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# Managing the Application of Technology

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The Trybula Foundation, Inc.

# Structure of Presentation

- **Semiconductors as a baseline**
- **Case Example of evaluating technology**
- **Introducing new technologies**
- **Methodology for Change**
  - Cost Drivers
  - Insertion
- **Summary**

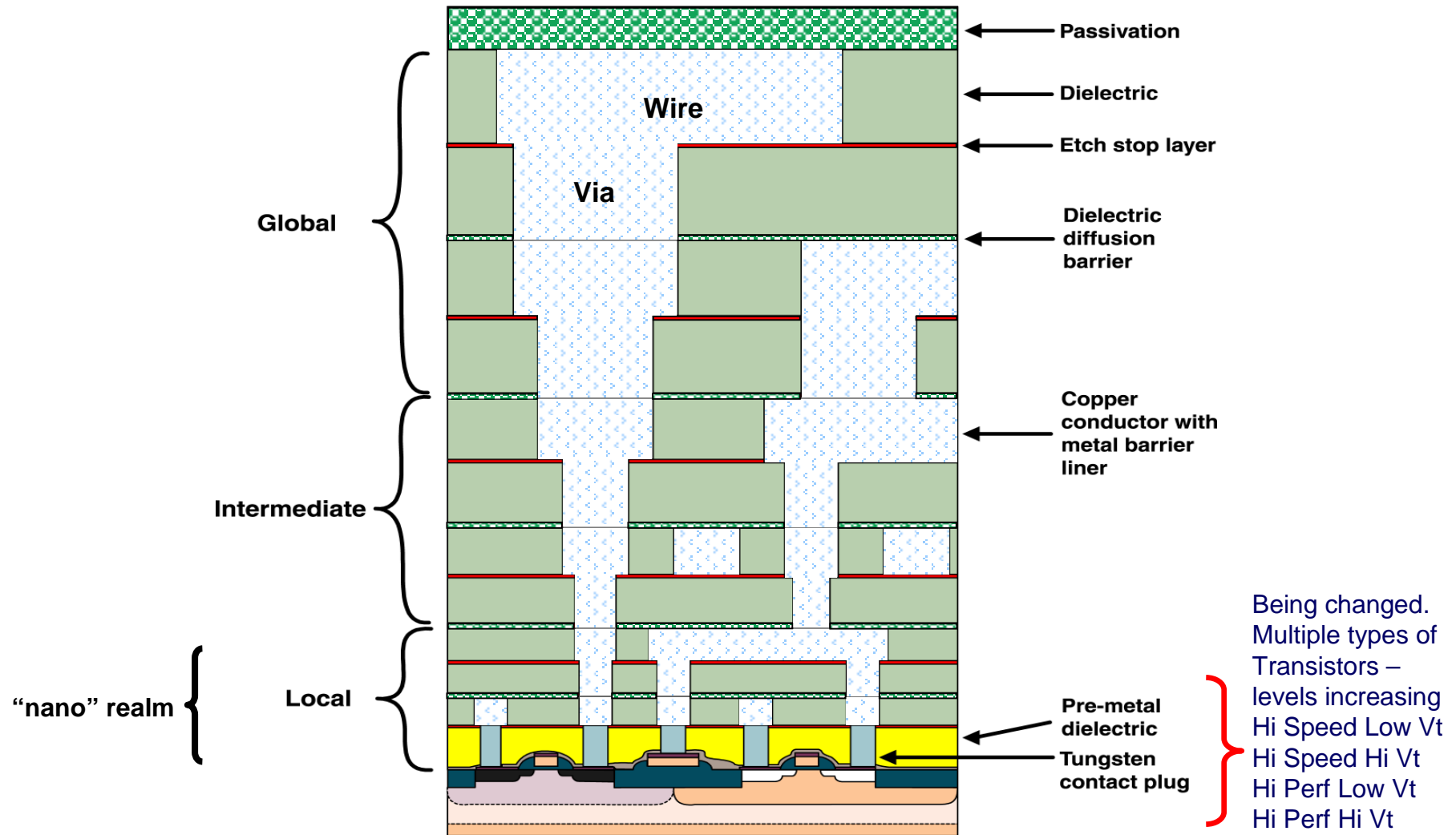


# Semiconductor Productivity

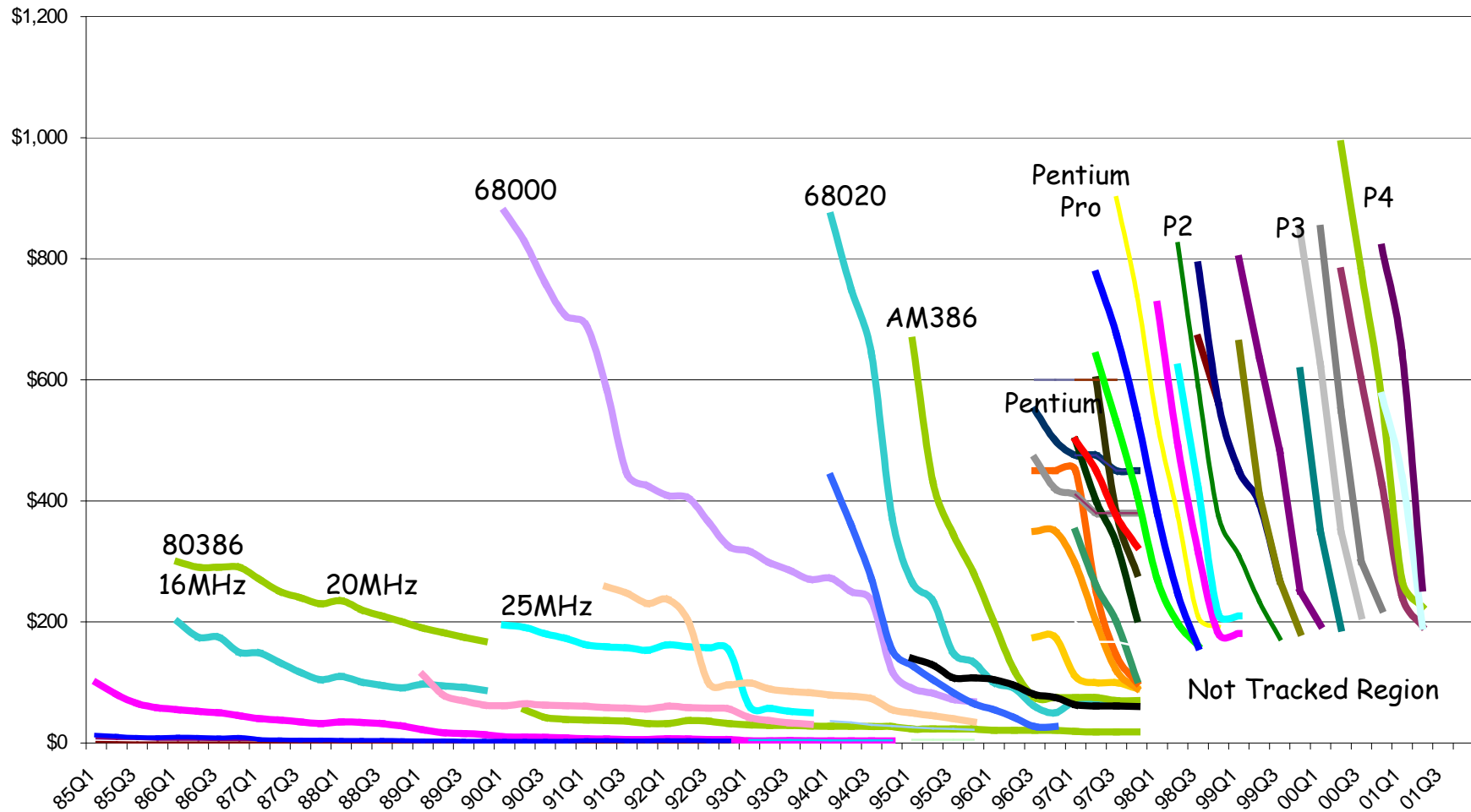
- **The semiconductor industry has invested at a uniquely prodigious rate the last 40 years to maintain a productivity improvement unprecedented in human history**
  - Doubling the number of transistors/bits available on a chip about every two years while reducing the cost of those transistors/bits ~30% annually
- **This amazing rate of productivity increase has enabled an improved standard of living in the US and the world in general**
  - Semiconductor improvements have also the basis for the continuous global superiority of the US military

# Semiconductor Process Overview

Typical Chip Cross Section

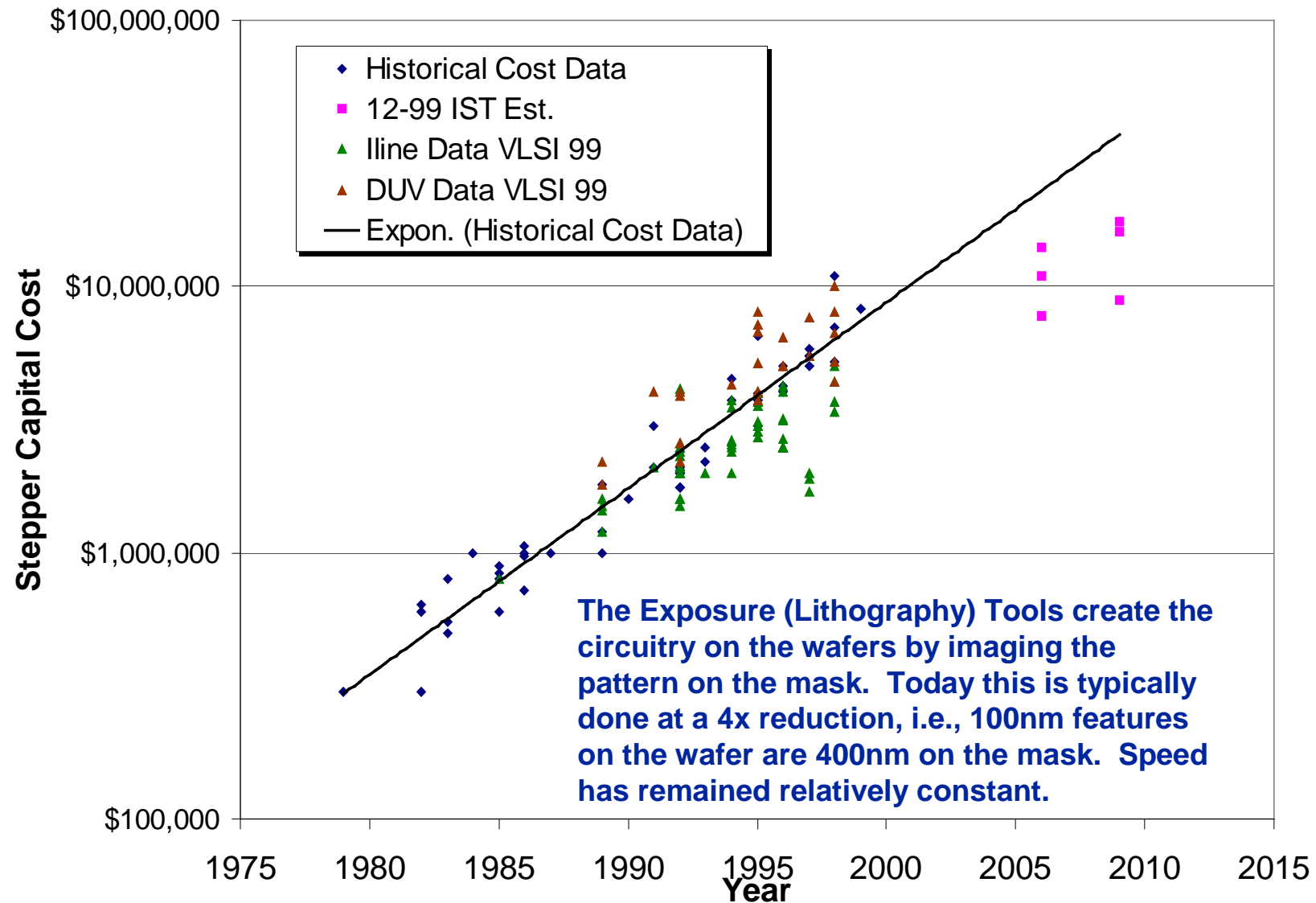


# Hyper-Competitive Industry MPU Selling Price over Time



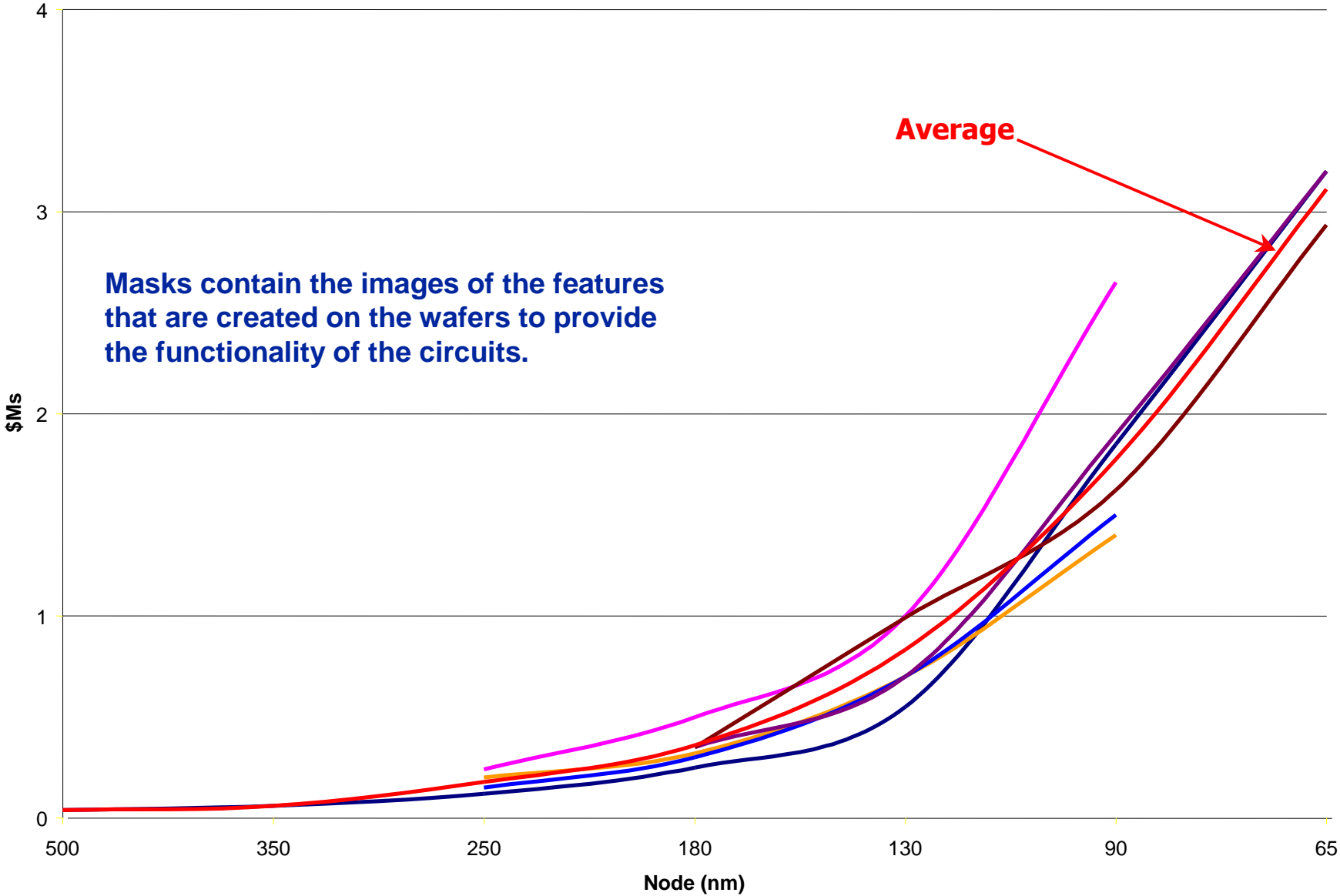
Based on information from DataQuest and MicroDesign Resources.

# Exposure Tool Costs are Growing



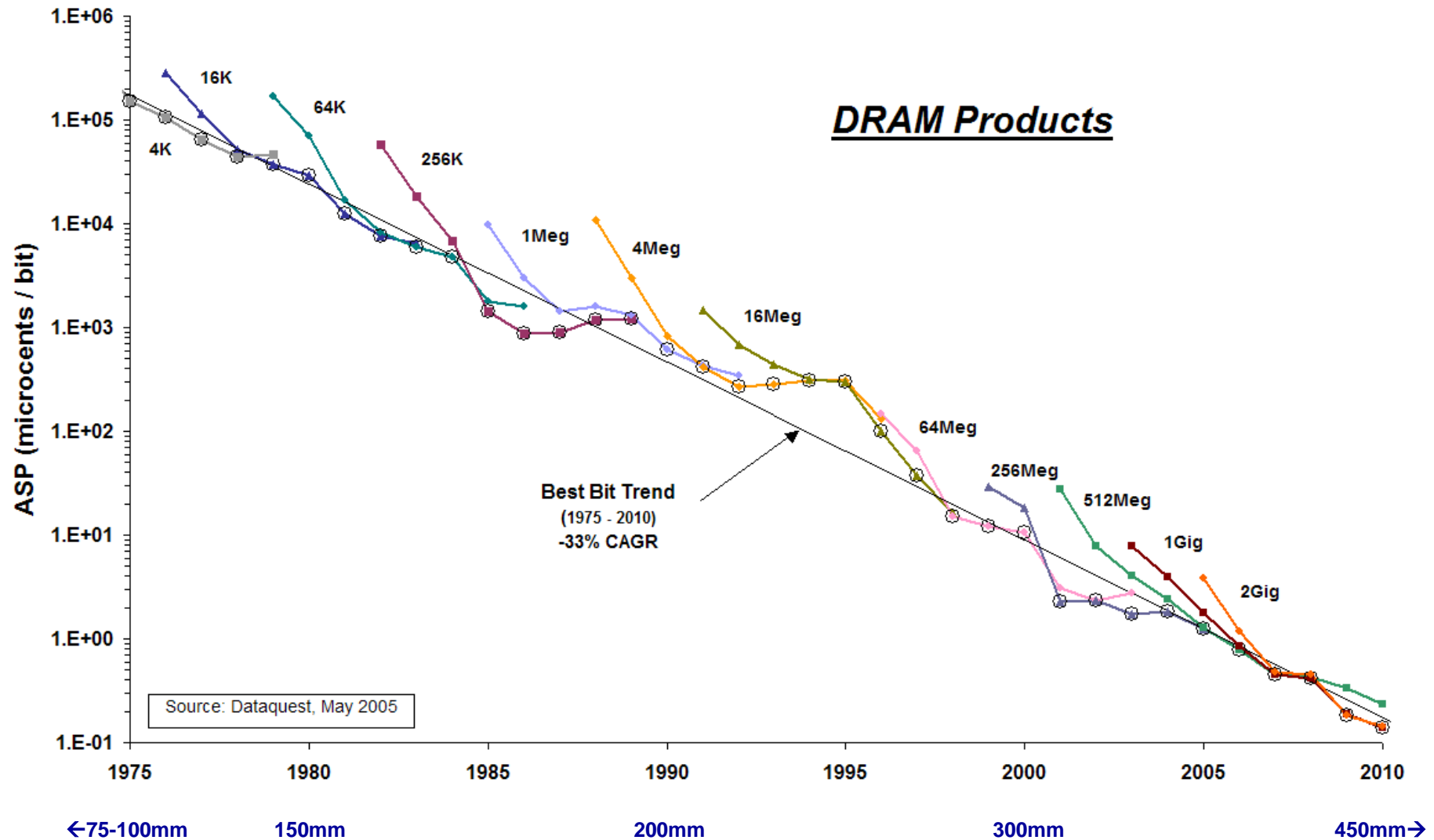
Based on Gene Fuller Data - ~2000

# Mask Set Cost Projections – Also Upward



# Productivity Sustains the Industry

## Example: DRAM Value Trends



Cost to process 1 cm<sup>2</sup> is about the same over this period (a few dollars)



# The Semiconductor Industry has had 40 years of unprecedented growth, how long will it continue?




LAWRENCE PETER BERRA  
"Yogi"  
Catcher  
Batted: Left Threw: Right  
Height: 5'8" Weight: 194 lbs.  
Born: St. Louis, Missouri 5/12/25

**Playing Record**  
1946-63 New York Yankees  
1965 New York Mets

Games	2120	Home Runs	358
At Bats	7555	Runs	1175
Hits	2150	Runs Batted In	1430
Doubles	321	Batting Average	.285
Triples	48		

Hall of Fame  
**INDUCTION DAY**  
August 6, 1972  
Cooperstown, New York

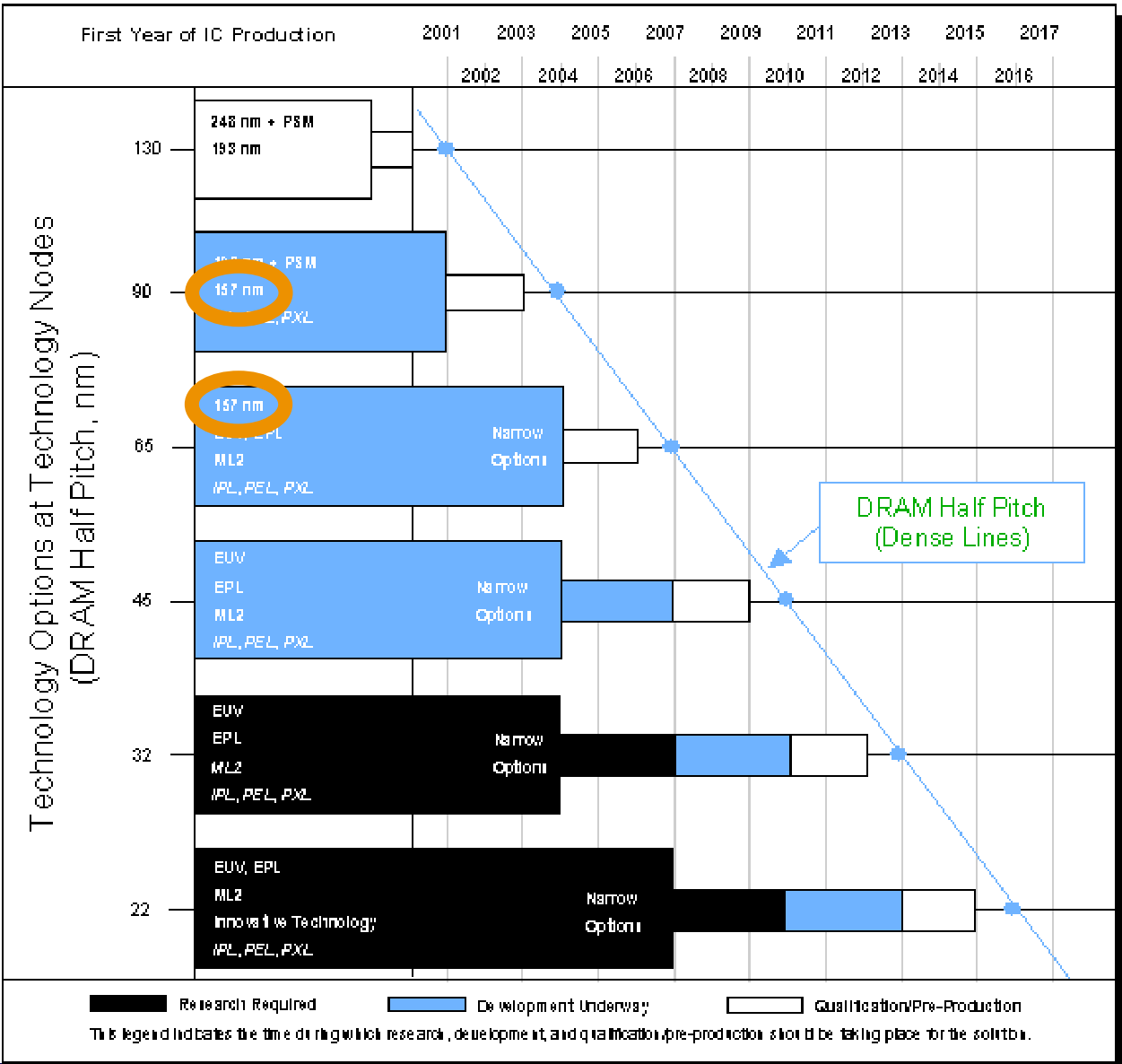


**“It's hard to make predictions, especially about the future.”**

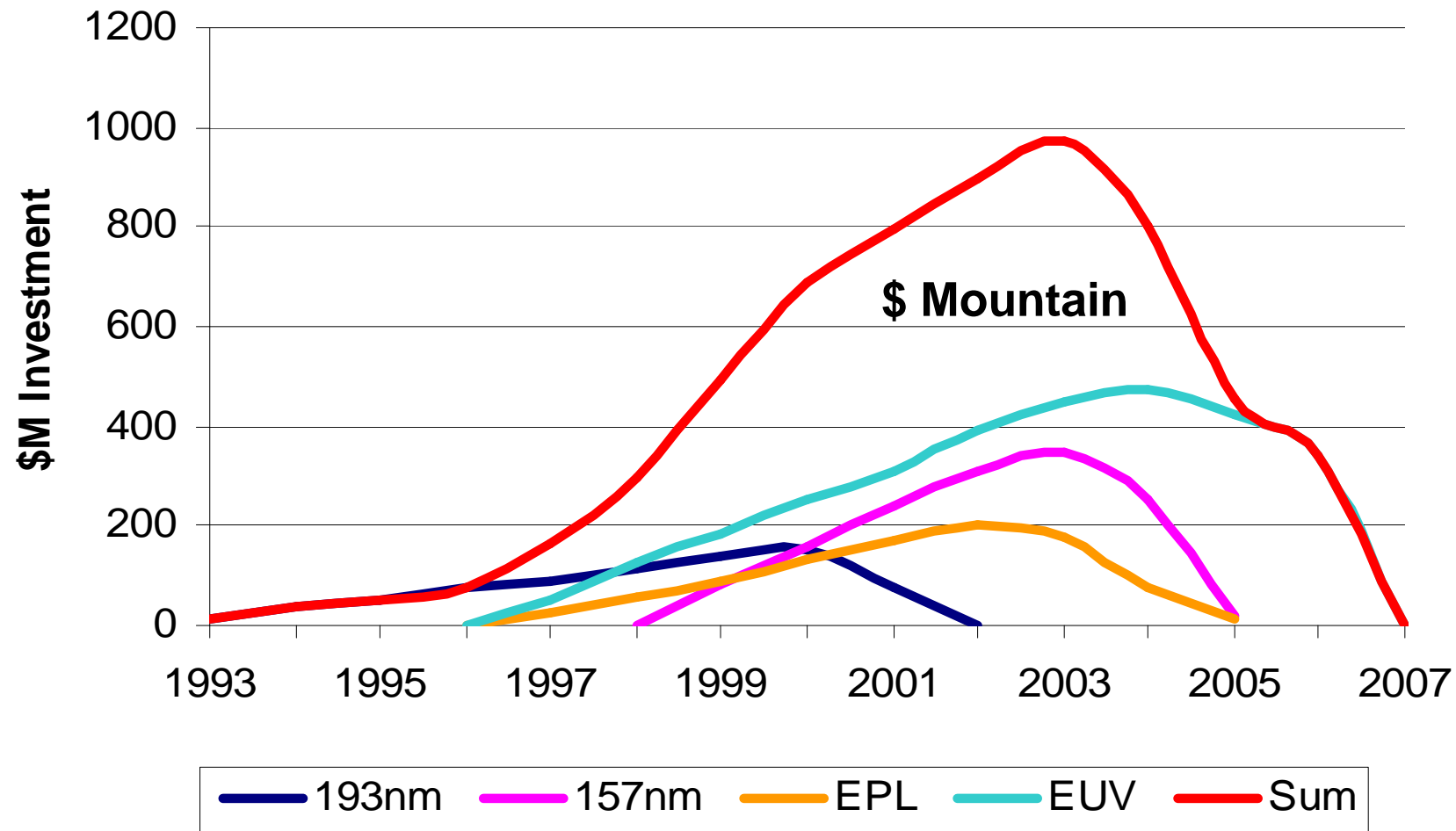
**- Yogi Berra**



# ITRS 2001 Version Predicting Litho



# The Lithography R&D Mountain Required World-wide Funding (1999 est.)



These numbers were revisited in 2002 and resulted in more than a 2X increase in total required funding!

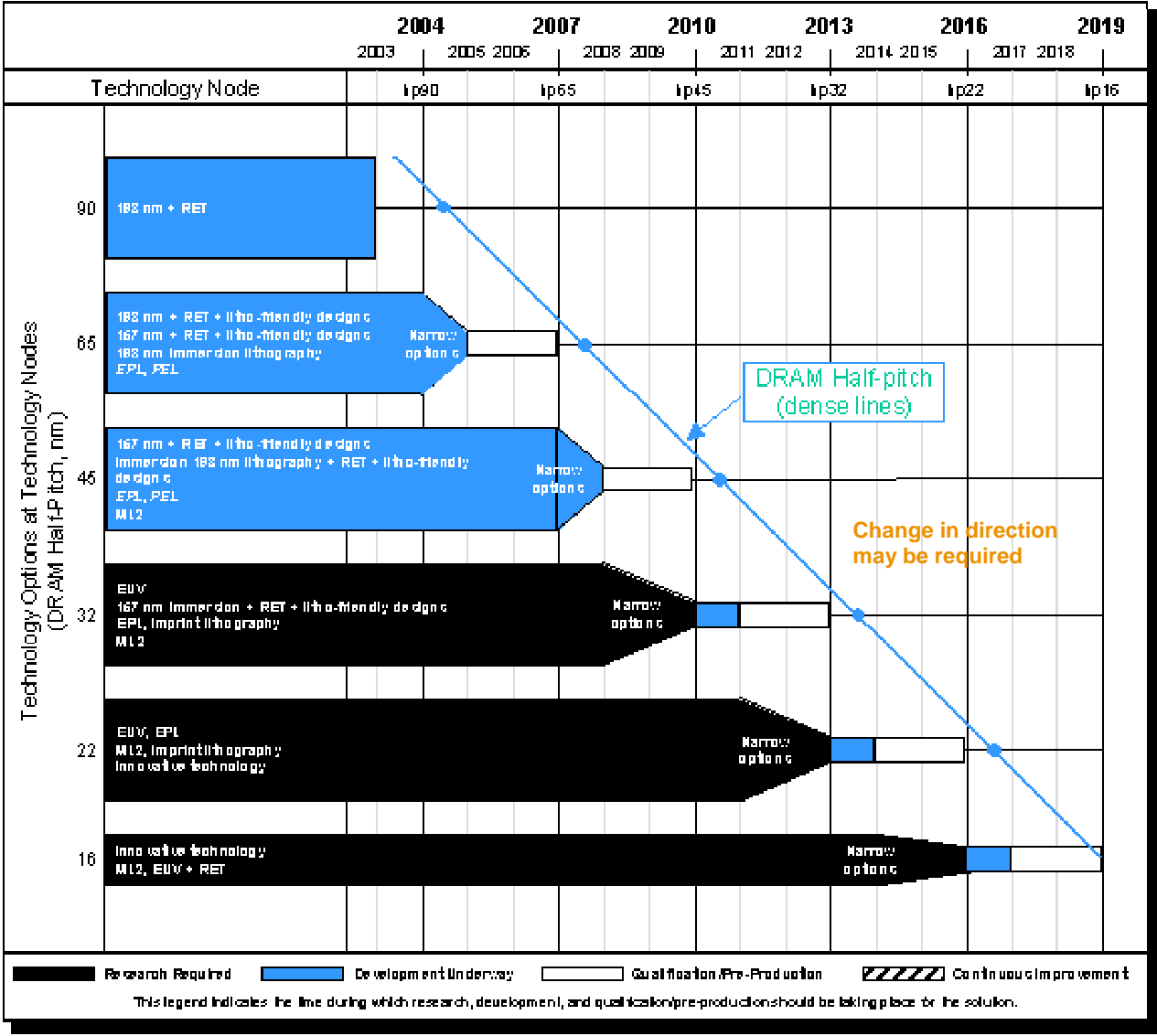


# A Problem Arose with 157nm!

- **The  $\text{CaF}_2$  has an issue with bi-refringence that needs to be compensated.**
- **The  $\text{CaF}_2$  meeting the specifications for compensation was more difficult to produce than anticipated.**
- **Concern arose about having a sufficient supply of  $\text{CaF}_2$  for industry needs.**
- **This raised sufficient concern that Immersion Lithography became interesting to the industry.**

$\text{CaF}_2$  is the chemical representation of Calcium Fluoride.

# ITRS 2003 Version Predicting Litho



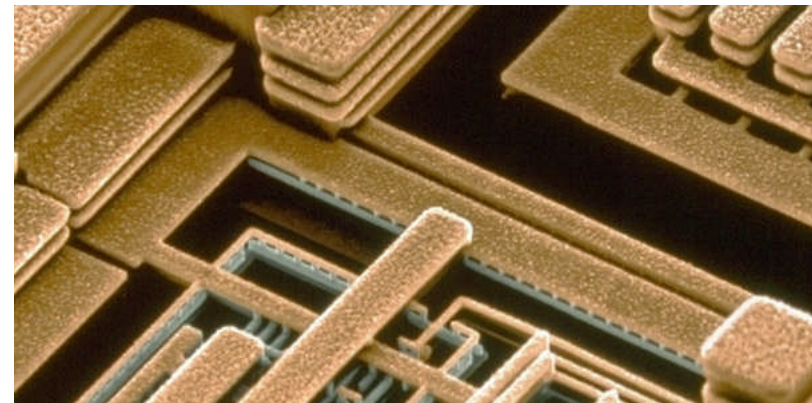
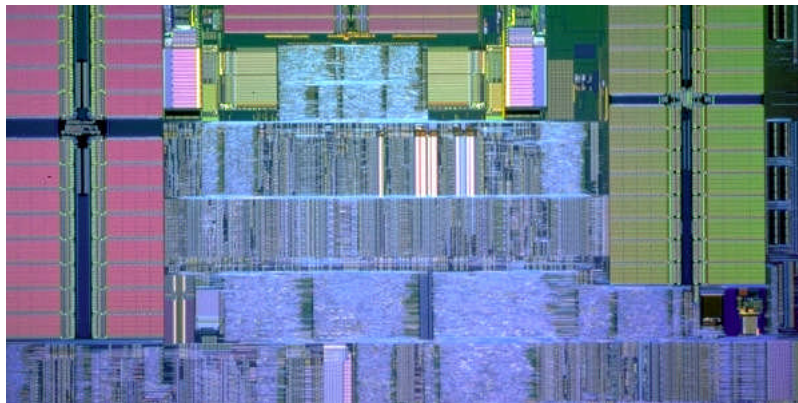
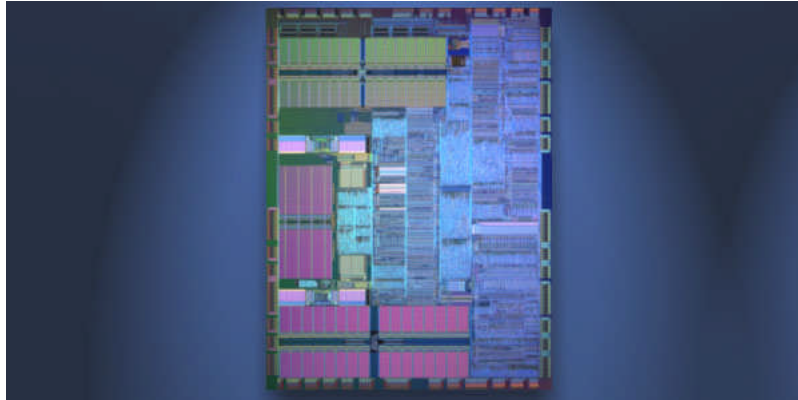
# Lesson Learned

**Cut your losses!**

**Even if \$2B has been spent!**



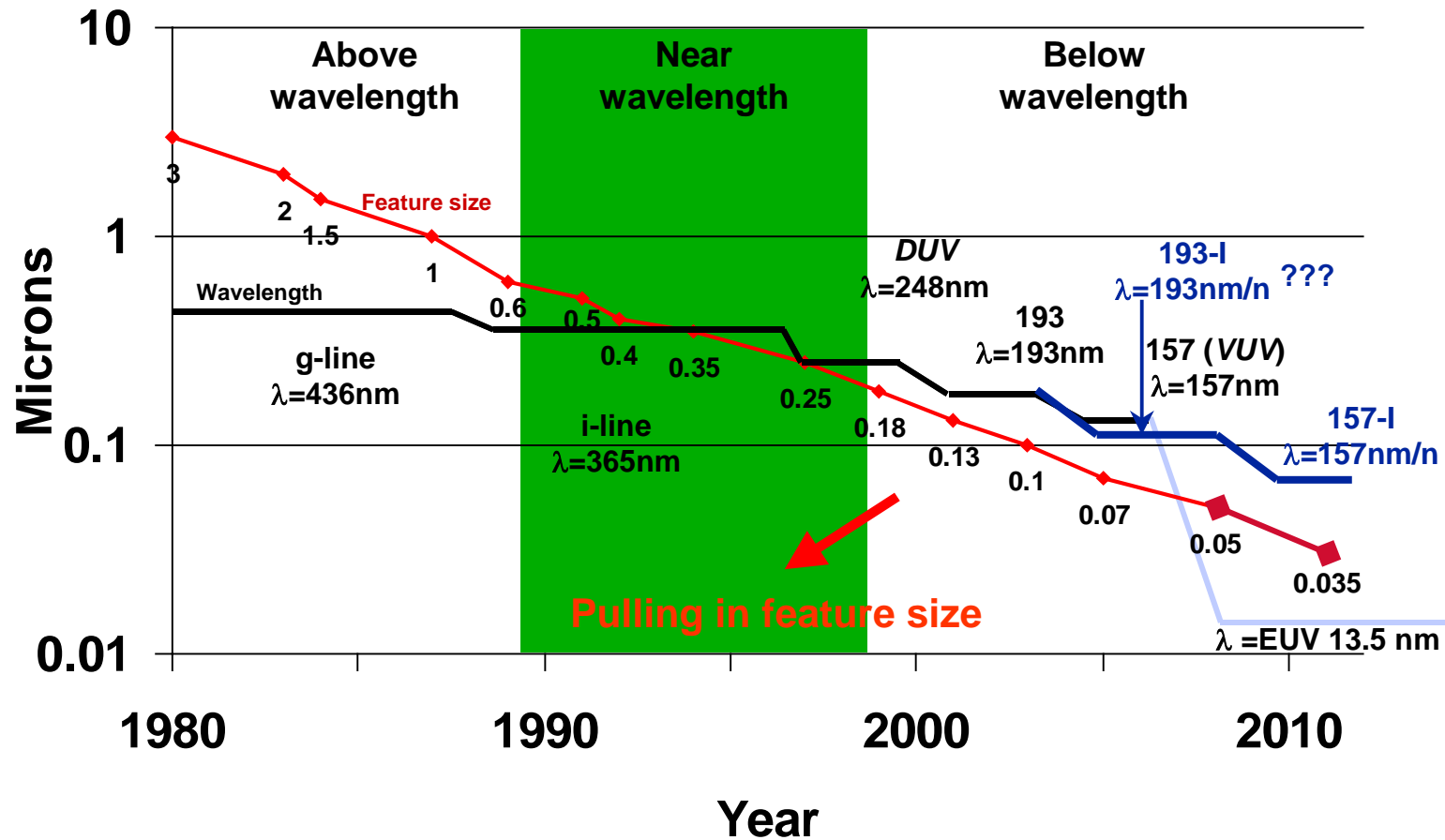
# Integrated Circuits



Images Courtesy of IBM Research Center Web Site

# History of Lithography

## Size versus Wavelength



Immersion Lithography effectively divides the wavelength by the index of refraction of the liquid. 193-I and 157-I stand for Immersion Lithography.

# Development Interdependency

**Every element of the “nano” manufacturing infrastructure must be ready for the “process” to succeed**

## **248nm Exposure Tool**

- Ready for production in 1991
- Only reached production in 1995

## **Why was there a 4 year delay?**

- Resists were not production worthy
- Resulting in insufficient experience
- Resulting in lack of willingness to take risks

**Learning: Complete infrastructure must be ready**

# Dangers of Cost Driven Savings

- **A new process that “saves” 15% would seem to be something for immediate implementation.**
- **Consider a 300mm wafer with 200 devices**
  - Selling price of the good devices is \$100
  - Manufactured cost is bare device is \$20
  - Yield is 95%
  - Effective company net is \$19,000 per wafer
  - Run rate is 5,000 wafers per week.
  - (total value is left as an exercise)
- **A 15% savings would yield \$14,250 per week in manufacturing cost savings. (~\$0.75M/year)**

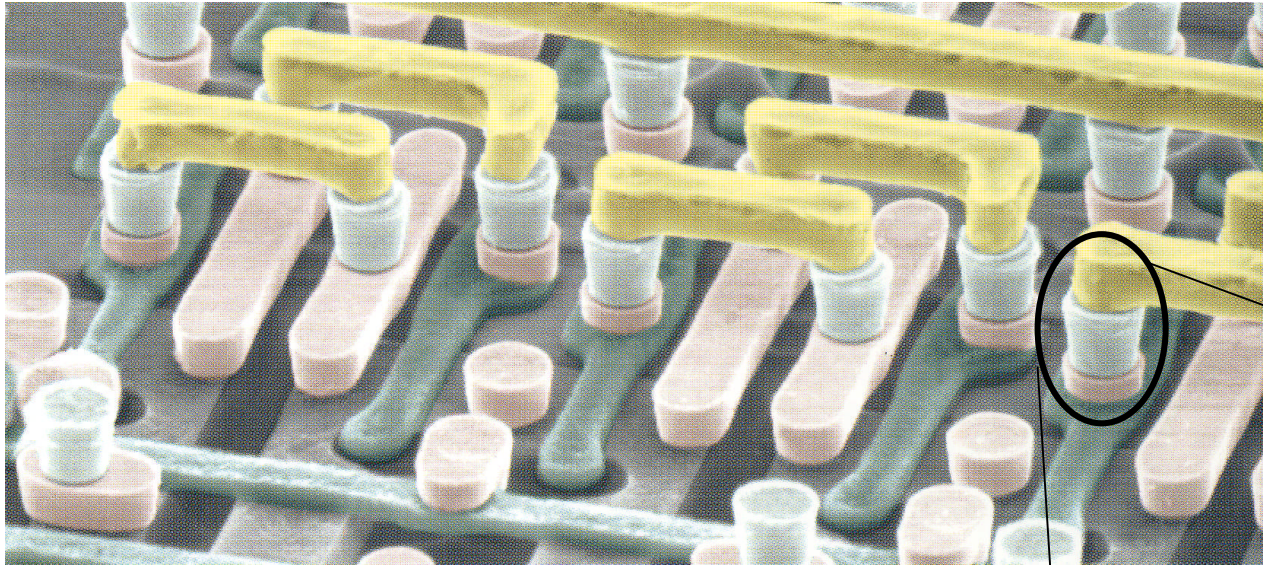
# Dangers of Cost Driven Savings

- **However, new process change over usually have yield loss and ramp up issues.**
- **Assume only 10% loss for 3 months until production is up to previous standards.**
- **10% loss is \$1,900 per wafer lost product revenue or ~\$10M per week!!!!**
- **A three month ramp to previous volumes and yields would cost \$130M**
- **Which choice would you make?**

# Semiconductors: First Nano Industry

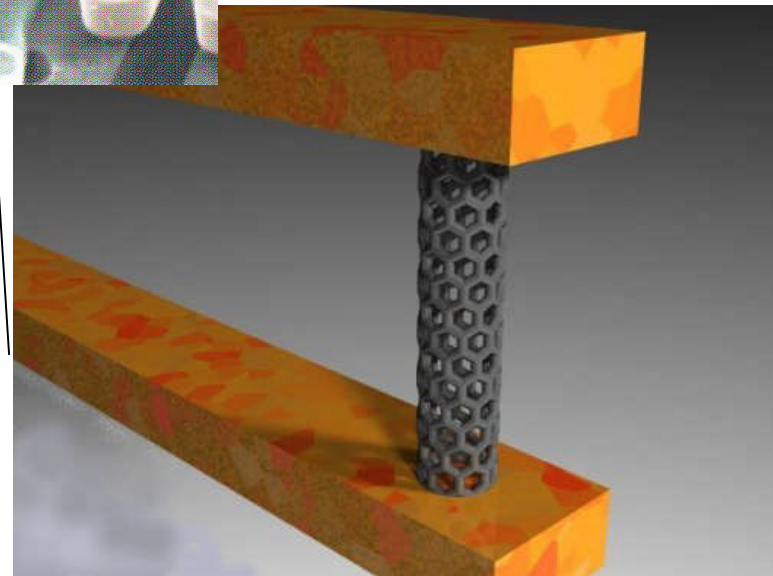
- **Model of early nanotech adoption, foundation for other nano industries**
  - People, capital, technology, infrastructure, experience, and culture will enable the transformation of nano into the advanced technology economies of the future
- **Lessons learned that will apply to follow-on nano industries**
  - Meeting technical challenges
    - New requirements in nano region; issues do not just scale
    - Operating environment is critical
    - Complete infrastructure must be ready (development interdependency)
  - Meeting economic/business challenges
    - High barrier to entry
    - Each new generation costs more
    - Shorter and shorter life cycles
    - Development issues and technology acceleration can crash infrastructure
    - Greatest benefits come to earliest successful entries
      - Being late means losing leading edge capabilities

# Interconnects



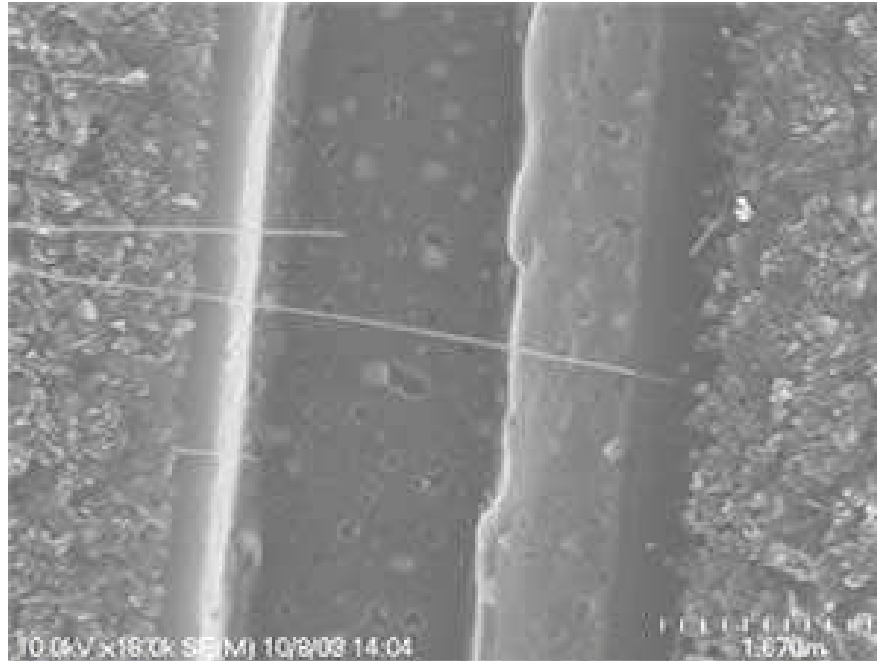
CNT advantages:

- (1) Small diameter
- (2) High aspect ratio
- (3) Highly conductive along the axis
- (4) High mechanical strength



Courtesy of M. Meyyappan

# Nanowires



Silicon nanowires are shown here growing horizontally over a "trench" on a silicon wafer. The silicon nanowires, which are about 17 nanometers in diameter – about 3000 times smaller size than the size of a human hair – are viewed with an electron microscope.

Ray Solanki, Oregon Science and Health University, Feb.23, 2004 issue Applied Physics Letter

# The Nanotech Challenge

- Learnings from semiconductor industry can assist in coordinating industry, university, government, and infrastructure roles as nano industries develop
- In advanced technologies, companies and countries that want to control their own destiny must be at the leading edge
  - Advanced technologies will drive the economy for the next 50 years  
*US Dept. of Commerce*
  - Enabler for national security and competitiveness
  - But competition is global and severe and already upon us

# Summary

- **Introducing new technology has risks.**
- **Successful technologies can still result in corporate losses**
- **Understanding technology includes understanding the infrastructure. Failure to consider the total picture can result in losses**
- **There will be many technology “losers”, but the successful will understand the technology and how to drive development to satisfy a consumer need.**

