50 Years of Mainframe Virtualization CP/40 to z/VM

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Abstract

- **2017 marks the 50th anniversary of CP/40 going into production and the 45th 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 for z Systems**

The focus of the presentation will be on the evolution of mainframe virtualization through 2000, but charts on subsequent VM enhancements are included for completeness

Speaker

- **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 working at GlassHouse Systems, Jim provides technical support for their mainframe customers in Canada 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 45 years of experience

- **Throughout the history of VM, IBM's ground-breaking virtualization software for mainframes, key design principles formed the backbone or DNA 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 7090) at MIT using IBM 1050 terminals**

- **In 1962 MIT started development of CTSS (Compatible Time-Sharing System) using the IBM 7090**
- **Ferranti-Packard 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)**

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 7044 to run multiple "conversational" users in a Fortran environment**
  - Formally announced in 1964 as "Quicktran"

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**

GE-645 SYSTEM
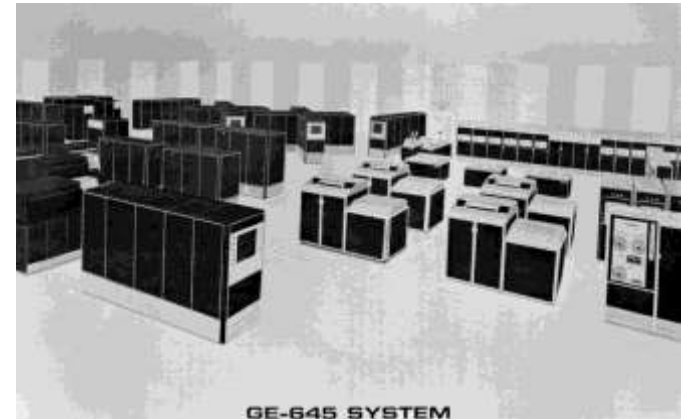
The IBM response

- **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, a modified version of the S/360 with Dynamic Address Translation, along with the TSS (Time Sharing System) 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

MTS – The Michigan Terminal System

- **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**
  - I used MTS at Simon Fraser University when I was in high school

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**
- **Two independent software components**
  - CP-40 – the Virtual Machine Control Program – supported 12 virtual machines
  - CMS – the Cambridge Monitor System, which could run native 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, RAX, DOS/APL, CMS, and CMS Batch
  - Gained wide-spread adoption (much more than the "official" TSS)

System/360 Model 67

"DAT box"
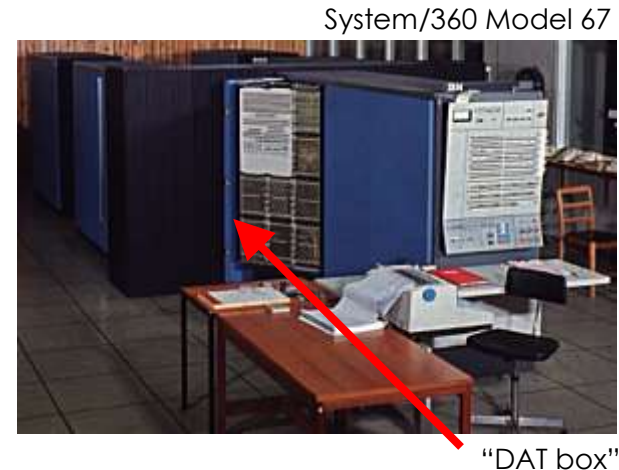
University of Newcastle Upon Tyne

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**
- **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

Which brings us to VM/370
The original 3 page announcement letter!

VM/370 – 5749-010 Release 1 content

- **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 was available in November 1972 with support for the S/370-135 and S/370-145
  - VM/370 R1 ICR1 (Independent Component Release) was planned for April 1973 with support for the S/370-155 II and S/370-158 and CTCs
  - VM/370 R1 ICR2 was planned for August 1973 with support for the S/370-168 and CMS Batch
  - VM/370 R1 ICR3 was planned for December 1973 with support for the S/370-165 II

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 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

- **Wheeler scheduler PRPQ developed by Lynn Wheeler to improve performance**
- **Basic System Extensions (BSEPP) and System Extensions (SEPP) products available for VM/370 R5 and R6**

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**
- **There are customers using OV/VM today!**

REXX

- **REXX (originally REX) was designed and first implemented as an 'own-time' project between March 20, 1979 and mid-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**

M.F. COWLISHAW
THE
A PRACTICAL APPROACH TO PROGRAMMING
SECOND EDITION
Rexx
LANGUAGE
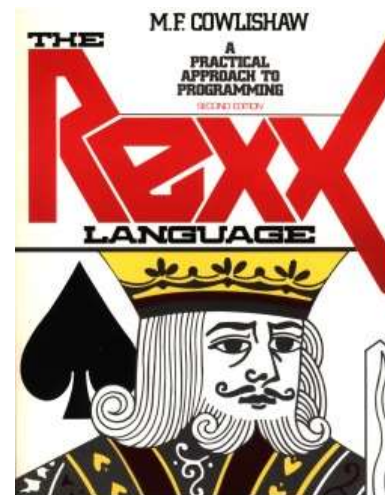
SHARE, VM, and the teddy bear

- **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!**

CMS Shared File System (SFS)

- **CMS was extended to include a Shared File System facility for the management and sharing of CMS files (base for future BFS)**
- **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 1981-10-21, GA 1982-03-27
  - Performance enhancements for 3081-D16
- **VM/SP HPO R2**
  - VM/SP R1 base, Announced 1981-10-21, GA 1982-08-18
  - SPMODE support for MVS/SP V=R guests
- **VM/SP HPO R3**
  - VM/SP R2 base, Announced 1981-10-21, GA 1982-05-31
  - 32MB support, 3880-11 paging subsystem

VM/SP High Performance Option – 5664-173

- **VM/SP HPO R3.4**
  - VM/SP R3 base, Announced 1983-09-15, GA 1984-02-23
  - High performance paging subsystem
  - VM/SP HPO R3.6 announced for 3090 support
- **VM/SP HPO R4.2**
  - VM/SP R4 base, Announced 1985-02-12, GA 1986-02-28
  - SNA, Vector, 3090 support
  - VM/SP HPO R4 had SNA support, but no support for 3090
- **VM/SP HPO R5**
  - VM/SP R5 base, Announced 1997-01-26, GA 1987-09-30, EOS 1993-12
  - SPOOL file limit relief, performance enhancements
- **VM/SP HPO R6**
  - VM/SP R6 base, announced but never delivered

VM/Extended Architecture

VM/XA Migration Aid and Systems Facility

■ **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

- **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 yyyy-mm-dd, GA yyyy-mm-dd, 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**
- **Melida Varian presented to a packed room and Paul Loftus walked by 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 Version 3

- **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 @server zSeries announcements with the z900, z/OS, and z/VSE
  - Last MLC version of VM

z/VM Version 4

- **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

- **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

- **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

- **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

z/VM Version 6

- **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

- **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

- **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

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's z Systems virtualization technology**
- **Mainframe virtualization has been a collaborative effort for 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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