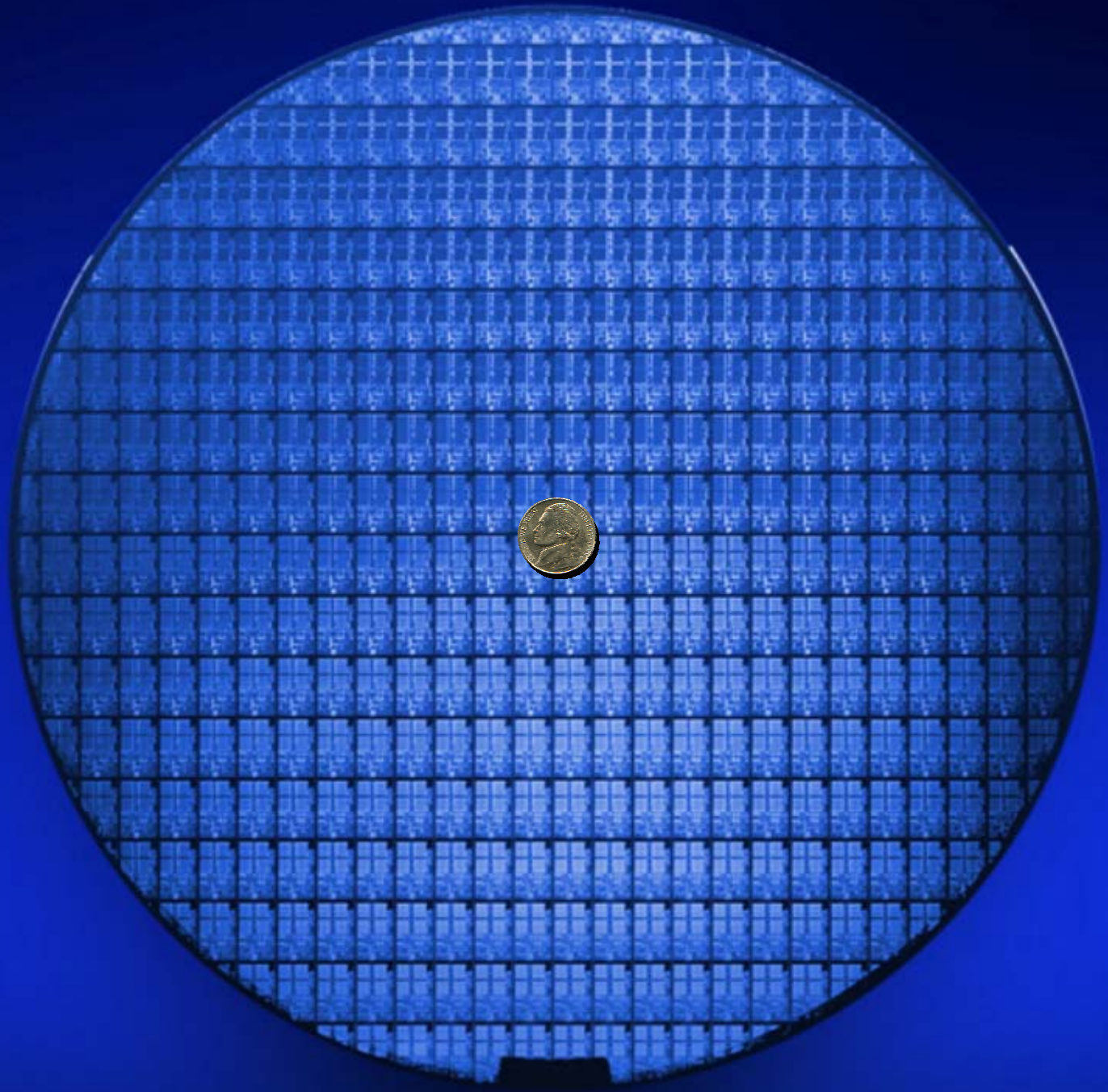
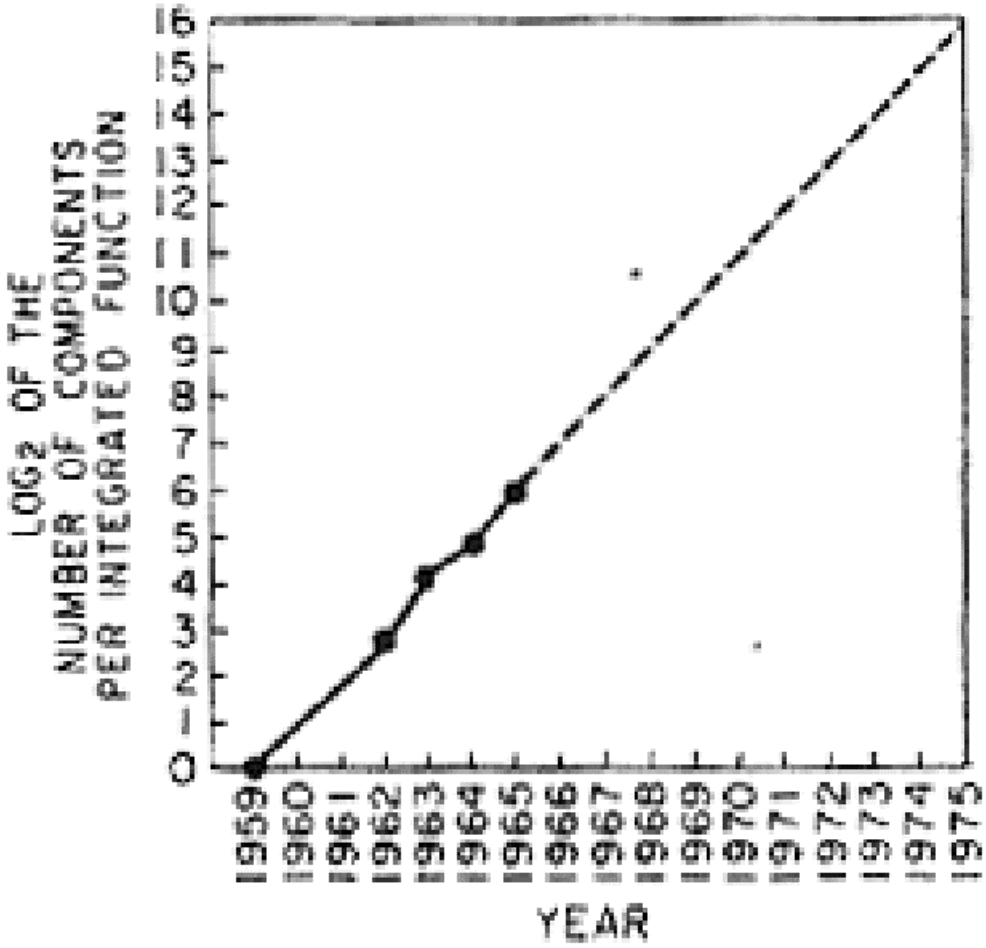
NO EXPONENTIAL IS FOREVER . . .

Gordon E. Moore

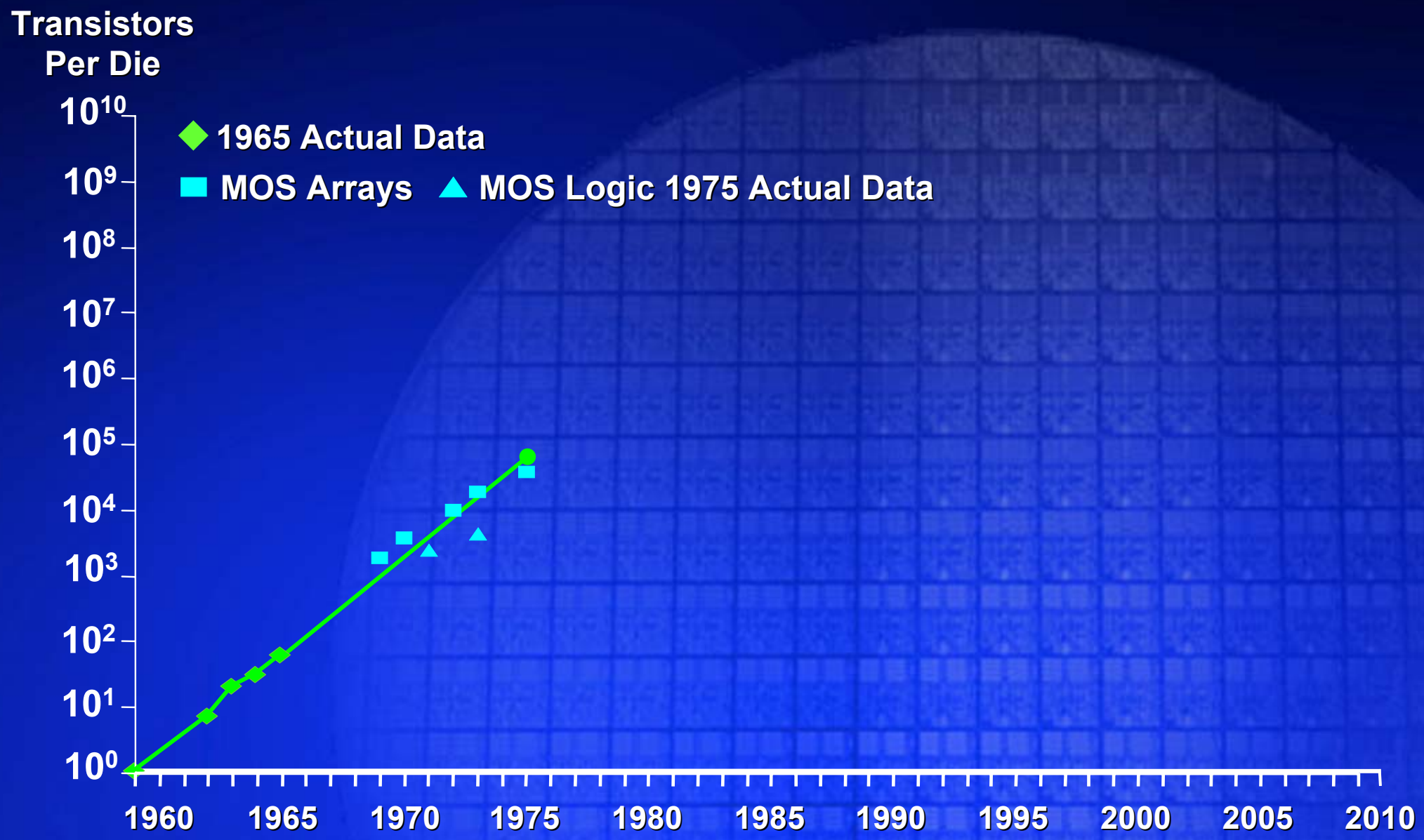
300mm Wafer



1965 Transistor Projection

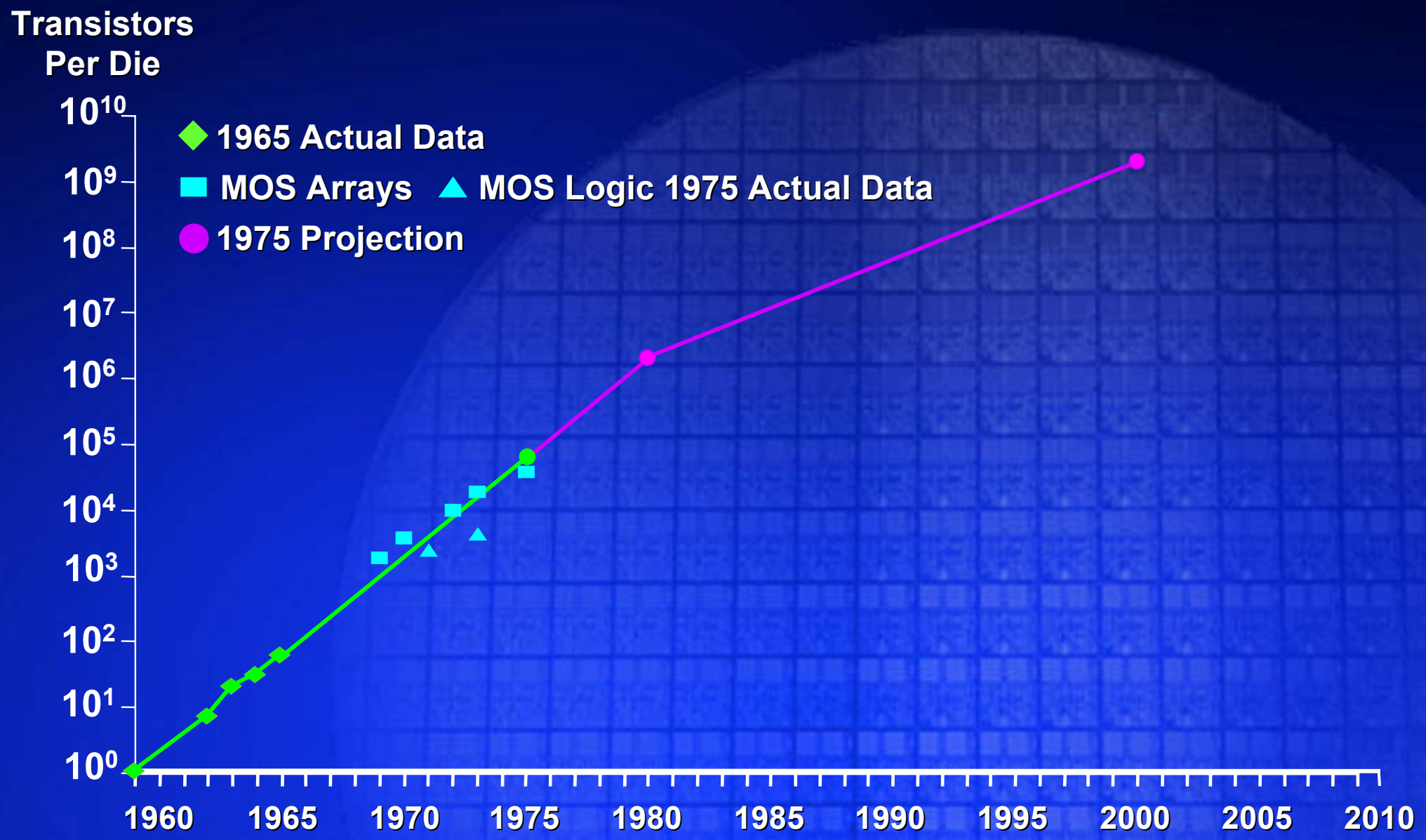


Integrated Circuit Complexity



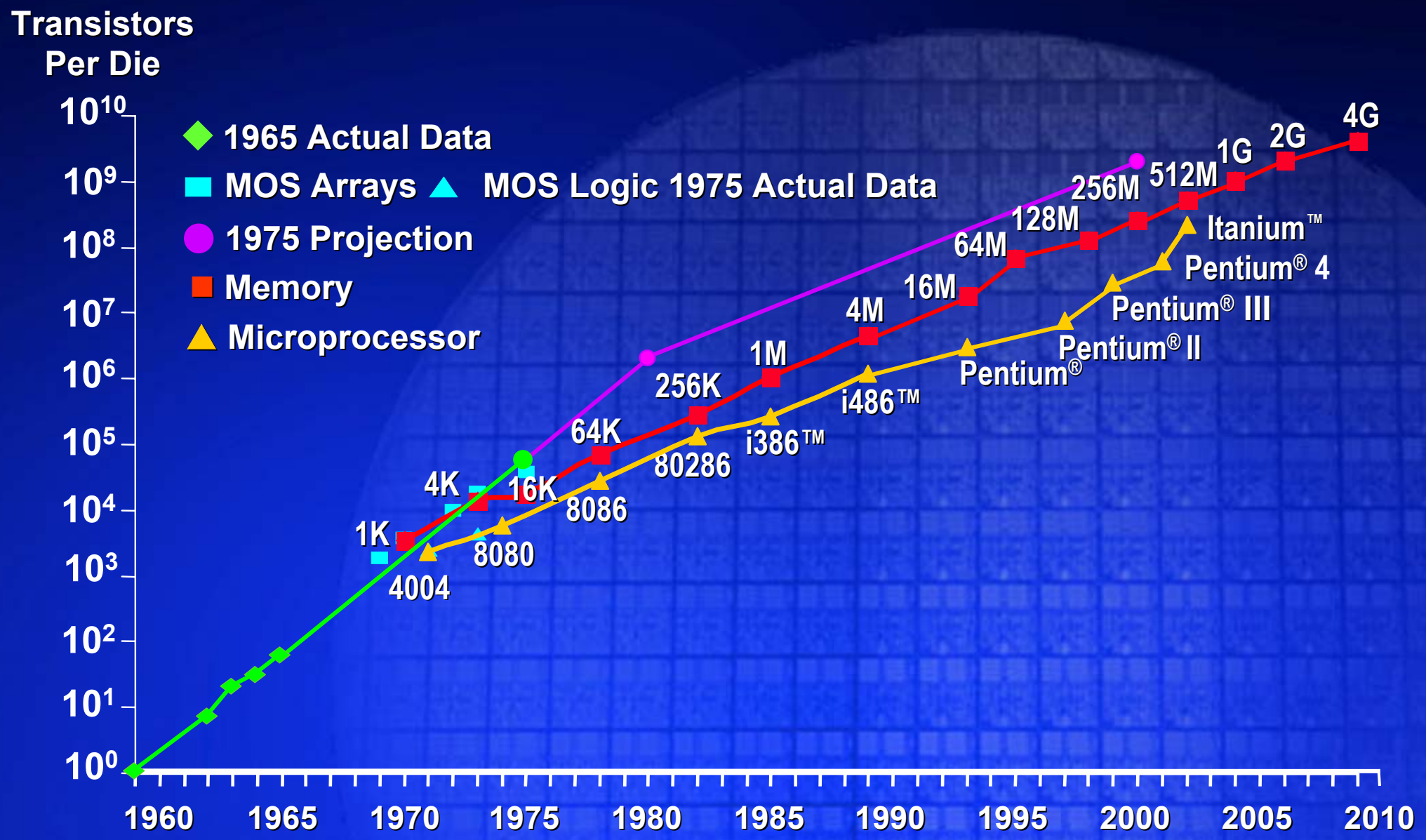
Source: Intel

Integrated Circuit Complexity



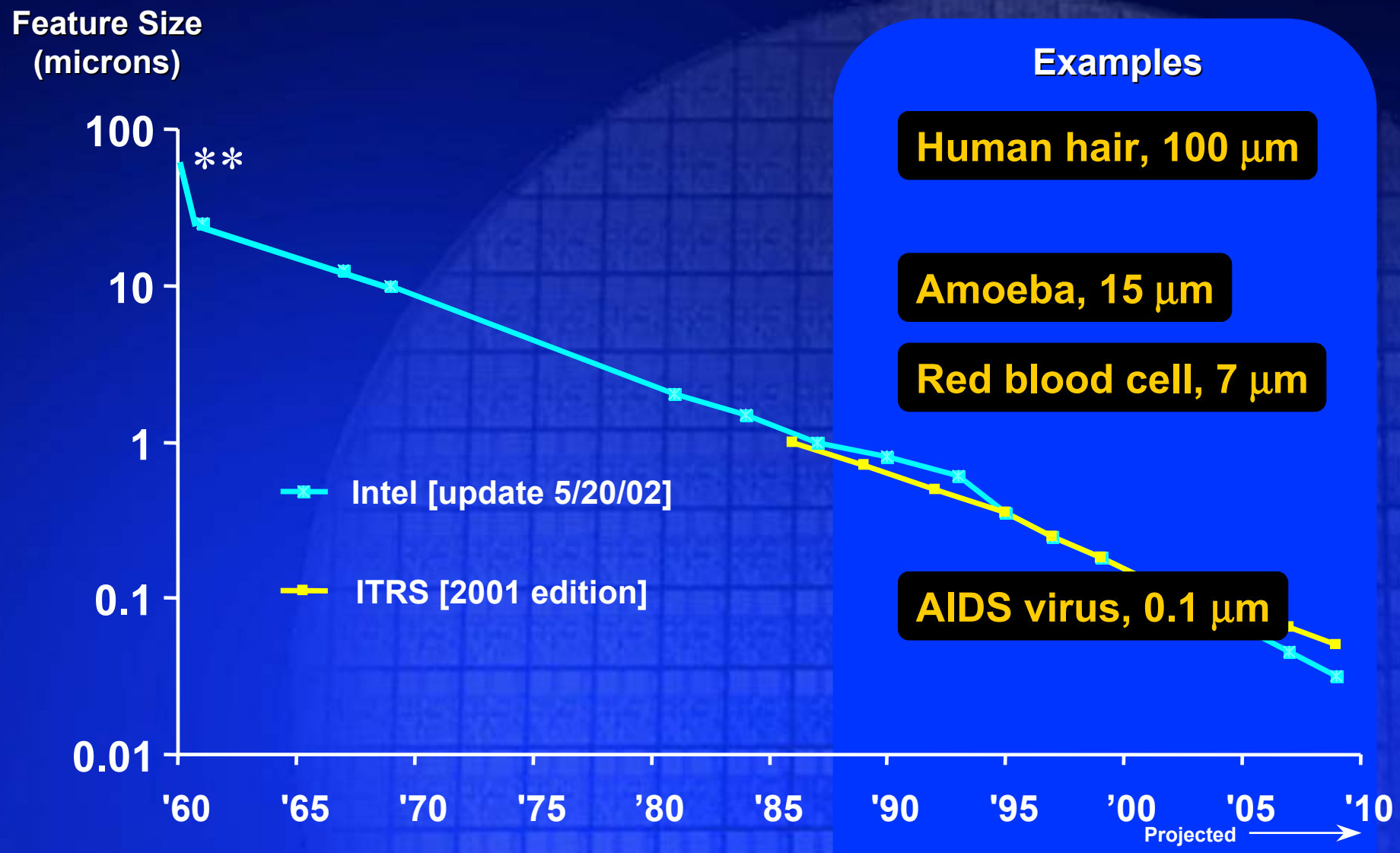
Source: Intel

Integrated Circuit Complexity



Source: Intel

Minimum Feature Size



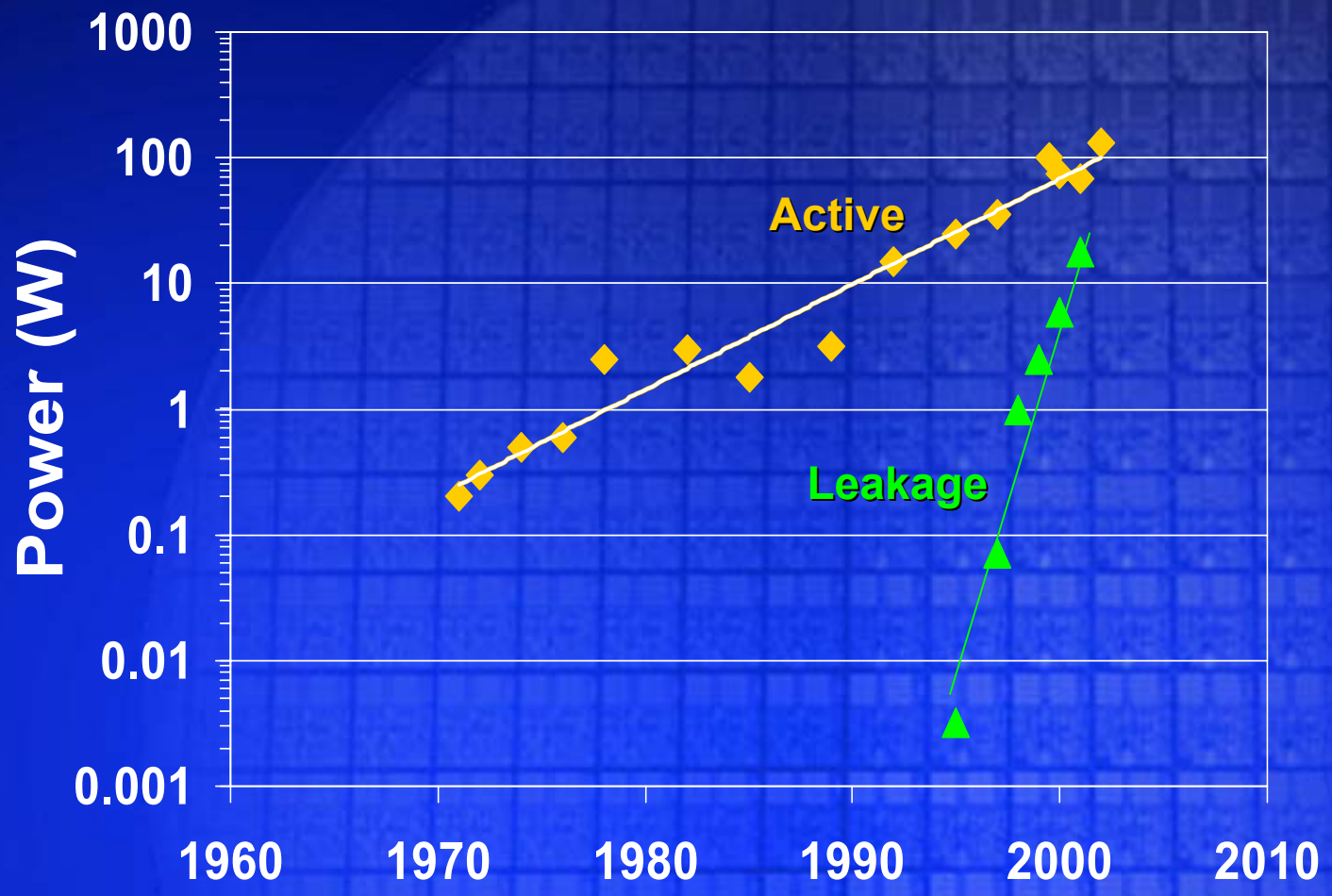
Examples

- Human hair, 100 μm
- Amoeba, 15 μm
- Red blood cell, 7 μm
- AIDS virus, 0.1 μm
- Buckyball, 0.001 μm

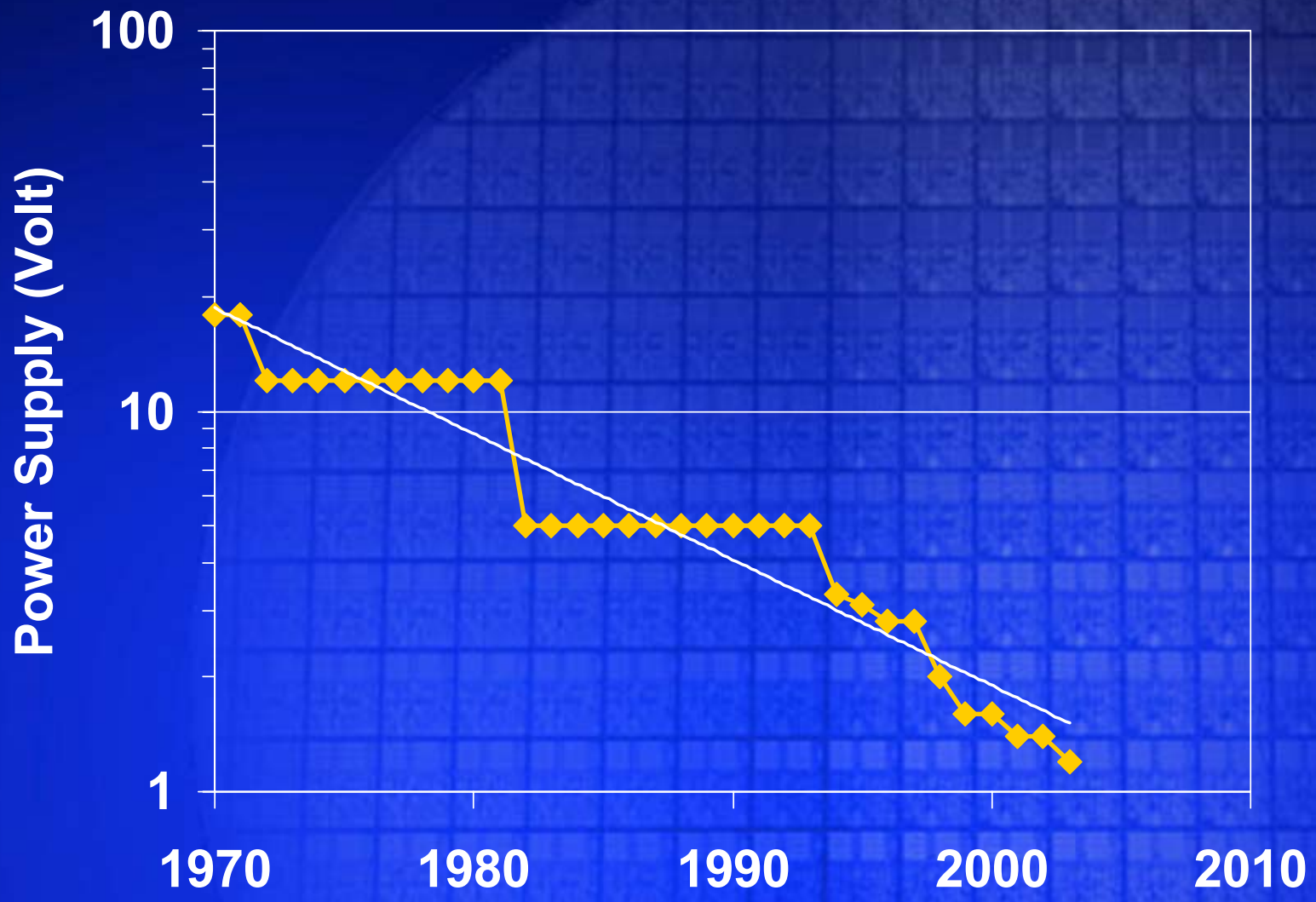
** Planar Transistor; remaining data points are ICs.
Source: Intel, post '96 trend data provided by SIA
International Technology Roadmap for Semiconductors (ITRS)
^ [ITRS DRAM Half-Pitch vs. Intel "Lithography"]

Processor Performance (MIPS)

Processor Power (Watts) - Active & Leakage

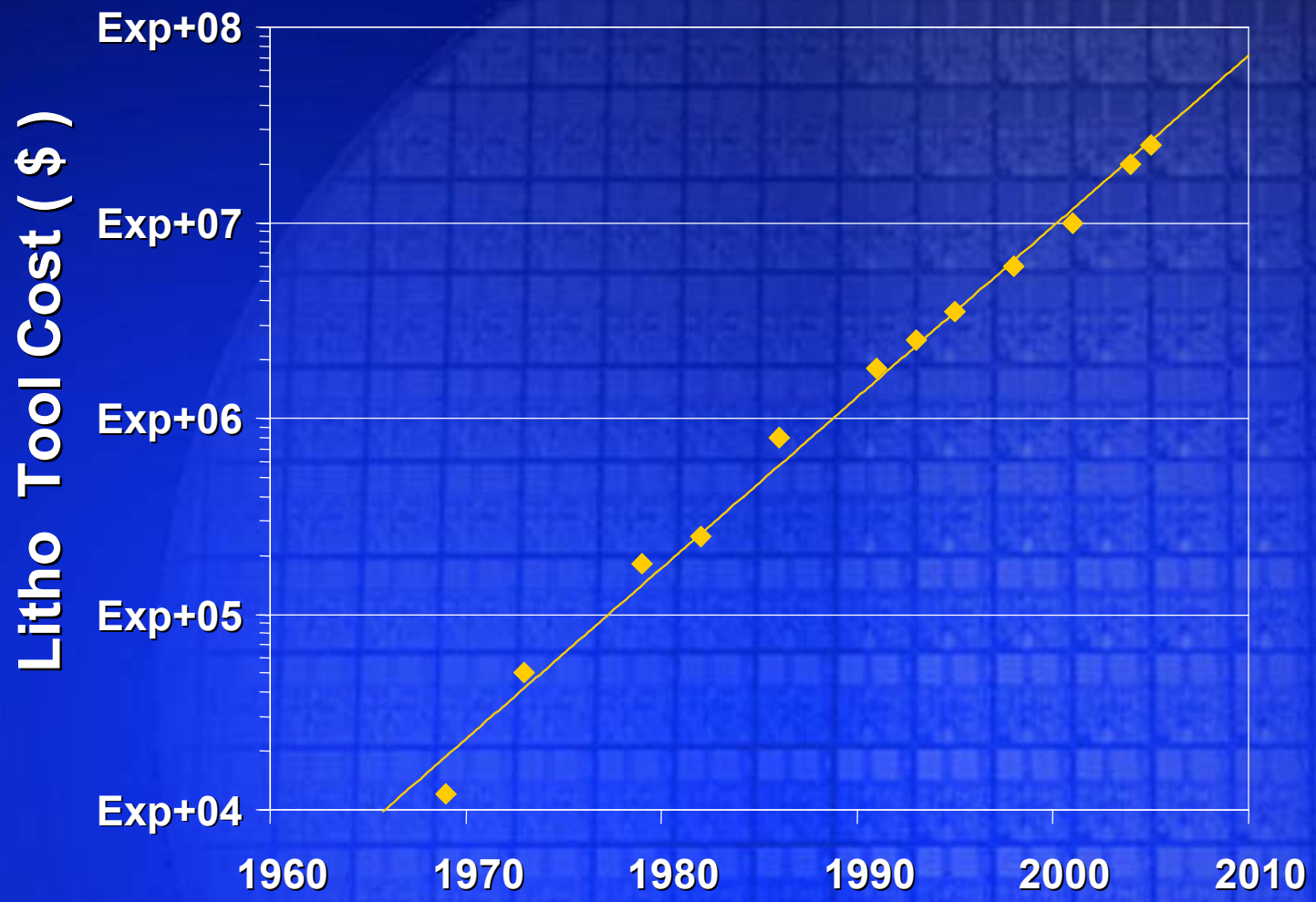


Processor Supply Voltage



193nm Step and Scan Production Tool

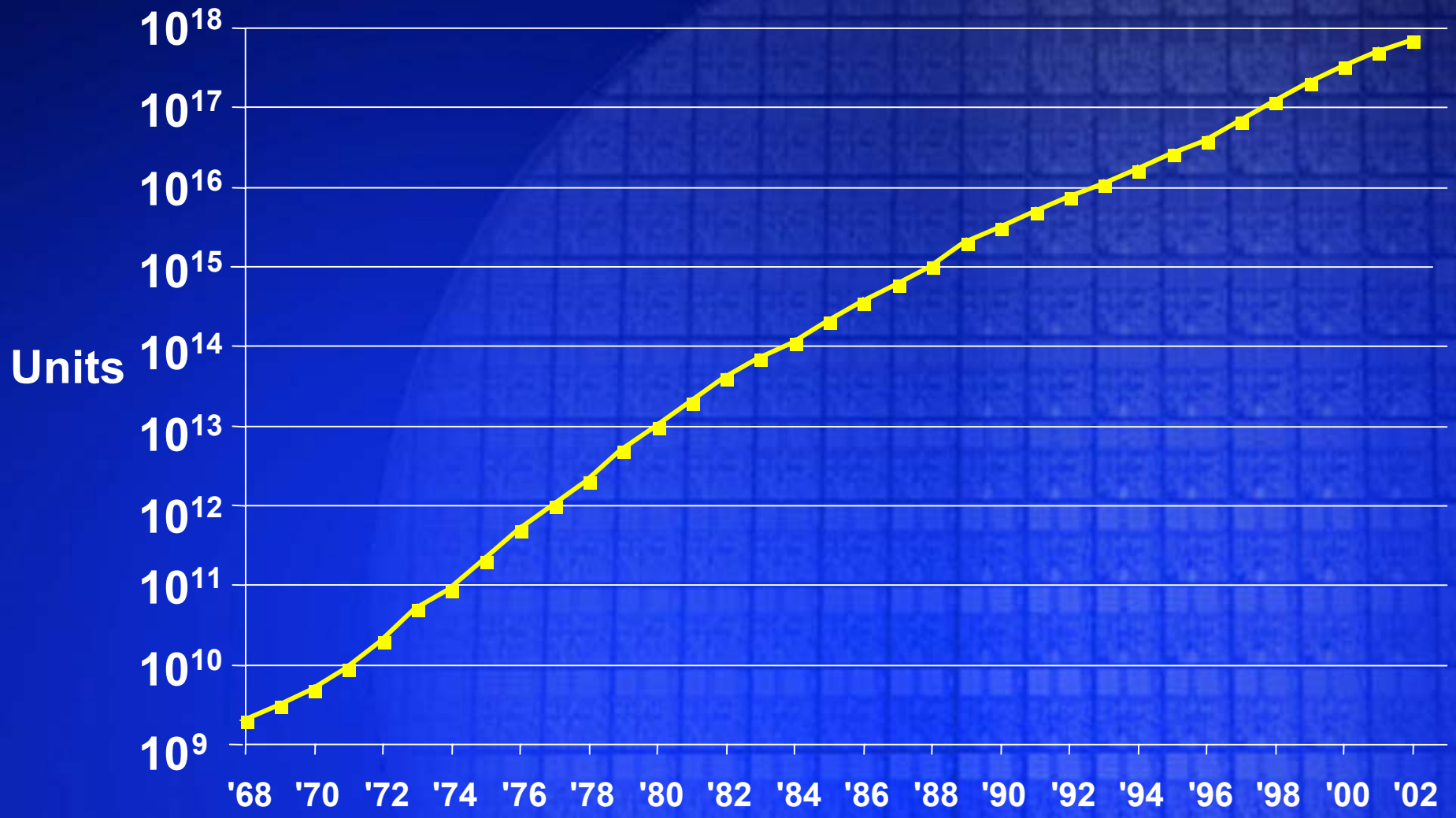
Lithography Tool Cost ($)



Worldwide Semiconductor Revenues

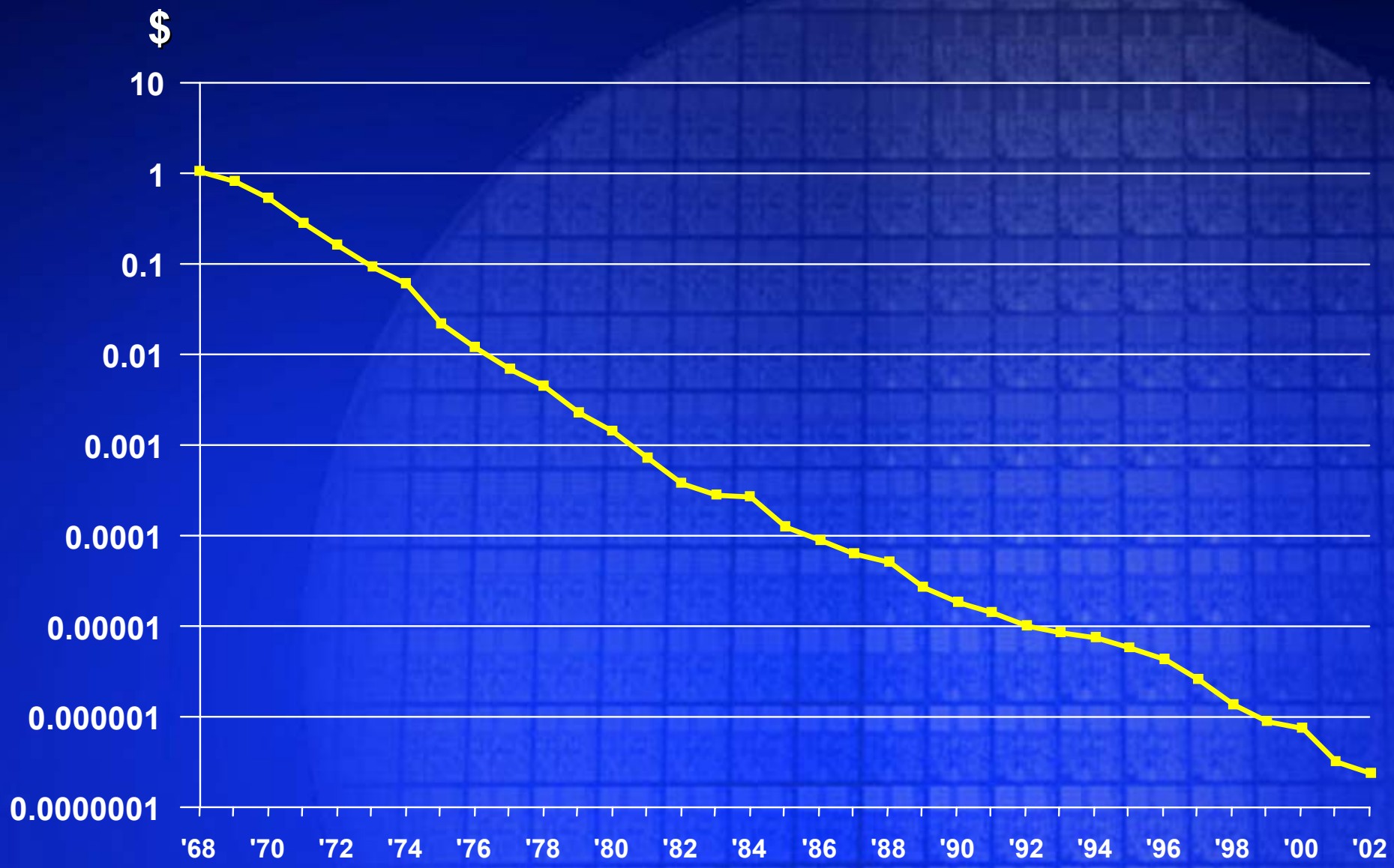
Source: Intel/WSTS,12/02

Transistors Shipped Per Year



Source: Dataquest/Intel, 12/02

Average Transistor Price By Year



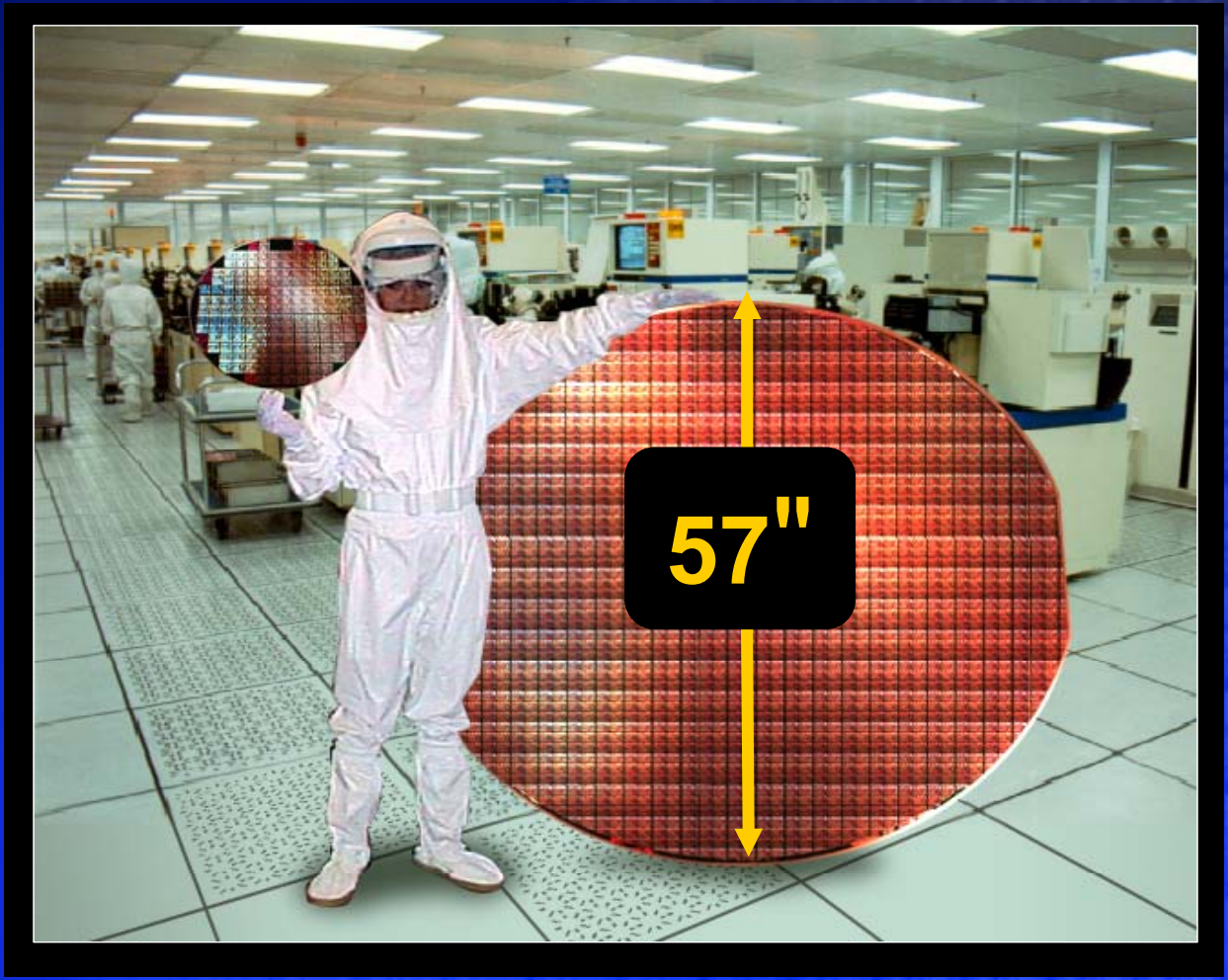
Source: Dataquest/Intel12/02

NO EXPONENTIAL IS FOREVER . . .

BUT

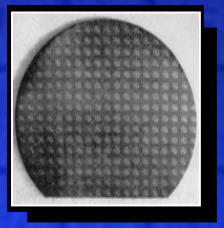
WE CAN DELAY “FOREVER”

Projected 2000 Wafer, circa 1975

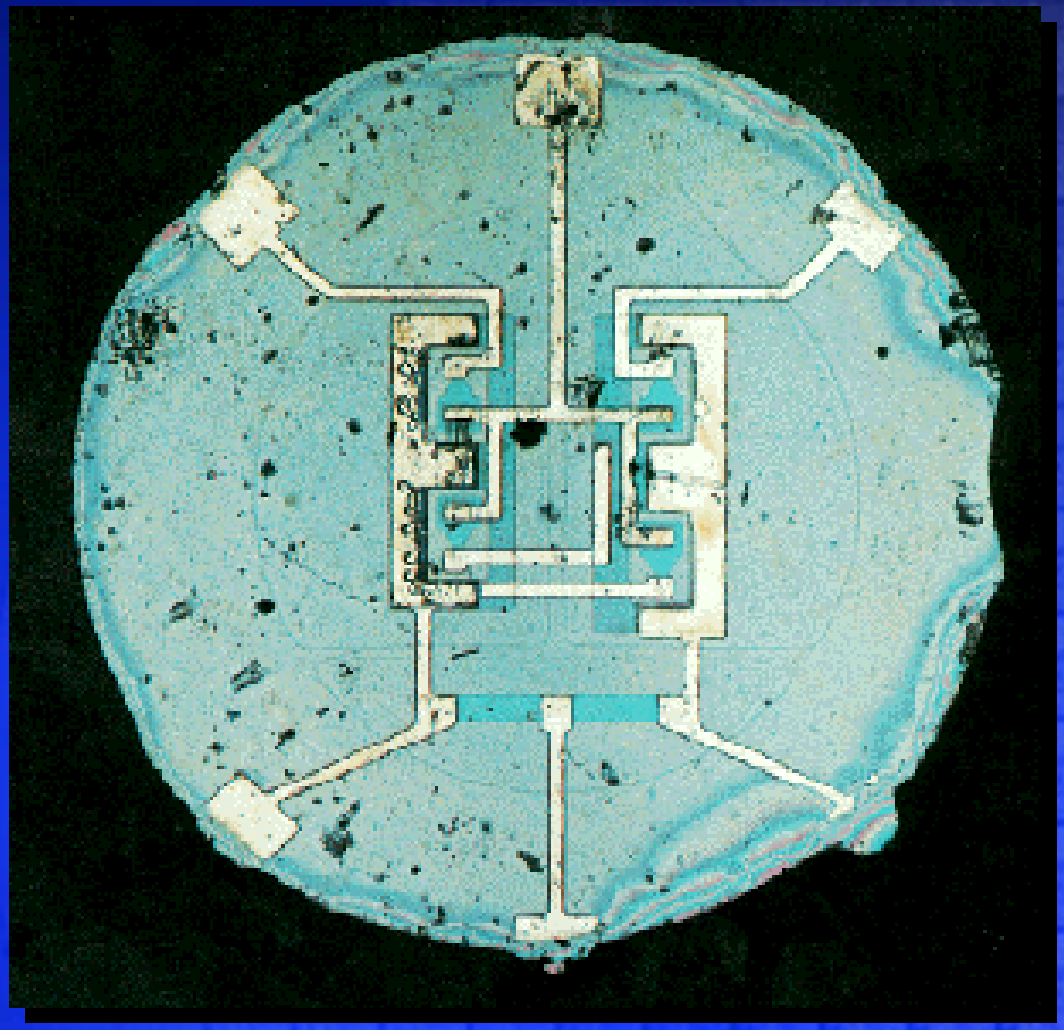


Moore was not always accurate

1” Wafer Of Planar Transistors, ~1959



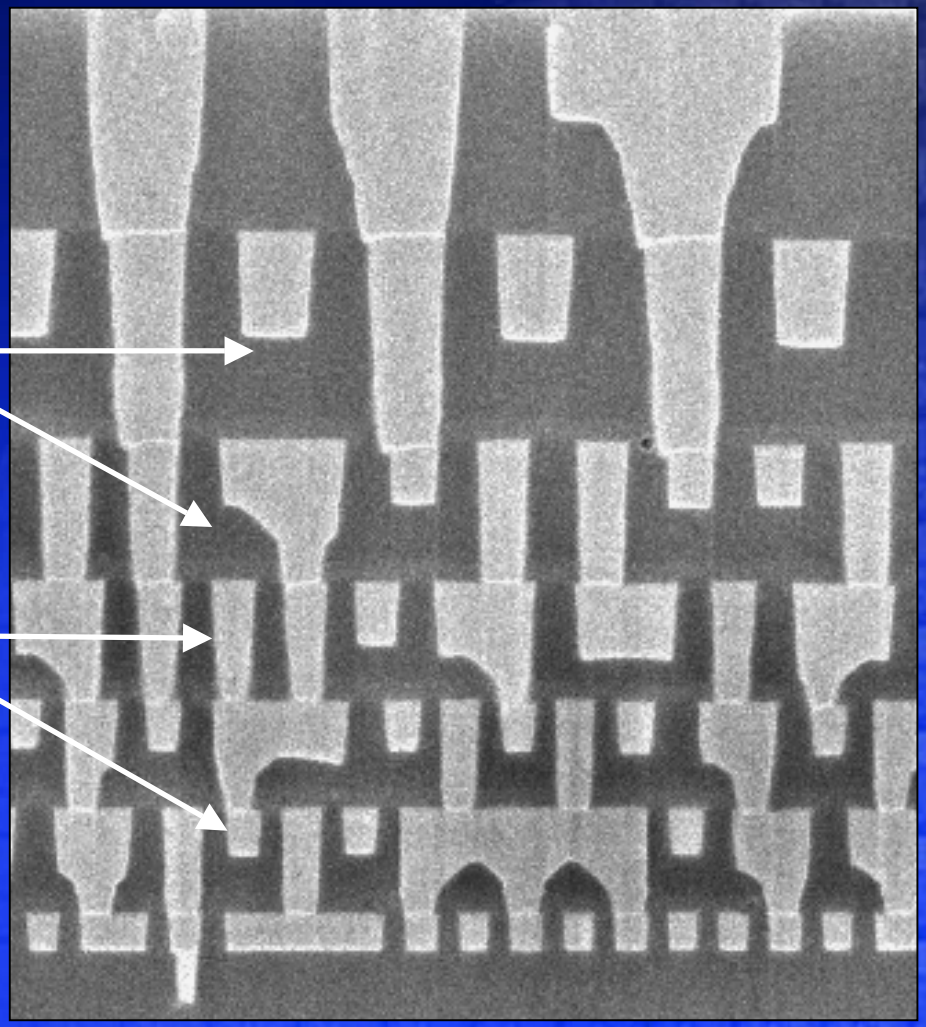
The First Planar Integrated Circuit, 1961



90 nm Generation Interconnects

Low-k CDO Dielectric

Copper Interconnects



M7

M6

M5

M4

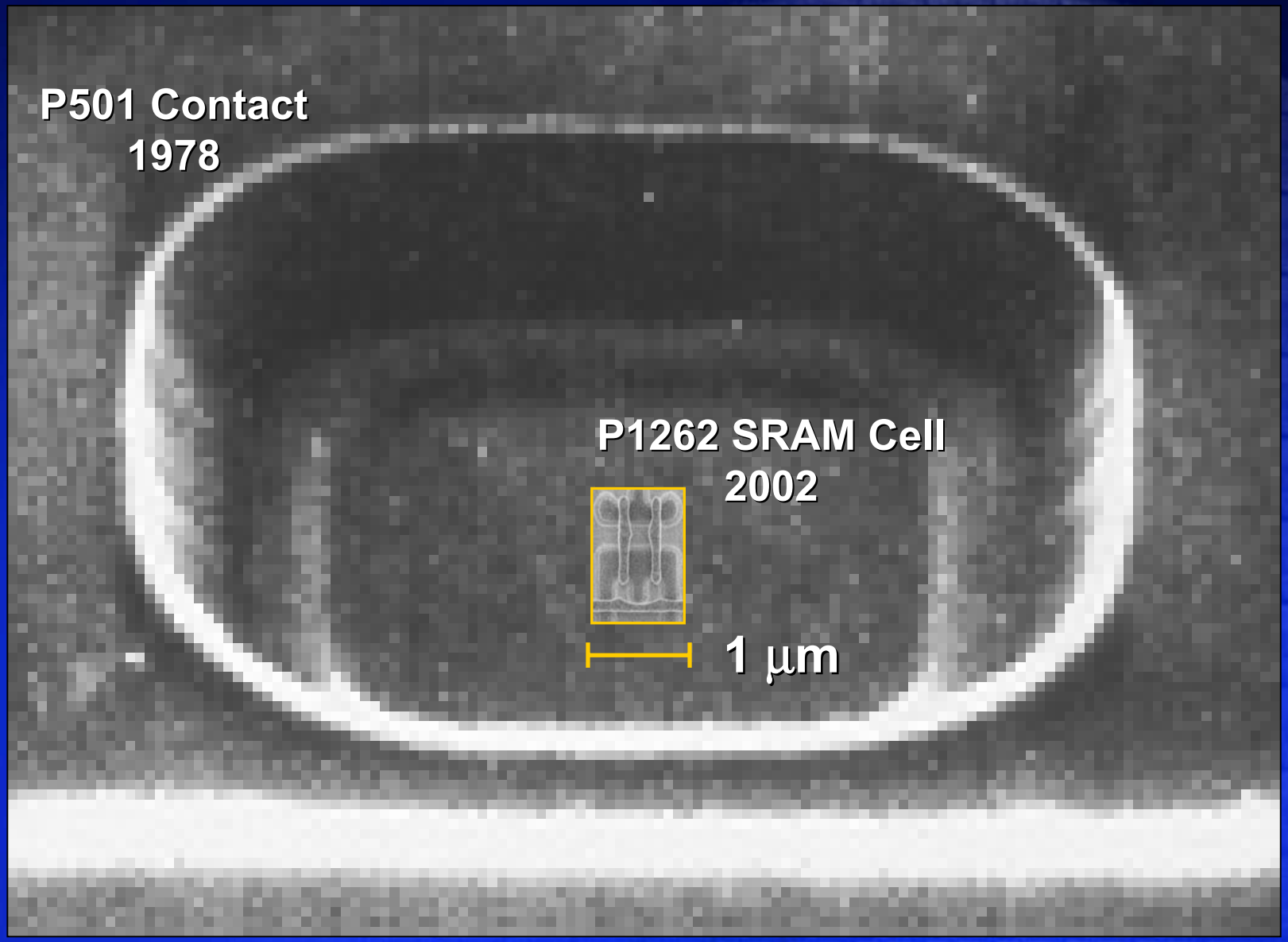
M3

M2

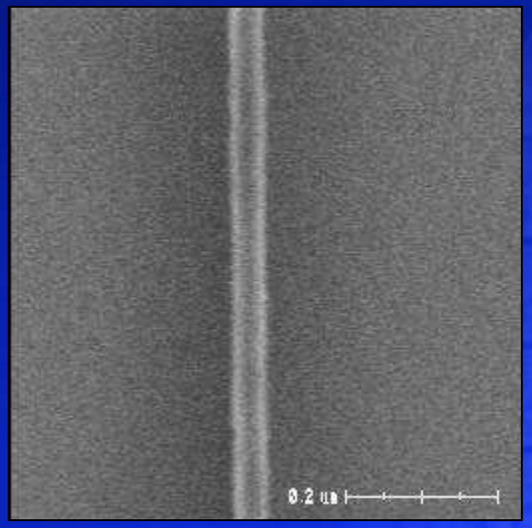
M1

Combination of copper + low-k dielectric now meeting performance and manufacturing goals

1 μm² SRAM Cell

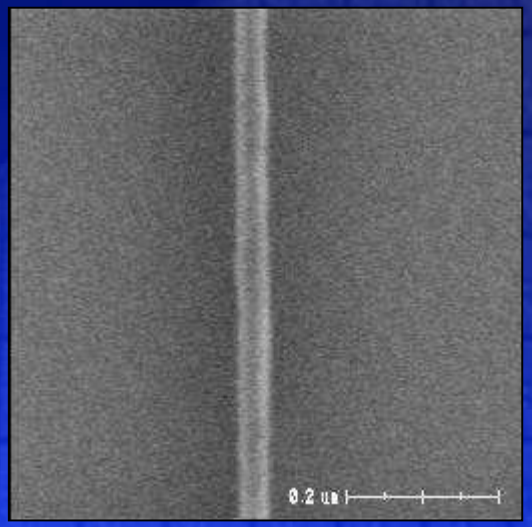


50nm Resist Lines With 193nm Light

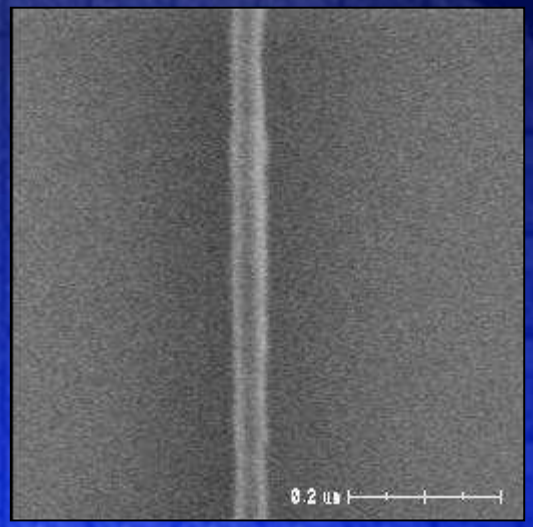


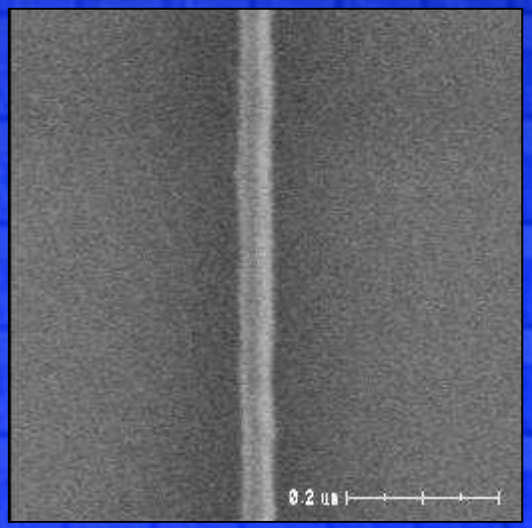
“best focus”

-0.2um focus

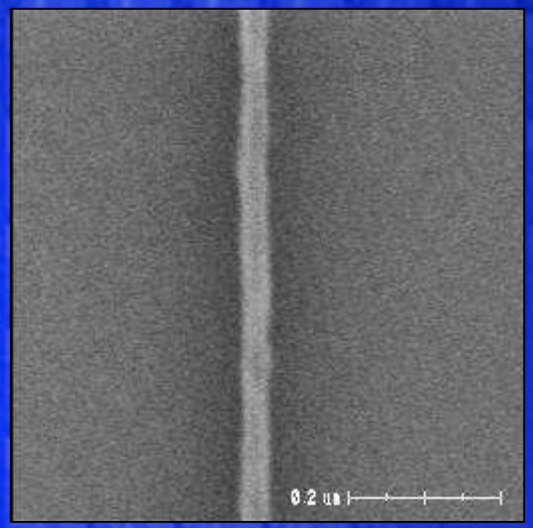


-0.3um focus



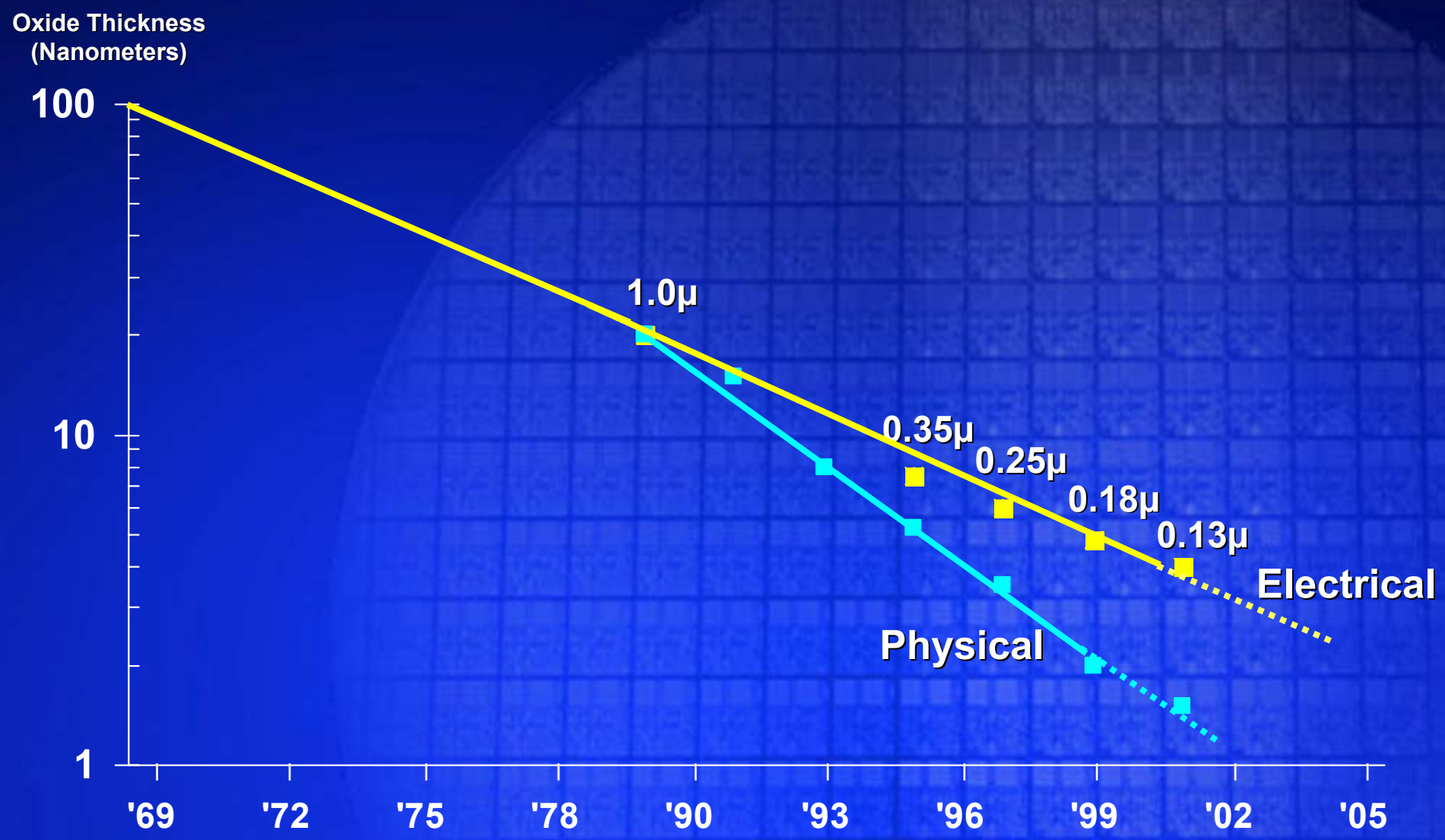


+0.2um focus



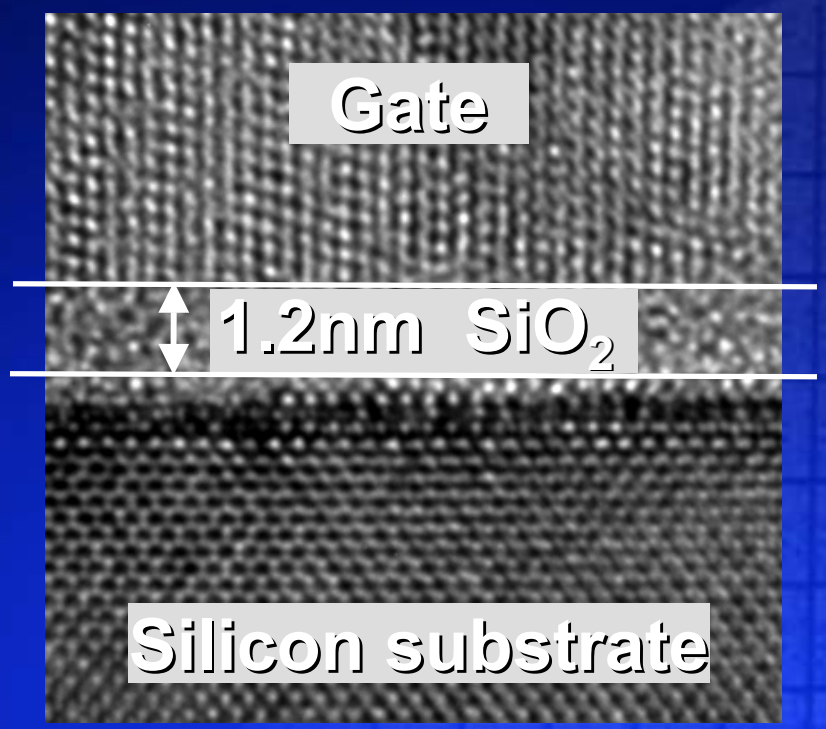
+0.3um focus

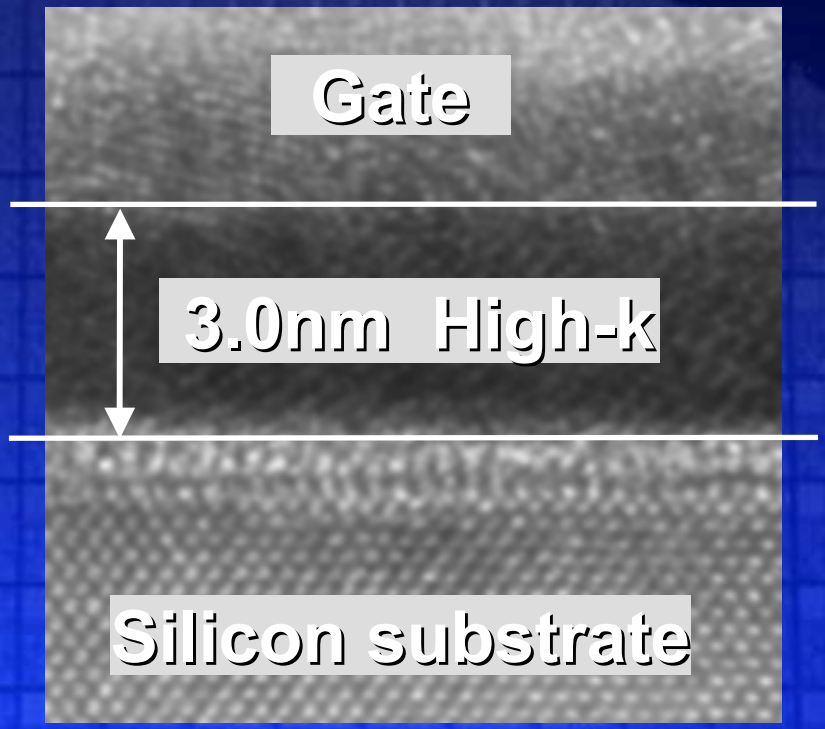
Minimum Insulator Thickness vs Time



Source: Intel

High K for Gate Dielectrics





	90nm process	Experimental high-k
Capacitance	1X	1.6X
Leakage	1X	< 0.01X

Source: Intel

New Materials and Device Structures Extending Transistor Scaling

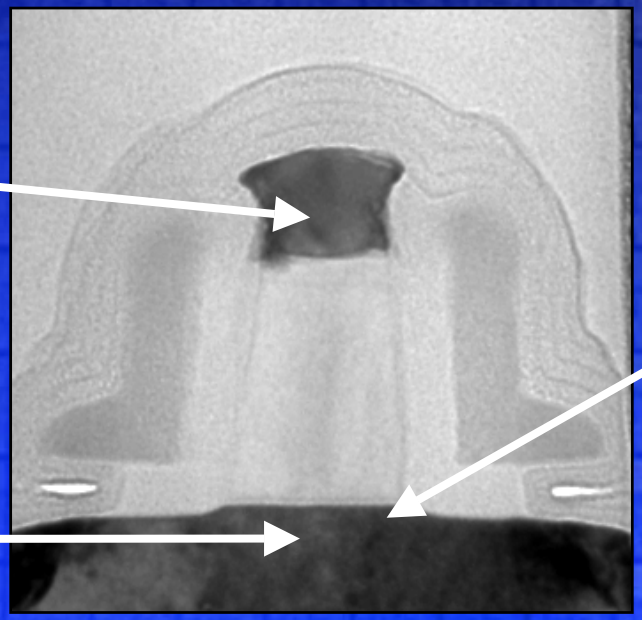
Changes Made

Gate

Silicide Added

Channel

Strained Silicon



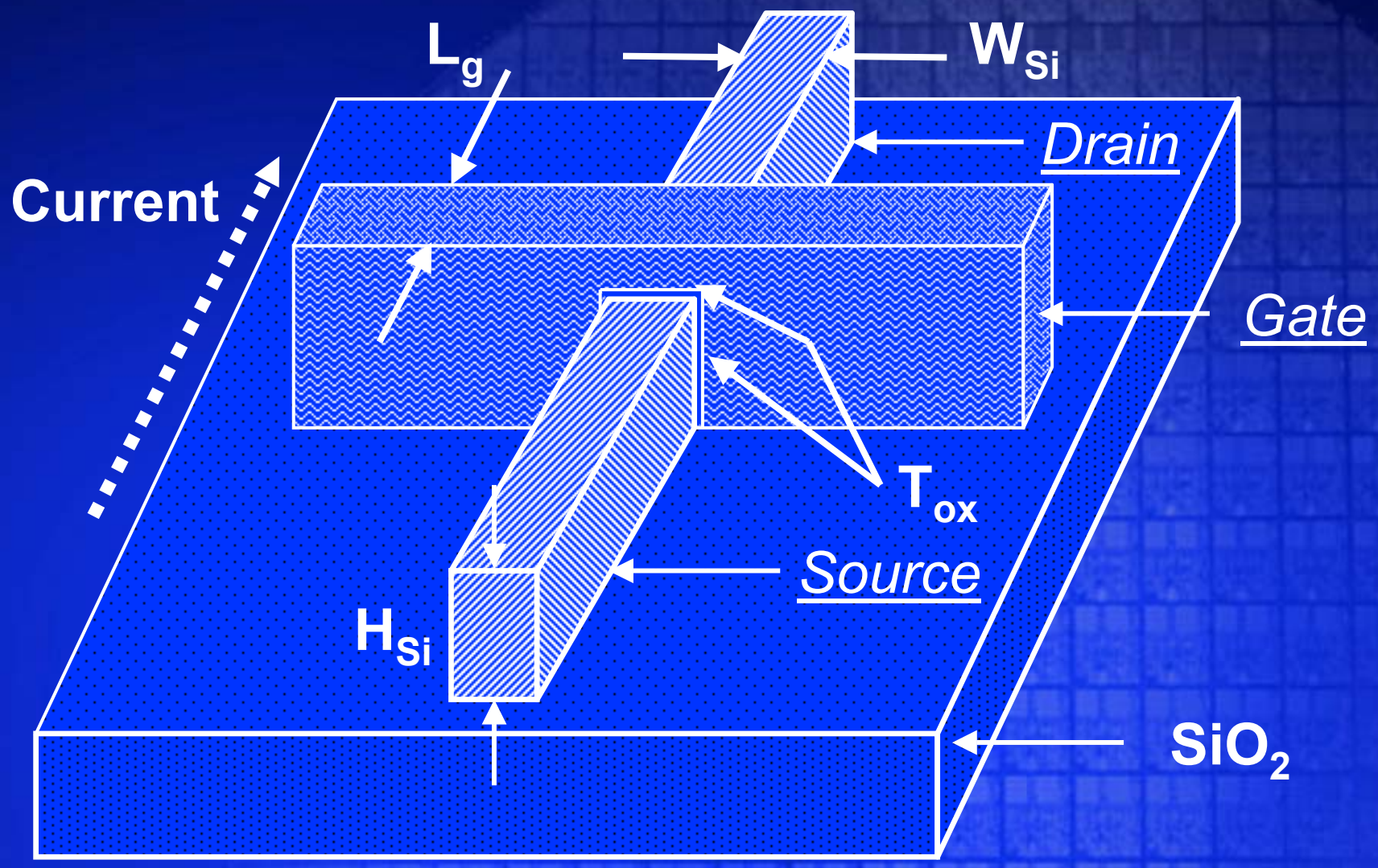
Transistor

Future Options

High-k Gate Dielectric

New Transistor Structure

Tri-Gate Transistor Structure



Technology Generations to Come

Double the Density
Reduce Line Width by 0.7x

130nm→90nm→60nm→45nm→30nm→?

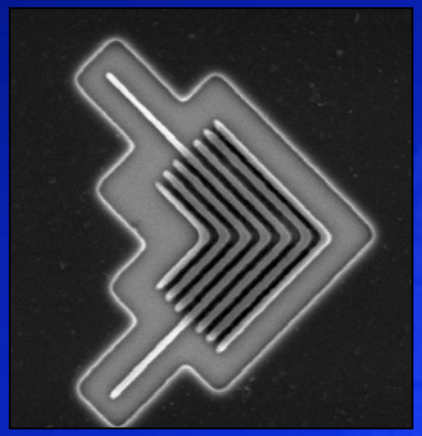
2 or 3 years between generations

∴

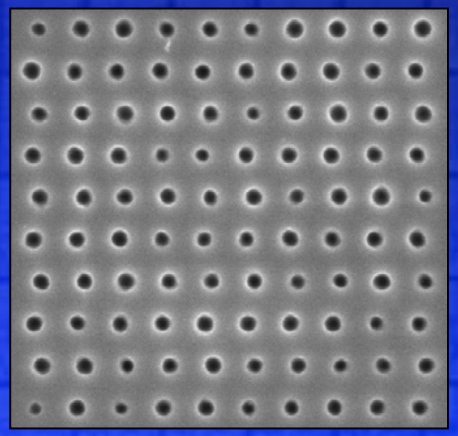
~10 ± 2 Years

EUV Printed and Etched Lines

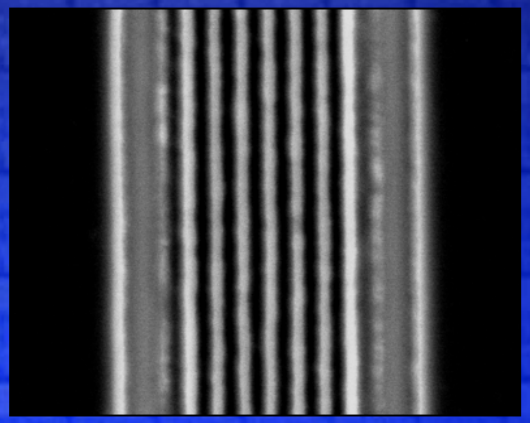
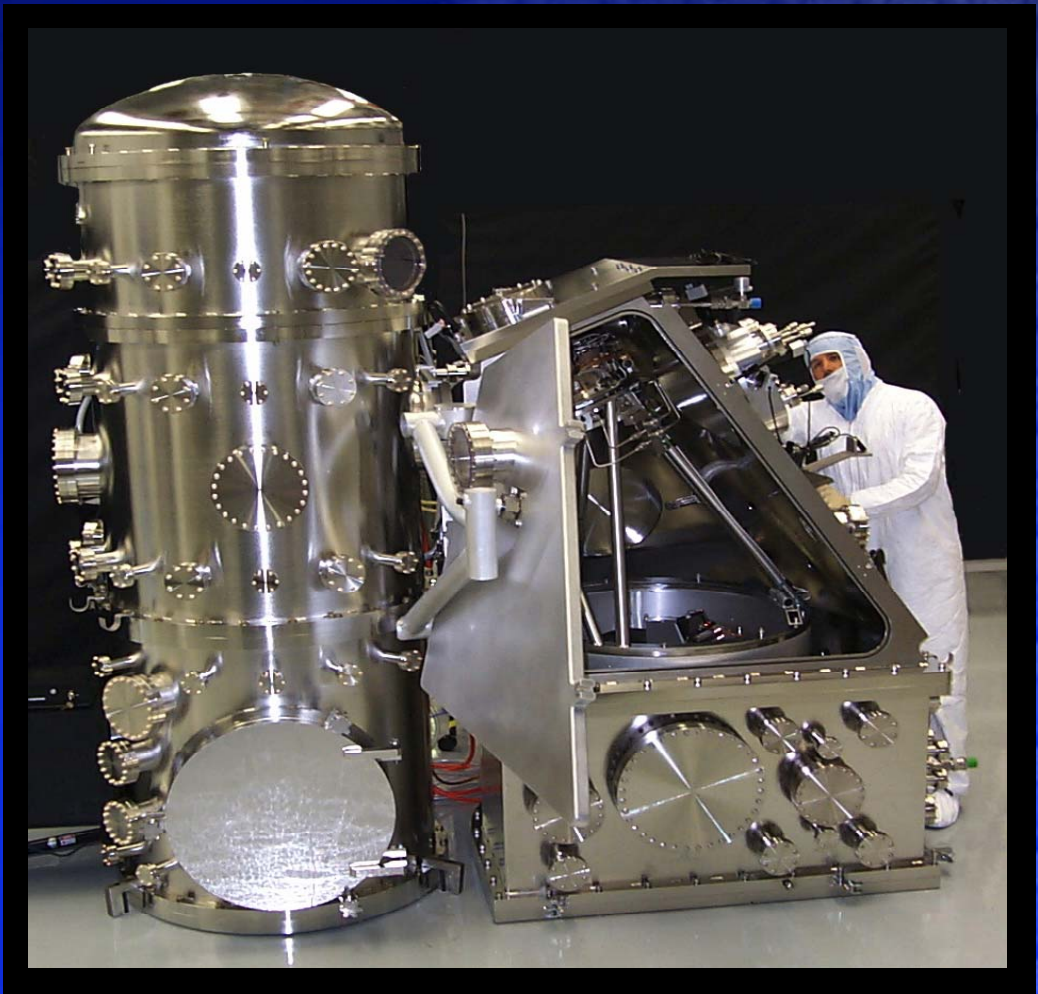
100 nm, k_1 = 0.75



80 nm, k_1 = 0.60



50 nm dense, k_1 = 0.37



Extreme Ultraviolet (EUV) Lithography