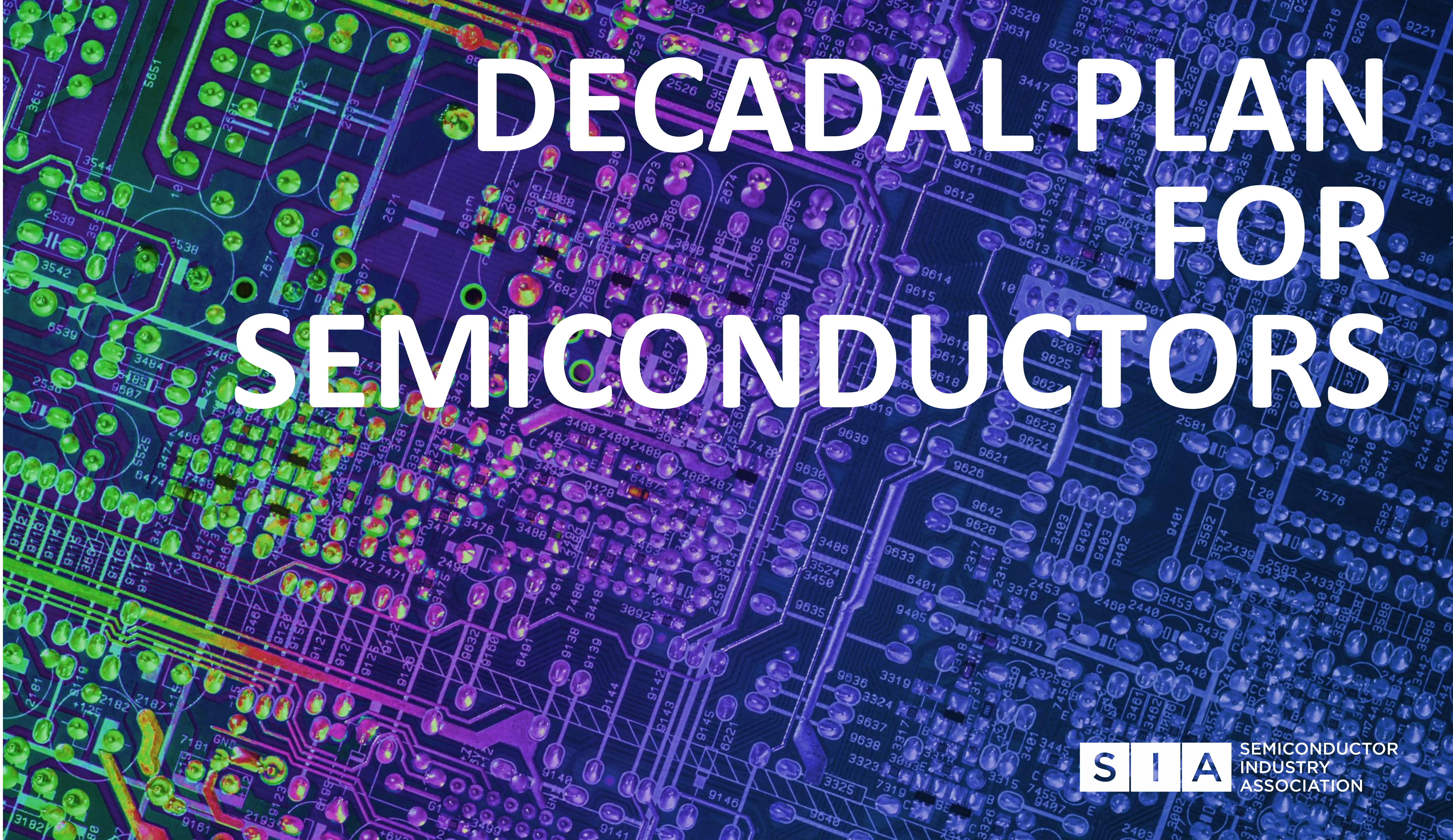
2020



DECADAL PLAN FOR SEMICONDUCTORS

SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

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.

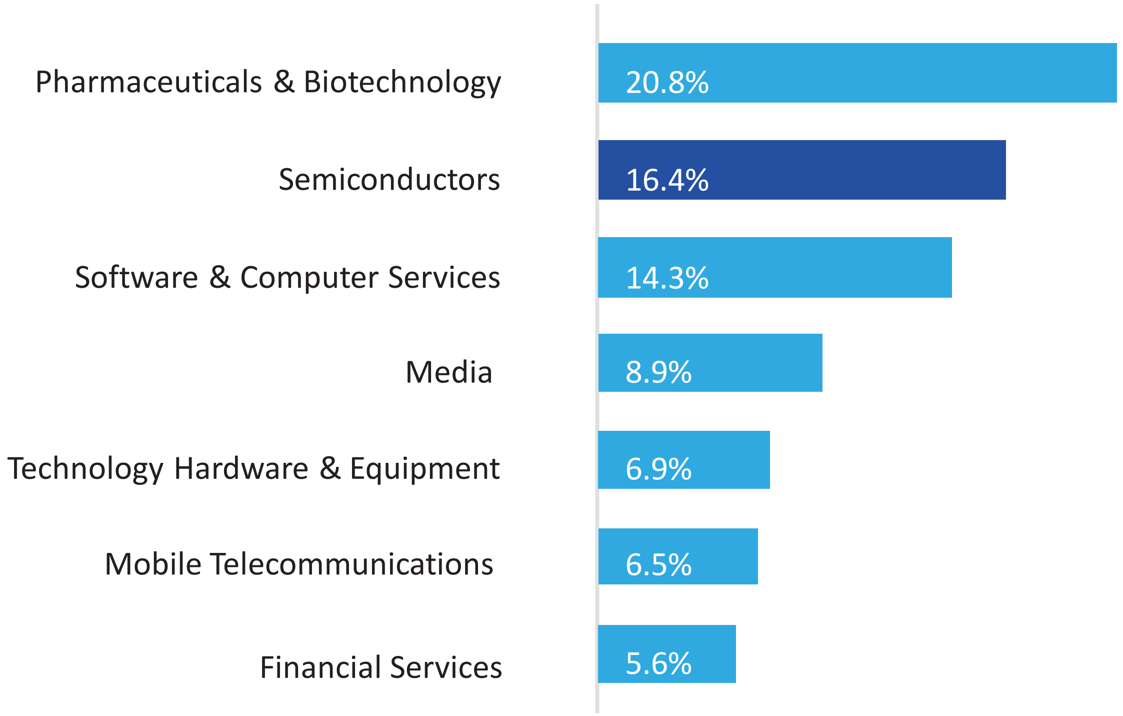
$193 BILLION

IN SALES, ACCOUNTING FOR ABOUT HALF OF GLOBAL MARKET SHARE

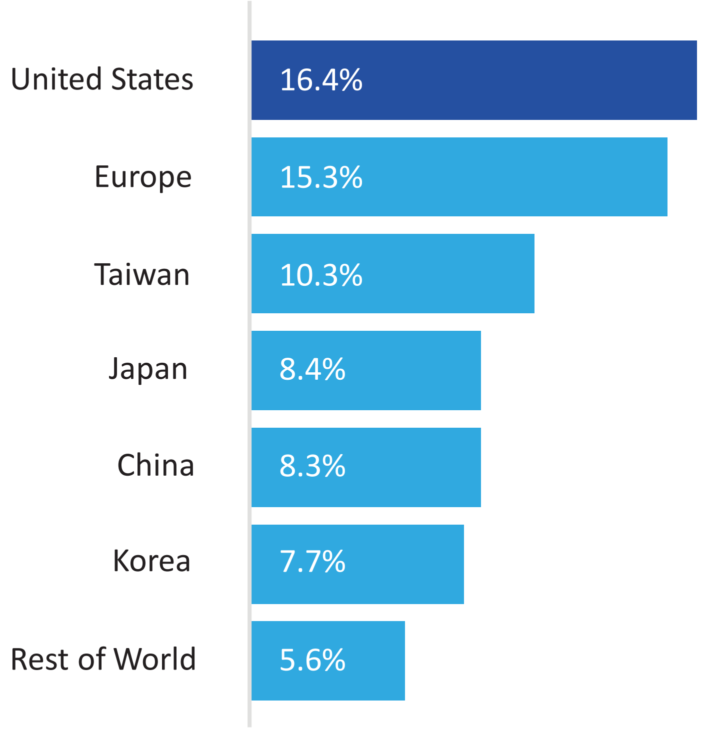
AN R&D INTENSIVE INDUSTRY

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

BY INDUSTRY



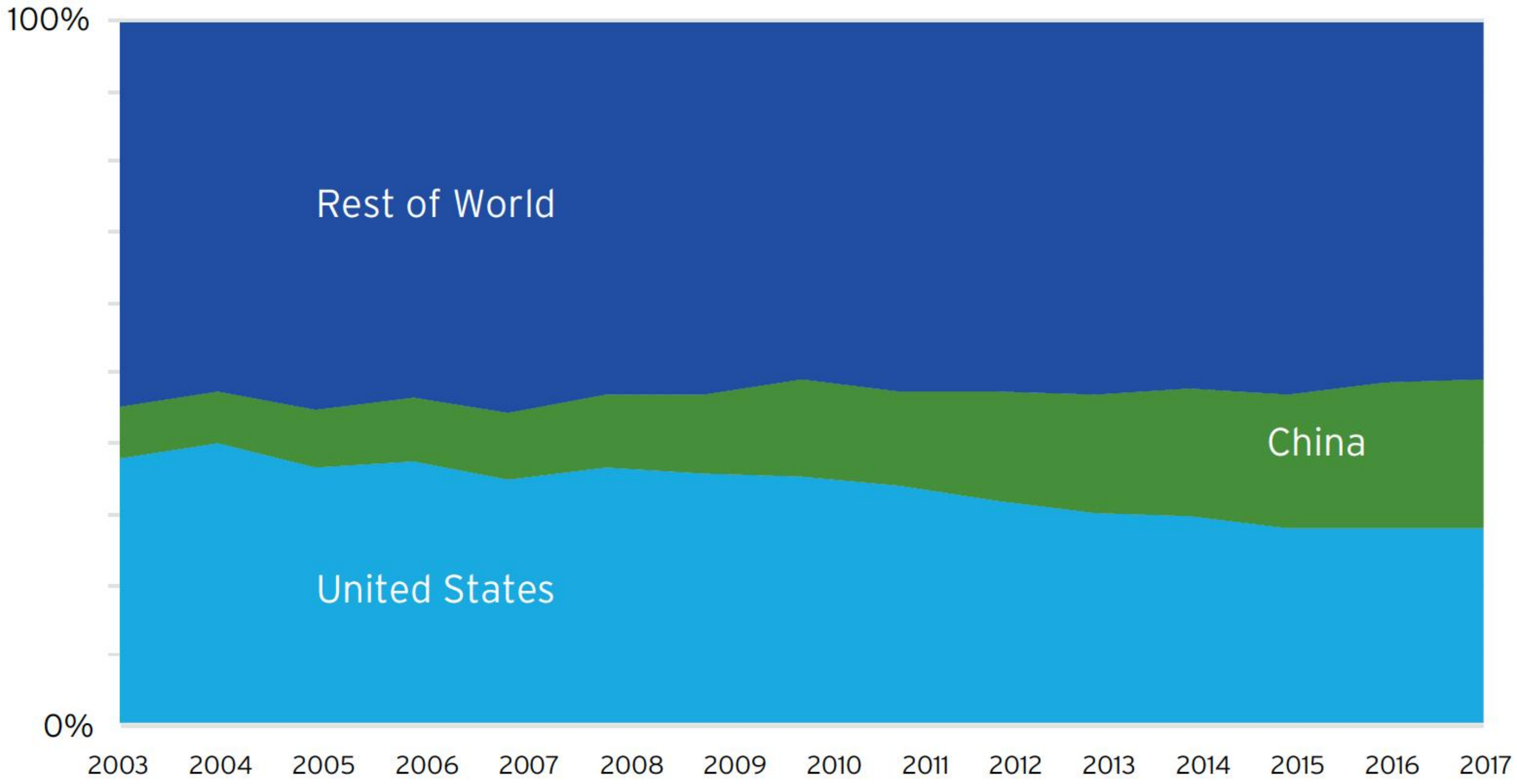
BY COUNTRY



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

INVESTMENT IN RESEARCH

GOVERNMENT R&D (SHARE OF TOTAL)



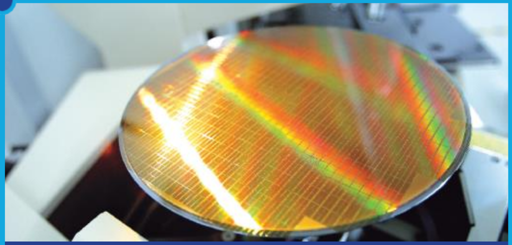
Source: OECD Science Indicators, April 2020

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



ADVANCED CHIP MANUFACTURING (OPTICAL LITHOGRAPHY)
Department of Energy

SUPERCOMPUTERS
National Labs (Department of Energy)

MINIATURIZATION OF TRANSISTORS (FinFET)
DARPA

SMARTPHONE TECH
NASA, Air Force

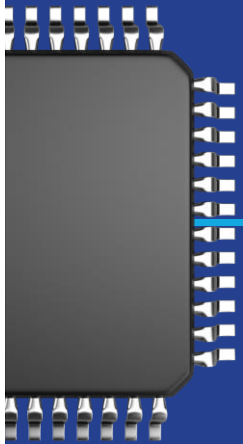
GPS
DARPA, Department of Defense

ADVANCED MATERIALS (GaAs)
DOD (OSD and DARPA)

LED LIGHTING TECH
Air Force, Department of Energy, Department of Defense

POWER ELECTRONICS (GaN)
DOD and DOE

40 YEARS OF POLICY MILESTONES



1981
R&D Tax Credit

1982
Semiconductor Research Corporation

1984
Semiconductor Chip Protection Act

1986
U.S. – Japan Semiconductor Trade Agreement

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

Semiconductor Research Corporation

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

SRC creates and manages **collaborations** between industry, gov't, and academics

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

SRC researches critical technology options focusing on fast fail and **tech transfer to industry**

- MRAM
- Cu Interconnects
- High K Dielectrics
- FinFET
- Nanosheets for GAA transistors

Disruptive Technologies

SRC by the Numbers

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

3 Government Agencies

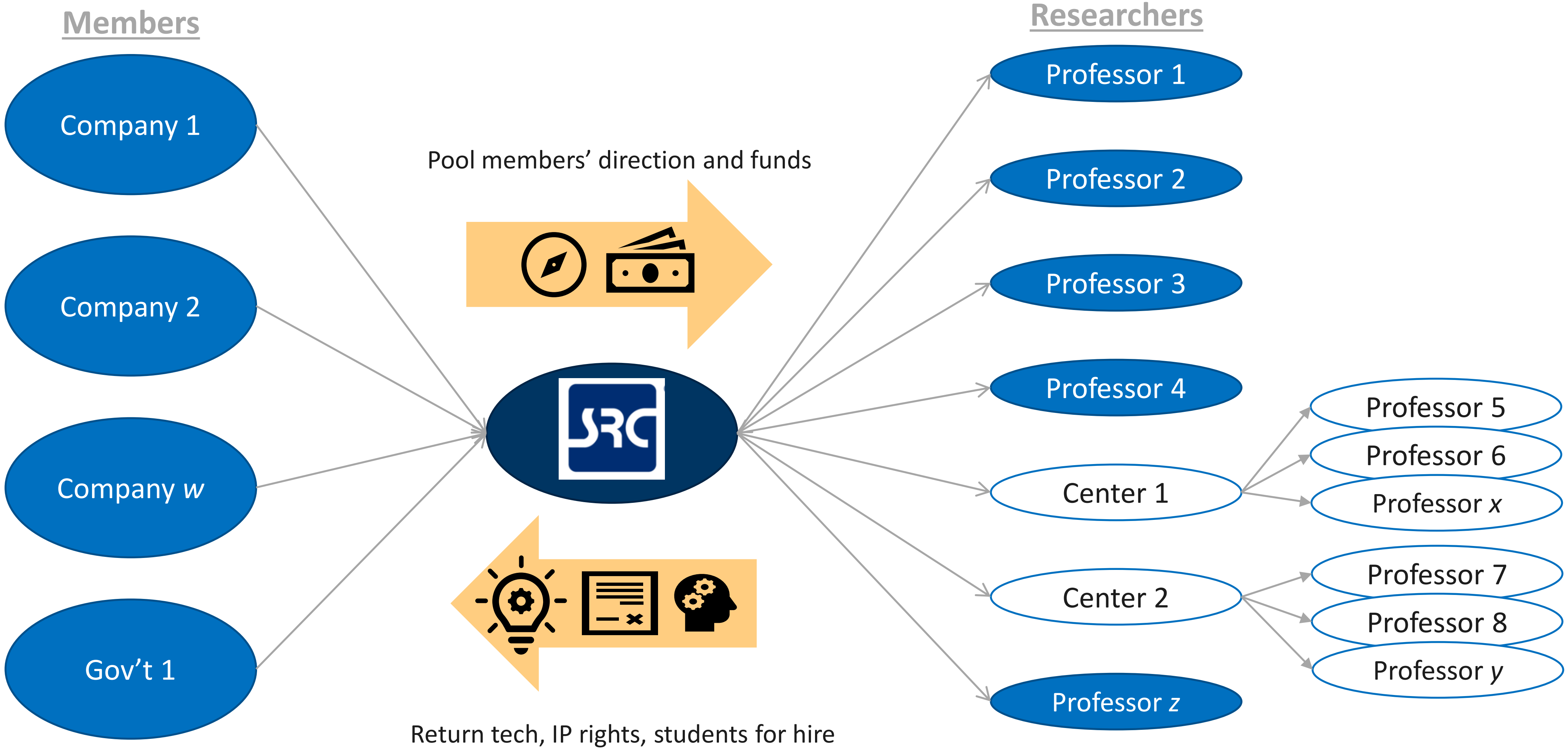
DARPA NSF NIST

AMD
ANALOG DEVICES
arm
EMD Performance Materials
GLOBALFOUNDRIES
IBM
intel
LOCKHEED MARTIN
Mentor A Siemens Business
Micron
MUBADALA
NORTHROP GRUMMAN
NXP
QUALCOMM
Raytheon Technologies
SAMSUNG
SK hynix
TEL
Texas Instruments
tsmc
Veeco

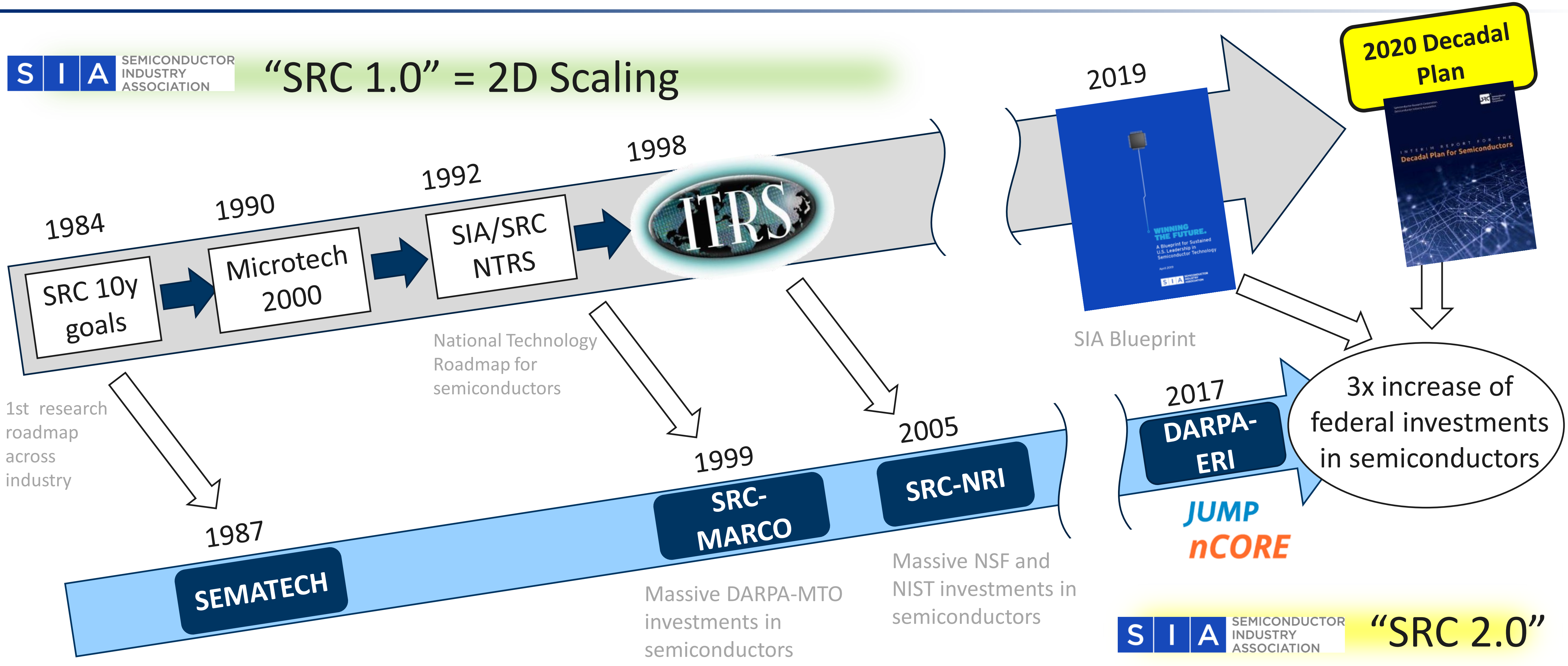
Vast network focused on research and workforce development for the future of the semiconductor industry

Public

How it Works: We Manage Collaborative Research

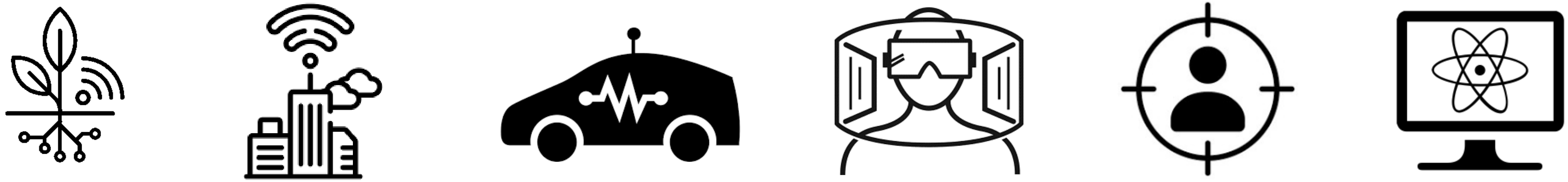


Roadmapping: *Forecast for Technology Requirements*



Generational Opportunities in Hyperscaled Computing, AI, 6G, and Quantum

"SRC 2.0"

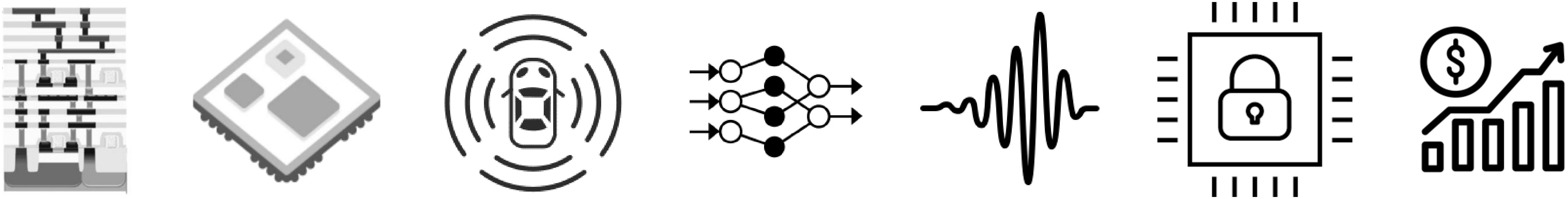


- **Sustainable** computing and communications, including data movement and the memory wall
- **Industry 4.0** – robotics, automation, and advanced manufacturing
- Rise of 5G+, **smart cities**, autonomous vehicles, V2V
- Human Machine Interface (**HMI**) including AR/VR
- Personalized, targeted **healthcare** 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

Weekly full committee teleconferences

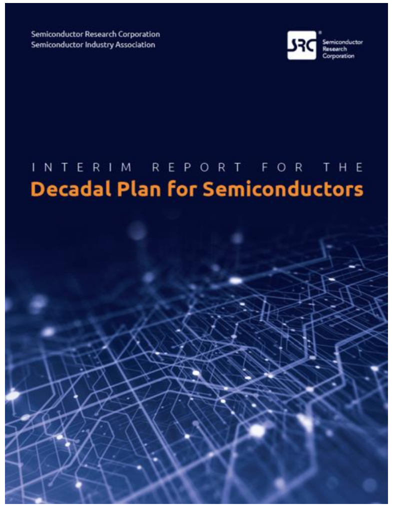
Fundamental studies

Planning topical workshops

Jan 2019 → Feb 2019 → Mar 2019 → Apr 2019 → Oct 2019 → Dec 2019 → Feb 2020 → Aug 2020 → Oct 2020 → Dec 2020 → Full report release

WE ARE HERE

- Executive committee formed
- Decadal Plan concept presented to the SIA CTO group
- Development funds secured
- Workshop on New Trajectories for Computing
- Workshop on New Trajectories for Analog Electronics
- Workshop on New Trajectories for Communication
- Workshop on ICT Security
- Workshop on Trajectories for Memory and Storage
- Interim report released



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

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

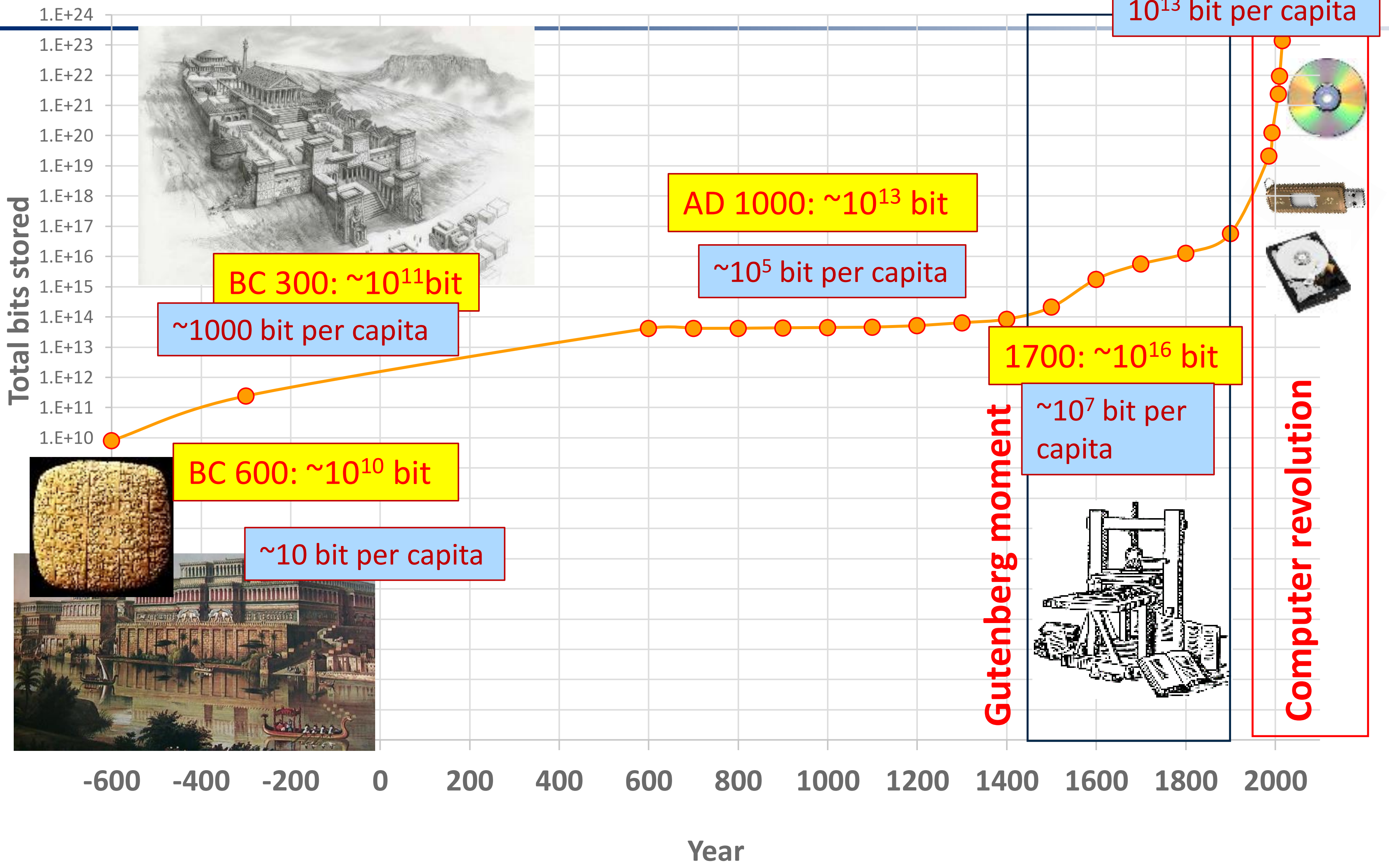
Semiconductor Research Corporation

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



Technology Decadal Plan

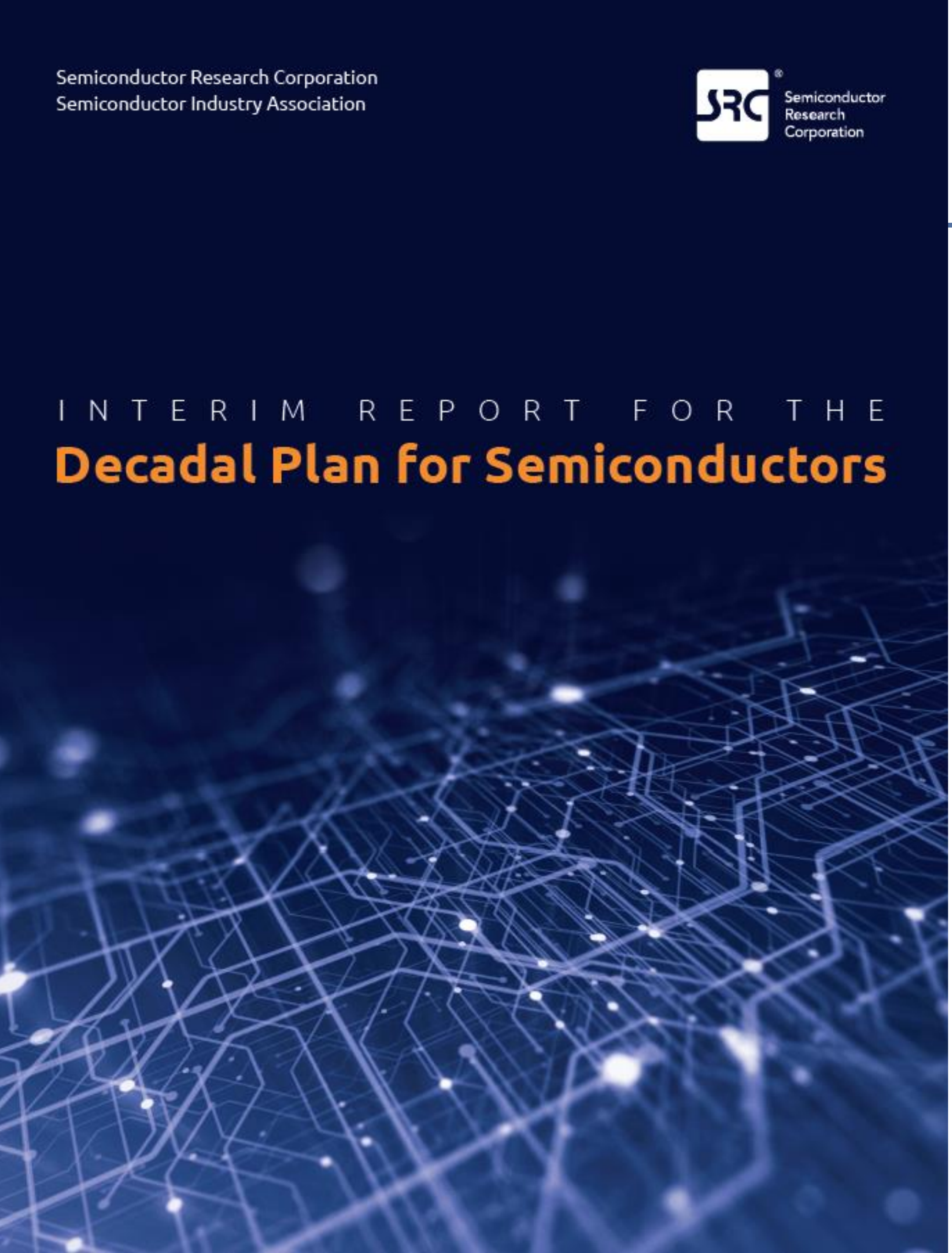
The current hardware-software (HW-SW) paradigm driving digital technologies is reaching its limits and must evolve

Two Simultaneous Seismic Shifts

Energy

Data

Decadal Plan Participants



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

Release date: October 15, 2020

Seismic shifts in information and communication technologies:

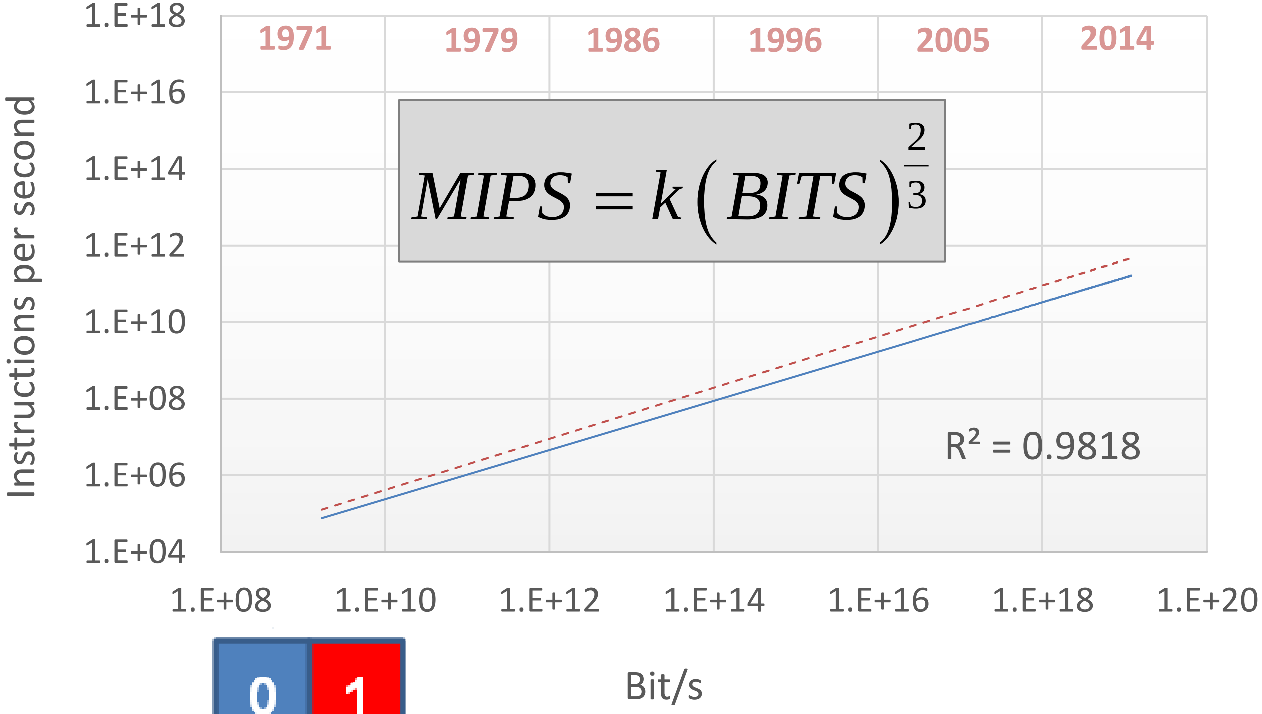
- **Compute energy vs. global energy production**
- **Need for smarter analog world-machine interfaces**
- **The growth of memory and storage demands**
- **Communication capacity vs. data generation imbalance**
- **Emerging security challenges in both highly interconnected systems and AI**

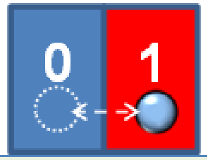
Public

MPU operations vs. binary transitions

$$\mu = f(\beta) = k\beta^{p}$$

k=0.1, p= 0.64 ≈ ⅔



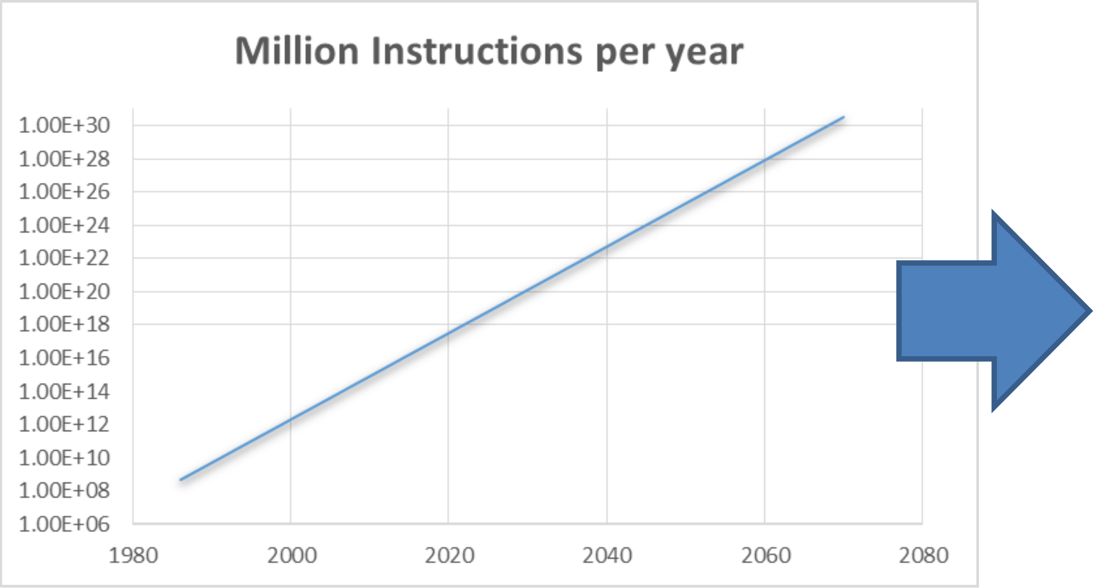


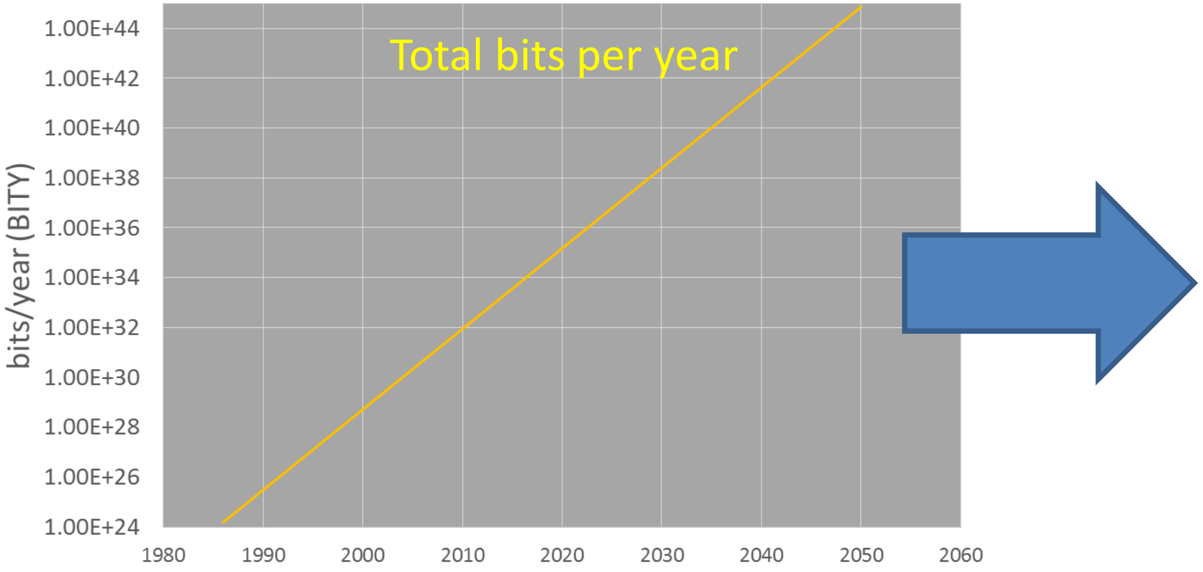
$$\beta = \alpha N_{tr} \cdot f$$

$$P = \beta E_{bit}$$

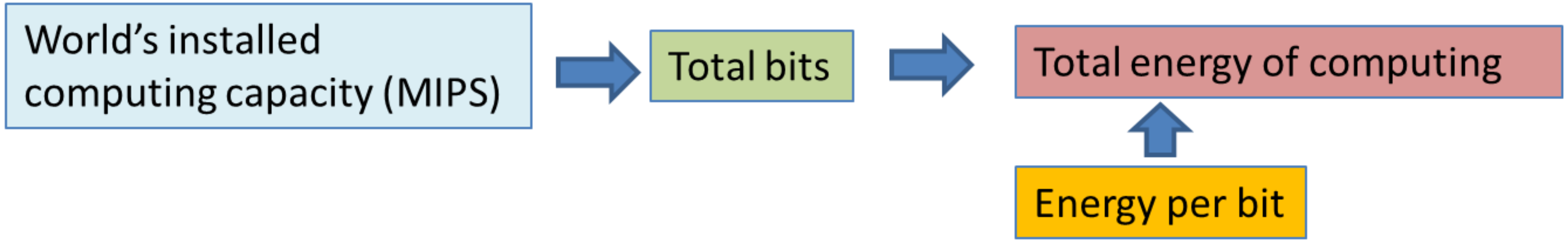
Company	Model	Year
Intel	4004	1971
Intel	8080	1974
MOS Technology	6502	1975
Motorola 68000	68000	1979
Intel	286	1982
Motorola	68020	1984
Intel	386DX	1985
ARM	ARM2	1986
Motorola	68030	1987
Motorola	68040	1990
DEC	Alpha 21064 EV4	1992
Intel	486DX	1992
Motorola	68060	1994
Intel	Pentium	1994
Intel	Pentium Pro	1996
IBM - Motorola	PowerPC 750	1997
Intel	Pentium III	1999
AMD	Athlon	2000
AMD	Athlon XP 2500+	2003
Intel	Pentium 4 Ext. Edition	2003
Centaur - VIA	VIA C7	2005
AMD	Athlon FX-57	2005
AMD	Athlon 64 3800+ X2	2005
IBM	Xbox360 "Xenon"	2005
Sony-Toshiba-IBM	PS3 Cell BE	2006
AMD	Athlon FX-60	2006
Intel	Core 2 Extreme X6800	2006
Intel	Core 2 Extreme QX6700	2006
P.A. Semi	PA6T-1682M	2007
Intel	Core 2 Extreme QX9770	2008
Intel	Core i7 920	2008
Intel	Atom N270	2008
AMD	E-350	2011
AMD	Phenom II X4 940	2009
AMD	Phenom II X6 1100T	2010
Intel	Core i7 980X	2010
Intel	Core i7 2600K	2011
Intel	Core i7 875K	2011
AMD	8150	2011
Intel	Xeon E3-1290v2	2012
Intel	Ivy Bridge-EX-15	2013
Intel	i7-5960X	2014

Computations per Year





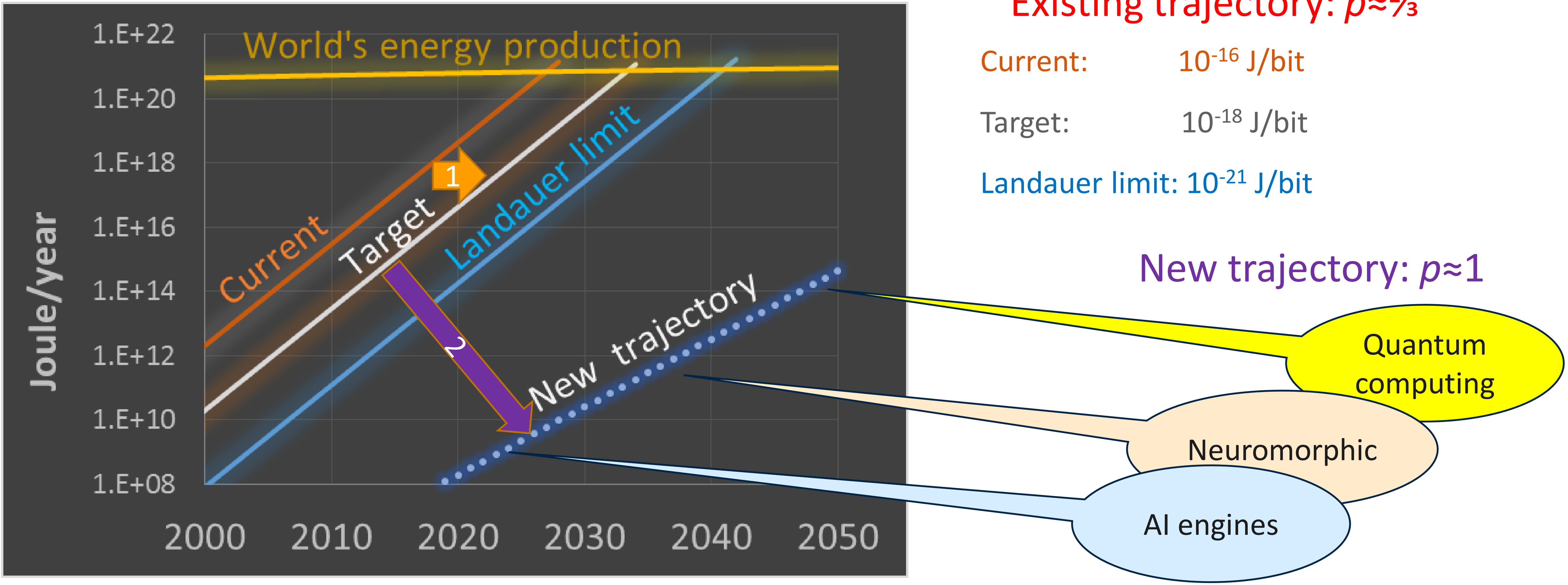
(based on research by Hilbert and Lopez: M. Hilbert and P. Lopez, "The World's Technological Capacity to Store, Communicate, and Compute Information", Science 332 (2011) 60-65



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

$$MIPS = k\left(BITS\right)^{p}$$



Existing trajectory: $p \approx ⅔$

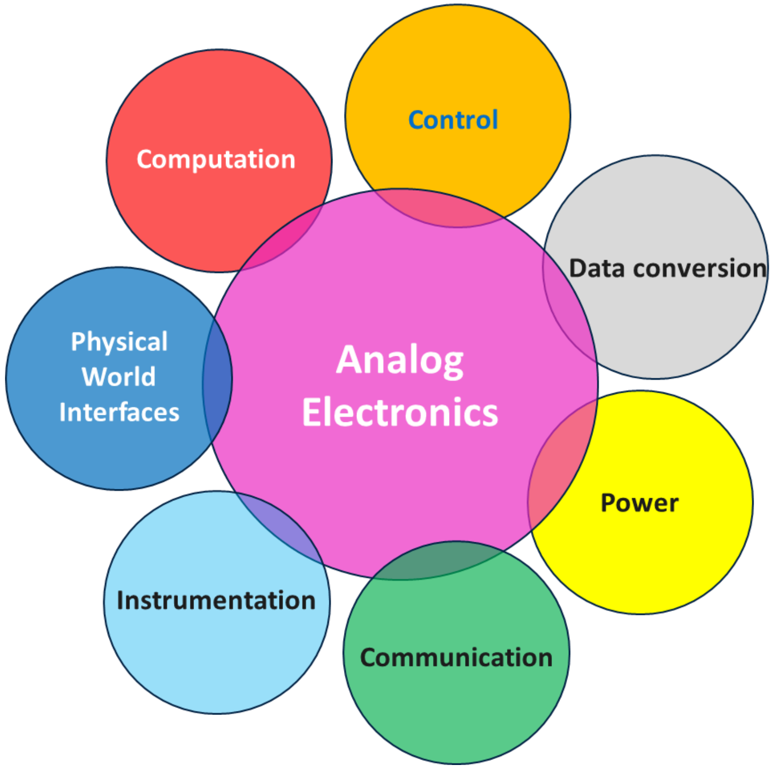
Current: 10^{-16} J/bit

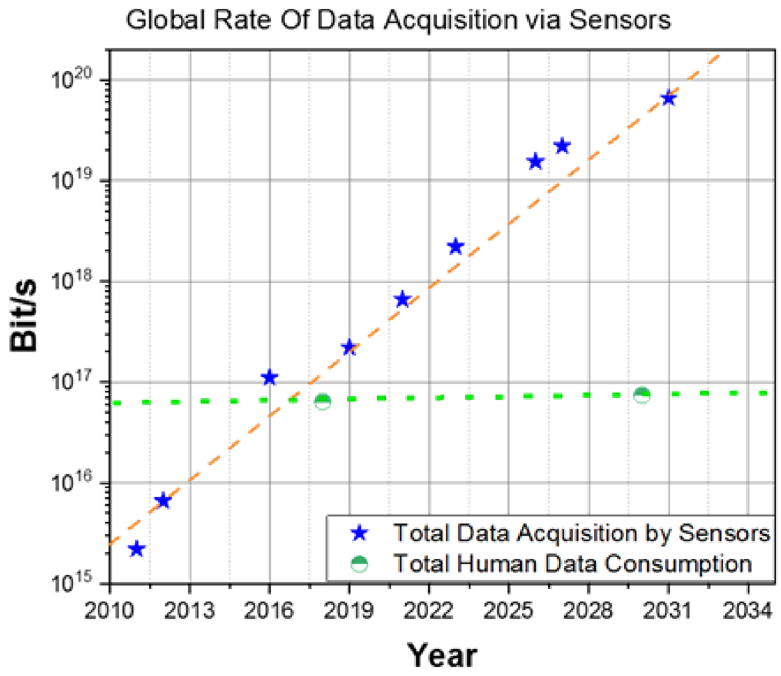
Target: 10^{-18} J/bit

Landauer limit: 10^{-21} J/bit

New trajectory: $p \approx 1$

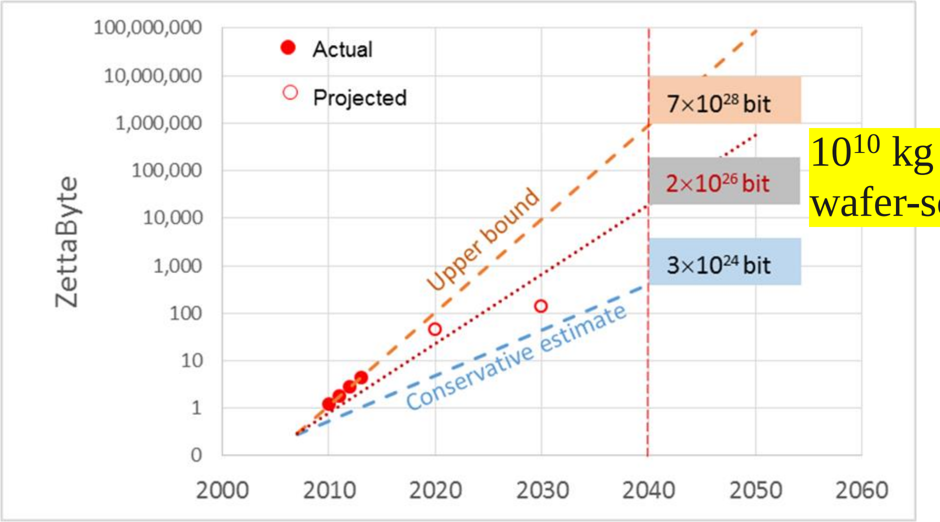
Analog Data Deluge



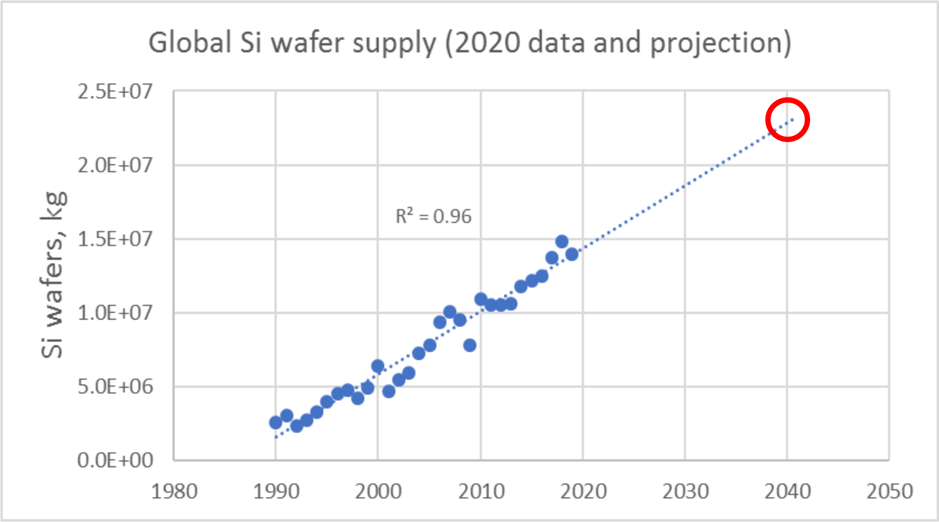


Grand Goal #1: Analog-to-information compression/reduction with a practical compression/reduction ratio of 10^5:1 driving to practical use of information versus "data" more comparable to the human brain.

Dramatic global Memory and Storage requirement increase



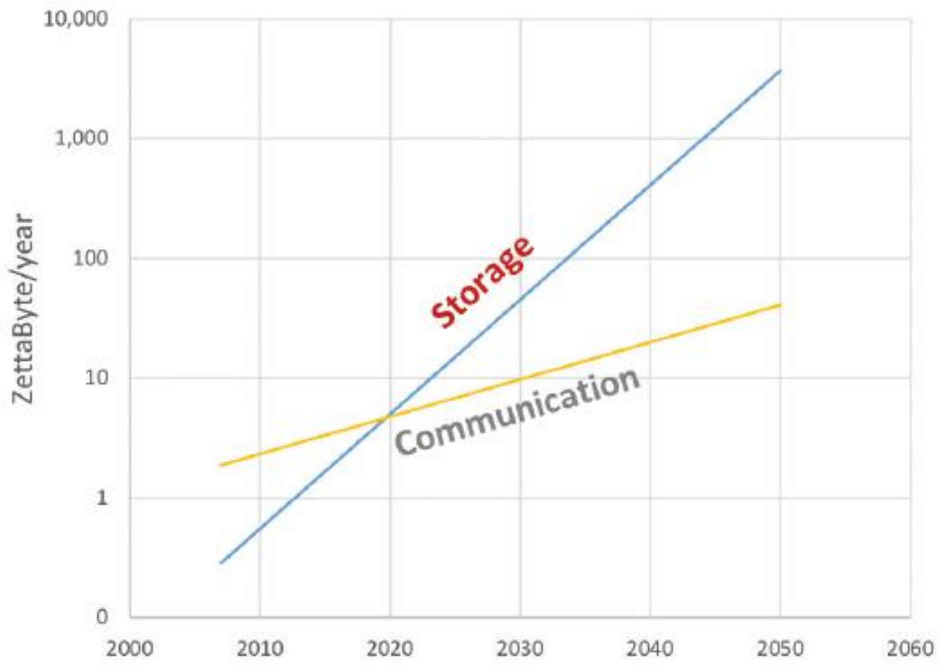
10^{10} kg of wafer-scale Si



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

Data to communication gap

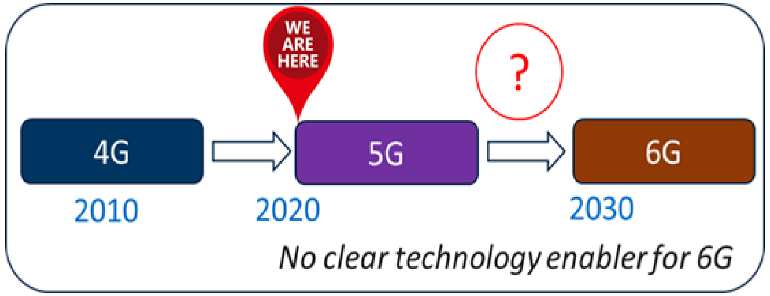
Gap between communication capacity and data capacity



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

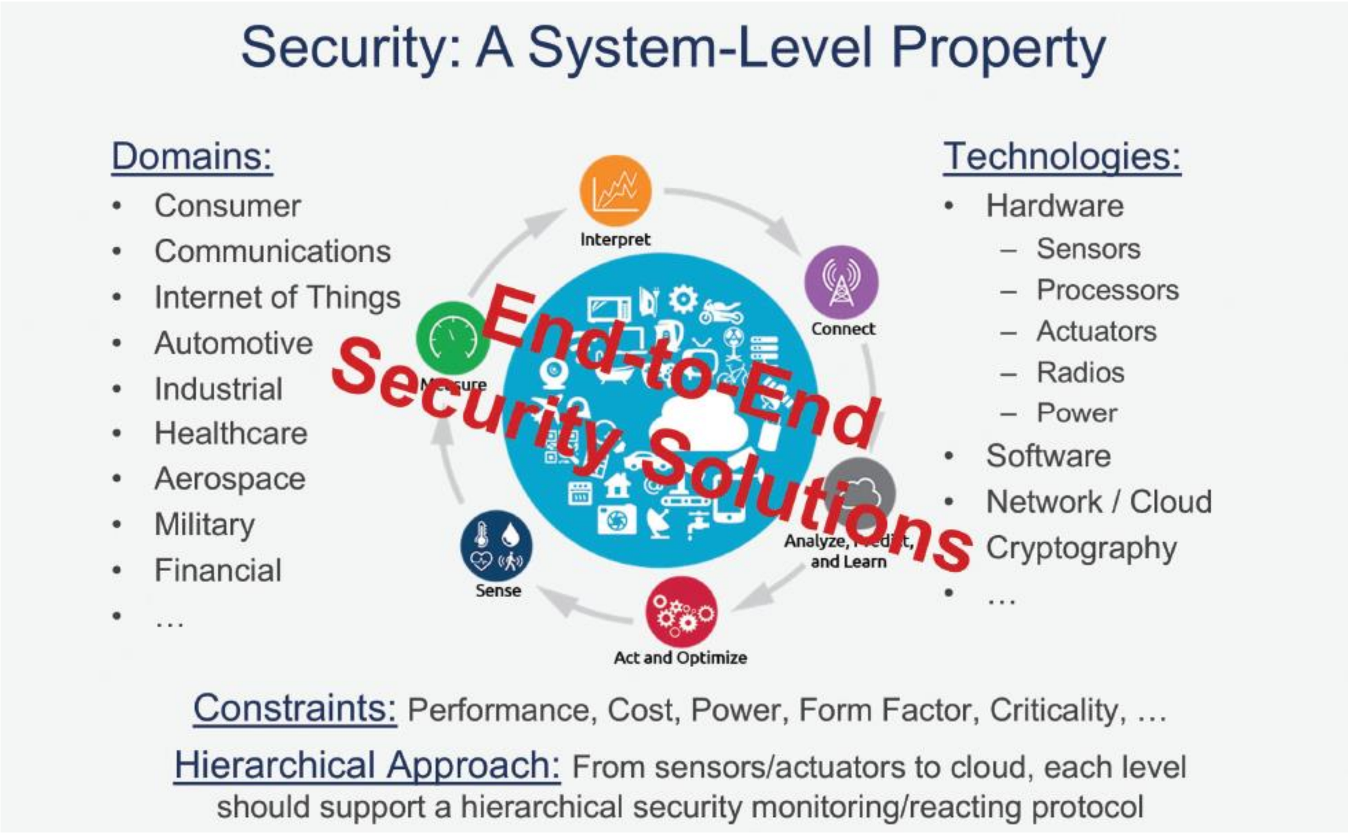
Grand Goal #3a: Advance communication technologies to enable moving around all stored data of 100-1000 zettabyte/year at the peak rate of 1Tbps@<0.1nJ/bit. **Grand Goal #3b:** Develop intelligent and agile networks that effectively utilize bandwidth to maximize network capacity.

Invest $700M annually in new trajectories for communication



Trust, Security and Privacy in a world of robots

Securing and trusting systems of machines and MtM comm



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

Beginning of new semiconductor era

2019

(SIA Blueprint)

2020

2020 Decadal Plan

2021

Analog $600M

Data Storage $750M

Communication $700M

Security $600M

Computation $750M

Semiconductor Technology Leadership Initiative

New Private-Public Partnership Initiatives

3x increase of federal investments in semiconductors

Decadal Plan Timeline: 2020 - 2030

1st rev	2nd rev	3rd rev	Final refresh
Dec 20/Jan 21	Dec 23/Jan 24	Dec 26/Jan 27	Dec 29/Jan 30

Topical workshops completed

Interim report released

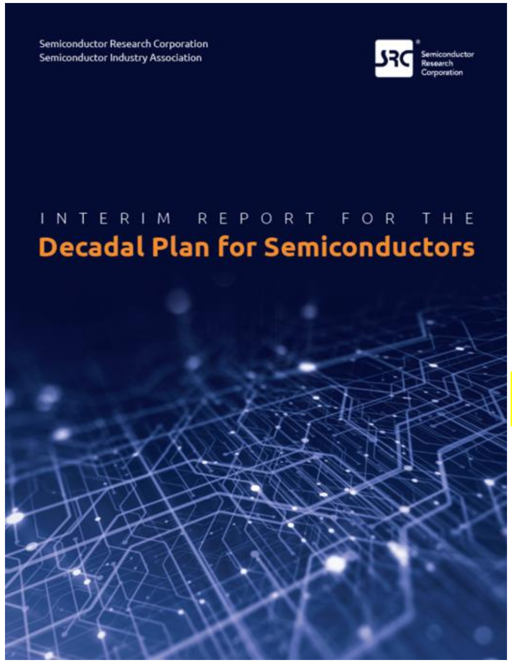
WE ARE HERE

Full report released

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

Foundations for the New Semiconductor Era laid

Oct 2020 → Nov 2020 → Dec 2020 → → → Oct 2021 → → 2030



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
- • • •

Fund innovations through increased R&D $$$

5G+/ 6G
AI++
Quantum Computing

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

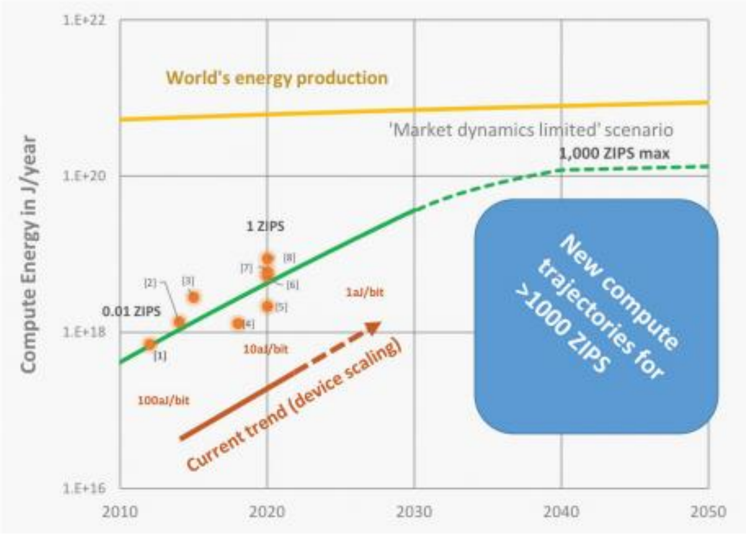
Sean Eilert
Fellow, Emerging Memory PathFinding Group
Micron Technology

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

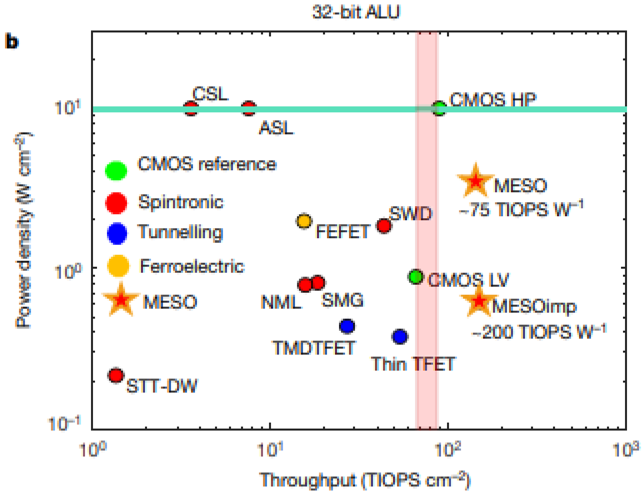
Debra Delise
General Manager, Security Center of Excellence
Analog Devices

Changing the Compute Energy Trajectory

"The Problem and Opportunity"

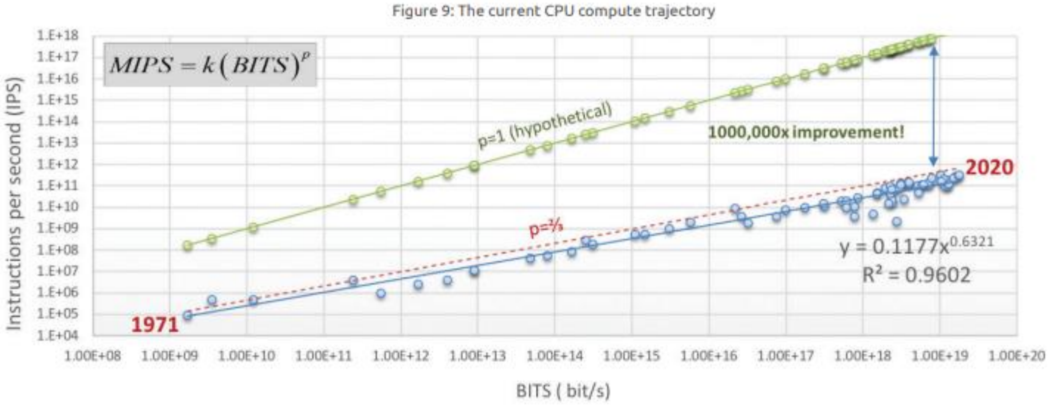


Many device options exist and new approaches are needed



https://doi.org/10.1038/s41586-018-0770-2

- 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…



Priority Research Themes

Turing → Shannon → Approximate computing

Shannon framework for computation

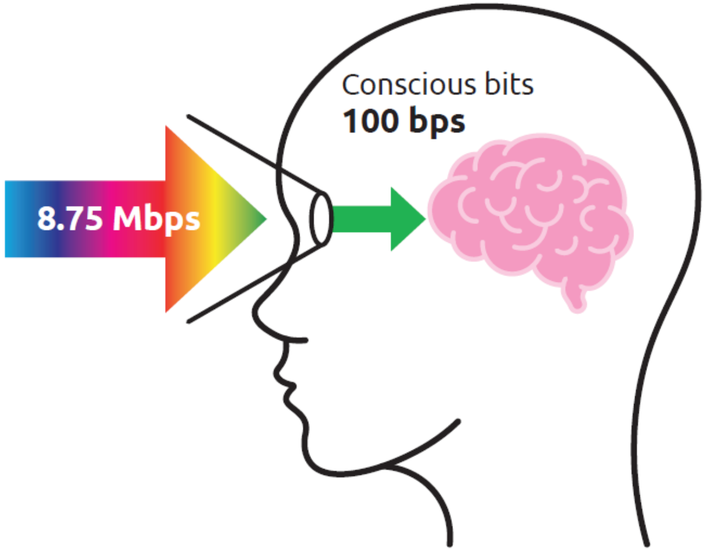
High-dimensional representation

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

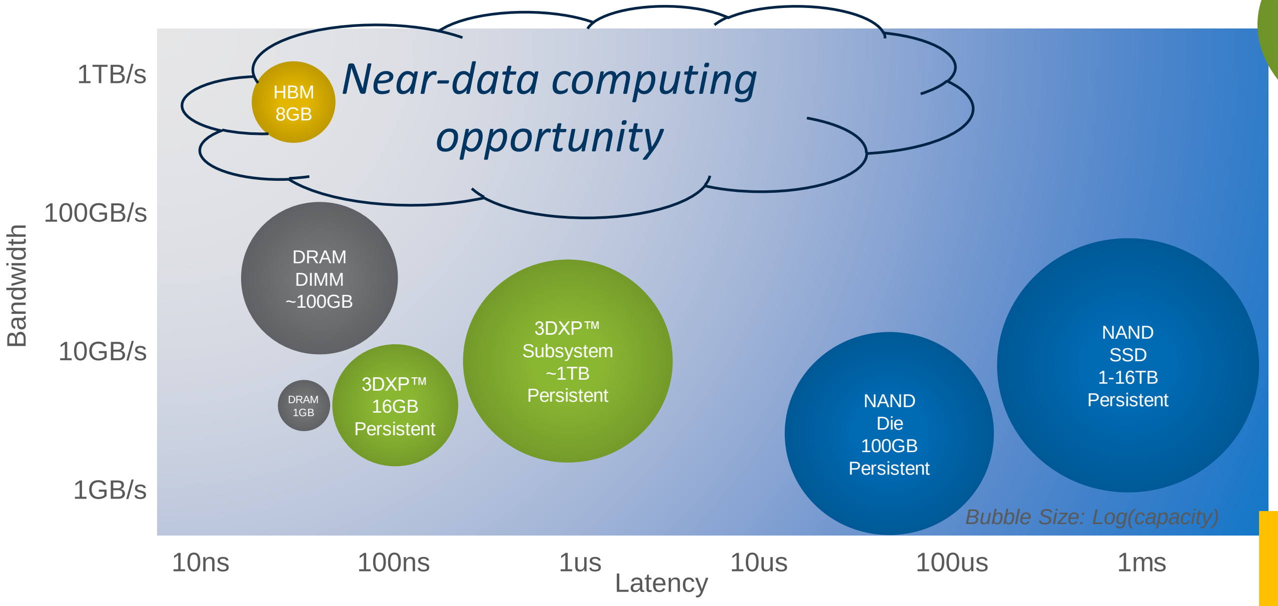
New Trajectories for Memory and Storage

Heterogeneous Computing Brings New Memory Requirements

Bandwidth for GPU & AI accelerators in Mobile applications

Bandwidth and capacity for domain specific datacenter

Persistence & low power for edge applications



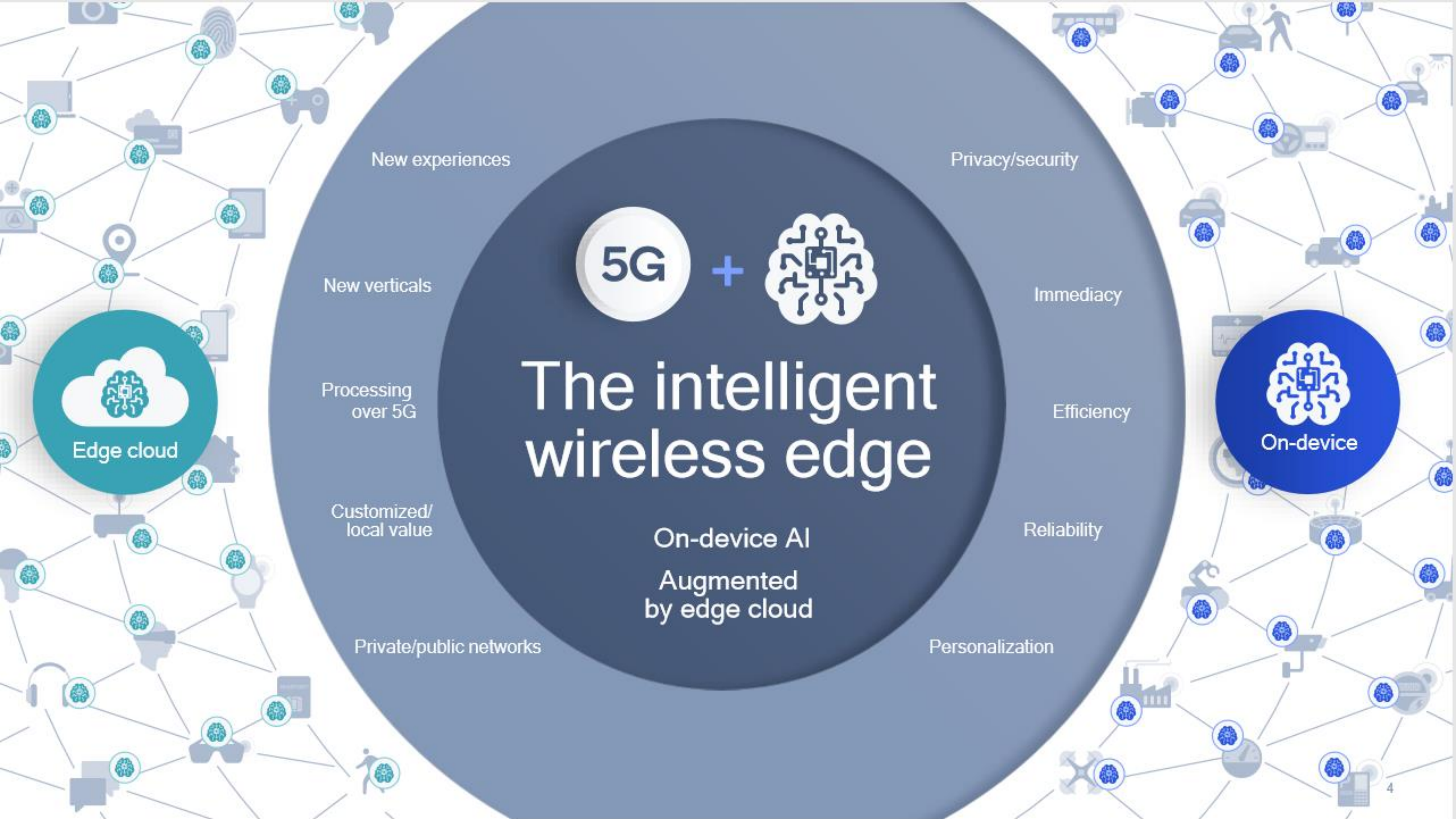
3D integration & Low temperature memory processes enable improved logic

Reduced data movement enables Bandwidth & Energy improvement

Energy-efficient near-data computing

. . . But adoption is limited by ease of programming

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


5G
The intelligent wireless edge
On-device AI
Augmented by edge cloud
New experiences
New verticals
Processing over 5G
Customized/ local value
Private/public networks
Privacy/security
Immediacy
Efficiency
Reliability
Personalization
Edge cloud
On-device

Emerging Security Challenges

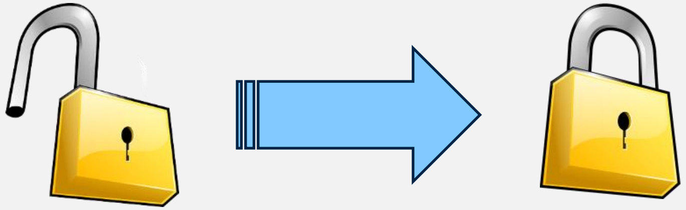
Ubiquitous Sensing & Connectivity

> 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

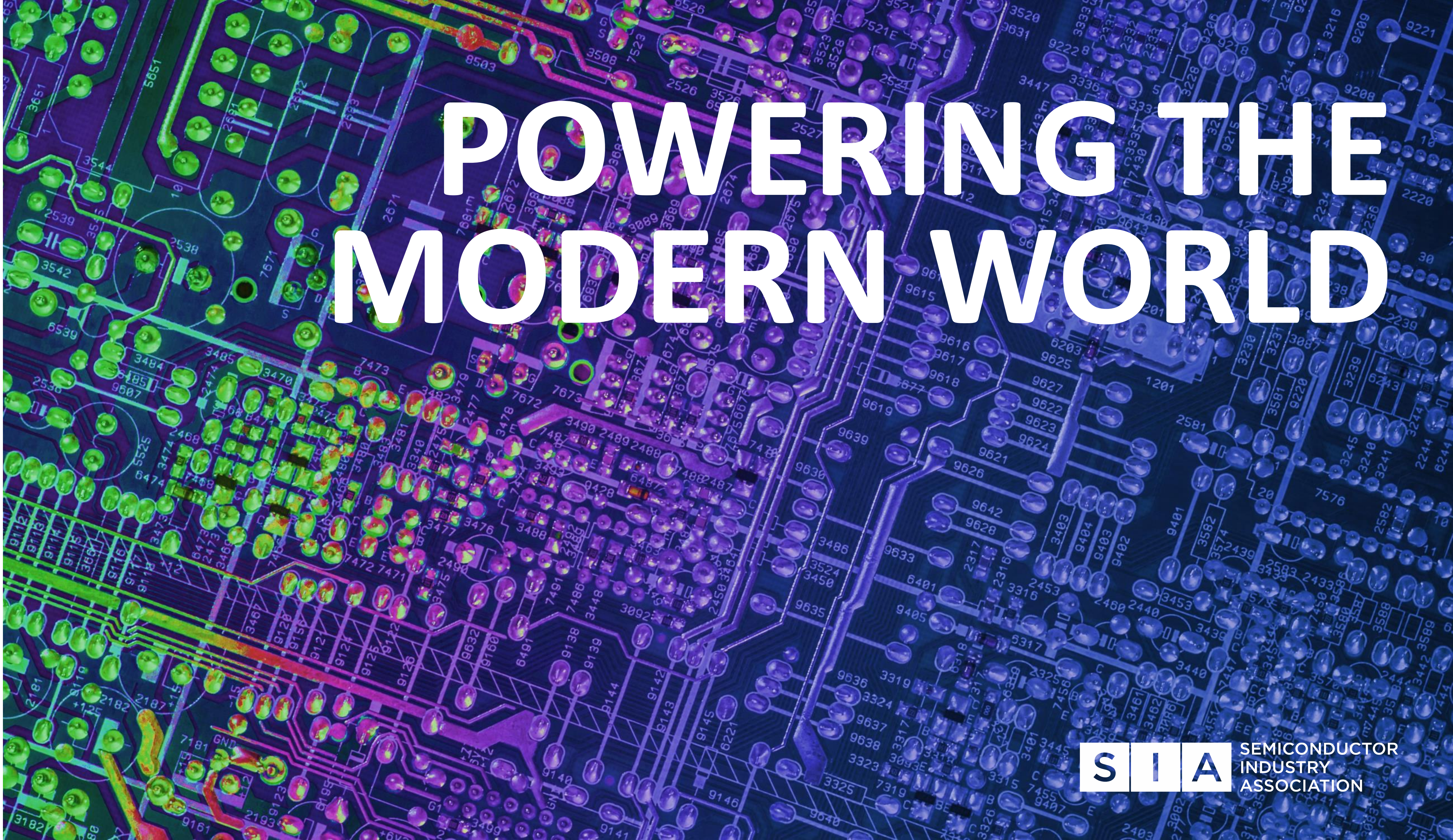
Security & Privacy of Heterogeneous Hardware Platforms

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?



POWERING THE MODERN WORLD

SEMICONDUCTOR INDUSTRY ASSOCIATION

2020