Globalization of Science & Technology: 
Impacts on and Lessons Learned from the Semiconductor Industry

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VP for Innovative Partnerships
Semiconductor Research Corporation

GSTOC Committee
National Academies
February 13, 2013
**U.S. semiconductor companies:**

- Provide 250,000 direct US jobs; more than one million more that are indirect.
- Made $153 billion in sales in 2011; over half the worldwide market.
- Enable America’s $1.1 trillion electronics industry.
- Are one of the largest US exporters.

*SIA members represent 80% of US semiconductor production.*
Moore’s Law: # transistors/chip doubles every 24 months
1982: Best available storage technology was the IBM 3350

80Gb cost $9,000,000 in 1982 dollars

Each unit:
- 635 MB
- $70,000

126 IBM 3350’s = storage in 1 iPod

80Gb cost <$100 in 2012 dollars

Moore’s Law Enable Unforeseen Applications

2012

iPod(5G) 80GB
In 1982...

Aug 17—the first compact disc goes on sale

Oct 1—Sony launches the first compact disc player
In 1982...

Time magazine’s Man of the Year was... 

*The Computer*
But in 1982 the U.S. semiconductor industry saw threats on the horizon.
US semiconductor market share was dropping... Federal funding for academic research on silicon was declining...
The pipeline of talent was drying up.

![Semiconductor Market Share](image)
In 1982...

**Objectives:**
- Define relevant research directions
- Explore potentially important new technologies
- Generate a pool of experienced faculty & relevantly educated students

Erich Bloch  
Robert Noyce  
Jack Kilby
Essential SRC Features

- Industry-driven (originally US), consensus-based goals embodied in:
  - Moore’s Law
  - ITRS (International Technology Roadmap for Semiconductors)
- Focus on pre-competitive university research (>5 yr time horizon)
- Members have rights to resulting IP
- Involves the current industry experts (provide input/ feedback/ oversight, mentoring, and tech transfer)
- Managed by an independent entity (facilitates interactions among members and with universities & government agencies)
- Nimble and adaptable (does not fund “bricks & mortar”; ~1/3 of projects turn over annually)
- Accountable; value-driven; efficient; effective
- Attracts world-class researchers (faculty & students)
Semiconductor Research Corporation
A Family of Distinct, Related Program Entities

Global Research Collaboration
Ensuring vitality of current industry

Focus Center Research Program Phase VI
STARnet
Early research engagement of key long horizon semiconductor challenges

Nanoelectronics Research Initiative
Beyond CMOS – the next switch and associated architectures

Energy Research Initiative
Emphasis on efficient/clean energy generation, storage and distribution

Education Alliance
Attracting and educating the next generation of innovators and technology leaders

Each entity has a distinct set of member companies and Government partners.
For more information go to www.src.org

Updated January 2013
SRC created an industry-guided global university research ecosystem

Since 1982...
- Over $1.6B invested by SRC participants
- 10,000+ students
- 2,000+ faculty members
- 250+ universities worldwide

In 2012...
- 1500 students
- 500 faculty
- 120 universities worldwide

20X increase over 1982
SRC’s Worldwide Reach

86 projects in 26 different countries outside the US since 2000
SRC Impact: Expanded University Research Related to Semiconductors

The SRC community publishes 20% of the world’s research on silicon; 7X more than AMD, IBM, Intel, TI, GLOBALFOUNDRIES, and Freescale combined.

- More than 200 SRC funded research publications have received >100 citations.
- Nearly two thirds of these have >15% citation by industry authored publications.
RF CMOS Technology Scaling in High-k/Metal Gate Era for RF SoC (System-on-Chip) Applications


Logic Technology Development (LTD), Intel Corporation, Hillsboro, Oregon, USA

*Integrated Platform Research/Radio Integration Research (RIR), Intel Labs, Intel Corporation, Hillsboro, Oregon, USA

Contact: e-mail chia-hong.jan@intel.com

8 SRC Graduated Students
7 Liaisons
4 TAB Advisors
54.5% SRC Participants
SRC Graduates Stay in the Field

Information reflects over 4200 graduates with known first hire data
SRC Creates Value Through Partnerships: Leveraging Strengths of Each Sector

- Maximizes technological progress
- Leverages investments
- Utilizes the strengths of each sector
- Expands and replenishes the professional community

Strategic Perspective, National Needs, Credibility, FUNDING

Creativity, Faculty Expertise, Student Resources

Tactical Perspective, “Can-Do” Attitude, FUNDING

Government

Universities

Industry
SRC is a Win-Win-Win-Win-Win

**Benefits to academic researchers**

- Insight on industry needs; opportunity to address “real world”, albeit long-term problems
- Input and feedback from industry at periodic reviews and via Liaisons
- E-seminars and e-workshops facilitate near real-time sharing of research results and tech transfer
- Interactions and opportunities for personnel exchanges among universities and industry
SRC is a Win-Win-Win-Win-Win

**Benefits to students**

- Understand the motivation for the research is based on real world problems
- Industry liaisons & mentors engage with students
- Participation in TECHCON, SRC’s annual technical conference at which students present research and network with industry representatives.
- Opportunities for student internships, co-ops and employment at SRC member companies.
SRC is a Win-Win-Win-Win-Win

**Benefits to Government**
- Managers get insight on industry needs
- Facilitates technology transfer
- Leverages research investment (various mechanisms used)
- Consortium provides broad industry engagement

**Benefits to industry**
- Leveraged research investment
- Early access to research
- Access to students
- Interaction with competitors/customers/suppliers
Consortia Support Competitiveness

Semiconductor Industry Market Share

- **US**
- **Japan**
- **ROW**

Federal funding for SEMATECH ended

GLOBALIZATION

Source: SIA
Globalization...

External factors
• Location of customers/markets
• Location of universities/skilled workforce
• Location of supply chain components

Internal decisions
• Location of manufacturing
• Location of design
• Location of R&D
Semiconductor Design & Manufacture

3rd Party IP

Functional Design (Architectural to Circuit)

Physical Design & Verification

Wafer Fabrication

Packaging Final Test

Shipping / Distribution

System integration, final product
Semiconductor Production is a Global Process
Value of High Tech Manufacturing By Region (percent)
Global S&T Workforce Education: China R&D and Education are Growing Faster

Source: NSF, S&E Indicators (2012)

Source: NSF, S&E Indicators (2010)
Globalization of Semiconductor Research: 2012 Winners of IEEE ICCAD Design Contest

Challenge #1
- **1st**: Xing Wei, Yi Diao & Tak-Kei Lam – The Chinese University of Hong Kong
- **2nd**: Kuang-Hung Chang, Hui-Ling Ting & Hui-Min Yang – National Tsing Hua University
- **3rd**: Ling-Ya Ni, Chien-Yu Lai, Kuan-Chang Wang & Chen-Kai Chu – National Taiwan University

Challenge #2
- **1st**: Myung-Chul Kim & Jin Hu – University of Michigan
- **2nd**: Xu He, Tao Huang, Wing-Kai Chow & Ka-Chun Lam – The Chinese University of Hong Kong
- **3rd**: Yi-Fang Chen and Chau-Chin Huang – National Taiwan University

Challenge #3
- **1st**: Geng-He Lin & Yen-Ting Yu – National Chiao Tung University
- **2nd**: Bei Yu & Jhih-Rong Gao – The University of Texas at Austin
- **3rd**: Chi-Yuan Liu, Sheng-Yen Chen & Iou-Jen Liu – National Taiwan University
Mentor Graphics

Mentor Graphics® is a leader in electronic design automation software. We enable companies to develop better electronic products faster and more cost-effectively. Our innovative products and solutions help engineers conquer design challenges in the increasingly complex worlds of board and chip design.

Quick Facts

Publicly held (NASDAQ: MENT)

Founded 1981, headquartered in Wilsonville, Oregon

Revenue in last reported 12 months: about $1,015 million

Over 70 offices worldwide →

Careers with Mentor

Apply your individual talents to the most complex hardware and software design problems in the world.

Why Mentor? →

Benefits →

Search for a Job Opening →

News and Press

MORE NEWS →

Mentor Graphics Signs Electro Source, Inc. as a Distributor for Canada

WILSONVILLE, Ore., February 7, 2013 — Mentor Graphics Corporation (NASDAQ: MENT) today announced it has signed Electro Source, Inc. (ESI), an established leader in delivering hardware... View News Article →

Mentor Graphics Announces New FloEFD Solution with Parametric (P)Fluid Modeling for Electromagnetic (EM) Applications
Job Openings

Please select your location on the map below to find regional job openings.

North America

Europe, Middle East, Africa

Asia/Pacific Rim
12 labs. 6 continents.
Semiconductor R&D Spending/Sales Comparison (Intel vs. Samsung vs. TSMC)

Source: Company reports, IC Insights
Globalization of Semiconductors and Research

- Individual companies have international corporate research activities (e.g. Intel, IBM)
- SEMATECH added international subsidiary in 1995
- ITRS became international in 1998
- SRC became global in 2000
- Non-US R&D centers
Globalization of SRC Research: Looking Ahead

• SRC helps members to build capacity worldwide

• Developing an academic center of excellence in Abu Dhabi in partnership with ATIC and GLOBALFOUNDRIES

• Approached by Skolkovo Institute of Science and Technology

★ SRC manages world-class research that addresses members/partners needs.
Other Trends in S&T Globalization Impacting DoD and US Competitiveness

• MOOC’s
• Wireless/mobile + cloud-based services
• Advances that lower barriers to entry
  – E.g., additive manufacturing
Some thoughts on how to maintain DoD S&T competitiveness

• Invest in people; encourage participation and leadership in professional organizations

• Provide opportunities for interaction among DoD S&E’s, academia, and industry—worldwide
  – A Liaison program for DoD S&E’s to interact with DoD supported students and researchers
  – On-line communities for sharing research info
<table>
<thead>
<tr>
<th>Desirable characteristic</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose, scope, and methodology</td>
<td>Addresses why the strategy was produced, the scope of its coverage, and the process by which it was developed.</td>
</tr>
<tr>
<td>Problem definition and risk assessment</td>
<td>Addresses the particular national problems and threats the strategy is directed toward.</td>
</tr>
<tr>
<td>Goals, subordinate objectives, activities, and performance measures</td>
<td>Addresses what the strategy is trying to achieve; steps to achieve those results; as well as the priorities, milestones, and performance measures to gauge results.</td>
</tr>
<tr>
<td>Resources, investments, and risk management</td>
<td>Addresses what the strategy will cost, the sources and types of resources and investments needed, and where resources and investments should be targeted by balancing risk reductions and costs.</td>
</tr>
<tr>
<td>Organizational roles, responsibilities, and coordination</td>
<td>Addresses who will be implementing the strategy, what their roles will be compared to others, and mechanisms for them to coordinate their efforts.</td>
</tr>
<tr>
<td>Integration and implementation</td>
<td>Addresses how a national strategy relates to other strategies’ goals, objectives, and activities—and to subordinate levels of government and their plans to implement the strategy.</td>
</tr>
</tbody>
</table>

Current Member Companies

IBM
AMD
Intel
Texas Instruments
Mentor Graphics
ATIC
Micron
Applied Materials
United Technologies
Nexans
Raytheon
First Solar
Freescale
NEC
ABB
Bosch
GLOBALFOUNDRIES
Criteria for Successful Roadmapping*

1. Restricted scope and figures of merit
2. Consensus on trends/targets (e.g. Moore’s Law)
3. Sufficient market assuring wide acceptance
4. Willingness to share information
5. Existence of a community of participants

* For details see SEMATECH White Paper “More than Moore'.
Lessons for Creating a Successful Consortium

✓ Identify the key problem(s)

✓ Agree upon the vision and mission

✓ Get leadership support, including resources, from a critical mass of companies

✓ Create a roadmap

✓ Agree upon (minimum) IP rights

✓ Addressing long-term challenges together is easier.
Semiconductor Demand Drivers: 2011 Growth

**Smartphone Shipments**
+63% (units)
Smartphone shipments overtook PC shipments in 2011

**PC Shipments**
+0.5% (Units)
Consumer shift away from traditional concept storage devices

**Tablets**
+254% (Units)
2010: 19.4M Units
2011: 68.7M Units

**LCD TV**
+7% (Units)
10% of LCD TV panels were 3D Capable in 2011

2011 Total Global Semiconductor Market
$300B

Sources: WSTS/Gartner/Canalys/IDC/DisplaySearch
Note: Military is <1% and is included in Industrial.
Lessons for Creating a Successful Consortium

✓ Management by an independent third party facilitates interactions among members and with universities and government agencies.

✓ Allow everyone to have a voice.

✓ Provide value.

✓ It helps if industry organizes itself and then partners with government.

✓ Be patient.
<table>
<thead>
<tr>
<th>Est. Research Start</th>
<th>Research/Influential Article</th>
<th>Researchers</th>
<th># of citations</th>
<th>Commercial Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>By Industry</td>
</tr>
<tr>
<td>1983</td>
<td>“Graph-based algorithms for Boolean function manipulation”, <em>IEEE Trans on Comput</em> 35 (1986) 677</td>
<td>Bryant CMU</td>
<td>1754</td>
<td>321 (18%)</td>
</tr>
<tr>
<td>1994</td>
<td>“Multilevel interconnections for ULSI and GSI era”, <em>Mat Sci &amp; Engn R-Reports</em> 19 (1997) 87</td>
<td>Murarka, RPI</td>
<td>258</td>
<td>54 (21%)</td>
</tr>
<tr>
<td>2000</td>
<td>“Recent advances on electromigration in very-large-scale-integration of interconnects”, <em>JAP</em> 94 (2003) 5451</td>
<td>Tu, UCLA</td>
<td>369</td>
<td>99 (27%)</td>
</tr>
<tr>
<td>1986</td>
<td>“Point-Defects and Dopant Diffusion in Silicon”, <em>Rev Mod Phys</em> 61 (1989) 289</td>
<td>Fahey, Plummer Stanford U</td>
<td>847</td>
<td>261 (31%)</td>
</tr>
<tr>
<td>2000</td>
<td>“Tin-lead (SnPb) solder reaction in flip chip technology”, <em>Mat Sci &amp; Engn R-Reports</em> 34 (2001) 1</td>
<td>Tu, Zeng, UCLA</td>
<td>293</td>
<td>45 (15%)</td>
</tr>
</tbody>
</table>
Citizenship/status: 47% PRTW; 53% student visa (37% non-export controlled, 16% export controlled)
SRC Undergraduate Students 2009-2013 Demographics

- **597** undergraduates at 14 universities
- **41%** Female and **59%** Male undergraduates
- **3.5** Average GPA
- **97%** Retained in STEM
- **47%** progress to graduate school and increasing
- **305** Faculty involved with undergraduate research