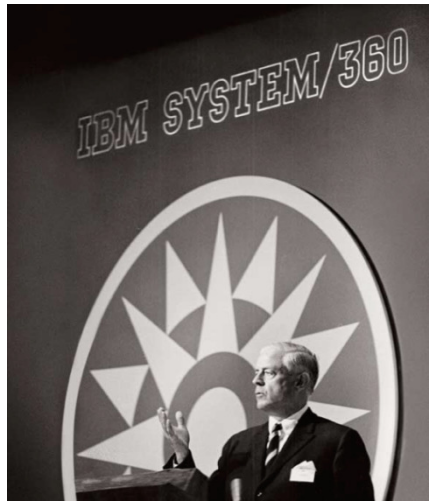
Svend Erik Bach
IBM Distinguished Engineer, retired
svend.erik.bach@gmail.com



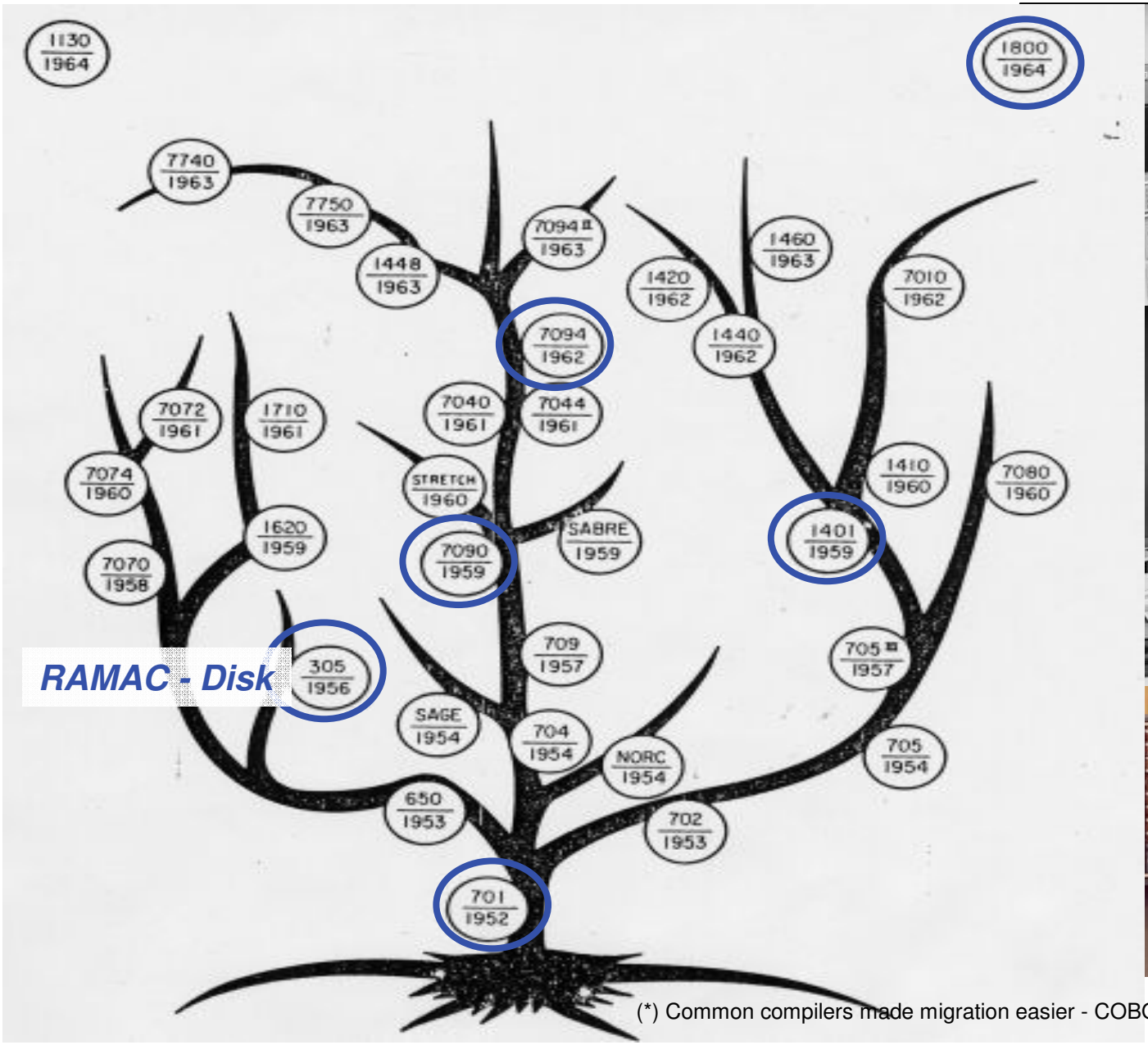
S/360 - Announced April 7, 1964

IBM Mainframes (EDPMs)…

The first 50 years of Evolution and Innovation

EDPMs - Electronic Data Processing Machines

During the 1950s, Data Processing came of age…



IBM 7090/7094

IBM 1401
all transistorized

IBM 701 Machines

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

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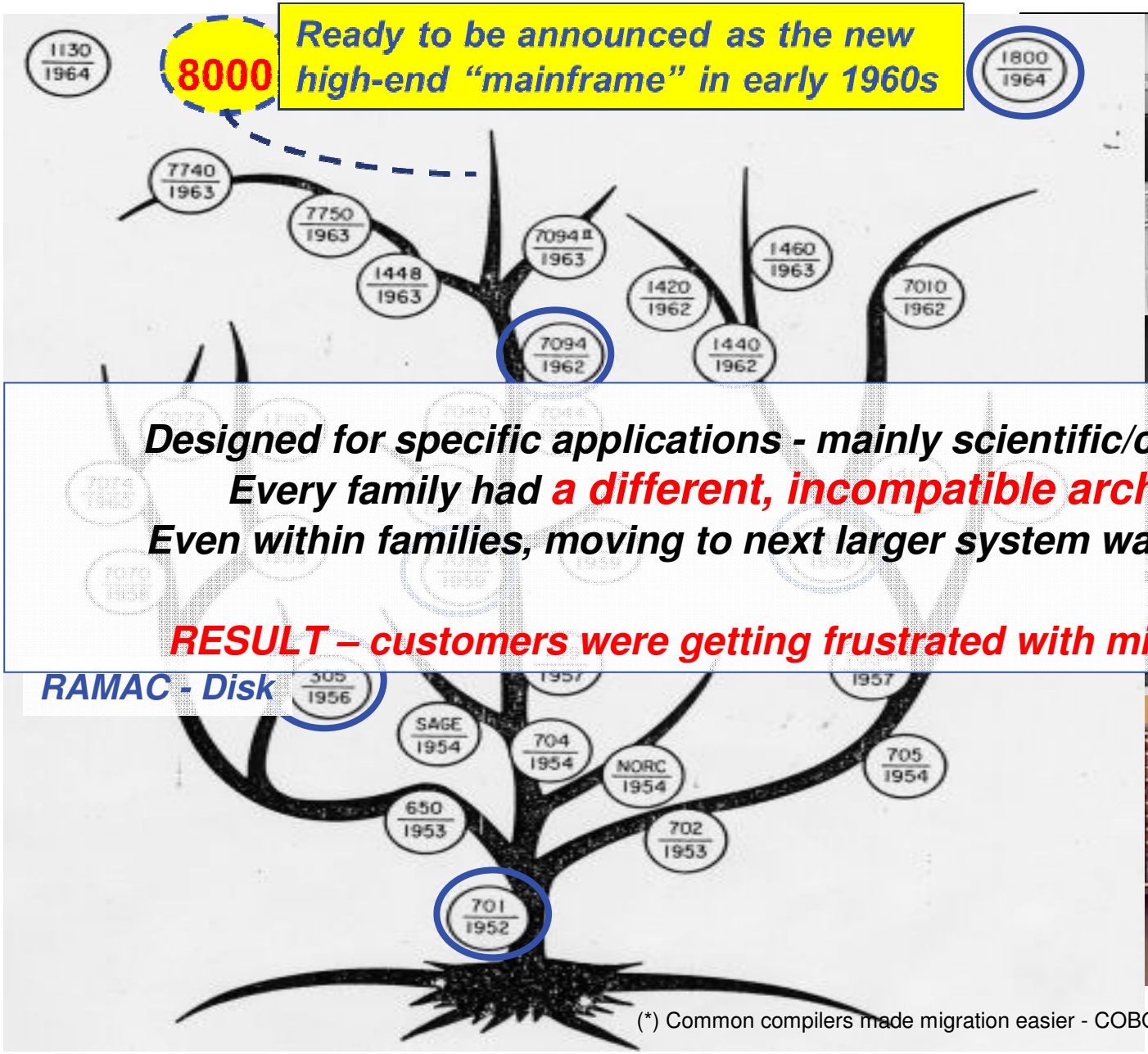


IBM 7090/7094

IBM 1401

all transistorized

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

IBM 701 Machines

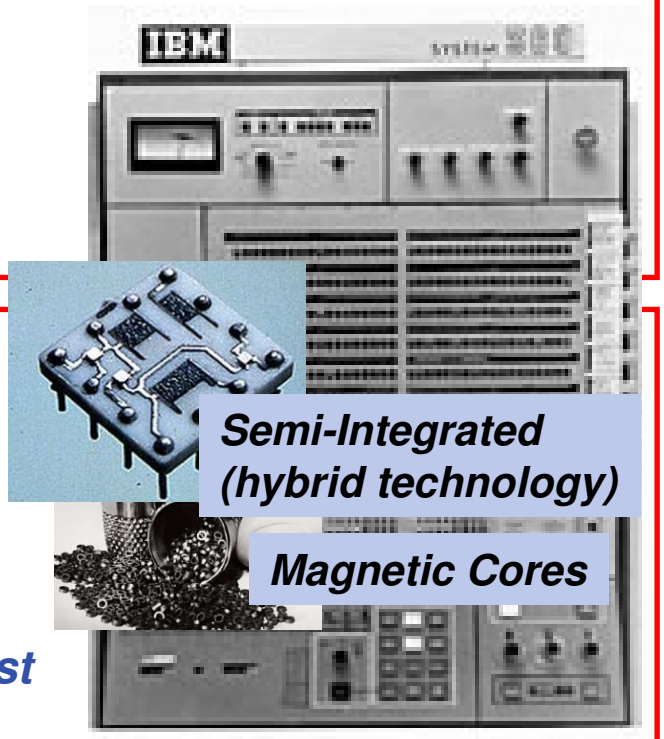
(*) Common compilers made migration easier - COBOL and FORTRAN

INNOVATION, S/360 happened, because it was the right time…

Heart Attack Decisions…

IBM decided in 1961 to drop *"the new 8000 system"* and address the issues… use a radical new approach building a "total cohesive New Product Line"

- **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**

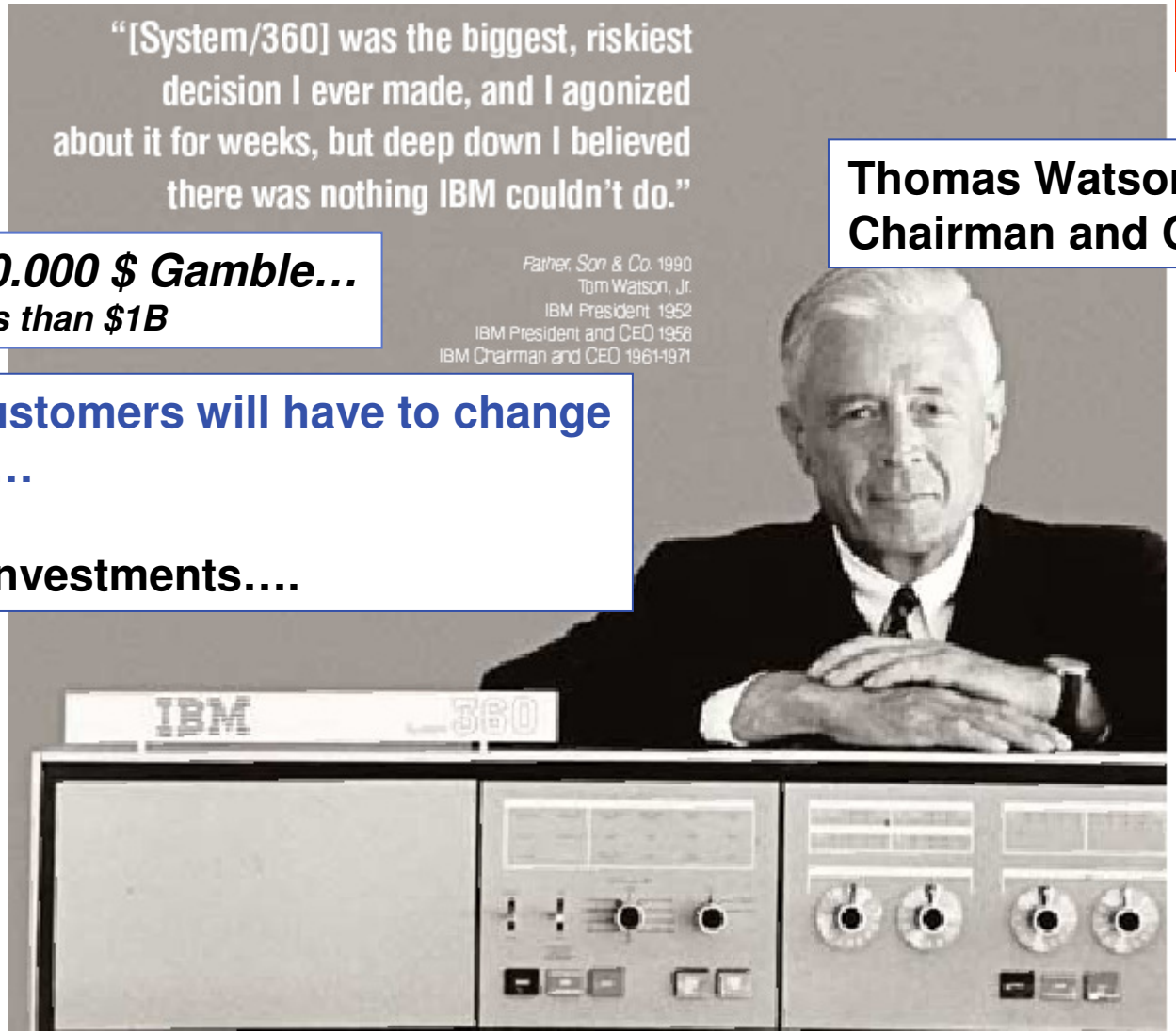


- ***Solid Logic Technology (SLT) – "leading edge"***
  Magnetic Core Memory - very reliable
- ***Use combinations of Microcode and HW***
  to implement different capacity levels at a realistic cost
- ***Emulators - (Microcode in "Read Only" Control Memory)***
  - IBM 1400, 7080, 7090 systems ("by flip of a switch)
  - faster than on native systems

SYSTEM 360

System/360 – Announced April 7, 1964

The ***360*** in the name referred to ***"All DEGREES IN A COMPAS"***



Thomas Watson, Jr.
Chairman and CEO, IBM

IBMs 5.000.000.000 $ Gamble…
Initial estimate less than $1B

Never again customers will have to change because of us…

Protection of investments….

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

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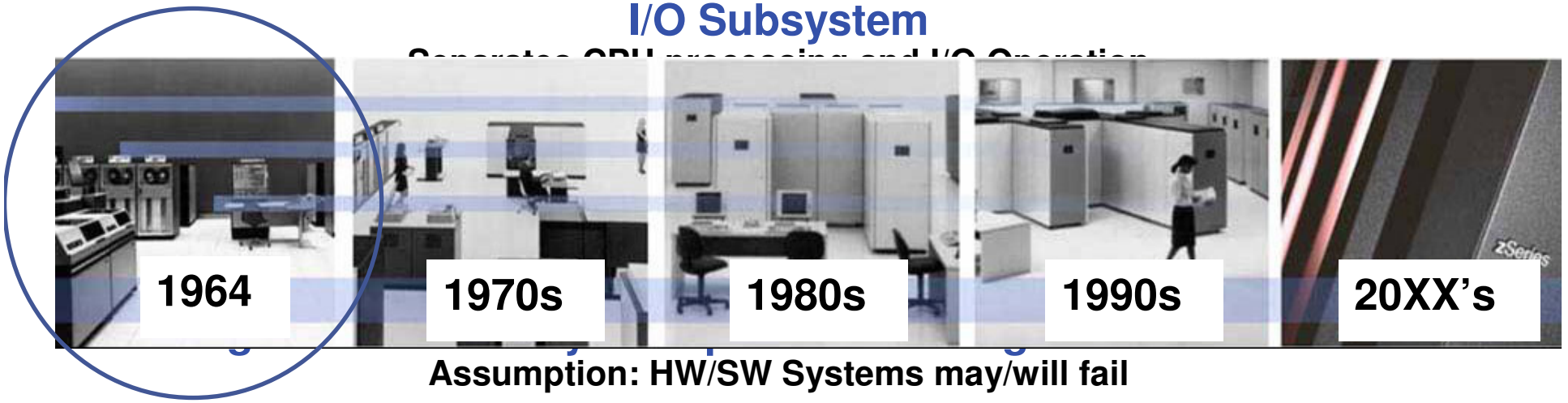

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S/360 - “AMAZING” positive feedback from the market

IBMs 5.000.000.000 $ Gamble…

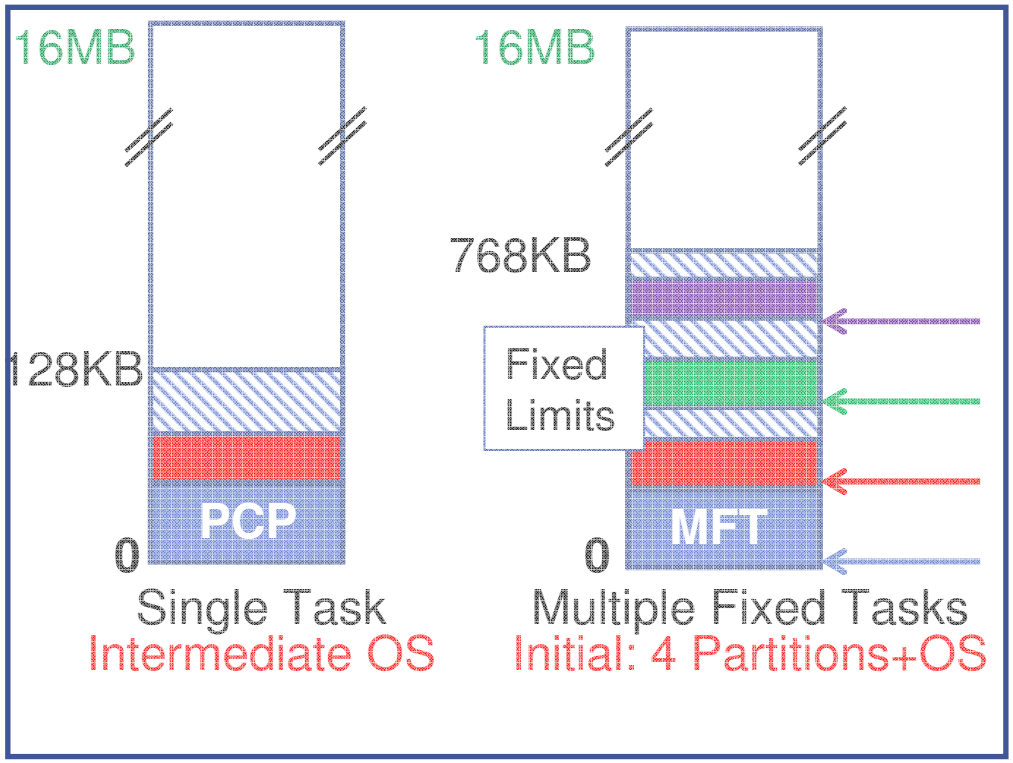
2000+ machines ordered within 8 weeks of the announcement…..
4000+ machines installed in 1966 - with 20.000 on orders

GOAL - ONE Operating System (OS/360)

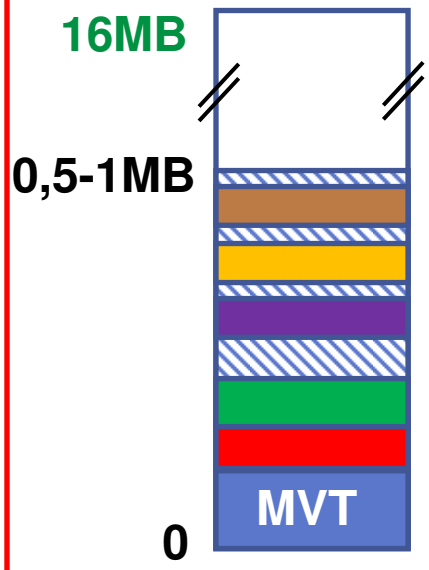
Multi-Programming / Variable # Concurrent Task / Variable Task Size / Multi-Processing

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)

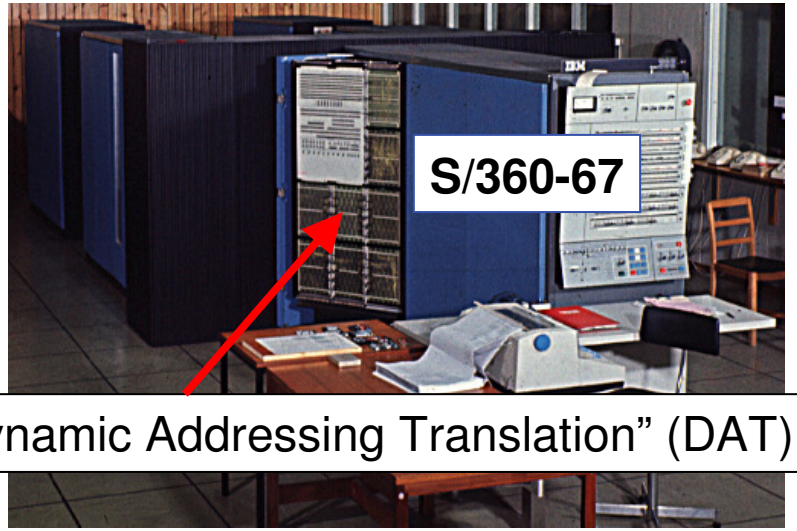
Multiple Variable Tasks

Initial: up to 15 tasks + OS

Innovations: Virtual Storage + CP/67 & CMS + MP ….

- **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)***



"Dynamic Addressing Translation" (DAT)

- **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**

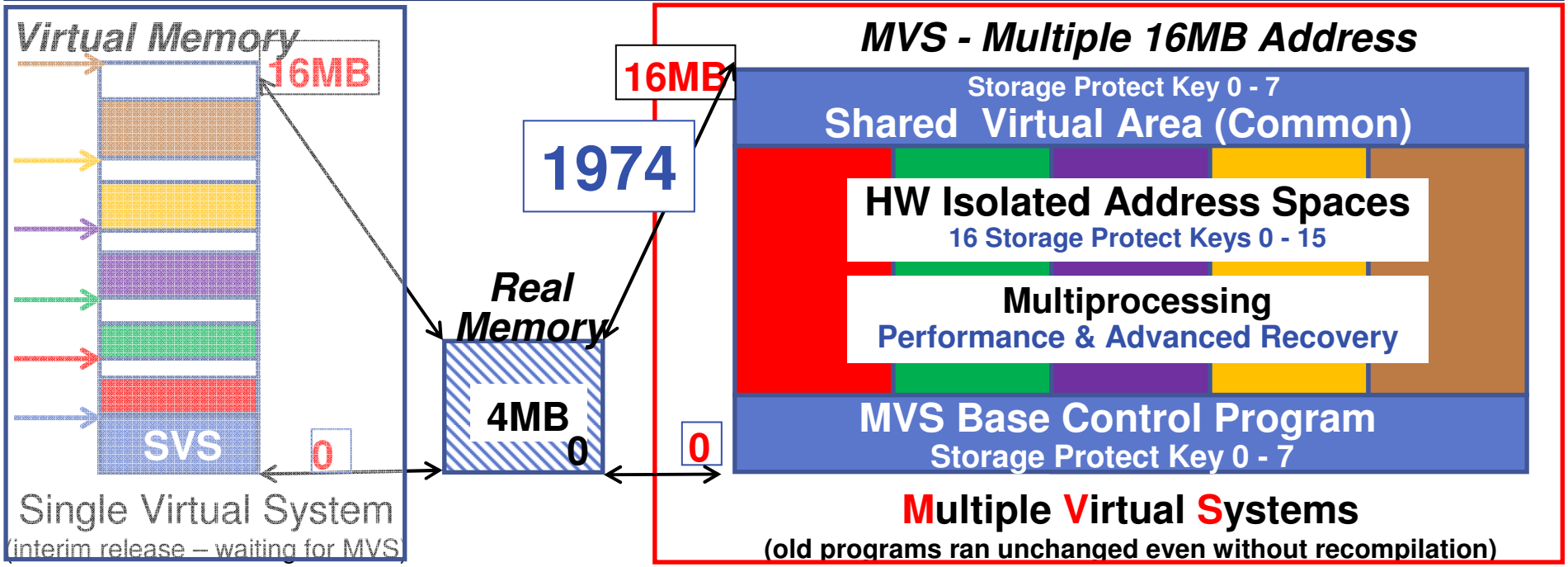
***A**uthorized **P**rogram **F**acility*

***S**ystem **R**esource **M**anager*
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)

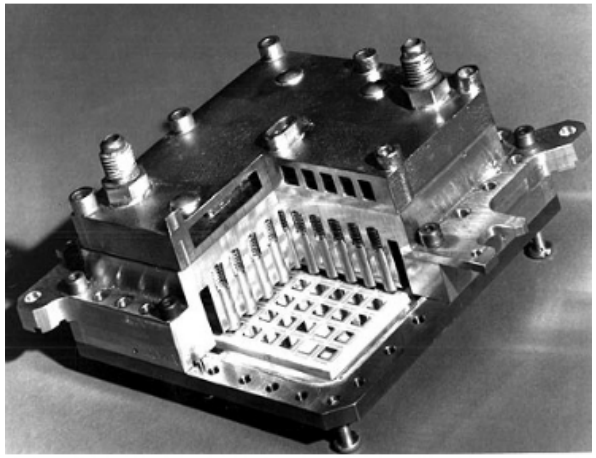
Essential Driver for Programmer Productivity



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

N-way support matures

308X 1/2/4 WAY
ES/9000-600 6WAY

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

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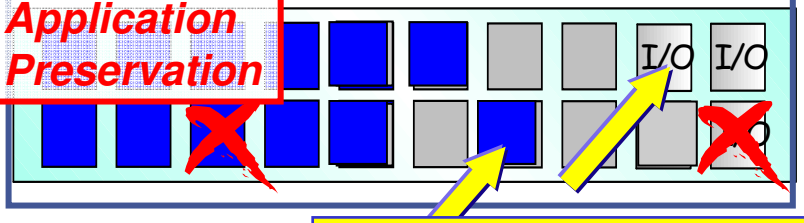
MCM = Multi Chip Module

20 PU's = Processor Units
8 CPU – 10 SPARE – 2 IO

Application Preservation



ADD / REMOVE
HW Capacity ON DEMAND

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

N-way support matures

308X 1/2/4 WAY
ES/9000-600 6WAY

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

Extended Addressing Architecture in the 1980ties

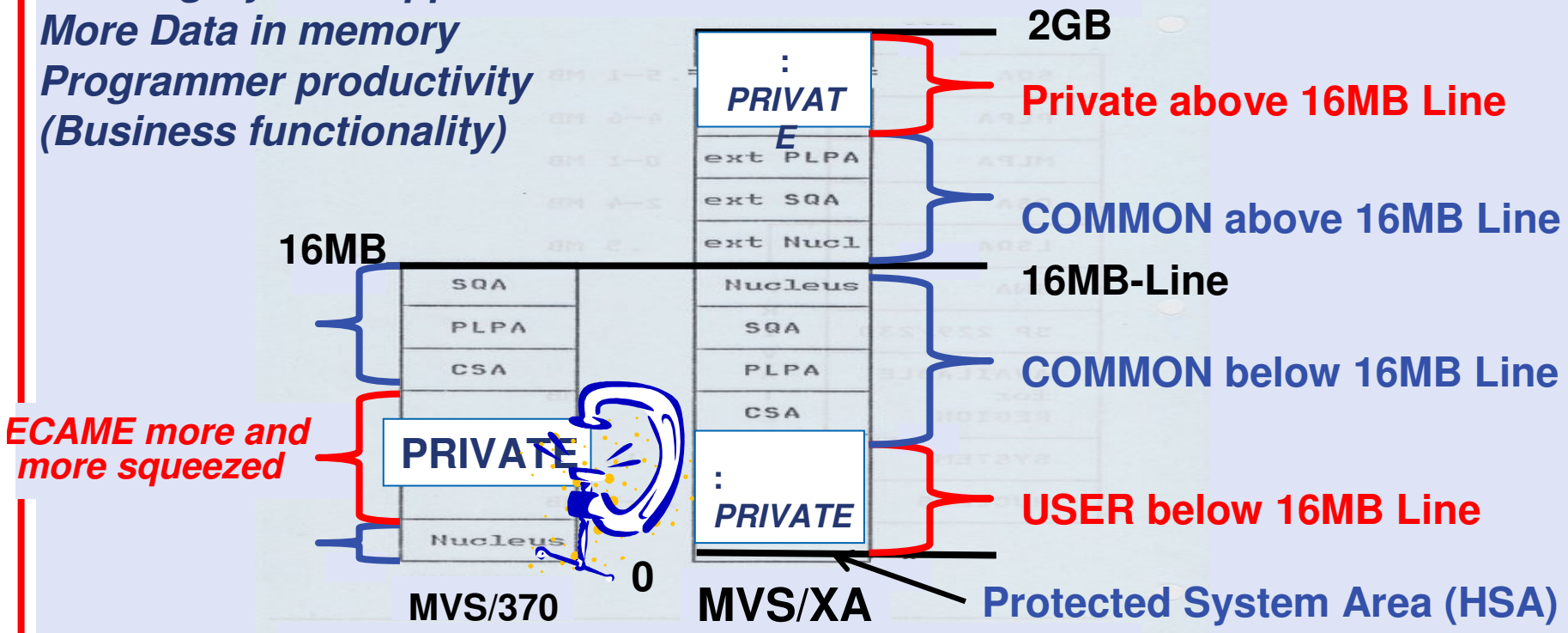
S/370 Extended Architecture (XA) - 1981 (shipped in 1983)

24-bit (16MB) or 31-bit addressing (2GB)

Bi-modal execution - both "types of programs" may co-execute simultaneously

Selling Virtual Storage !

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

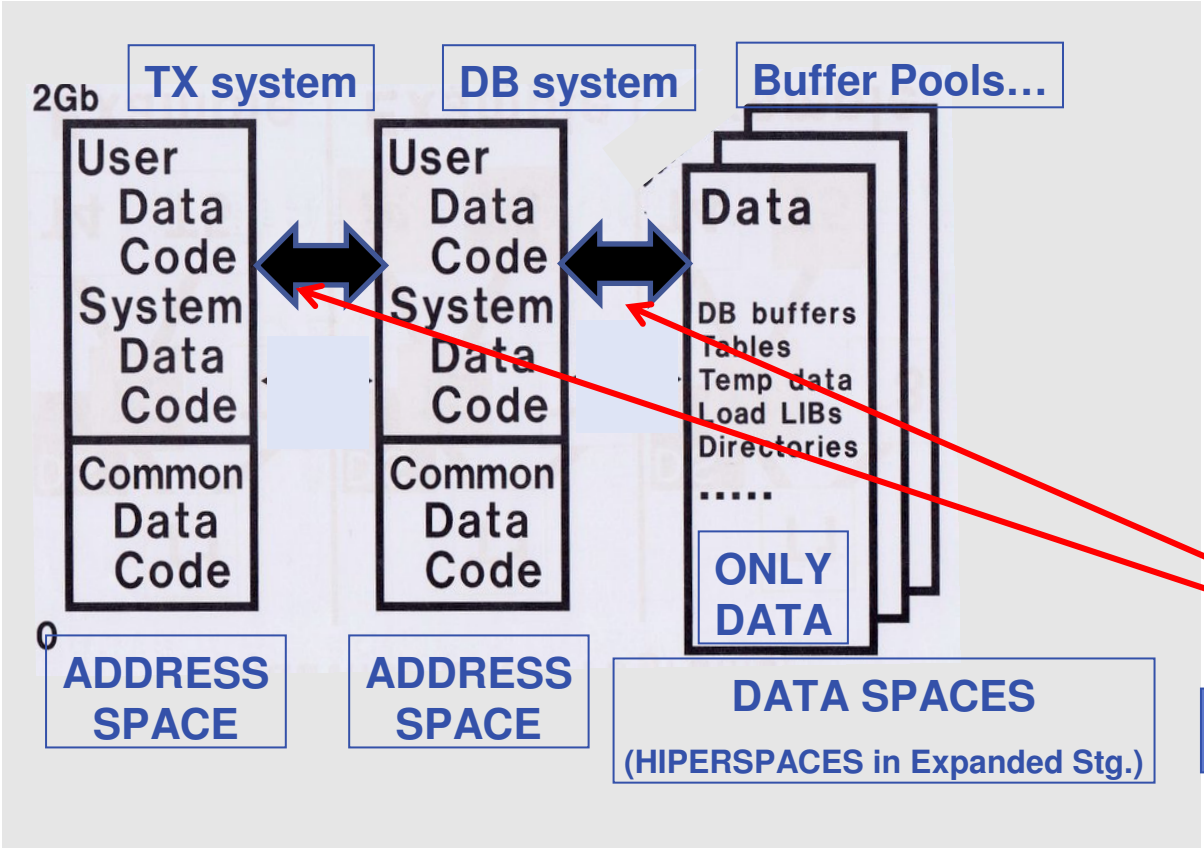


Extended Execution and (Data) Addressing Architecture …..

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 strenght of XM

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

HW Controlled Access

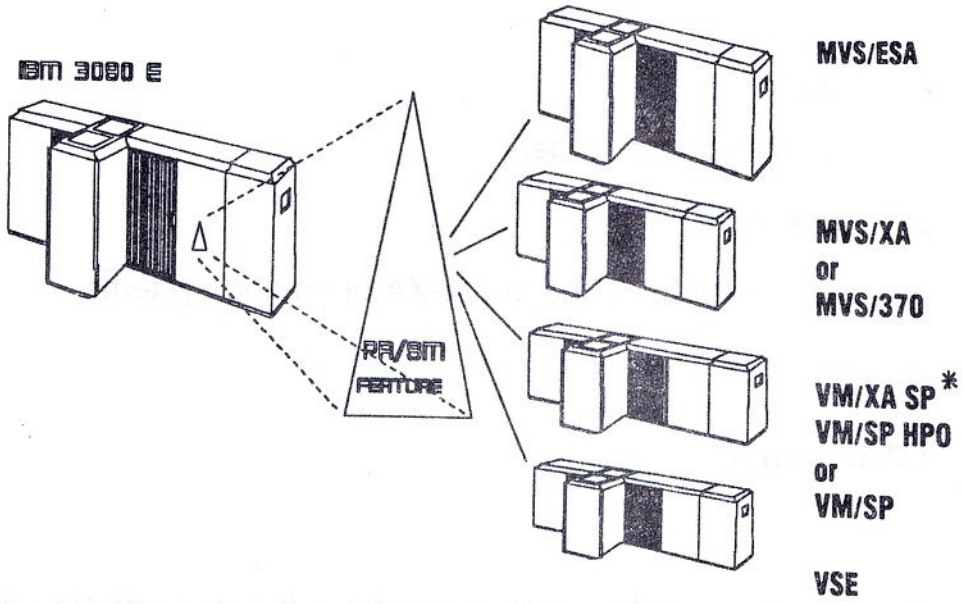
Virtualization of Processor Systems in the 1980ties

- **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

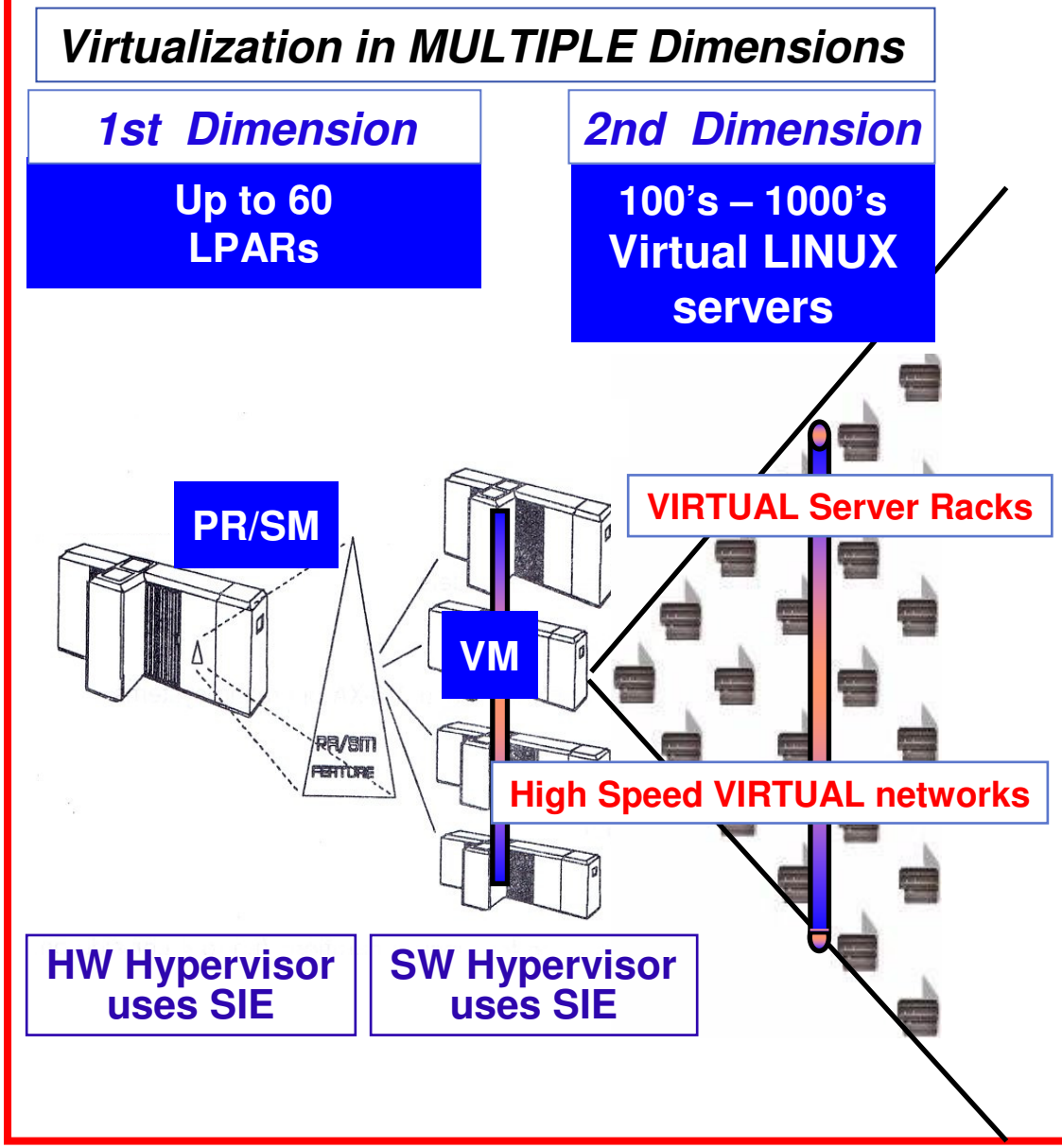
1990ties and on…

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

System z mainframe virtualization - not an "add-on", but a "built-in"



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

Breaking Down the walls of the Glass House - late 80ties/early 90ties

- ***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**
  - **EMIF – "VIRTUALIZATION" of CHANNELS**
  - **1st step towards Fiber Channel Protocol (Open Standard)**

Reports of the death of the mainframe… 1991

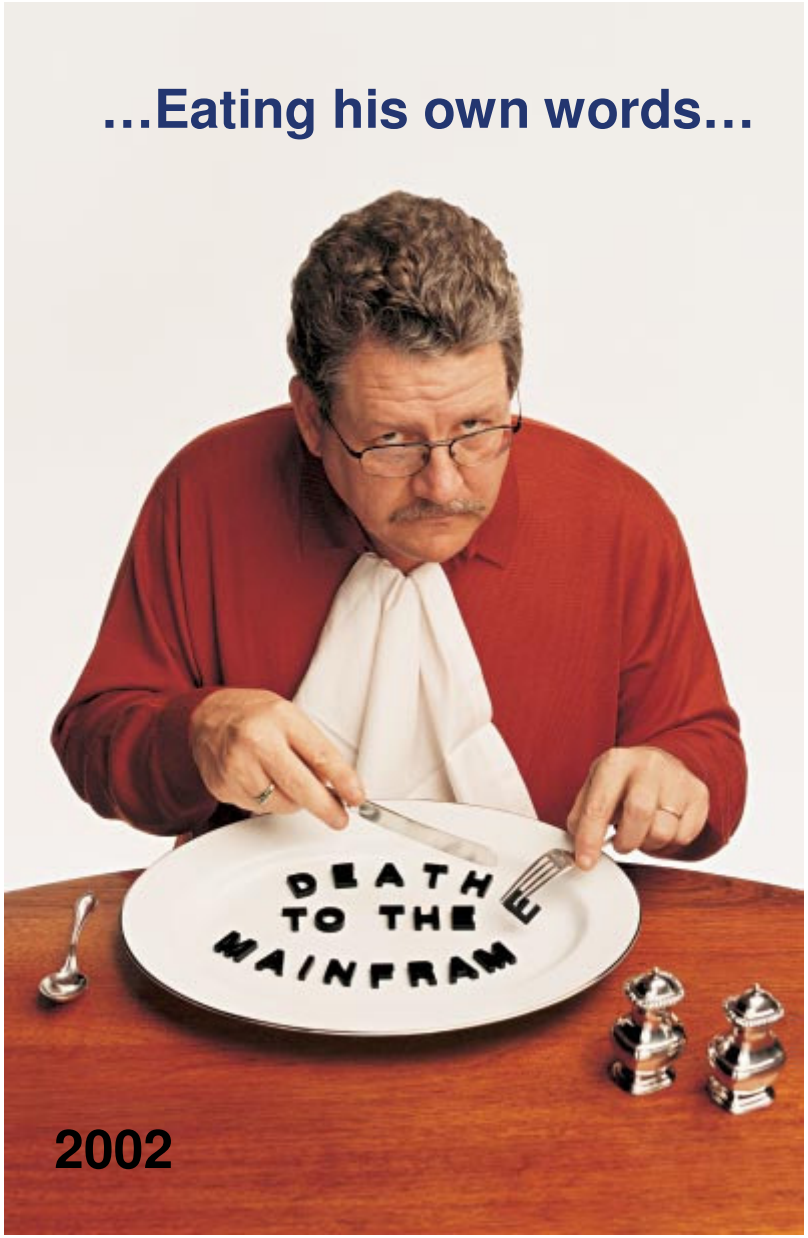
Near Deaths Experience –

- **"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

…Eating his own words…



MAJOR change of technology & architecture in the 90ties

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

ES/9000

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

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

9672

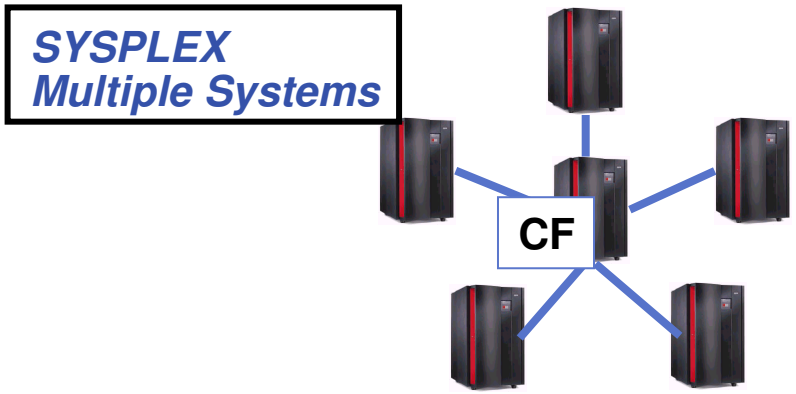
CMOS
15MIPS engine
6way - 65MIPS

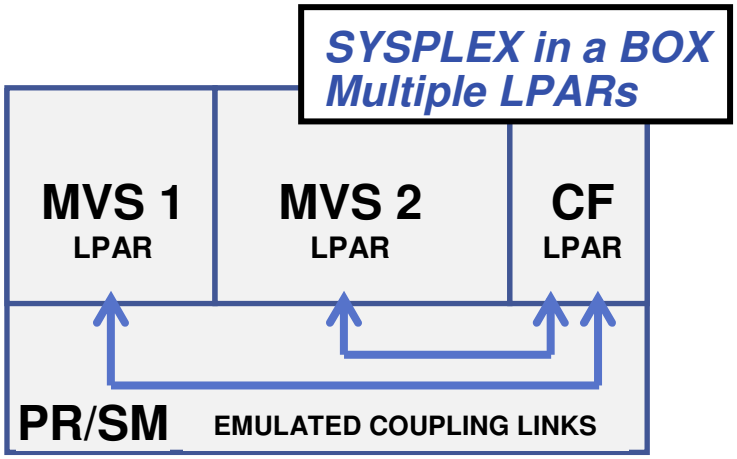
Double the capacity
Bipolar - avg. 5 years
CMOS - 1 to 2 years

MAJOR change of technology & architecture in the 90ties

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

Breaking Down the Glass House – late 90ties, 2000 and on…

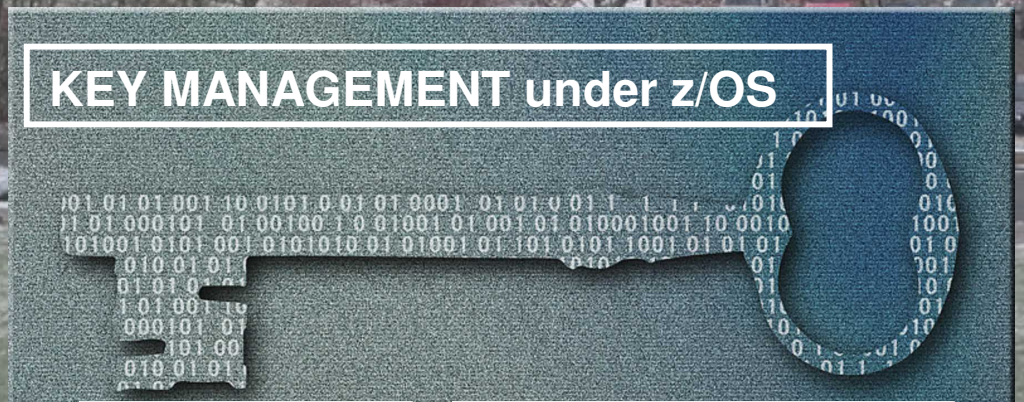
- **64 bit addressing – ultimate addressing capability**
  - **24-bit, 31-bit, 64-bit PROGRAMS RUN CONCURRENTLY *(Tri-Modal)***
- **Business Oriented Workload Management**
  - **MOVE RECOURCES to WORK - CPU, Memory, Channels *within/between ALL LPARs***

- **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



z/OS

z/VM

Linux **Linux** **Linux**

Virtualization with partitions

z/OS, zVM, System z & PRSM/LPAR has the highest security certifications on the market

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

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

Pure Systems
Integrated Packaging/Mgnt

DB2 Analytics
Transparent usage from DB2

z12/z114

z Architecture
z/OS
zVM - zLinux
ALL Applications

Resilient
Secure
Workload Mgnt
Scalable
ACCELERATORS

HMC

10 GbE IEDN

1 GbE INMN

zBx

Select IBM Blades

Optimizers

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

DataPower XI50z

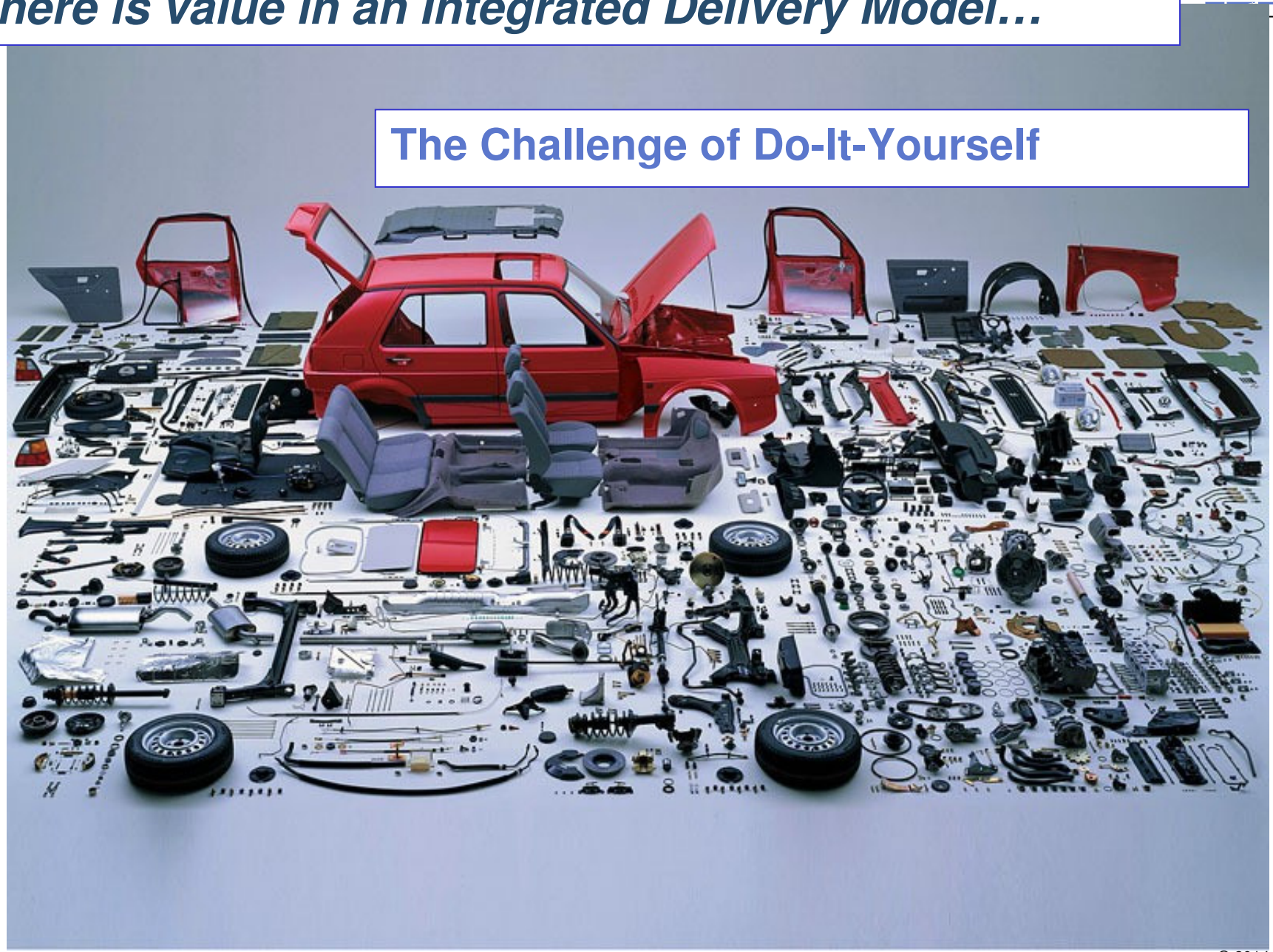
DataPower Optimizer…

Unified System(HW) and Workload Mgnt
Single Interface to multiple hypervisors

Data Center "Processor Infrastructure" in a Box
"Breaking down the Server Walls"

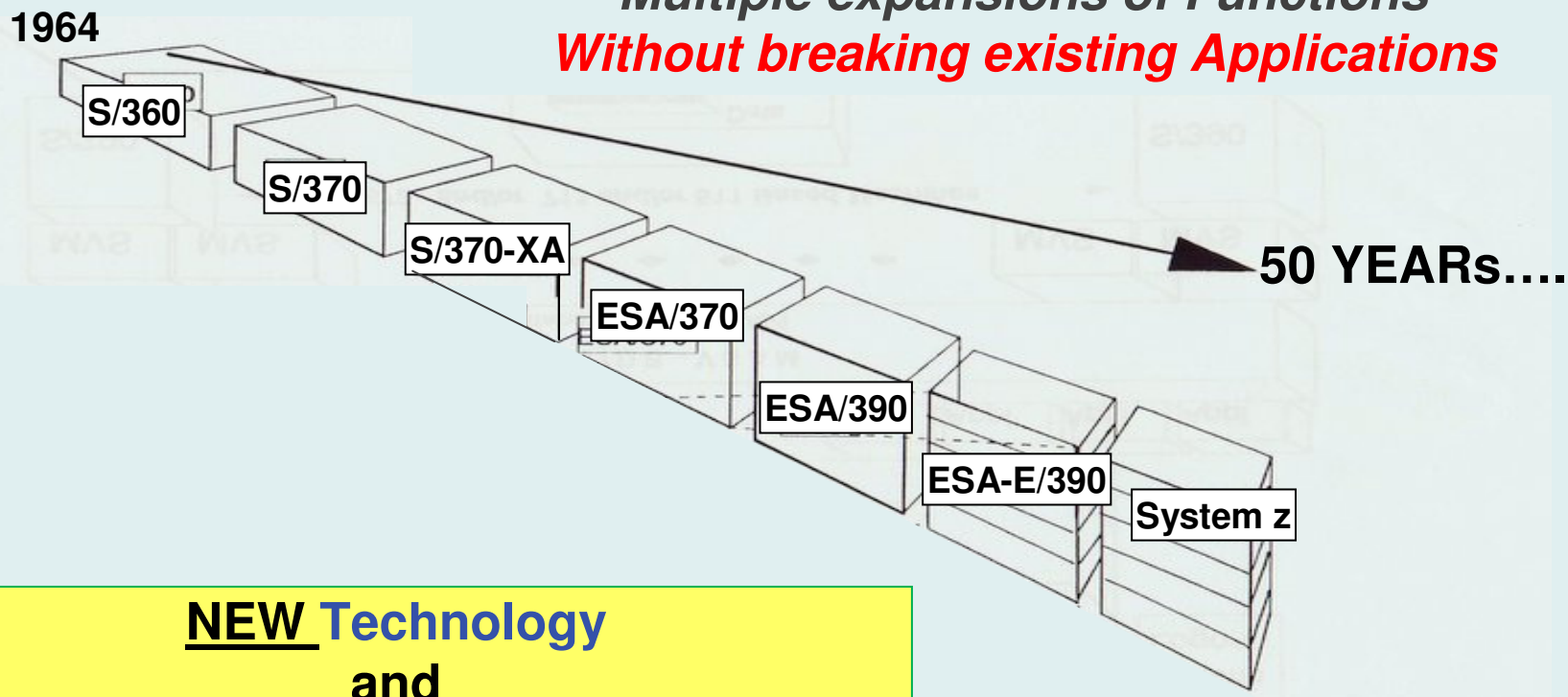
25

There is value in an Integrated Delivery Model…



"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



NEW Technology
and
NEW System Programming Model

WITHOUT CHANGING

The Application Model

"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

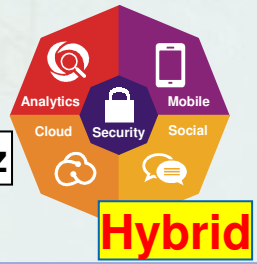
0,01-1,7MIPS
1-way

Price per instruction per second:

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)

50 YEARs….

System z



Hybrid

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

NEW Technology
and
NEW System Programming Model

WITHOUT CHANGING

The Application Model

GREEN techology

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

"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