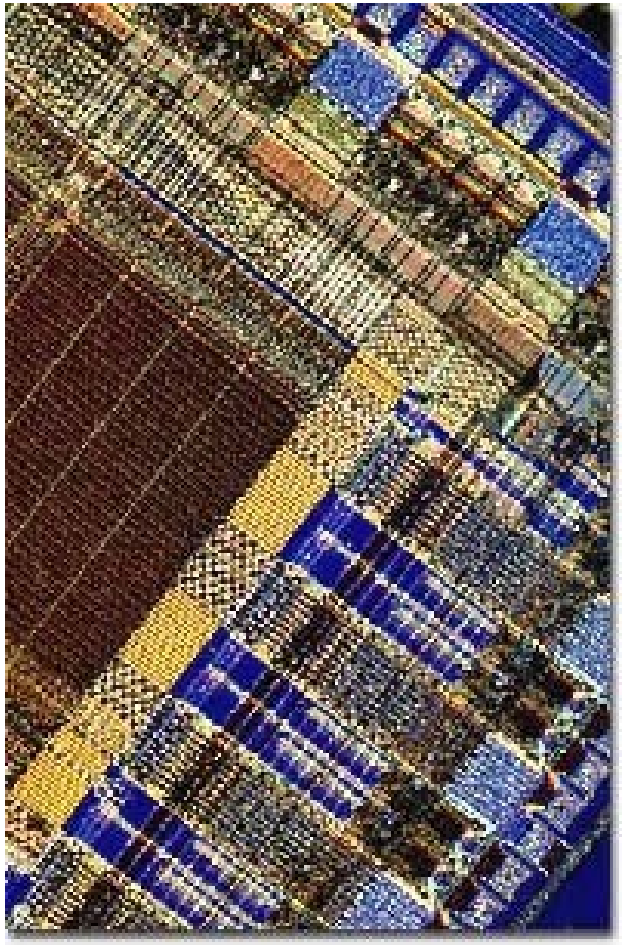
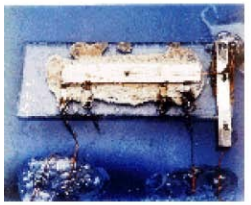
Digital Integrated Circuit Design and Architecture

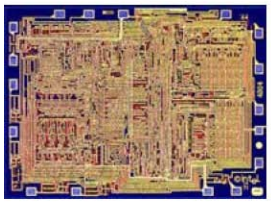


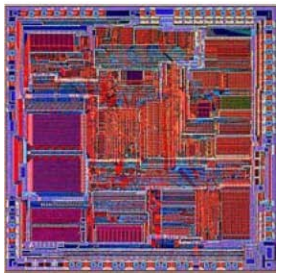
Chapter 1: Introduction

Some History

- Invention of the transistor (BJT) 1947
  - Shockley, Bardeen, Brattain – Bell Labs
- Single-transistor integrated circuit 1958
  - Jack Kilby – Texas Instruments
- Invention of CMOS logic gates 1963
  - Wanlass & Sah – Fairchild Semiconductor
- First microprocessor (Intel 4004) 1970
  - 2,300 MOS transistors, 740 kHz clock frequency
- **Very Large Scale Integration 1978**
  - Chips with more than ~20,000 devices





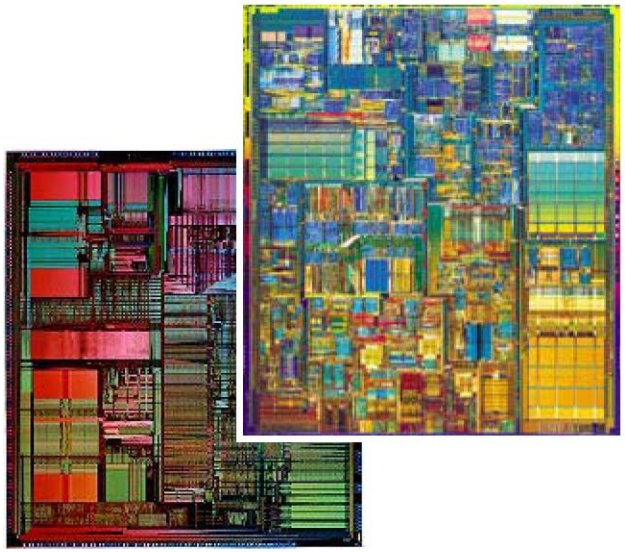


More Recently

Ultra **L**arge **S**cale **I**ntegration

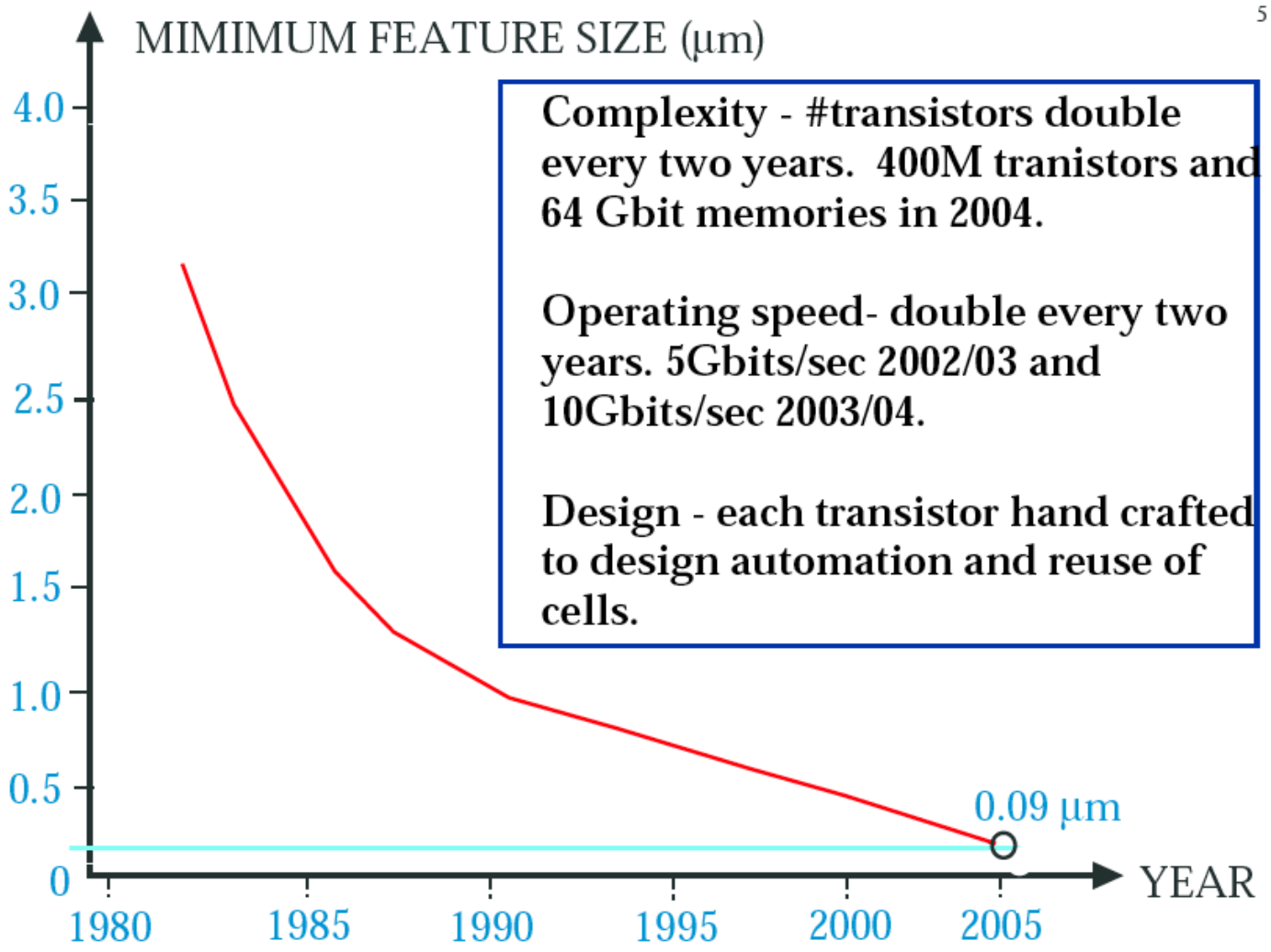
System **o**n **C**hip (**SoC**)

20 ~ 30 million transistors in 2002



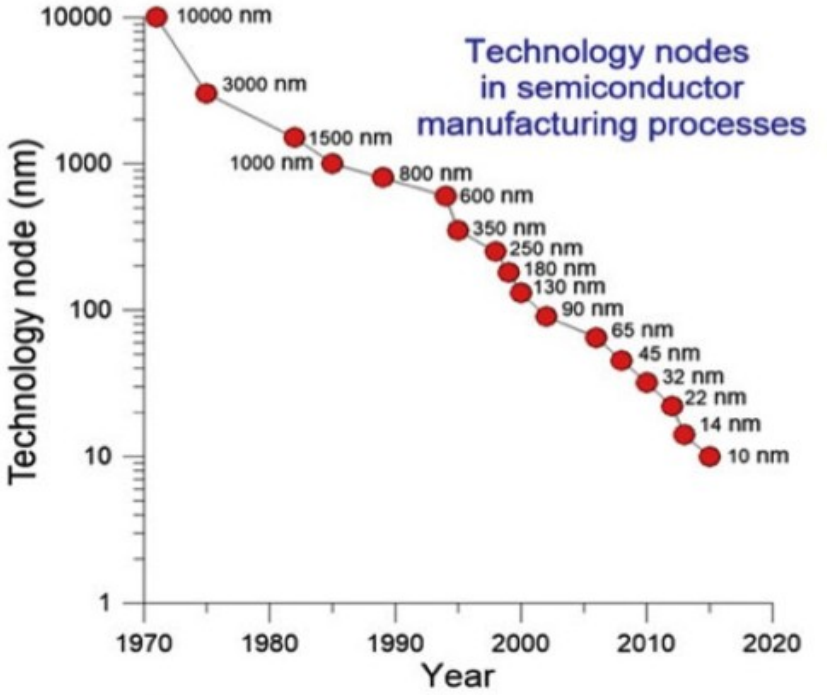
The chip complexity has increased by a factor of 1000 since its first introduction, but the term **VLSI** remained virtually universal to denote digital integrated systems with high complexity.

Evolution of Minimum Feature Size



Evolution of Minimum Feature Size

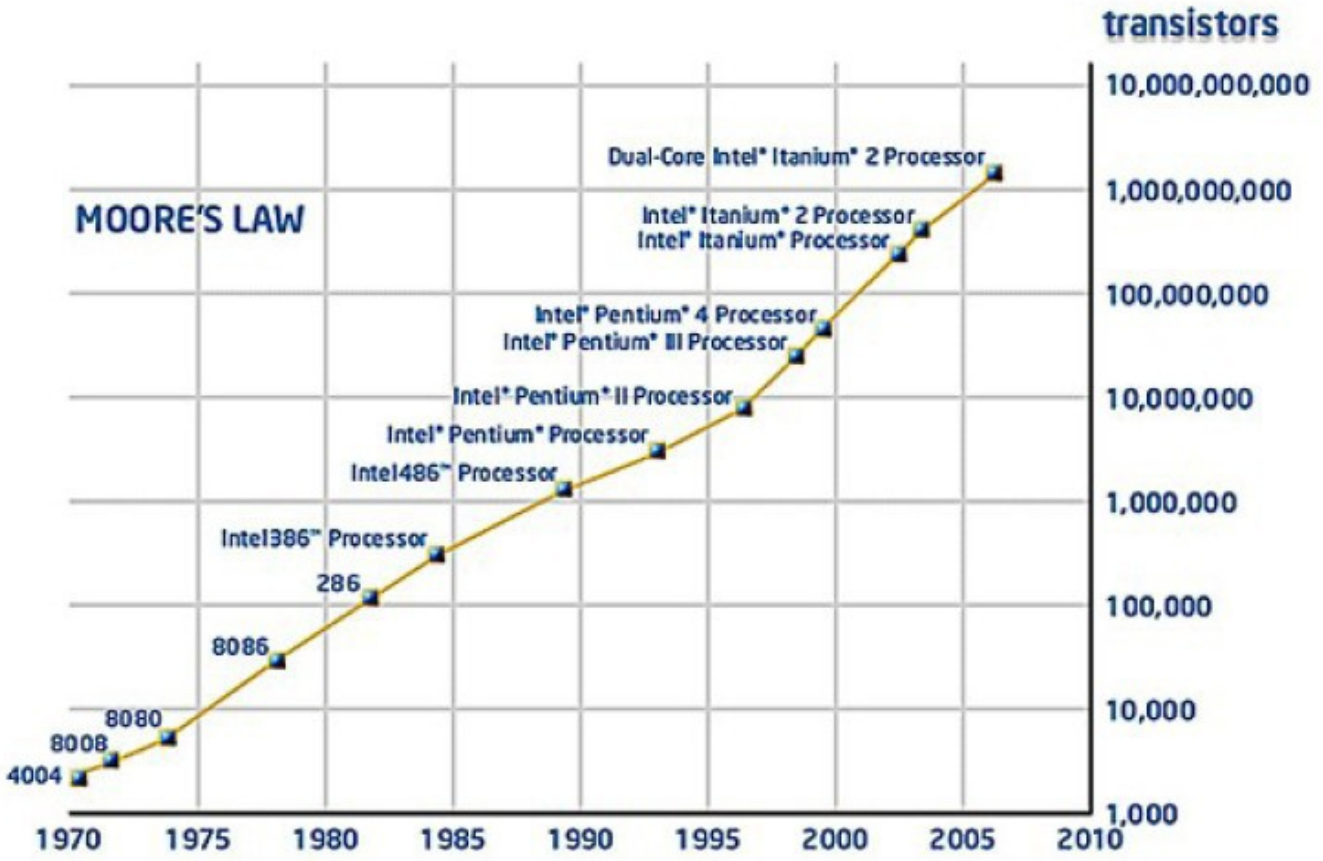
- Continuous increasing in integration density



Quora

https://www.quora.com/How-exactly-do-processors-manage-to-get-more-efficient-and-do-more-work-for-less-power

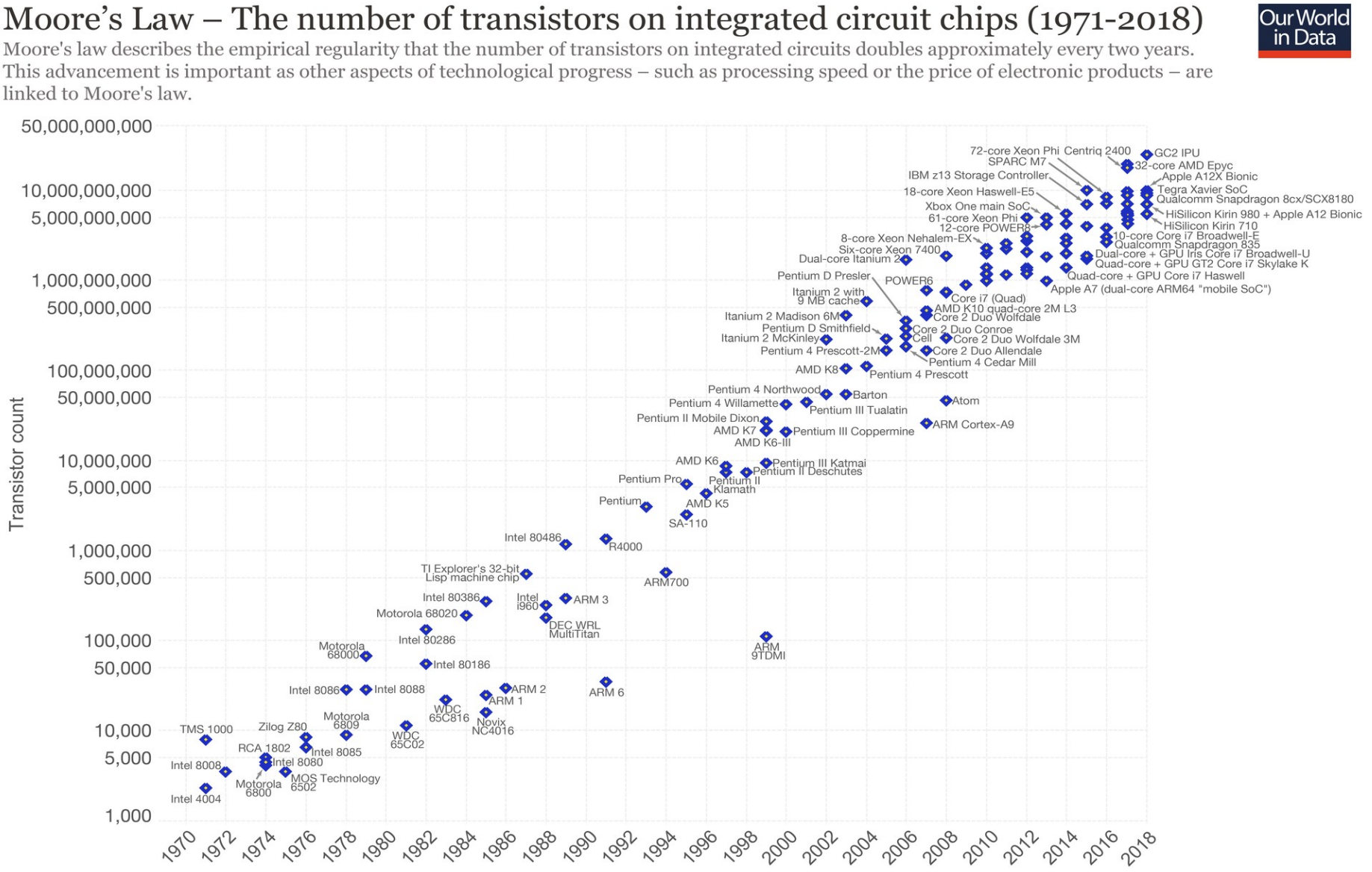
“Moore's” Law and Impact on Micro-Computers



from http://www.intel.com/technology/mooreslaw/?iid=search

“As long as downward scaling of CMOS technology remains strong, other technologies are likely to remain the technology of tomorrow.” - Intel Research Scientist

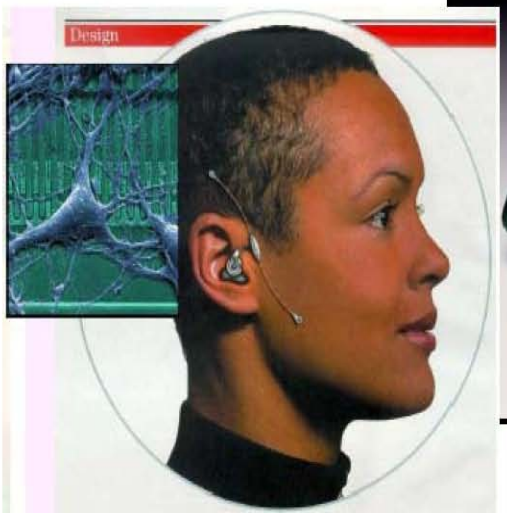
Moore’s law in Semiconductor industry

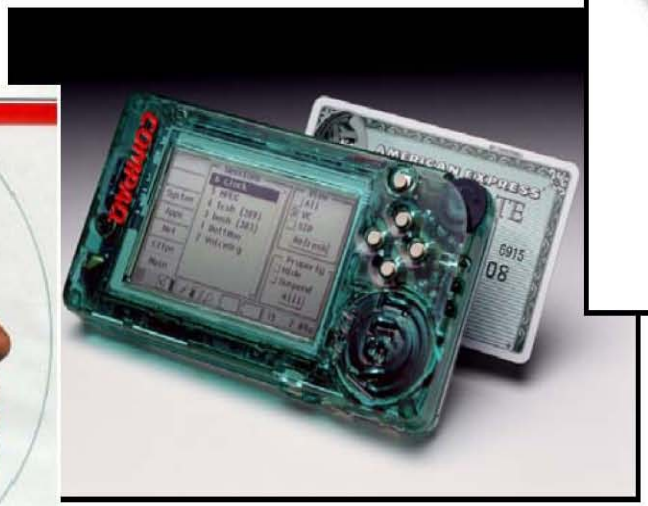


Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

Industry Trends

High performance
Low power dissipation
Wireless capability
etc…





More portable, wearable, and more powerful devices for ubiquitous and pervasive computing…

Economic Impact

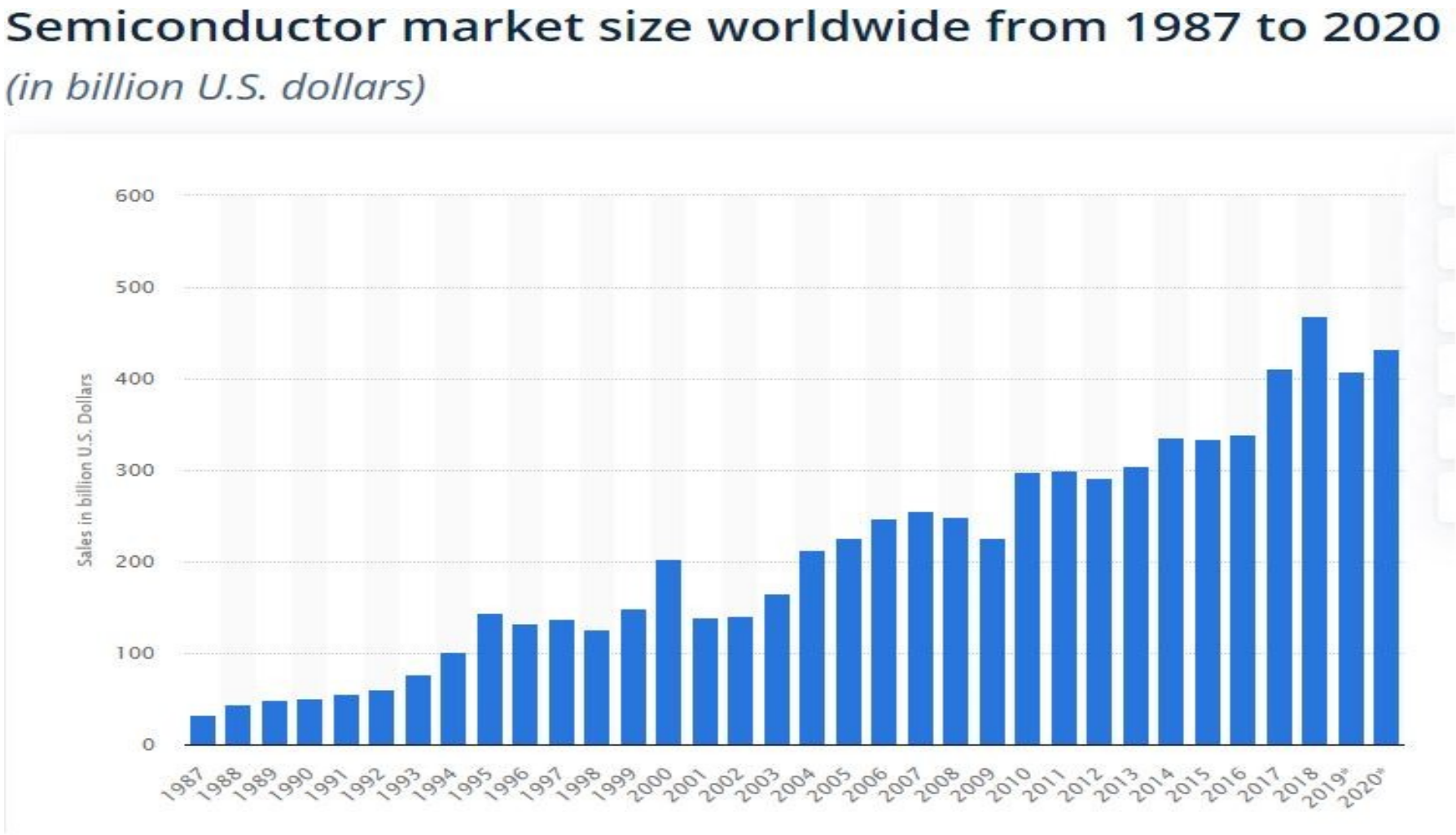
- The semiconductor industry has shown two important trends thru the years:

  1 - continuously increasing integration density

  2 - decreasing unit costs

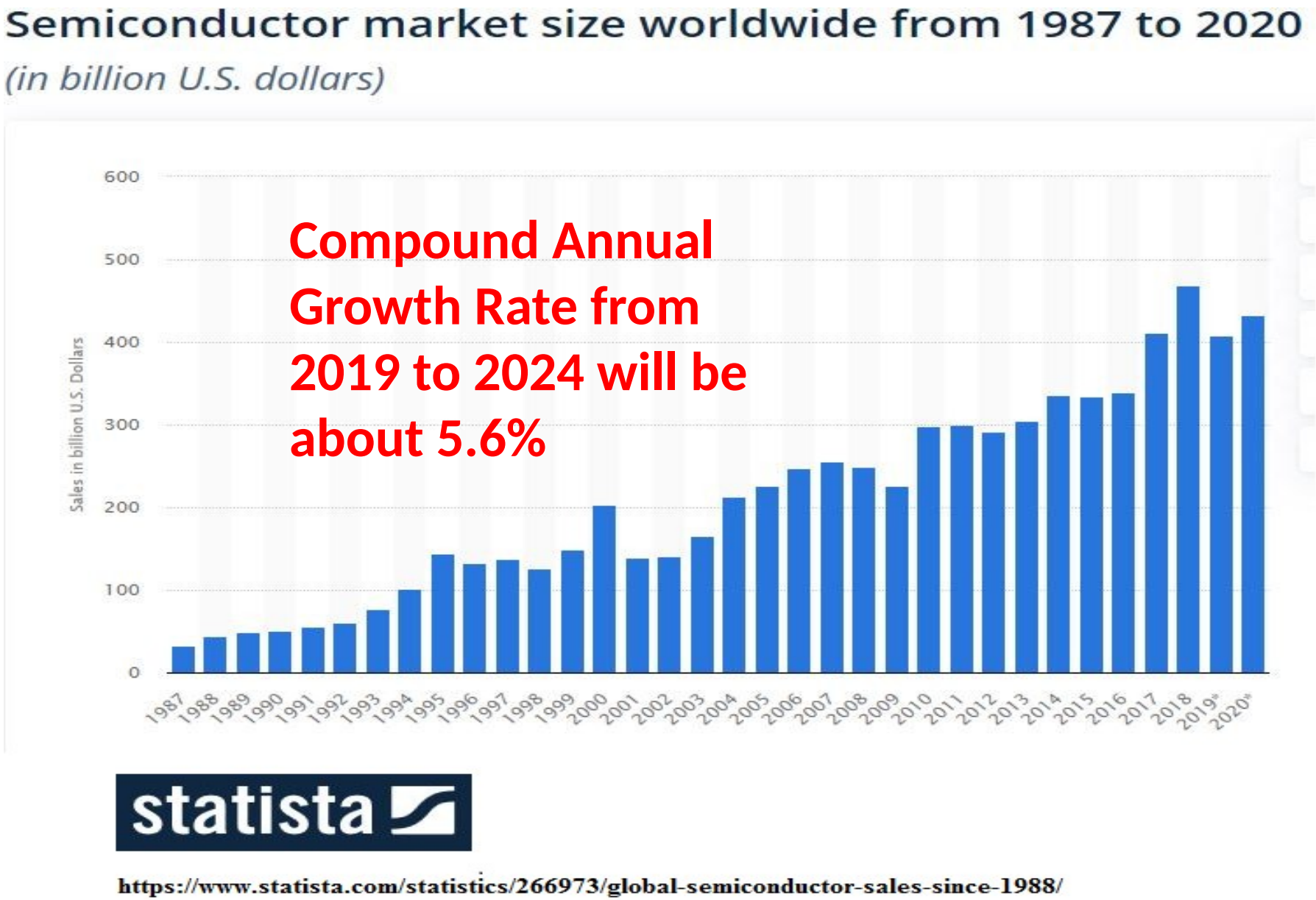
- As a result of there two trends, the semiconductor industry has been one of the fastest growing sectors in the worldwide economy

Economic Impact



https://www.statista.com/statistics/266973/global-semiconductor-sales-since-1988/

Economic Impact



Some Complicated Examples

Intel Pentium 4

0.13μ process

55 million transistors

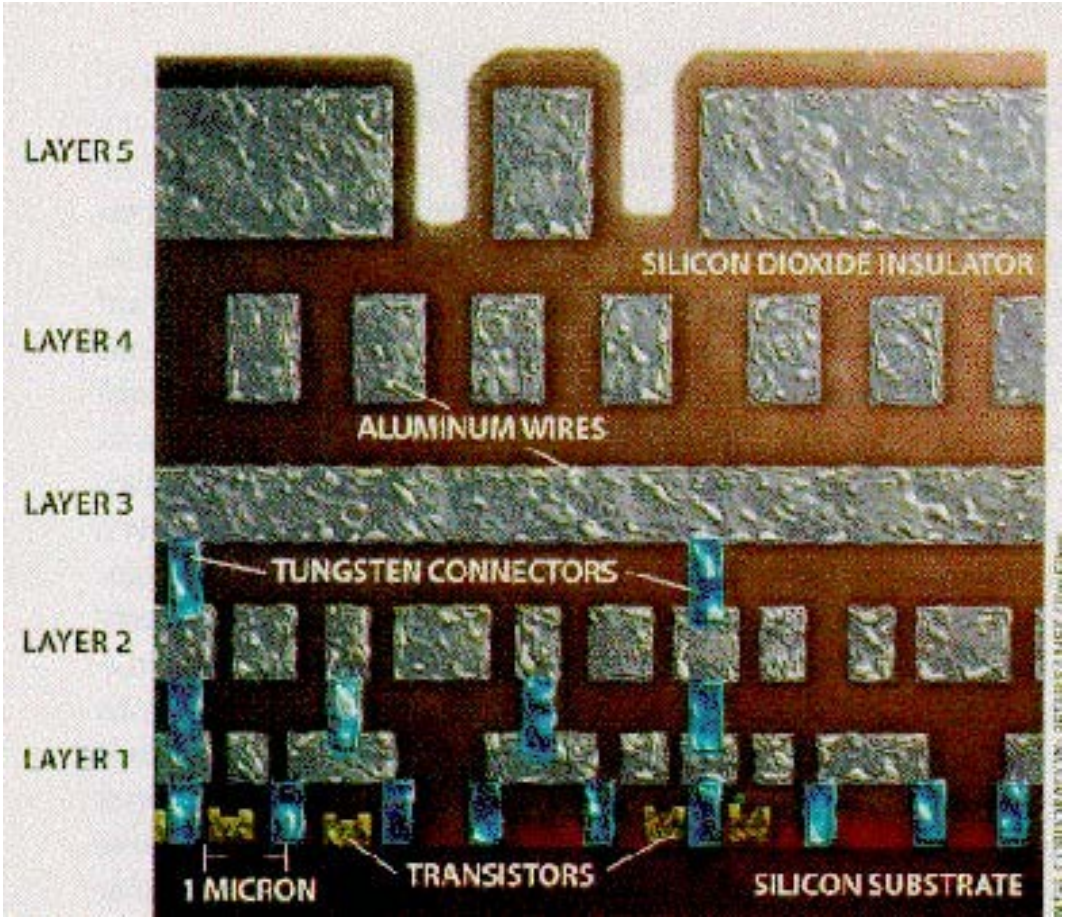
2.4GHz clock

145mm^2

First microprocessor (Intel 4004) 1970

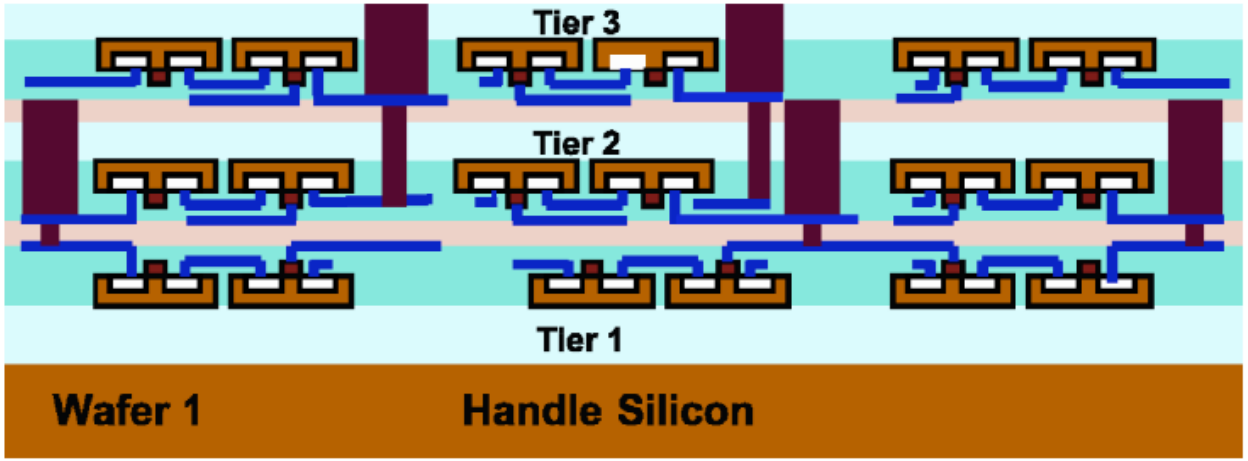
2,300 MOS transistors, 740 kHz clock frequency

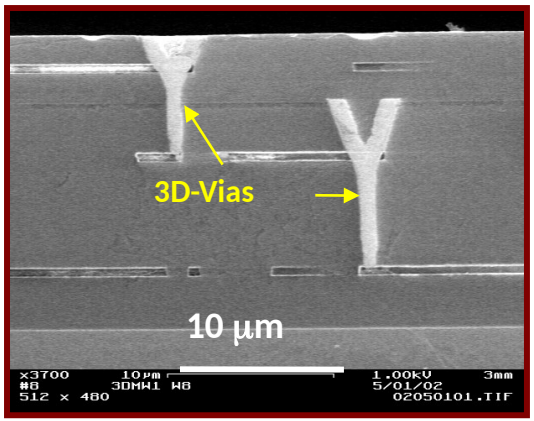
Cross section of 5 Layer IC



State of the art Technologies:

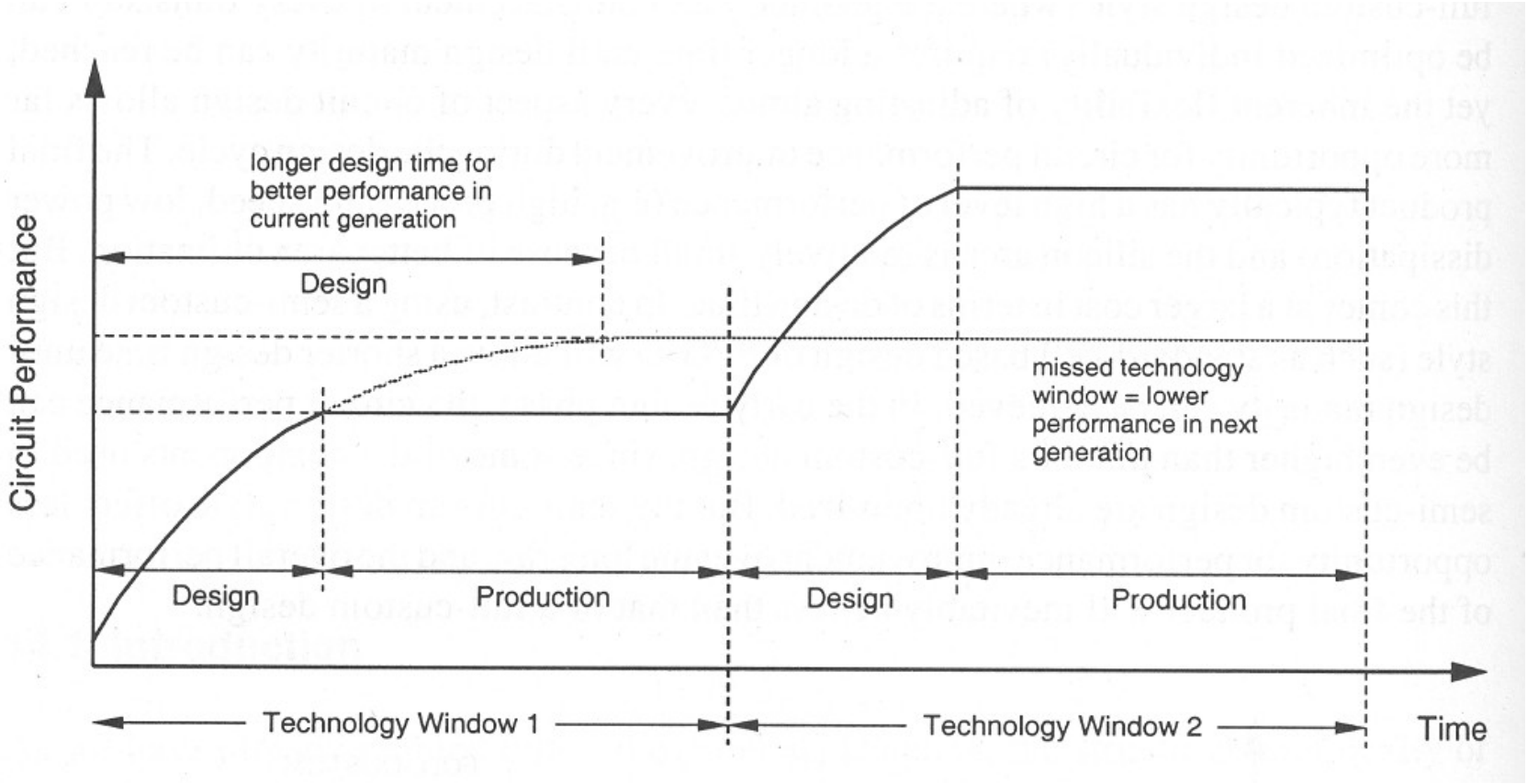
- 3-D Integration of 3 ICs (for example DDR4 memory)
- Challenges:
  - How to design 3-D chips?
  - CAD Tools
  - Testing
  - Yield and Power Dissipation



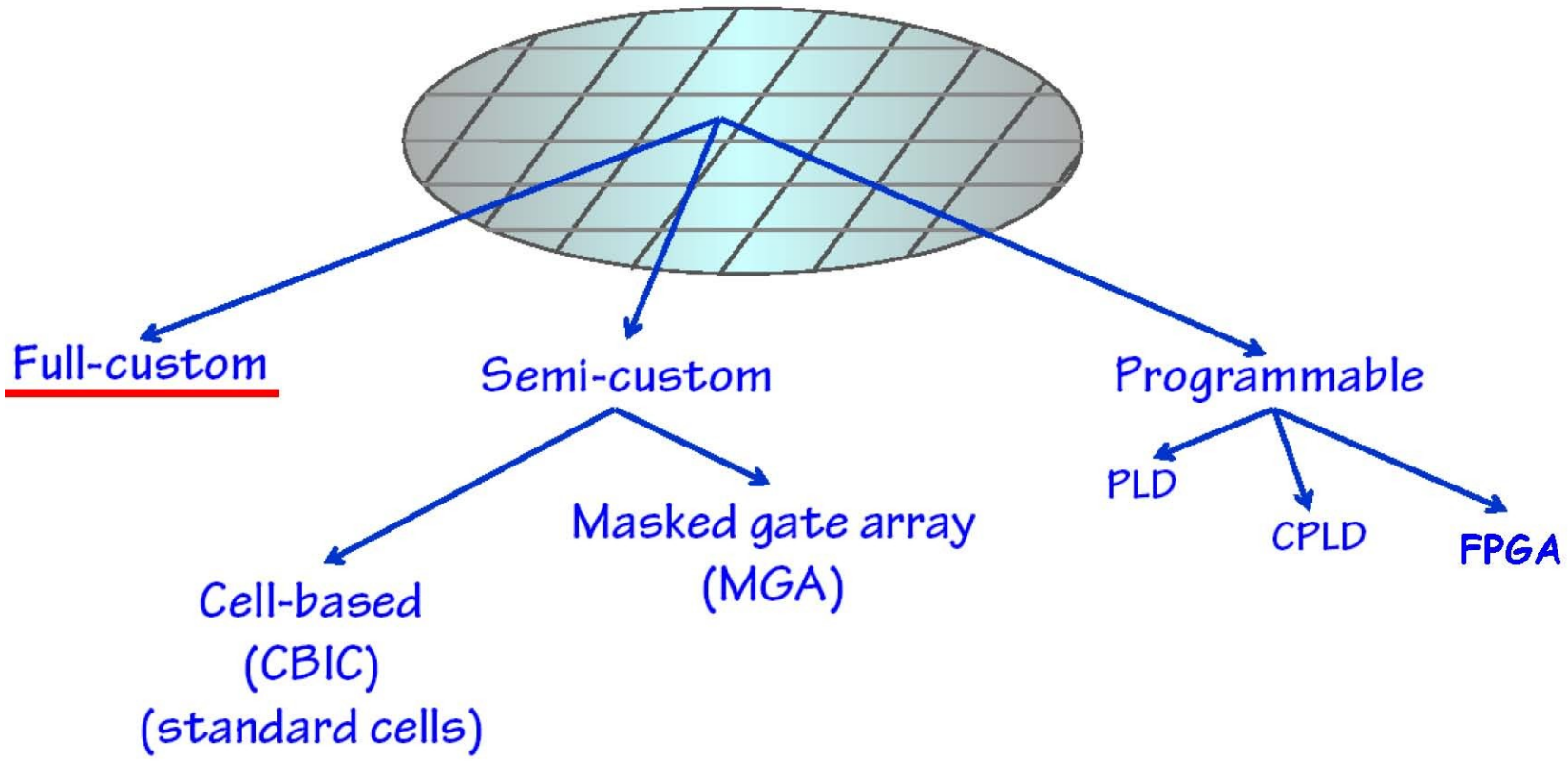


Photos from Vyshnavi Suntharalingam presentation MIT Lincoln Laboratory, Lexington, MA

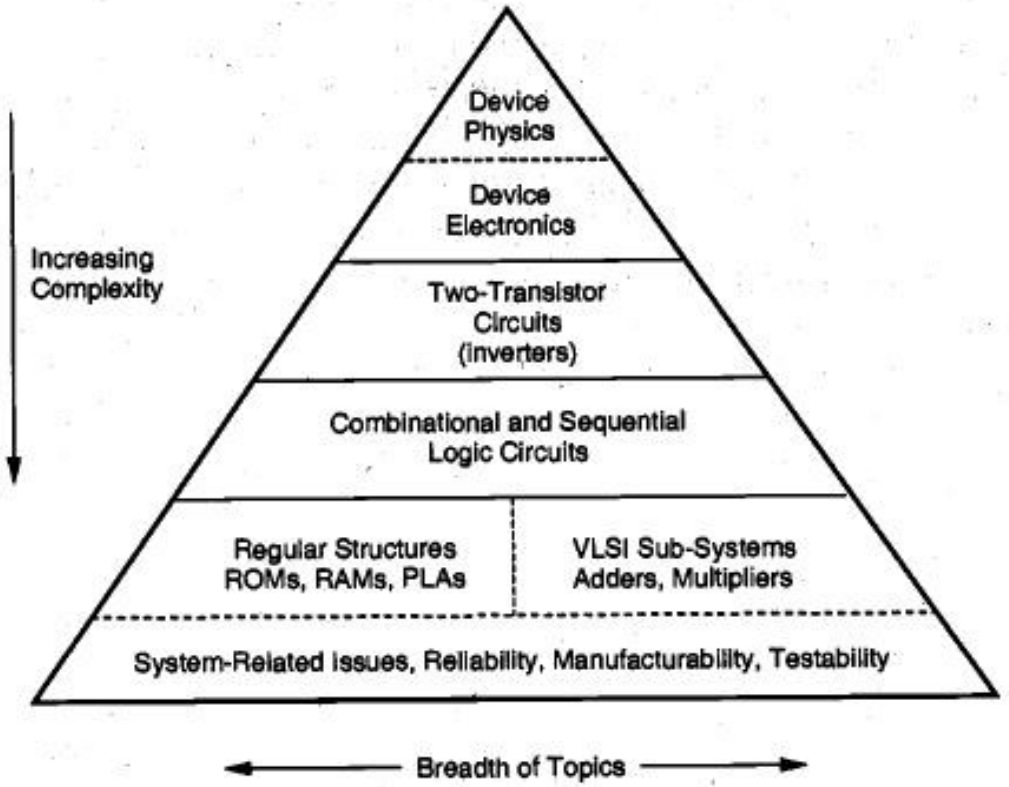
Life Cycle of ICs



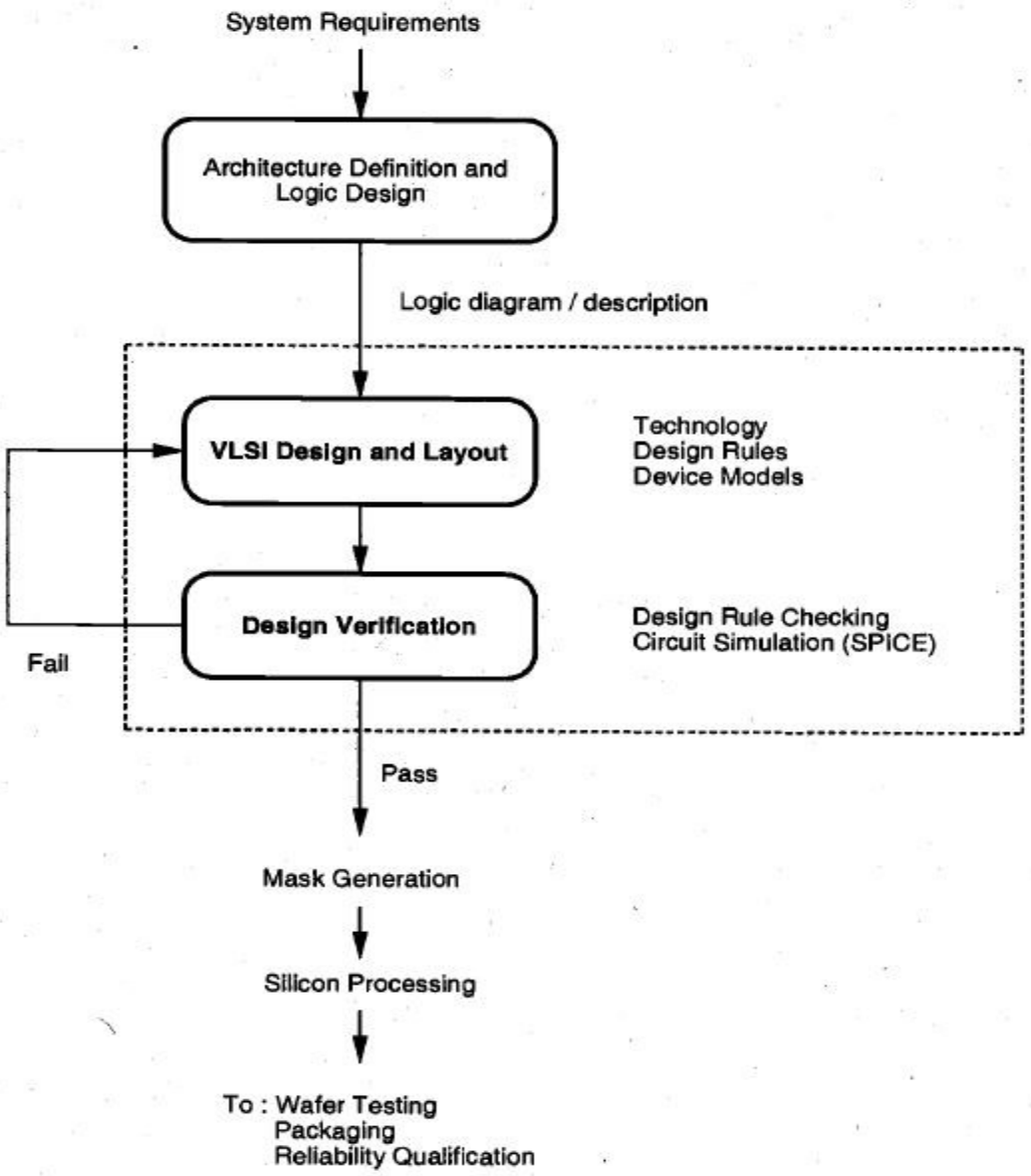
VLSI Design Styles



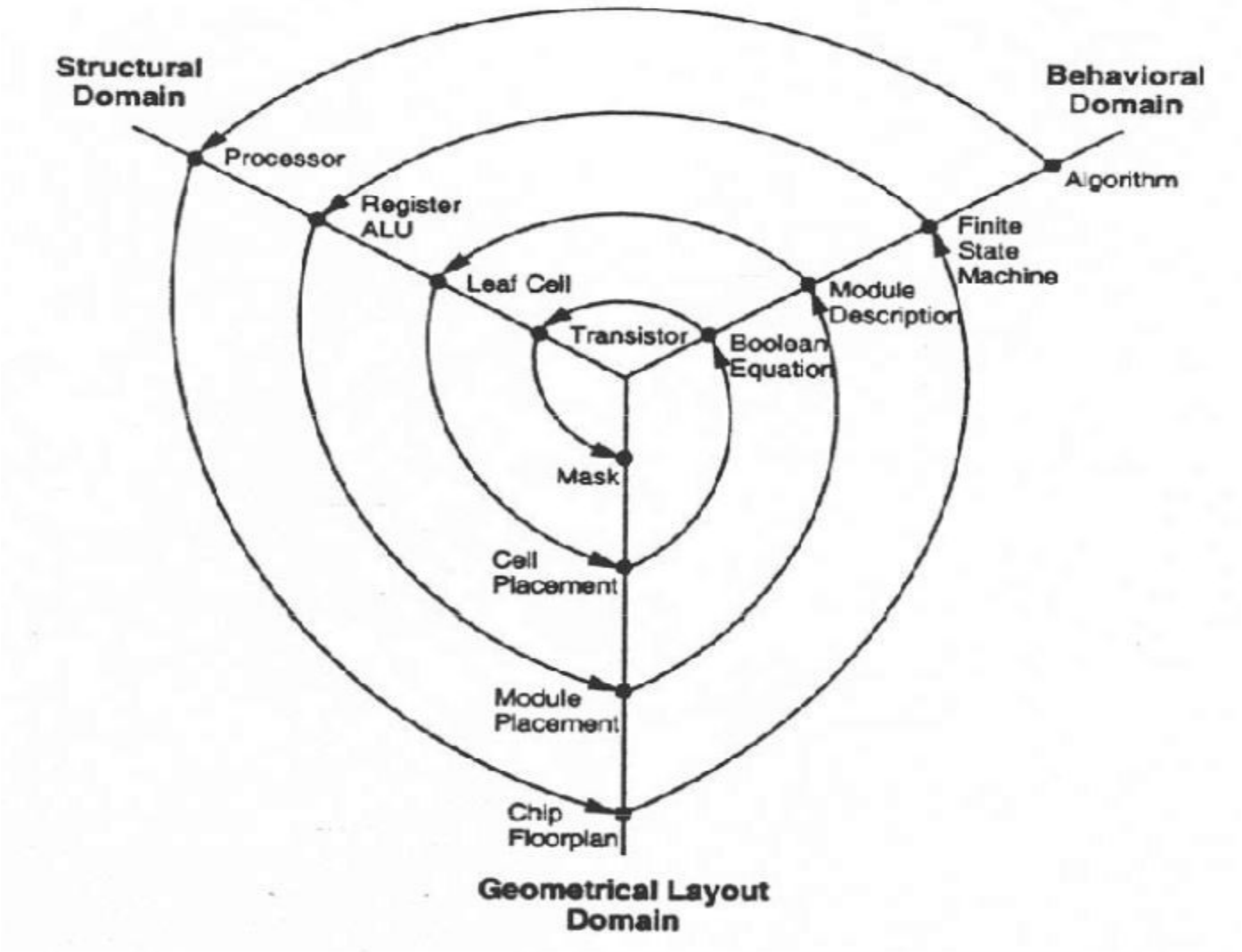
CSE463 Class Organization



The flow of circuit design procedures



Design Cycle: The Y - Chart



Structured Design Principles

- **Hierarchy:** “Divide and conquer” technique involves dividing a module into sub-modules and then repeating this operation on the sub-modules until the complexity of the smaller parts becomes manageable.
- **Regularity:** The hierarchical decomposition of a large system should result in not only **simple**, but also **similar** blocks, as much as possible. Regularity usually reduces the number of different modules that need to be designed and verified, at all levels of abstraction.
- **Modularity:** The various functional blocks which make up the larger system must have **well-defined functions** and **interfaces**.
- **Locality:** Internal details remain at the local level. The concept of locality also ensures that connections are mostly between neighboring modules, **avoiding long-distance connections** as much as possible.