Semiconductor Industry Perspective

National Academy of Engineering Workshop on the Offshoring of Engineering

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A Few Introductory Comments

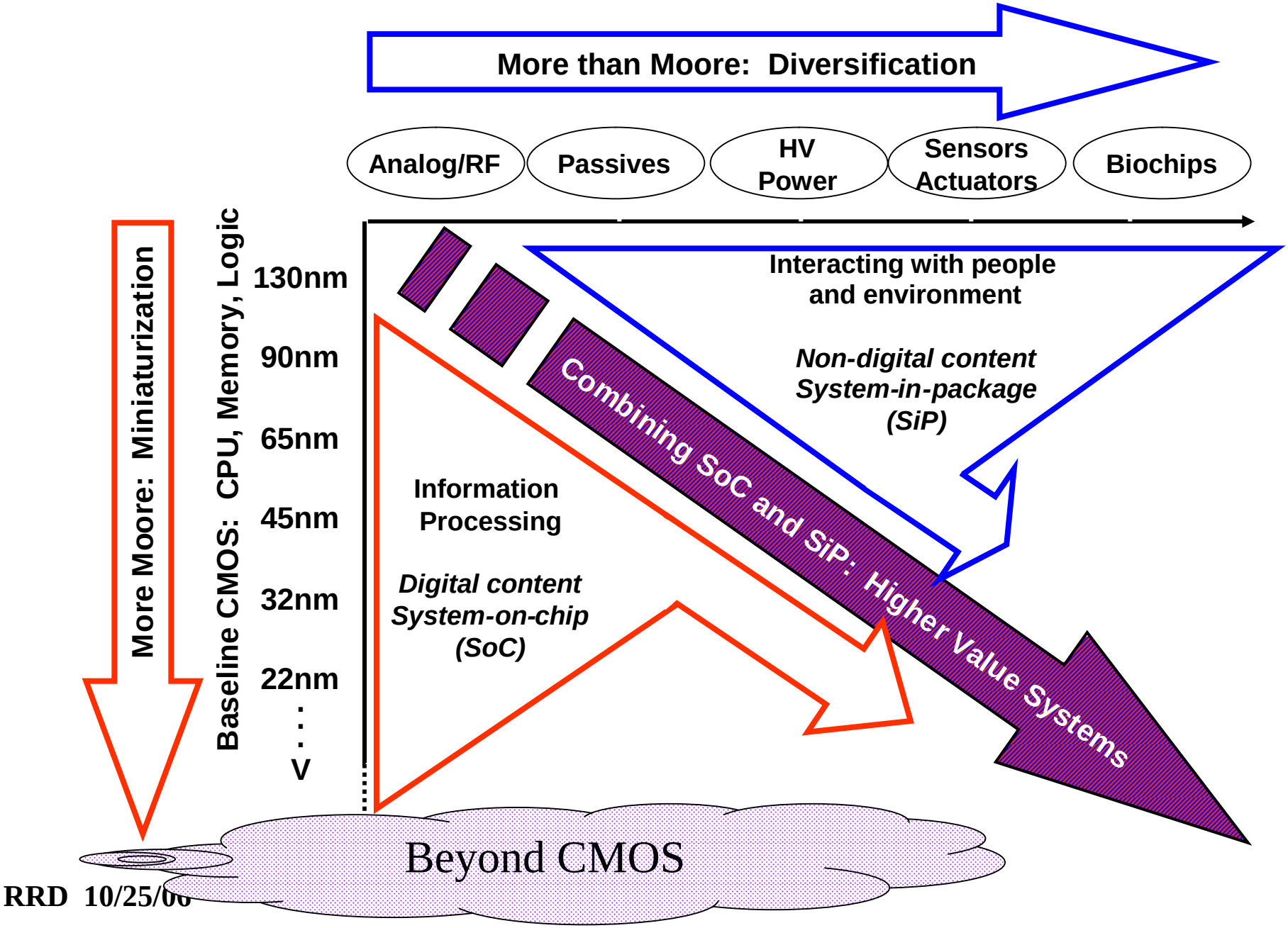
- **Prof. Brown's paper is very valuable, especially on:**
  - **Relevant data/statistics**
  - **Analysis of trends**
  - **Conclusions wisely tempered by significant caveats (e.g., difficulty of comparing engineering compensation data between countries)**
- **Moore's Law "nit": doubling of transistors per *area* has never been faster than 2 years (recent pace); historically, it was 3-year doubling/area (area/chip used to increase, giving 18-month doubling per *chip*)**
- **Strong agreement on need for the proposed H-1B visa and green card legislation (the "Skill Bill")**

Design and Manufacturing

System-on-Chip *plus* System-in/on-Package

- The current paper doesn't address packaging, which is entering a new era of integration complexity.
  - Stacked-Die
  - Integrated Passives
  - Through-Hole Vias
- SOC/SIP/SOP displacing printed-circuit board area
- Complex package technology changes the landscape of system design and manufacturing.
- Opportunity for a follow-on study

IC-Value Drivers: Moore's Law & More



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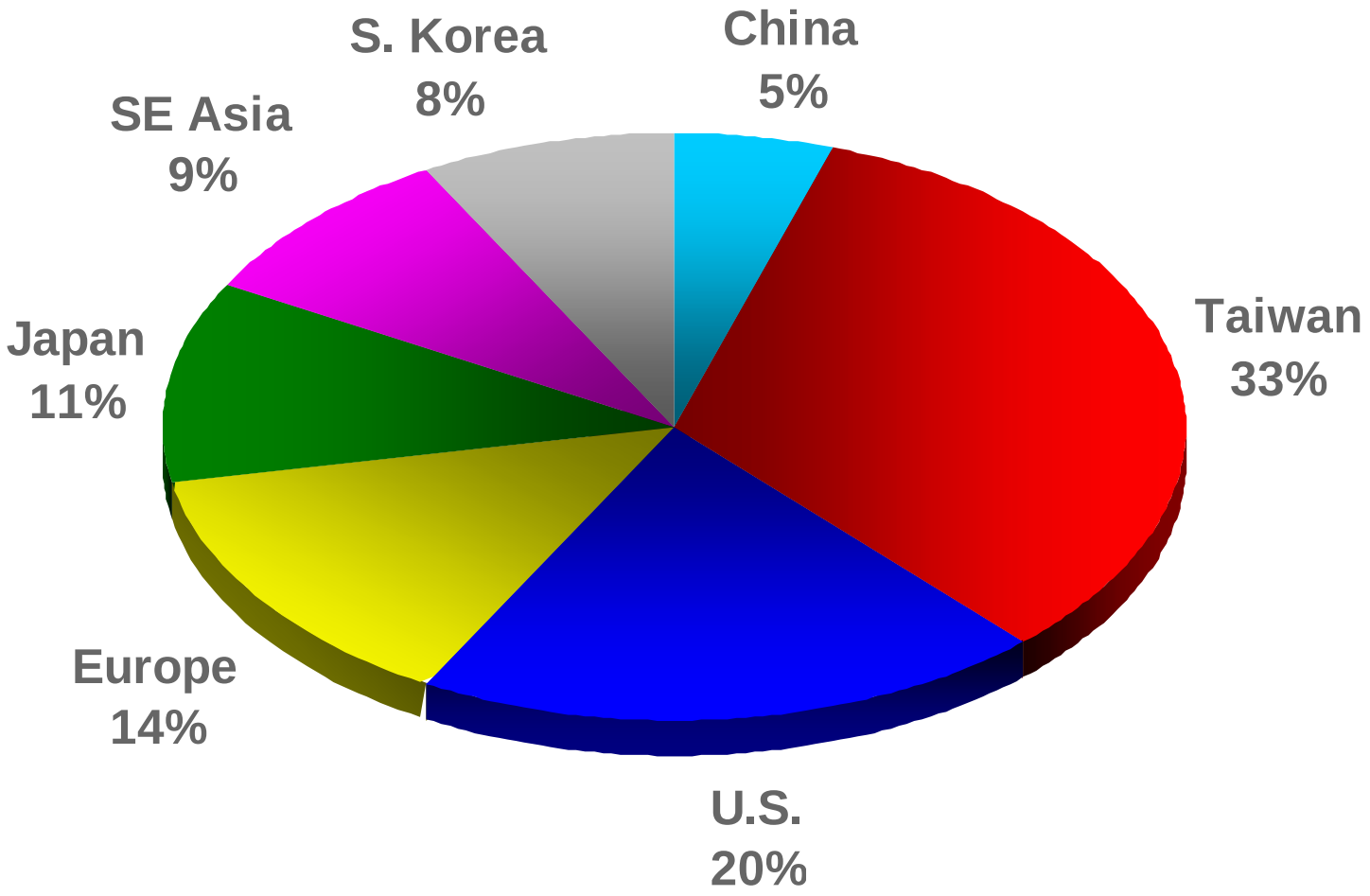
Rad-Hard ITAR Issue

- The most recent change in the language of U.S. rad-hard IC regulations could require a lengthy licensing process for design and manufacture of commercial leading-edge CMOS in the U.S., which would:
  - Put U.S. design and manufacturing at a competitive disadvantage for time-to-market
  - Encourage further off-shoring of new IC design and manufacturing
- Industry and government experts have agreed to a realistic modification to the rad-hard criteria, but implementation is currently stalled.

Impact of Foundries

- Foundries (and design-support companies) do have a positive impact on engineering jobs by enabling fabless SC companies.
- However, the impact on U.S. engineering jobs would be even greater if we had significant cost-competitive foundry capacity in the U.S. -- this has more to do with taxes than labor cost.
- The paper also mentions benefit to IDMs who may offer foundry service, especially during downturns.
- In addition, some IDMs benefit from use of the low-cost "subsidized capacity" in Asian foundries to cover market demand peaks for maturing technologies.
- Capital-intensive R&D eventually follows leading-edge manufacturing.

2/3 of New 300mm Fabs
(under construction, equipping, or in production)
are in Asia



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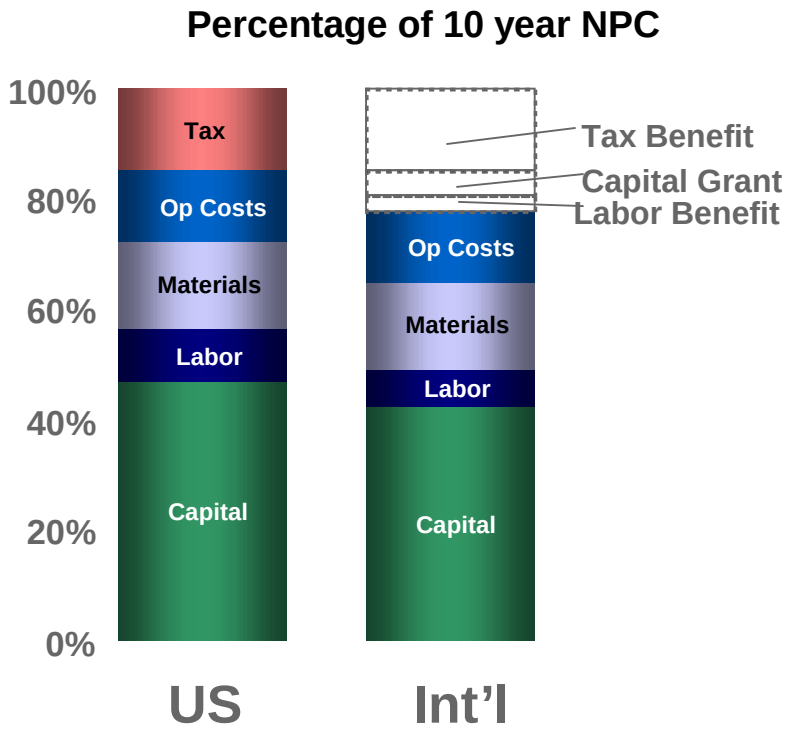
Source: Strategic Marketing Associates, May 2004

Semiconductor Manufacturing Site Considerations

- Cost competitive (tax and infrastructure)
- Proximity to R&D
- Workforce availability
- Proximity to customers
- Available infrastructure

Wafer FAB Cost Model: Key Assumptions & Drivers

- **Cost model comparison based on a 10-year NPC**
  - Production starting in year 3
    - **Ramp with "current generation" technology products and transition to next-gen products after 5 years**
- **What factors dominate ?**
  - Cost differences driven by tax treatment, capital grants, other local factors
    - **Other local factors: utilities, labor, logistics**



	Concept 300mm FAB 10yr NPC
Int'l	$5.6B-$6.1B
US	$6.7B-$6.8B

Comparative Taxes/Incentives

U.S.	• 35% corporate tax rate • Various state-level incentives
ISRAEL	• Up to 20% capital grant • 10% tax rate – 2-year tax holiday
CHINA	• 5-year tax holiday • After holiday, ½ normal rate for next 5 years
MALAYSIA	10-year tax holiday
IRELAND	12.5% corporate tax rate

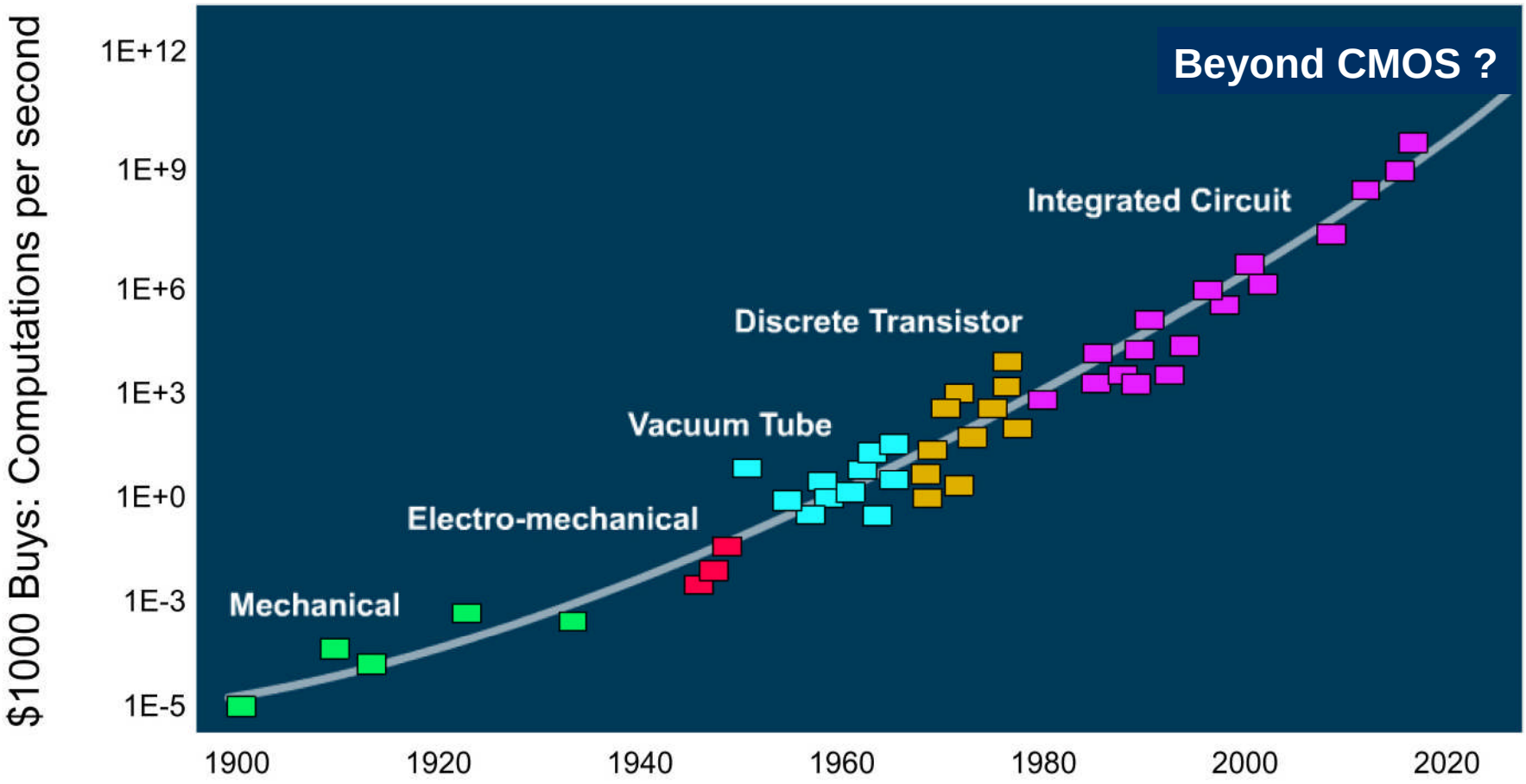
The U.S needs, at least, a permanent R&D tax credit

Source: SIA

R&D

Eras of Progress

in Information Technology & Productivity



Major innovation **needed for "beyond CMOS" – <u>what could it be</u>?**

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Chart: Ray Kurzweil

We also need a constant stream of R&D breakthroughs to continue scaling CMOS:

Production Year:	2001	2004	2007	2010	2013	2016 …
Litho Half-Pitch [nm]:	130	90	65	45	32	22
Overlay Control [nm]:	45	32	16	11	8	5.5
Gate Length [nm]:	65	37	25	18	13	9
CD Control [nm]:	6.3	3.3	2.6	1.9	1.3	0.9
T_{OX} (equivalent) [nm]:	1.3-1.6	1.2	1.1	0.65	0.5 (UTB)	0.5 (MG)
I_{ON} (NMOS) [μA/μm]:	900	1110	1200	2050	2198	2713
I_{OFF} (NMOS) [μA/μm]:	0.01	0.05	0.2	0.28	0.29	0.11
Interconnect K_{EFF}:	-	3.1-3.6	2.7-3.0	2.5-2.8	2.1-2.4	1.9-2.2

data from the 2001, 2004, and 2005 editions of the ITRS

Semiconductor R&D Pipeline

Pre-competitive → Competitive

Directly-funded University Research

SEMATECH

~ 5-20 Years

imec

SC Company Internal R&D

0-5+ Years

Univ. Research Consortia: SRC, MARCO, NERC

~ 3-8 Years

Production Fabs

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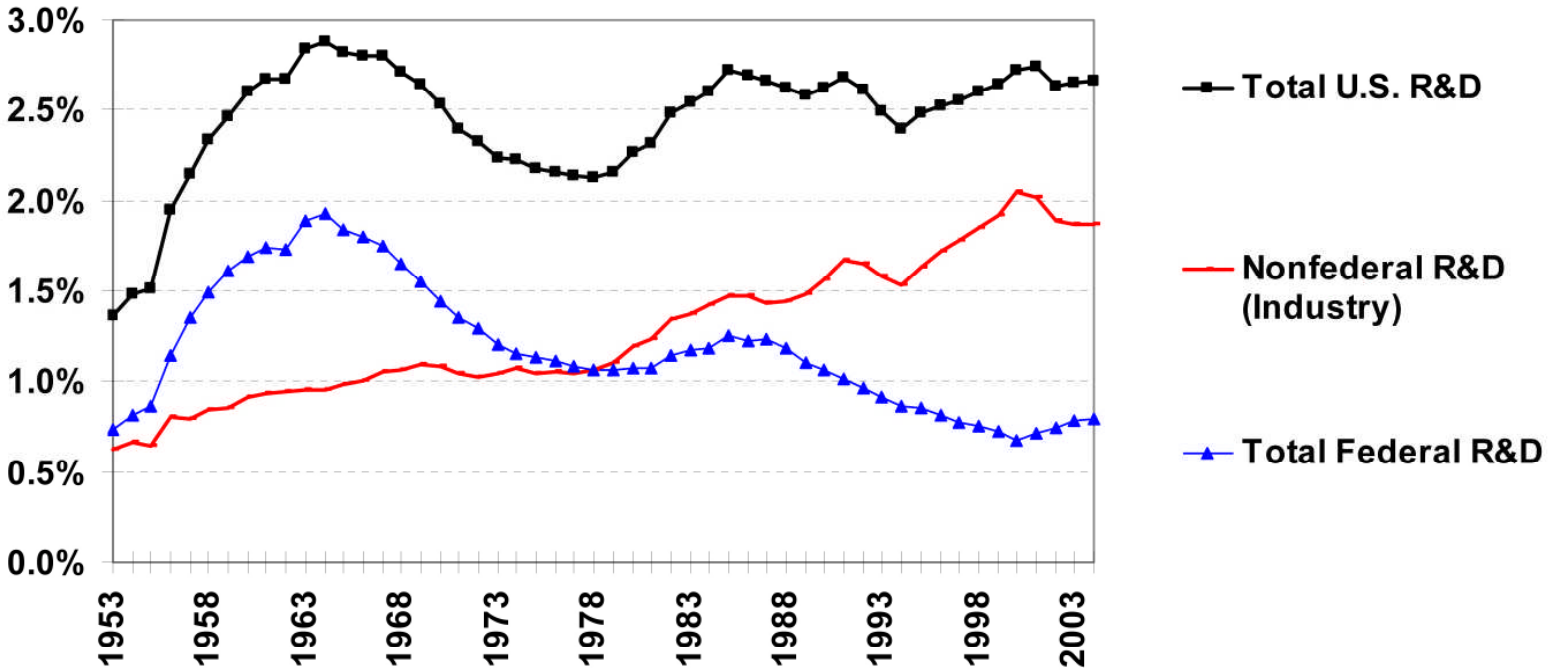
U.S. R&D as Percent of Gross Domestic Product

Total, Industrial, and Federal R&D - 1953-2004



Source: NSF, Division of Science Resources Statistics.
2004 data are projections. Includes defense and nondefense R&D.
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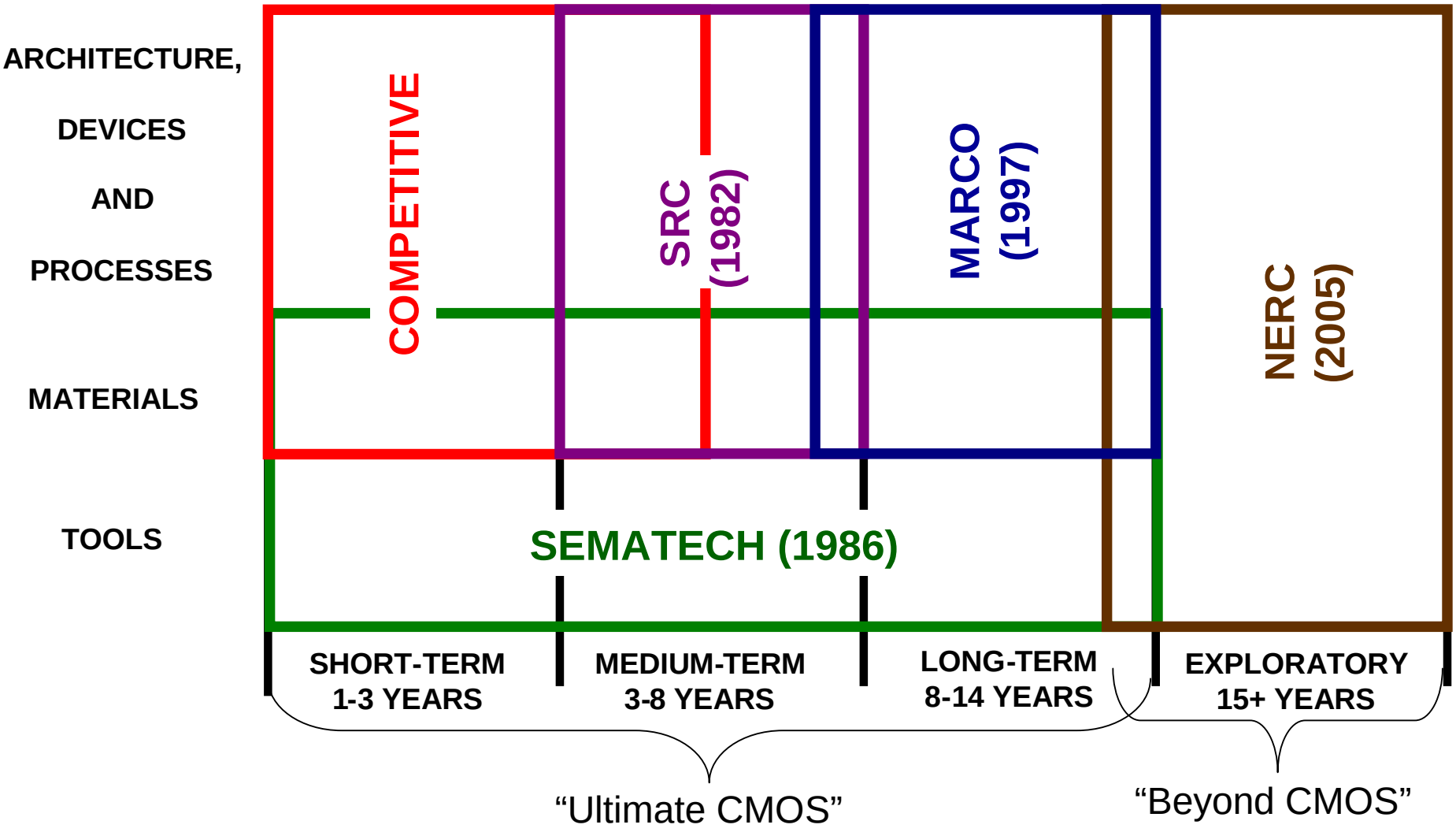
Industry R&D is now more focused on near-term, except for …

U.S. IC Consortia: *25 Years of Filling the SC R&D Pipeline with U.S. Graduates*



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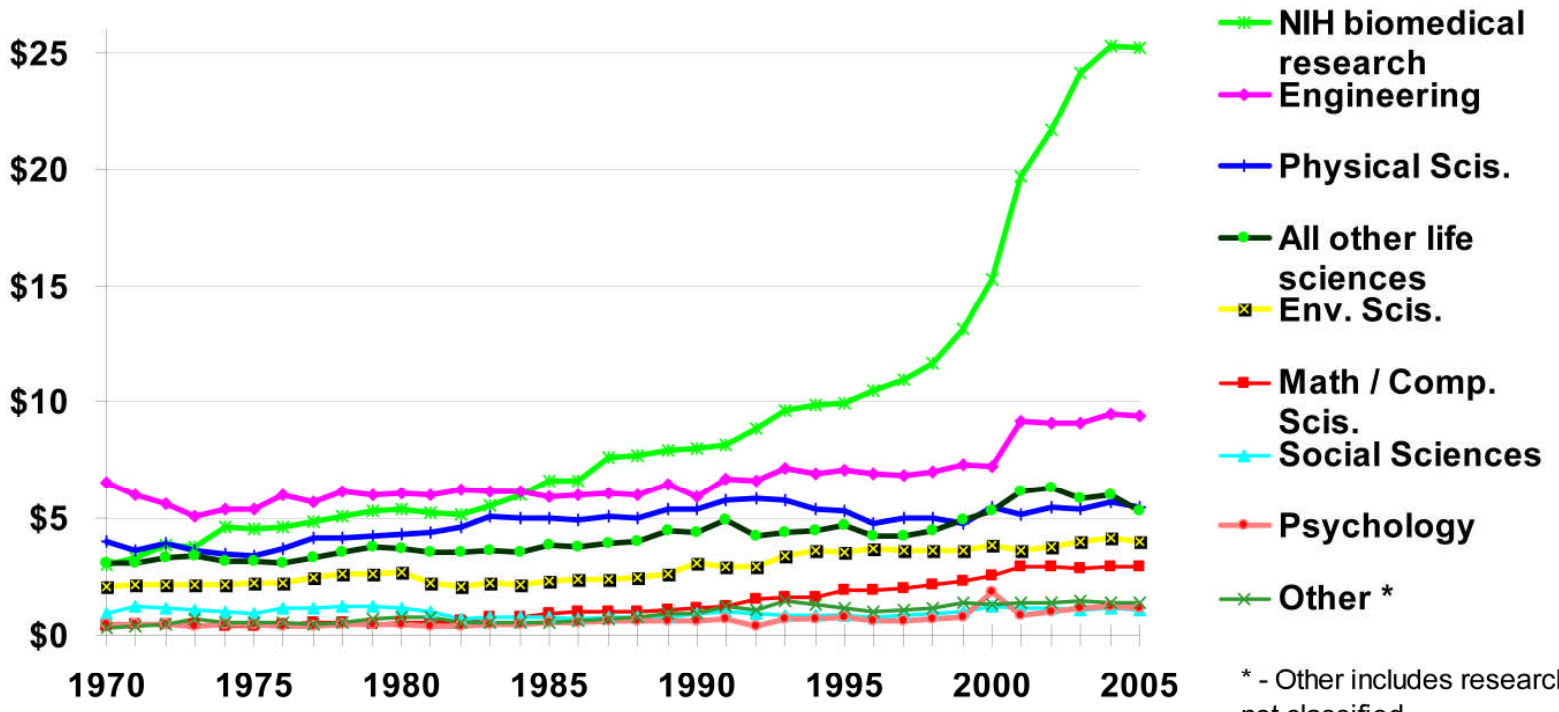
U.S. Semiconductor R&D Needs the World's "Best and Brightest"

- **The quests for "ultimate CMOS" & "beyond CMOS" are difficult & exciting technical/scientific challenges.**
- **The best university SC research and education is still in the U.S.**
- **We need to retain as many graduates as possible, especially with advanced degrees, to win the global innovation competition.**
- **The SIA strongly supports pending legislation which enhances H-1B/green-card opportunities for science and engineering graduates of U.S. schools.**

Trends in Federal Research by Discipline, FY 1970-2005

obligations in billions of constant FY 2006 dollars



* - Other includes research not classified (includes basic research and applied research; excludes development and R&D facilities)

Life sciences - split into NIH support for biomedical research and all other agencies' support for life sciences.

Source: National Science Foundation, *Federal Funds for Research and Development FY 2003, 2004, 2005,* 2006. FY 2004 and 2005 data are preliminary. Constant-dollar conversions based on OMB's GDP deflators.

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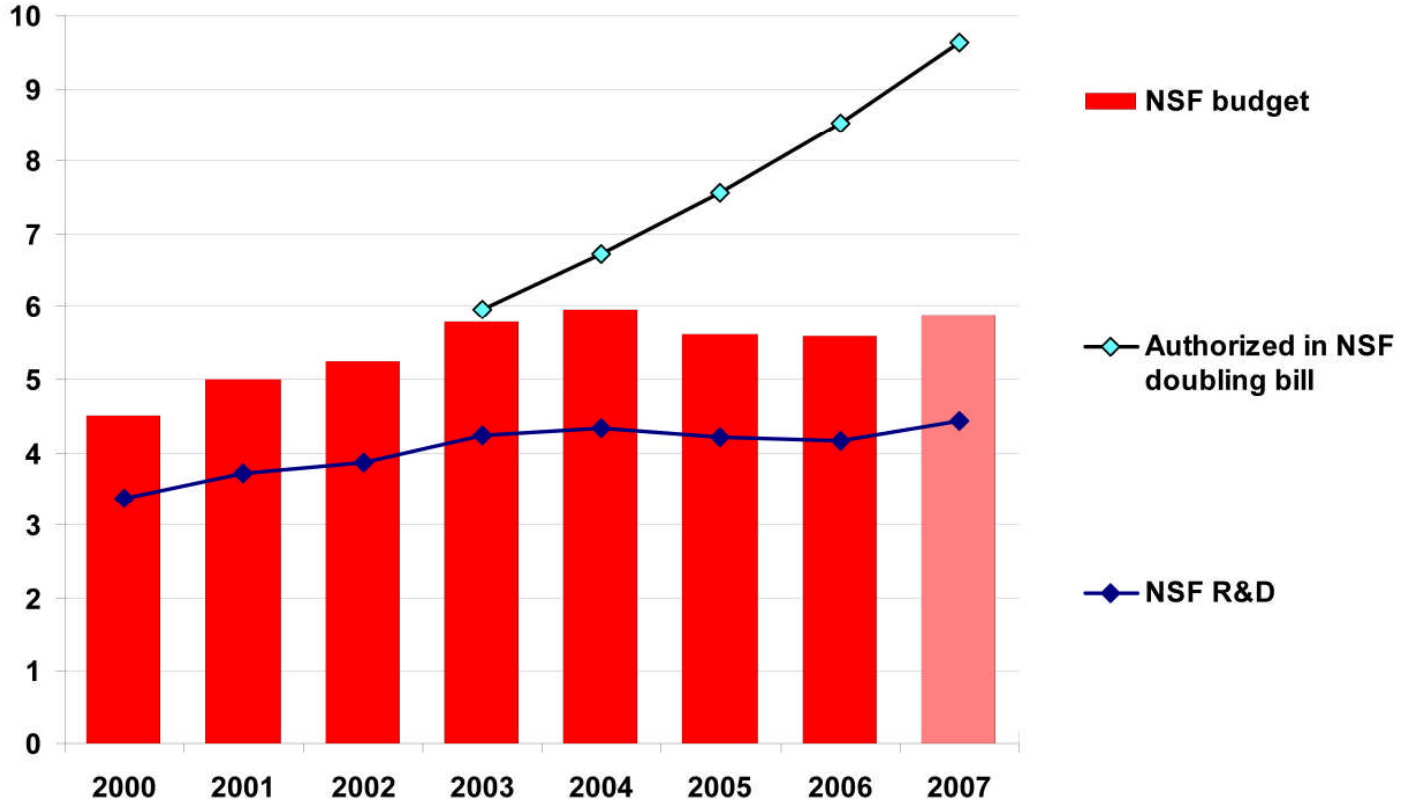
SC engineering research recently boosted by NNI, etc.

National Science Foundation Budget, FY 2000-2007

(budget authority in billions of constant FY 2006 dollars)



Source: National Science Foundation, Public Law 107-368, and latest AAAS estimates of FY 2007 budget. FY 2007 is budget request.
Authorized levels are authorizations in Public Law 107-368 (Dec. 2002).
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ACI is our next hope for "doubling" -- to provide more research and R&D workforce for the SC and other U.S. high-tech industry

Summary of Recommendations

Affecting Off-Shoring of SC Design, Mfg., & R&D

- **Increased federal funding of "exciting/innovative" university research in math, physical sciences, and engineering – e.g., via ACI budget doubling**
- **H-1B visas and green cards for math, physical science, and engineering graduates of U.S. universities**
- **Turn the proposed, realistic, rad-hard IC technology criteria into official ITAR regulations**
- **Permanent R&D tax credit**