

SEMICON®WEST

BUILDING A PATH FORWARD

ACCELERATING THE R&D
OF MEASUREMENT,
ABATEMENT, AND
ALTERNATIVES

DR. TODD R. YOUNKIN

PRESIDENT & CEO
SEMICONDUCTOR RESEARCH CORPORATION (SRC)
TODD.YOUNKIN@SRC.ORG



#SEMICONWest



OUTLINE

- BOTTOM LINE UP FRONT (BLUF)
- WHO AM I AND WHO IS SRC?
- WHAT HAS SRC HISTORICALLY DONE IN ESH?
- WHAT IS SRC CURRENTLY DOING IN ESH (AND PFAS)?
- WHAT COULD SRC DO IN ESH OR “SSM” THRU REGIONAL R&D LIKE THROUGH NSTC?
- CALL TO ACTION

ESH = Environment, Safety, and Health
SSM = Sustainable Semiconductor Manufacturing

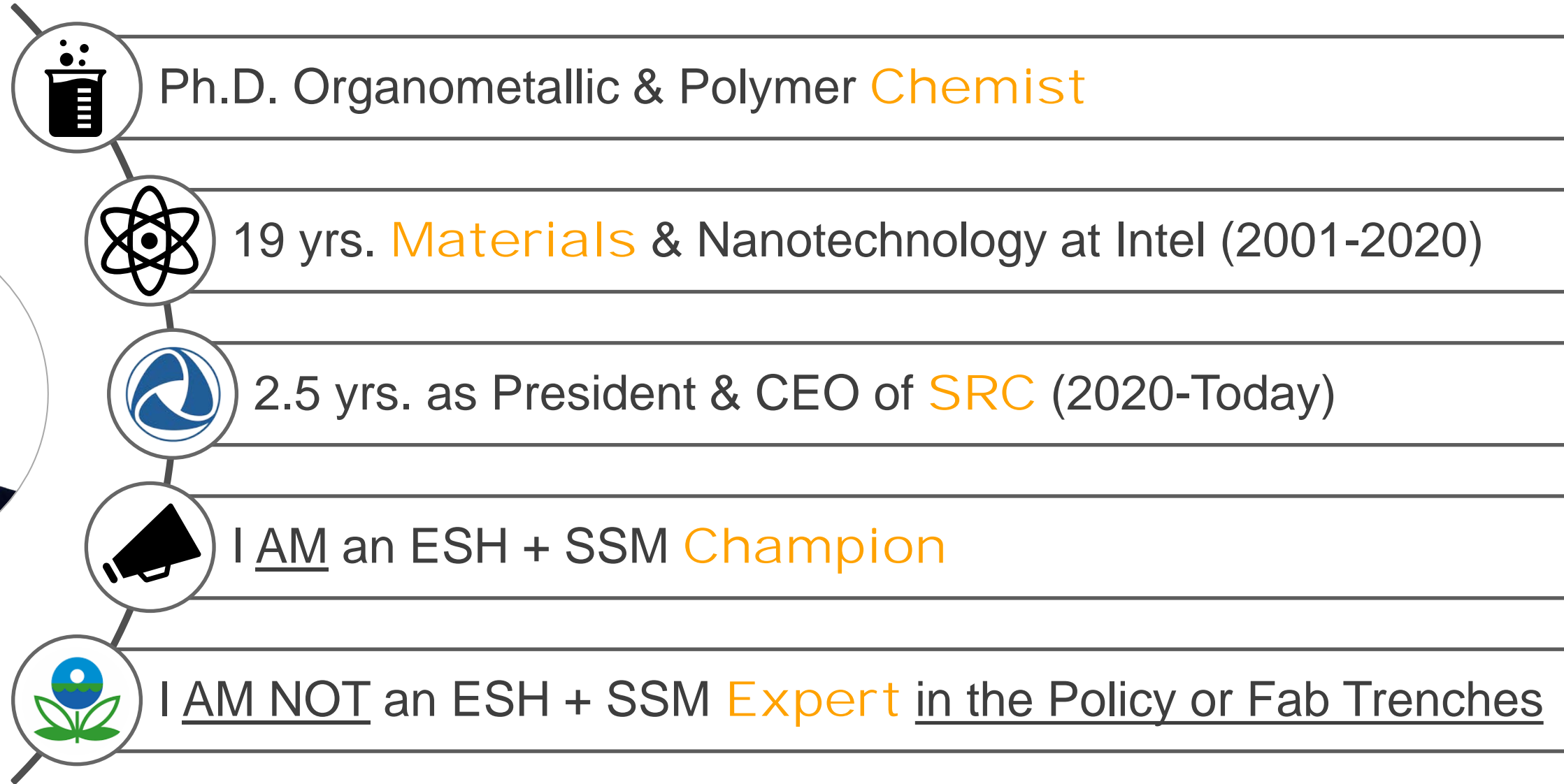
*ESH = Environment, Safety, and Health

**PFAS = Per- and PolyFluoroAlkyl Substances

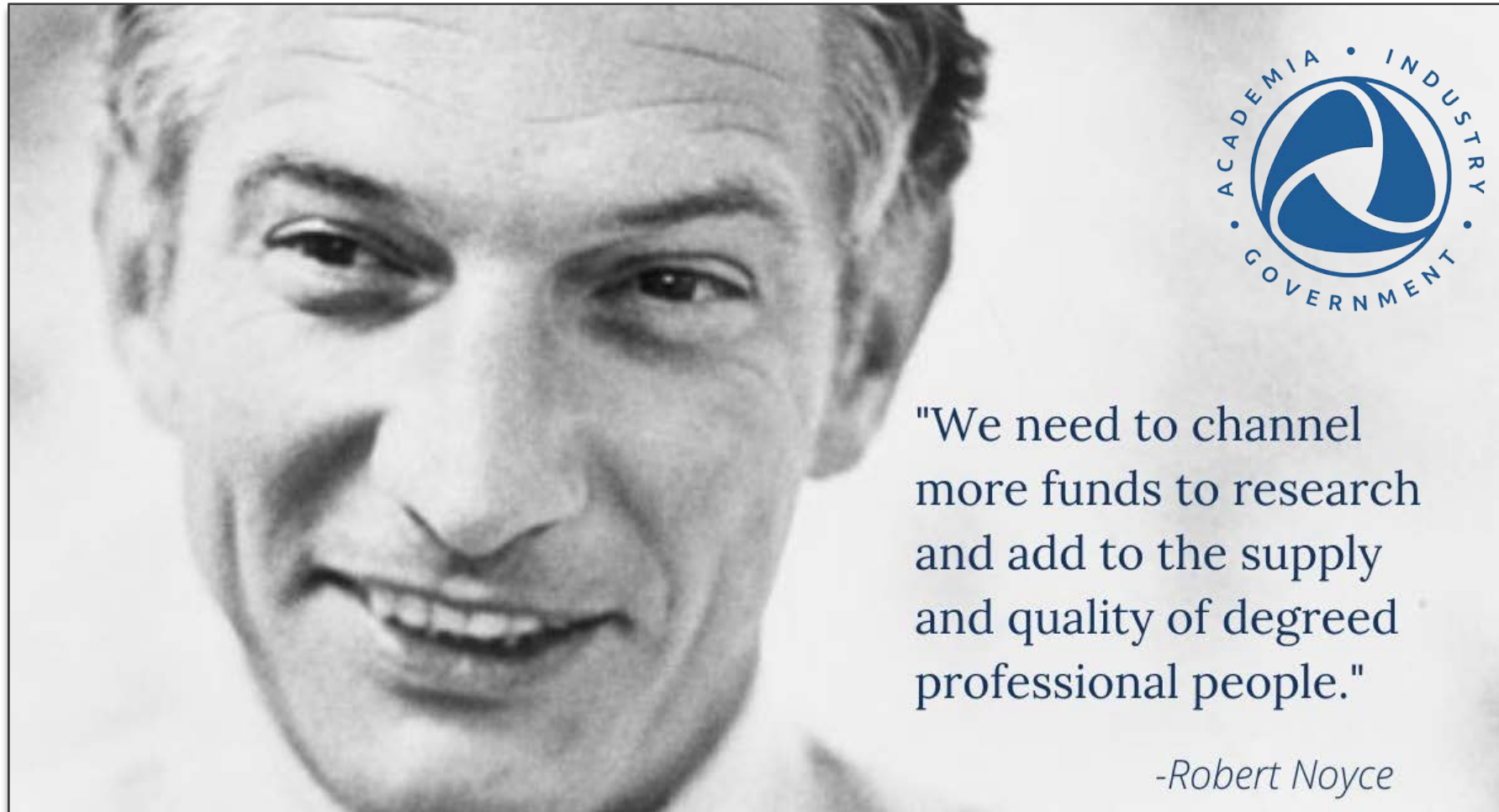
BLUF

- SRC WORKS AT THE 5-15 YR. TIME HORIZON, **ACCELERATING** LEARNINGS AND SOLUTIONS INTO INDUSTRY
- SRC HAS A 29-YR. COMMITMENT TO ESH* **R&D AND WFD** FOR SEMI
- **PFAS**** IS A CLASS OF **THOUSANDS OF CHEMICALS** WITH A COMPLICATED CHEMICAL AND POLICY LANDSCAPE
- THIS CLASS OF MATERIALS IS OF **GROWING PUBLIC CONCERN** AND REGULATORY AGENCIES ARE RESPONDING
- PFAS ARE **CRITICALLY IMPORTANT** TO SEMICONDUCTOR MANUFACTURING
- CURRENTLY **NO KNOWN SUBSTITUTES** FOR MOST, POSSIBLY ALL, OF THE APPLICATIONS THAT USE PFAS
- SRC **APPLAUDS** THE EFFORTS OF **SIA'S PFAS CONSORTIUM** AND **SEMI'S CLIMATE CONSORTIUM**
- REGIONAL GOV'TS NEEDED TO HELP INDUSTRY MAKE A COLLECTIVE COMMITMENT TO THE R&D OF **SOLUTIONS**
- WE MUST PROVIDE **SUFFICIENT TIME** TO IDENTIFY AND QUALIFY SUITABLE REPLACEMENTS
- THIS REQUIRES **SIZEABLE INVESTMENTS, GOAL CLARITY, AND A SENSE OF SHARED URGENCY**

WHO AM I?



SRC – IT'S SIMPLE YET POWERFUL



41 Years

Neutral, Trusted, Science-Driven

>\$2.5B in R&D Investments
>16,000 SRC Scholar Alumni

Drive & adapt to industry needs

COLLABORATIVE R&D CREATES TECH TRANSFER AND HIRES!

3
Gov't Agencies



28
Industry Titans



1-2 years
Pool members' direction and funds



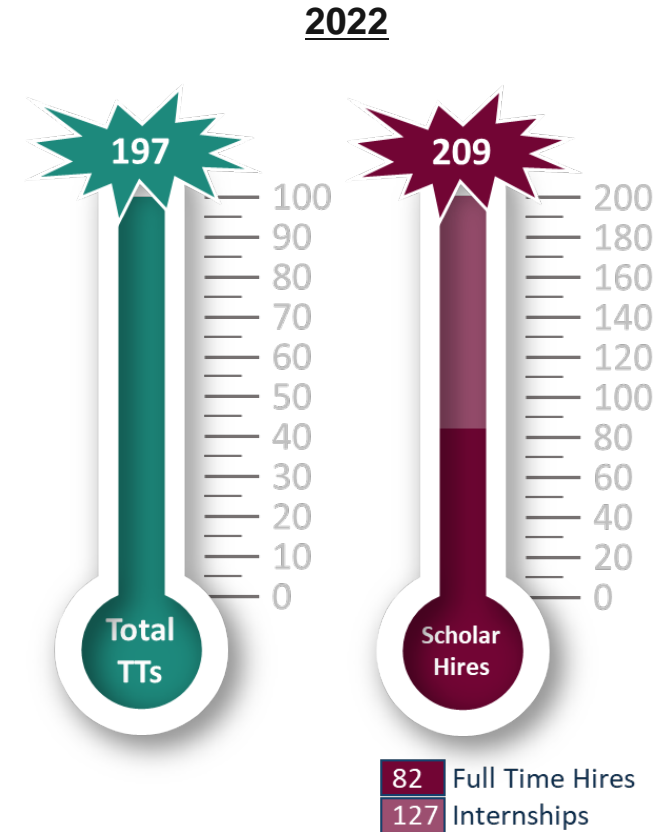
~\$100M in '23

3-5 years
Term of typical R&D or WFD Scope

~3k Scientists & Engineers



Key Perf. Indicators
Tech Transfers (TTs)
Scholars for Hire



In 2022, SRC exceeded its Technology Transfer and Scholar Hiring goals.
With support, SRC can scale up to 5x↑ annually to improve its reach and speed.

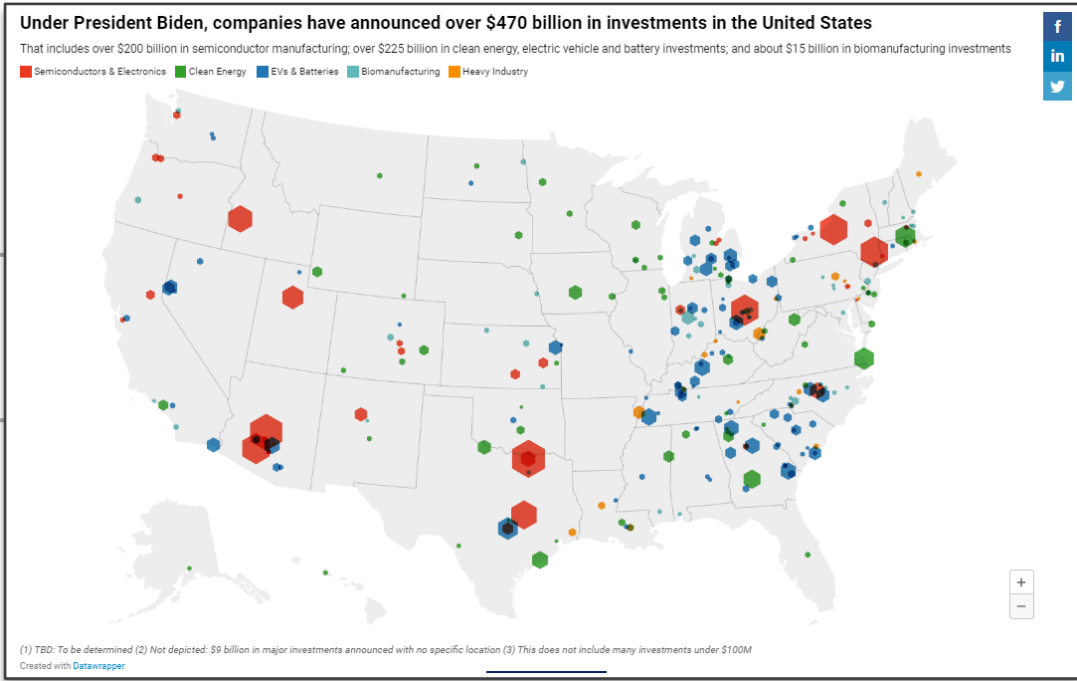
CHIPS ACT HAS SPURRED \$214B IN PRIVATE SEMI ANNOUNCEMENTS



U.S. Chips & Science Act

August 9, 2022

\$39B for Manufacturing; \$11B for R&D



<https://www.whitehouse.gov/invest/>

SRC Member Companies

- Analog Devices (OR)
- EMD Electronics (PA)
- GF (NY)
- IBM (NY)
- Intel (AZ, OH, NM)
- Micron (ID, NY)
- NXP (TX)
- Samsung (TX)
- SK Group (GA, MI)
- Texas Instruments (TX, UT)
- TSMC (AZ)



11 SRC Member Companies have announced \$190B (89%) in new U.S. semiconductor investments with ~35k direct jobs (~200k jobs estimated)

SRC'S THREE PILLARS FOR SEMI'S "ROARING 20S"

Prosperity

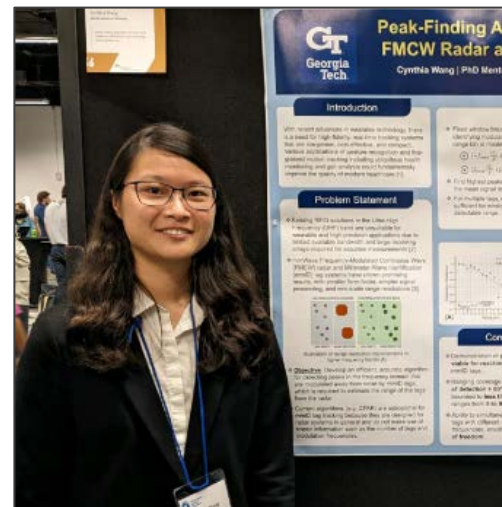


Nov 2020

2030 Decadal Plan for Semiconductors
3x↑ in Annual Funding
NIST Roadmap for Microelectronics and
Advanced Packaging (MAPT)

www.src.org/about/nist-mapt-roadmap

The People



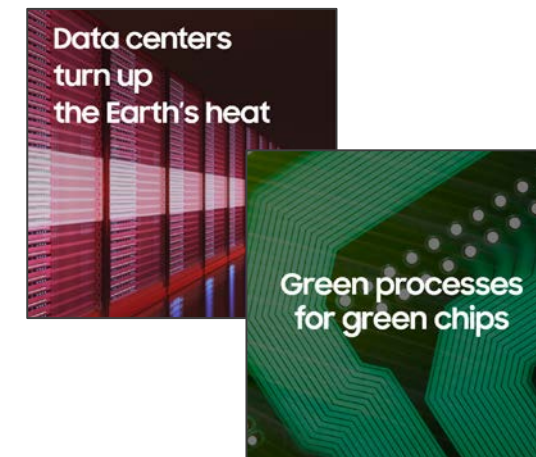
Apr 2021

Broadening Participation Pledge
3x↑ Scholar Pipeline (AA-PostDoc)
Greater Diversity, Equity, & Inclusion
Ignite passion for Semi in US
Workforce Advisory Board (WAB)

www.src.org/about/broadening-participation/

The Planet

Images from *Samsung*



Oct 2021

Commitment to Sustainability
Green Materials & Processes
Energy Efficient ICT Systems
**Win Hearts & Minds of
Next Gen Innovators**

<https://www.src.org/about/sustainability/>

Since Spring '22, SRC has used these 3 criteria to direct **\$350M+** in R&D & WFD investments

OUR COMMITMENT TO SUSTAINABILITY

SRC will drive an R&D agenda that delivers **greener materials and processes** for semiconductor manufacturing, creates chips and packages with **radically improved energy efficiency**, and drives a revolution in the efficiency of future information and communication technology systems **at scale**.

READ MORE AT [SRC.ORG/SUSTAINABILITY](https://src.org/sustainability)



An Open Letter to the SRC Board Published on **Sustainability Day** (Last Wed in Oct)

*ESH = Environment, Safety, and Health

SRC'S ESH* PROGRAM, HISTORICALLY AND TODAY

- 29 YRS OF CONSECUTIVE INVESTMENT IN SUSTAINABLE SEMI MANUFACTURING (SSM)
- >\$65M INVESTED, 1994 THRU DEC, 2027

- OUR ACTIVE ESH PROGRAM IS \$1.25M/YR.
- 3 YR, UNIVERSITY-LED RESEARCH PROJECTS
- 6 CORPORATE MEMBERS LED BY INDUSTRY EXPERTS

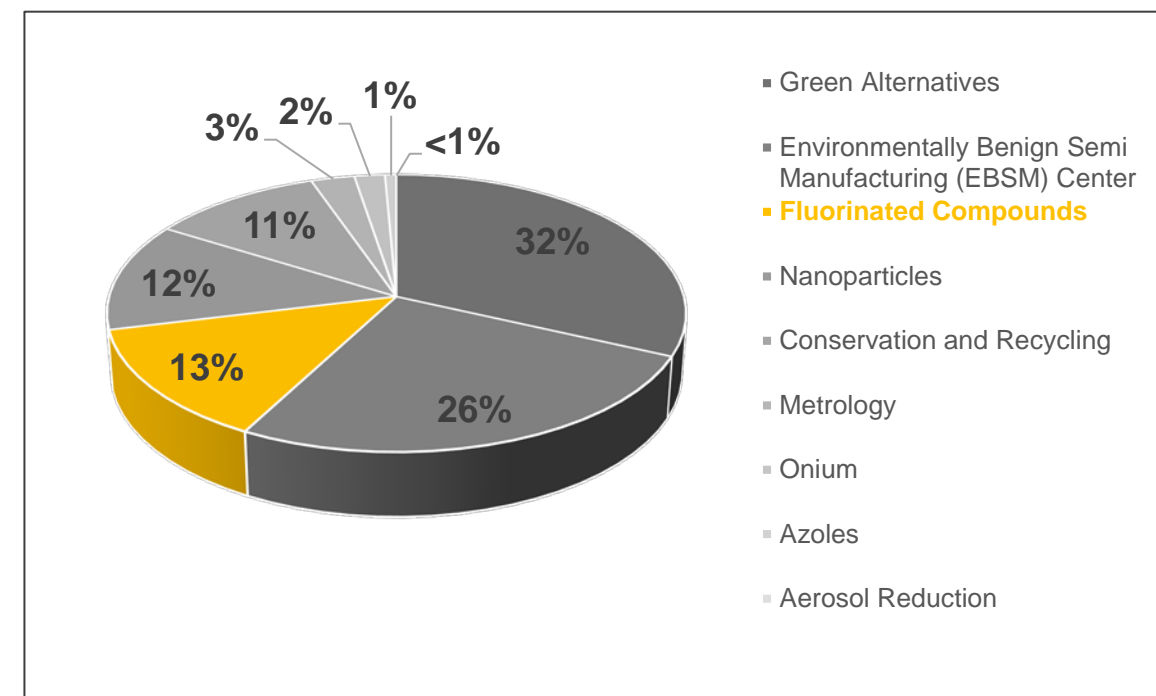


Advisory Board Member	Member Company
Tim Yeakley, Chair	Texas Instruments
David Speed, Vice Chair	Globalfoundries
Brooke Tvermoe	IBM
Bob Leet	Intel
Ralph Dammel	Merck KGaA (EMD Electronics)
Stefan Uhlenbrock	Micron



29 YRS OF FLUORINATED R&D PROJECTS (PFC, PFOS, PFAS, PFAS, ETC.*)

- ESH HAS EVALUATED AND ENABLED ENVIRONMENTALLY FRIENDLY MANUFACTURING SOLUTIONS FOR WAFER FABRICATION AND PACKAGING / TESTING
- RECENTLY BINNED HISTORICAL PROJECTS INTO CATEGORIES & MATERIAL CLASSES
- MANY ARE INTER-RELATED, BUT “**FLUORINATED COMPOUNDS**” BEST MATCH THE CURRENT MINDSET ON PFAS AND FLUORINATED “FOREVER CHEMICALS”
- LIKELY UNDERREPRESENTING SRC’S INVESTMENT SINCE SOME OF THE GREEN ALTERNATIVES (~32%) AND EBSM RESEARCH CENTER (~26%) OBJECTIVES ARE HARD TO BIN



ESTIMATE ~13% (~\$8.5M) OF OUR ESH PORTFOLIO SINCE 1994

*PFC = PerFluorinated Compounds, PFOS = PerFluorOctane Sulfonate, PFAS = PerFluoroAlkyl Sulfonate compounds, PFAS = Per- and PolyFluoroAlkyl Substances

*EBSM = 2001 Research Center with SRC, Sematech, NSF, plus 19 Companies, Universities, and Affiliates

A RECENT ESH SUCCESS STORY

NOVEL ELECTRICAL DISCHARGE PLASMA-BASED PROCESS FOR THE TREATMENT OF FAB WASTEWATER



2019-2021

Clarkson team “**demonstrated viability**,” developing “a process that is the most effective and efficient technology for the removal of long-chain, short-chain, and even ultra short-chain PFAS from factory wastewater” thanks, in part, to SRC’s industry engagement.



2022 IBM Intern

2021 Karecki Award

Ms. Osakpolo "Faith" Isowamwen. Her advisor calls her a “brilliant, independent and hardworking individual but as a researcher who thinks and stays two steps ahead” and “is determined to **pursue a career with a strong environmental focus.**”



2022 SRC Sustainable Future Award

The inaugural SRC award was granted at TECHCON-2022 in Austin, TX to **Prof. Selma Mededovic of Clarkson University** for leading this groundbreaking industry-relevant and impactful research.



2022-2024

Prof. Selma Mededovic and Thomas Holsen, (shown here w/ **DMAX Plasma, LLC., 2019 SBIR**) win a 3-year SRC sponsored research agreement to build upon the momentum of their outstanding research, to date.

CURRENT ESH TECHNICAL PRIORITIES

ALIGNED TO MICROELECTRONICS & ADVANCED PACKAGING TECHNOLOGIES AS THE DRIVERS

01

Growing emphasis on understanding and removal of Per- and Polyfluoroalkyl Substances (**PFAS**)

02

Treatment and abatement technologies for effluent, emission, and waste management

03

Alternative chemistries that eliminate or reduce hazardous materials or pose environmental and human health risk

04

Improvement of processes and systems to **reduce energy** and **minimize waste** generation

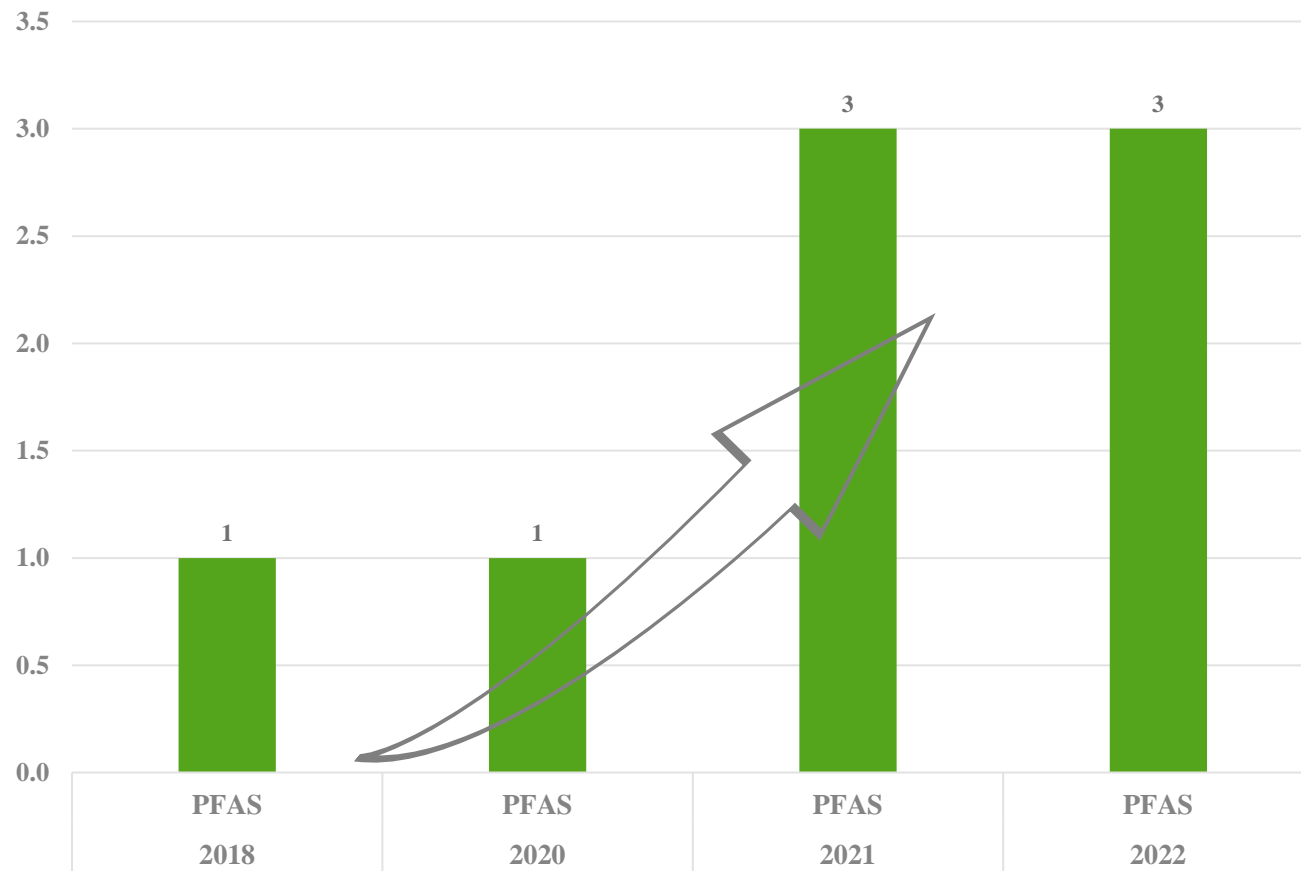
05

Reduction and return of **high purity water**

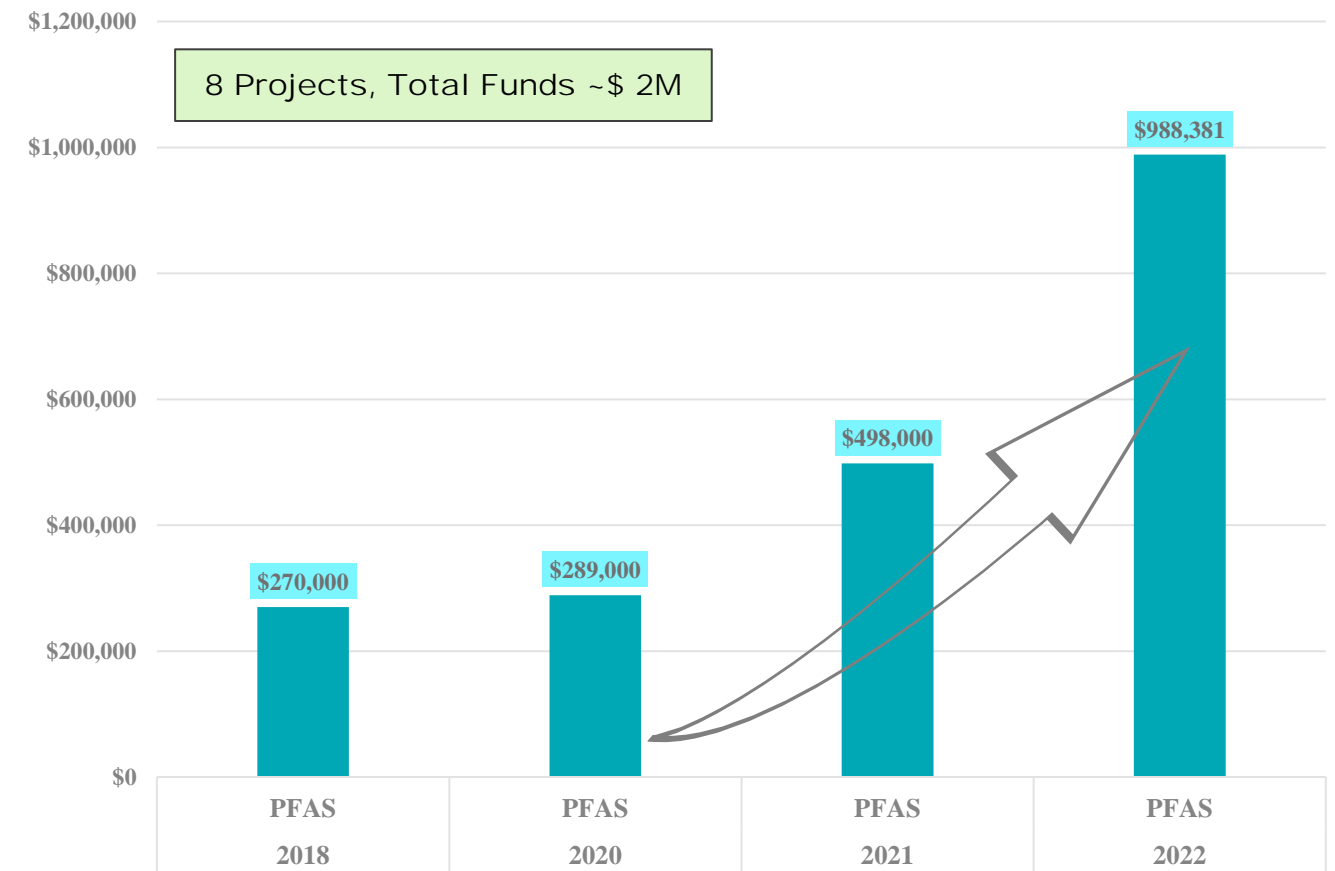
Real world measurement and metrology is a key element of all these objectives

PFAS-ONLY PROJECTS AND FUNDING HAVE SEEN INCREASED FOCUS

Number of Project Starts by Year

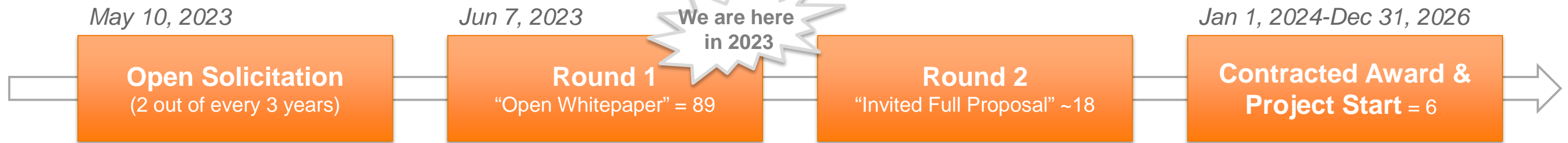


PFAS Research Funding (\$,USD) by Year



Increased Focus on PFAS

SRC GETS ~3-5X MORE GOOD IDEAS THAN DOLLARS AVAILABLE



89 Round 1 Whitepapers received from 85 Principal Investigators out of 65 Universities from 3 countries

Total requested funding = **\$10.5M/yr. or \$31.5M**

Only 6% of ideas received (\$630k/yr.) will be funded for Jan 1, 2024 start

Our Technical Advisory Boards (TABs) have consistently stated that SRC could award and direct ~3-5x more proposals without any loss of merit

Become a member

Broad Category	Category	Number of Whitepapers
Non-PFAS (60)	Green Manufacturing - Other	13
	Other ESH	47
PFAS (29)	Analytical - PFAS	10
	Green Manufacturing - PFAS	5
	Toxicity - F Chem	1
	Toxicity - PFAS	2
	Treatment - PFAS	11
Total		89

The WHAT



January 2021
2030 Decadal Plan for
Semiconductors

181 participants
81 organizations

The HOW



**Includes
ESH or SSM**

March 2023
NIST Microelectronics & Advanced
Packaging Technologies (MAPT)
Roadmap - Interim

279 participants
109 organizations

MAPT ROADMAP // CH.2 - SUSTAINABILITY AND ENERGY EFFICIENCY



Mar'23 SRC - Publishes Interim Microelectronics and Advanced Packaging Technologies Roadmap, Seeks Public Comments

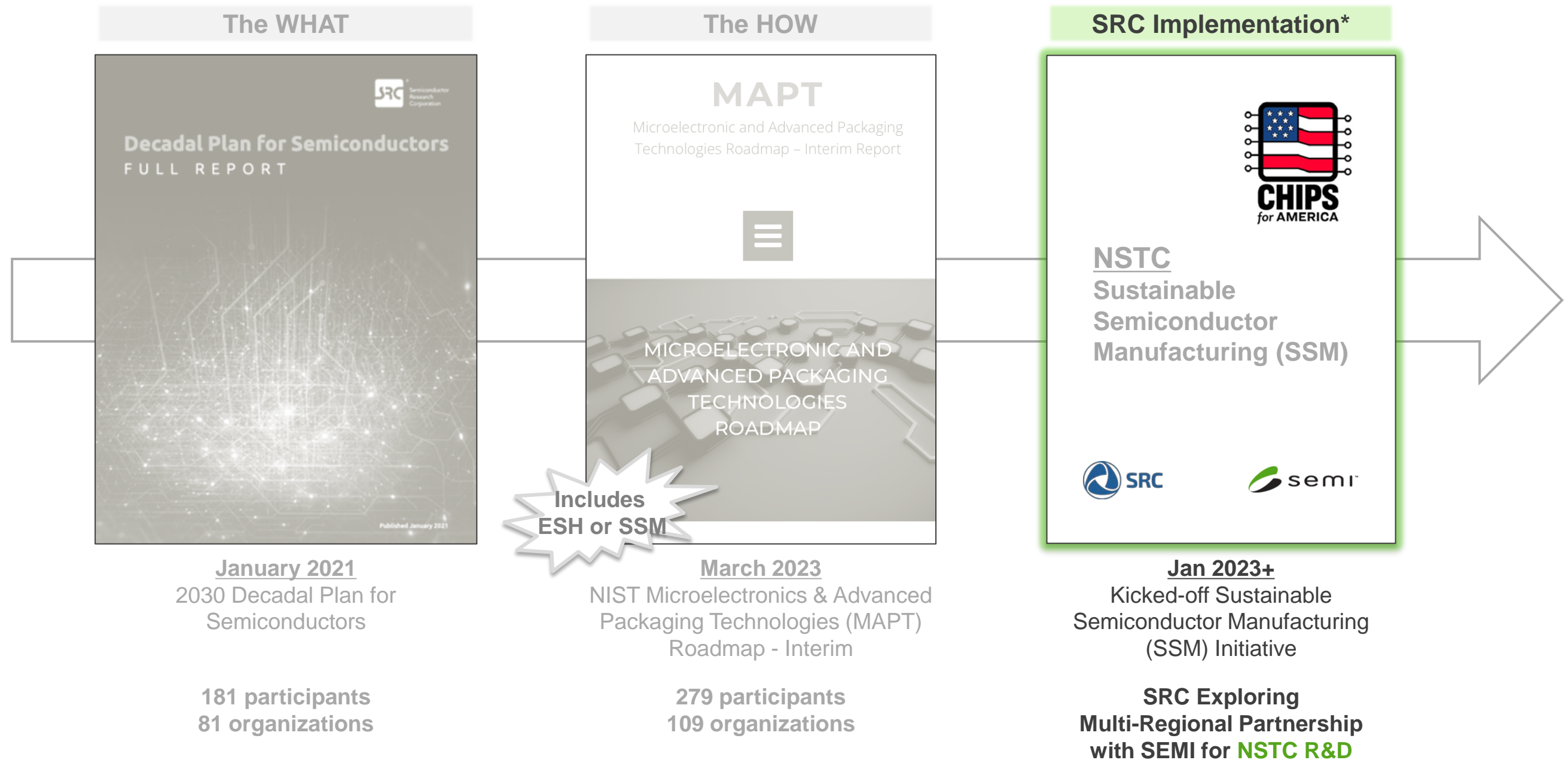
<https://www.src.org/about/nist-mapt-roadmap/>

“One of the greatest challenges facing the semiconductor industry today is the use of PFAS, a chemical class representing thousands of different compounds that are used pervasively throughout multiple industries including the semiconductor industry...”

Table 2. Overview of PFAS use within semiconductor manufacturing.

Application	PFAS Attributes
Photolithography: photoacids, antireflective coatings, immersion barriers, surfactants	Thermal stability (low and high temperatures); low volatility; chemically resistant; good compatibility with photoresist; transparent at key wavelengths; strong non-nucleophilic photoacids; inert; good solubility
Etching gases/chamber cleans: tetrafluoromethane (CF ₄); hexafluorobutadiene (C ₄ F ₆); octafluorocyclobutane (C ₄ F ₈)	High selectivity, surface reaction, and etch rate. F-containing gas forms a volatile compound with Si substrate.
Advanced packaging materials: Adhesives, substrate buildup, flux	Chemical compatibility, required photoactive hydrophobicity/ wetting control, reduces surface energies, high temperature stability, defoaming, surfactant
Wet etch chemistries	Nonfoaming, high selectivity for SiO ₂ , low particulate adhesion, excellent surface smoothness, nonreactive with other chemicals in etch formulation
Heat transfer fluids/thermal test fluids: Used to maintain process temperatures (-60°C to 80°C) in test equipment	Low viscosity and the low temperature dependence of viscosity, appropriate dielectric properties, wide operating temperature range, low surface tension, chemical stability

*SRC is also pursuing a Manufacturing USA Institute and working to support and feed other NSTC technical centers, the NAPMP, and the NIST Metrology program



January 2021
2030 Decadal Plan for Semiconductors

181 participants
81 organizations

March 2023
NIST Microelectronics & Advanced Packaging Technologies (MAPT) Roadmap - Interim

279 participants
109 organizations

Jan 2023+
Kicked-off Sustainable Semiconductor Manufacturing (SSM) Initiative

SRC Exploring Multi-Regional Partnership with SEMI for NSTC R&D

BUILDING A PATH FORWARD

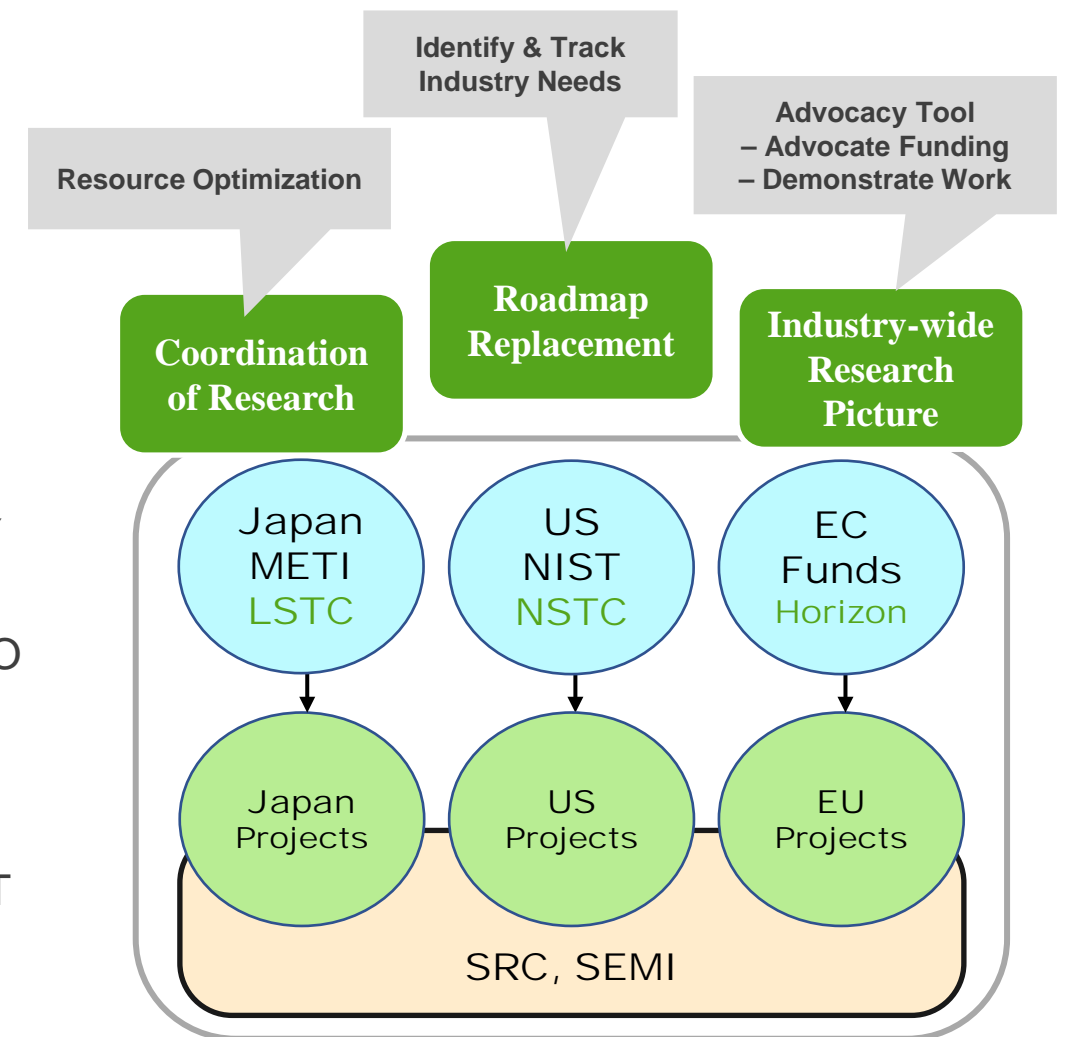
#SEMICONWest

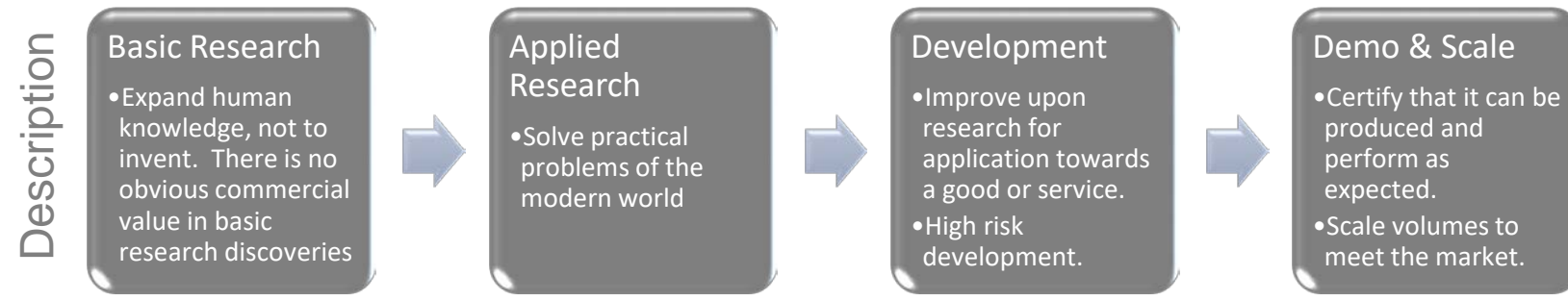


SUSTAINABLE SEMICONDUCTOR MANUFACTURING (SSM)

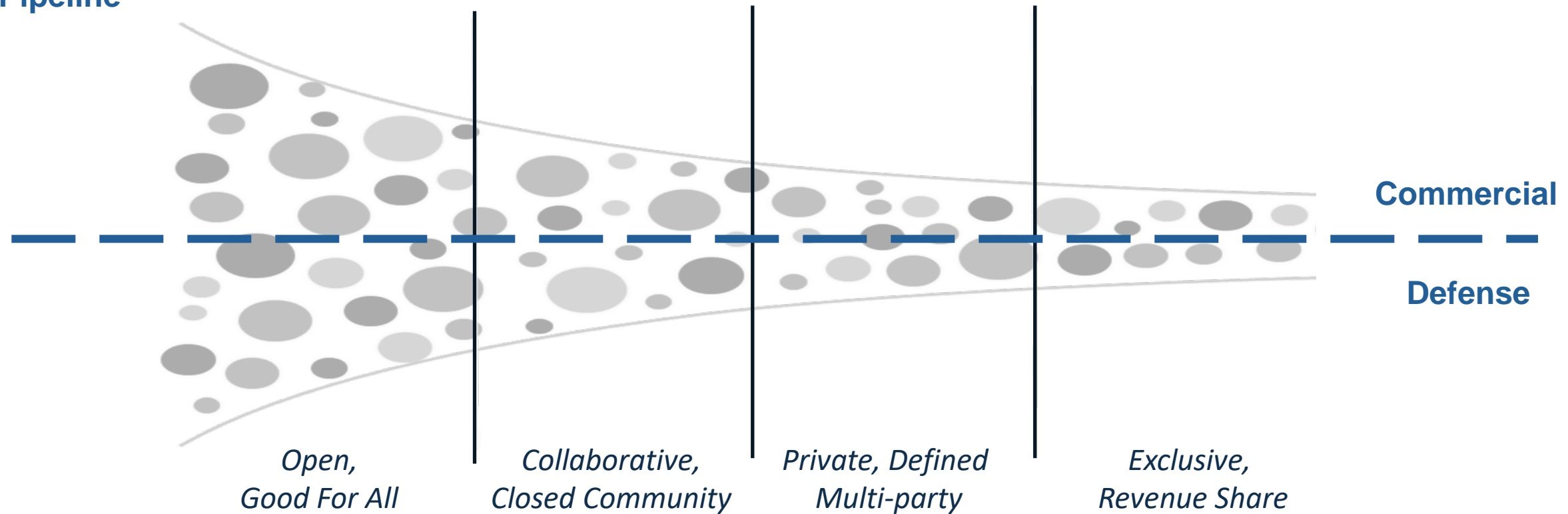
PROPOSED INITIATIVE

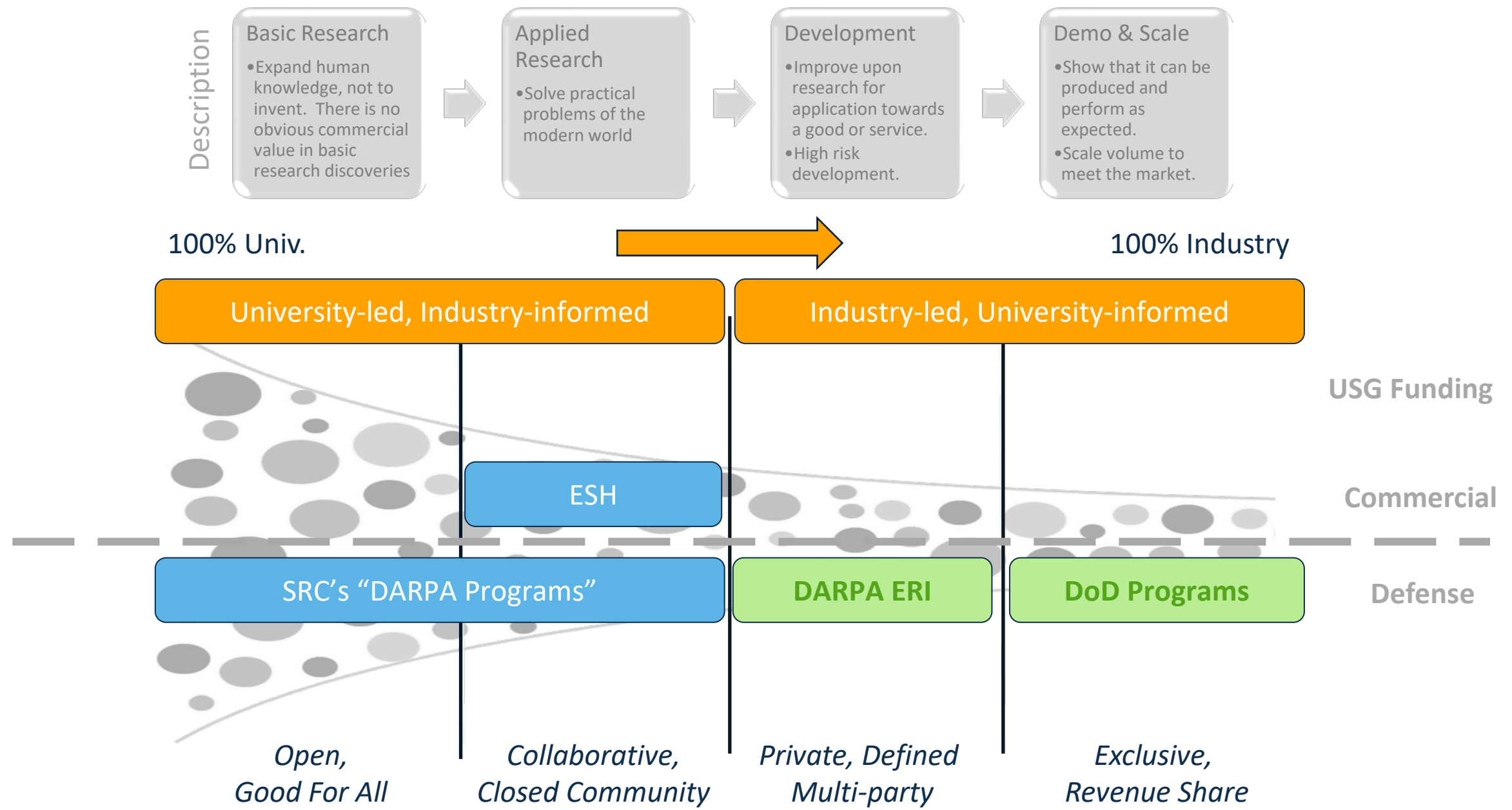
- REGIONAL GOVT'S PROVIDE FUNDS TO INDUSTRY & ACADEMIA TO EXPLORE SUSTAINABLE SEMI MANUFACTURING (SSM) **R&D PROJECTS** FOR THEIR REGION
 - Japan - METI and LSTC
 - US - NIST and the NSTC
 - EU Commission (Horizon Europe)
- SSM PROJECTS SHOULD INCLUDE:
 - Develop safe alternatives to PFAS-containing chemicals**
 - Develop safe alternatives to greenhouse gasses**
 - Reduce water use, electricity use, and waste generation**
- GOV'T FUNDING SHOULD BE IN THE FORM OF **MATCHING DOLLARS** DIRECTED BY INDUSTRY ON SSM PROJECTS
- PROJECTS COULD BE CONTRACTED THROUGH SRC AND/OR SEMI, WHICH CAN ALSO PROVIDE A **DATA SHARING** ROLE AND **CENTRAL COORDINATION**
- THIS (PROPOSED) **ALLIANCE** WILL ELIMINATING REDUNDANCIES AND CAN LEVERAGING LEARNINGS BETWEEN REGIONS TO DRIVE A BIGGER AGENDA
- AN **INDUSTRY-WIDE STRATEGY** IS URGENTLY NEEDED TO DEAL WITH 3-M'S SHUT DOWN OF PFAS PRODUCTION AND GROWING ENVIRONMENTAL REGULATIONS IN AREAS WITH NO KNOWN ALTERNATIVES

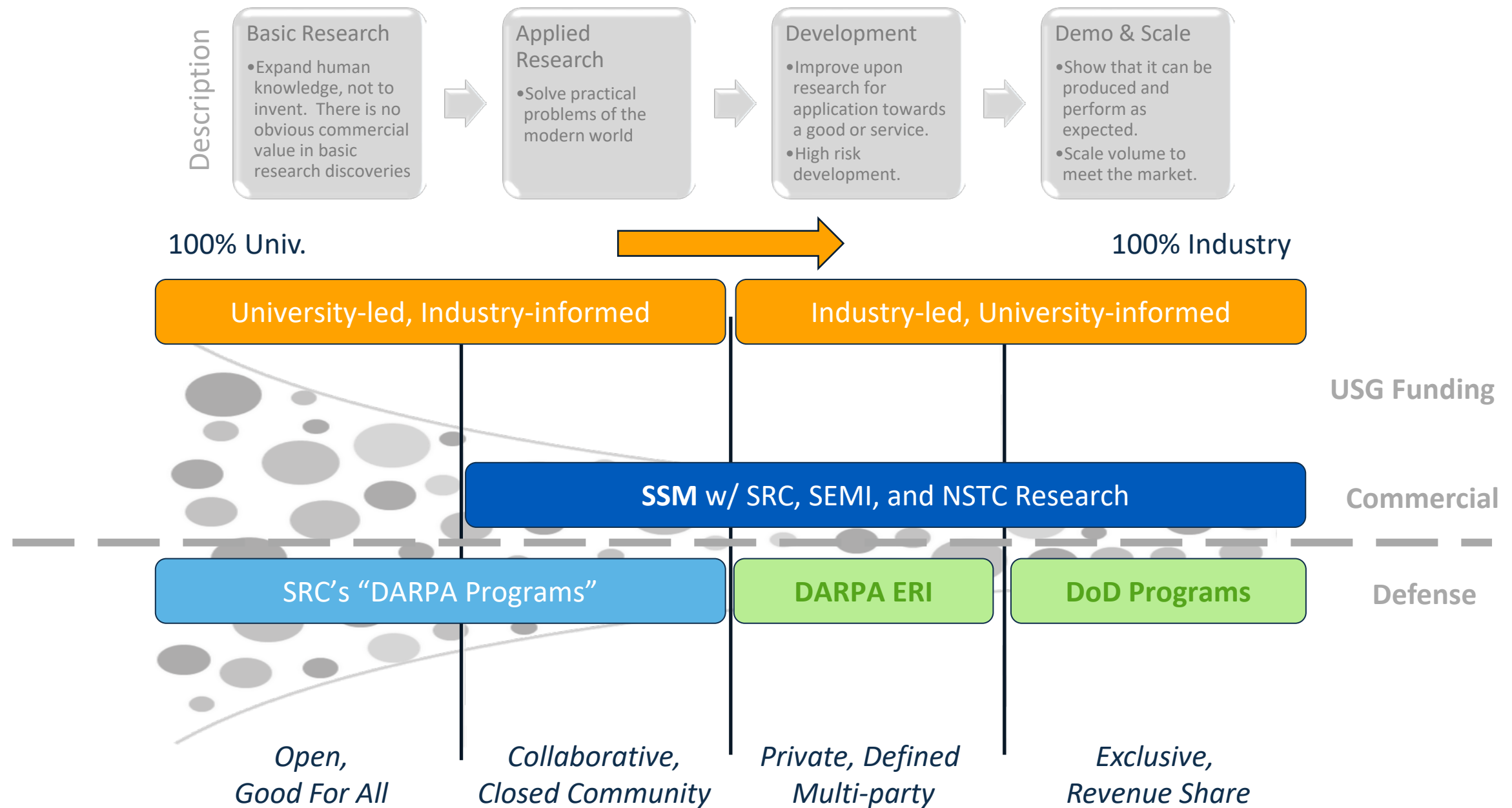




R&D Pipeline







Engage the Next Generation!



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

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

Convey to scholars that opportunities are abundant for the next 20-30 years

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

*SOTA = State of the Art

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

THERE IS NO PLANET B!



SRC'S CALL TO ACTION

- TO MEET THE NEEDS OF SRC'S MEMBERS AND THE INDUSTRY WE SERVE, SRC WILL CONTINUE TO:
 - INVEST IN OUR **THREE PILLARS** (PROSPERITY, PEOPLE, AND THE PLANET) AND
 - INVEST IN **ESH** THRU ACADEMIC PROJECTS ON MEASUREMENTS, ABATEMENT, AND ALTERNATIVES
- THERE IS AN OPPORTUNITY TO BUILD UPON OUR WORK, THRU SSM THAT EMPHASIZES:
 1. THE DEVELOPMENT OF SAFE ALTERNATIVES TO PFAS-CONTAINING CHEMICALS
 2. THE DEVELOPMENT OF SAFE ALTERNATIVES TO GREENHOUSE GASSES
 3. THE REDUCTION OF WATER USE, ELECTRICITY USE, AND WASTE GENERATION
- SSM MUST BE A **PARTNERSHIP** THAT FUNDS/ENGAGES ALL PARTS OF THE ECOSYSTEM
- REGIONAL GOV'TS ARE NEEDED TO HELP INDUSTRY **JUMP-START** A COLLECTIVE COMMITMENT TO THE R&D OF SOLUTIONS THAT ARE IMPORTANT TO DIFFERENT STAKEHOLDERS
- WE MUST PROVIDE SUFFICIENT TIME TO IDENTIFY AND QUALIFY SUITABLE REPLACEMENTS
- SSM REQUIRES **SIZEABLE INVESTMENTS, GOAL CLARITY, AND A SENSE OF SHARED URGENCY**

SEMICON[®]WEST

BUILDING A PATH FORWARD

THANK YOU

todd.younkin@src.org



#SEMICONWest



2030 DECADAL PLAN FOR SEMICONDUCTORS



Nov' 20 - Newly-Announced \$3.4 Billion Plan Aims to Stimulate US Semiconductor R&D

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

Five “Seismic Shift” Research Priorities



Smart Sensing

The Analog Data Deluge



Memory & Storage

The Growth of Memory and Storage Demands



Communication

Communication Capacity vs. Data Generation



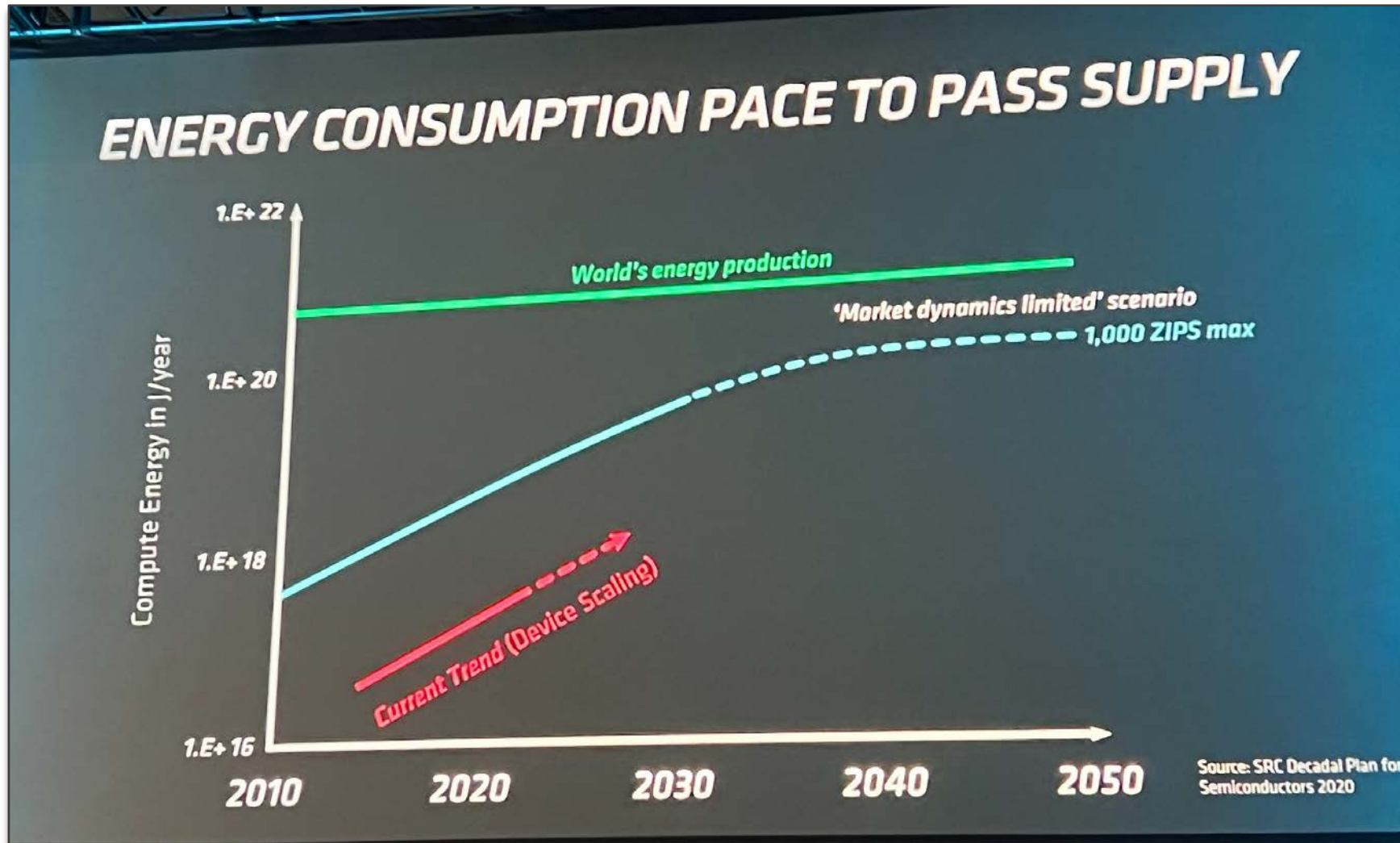
Security

ICT Security Challenges



Energy Efficiency

Compute Energy vs. Global Energy Production



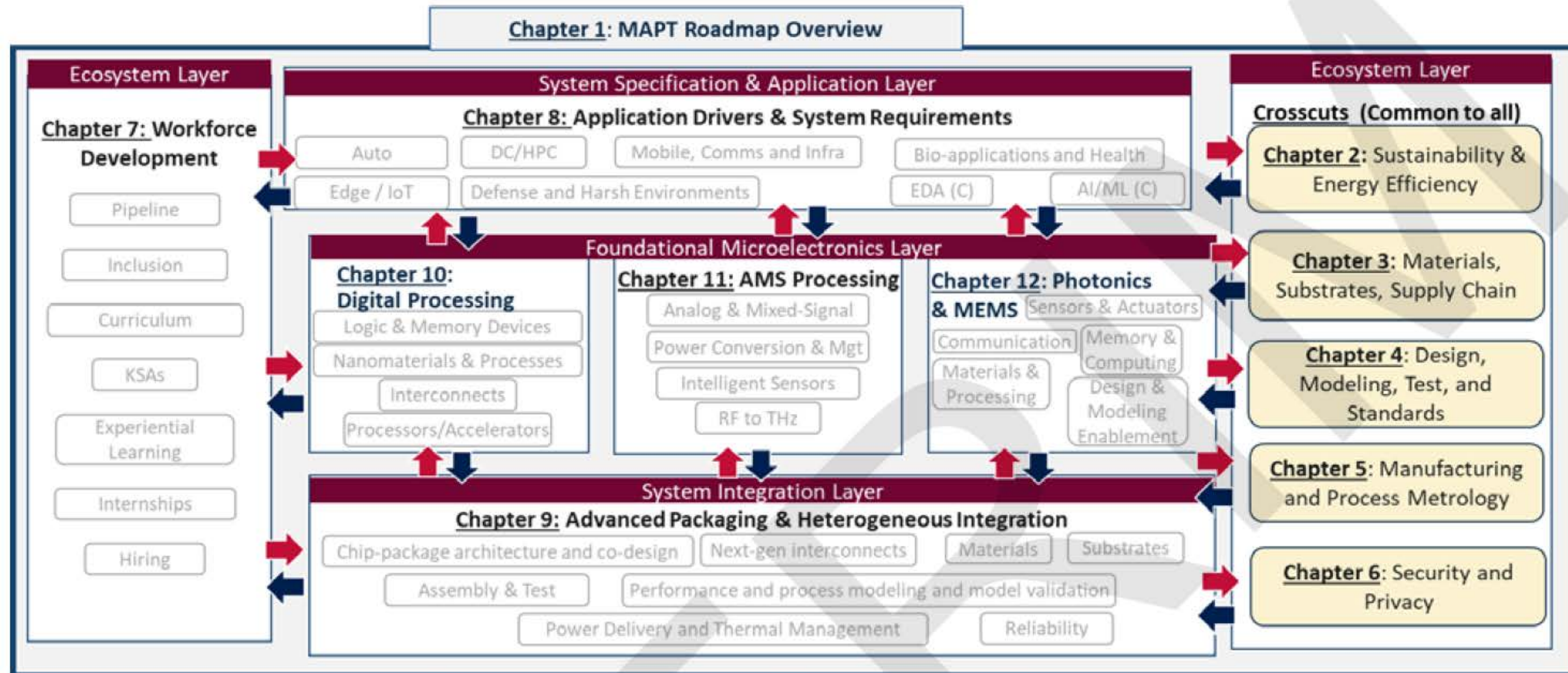
"SRC has done a great job with their Decadal Plan to highlight this issue....of course it's not just the energy used, it's the impact on Planet Earth."



Mark Papermaster,
AMD CTO

[Semi Engineering - What Future Processors Will Look Like](#)

NIST MAPT ROADMAP – ORGANIZATIONAL STRUCTURE



INTERIM SUMMARY – SUBJECT TO CHANGE