S/360 - Announced April 7, 1964

IBM Mainframes (EDPMs)...

The first 50 years of Evolution and Innovation

EDPMs - Electronic Data Processing Machines
During the 1950s, Data Processing came of age.

(*) Common compilers made migration easier - COBOL and FORTRAN

IBM 7090/7094
IBM 1401 all transistorized
IBM 701 Machines

RAMAC Disk
During the 1950s, Data Processing came of age...

Ready to be announced as the new high-end “mainframe” in early 1960s

IBM 7090/7094

Designed for specific applications - mainly scientific/computational
Every family had a different, incompatible architecture
Even within families, moving to next larger system was a migration

RESULT – customers were getting frustrated with migration cost

(*) Common compilers made migration easier - COBOL and FORTRAN
IBM decided in 1961 to drop “the new 8000 system” and address the issues…

- a family of (5) increasingly powerful computers (LARGEST = 2/300 x SMALLEST)
- compatible => with the same architecture
- running the same operating system
- using the SAME (44) new peripheral devices
- for all types of applications

- Solid Logic Technology (SLT) – “leading edge”
  Magnetic Core Memory - very reliable

- Use combinations of Microcode and HW
  to implement different capacity levels at a realistic cost

- Emulators - (Microcode in “Read Only” Control Memory)
  - IBM 1400, 7080, 7090 systems (“by flip of a switch”)
  - faster than on native systems
IBM's 5,000,000,000 $ Gamble…
Initial estimate less than $1B

Never again customers will have to change because of us…

Protection of investments….

“[System/360] was the biggest, riskiest decision I ever made, and I agonized about it for weeks, but deep down I believed there was nothing IBM couldn’t do.”

Thomas Watson, Jr.
Chairman and CEO, IBM

The 360 in the name referred to “ALL DEGREES IN A COMPAS”
The S/360 Principles of Operation – S/360 POP

Separates Architecture from Implementation

SAME Instruction Sets (standard & optional) across all systems - may be implemented differently - HW and/or Microcode

UPWARDS Binary Program Compatibility - (and some downwards)

Same Addressing scheme - 24 bit (32bit architecture)

I/O Subsystem
Separates CPU processing and I/O Operation
Specialized Processors (Channels) to move DATA between IO-devices & Memory
SAME STANDARDIZED I/O Interface on Systems and IO devices

Unique Interrupt structure
I/O, Program, Supervisor Call, External, Machine Check etc..

Storage Protection keys - Supervisor & Program State - Isolation
Assumption: HW/SW Systems may/will fail

Expandable in future according to
Technological Capabilities & Market requirements
The S/360 Principles of Operation – S/360 POP

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S/360 - “AMAZING” positive feedback from the market

IBM 5,000,000,000 $ Gamble...

2000+ machines ordered within 8 weeks of the announcement.....
4000+ machines installed in 1966 - with 20,000 on orders

"Monty Python and the Holy Grail"
GOAL - ONE Operating System (OS/360)
Multi-Programming / Variable # Concurrent Task / Variable Task Size / Multi-Processing

Reality – CHALLENGE TO IMPLEMENT THE VISION during the 1960ties...
- limited amount of REAL memory (MIN 8KB / MAX 8MB / Reality MAX 0.5-1MB)
- Basic (BOS - 8KB), TAPE (TOS - 16KB), DASD (DOS more than 16KB) and OS/360-versions

1967
Variable Number and Size of Tasks
BUT - Risk for FRAGMENTATION
Batch
+ Online
+ TSO (interactive)

Multiple Variable Tasks
Initial: up to 15 tasks + OS
S/360 Model 67 - first IBM system with Virtual Storage (DAT) and Multi Processor (MP) capabilities

Control Program/67 (CP/67) with the Cambridge Monitor System (CMS)
- The “unofficial” operating system from the IBM Cambridge Scientific Center
- 1st “version of Virtual Machine (VM)

VM/370 released in 1972 - together with mainstream OS (MVS) and HW DAT on S/370-148
- Virtualization of ALL elements
- Each user runs in a separate ADDRESS Space
- Became the basis for PR/SM-LPAR
- Became the basis (with PR/SM) for server consolidation using zLinux

(*1) – Virtual Machine Facility/370
The 1970ties… the architecture matures and expands

S/370 Architecture Extended with Virtual Storage Addressing - August 1972
Dynamic Address Translation in HW - DAT
4KB PAGES & 64KB SEGMENT sizes - (optional 2KB & 1MB)

Integrated Memory Chips

Authorized Program Facility

System Resource Manager Priority, Working Sets, RT,…

BASE technology for…..
Real Time Online Tx and DB Systems like CICS, IMS - DL/I (and DB2)
Interactive Work like TSO (CMS)

Essential Driver for Programmer Productivity

Virtual Memory

16MB

Real Memory

1974

Shared Virtual Area (Common)

16 Storage Protect Keys 0 - 15

Multiprocessing

Performance & Advanced Recovery

MVS Base Control Program

Storage Protect Key 0 - 7

16 Storage Protect Keys 0 - 15

MVS - Multiple 16MB Address

HW Isolated Address Spaces

Multiple Virtual Systems

(old programs ran unchanged even without recompilation)

Storage Protect keys - Protect System Code from Middleware from Applications – key, store, fetch
NEW Technology in 1980 - Base for Growth & Reliability

- IBM 3081 introduced new TECHNOLOGY
  BASE technology for ALL systems up to TODAY
  Important for Availability & Dynamic Scalability

- Thermal Conduction Modules (TCMs)
  – Very efficient WATER cooling technology
  – Ceramic Multilayer with mounted chips

- Processor Controller – Service Console
  – LOG, Analyze Call Out/Home - Remote Support

- System Programmer out of the Machine Room - Console up to 1500 meters away

**Up to 133 chips, 704 circuits/chip**
**28-33 wired ceramic layers**
**350,000 Holes -> vertical wires**
**16,000 chip contact points**
**Extremely Reliable**

16/19 TCMs to build a UNI (370,000+ circuits), around 2000 chips
54/56 TCMs to build a 4way

**N-way support matures**
308X 1/2/4 WAY
ES/9000-600 6WAY
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MCM = Multi Chip Module
20 PU’s = Processor Units
8 CPU – 10 SPARE – 2 IO

16/19 TCMs to build a UNI (370.000+ circuits), around 2000 chips
54/56 TCMs to build a 4way

Decades of years (40+) for MTBF for HW errors which require unplanned interruption of processing to repair Concurrent Maintenance – Concurrent Upgrade

ADD / REMOVE HW Capacity ON DEMAND

SW Charges based on Capacity Used
ROLLING AVERAGE over 4 hours
(NO charge for short peaks…)

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ES/9000-600 6WAY

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Extremely Reliable
Extended Addressing Architecture in the 1980ties

S/370 Extended Architecture (XA) - 1981 (shipped in 1983)

- 24-bit (16MB) or 31-bit addressing (2GB)
- Bi-modal execution - both “types of programs” may co-execute simultaneously

Virtual Storage Constraint Relief
Growing System/Applications functional code
More Data in memory
Programmer productivity (Business functionality)

Selling Virtual Storage!
Extended Execution and (Data) Addressing Architecture

Cross Memory (XM) and Data Spaces

Programs may execute instructions out of MULTIPLE Address Spaces

Data Spaces – Data-in-Memory (Data Bases, and other large data structures)

The strength of XM

• Integration
• Data-in-memory
• Sub-Second RT
• Reduced serialization

HW Controlled Access
Start Interpretive Execution (SIE) facility in 1980
Gives a “GUEST” full control over the processor HW. Initial used by VM/XA, then by PR/SM

Processor Resource/Systems Manager (PR/SM) in 1987 establish

Multiple Operating Systems on same HW
Multiple Architecture Levels on same HW
HW Isolation

LOGICAL Partitions (LPAR’s) - initial 10 - now 60

Sharing of CPU at % level
Dynamic Adjustable

LPAR’s may ABSORB excess capacity from other LPARs...

Memory & Channels - Dynamic Re-Allocation

Security Control

1990ties and on...

SHARING of CHANNELS
and other I/O resources

Dynamic Re-Allocation of Resources among LPARs under Workload Mgr control
According to BUSINESS POLICIES

Virtualization is transparent for OS/Application execution and IO operation
Virtualization in MULTIPLE Dimensions

1st Dimension
Up to 60 LPARs

2nd Dimension
100’s – 1000’s Virtual LINUX servers

Very Large
Shared Resource Space
“2+” Dimensions of Virtualization
Allows for consolidation and tight integration of

Multiple
CORE Business Applications
together with
Large Server Farms
(Virtual Racks & Virtual Networks)
on the same footprint
with
HW Enforced Isolation

ABLE to ABSORB PEAKS for LARGE WEB-networks with VARIABLE and UNPREDICTABLE loads

PR/SM

VIRTUAL Server Racks

High Speed VIRTUAL networks

HW Hypervisor uses SIE

SW Hypervisor uses SIE
Growing focus on Implementation of Industry Standards

- POSIX – UNIX API’s made available as a general integrated API
- TCP/IP in co-existence with VTAM

ESCON – Extension of I/O architecture

- GLASS FIBER technology
- Higher Speeds and 10/17 KM distances
- ”Emulation support” of old NON-ESCON devices
- EMI – ”VIRTUALIZATION” of CHANNELS
- 1st step towards Fiber Channel Protocol (Open Standard)
Near Deaths Experience –

- “I predict that the last mainframe will be unplugged on March 15, 1996.”
  – Stewart Alsop, March 1991

- “It’s clear that corporate customers still like to have centrally controlled, very predictable, reliable computing systems – exactly the kind of systems that IBM specializes in.”
  – Stewart Alsop, February 2002

Source: IBM Annual Report 2001
A new Bi-Polar system (H7) was ready to announce in 1994, but was cancelled. Was it an "inspiration" from the S/360 decision in 1961...?

- **CMOS technology in 1994** - moves from 6way to 16way during the 90ties
  - Low Power - High Density
  - 1994 - S/390 Parallel Transaction Server (15MIPS => 65 MIPS/6-way)
  - 1996/7 - System/390 G3/G4 => capacity exceeds than last IBM H6-bipolar
  - 2000 - z900 (1 to 16WAY) => capacity higher than PCM Bipolar

Up to 6K circuits/chip
400 chips/CP
3 MIPS/KWatt

400K circuits/chip - more than 340.000K today
4 chips/CP - up to 4 CP/chip today
60 MIPS/KWatt - more than 1500 today

ES/9000
Bipolar - H6 (1993)
65MIPS engine
10way - 465 MIPS

9672
CMOS
15MIPS engine
6way - 65MIPS

Double the capacity
Bipolar - avg. 5 years
CMOS - 1 to 2 years
Parallel Sysplex – Coupling of Systems and/or LPARs

- Multiple systems “BEHAVES” like ONE (initial 16 later 32…)
- COUPLING FACILITY - Shared INTELLIGENT memory - UNIQUE invention
- Coupling Links – High Speed / Low Latency
- ”Kind of” Direct Memory Access protocol

- Unmatched Availability
- Run for multiple years replacing OS, HW, SW
- Cost ”independent” of # of systems coupled
- CMOS and Bi-Polar systems

OLTP Workload Balancing
DB Sharing
(WEB-balancing)
Global Ressource Sharing
Common Interface
64 bit addressing – ultimate addressing capability
  – 24-bit, 31-bit, 64-bit PROGRAMS RUN CONCURRENTLY (Tri-Modal)

Business Oriented Workload Management
  – MOVE REOURCES to WORK - CPU, Memory, Channels within/between ALL LPARs

FICON - Industry Standard FCP I/O protocol architecture + EXTENTIONS

Open Systems Adapter (OSA) - Industry Standard network protocols

Full range of UNIX API’s, File Systems, Security - implemented within z/OS

WEB serving & JAVA - System/Subsystem support (e.g. CICS) - 1995/1996

Linux on mainframe - announced by a “CONCIOUS MISTAKE” in 2000
  – Integrated Facility for Linux - IFL engines

Trend - Consolidation using Virtualization
  – Triggering Factors – Simplification, Cost reduction, Flexibility
Security Is Limited By The Weakest Link
Security Is Limited By The Weakest Link

The Common Criteria program developed by NIST and NSA establishes an organizational and technical framework to evaluate the trustworthiness of IT Products and protection profiles.

- Key Management under z/OS
- z/OS, z/VM, System z & PRSM/LPAR has the highest security certifications on the market
  - z/OS, z/VM, Linux
  - z/OS, z/VM, Linux
  - System z, Linux, Linux

Virtualization with partitions

- Plus Crypto instructions, Crypto CO-processors, Crypto PCI cards
**Current System z - Data Center in a Box… 2010 and on...**

**HYBRID SOLUTION - Supports Business Innovation…**

Data nearness/”sharing” between platforms
Supports trend of ”distributed/hybrid” applications

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**z12/z114**

- z Architecture
- z/OS
- zVM - zLinux
- ALL Applications
- Resilient
- Secure
- Workload Mgmt
- Scalable

**ACCELERATORS**

**10 GbE IEDN**

**1 GbE INMN**

**Select IBM Blades**

**zBX**

- Window, Linux, AIX
- x86-POWER
- Architecture
- (Blade technology)

**DataPower Optimizer…**

**Unified System(HW) and Workload Mgmt**

Single Interface to multiple hypervisors

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**Data Center “Processor Infrastructure” in a Box**

“Breaking down the Server Walls”

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DB2 Analytics

Transparent usage from DB2

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There is value in an Integrated Delivery Model...

The Challenge of Do-It-Yourself
“Never again customers will have to change because of us..”

Multiple expansions of the Architecture
Multiple iterations of Technology
Multiple expansions of Functions
Without breaking existing Applications

1964

S/360
S/370
S/370-XA
ESA/370
ESA/390
ESA-E/390
System z

50 YEARs….

NEW Technology
and
NEW System Programming Model

WITHOUT CHANGING

The Application Model
Multiple expansions of the Architecture
Multiple iterations of Technology
Multiple expansions of Functions
Without breaking existing Applications

1964 - 600 cent/inst. (36,000,000 Dkr/MIPS)
1970 - 180 cent/inst. (10,800,000 Dkr/MIPS)
1980 - 50 cent/inst. (3,000,000 Dkr/MIPS)
1990 - 10 cent/inst. (600,000 Dkr/MIPS)
2000 - 0,3 cent/inst. (18,000 Dkr/MIPS)
2014 - 0,1 cent/inst. (6,000 Dkr/MIPS)

NEW Technology
and
NEW System Programming Model
WITHOUT CHANGING
The Application Model

GREEN technology
1993: 3 MIPS/KWatt
1994: 70 MIPS/KWatt
2012: 1600 MIPS/KWatt

1.600 to 60.000+ MIPS
1-way up to 101(120)-way

50 YEARs....
“The reports of the death of the mainframe have been exaggerated”

freely after…Mark Twain

Age is a question of mind over matter

If you don’t mind, it doesn’t matter

Leroy (Satchel) Page
1906 -1982

1964 1970s 1980s 1990s 2014 and on…