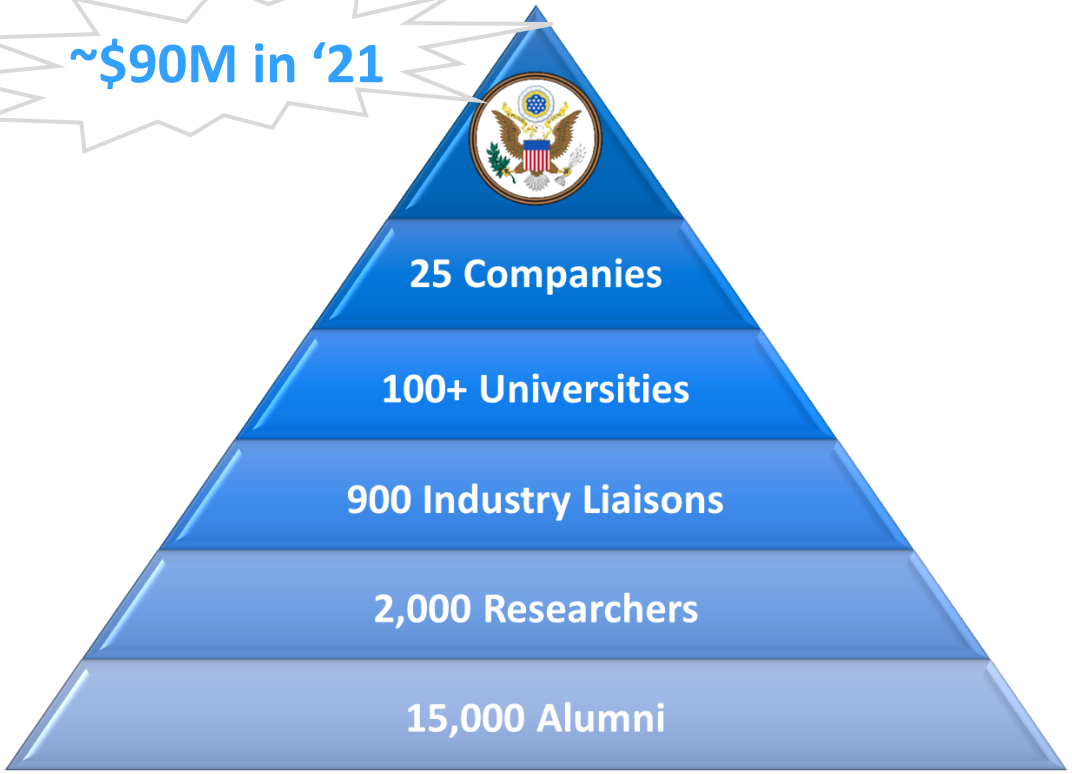
Semiconductor Research Corporation

The Semiconductor Industry's Heyday - Is it Behind or Ahead?

Todd Younkin
President and CEO
Todd.Younkin@src.org

Premier Microelectronics Consortium Since 1982

~$90M in ‘21



Private Sector and Interagency, Participation and Governance

DARPA NSF NIST

AMD ANALOG DEVICES APPLIED MATERIALS arm ASM INTERNATIONAL

Chemonics EMD PERFORMANCE MATERIALS GlobalFoundries IBM intel

LOCKHEED MARTIN MEDIATEK Micron MUBADALA

NORTHROP GRUMMAN NXP QUALCOMM Raytheon Technologies SAMSUNG

SIEMENS SK hynix TEL TEXAS INSTRUMENTS tsmc Veeco

SRC is a trusted advisor with a vast network, community, and shared dedication to research, prototyping, and workforce training in advanced semiconductor technologies

The Future is Bright

- I started at Intel in 2001, excited about nanotechnology and Intel's race to the atomic length scale. **It did not disappoint.**
- Recently, the talent pipeline has started to dry up, significantly. The student population is not receptive to the "2D scaling forever" story. **That narrative is not finding a way into their hearts and minds!**
- Together, we must seek a new narrative. One that helps students realize we have hard yet interesting problems that **can't be solved without them.**
- All can see the generational opportunities in hyperscaled computing, artificial intelligence, 5G+, autonomous vehicles, and quantum. We know these emerging frontiers will **change the world around us!**
- **Yet, collectively, we must apply disciplined imagination.** Microelectronics is not static! The future we imagine rests on continued, cost-effective, and innovative **breakthroughs in hardware**. Materials, integration, packaging, design, architecture, and security are all critical elements for success.

There is a bright future. Fascinating opportunities for the next 20 - 30 years, the kind you can build a career on as a young scientist or engineer.

Oldsmobile Was the Pinnacle of Innovation !?!

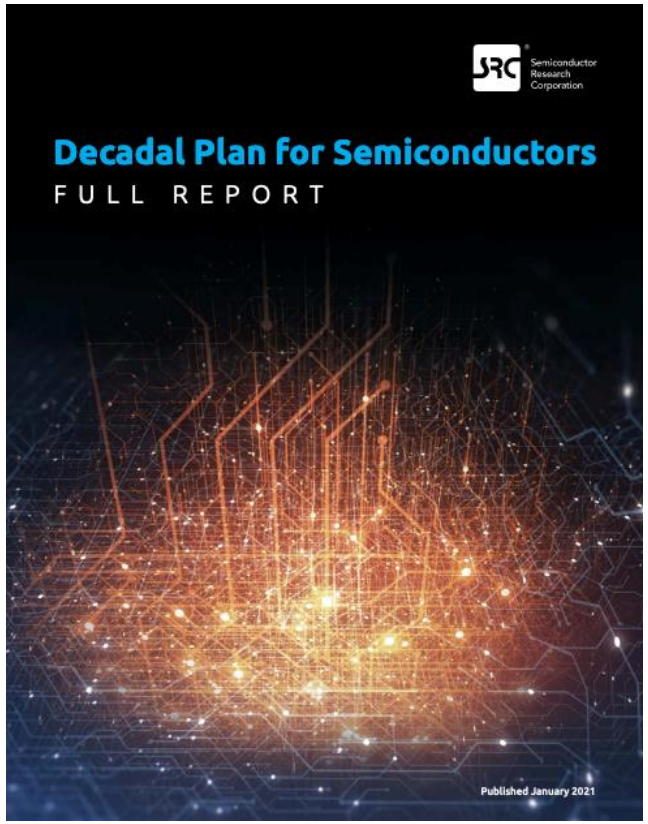
1981: Oldsmobile Cutlass – 454,188 units sold

2020: Ford F-Series - 787,422 units sold

Materials, Manufacturing, Safety (incl. ADAS), Automation, Hybrid Engine, Design, Reliability, Supply Chain, etc.

Five “Seismic Shift” Research Priorities

That Will Define The Future of Semiconductors and ICT



The ICT opportunities of tomorrow are simply unachievable with current hardware technologies.

A crisis is at hand, and the current paradigm must shift to create new value propositions with semiconductor technologies as the key driver.

- Smart Sensing — **The Analog Data Deluge**
- Memory & Storage — **The Growth of Memory and Storage Demands**
- Communication — **Communication Capacity vs. Data Generation**
- Security — **ICT Security Challenges**
- Energy Efficiency — **Compute Energy vs. Global Energy Production**

Our Decadal Plan for Semiconductors provides 5 “Loonshots”[1] with clear, measurable goals for 2030 and beyond. We will work with our community to have it inform and organize our investments, progress, and scientific debate.

[1]Highly recommended reading = *Loonshots: How to Nurture the Crazy Ideas That Win Wars, Cure Diseases, and Transform Industries*, Safi Bahcall, March 2019

Overarching Seismic Shift Goals of Decadal Plan

Annual Investment Required		
+$600M	 Smart Sensing	1. Fundamental **breakthroughs in analog hardware** are required to generate smarter world-machine interfaces that can sense, perceive, and reason. Pursue analog-to-information compression/reduction with a **practical compression/reduction ratio of 10^5:1** for practical use of information more analogous to the human brain.
+$750M	 Memory & Storage	
+$700M	 Communication	
+$600M	 Security	
+$750M	 Energy Efficiency	

Overarching Seismic Shift Goals of Decadal Plan

Annual Investment Required		
+$600M	Smart Sensing	1. Fundamental breakthroughs in analog hardware are required to generate smarter world-machine interfaces that can sense, perceive, and reason. Pursue analog-to-information compression/reduction with a practical compression/reduction ratio of 10^5:1 for practical use of information more analogous to the human brain.
+$750M	Memory & Storage	2. The growth of **memory demands will outstrip global silicon supply**, presenting opportunities for radically new memory and storage solutions. Develop emerging **memories/memory fabrics with >10-100X density and energy efficiency improvement** for each level of the memory hierarchy. Discover new **storage systems and storage technologies with >100x storage density** capability.
+$700M	Communication	
+$600M	Security	
+$750M	Energy Efficiency	

Overarching Seismic Shift Goals of Decadal Plan

Annual Investment Required		
+$600M	Smart Sensing	1. Fundamental breakthroughs in analog hardware are required to generate smarter world-machine interfaces that can sense, perceive, and reason. Pursue analog-to-information compression/reduction with a practical compression/reduction ratio of 10^5:1 for practical use of information more analogous to the human brain.
+$750M	Memory & Storage	2. The growth of memory demands will outstrip global silicon supply, presenting opportunities for radically new memory and storage solutions. Develop emerging memories/memory fabrics with >10-100X density and energy efficiency improvement for each level of the memory hierarchy. Discover new storage systems and storage technologies with >100x storage density capability.
+$700M	Communication	3. Always-available communication requires new research directions that address the imbalance of **communication capacity vs. data-generation rates**. Develop communication that enables **data movement of 100-1000 zettabyte/year at the peak rate of 1Tbps@ <0.1nJ/bit**. Develop intelligent and agile networks that effectively utilize bandwidth to maximize network capacity.
+$600M	Security	
+$750M	Energy Efficiency	

Overarching Seismic Shift Goals of Decadal Plan

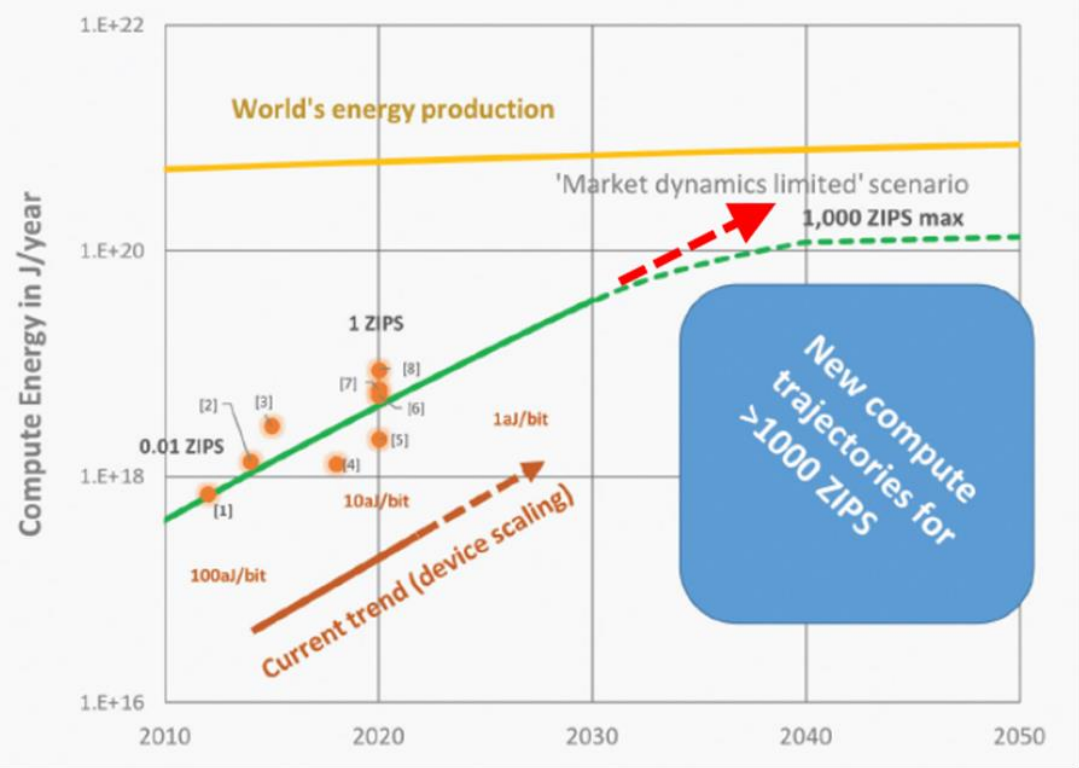
Annual Investment Required		
+$600M	Smart Sensing	1. Fundamental breakthroughs in analog hardware are required to generate smarter world-machine interfaces that can sense, perceive, and reason. Pursue analog-to-information compression/reduction with a practical compression/reduction ratio of 10^5:1 for practical use of information more analogous to the human brain.
+$750M	Memory & Storage	2. The growth of memory demands will outstrip global silicon supply, presenting opportunities for radically new memory and storage solutions. Develop emerging memories/memory fabrics with >10-100X density and energy efficiency improvement for each level of the memory hierarchy. Discover new storage systems and storage technologies with >100x storage density capability.
+$700M	Communication	3. Always-available communication requires new research directions that address the imbalance of communication capacity vs. data-generation rates. Develop communication that enables data movement of 100-1000 zettabyte/year at the peak rate of 1Tbps@ <0.1nJ/bit. Develop intelligent and agile networks that effectively utilize bandwidth to maximize network capacity.
+$600M	Security	4. Breakthroughs in hardware research are needed to address **emerging security challenges** in highly interconnected systems and AI. Advances in privacy and security hardware that **keep pace with new technology threats and use cases** (e.g., trustworthy AI systems, secure hardware platforms, and emerging postquantum and distributed cryptographic algorithms).
+$750M	Energy Efficiency	

Overarching Seismic Shift Goals of Decadal Plan

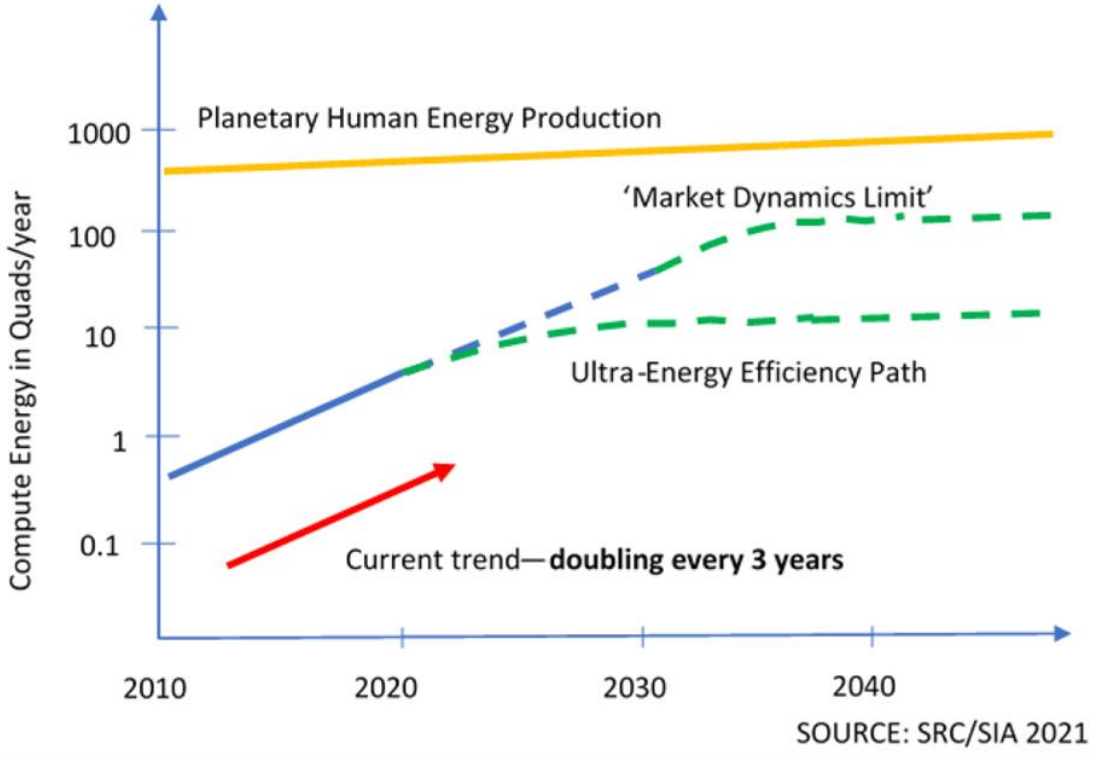
Annual Investment Required		
+$600M	Smart Sensing	1. Fundamental breakthroughs in analog hardware are required to generate smarter world-machine interfaces that can sense, perceive, and reason. Pursue analog-to-information compression/reduction with a practical compression/reduction ratio of 10^5:1 for practical use of information more analogous to the human brain.
+$750M	Memory & Storage	2. The growth of memory demands will outstrip global silicon supply, presenting opportunities for radically new memory and storage solutions. Develop emerging memories/memory fabrics with >10-100X density and energy efficiency improvement for each level of the memory hierarchy. Discover new storage systems and storage technologies with >100x storage density capability.
+$700M	Communication	3. Always-available communication requires new research directions that address the imbalance of communication capacity vs. data-generation rates. Develop communication that enables data movement of 100-1000 zettabyte/year at the peak rate of 1Tbps@ <0.1nJ/bit. Develop intelligent and agile networks that effectively utilize bandwidth to maximize network capacity.
+$600M	Security	4. Breakthroughs in hardware research are needed to address emerging security challenges in highly interconnected systems and AI. Advances in privacy and security hardware that keep pace with new technology threats and use cases (e.g., trustworthy AI systems, secure hardware platforms, and emerging postquantum and distributed cryptographic algorithms).
+$750M	Energy Efficiency	5. Ever-rising **energy demand for computing vs. global energy production** is creating new risk, and new computing paradigms offer opportunities to dramatically improve energy efficiency. Discover computing paradigms/architectures with a radically new computing trajectory demonstrating **>1,000,000x improvement in energy efficiency**.

Compute Energy vs. Global Energy Production

Seismic Shift #5



2030 Decadal Plan for Semiconductors

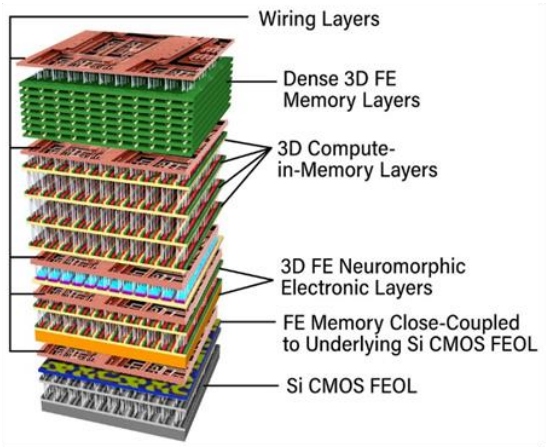


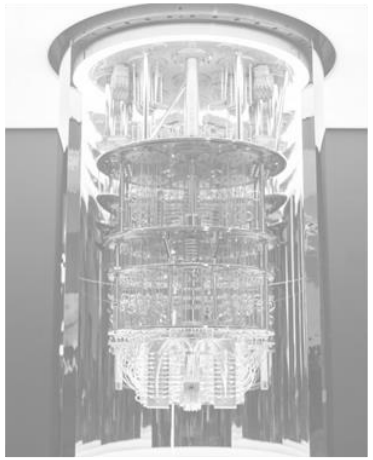
DOE-AMO Workshop, Apr 21-23, 2021

This is not only critical for our society and planet, but sustainable microelectronics can **win the hearts & minds of young innovators**.

Microelectronics & Advanced Packaging Technologies (MAPT)

We must evaluate market-driven opportunities "side-by-side" to realize lasting innovations





Priority 1

2.5D and 3D Advanced Packaging

Image: DARPA/Intel
https://www.darpa.mil/program/common-heterogeneous-integration-and-ip-reuse-strategies

Priority 2

3D Super Chips

Image: SIRO, Penn State, Prof. Vijay Narayanan
https://news.psu.edu/story/625834/2020/07/15/research/over-10-million-awarded-penn-state-energy-center

Priority 3

Hardware for New Paradigms

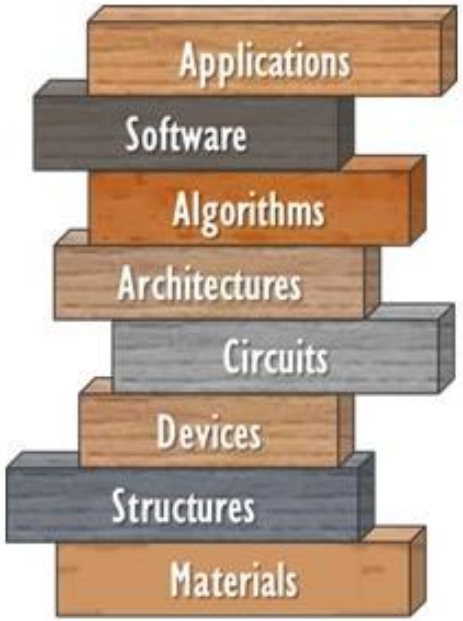
Image: IBM Q system displayed at CES 2020
https://www.fierceelectronics.com/electronics/what-quantum-computing

It is great to see that "**hardware is back!**," but we must invest strategically to meet the needs and create opportunity for the entire semiconductor ecosystem in the coming decades.

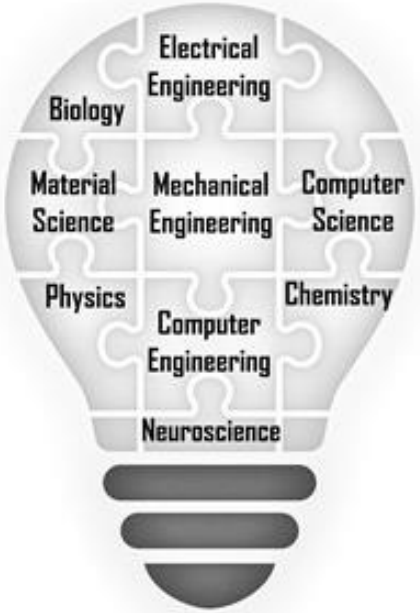
Semiconductor Technology Breakthroughs Rely On

Holistic Optimal Solutions

Driven by Hardware/Software Co-Optimization



Interlocked Multidisciplinary Research



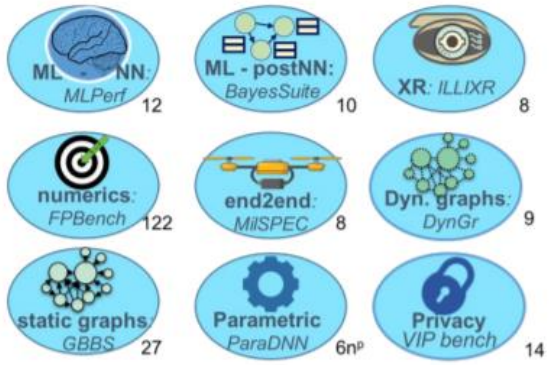
Diverse teams combined with inclusive work environments which leads to greater innovation, agility, performance, and engagement

One Good Example

5-yr., $33M Applications Driving Architectures (ADA) Center in the SRC/DARPA JUMP Program

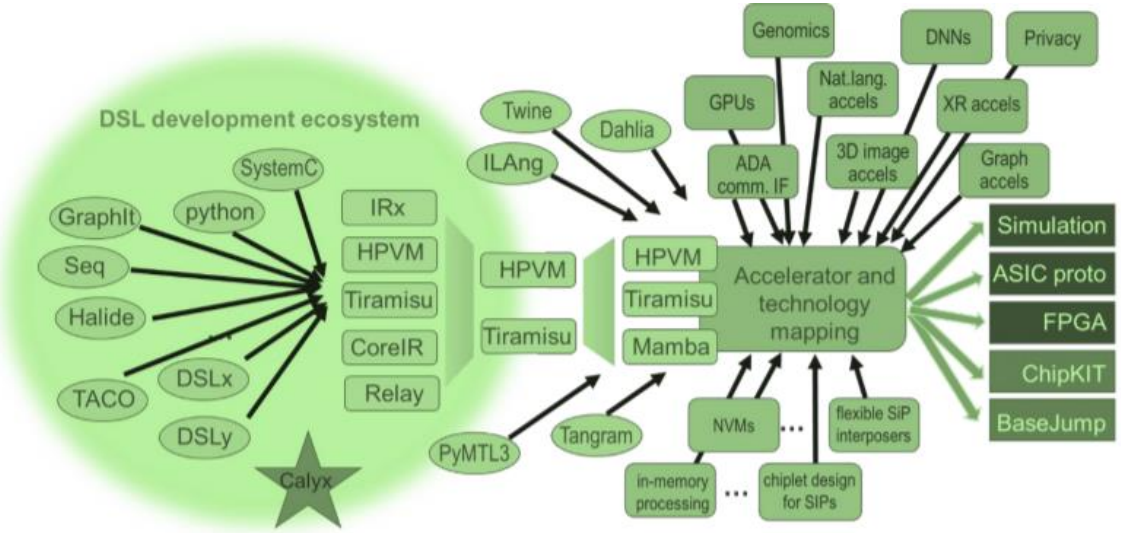
Valeria Bertacco (University of Michigan), Director & David Brooks (Harvard), Assistant Center Director

Application Drivers and Application Benchmarks



Guide future architecture choices and solutions. Grow application drivers.

Design Flows



HW/SW linkage between app-centric DSLs to accelerated heterogeneous systems

Meaningful Hardware Demonstrators

CHIPKIT

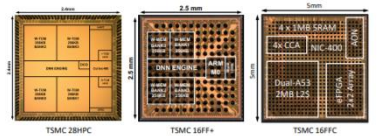
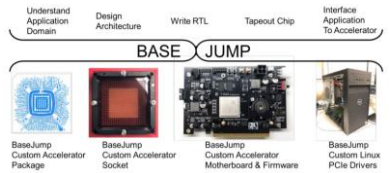


Fig. 1. Three recent chips [1], [2], [3] built using the CHPIKIT framework.

BaseJump



Driving insight in relevant hardware

We Must Invest in Our Industry's Future

Future Leaders

Drive holistic, optimal solutions in HW/SW through interlocked multidisciplinary research

Help students see we have hard yet interesting problems that can't be solved without them

Create industrial relationships and internship experiences that provide insight into SOTA*

*SOTA = State of the Art

Diverse teams and inclusive environments result in greater innovation.

We need an aspirational new narrative that ignites the next generation of talent

SRC's Call to Action!

- The ICT opportunities of tomorrow are **unachievable** with emerging hardware technologies as the underlying hardware is up against fundamental physical limits.
- A crisis is at hand, where the current hardware paradigm must shift to create the desired value with heterogeneity from **microelectronic and advanced packaging technologies (MAPT)** as the key driver.
- To stay at the leading edge of hardware innovation, we must **invest in early-stage ideas and tech maturation**, exploring critical options through a fast-fail and tech-transfer mindset.
- It is equally important that we are committed to **workforce development and broadening participation**. There is a bright future for semiconductors, but we must change our narrative to win over the hearts and minds of next gen innovators.

The greatest risk is not investing in semiconductor R&D for our future

Recommendations – Slide 1 of 2

- **Think of STEAM, not STEM!** Art, music, and language are important elements for the education of creative and innovative scientists and engineers.
- Use interlocked multidisciplinary education and research that tackles **different length scales (from atoms to kms)** to consider and address the true pain points and opportunities for semiconductors and microelectronics.
- Lower the barrier for entry and reduce the cycle time for **meaningful hardware exploration by academics**.
- Balance education and research with both “hands on”/ making things along with an understanding of theory, simulation, and programming. **Make “bilingual” students or pair students and faculty** on shared projects.
    - Nanofabrication and packaging capabilities, a “maker’s lab,” and AR/VR labs are all required educational elements. The challenge is creating a critical mass.

Recommendations – Slide 2 of 2

- Foster **stronger relationships with industry**, including the use of internships to complement a student's academic education. (SRC had 82 internships in 2020)

- Seek and find ways to move beyond the "$90k/year" **single PI grant model** set in the late 90s. In the U.S., it is insufficient funds (~50% USD inflation since 2000) and brings too many strings that stifle innovation.

- **Move the needle on broadening participation.** Graduate studies must learn from lessons learned and gains in undergraduate studies and be held accountable to realize results.
  - NSF Research Experiences for Undergraduates (REU) program
  - ROTC-based or –affiliated programs that help meet the needs of USG/DoD agencies
- We need more women, URM, and US Citizens in Chem/Mat Sci, EE/ECE, and CS! **Diversity of thought improves innovation.**

Check out our Broadening Participation Pledge!
https://www.src.org/about/broadening-participation/

Todd Younkin, President and CEO: todd.younkin@src.org

David Henshall, Director of Business Development and Government Relations: david.henshall@src.org

Victor Zhirnov, Chief Scientist: victor.zhirnov@src.org