DECADAL PLAN FOR SEMICONDUCTORS
A VITALLY IMPORTANT INDUSTRY

1/2
U.S. MANUFACTURERS’ PRODUCTION IS DONE DOMESTICALLY IN MORE THAN 70 MAJOR FABS ACROSS 18 STATES

#5
EXPORT FROM THE U.S. AFTER AIRCRAFT, REFINED OIL, CRUDE OIL, AND AUTOMOBILES

1/5
REVENUE INVESTED IN R&D, AMONG THE HIGHEST IN U.S.

250 THOUSAND
DIRECT JOBS, AND OVER 1 MILLION ADDITIONAL SUPPORTED JOBS IN THE U.S.

$193 BILLION
IN SALES, ACCOUNTING FOR ABOUT HALF OF GLOBAL MARKET SHARE
AN R&D INTENSIVE INDUSTRY

R&D EXPENDITURES AS A PERCENT OF SALES (2019)

**BY INDUSTRY**

- Pharmaceuticals & Biotechnology: 20.8%
- Semiconductors: 16.4%
- Software & Computer Services: 14.3%
- Media: 8.9%
- Technology Hardware & Equipment: 6.9%
- Mobile Telecommunications: 6.5%
- Financial Services: 5.6%

**BY COUNTRY**

- United States: 16.4%
- Europe: 15.3%
- Taiwan: 10.3%
- Japan: 8.4%
- China: 8.3%
- Korea: 7.7%
- Rest of World: 5.6%

Source: The 2019 EU Industrial R&D Investment Scoreboard.
INVESTMENT IN RESEARCH

GOVERNMENT R&D (SHARE OF TOTAL)

Source: OECD Science Indicators, April 2020

ACTION NEEDED

TRIPLE INVESTMENT IN SEMICONDUCTOR - SPECIFIC RESEARCH

DOUBLE INVESTMENT IN KEY FIELDS (e.g. materials science, computer science, applied mathematics)
FEDERAL SEMICONDUCTOR R&D: SUCCESS STORIES
40 YEARS OF POLICY MILESTONES

- 1981: R&D Tax Credit
- 1982: Semiconductor Research Corporation
- 1984: Semiconductor Chip Protection Act
- 1989: Semiconductor Chip Protection Act
- 1996: World Semiconductor Council
- 1997: Information Technology Agreement Eliminates Duties on IT Products
- 2000: International Technology Roadmap for Semiconductors
- 2007: America COMPETES Act
- 2015: R&D Tax Credit Made Permanent
- 2016: ITA Expansion Eliminates Even More Duties on IT Products
- 2017: Corporate Tax Reform
- 2018: Department of Defense Electronics Resurgence Initiative
SIA-SRC Partnership and the Decadal Plan for Semiconductors

Todd Younkin
President and CEO
Todd.Younkin@src.org
Who We Are: **Consortium Excellence Since 1982**

**SRC**

- Founded to retain and grow market share by **driving innovation** that overcomes threats
- Creates and manages **collaborations** between industry, gov’t, and academics
- Researches critical technology options focusing on fast fail and **tech transfer to industry**

- $2.2B+ in research funding since 1982
- Over 2,000 research projects globally
- 14,000+ SRC-sponsored students
- 700+ patents issued

**Disruptive Technologies**

- MRAM
- Cu Interconnects
- High K Dielectrics
- FinFET
- Nanosheets for GAA transistors
SRC by the Numbers

Vast network focused on research and workforce development for the future of the semiconductor industry

21 Companies
100+ Universities
800+ Industry Liaisons
2,000+ Researchers
15,000+ Alumni

3 Government Agencies
- DARPA
- NSF
- NIST

Public
How it Works: We Manage Collaborative Research

Members
- Company 1
- Company 2
- Company w
- Gov't 1

Researchers
- Professor 1
- Professor 2
- Professor 3
- Professor 4
- Center 1
- Center 2
- Professor 5
- Professor 6
- Professor x
- Professor 7
- Professor 8
- Professor y
- Professor z

Pool members’ direction and funds

Return tech, IP rights, students for hire
**Roadmapping: Forecast for Technology Requirements**

“SRC 1.0” = 2D Scaling

- **1984**: SRC 10y goals
- **1987**: SEMATECH
- **1990**: Microtech 2000
- **1992**: SIA/SRC NTRS
- **1998**: National Technology Roadmap for semiconductors

- **1999**: SRC-MARCO
- **2005**: SRC-NRI

- **2017**: DARPA-ERI
- **2019**: SIA Blueprint

**2020 Decadal Plan**

- 3x increase of federal investments in semiconductors

**Public**

“SRC 2.0”
Generational Opportunities in Hyperscaled Computing, AI, 6G, and Quantum

- **Sustainable** computing and communications, including data movement and the memory wall
- **Industry 4.0** – robotics, automation, and advanced manufacturing
- Rise of 5G+, **smart cities**, autonomous vehicles, V2V
- Human Machine Interface (HMI) including AR/VR
- Personalized, targeted **healthcare** and **therapies**
- **Quantum** computing, information, and positioning systems
That Future Rests on Continued, Cost-Effective Breakthroughs in Hardware

“SRC 2.0”

- Materials and advances in 3D monolithic and heterogeneous integration
- Research that builds upon the rapid rise of 2.5-3D-SoIC and SiP standards, including photonics
- Systems that meet the needs of extreme environments, including cryo, auto, and space
- Architectures that address the compute and memory divide in all domains, including bio-inspired
- Accelerated and automated design and validation tools for analog, mixed signal, and digital
- Hardware and software security that keeps members in front of competitors
- Programming languages that easily scale, help semi scale, and create market opportunities
Decadal Plan **Timeline:** 2019 - 2020

- **Jan 2019:** Executive committee formed
- **Feb 2019:** Development funds secured
- **Mar 2019:** Decadal Plan concept presented to the SIA CTO group
- **Apr 2019:** Workshop on New Trajectories for Computing
- **Oct 2019:** Workshop on New Trajectories for Analog Electronics
- **Dec 2019:** Workshop on New Trajectories for Communication
- **Feb 2020:** Workshop on ICT Security
- **Aug 2020:** Workshop on Trajectories for Memory and Storage
- **Oct 2020:** Interim report released
- **Dec 2020:** Full report release

**Weekly full committee teleconferences**
- **Fundamental studies**

**Planning topical workshops**
- **Jan 2019**:
- **Feb 2019**:
- **Mar 2019**:
- **Apr 2019**:
- **Oct 2019**:
- **Dec 2019**:
- **Feb 2020**:
- **Aug 2020**:
- **Oct 2020**:
- **Dec 2020**:

**Interim Report** Published Oct-15, ’20
Decadal Plan for Semiconductors - 5 Seismic Shifts

https://www.src.org/about/decadal-plan/

- **Fundamental breakthroughs in analog hardware** are required to generate smarter world-machine interfaces that can sense, perceive and reason.

- The growth of memory demands will outstrip global silicon supply presenting opportunities for **radically new memory and storage solutions**.

- Always available communication requires new research directions that address the **imbalance of communication capacity vs. data generation rates**.

- Breakthroughs in hardware research are needed to address **emerging security challenges** in highly interconnected systems and AI.

- Ever rising energy demands for computing vs. global energy production is creating new risk, and new computing paradigms offer opportunities with **dramatically improved energy efficiency**.

**Full Report Will Serve As A Guide Towards 2030 and Beyond**
Thank You

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Decadal Plan for Semiconductors
2030 ICT research goals

Victor Zhirnov
December 2, 2020
Information along with Energy has been the Social-Economic Growth Engine of civilization since its very beginning.

- BC 600: \( \approx 10^{10} \) bit, \( \approx 10 \) bit per capita
- BC 300: \( \approx 10^{11} \) bit, \( \approx 1000 \) bit per capita
- AD 1000: \( \approx 10^{13} \) bit, \( \approx 10^5 \) bit per capita
- 1700: \( \approx 10^{16} \) bit, \( \approx 10^7 \) bit per capita

2016: \( 10^{23} \) bit, \( 10^{13} \) bit per capita
The current hardware-software (HW-SW) paradigm driving digital technologies is reaching its limits and must evolve.

Two Simultaneous Seismic Shifts

Energy

Data
Seismic shifts in information and communication technologies:

- Compute energy vs. global energy production
- Need for smarter analog world-machine interfaces
- The growth of memory and storage demands
- Communication capacity vs. data generation imbalance
- Emerging security challenges in both highly interconnected systems and AI
MPU operations vs. binary transitions

\[ \mu = f(\beta) = k \beta^p \]

\[ k = 0.1, \quad p = 0.64 \approx \frac{2}{3} \]

\[ \beta = \alpha N_{tr} \cdot f \]

\[ P = \beta E_{bit} \]
Computations per Year

Total energy of computing a need to change ‘computational trajectory’

(based on research by Hilbert and Lopez: M. Hilbert and P. Lopez, “The World’s Technological Capacity to Store, Communicate, and Compute Information”, Science 332 (2011) 60-65)

\[ MIPS = k \left( \text{BITS} \right)^p \]

Existing trajectory: \( p \approx \frac{3}{2} \)
- Current: \( 10^{-16} \) J/bit
- Target: \( 10^{-18} \) J/bit
- Landauer limit: \( 10^{-21} \) J/bit

New trajectory: \( p \approx 1 \)

Quantum computing
Neuromorphic
AI engines
Grand Goal #1: Analog-to-information compression/reduction with a practical compression/reduction ratio of $10^5:1$ driving to practical use of information versus “data” more comparable to the human brain.
Dramatic global Memory and Storage requirement increase

Grand Goal #2: Discover storage technologies with >100x storage density capability and new storage systems that can leverage these new technologies
Gap between communication capacity and data capacity

Example: while currently it is possible to transmit all world’s stored data in less than one year, in 2040 it is predicted to require at least 20 years.

Grand Goal #3a: Advance communication technologies to enable moving around all stored data of 100-1000 zettabyte/year at the peak rate of 1Tbps@<0.1nJ/bit. Grand Goal #3b: Develop intelligent and agile networks that effectively utilize bandwidth to maximize network capacity.

Invest $700M annually in new trajectories for communication.
The systems of the future are actually systems of systems with limitless possibilities for communication and signaling. Devices have permeated the physical world, and thus trust in these devices becomes a matter of safety.

Grand Goal #4: Develop security and privacy advances that keep pace with technology, new threats, and new use cases, for example, trustworthy and safe autonomous and intelligent systems, secure future hardware platforms, and emerging postquantum and distributed cryptographic algorithms.

Invest $600M annually in new trajectories for communication. Selected priority research themes are outlined below.

* Digital trust is beyond security – it is about confidence level in digital security integrity and accountability.
Beginning of new semiconductor era

2019
2020
2021

2020 Decadal Plan

Semiconductor Technology Leadership Initiative

New Private-Public Partnership Initiatives

Analog $600M
Data Storage $750M
Communication $700M
Security $600M
Computation $750M

3x increase of federal investments in semiconductors

(SIA Blueprint)
Decadal Plan Timeline: 2020 - 2030

Full report released

Interim report released


Topical workshops completed

We are here

Circulate the Decadal Plan within Government

Executive Committee leads the execution tasks of the Decadal Plan

Monitor progress and update/prioritize the research needs

Refresh the Decadal Plan on a ~2 - 3 year cadence

Advisory Boards for forthcoming initiatives

Detailing specific tasks

Acquisition of the 1st cycle of the Government Funding for the Decadal Plan driven R & D

Foundations for the New Semiconductor Era laid

Fund innovations through increased R&D $$$

5G+/ 6G
AI++
Quantum Computing

1st rev 2nd rev 3rd rev Final refresh

1st rev 2nd rev 3rd rev Final refresh
Panel: Decadal Plan for Semiconductors

Jim Ang – (Moderator)
Chief Scientist for Computing, Physical & Computational Sciences Directorate
Pacific Northwest National Laboratory

Gilroy Vandentop
Director of Corporate University Research
Intel

Jim Wieser
Director of University Research and Technology
Texas Instruments

Sean Eilert
Fellow, Emerging Memory PathFinding Group
Micron Technology

Ramesh Chauhan
Principal Engineer, Corporate Research & Development Division
Qualcomm Technology

Debra Delise
General Manager, Security Center of Excellence
Analog Devices
Changing the Compute Energy Trajectory

“The Problem and Opportunity”

Many device options exist and new approaches are needed

- Why are we stuck at $p=2/3$?
- Can compute in memory change this?
- Can a new AI class change this?
- Can new device options change this?
- How will QC impact this?
- Seems we need all of the above...

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Turing  →  Shannon  →  Approximate computing

Shannon framework for computation

High-dimensional representation

AI processors: “Cambrian Explosion” needs to happen!

Decouple the compute power from energy consumption in Quantum Computers
New Trajectories for Analog Electronics

“Interface to the Real World”

- Sensing
- Bio-Inspired Model
- Energy Savings
  - Communications
  - Computing/Processing
  - Power Management
- Holistic Co-Design

Priority Research Themes

- Analog-to-Digital
- Analog-to-Information
- Sensing to Action

Goal: 100,000:1 Data Reduction

Sensing to Action goal will not be possible without integrated system solutions with significant increase in design methods and productivity.

- Trainable neuromorphic signal converters
- Analog Bioinspired Machine Learning
- THz Regime Analog
- Analog Development Methodology
New Trajectories for Memory and Storage

Heterogeneous Computing Brings New Memory Requirements

- Reduced data movement enables bandwidth & energy improvement
- 3D integration & Low temperature memory processes enable improved logic
- Energy-efficient near-data computing

Bandwidth for GPU & AI accelerators in Mobile applications

Persistence & low power for edge applications

Bandwidth and capacity for domain specific datacenter

Near-data computing opportunity

Near-data computing framework is a key enabler for compute bandwidth scaling and energy savings

HBM
8GB

HBM
8GB

DRAM
-100GB

3DXP™ 16GB Persistent

3DXP™ Subsystem
-1TB Persistent

NAND Die 100GB Persistent

NAND SSD 1-16TB Persistent

Bandwidth

1TB/s

100GB/s

10GB/s

1GB/s

10ns 100ns 1us 10us 100us 1ms

Latency
The intelligent wireless edge

On-device AI
Augmented by edge cloud
Emerging Security Challenges

**Ubiquitous Sensing & Connectivity**

> 2.5 Quintillion Bytes of data created everyday

- System/Platform Security
- Data Protection
- Privacy
- Trusted Decision Making

**Priority Research Themes**

Breakthroughs in Hardware Research needed to achieve security & privacy of complex systems

GOAL: Unlock the Opportunity through Security

- Trusted Artificial Intelligence Systems
- Security & Privacy of Heterogeneous Hardware Platforms
- Emerging Cryptography
- Securing Edge -> Cloud & Distributed Processing
Overarching Panel Questions

• How will research impact future electronics solutions across many applications?
• What do you see as key semiconductor electronics/technology gaps for future applications?
• What fundamentally needs to change in approach for future semiconductor research and technology?
• What is needed from the semiconductor perspective to address the important area of Energy/Power?
• Do we foresee any specific needs regarding resources to carry semiconductor hardware (& software) towards addressing future application needs?