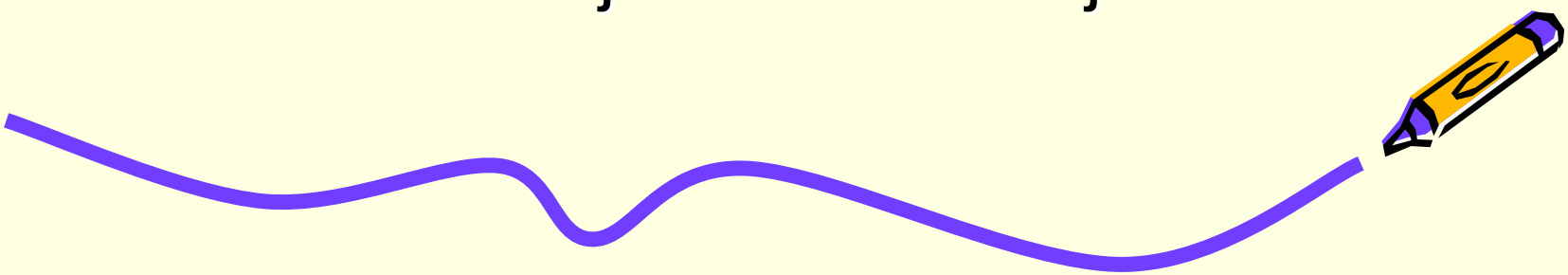
High-Performance System Design

Prof. Vojin G. Oklobdzija



Overview of the course

Requirements:

- Knowledge of CMOS digital circuits
- Basic knowledge of analog circuits
- Knowledge of Logic Design

Textbook:

- "High-Performance System Design: Circuits and Logic", by V.G. Oklobdzija, IEEE Press 1999.
- "Design of High-Performance Microprocessor Circuits", by A. Chandrakasan, W. Bowhill, F. Fox, IEEE Press 2000.

Topics to be covered:

I. Logic Design:
   A. Basic relations and analysis of CMOS
   B. Differential Logic – Issues

II. High-performance sub-micron CMOS circuits.
   A. New Pass-Transistor Differential CMOS
   B. High-Speed and Low Power CMOS
   C. Examples from DPL and CPL.

III. Low-Power Logic:

IV. Timing and Clocking:

V. Arithmetic Algorithms and Technology Mapping:

Grading

- Quizzes & Take Home Exams.....60%
- Midterm Exam 40%

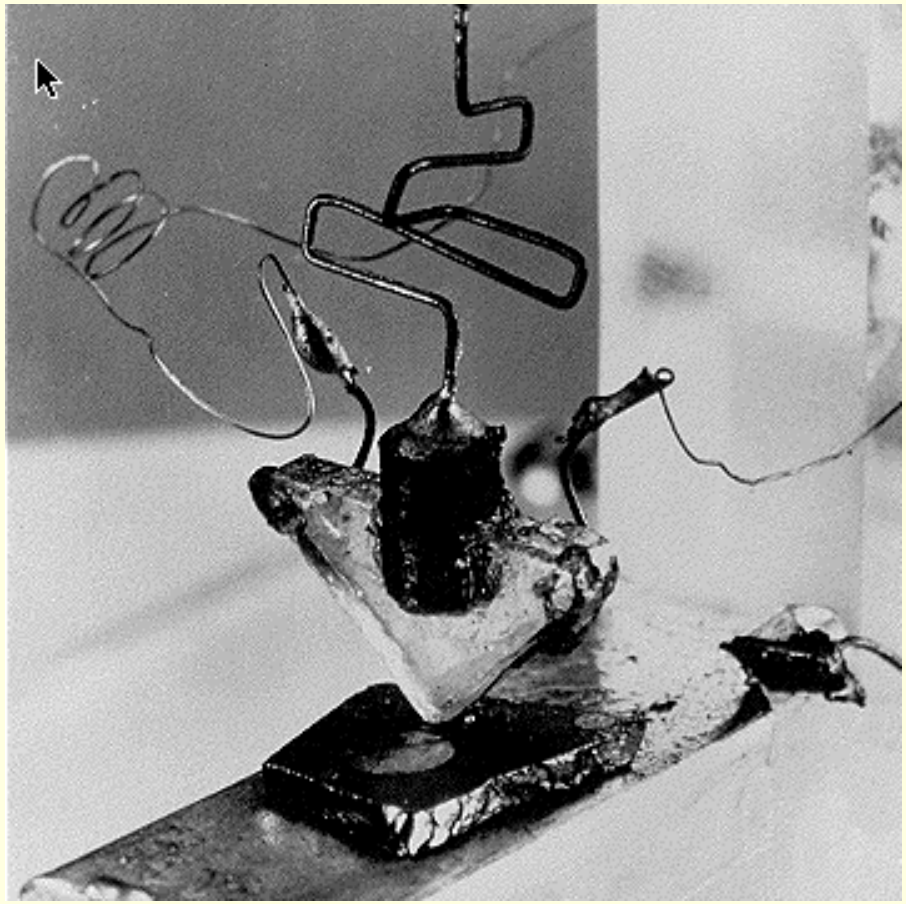
- This may be adjusted after the second week of classes

Historical Overview

- Invention of the transistor by Bardeen, Brattain and Shockley unveiled by Bell Laboratories on June 30, 1948.

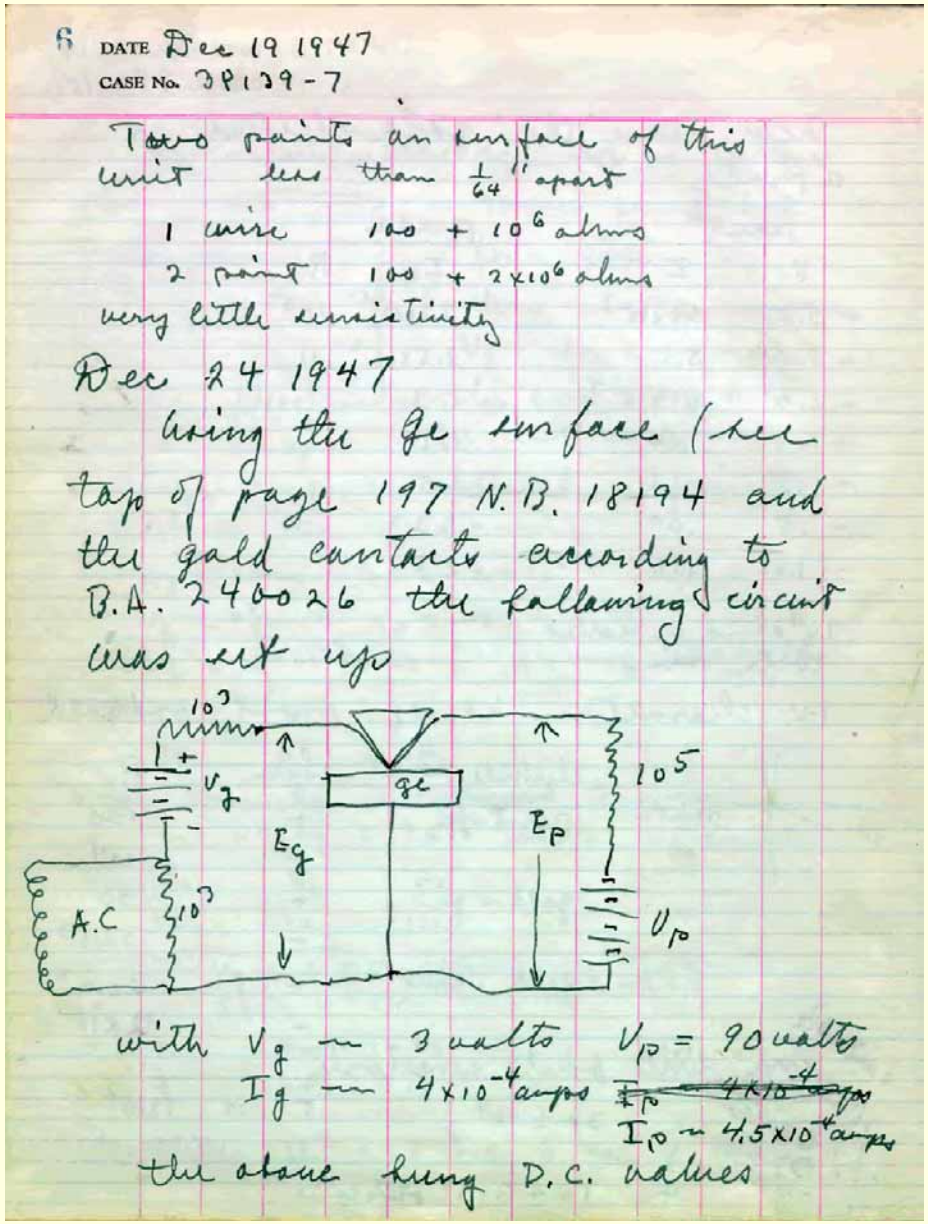
Historical Overview

- On December 16, 1947 Bardeen and Brattain built the point-contact transistor, made from strips of gold foil on a plastic triangle, pushed down into contact with a slab of germanium.



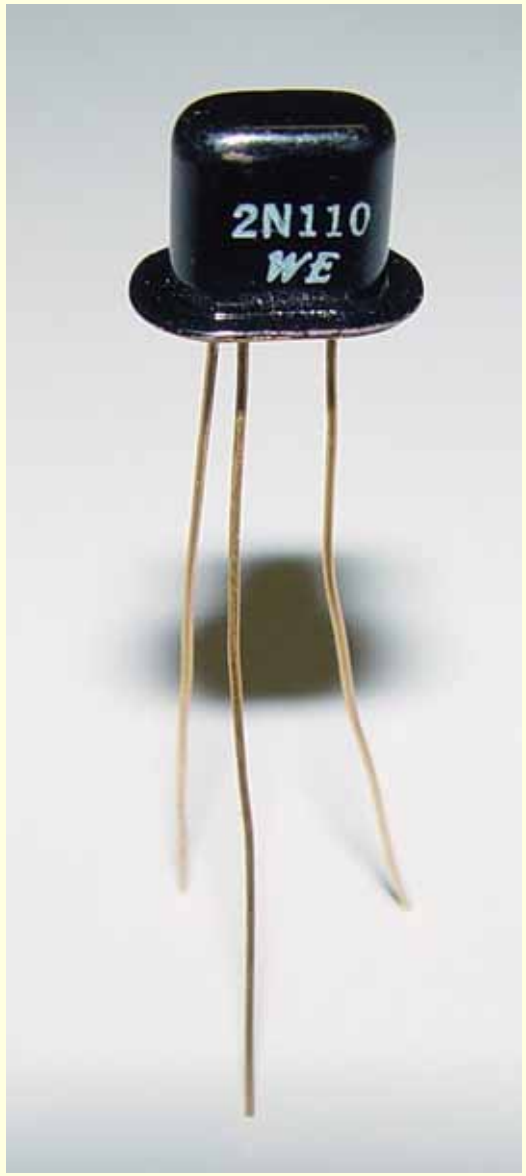
Historical Overview

- December 24th, 1947 entry into Walter Brattain's laboratory notebook describing point-contact transistor operation.



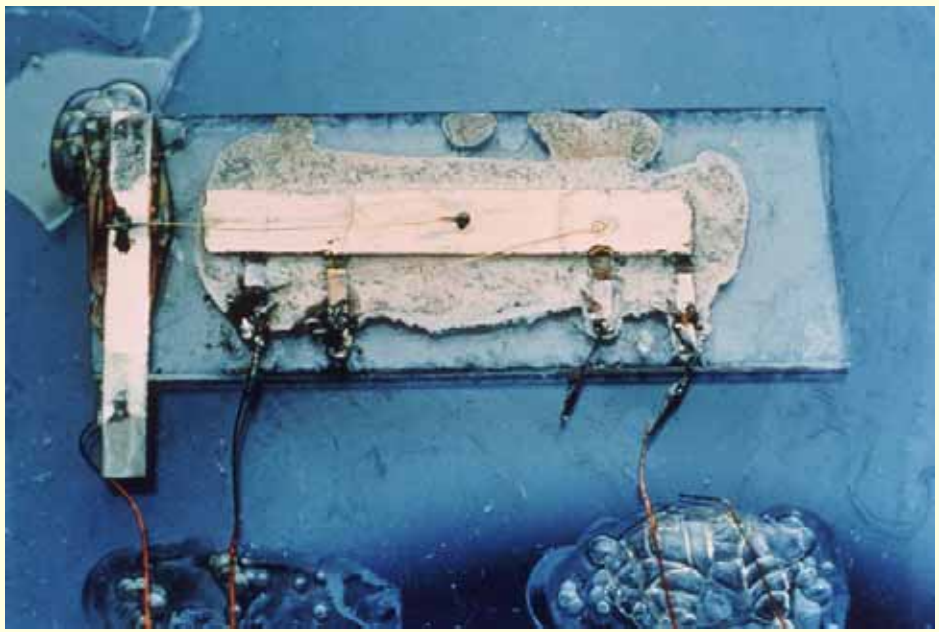
Historical Overview

- Masaru Ibuka and Akio Morita, founded a new company named Sony Electronics that mass-produced tiny transistorized radios.



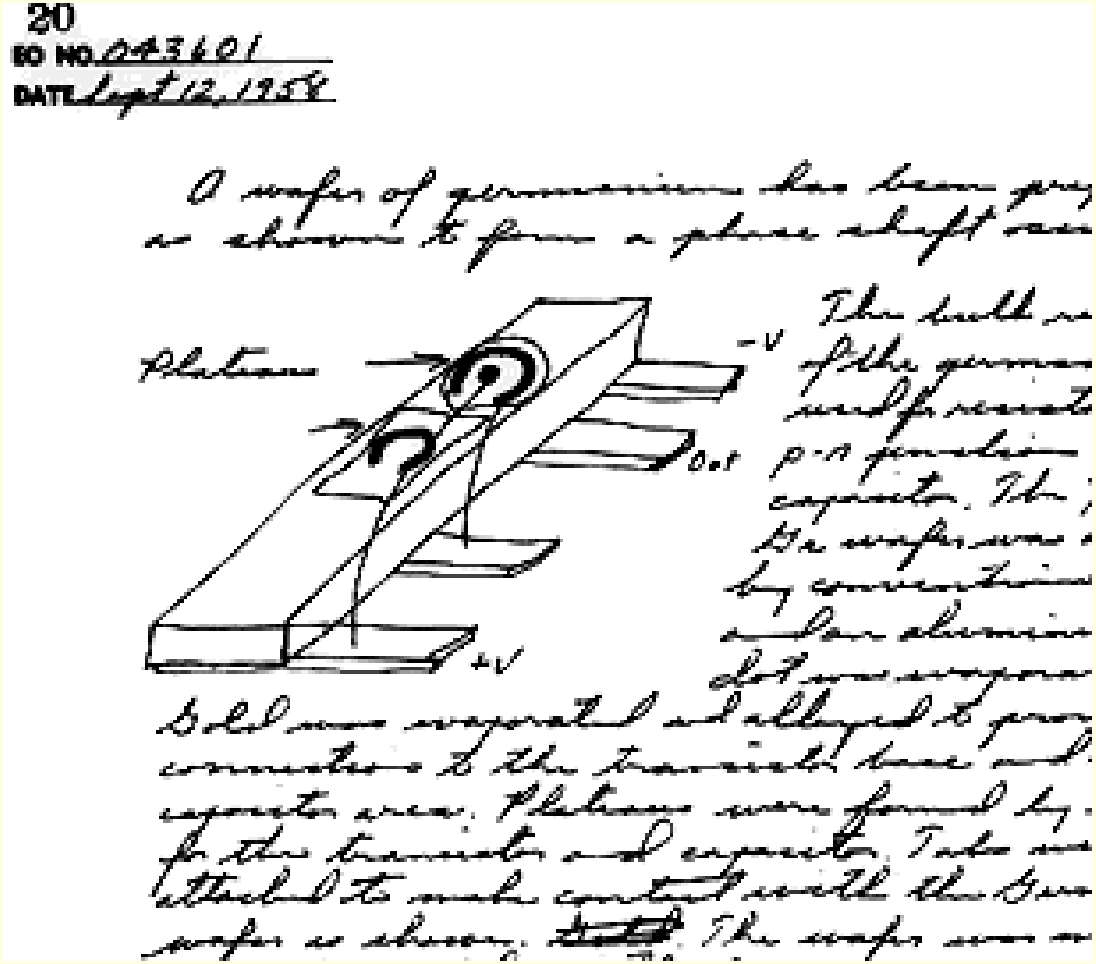
Historical Overview

- The invention of transistor was followed by the next important milestone, development of the integrated circuit by Kilby and Noyce in 1958.



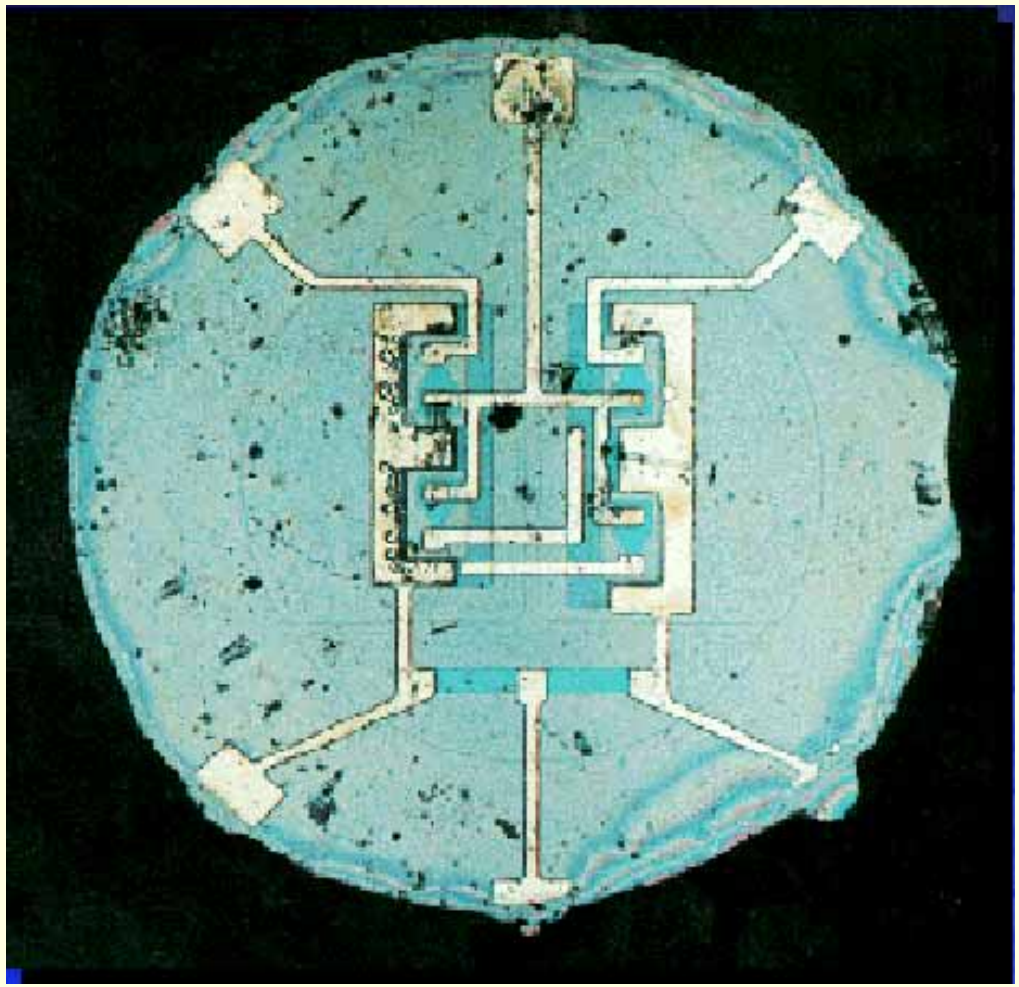
Historical Overview

Kilby's entry in his notebook dated September 12, 1958 describing integrated circuit. US Patent No. 3,138,743 was filed on February 6, 1959.



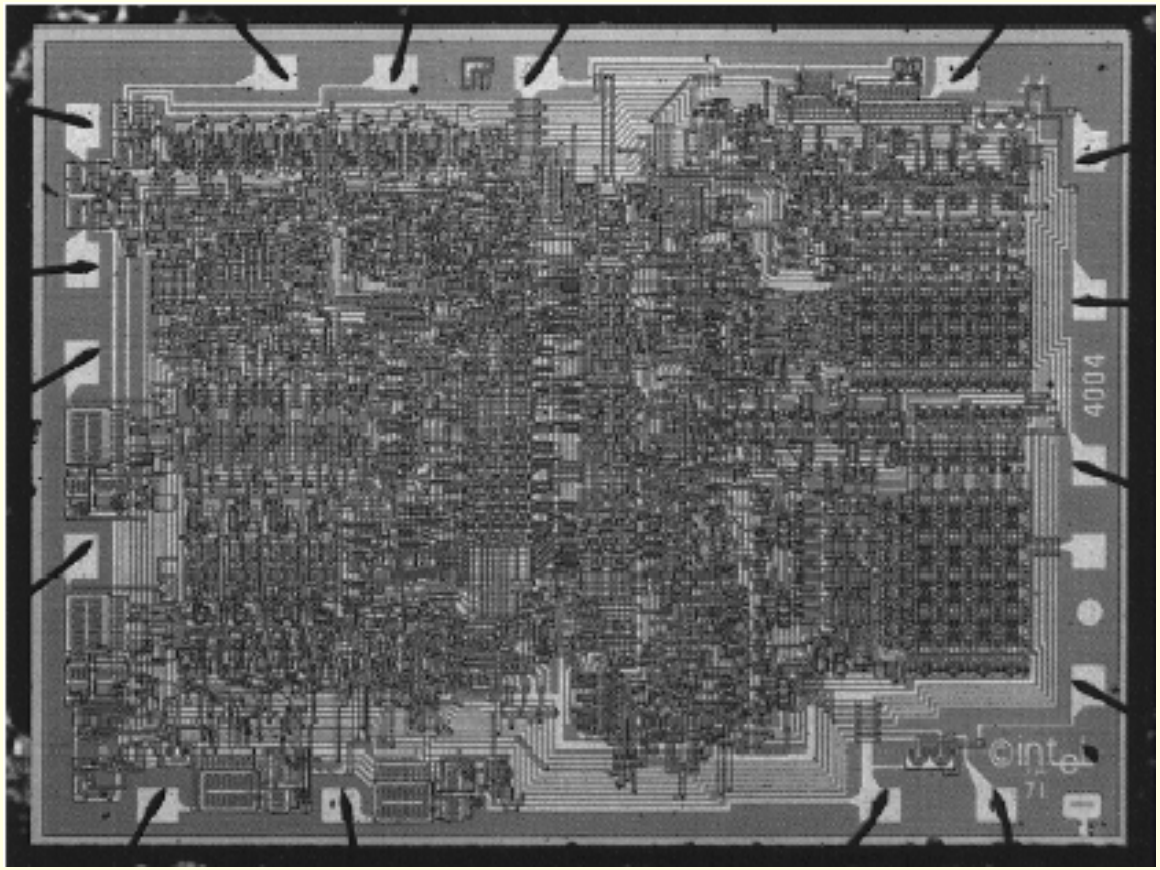
Historical Overview

The first planar integrated circuit, 1960. Designed and built by Lionel Kattner and Isy Haas under the direction of Jay Last at Fairchild Semiconductor.



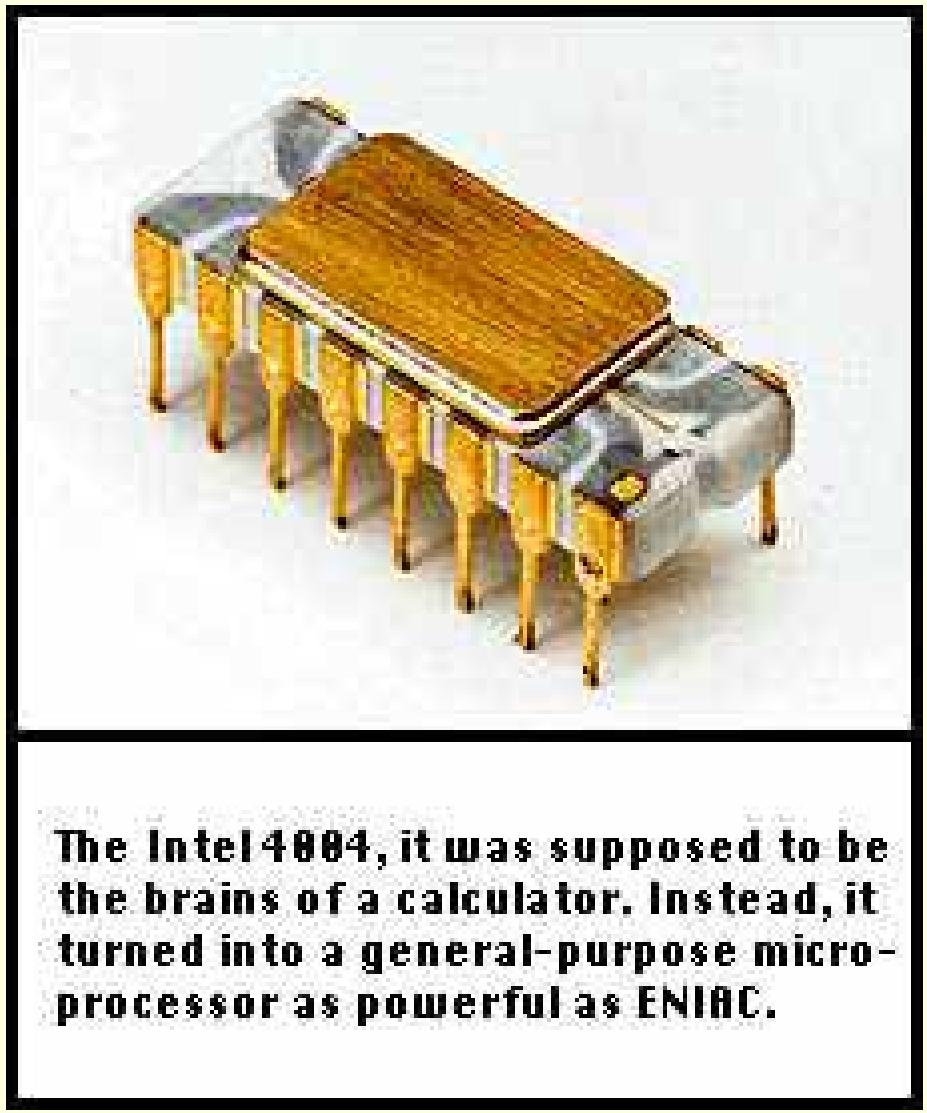
Historical Overview

The first microprocessor announced in 1971, Intel 4004 developed by Shima, Faggin and Hoff



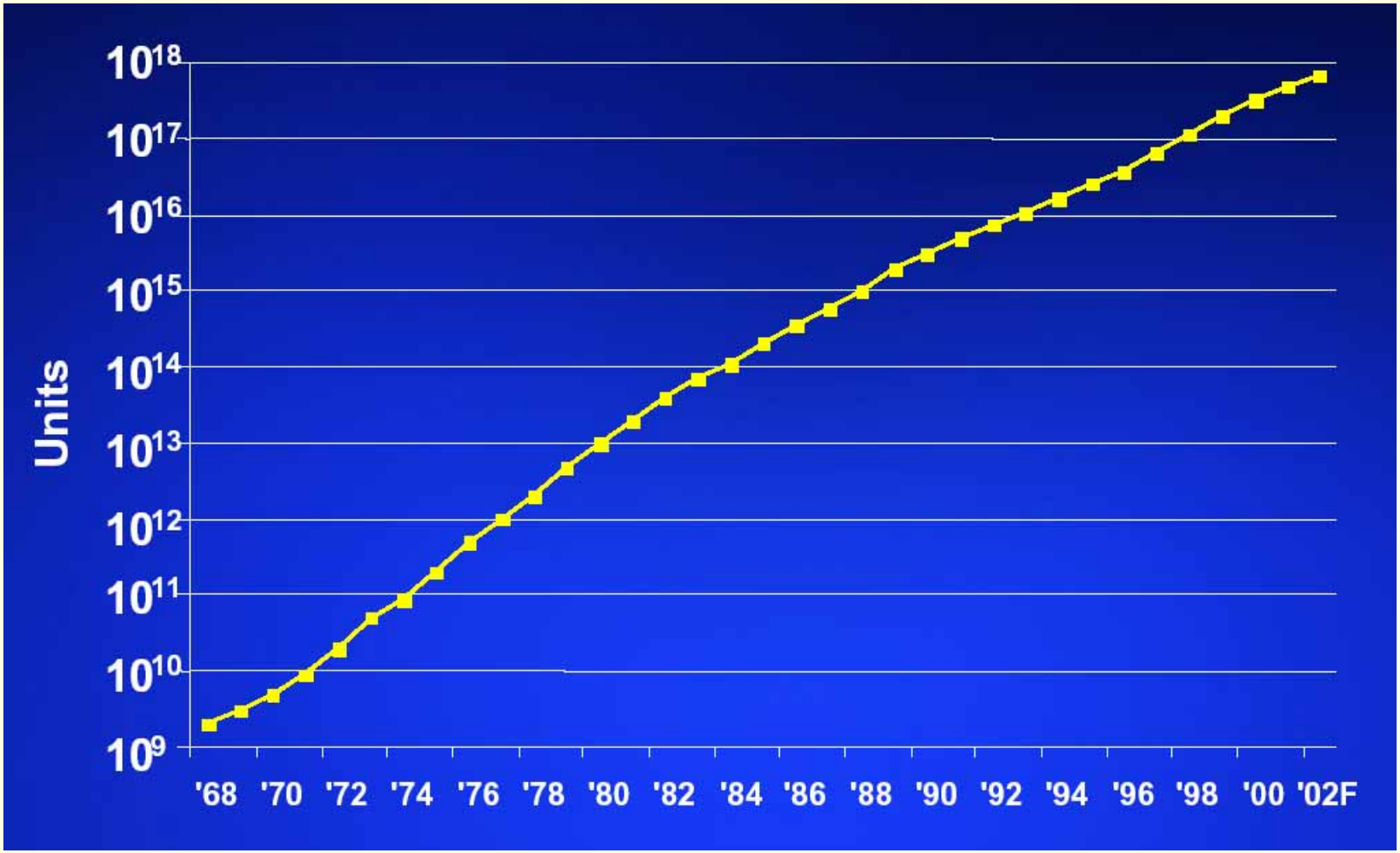
Historical Overview

This first microprocessor, Intel's 4004 containing 2,108 transistors was build by Masatoshi Shima, Federico Faggin and Marcian E. "Ted" Hoff, under direction of Robert Noyce, in 1971.



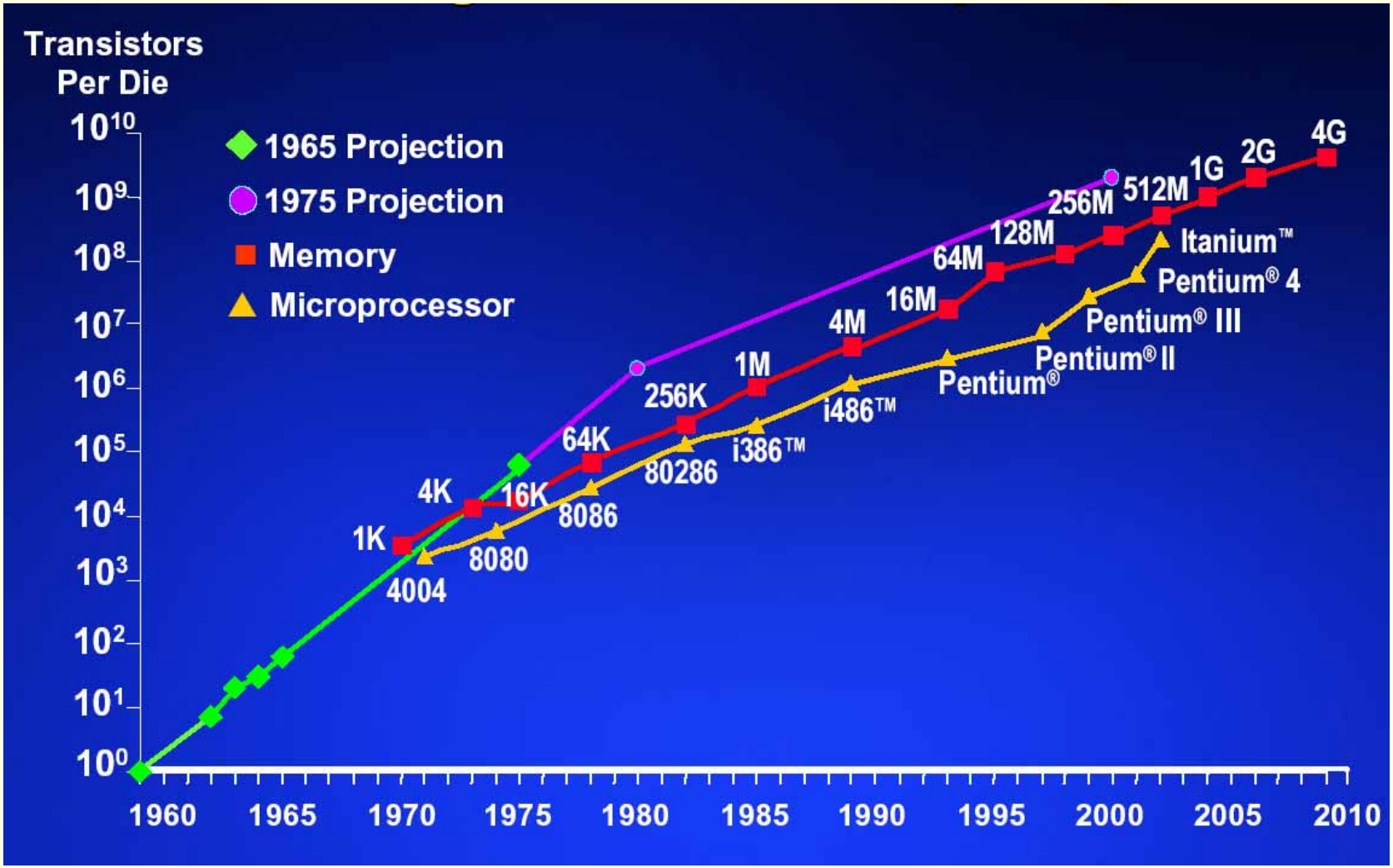
Historical Overview

Number of transistors shipped per year



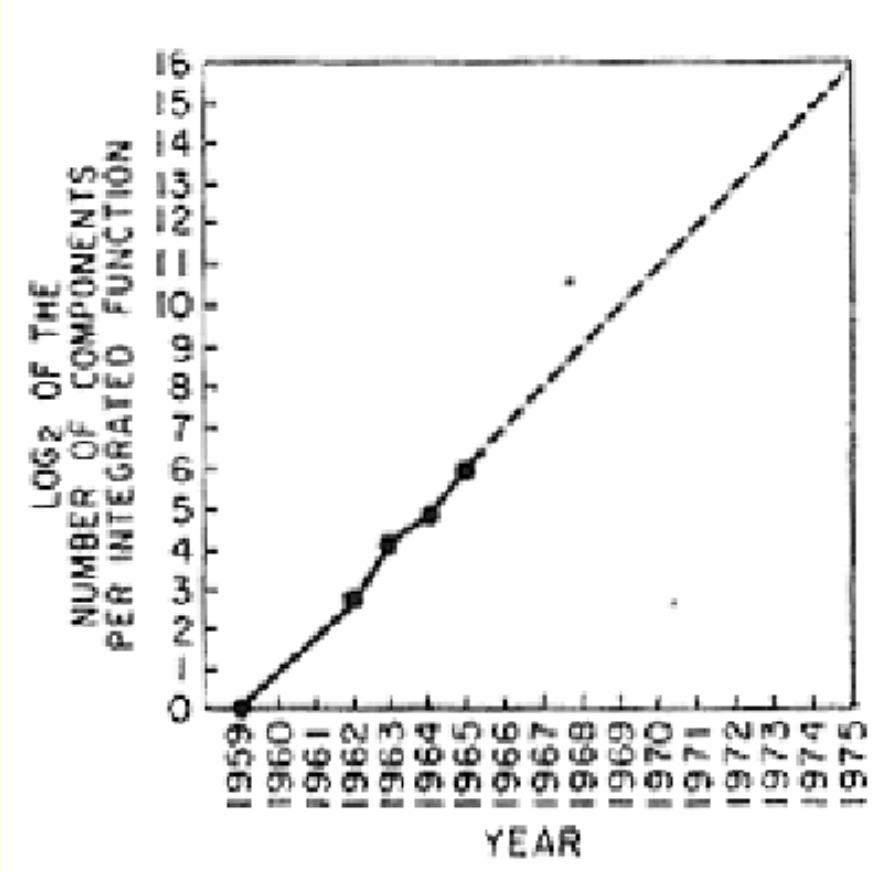
Historical Overview

Moore's law



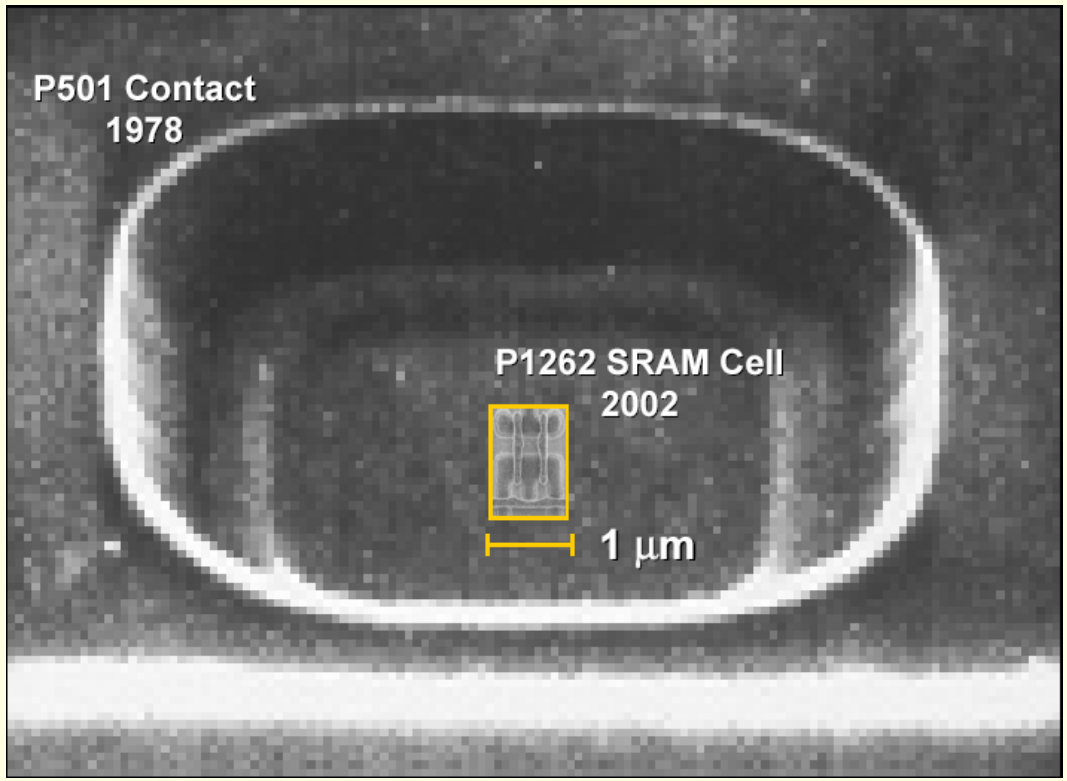
Historical Overview

Original Moore's prediction in 1965, (Electronics, Vol. 38, No.8, April 19, 1965)



Historical Overview

SRAM memory cell of 2002 memory fits comfortably into a contact space of 1978 memory



Historical Overview

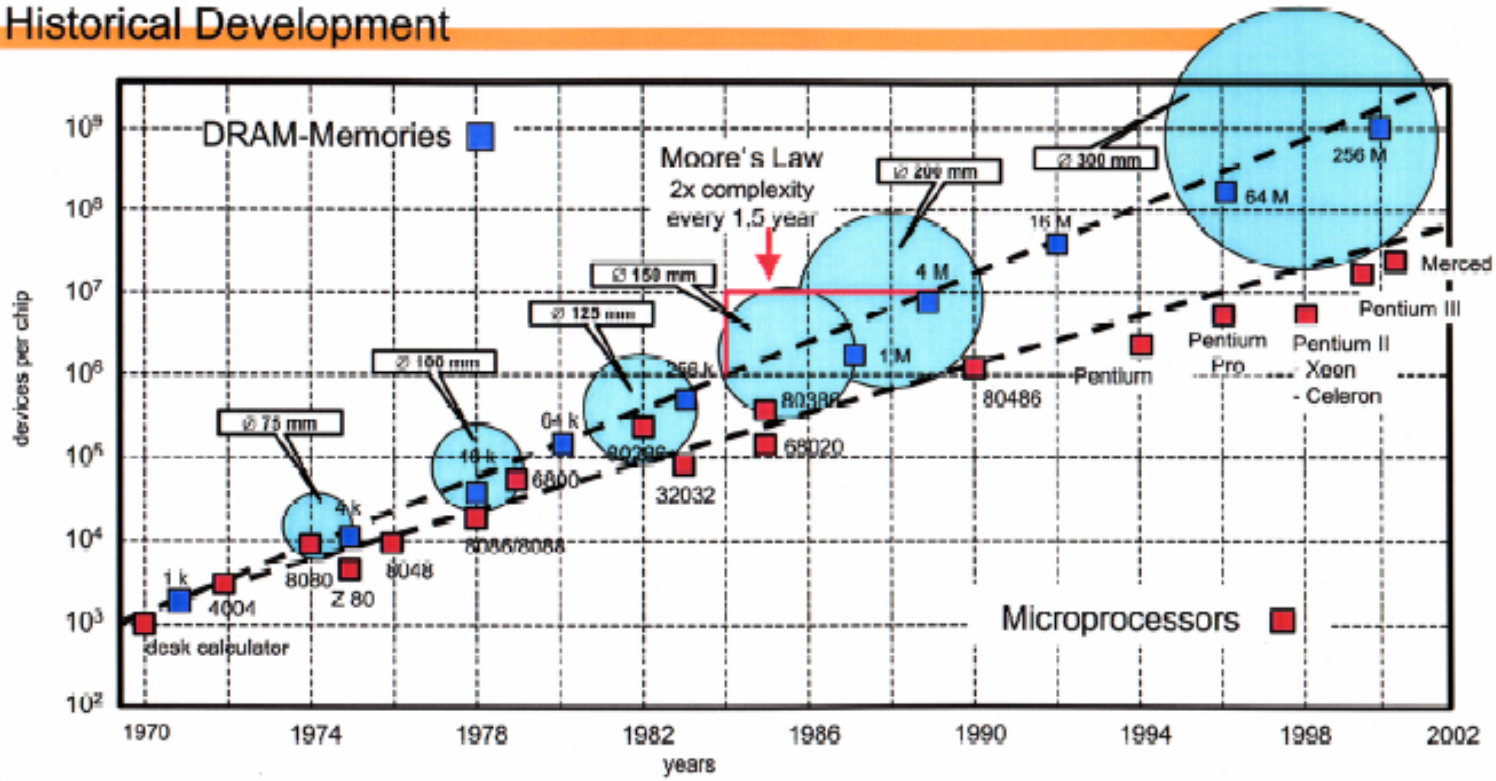
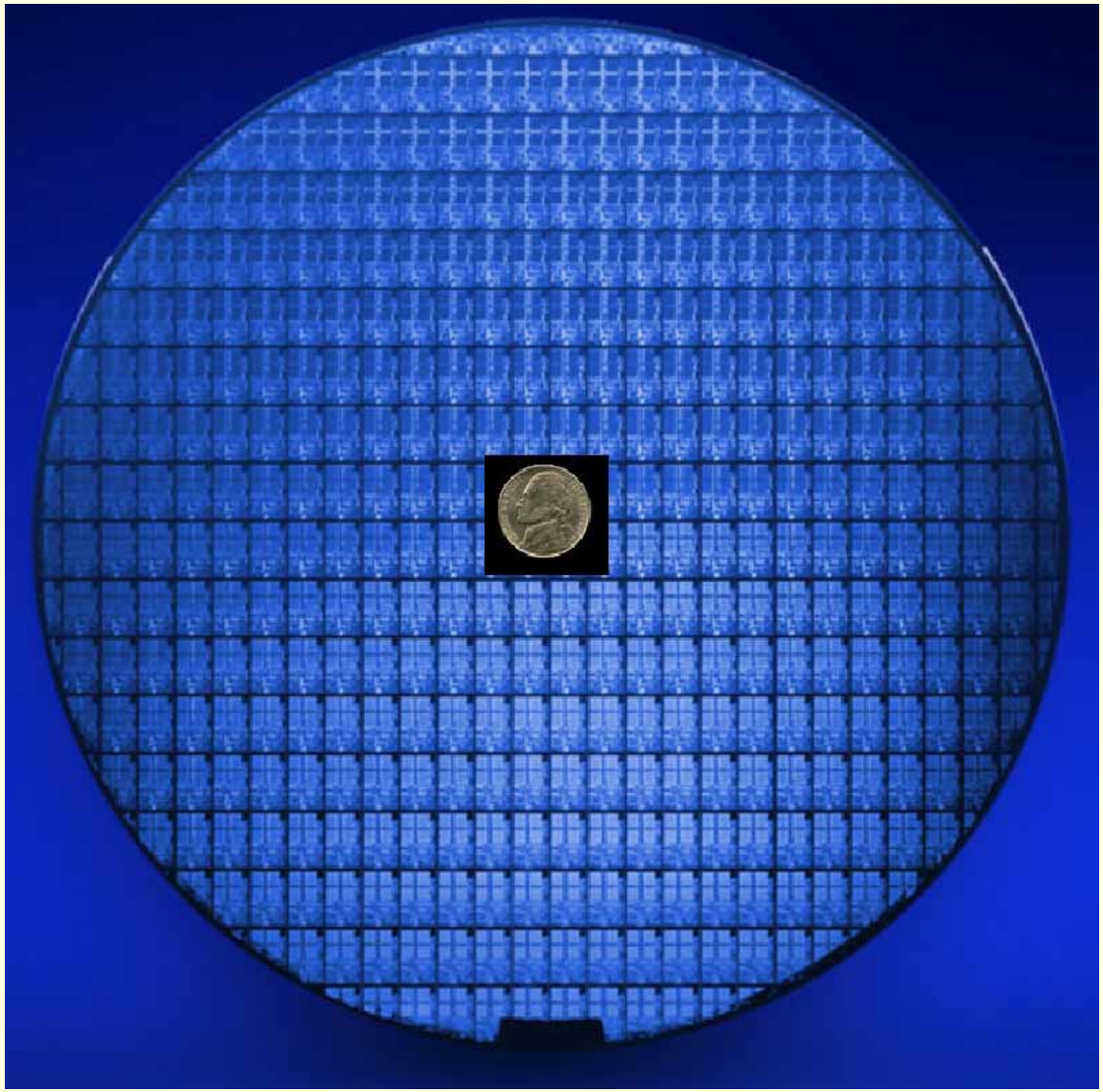


Figure 2: *Moore's law states that the performance of microelectronics, e.g., the number of devices on a chip, doubles every 18-24 months. The evolution has so far followed this prediction very well. For the future, there are different extrapolations, depending upon assumptions on the development of process technology. Also shown in the figure is the rapid development of the size of the silicon wafers.*

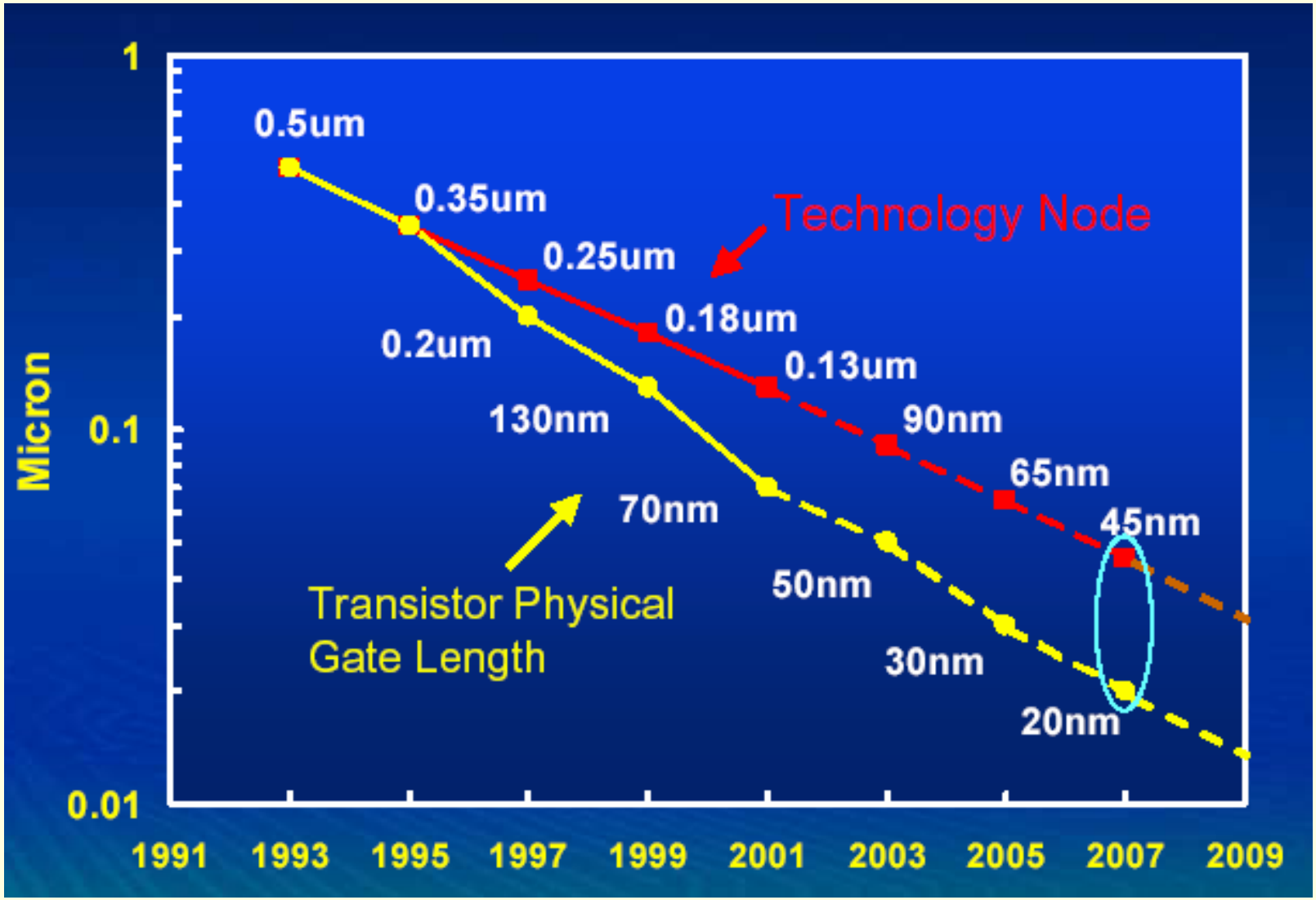
Historical Overview

Size of the 12” wafer as compared to a nickel coin



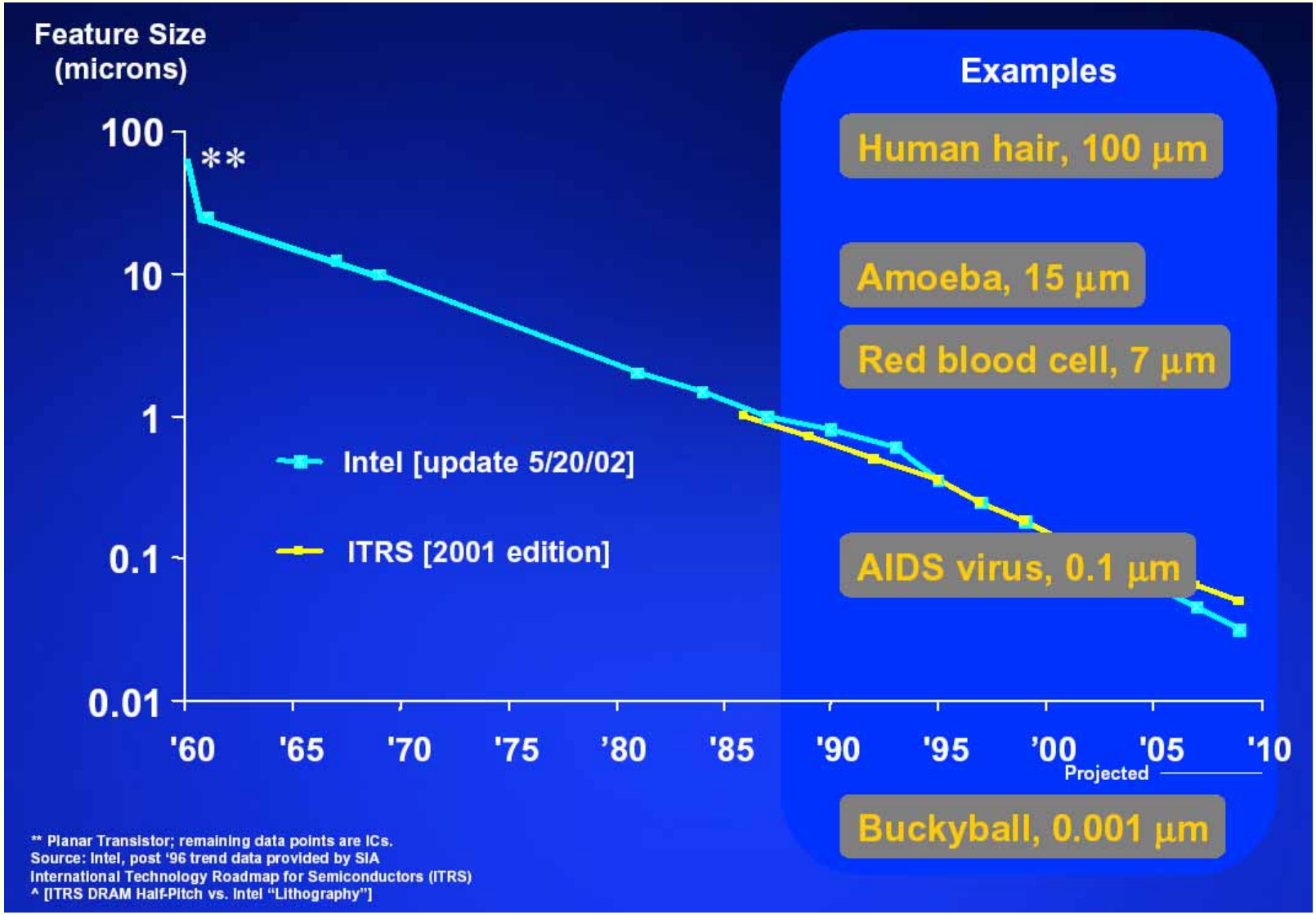
Historical Overview

Technology scaling over the years



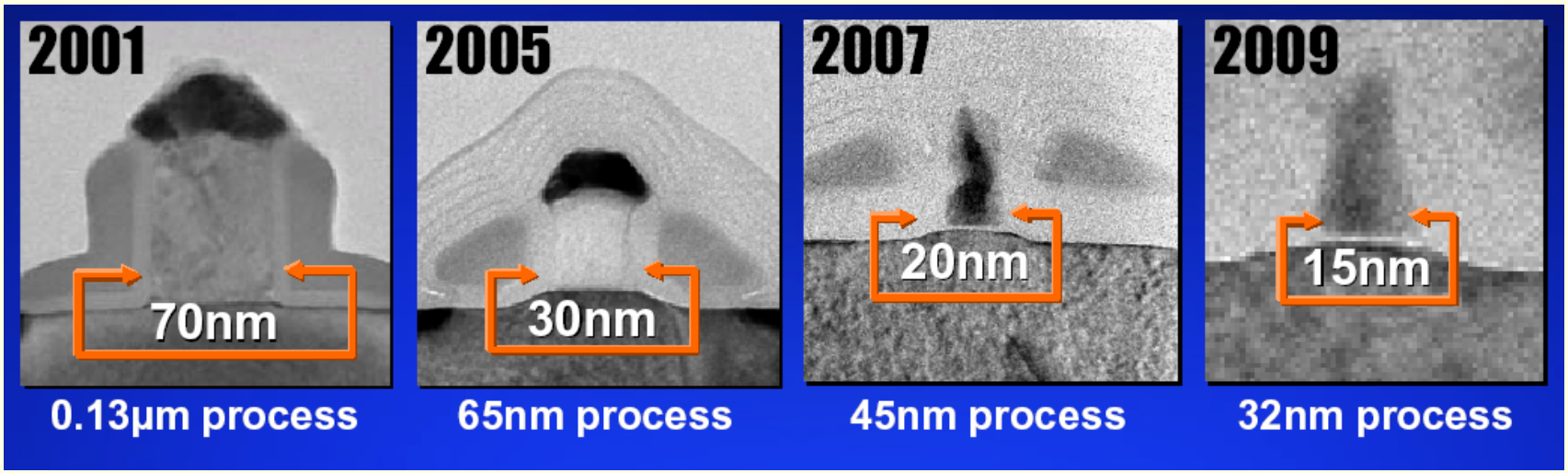
Historical Overview

Comparison of technology features with the real world examples



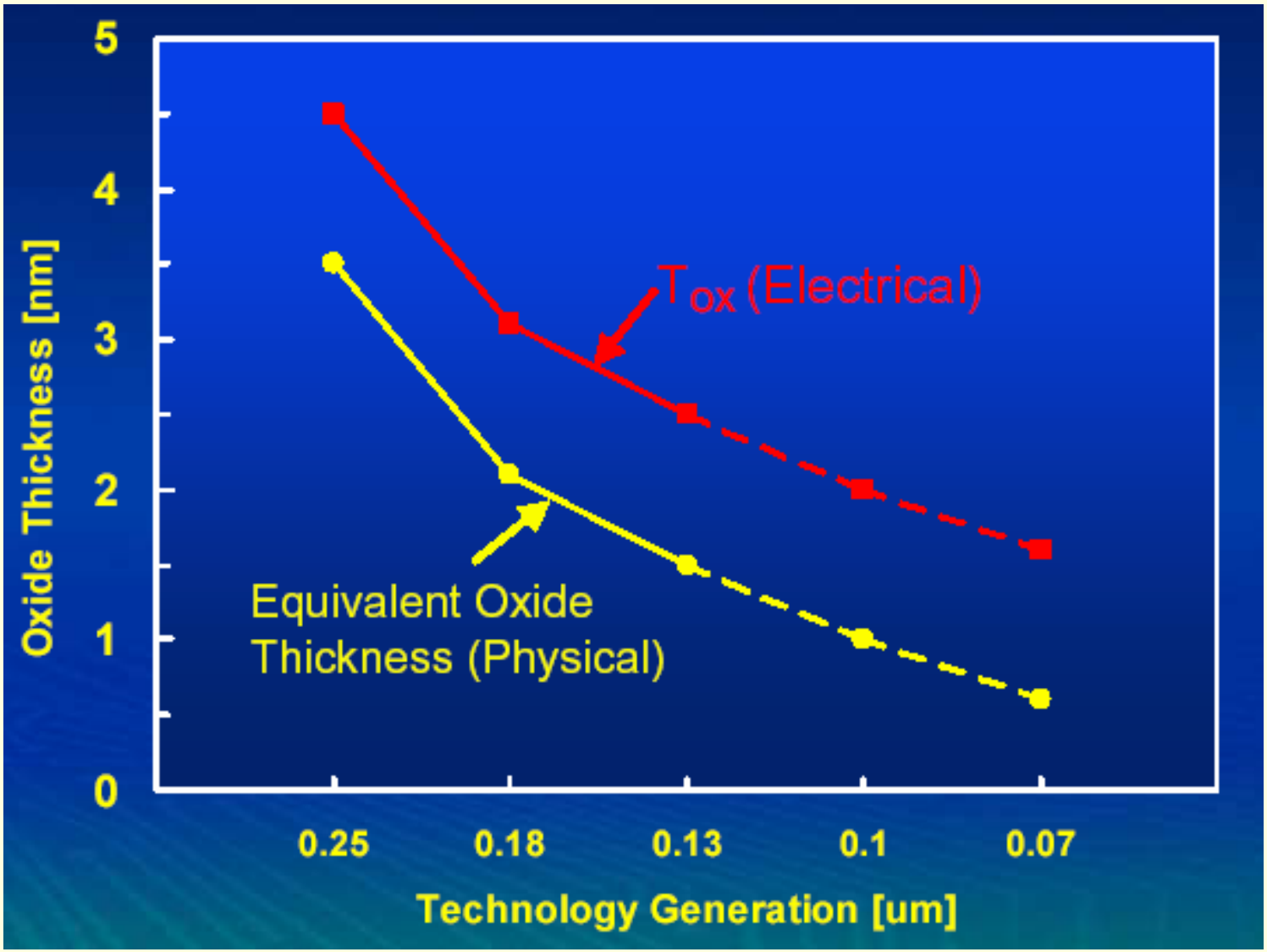
Historical Overview

It is believed that the technology will move to about 20-30nm features without any fundamental problems. Experimental fabrication results even confirm that this is possible. Some of the transistors that will be used in next generations of technology such as 2005, 2007 and 2009 are shown:



Historical Overview

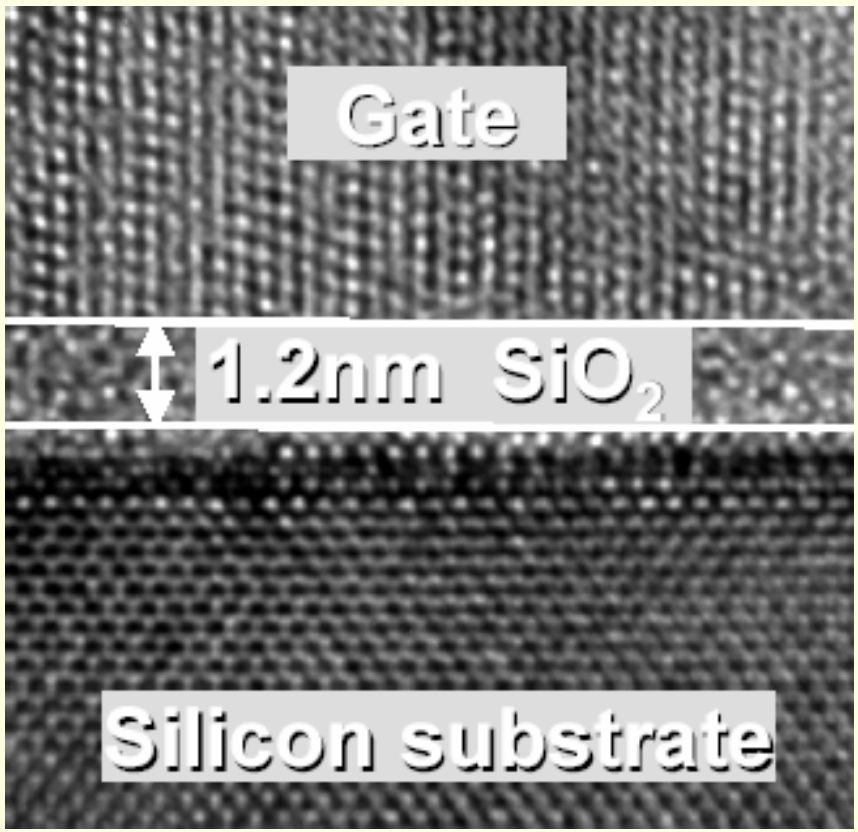
Scaling of the silicon oxide over the technology generations

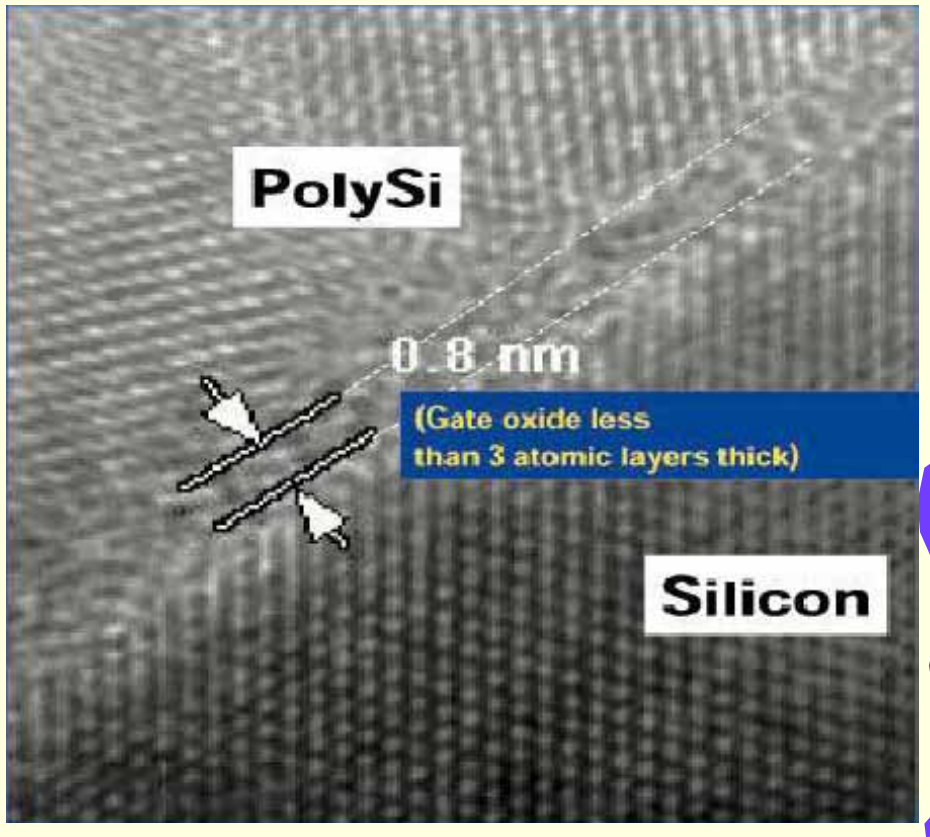


Historical Overview

Oxide thickness for 100nm technology (a), oxide thickness for 70nm technology (b), it is less than 3 atomic layers thick.

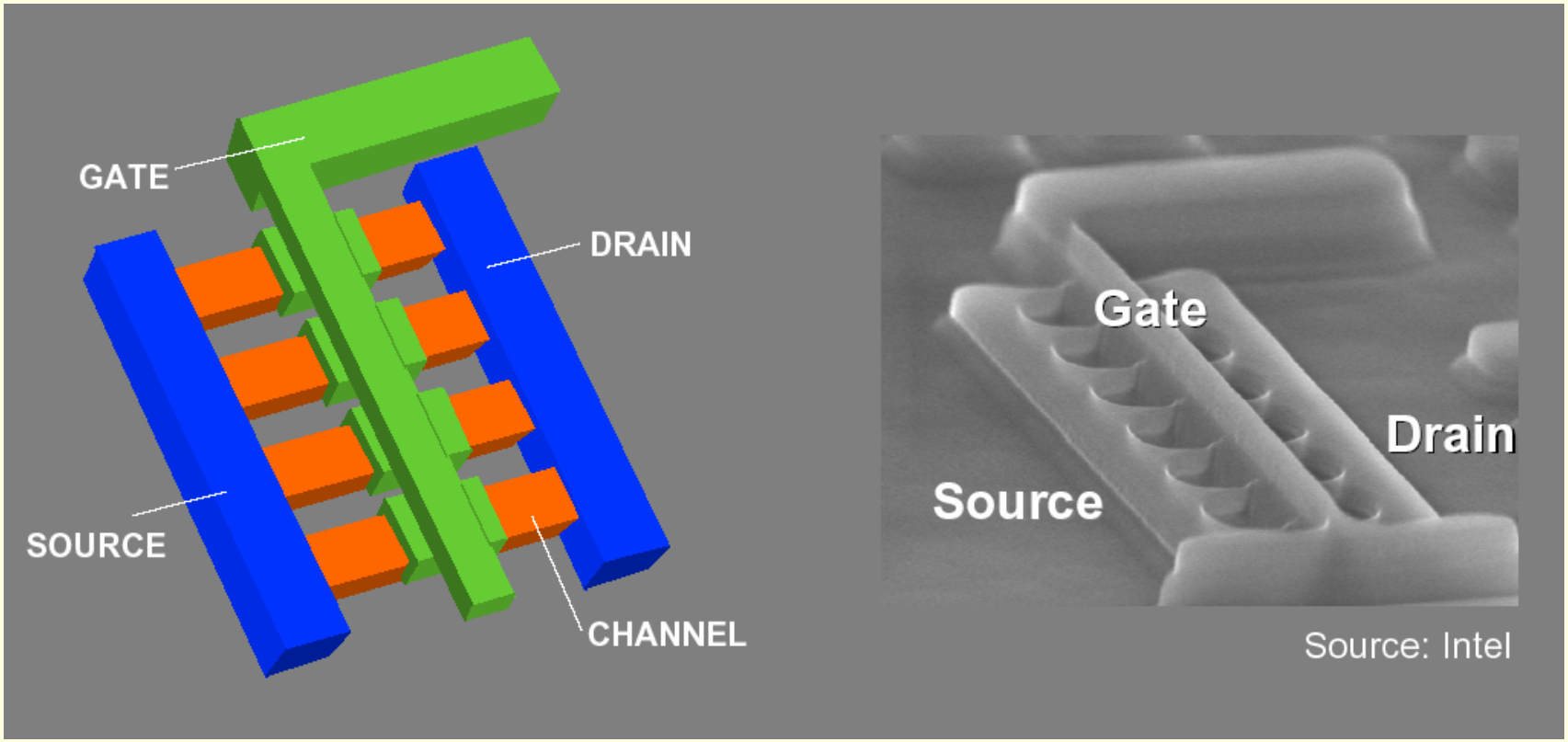
(a) (b)





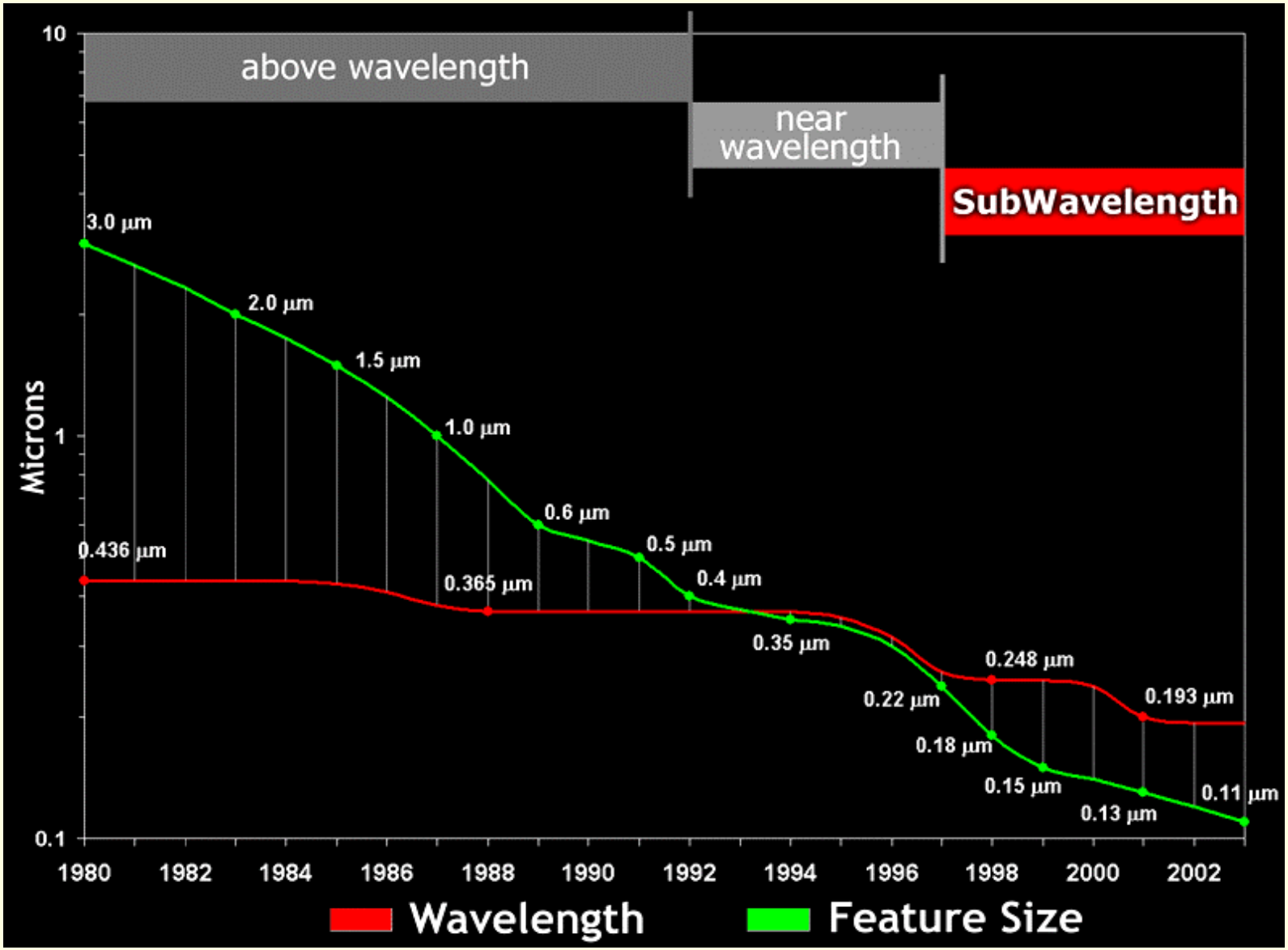
Historical Overview: Future

Experimental three-gate transistor structure (the channel is surrounded by the gate on all three sides)



Historical Overview

The relationship of the light used for the optical lithography to the transistor lines



Historical Overview

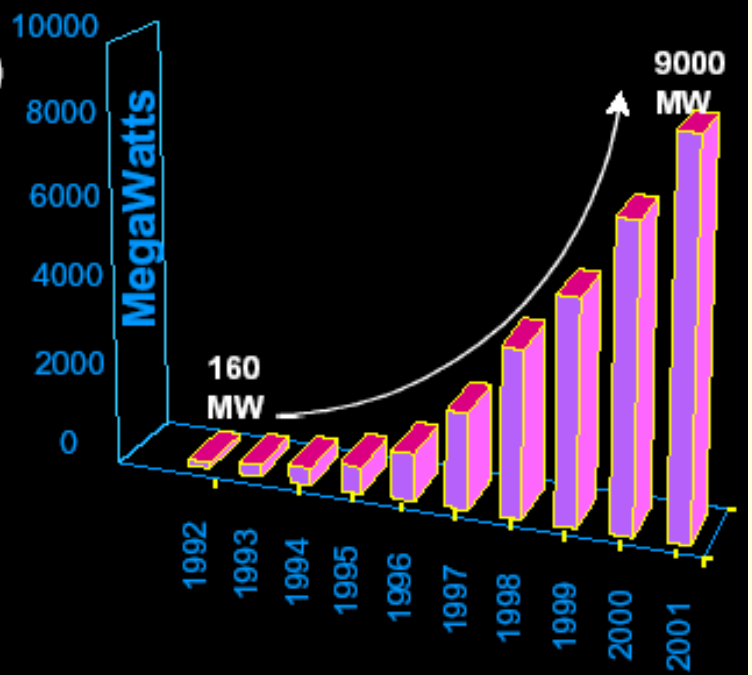
Extreme Ultraviolet Litography machine used for 70nm fabrication process, costing several millions of dollars

Historical Overview

Total power consumption increase in the world due to personal computer CPU chips only

- Total power consumption of CPUs in world's PCs:
  - 1992: 160 MWatts (87M CPUs)
  - 2001: 9,000 MWatts (500M CPUs)
- That's 4 Hoover Dams!

Courtesy: United States Department of the Interior
Bureau of Reclamation - Lower Colorado Region



[Source: Dataquest (for Installed base) + estimates for avg. Installed CPU power]
Projected with PentiumII™ Power