 to/from a remote workstation like the 2780 using the SRP2780 program

IBM 2741

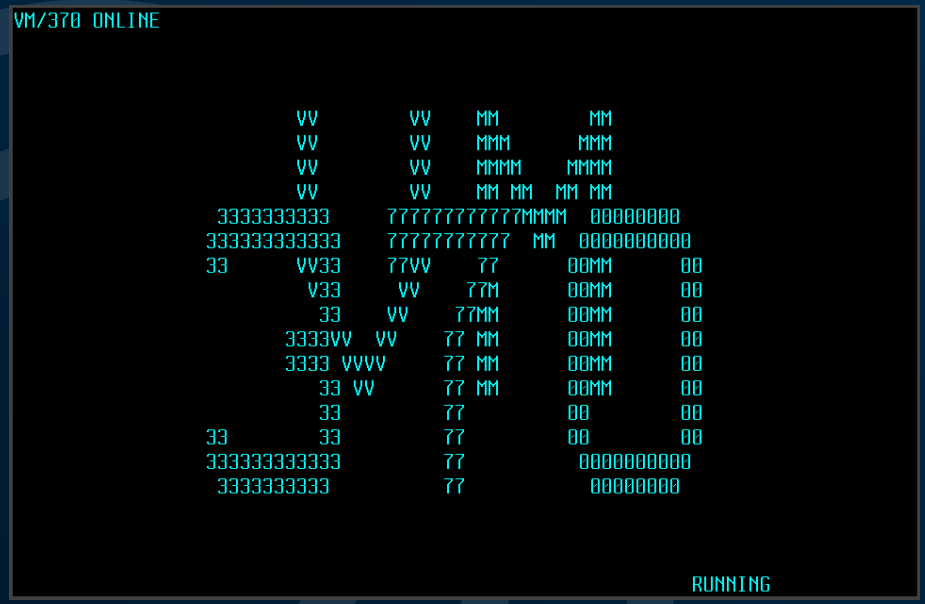


IBM 2780

CP-67/CMS releases

- **May 1968: Version 1 was released to eight installations**
  - It was made available as part of the IBM Type-III Library in June
  - Two time-sharing businesses were launched based on the resale of CP-67/CMS: National CSS and IDC
  - These ventures drew attention to the viability of CP-67/CMS, the S/360-67, and virtual memory
  - As of April 1969, CP-67/CMS had been installed at fifteen sites
- **June 1969: Version 2 was released**
- **November 1971: Version 3.1 was released, capable of supporting sixty CMS users on a S/360-67 (included the 1st "Wheeler Scheduler")**
- **Early 1972: Version 3.2 was released, a maintenance release with no new functions**
  - CP-67 was now running on 44 processors, ¼ of which were inside IBM

VM/370


VM/370 ONLINE
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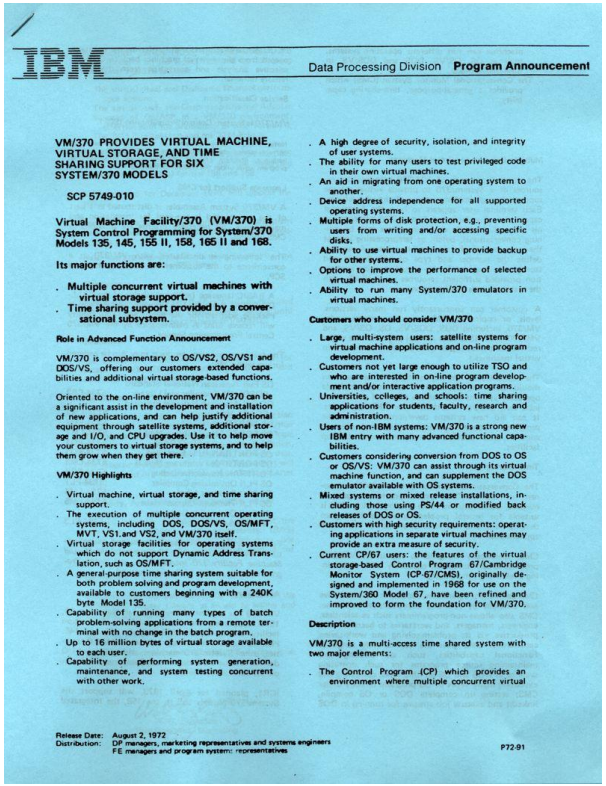
RUNNING

Which brings us to VM/370

The original 3 page "blue" letter!



IBM

Data Processing Division **Program Announcement**

VM/370 PROVIDES VIRTUAL MACHINE, VIRTUAL STORAGE, AND TIME SHARING SUPPORT FOR SIX SYSTEM/370 MODELS

SCP 5749-010

Virtual Machine Facility/370 (VM/370) is System Control Programming for System/370 Models 135, 145, 155 II, 158, 165 II and 168.

Its major functions are:

- **Multiple concurrent virtual machines with virtual storage support.**
- **Time sharing support provided by a conversational subsystem.**

Role in Advanced Function Announcement

VM/370 is complementary to OS/VS2, OS/VS1 and DOS/VS, offering our customers extended capabilities and additional virtual storage-based functions.

Oriented to the on-line environment, VM/370 can be a significant assist in the development and installation of new applications, and can help justify additional equipment through satellite systems, additional storage and I/O, and CPU upgrades. Use it to help move your customers to virtual storage systems, and to help them grow when they get there.

VM/370 Highlights

- Virtual machine, virtual storage, and time sharing support.
- The execution of multiple concurrent operating systems, including DOS, DOS/VS, OS/MFT, MVT, VS1.and VS2, and VM/370 itself.
- Virtual storage facilities for operating systems which do not support Dynamic Address Translation, such as OS/MFT.
- A general-purpose time sharing system suitable for both problem solving and program development, available to customers beginning with a 240K byte Model 135.
- Capability of running many types of batch problem-solving applications from a remote terminal with no change in the batch program.
- Up to 16 million bytes of virtual storage available to each user.
- Capability of performing system generation, maintenance, and system testing concurrent with other work.
- A high degree of security, isolation, and integrity of user systems.
- The ability for many users to test privileged code in their own virtual machines.
- An aid in migrating from one operating system to another.
- Device address independence for all supported operating systems.
- Multiple forms of disk protection, e.g., preventing users from writing and/or accessing specific disks.
- Ability to use virtual machines to provide backup for other systems.
- Options to improve the performance of selected virtual machines.
- Ability to run many System/370 emulators in virtual machines.

Customers who should consider VM/370

- Large, multi-system users: satellite systems for virtual machine applications and on-line program development.
- Customers not yet large enough to utilize TSO and who are interested in on-line program development and/or interactive application programs.
- Universities, colleges, and schools: time sharing applications for students, faculty, research and administration.
- Users of non-IBM systems: VM/370 is a strong new IBM entry with many advanced functional capabilities.
- Customers considering conversion from DOS to OS or OS/VS: VM/370 can assist through its virtual machine function, and can supplement the DOS emulator available with OS systems.
- Mixed systems or mixed release installations, including those using PS/44 or modified back releases of DOS or OS.
- Customers with high security requirements: operating applications in separate virtual machines may provide an extra measure of security.
- Current CP/67 users: the features of the virtual storage-based Control Program 67/Cambridge Monitor System (CP-67/CMS), originally designed and implemented in 1968 for use on the System/360 Model 67, have been refined and improved to form the foundation for VM/370.

Description

VM/370 is a multi-access time shared system with two major elements:

- The Control Program (CP) which provides an environment where multiple concurrent virtual machines can run different operating systems, such as OS, OS/VS, DOS and DOS/VS, in time-shared mode.
- The Conversational Monitor System (CMS) which provides a general-purpose, time-sharing capability.

Multiple Concurrent Virtual Machines

The control program of VM/370 manages the resources of a System/370 to provide virtual storage support through implementation of virtual machines. Each terminal user appears to have the functional capabilities of a dedicated System/370 computer at his disposal. Multiple virtual machines may be running conversational, batch, or teleprocessing jobs at the same time on the same real computer. A user can define the number and type of I/O devices and storage size required for his virtual machine application provided sufficient resources are available with the real machine's configuration.

A customer can concurrently run many versions, levels, or copies of IBM operating systems under VM/370, including DOS, DOS/VS, OS, OS/VS, and VM/370 itself. (See sales manual pages for the major restrictions pertaining to the operation of systems in virtual machines.)

The capability of running multiple virtual machines should assist the customer in scheduling multiple operating systems and various mixes of production jobs, tests, program maintenance, and FE diagnostics. It can aid new systems development, reduce the problems of converting from one operating system to another, and provide more economical backup facilities.

Time Sharing

The Conversational Monitor System (CMS) component of the VM/370 system provides a general-purpose, conversational time sharing facility that is suitable for general problem solving and program development, and can serve as a base for interactive applications.

CMS, specifically designed to run under VM/370, provides broad functional capability while maintaining a relatively simple design.

CMS can help programmers become more productive and efficient by reducing unproductive wait time. CMS also allows non-programmers such as scientists, engineers, managers, and secretaries to become more productive via its problem-solving and work-saving capabilities. CMS gives the user a wide range of functional capabilities, such as; creating and maintaining source programs for such operating systems as DOS and OS on CMS disks; compiling and executing many types of OS programs directly under CMS; setting up complete DOS or OS compile, linkedit and execute job streams for running in DOS or OS virtual machines; and transferring the resultant output from those virtual machines back to CMS for selective analysis and correction from the user's remote terminal.

Service Classification

VM/370 is System Control Programming (SCP).

Note: VM/370 does not alter or affect in any way the current service classification of any IBM operating system, language, program product, or any other type of IBM program while under the control of VM/370.

Language Support for CMS

A VM/370 System Assembler is distributed as a part of the system and is required for installation and maintenance. All necessary macros are provided in CMS libraries.

The following is distributed with VM/370 as a convenience to the customer but is not part of the SCP.

A BASIC language facility consisting of the CALL-OS BASIC (Version 1.1) Compiler and Execution Package adapted for use with CMS. This facility will receive Class A maintenance by the VM/370 Central Programming Service.

The following program products may also be ordered for use with CMS:

OS Full American National Standard COBOL V4 Compiler and Library	5734-CB2
OS Full American National Standard COBOL V4 Library	5734-LM2
OS FORTRAN IV (G1)	5734-FO2
OS FORTRAN IV Library Mod I	5734-LM1
OS Code and Go FORTRAN	5734-FO1
OS FORTRAN IV H Extended	5734-FO3
OS FORTRAN IV Library Mod II	5734-LM3
FORTRAN Interactive Debug	5734-FO5
OS PL/I Optimizing Compiler	5734-PL1
OS PL/I Resident Library	5734-LM4
OS PL/I Transient Library	5734-LM5
OS PL/I Optimizing Compiler and Libraries	5734-PL3

Further details on language support and execution-time limitations appear in the manual *IBM Virtual Machine Facility/370: Introduction*, and in the *Program Product* section of the sales manual.

Availability

VM/370 has a planned availability of November 30, 1972, supporting the Dynamic Address Translation facility on the System/370 Models 135 and 145. Planned support for certain advanced VM/370 facilities, other System/370 machines, and additional I/O devices will be via Independent Component Releases on the dates shown below.

ICR1, planned for April 1973, will support the System/370 Models 155 II, the 158, the Integrated File Adapter Feature (4655) for 3330 Model 1 and 3333 Model 1 on the Model 135, and the following additional VM/370 facilities:

- The Virtual=Real and Dedicated Channel performance options.
- The virtual and real Channel-to-Channel Adapter.
- Support of OS/ASP in a VM/370 environment, effective with the availability of ASP Version 3.
- The 3811 Control Unit and the 3211 Printer.

ICR2, planned for August 1973, will support the CMS Batch Facility, the Model 168, and the Integrated Storage Controls (ISCs) for the 158 and 168.

ICR3, planned for December 1973, will support the 165 II.

See the respective program product announcement letters for planned availability of the program products for CMS.

Note: VM/370 requires the system timing facilities (i.e., the Clock Comparator and the CPU Timer).

Maintenance

Maintenance for VM/370 Release 1 will be provided by the VM/370 Central Programming Service until nine months after the next release of VM/370.

Education

See Education Announcement Letter E72-14 for details of VM/370 Introduction (no charge) and additional educational plans.

Publications

IBM Virtual Machine Facility/370: Introduction (GC20-1800), is available from Mechanicsburg. Other manuals to be available at a later date include logic manuals, as well as planning, system generation, command language, system operator, terminal user, and programmer guides. Titles and form numbers will be announced in a future Publications Release Letter (PRL).

Reliability, Availability and Serviceability (RAS)

VM/370 provides facilities which supplement the reliability, availability, and serviceability (RAS) characteristics of the System/370 architecture. See the sales manual or the introduction manual for details.

MINIPERT

VM/370 planning information is available in the MINIPERT Master Library as an aid to selling and installing System/370.

No RPQs will be accepted at this time.

Detailed information on the VM/370 system is in sales manual pages.

W. W. Eggleston
Vice President, Marketing

Release Date: August 2, 1972
Distribution: DP managers, marketing representatives and systems engineers
FE managers and program systems representatives

P72-91

My introduction to VM/370

- I joined the IBM Canada Western Region Computing Centre in June 1973
- At that time the WRCC had 8 sites with S/360 machines – including a S/360-67 in Vancouver that ran OS/MVT during the week for customer batch processing
- The WRCC also had a S/360-40 to support the IBM Vancouver Lab which developed DOS/360 software (VANDL/I and GIS DOS)
- The S/360-40 machine would be replaced by a S/370-145 which was planned to run VM/370 and DOS/VS
- So I got to install CP/67 on the S/360-67 to “learn” on weekends prior to delivery of the S/370-145
- I installed several VM/370 releases (and DOS/VS releases) over the period from late 1974 to late 1978 when I left Vancouver

VM/370 – 5749-010 Release 1 content[1]

- **S/370 was announced in June 1970, but these were not announced as being virtual storage capable**
- **Virtual storage for S/370 was announced on August 2, 1972, with OS/VS, DOS/VS, VM/370**
  - VM/370 R1 announced on 1972-08-02 and available on 1972-11-30 with support for the S/370-135 and S/370-145
  - VM/370 R1 ICR1 (Independent Component Release) in April 1973 with support for the S/370-155 II and S/370-158 and CTCs
  - VM/370 R1 ICR2 in August 1973 with support for the S/370-168 and CMS Batch
  - VM/370 R1 ICR3 in December 1973 with support for the S/370-165 II

1. VM/370 Sales Manual

Remote Spooling Communications Subsystem (RSCS)

- **CPREMOTE did not provide a complete inter-system file transfer solution**
- **SCNODE was built a replacement using a subsystem supervisor called MSUP and the early network was called SCNET**
- **With VM/370, enhancements were made to the spool and hypervisor to add interfaces for a more robust solution**
  - The TAG command and interfaces provided routing information in the spool files
- **The RSCS component of VM/370 was released in 1975**
- **RSCS was enhanced to support the NJE protocols and was released as the VNET PRPQ in 1976, which later became the RSCS V1 product**
- **VNET was the name of the internal network and BITNET was the name of the external academic network, both of which used RSCS**

VM/370 – chargeable extensions

- **Resource Manager PRPQ (aka the Wheeler Scheduler) developed by Lynn Wheeler to improve performance delivered in August 1976**
  - Unlike the rest of the operating system, the new scheduler was not free, but it was worth paying for as you could suddenly support ten percent more users
- **VM/Systems Extensions and VM/Basic System Extensions, which incorporated the Wheeler Scheduler, replaced some of the most common user modifications, such as accounting to disk (rather than to real punched cards), page migration, swap table migration, and shadow table maintenance enhancements**
- **VMAP written by Chuck Tesler, an IBM SE in Los Angeles, also became available for VM/370 R5 and was an extremely important tool to keep systems running efficiently**

VM/System Product

VM/SP – 5664-167

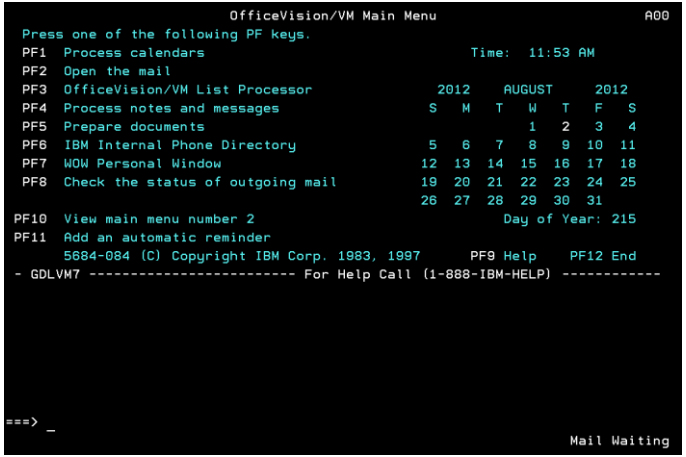
- **VM/SP R1**
  - Announced 1980-02-11, GA 1980-12-12
  - MP, enhanced AP, CCS, EXEC2, SCIF, IUCV, **XEDIT**
  - 3278-5, 3279, 3380 data streaming, 3800
- **VM/SP R2**
  - Announced 1981-10-21, GA 1982-09-02
  - Programmable Operator (PROP)
  - CMS Productivity Aids – NOTE, SENDFILE, RECEIVE, RDRLIST, FILELIST
  - EXECIO
- **VM/SP R3**
  - Announced 1983-03-17, GA 1983-11-18
  - **Rexx**, *BLOCKIO, PER, CMSIUCV

XEDIT (and EDGAR)

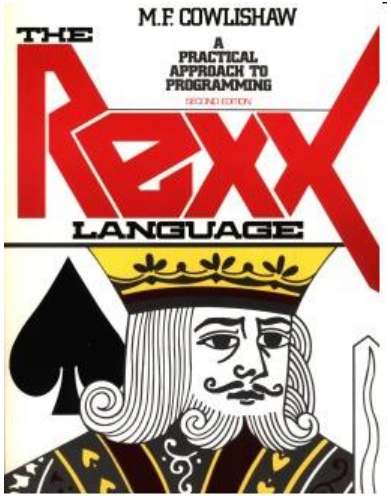
- **EDGAR (the "Display Editing System") was a full-screen editor product written by IBMer Bob Carroll which came out in 1976**
  - Edgar was the first full-screen editor IBM made available to customers, although customers had previously written and distributed full-screen editors themselves
- **XEDIT was written by IBMer Xavier de Lamberterie as a full-screen 3270 editor**
  - XEDIT supported macros written in EXEC and EXEC2 (and later REXX)
- **Inside IBM, there was a "war" on which editor to include in VM/SP to replace the line mode editor, EDIT, so a vote was held and XEDIT won and was released in 1980 in VM/SP Release 1**
- **Within no time, programmers and end users were building large, sophisticated applications based entirely on XEDIT, stretching it to its limits and doing things with it that IBM had never envisioned**

PROFS

- **Late in 1981, IBM released the PROFS PRPQ, which had been developed jointly by AMOCO and IBM**
- **Many releases were made available (1983-1997), some of which were:**
  - PROFS V1R1 was released in June 1983
  - PROFS V2R1 was released in December 1985
  - PROFS Extended Mail, supporting connections to the Internet, was released in December 1987
  - OfficeVision/VM (aka PROFS V3) was released in October 1989
- **By 1987, there were said to be a million PROFS users outside IBM, and IBM itself had become heavily dependent on PROFS**



Rexx (REstructured eXtended eXecutor)



- Rexx (originally Rex – the Reformed Executor) was designed and first implemented as an 'own-time' project between 1979 and 1982 by Mike Cowlishaw of IBM, originally as a scripting programming language to replace the languages EXEC and EXEC 2
- Distributed internally over VNET, Rex was quickly adopted across the internal IBM VM community
- Rexx was also intended by its creator to be a simplified and easier to learn version of the PL/I programming language
- It was first described in public at the SHARE 56 conference in Houston, Texas in 1981 where customer reaction, championed by Ted Johnston of SLAC, led to it being shipped in VM/SP R3

SHARE, VM, and the teddy bear

- **The MVS Group had the turkey as their mascot**
  –Changed in the early 1980s to the eagle
- **At SHARE 60 in 1983 the VM Group decided to identify newcomers with yellow stickers and old timers with blue stickers, but no one could remember which was which**
- **Carol Jobusch bought a few hundred teddy bear stickers to identify the “warm, cuddly” old timers, and a mascot was born!**

VM/SP – 5664-167

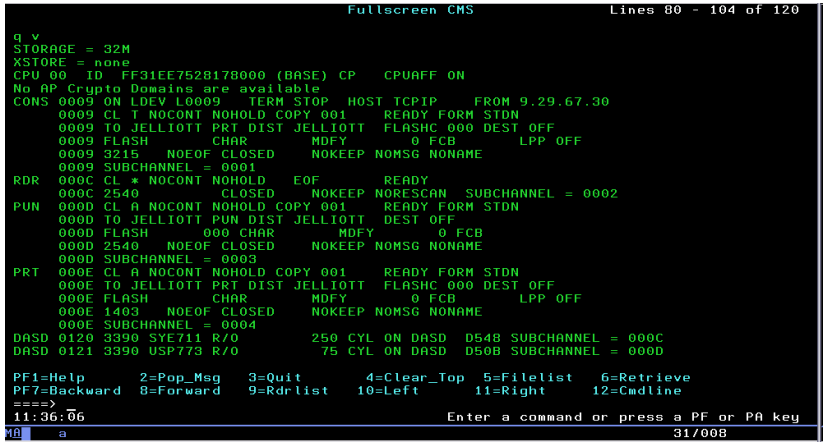
- **VM/SP R4**
  - Announced 1984-08-22, GA 1985-11-06
  - **SNA**
- **VM/SP R5**
  - Announced 1985-10-07, GA 1987-06-17, EOS 1993-012
  - APPC/VM, TSAF, AFP
  - CMS Session Services and **Fullscreen CMS**
  - Support for RACF/VM
- **VM/SP R6**
  - Announced 1987-10-20, GA 1988-12-31, EOS 1994-06
  - Shared File System (**SFS**), Callable Services Library (CSL)

Native SNA comes to VM (sort of)

- **SNA support had been in VM for since VM/SP R1 through VCNA**
  - Through VTAM on OS/VS1 or DOS/VSE guests
  - Required VM systems programmers to learn another operating system
- **VM/SP R4 included a new operating system, the Group Control System (GCS) which simulated the required parts of MVS/SP required to run VTAM**
  - RSCS was re-written to run on GCS as RSCS V2
  - A “native” VTAM V3 and NCCF V2 became available for GCS
  - SNA utilities (such as SSP) became available on GCS as well
- **GCS was supplied as “restricted source” as it was written, mostly, in PL/X**

CMS Session Services / Full screen CMS

- Full screen CMS uses the support provided by CMS Session Services to define virtual screens and windows
- Users may enter data almost anywhere on the CMS screen, even by typing over existing text
- Unique CMS PF keys are available and the display status information, which indicates the state of the virtual machine, provide longer and more descriptive status notices
- CMS Session Services commands may be issued from EXECs or from CMS and XEDIT environments
- Was never very popular, but still very useful (I use it frequently)!



CMS Shared File System (SFS)

- **CMS was extended to include a Shared File System facility for the management and sharing of CMS files**
  – SFS was also the base for the future Byte File System
- **This support is in addition to existing support for CMS files on minidisks and includes the following added capability**
- **Files stored in the SFS facility can be shared by multiple CMS users**
- **Files stored in the SFS can be shared across multiple VM systems**
- **Sharing is at the file level, providing multiple readers and one writer access to a file at the same time**
- **Users enrolled in the SFS are given a space authorization, but actual DASD space is not physically allocated**

VM/IS (VM/Integrated System) – 5664-301

- **Packaged version of VM/SP R4 and related products for 43xx processors**
- **Announced 1985-02-12, GA 1985-12-17, EOS 1992-10-30**
- **Based on VM/SP Release 4 modified for the entry-level environment**
- **Enhanced usability and installation**
- **Application ‘snap-on’ capability**
- **Eight optional packages provide additional application solutions:**
  - Text/Office System
  - Intelligent Workstation Support
  - Engineering/Scientific Program Development Support
  - Database Query
  - APL Language Support
  - Problem Solving Languages
  - Networking Support
  - Communication Controller Support

VM/SP High Performance Option

VM/SP High Performance Option – 5664-173

- **VM/SP HPO R1**
  - VM/SP R1 base, Announced October 1981, GA January 1982
  - Performance enhancements for 3081-D16 (entry model 3081), PROFS
- **VM/SP HPO R2**
  - VM/SP R1 base, Announced October 1981, GA July 1982
  - SPMODE support for MVS/SP V=R guests, Preferred machine assist, 4K keys, V=R recovery
- **VM/SP HPO R2.5**
  - VM/SP R1 base, Announced December 1982, GA April 1983
  - 32 MB support, Dispatcher enhancements
- **VM/SP HPO R3**
  - VM/SP R2 base, Announced October 1981, GA April 1983
  - 3880-11 paging subsystem
- **VM/SP HPO R3.2**
  - VM/SP R2 base, Announced September 1983, GA December 1983
  - Hardware segment protect

1. VM/SP High Performance Option announcement letter

VM/SP High Performance Option – 5664-173

- **VM/SP HPO R3.4**
  - VM/SP R3 base, Announced February 1984, GA September 1984
  - High performance paging subsystem, Dyadic enhancements, 3880-23, 4381-3
- **VM/SP HPO R3.6**
  - VM/SP R3 base, Announced February 1985, GA November 1985
  - 3090 support
- **VM/SP HPO R4.0**
  - VM/SP R4 base, Announced August 1984, GA December 1985
  - Native SNA, 3880-23
- **VM/SP HPO R4.2**
  - VM/SP R4 base, Announced February 1985, GA January 1986
  - Vector Facility, 3090 support
- **VM/SP HPO R5**
  - VM/SP R5 base, Announced January 1987, GA October 1987
  - SPOOL file limit relief, performance enhancements
- **VM/SP HPO R6**
  - VM/SP R6 base, Announced May 1989, GA June 1989
  - Shared File System

VM/Extended Architecture

VM/XA Migration Aid and Systems Facility – 5664-169

- **VM/XA Migration Aid**
  - Tool to assist in migration from MVS/370 to MVS/XA
  - First use of the **Interpretive Execution Facility (SIE)**
  - R1 announced 1981-10-21, GA 1984-02-06
  - R2 announced 1984-02-15, GA 1984-10-31
  - The intention was (as with VM/370) that this product would have a short life until customers had completed their migration to MVS/XA
  - As with VM/370, customers decided to use it for more than migration!

VM/XA Migration Aid and Systems Facility – 5664-169

- **VM/XA Systems Facility**
  - Support of CMS and production guest environments
  - Exploitation of SIE Assist for I/O performance
  - R1 announced 1985-02-12, GA 1985-09-30
  - R2 announced 1986-02-11, GA 1987-06-11
- **VM/XA MA and VM/XA SF had the same program product number, which resulted in some confusion**
  - VM/XA SF R2 for service purposes was VM/XA MA R3
  - VM/XA SF R4 for service purposes was VM/XA MA R4

VM/XA SP – 5664-308

- **R1 announced 1987-06-11, GA 1988-02-15**
  - Large scale, bimodal CMS 5.5 (24 and 31-bit)
- **R2 announced 1987-06-11, GA 1988-04-19**
  - SNA, US DoD C2 security evaluation
- **R2.1 announced 1989-10-24, GA 1989-12-29, EOS 1994-06**
  - Support for production use in an LPAR
- **Multiple High Performance Guest Support Facility (MHPGSF) to support V=F guests on VM/XA SP**
  - Renamed Processor Resource/Systems Manager (PR/SM) when Logical Partitions (LPAR) announced

VM/Enterprise Systems Architecture

VM/ESA Version 1 – 5684-112

- **V1.1 announced 1990-09-05, GA 1991-03-29, EOS 1993-12 (ESA) 1994-12 (370)**
  - Converged VM/SP, VM/SP HPO, VM/XA SP
  - 370 and ESA features
- **V1.1.1 announced 1990-09-05, GA 1991-12-27, EOS 1994-12**
  - **CMS Pipelines**
- **V1.1.5 announced ?, GA ?, EOS 1999-10**
  - 370-only release
- **V1.2 announced 1992-06-16, GA 1992-12-18, EOS 1995-03**
  - System configuration
- **V1.2.1 announced 1993-05-20, GA 1993-07-09, EOS 1996-10**
  - Virtual disks
- **V1.2.2 announced 1994-04-06, GA 1994-06-10, EOS 1999-04**
  - SPXTAPE, Minidisk cache, VMLINK, LOGON BY

CMS Pipelines

- CMS Pipelines began with John Hartmann of IBM Denmark who offered Pipelines to an enthusiastic VM community, initially as a PRPQ
- CMS Pipelines is a programmer productivity tool for simple creation of powerful, reusable REXX (or assembler) programs
- CMS Pipelines lets you solve a complex problem by breaking it up into a series of smaller, less complex programs
- These simple programs, called stages, can then be hooked together to get the results you want, and a series of stages is called a pipeline
- John was scheduled to present CMS Pipelines at SHARE in San Francisco in February 1991, but the 1st Gulf War prevented that
- Melinda Varian presented to a packed room and Paul Loftus (who was the VM lab director at the time) attended and committed to include CMS Pipelines as part of VM/ESA 1.1.1

VM/ESA Version 2 – 5654-030

- **V2.1 announced 1994-09-13, GA 1995-10-27, EOS 1999-04**
  - OpenEdition, CMS GUI
- **V2.2 announced 1996-09-10, GA 1996-12-20, EOS 2001-01**
  - Year 2000, OSA/SF
- **V2.3 announced 1998-03-24, GA 1998-03-27, EOS 2002-03**
  - TCP/IP, Java/NetRexx, LE (in base)
- **V2.4 announced 1999-05-24, GA 1999-07-23, EOS 2003-06**
  - Dynamic CP exits

Virtual Image Facility and the Integrated Facility for Linux

- **Virtual Image Facility (VIF) announced 2000-08-01, GA 2000-09-29**
  - VIF offered a complete server environment for multiple Linux systems on one S/390 server
  - VIF was an easy-to-use, high-performance environment that provided the capability to create a significant number of Linux images
  - An internal network provides high-speed communication among Linux images.
  - Lower cost, but function was **very limited** compared to VM/ESA
- **Integrated Facility for Linux (IFL) announced 2000-08-01, GA 2000-09-29**
  - 9672 G5, 9672 G6, and MP3000 processors characterized with micro-code to only run Linux and VIF (and later full function VM)
  - Designed to allow customers to run Linux on S/390 without impacting "legacy" (i.e., OS/390 and related) software costs

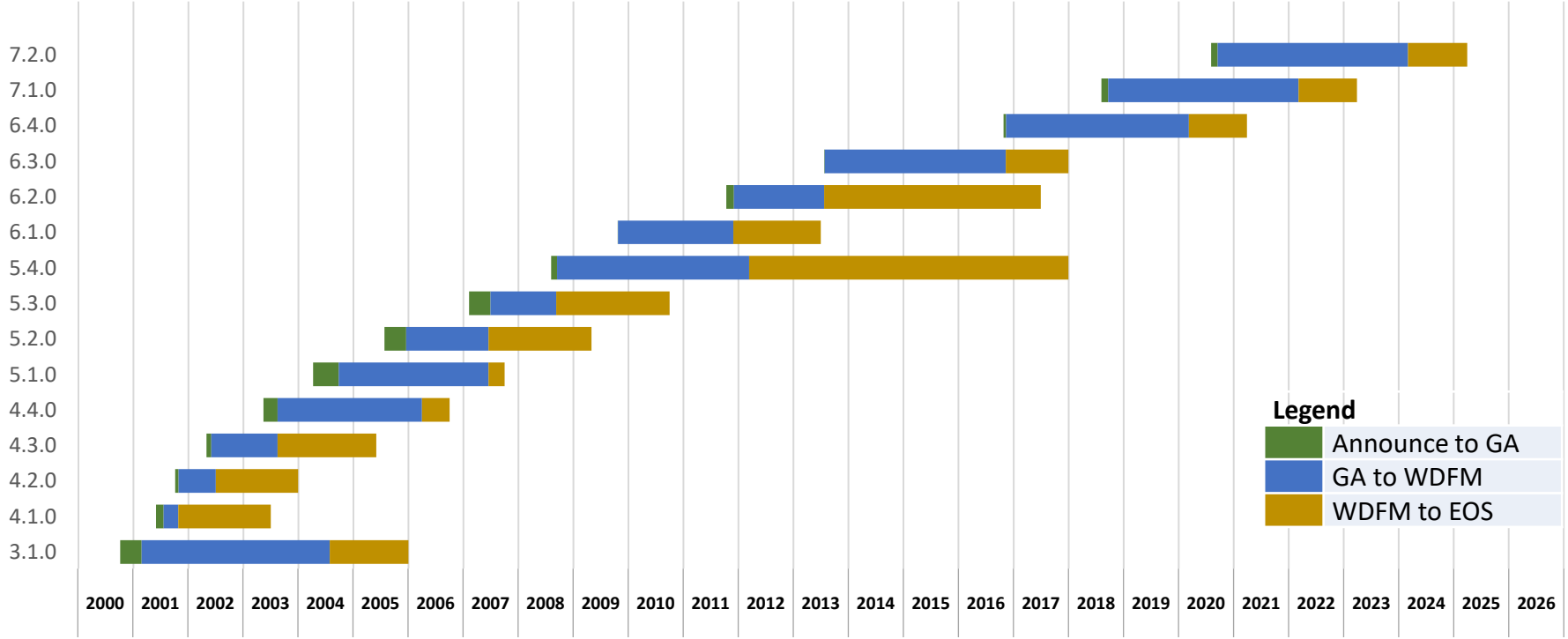
z/VM

z/VM over the last 22 years!

- IBM has now announced 15 releases of z/VM (plus one more coming this fall)

V.R.M	Announce	GA	WDFM	EOS
3.1.0	2000-10-03	2001-02-23	2004-07-27	2005-12-31
4.1.0	2001-05-29	2001-07-20	2001-10-25	2003-06-30
4.2.0	2001-10-04	2001-10-26	2002-06-30	2003-12-30
4.3.0	2002-04-30	2002-05-31	2003-08-14	2005-05-31
4.4.0	2003-05-13	2003-08-15	2006-03-31	2006-09-30
5.1.0	2004-04-07	2004-09-24	2007-06-15	2007-09-30
5.2.0	2005-07-25	2005-12-16	2007-06-15	2009-04-30
5.3.0	2007-02-06	2007-06-29	2008-09-08	2010-09-30
5.4.0	2008-08-05	2008-09-12	2012-03-12	2017-12-31
6.1.0	2009-10-20	2009-10-23	2011-11-28	2013-06-30
6.2.0	2011-10-12	2011-12-02	2013-07-23	2017-06-30
6.3.0	2013-07-23	2013-07-26	2016-11-10	2017-12-31
6.4.0	2016-10-25	2016-11-11	2020-03-09	2021-03-31
7.1.0	2018-08-07	2018-09-21	2022-03-07	2023-03-31
7.2.0	2020-08-04	2020-09-16		
7.3.0	2022-04-05 (preview)			

z/VM lifecycle



z/VM Version 3 – 5654-A17

- **V3.1 announced 2000-10-03, GA 2001-02-23, EOS 2005-12-31**
  - Enabling 64-bit guest operating systems
  - Real storage constraint relief
  - Native FlashCopy support for Enterprise Storage Server
  - Announced as part of the zSeries announcements with the z900, z/OS, and z/VSE
  - Last MLC version of VM

z/VM Version 4 – 5739-A03

- **The switch to zIPLA (One-Time Charge) pricing**
  - Straight line (per core) pricing at a much lower price point than VM/ESA or z/VM V3
- **V4.1 announced 2001-05-29, GA 2001-07-20, EOS 2003-06-30**
  - New pricing structure – dramatic price reduction
  - Support for the IBM Integrated Facility for Linux
  - Improved performance for Linux guests
  - "G5" technology (9672-G5 or MP3000) and later ONLY
- **V4.2 announced 2001-10-04, GA 2001-10-26, EOS 2003-12-30**
  - HiperSockets high-speed internal TCP/IP network
  - Guest support for FICON CTCA communications
  - Guest LAN support
  - Ease-of-use functions for managing Linux images

z/VM Version 4 – 5739-A03

- **V4.3 announced 2002-04-30, GA 2002-05-31, EOS 2005-05-31**
  - Fibre Channel Protocol (FCP) support
  - TCP/IP stack security, performance and configurability
  - z/VM self-management to achieve guest performance goals
  - Better utilization of large real storage
- **V4.4 announced 2003-05-13, GA 2003-08-15, EOS 2006-09-30**
  - Virtual LANs (VLANs)
  - External IP connectivity for Guest LANs through virtual switching (VSWITCH)
  - Improved logical-partitioning scalability due to logical channel subsystems
  - Better control, definition and dynamic reconfiguration of hardware I/O
  - Support for the new C/C++ for z/VM compiler

z/VM Version 5 – 5741-A05

- **Enterprise level zIPLA pricing with volume discount**
- **V5.1 announced 2004-04-07, GA 2004-09-24, EOS 2007-09-30**
  - New pricing model based on engine-based Value Units
  - Install, IPL, and operate from SCSI FCP disks
  - Install of z/VM from a DVD to SCSI FCP disks and to 3390 DASD
  - PCIX Cryptographic Coprocessor (PCIXCC) guest support
  - Internet Protocol Version 6 (IPv6) support
  - z/Architecture (64-bit) mode only
- **V5.2 announced 2005-07-25, GA 2005-12-16, EOS 2009-04-30**
  - Exploitation of large real memory providing 2 GB real-storage constraint relief
  - Crypto Express2 Accelerator for SSL acceleration
  - Improved FCP channel utilization and sharing among operating system images
  - Coordination of DirMaint™ and RACF® changes

z/VM Version 5 – 5741-A05

- **V5.3 announced 2007-02-06, GA 2007-06-29, EOS 2010-09-30**
  - Improved memory utilization to help relieve storage constraints
  - Simulation of zAAP and zIIP specialty processors for z/OS testing
  - Comprehensive security with a new LDAP server and RACF feature, including support for password phrases
  - Delivery of RSCS as a priced, optional feature
- **V5.4 announced 2008-08-05, GA 2008-09-12, EOS 2017-12-31**
  - Increased flexibility with support for new z/VM-mode logical partitions
  - Dynamic addition of memory to an active z/VM LPAR
  - Capability to install Linux on System z from the HMC
  - Operation of the SSL server in a CMS environment
  - Last release to support z9 and earlier

z/VM Version 6 – 5741-A07

- **V6.1 announced 2009-10-20, GA 2009-10-23, EOS 2013-06-30**
  - Enhanced performance of virtual networking environments
  - Faster access to data when utilizing FICON Express8
  - Guest support for Extended Address Volumes (EAVs) to help simplify storage management and relieve address constraints
  - Lifecycle management of virtual servers through support of the IBM zEnterprise Unified Resource Manager (zManager)
- **V6.2 announced 2011-10-12, GA 2011-12-02, EOS 2017-06-30**
  - Multi-system virtualization clustering technology allowing up to four z/VM instances to be clustered in a Single System Image (SSI)
  - Live Guest Relocation to move Linux virtual servers without disruption to the business, helping to avoid planned outages

z/VM Version 6 – 5741-A07

- **V6.3 announced 2013-07-23, GA 2013-07-26, EOS 2017-12-31**
  - Improved economies of scale with z/VM support for 1 TB of real memory
  - Improved performance with HiperDispatch
  - Adoption of OpenStack as part of the IBM cloud strategy
  - Simplified migration to z/VM V6.3 with upgrade in place, which reduces the effect of an upgrade on active workloads
  - Highly secure industry-standard support that is required for banking and financial-industry applications

z/VM Version 6 – 5741-A07

- **V6.4 announced 2016-10-25, GA 2016-11-11**
  - Support for up to 2 TB of memory
  - Easier migration with enhanced upgrade-in-place infrastructure that provides an improved migration path from previous z/VM releases
  - Improved operations with ease-of-use enhancements requested by clients
  - Improved Small Computer System Interface (SCSI) support for guest attachment of disk and other peripherals, and hypervisor attachment of disk drives to z Systems and LinuxONE
  - Increased scalability by exploiting Guest Enhanced DAT to allow virtual machines to take advantage of large (1 MB) pages, decreasing the memory and overhead required to perform address translation
  - Integration of new CMS Pipelines functionality, not previously incorporated within z/VM, that allows a much more inclusive set of tools for application developers

z/VM Version 7 – 5741-A09

- **V7.1 announced 2018-08-07, GA 2018-09-21, EOS 2023-03-31**
  - Integrates the Single System Image (SSI) function into the base, at no additional cost, and withdraws the SSI feature.
  - Increases the level of engagement with the z/VM user community.
  - Enhances the dump process to reduce the time required to create and process dumps.
  - Upgrades to a new Architecture Level Set. This requires an IBM zEnterprise EC12 or BC12, or later
  - Provides the base for additional functionality to be delivered as service after general availability.
  - Enhances the dynamic configuration capabilities of a running z/VM system with Dynamic Memory Downgrade support

z/VM Version 7 – 5741-A09

- **V7.2 announced 2020-08-04, GA 2020-09-18**
  - Timely, client-driven functions previously delivered in the service stream of z/VM 7.1
  - Centralized service management, a simplified process for applying and deploying maintenance across multiple non-Single System Image (SSI) z/VM systems
  - Even greater availability and data redundancy for Geographically Dispersed Parallel Sysplex (GDPS) environments and improved direct access storage device (DASD) scalability for clients exploiting Multi-Target Peer-to-Peer Remote Copy (MT-PPRC)
  - An enhanced test and debug environment provided by z/VM ADJUNCT support
  - A new Architecture Level Set (ALS) that requires one of the following IBM Z or IBM LinuxONE servers, or later: IBM z13, IBM z13s, LinuxONE Emperor, LinuxONE Rockhopper

Summary

Summary

- From CP-67/CMS as a research project in 1967 and VM/370 as a migration tool in 1972, VM has evolved to today's z/VM as the core of IBM zSystems virtualization technology
- Mainframe virtualization has been a collaborative effort for over 50 years between the IBM labs, IBM internal users, and customers
- Virtualization is now considered "standard" in the industry and all virtualization solutions owe much to the IBM mainframe VM family of offerings

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