Trusted & Assured Microelectronics (T&AM) Education & Workforce Development (EWD)

SCalable Asymmetric Lifecycle Engagement (SCALE) Overview

Peggy E. Williams, Ph.D.
SCALE Defense Agency – Industry Liaison
NSWC Crane
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Dr. Kara Perry, T&AM Education & Workforce Development Co-Lead OUSD(R&E) OASD(CT)
Karin DuBois, Amentum Contract Support
Angie Taylor, Peerless Technologies – Business Analyst
Dr. Mona Vakilifathi, ETW Solutions

A ready workforce is required for the U.S. to lead high-performance microelectronics for decades to come

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BLUF

- A skilled technical workforce is required to ensure success of Department of Defense (DoD) modernization initiatives
- National security needs encompass those disciplines with the lowest representation of domestic students
- T&AM has invested in the SCalable Asymmetric Lifecycle Engagement (SCALE) Program to:
  - connect specially trained clearable students with ME defense sector
  - deliver tailored curriculum and provide student access to SOTA tools and processes to produce a more ready workforce
  - scale to meet the national needs; nationally coordinated and regionally executed
- T&AM has invested in Microelectronics (ME) Security Training (MEST) Center to:
  - upskill the existing workforce and improve retention
  - provide DoD personnel access to the newest, cutting-edge microelectronics education and tools from world-class leaders in academia free of charge

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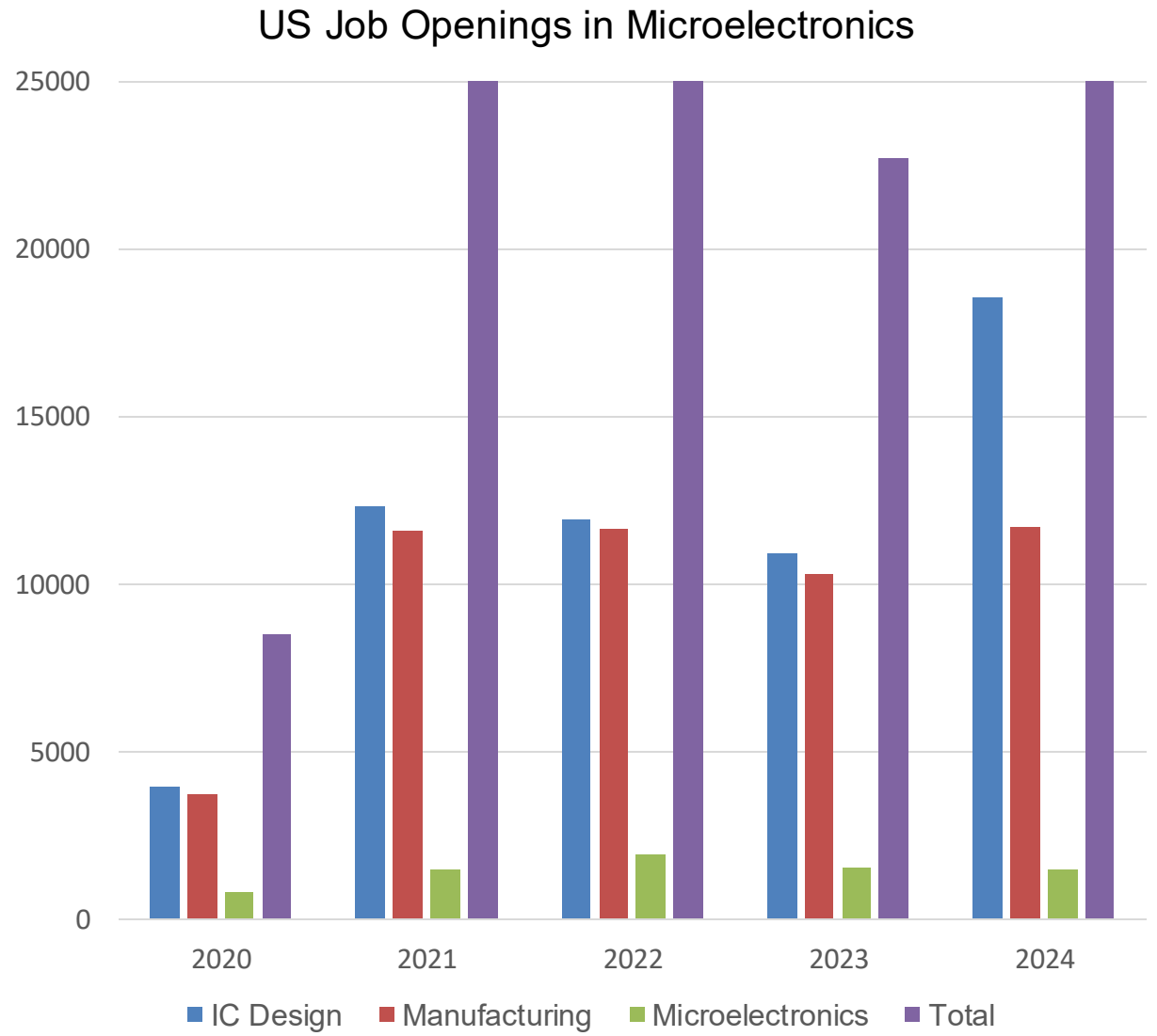
Urgency of Need for Increased Microelectronics Workforce

SCALE
Scalable Asymmetric Lifecycle Engagement
Developing the U.S. Defense Microelectronics Workforce

- US demand for microelectronics employees is increasing rapidly, particularly in the public sector
- At same time, the number of students dropped with the pandemic – the Indiana Commission for Higher Education (ICHE) indicated that this was “the lowest rate—and sharpest decline—in at least a generation”



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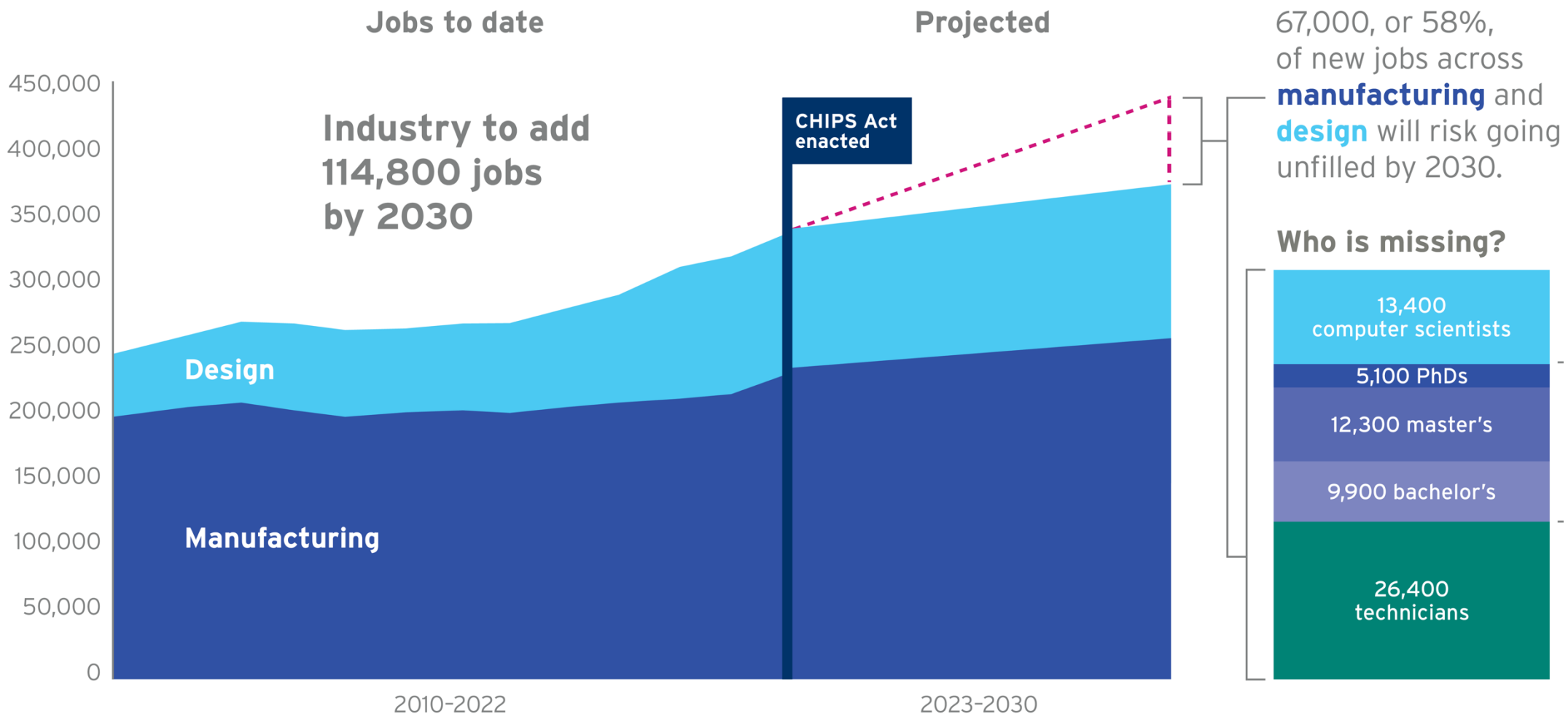
Current and Projected Microelectronics Workforce Needs: Industry Projections



Source: Semiconductor Industry Association, Chipping Away Report, July 2023

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T&AM Education and Workforce Development - What Informs Investments?

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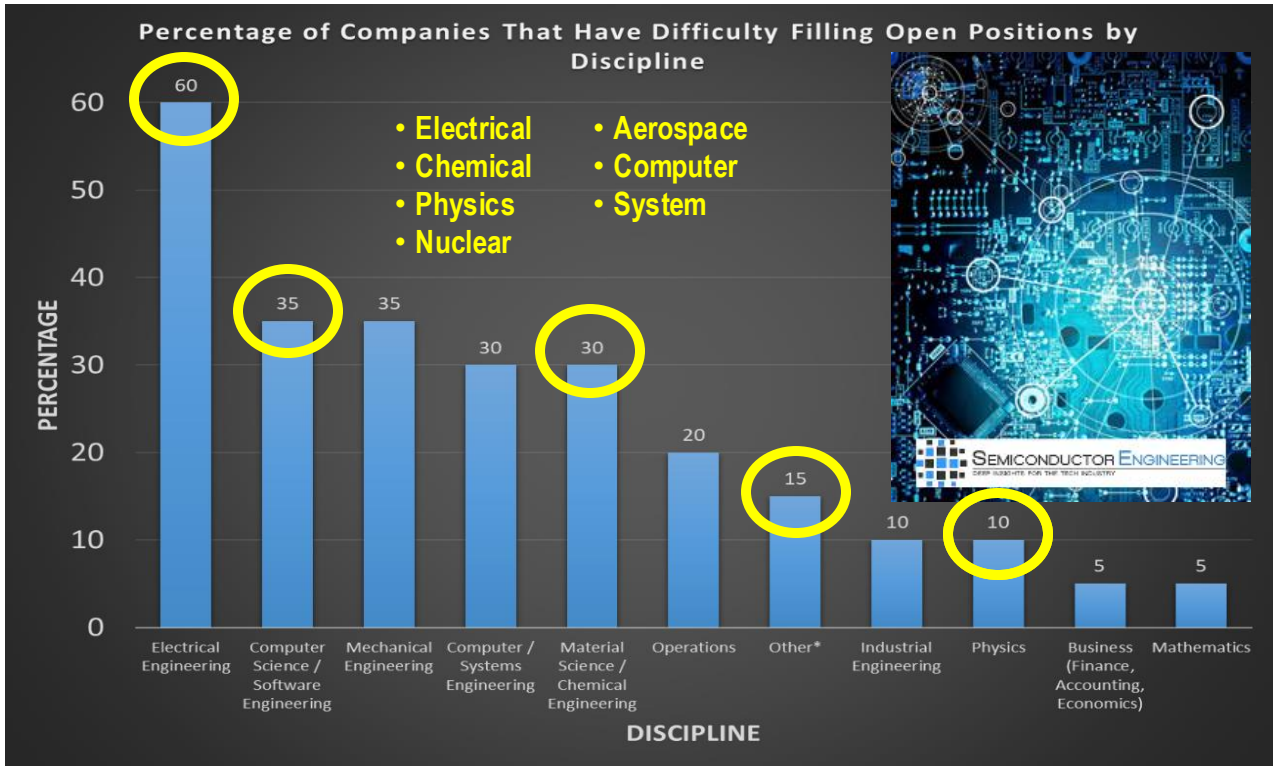


State of the Microelectronics Industry

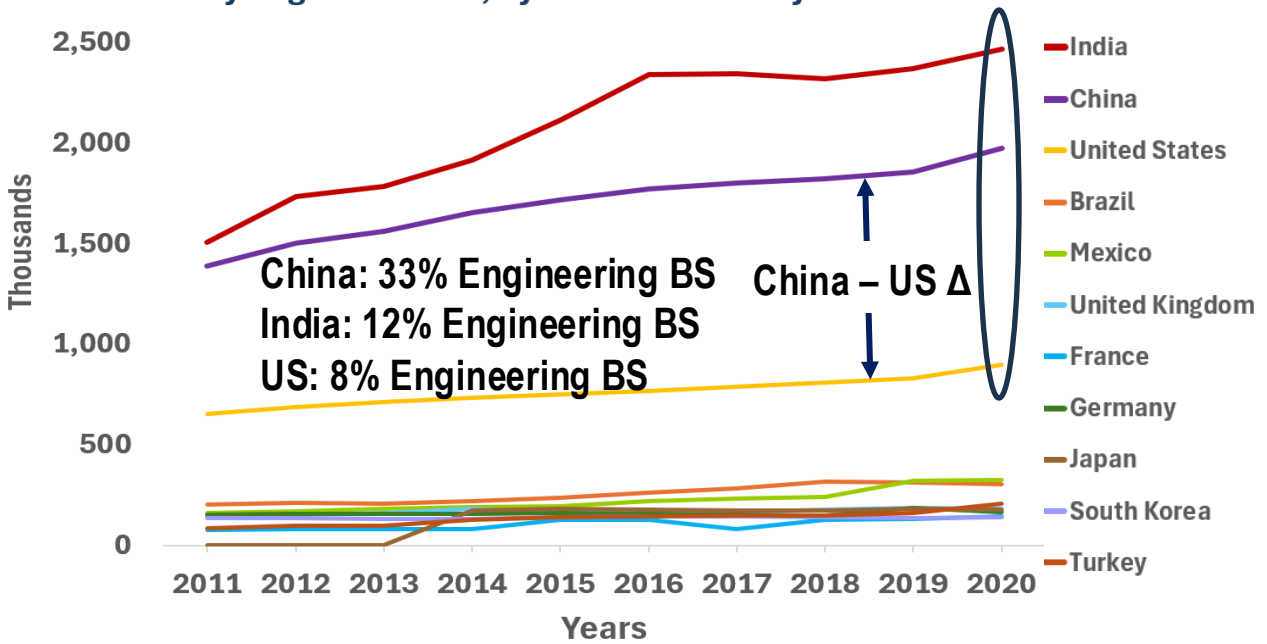
➢ *Interdisciplinary & Unique Needs Within a Competitive STEM Market*

Global Science & Engineering Indicators

➢ *Global Supply of High Demand Engineers Far Outpaces US Supply, Especially From China*

NATIONAL SCIENCE BOARD
SCIENCE & ENGINEERING INDICATORS 2024

First university degrees in S&E, by selected country: 2011 - 20



T&AM Education and Workforce Development - What Informs Investments?

State of US Science & Engineering

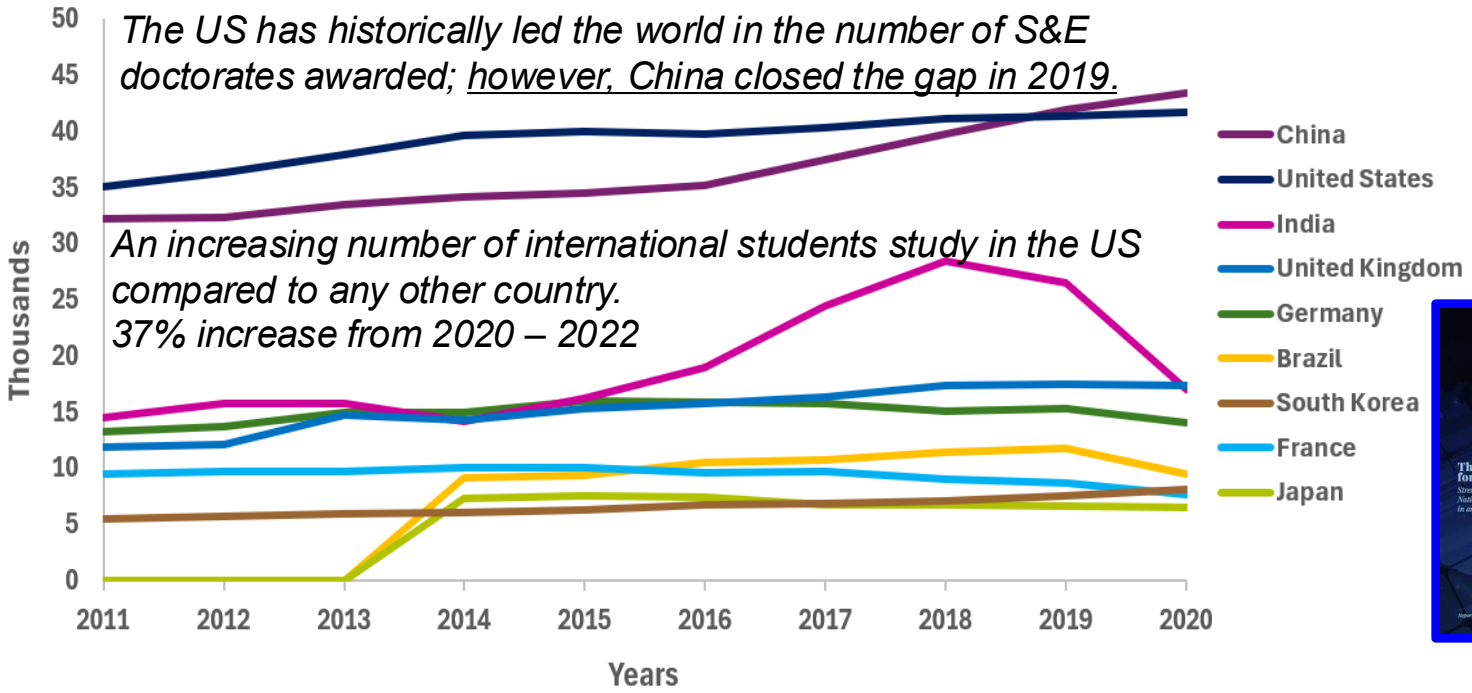
For National Security STEM Discipline Needs:

- ***Lowest overall domestic student representation***
- ***Largest influx of international students***

S&E doctoral degrees, by selected countries: 2011 - 20

The US has historically led the world in the number of S&E doctorates awarded; however, China closed the gap in 2019.

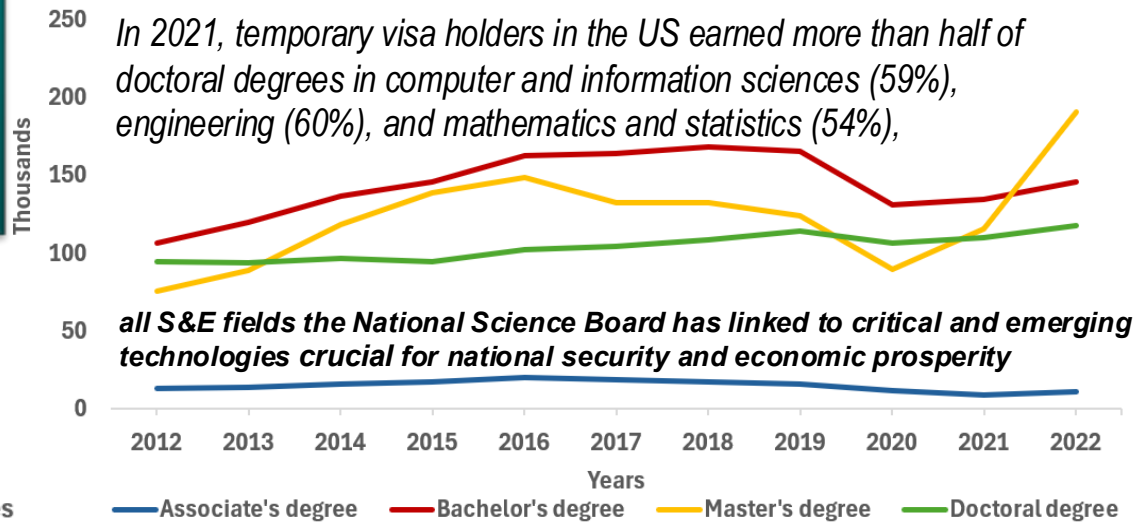
An increasing number of international students study in the US compared to any other country.
37% increase from 2020 – 2022



S&E student temporary visa holders enrolled in US higher education institutions, by level of enrollment: 2012 - 22

In 2021, temporary visa holders in the US earned more than half of doctoral degrees in computer and information sciences (59%), engineering (60%), and mathematics and statistics (54%),

all S&E fields the National Science Board has linked to critical and emerging technologies crucial for national security and economic prosperity



As much as emerging technologies will, "***the war for talent will likely play the central role*** in the outcome of long-term technological competition."

The National Security Innovation Base (NSIB) struggles to attract, recruit, and retain a workforce willing and able to tackle tough challenges and find innovative solutions. Universities are confronting a dearth in American talent generation and retention. Much of that shortfall is filled with foreign students, a large share of them from China.

DoD Specific Workforce Needs

DoD and defense industrial base (DIB) have the additional challenges when it comes to competing for talent:

1) Workforce must be clearable
   - Universities are confronting a dearth in American talent generation and retention
   - Much of that shortfall is filled with a large share of foreign students from adversarial nations, 25 – 80% depending on degree field and level.[1]

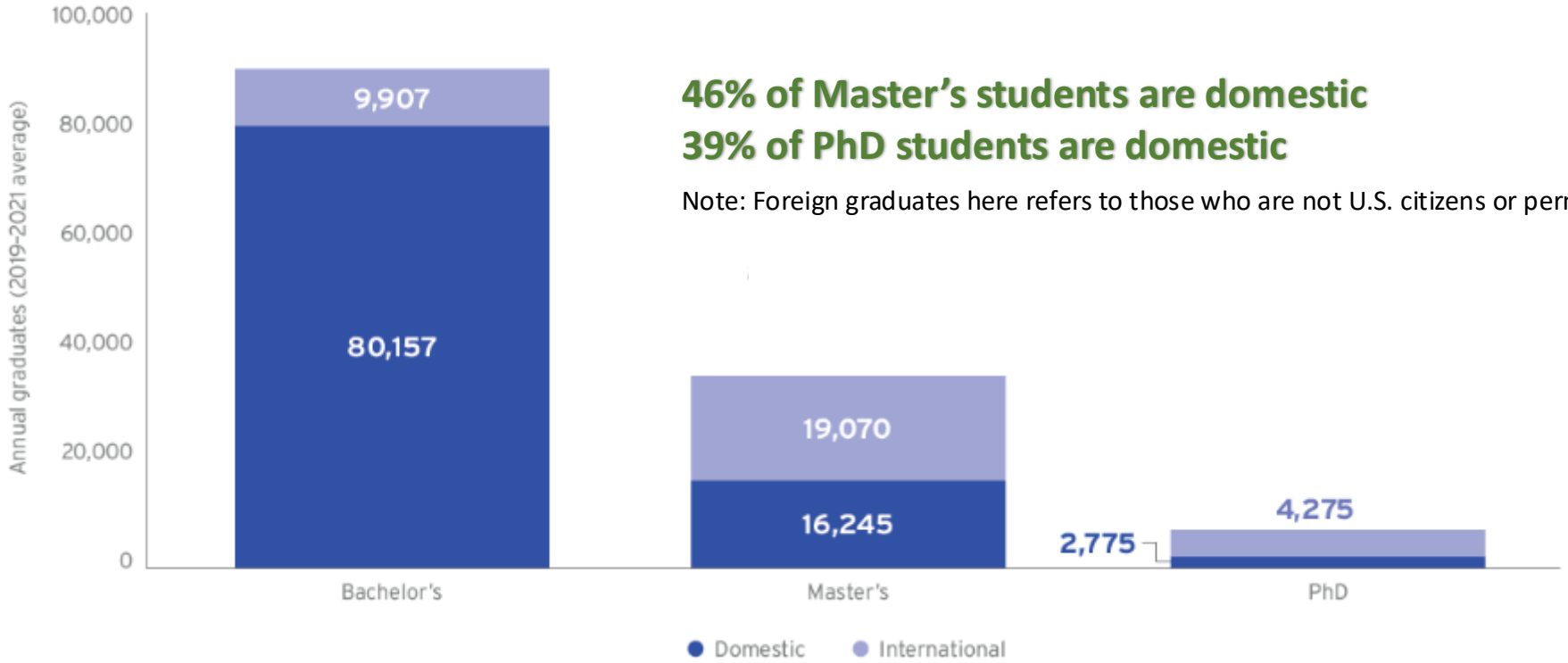
[1] The Contest for Innovation: Strengthening America's National Security Innovation Base in an Era of Strategic Competition. Report of the Task Force on 21st Century National Security Technology and Workforce. 2019

Clearable Workforce

SEMICONDUCTOR INDUSTRY ASSOCIATION

SIA July 2023 Report "CHIPPING AWAY: ASSESSING AND ADDRESSING THE LABOR MARKET GAP FACING THE U.S. SEMICONDUCTOR INDUSTRY"

Annual graduates in semiconductor-related **engineering fields** by degree level and citizenship at U.S. colleges and universities



46% of Master's students are domestic

39% of PhD students are domestic

Note: Foreign graduates here refers to those who are not U.S. citizens or permanent residents

https://www.semiconductors.org/chipping-away-assessing-and-addressing-the-labor-market-gap-facing-the-u-s-semiconductor-industry/

DoD Specific Workforce Needs

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1) Workforce must be clearable
   - Universities are confronting a dearth in American talent generation and retention
   - Much of that shortfall is filled with a large share of foreign students from adversarial nations, 25 – 80% depending on degree field and level.[1]
2) National security interests require a unique blend of skillsets/education
   - Due to unique mission sets, DoD faces challenges in filling roles developing specialized technologies which are not supported by commercial markets
   - For example, DoD has unique workforce needs in radiation hardened microelectronics and other extreme environments, advanced packaging, System on Chip (SOC) Security, etc.

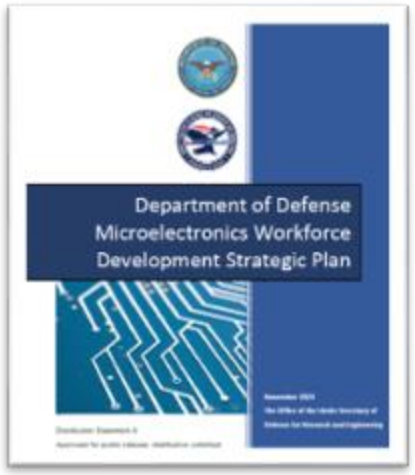
[1] The Contest for Innovation: Strengthening America's National Security Innovation Base in an Era of Strategic Competition. Report of the Task Force on 21st Century National Security Technology and Workforce. 2019

Education & Workforce Development: Mission

A ready workforce is required for the U.S. to lead high-performance microelectronics for decades to come

Mission: Attract, Develop, Maintain a Ready DoD Microelectronics Workforce

- **Attract** STEM students into T&AM fields of study via replicable, scalable PPAP model
- **Develop** clearable, ME knowledgeable workforce for DoD modernization needs
- **Maintain** an agile and adaptive workforce that meets current and future DoD needs



Confirmed by DoD ME WD Strategic Plan's prioritized roadmap, the Mission continues

- **Outreach** for earlier and broader ME exposure including K-12, and veterans.
- **Advance** PPAP knowledge sharing education continual improvement, specialized curricula
- **Retain** clearable, dynamic experienced workforce that targets DoD/DIB needs, e.g. RadHard, AI

Data-driven investments based on stakeholder needs

K-12 STEM · Technical Certificates · Undergraduate · Master's · PhD · Existing Workforce · Microelectronics Leadership

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SCalable Asymmetric Lifecycle Engagement

Develop meaningful program for US citizen students to establish relationships with potential employers, which lead to employment after graduation with the US Government and/or DIB

Matching Science, Technology, Engineering, and Mathematics (STEM) students with specialized curricula and relevant KSAs **to Gov't/DIB technical workforce needs**

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SCalable Asymmetric Lifecycle Engagement
Developing the U.S. Defense Microelectronics Workforce

UNIVERSITY CONSORTIUM
Lead: Purdue

PPAP Advisory Board
Academia, Industry, DoD/Nat'l Labs

TECH AREA 1	TECH AREA 2	TECH AREA 3	TECH AREA 4	TECH AREA 5	TECH AREA 6
Radiation Effects	Adv. Packaging	SOC System	Trusted AI	Supply Chain	RFOE
UNIVERSITY LEAD Vanderbilt	UNIVERSITY LEAD Purdue	UNIVERSITY LEAD Ohio State	UNIVERSITY LEAD IU / Notre Dame	UNIVERSITY LEAD TBD	UNIVERSITY LEAD TBD

Public-Private-Academic Partnership

A Ready Workforce

Scalable: Extend the program across multiple universities.
Replicable: Extend the program across other technology areas.
Asymmetric: Produce clearable, knowledgeable workforce
Nationally coordinated and regionally executed: network of stakeholders and universities.

Scope and Technical Objectives

Security. Train students and faculty in ITAR, EAR, CCL, and related regulations and to provide facilities to meet program requirements; security clearances for students.

Curricular innovation. Tailored curriculum and targeted research experiences; designed based on DoD prioritized needs; collaboration between practitioners and educators.

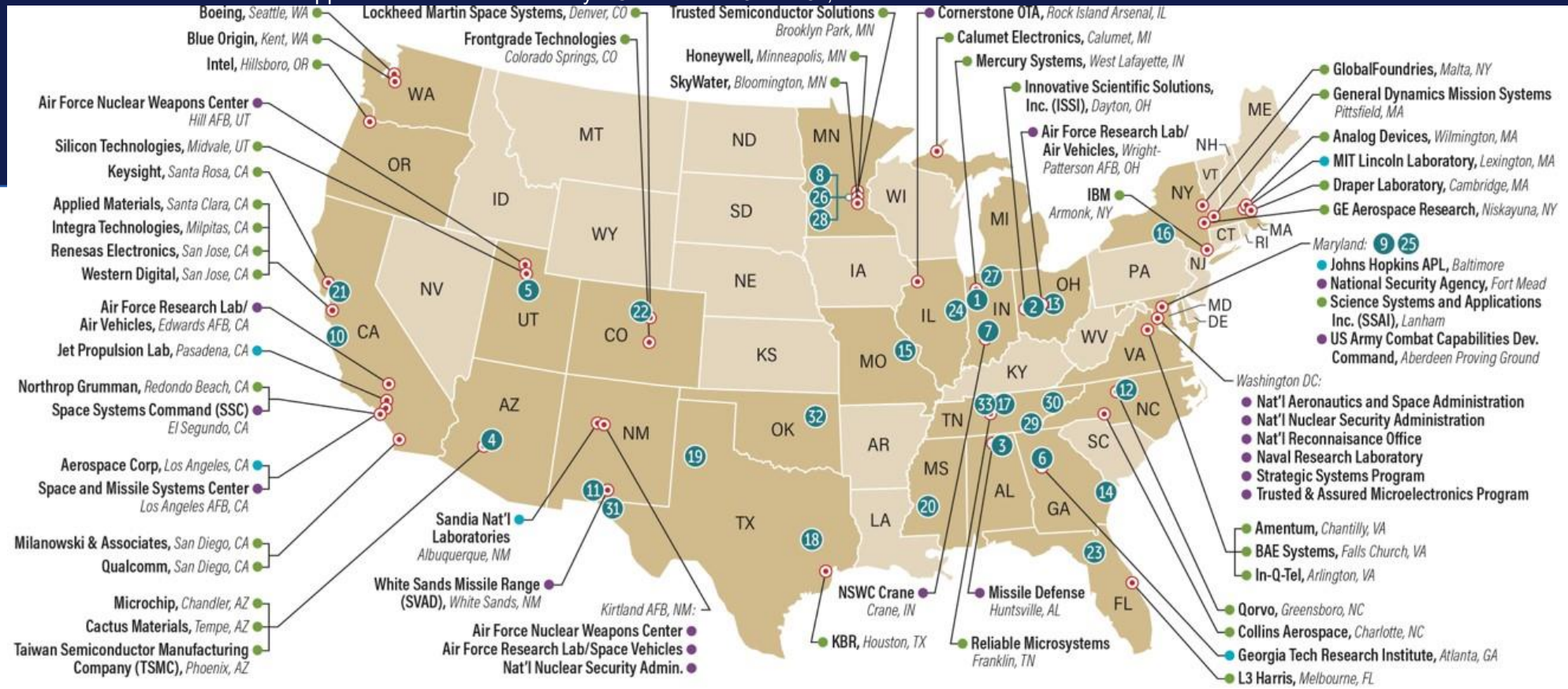
Recruiting. Early exposure to the program including K-12 and community colleges; incentives; identity building through cohorts.

Projects, Research, and Internships. Mentored research experiences; near-peer and DoD/DIB mentoring; internships.

Metrics-driven, iterative model development. Model will be updated through an iterative, design-based method; metrics include both outcome evaluations and process assessments.

SCALE Map

- Growth to 80 Gov/DIB partners
- >100 faculty across >30 universities



Institution Type → ● Government ● Federally Funded Research and Development Centers ● Industry

Institution Topic Areas → (ESS/TAI) = Embedded Systems Security/Trusted AI; (HI/AP) = Heterogeneous Integration/Advanced Packaging; (RH) = Radiation Hardened; (CS) = Compound Semi; (SoC) = System on Chip; (CSME) = Center for Secure Microelectronics Ecosystem; (EDGE) = Education Group for Diversification and Growth in Engineering

↓ Partners

1. **Purdue University,** *West Lafayette, IN* (HI/AP, RH, SoC)
2. **Air Force Institute of Technology,** *Wright-Patterson AFB, OH* (RH)
3. **Alabama A&M University,** *Huntsville, AL* (RH)
4. **Arizona State University,** *Tempe, AZ* (HI/AP, RH, CSME)
5. **Brigham Young University,** *Provo, UT* (RH)
6. **Georgia Institute of Technology,** *Atlanta, GA* (HI/AP, RH, SoC)
7. **Indiana University,** *Bloomington, IN* (ESS/TAI, RH)
8. **Metropolitan State University,** *St. Paul, MN* (RH)
9. **Morgan State University,** *Baltimore, MD* (SoC)
10. **Naval Post Graduate School,** *Monterey, CA* (RH)
11. **New Mexico State University,** *Las Cruces, NM* (RH)
12. **North Carolina A&T State University** *Greensboro, NC* (RH)
13. **Ohio State University,** *Columbus, OH* (SoC)
14. **Savannah State University,** *Savannah, GA* (RH)
15. **St. Louis University,** *St. Louis, MO* (RH)
16. **SUNY Binghamton,** *Binghamton, NY* (HI/AP)
17. **Tennessee State University,** *Nashville, TN* (RH)
18. **Texas A&M University,** *Commerce, TX* (RH, CSME)
19. **Texas Tech University,** *Lubbock, TX* (CS)
20. **Tougaloo College,** *Tougaloo, MS* (RH)
21. **University of California,** *Berkeley, CA* (SoC)
22. **University of Colorado Boulder,** *Boulder, CO* (CS)
23. **University of Florida,** *Gainesville, FL* (CSME)
24. **University of Illinois Urbana-Champaign,** *Champaign, IL* (CS)
25. **University of Maryland,** *College Park, MD* (RH)
26. **University of Minnesota,** *Minneapolis, MN* (RH)
27. **University of Notre Dame,** *South Bend, IN* (ESS/TAI)
28. **University of St. Thomas,** *Minneapolis, MN* (RH)
29. **University of Tennessee,** *Chattanooga, TN* (RH)
30. **University of Tennessee,** *Knoxville, TN* (EDGE)
31. **University of Texas,** *El Paso, TX* (HI/AP)
32. **University of Tulsa,** *Tulsa, OK* (ESS/TAI)
33. **Vanderbilt University,** *Nashville, TN* (RH)

Fast Facts on SCALE

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Scalable Asymmetric Lifecycle Engagement
Developing the U.S. Defense Microelectronics Workforce

Growth	FY20	FY21	FY22	July 2023	Dec 2024
Current	25	191	278	316	705
Total	25	218	385	607	**1024**

- Over ***4000% growth*** since program inception 4 years ago!
- 96% retention rate in SCALE program

- March 2023:
  - **$160k/student win**
  - **ROI = 1.9***
- March 2024:
  - **$120k/student win**
  - **ROI = 2.5**
- **December 2024**
  - **ROI = 3.5**

**for every $1 invested, you receive a value of $2.90 back*

- Over **65%** of graduating undergrads entering defense ME sector or went on to graduate school (**WIN**)
  - vs ~30% non-SCALE students
- 44% SCALE undergraduates went on to graduate school
  - *vs ~20% non-SCALE students*

	SCALE Totals	RH	HIAP	SOC	AI/ESS
Current students	**705**	242	172	230	49
Total students	**1090**	404	255	321	105
Students with internship / research experiences	**478**	166	110	13	57
Alumni	**352**	102	50	66	32
Students placed	**319**	84	43	59	31
Withdrawn	**33**	18	7	7	1

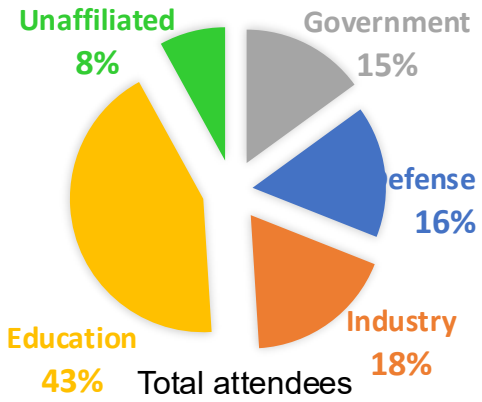
Newest SCALE Initiatives

- Growth in Engineering
  - working with *EDucation group for Growth in Engineering* (EDGE) to develop a national education program to attract, educate, train, and retain a broad population in semiconductor sciences and technologies
- Veterans
  - conducting a study to identify ways to engage with veterans and bring them into ME for DoD/DIB
- K-12 pilot
  - working with teachers to help them develop modules to teach in their classrooms while providing required professional development and vertical alignment, along with sustainability

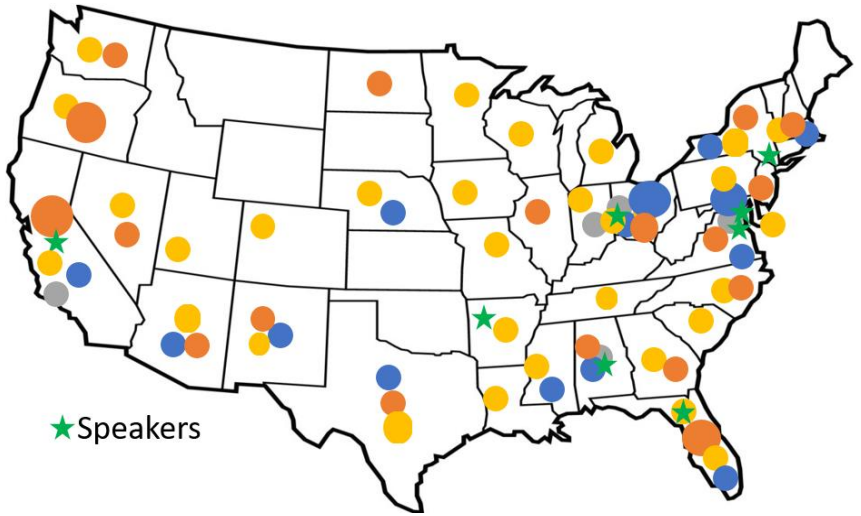
National Microelectronics Security Training Center (MEST)

Develop and provide training programs on ME design and security to the Gov'n/DIB

- **On-site/online Short-term Training:** MEST faculty and engineers visit org site to provide 3-5 days training on specific topic and award certificates
- **Semester Long Courses:** In-depth courses spanning several weeks or months, providing thorough understanding of microelectronics/security concepts
- **On-campus Lab Sessions:** Short term (up to two weeks) practical training thru access to Physical Assurance other Hardware Security Labs
- **Chip, PCB, and Assembly Design and Fabrication:** Comprehensive courses covering the entire process of microelectronics design; from chip-level design to PCB, assembly and fabrication
- **Industry Driven Courses:** Tailored courses designed/delivered by industry experts
- **Continuing Education Seminars:** Interactive webinars delivered virtually, offering timely insights and knowledge on microelectronics/security for busy professionals



https://mestcenter.org/index.php/about-us/



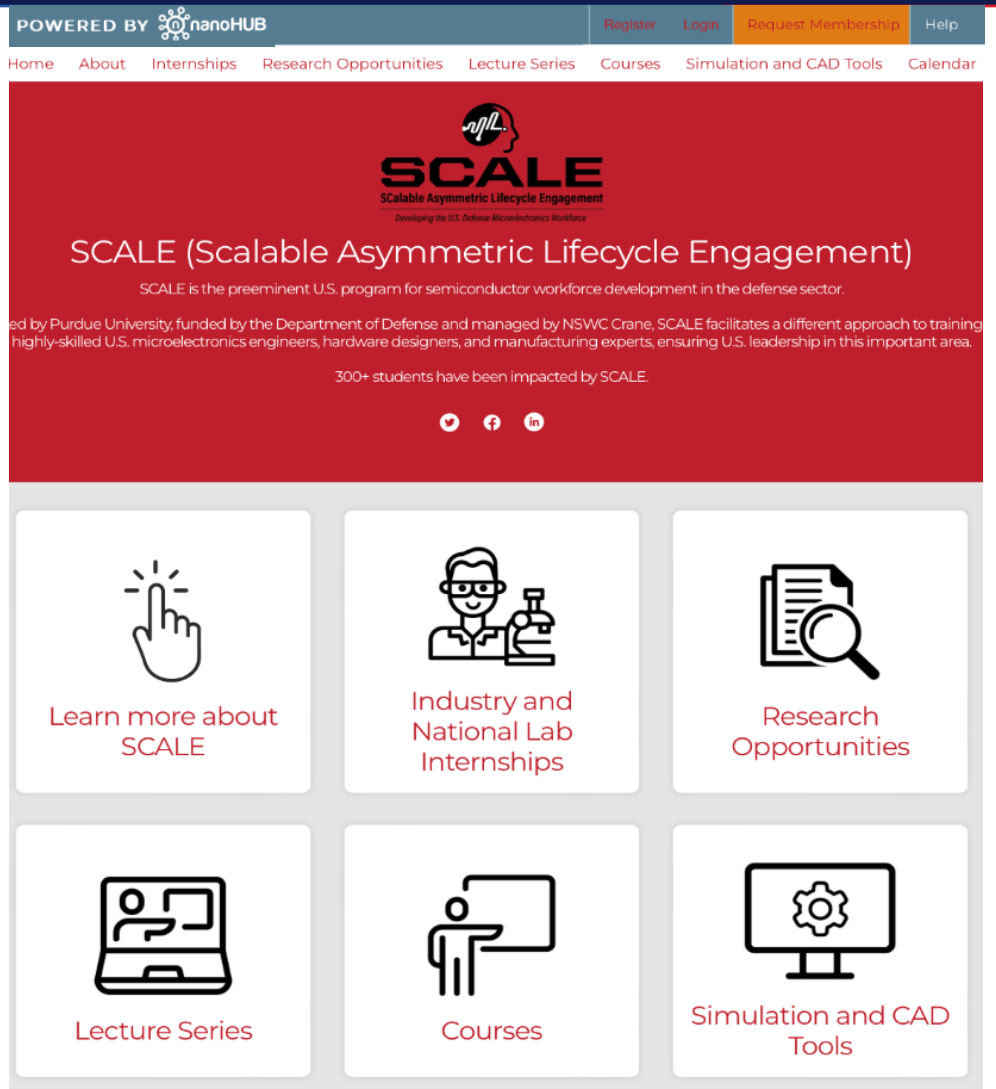
Number of Webinars Held	50
Total Webinar Attendees	4,300
Total Training Attendees	1,506

Offering	# Hours
Long courses	21,825
Short course	2,850
Tutorial	900
Webinars	4,000
Hands-on trainings	2,300

Online resources using nanoHUB – SCALE & MEST

- For SCALE students
  - Access educational material
  - Hands-on learning with online simulations
  - Find research opportunities & internships
- For SCALE PIs & staff
  - Share educational content & events
  - Re-use educational content developed by partners
  - Control access and collect statistics (data App)
- For DoD and industrial partners
  - Learn about SCALE
  - SCALE impact statistics
  - Share events & opportunities

- **Increase interactive learning**
- **Repository available to all SCALE/MEST**



nanoHUB - online resources

Simulation tools for online hands-on learning

Devices & materials

Schrödinger

SILVACO

Thermo-Calc Software

nanoHUB provides SW to all universities across the country

AI & ML

TensorFlow

MathWorks®

PyTorch

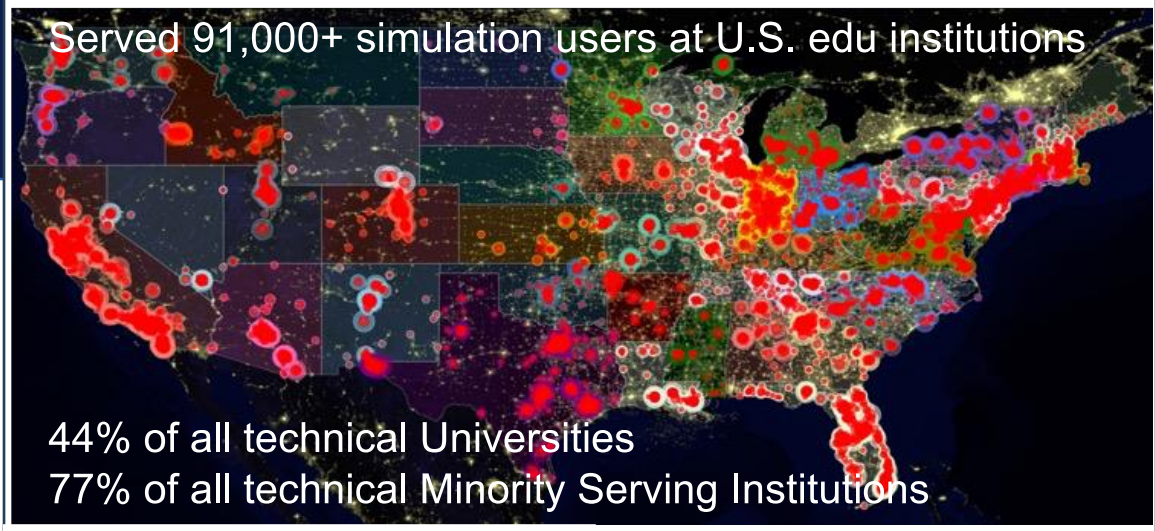
EDA

cadence

SYNOPSYS®

SIEMENS

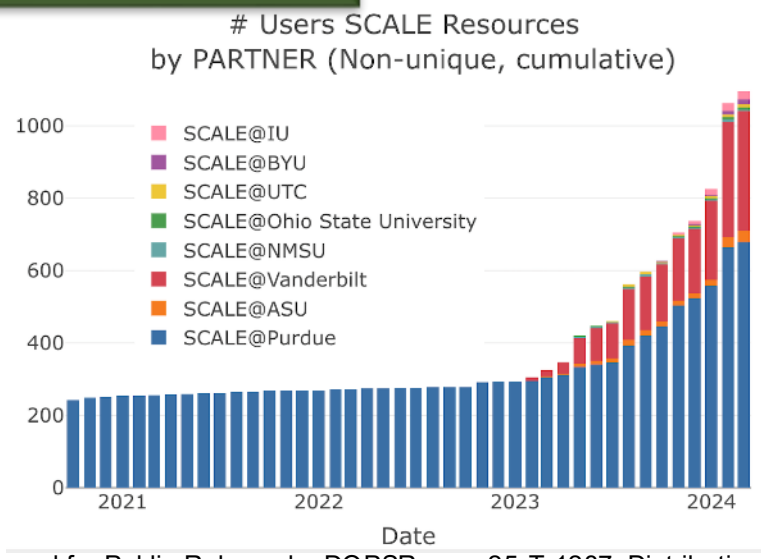
nanoHUB – online simulation & data

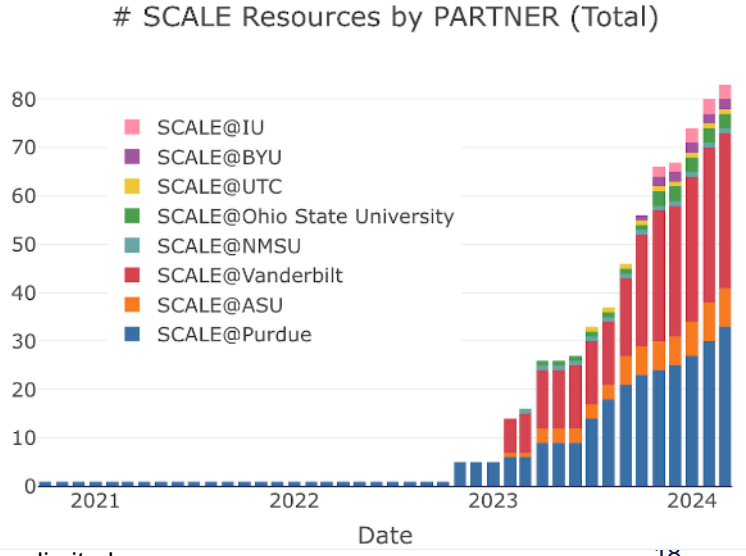


3,939 Univ. in Carnegie list ~ 1969 Technical
cum 880/1969=44%

468 MSIs in Carnegie list ~ 269 Technical
cum. 206/269 => 77%

SCALE resources & impact





How Partners Engage with SCALE Program

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Provision of workforce needs and Knowledge, Skills, and Abilities (KSAs)

- Participate in data calls, surveys, and/or workshops for KSA updates and needs assessments for relevant technical verticals (biannually)

Provision of SCALE program feedback for continuous improvement

- Engage with career pathways working groups
- Quarterly touch points

Provision of SCALE employee performance feedback

- Participate in data calls and surveys to provide feedback on SCALE student intern or full-time employee performance for continuous program improvement

Partner organization participation at SCALE events or meetings

- SCALE full program annual meetings
- Technical Vertical annual reviews

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How Partners Engage with SCALE Students

Provide internship, co-op, and full-time early career opportunities for SCALE students

- SCALE Job Board (“passive” – job posting system)
- SCALE Web App (“active” – can use to proactively reach out to SCALE students of interest)
- Event hosting – info sessions, skills workshops, career nights, all can be virtual or in-person depending on objectives

Mentoring

- Serve as a mentor for SCALE Up mentoring circle program, pairing 1-2 mentors with 8-10 students for regular, monthly sessions to discuss career development
- 1-semester commitment

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Summary

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- National security needs encompass those disciplines with the lowest representation of domestic students
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BACKUP

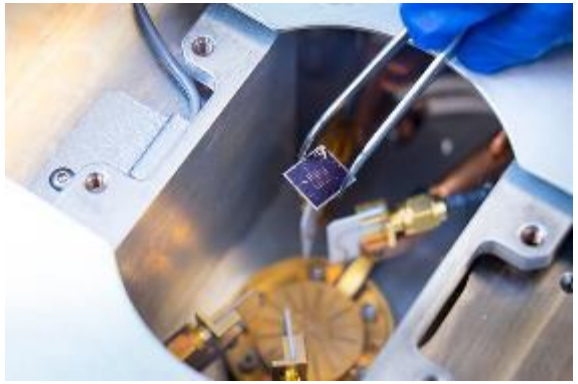
Scalable Asymmetric Lifecycle Engagement (SCALE)
TOPIC AREAS

Radiation Hardened Microelectronics

- Radiation in natural and manmade environments can greatly affect the operation and long-term performance of microelectronics
- Radiation hardening is making electronic components and circuits resistant to damage or malfunction caused by high levels of ionizing radiation
- Mitigation approaches include radiation-hardening by process and radiation-hardening by design
- *Participating Universities:* Vanderbilt, AFIT, St. Louis, Brigham Young, **Arizona State University**, Georgia Tech, Purdue, NM State, Univ of TN-Chattanooga, Indiana University

System-on-Chip

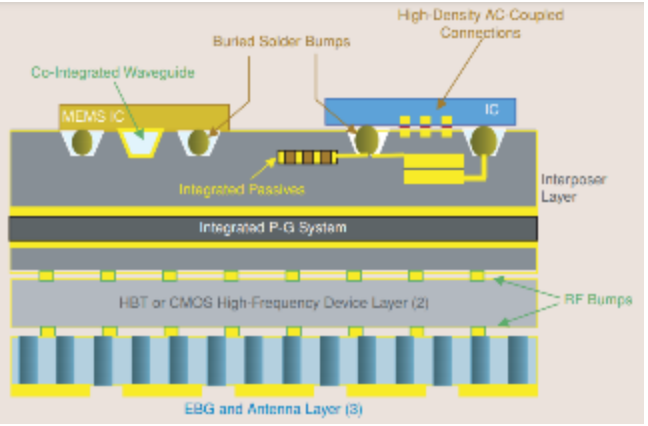
- Moore's law has led to an exponential increase in the number of devices that can fit onto a single chip
- This has led to a new era where most electronic systems contain chips that integrate various (hitherto discrete) components such as microprocessor, DSPs, dedicated hardware processing engines, memories, and interfaces to I/O devices and off-chip storage
- Designing SoCs is a highly complex process - design teams must perform the challenging tasks of developing a functional specification, partitioning and mapping of functions onto hardware components and software, design of a communication architecture to interconnect the components, functional/performance/power analysis and validation, and more
- *Participating Universities:* Ohio State, Georgia Tech, Purdue, UC-Berkeley



Scalable Asymmetric Lifecycle Engagement (SCALE)
TOPIC AREAS

Heterogeneous Integration / Advanced Packaging

- To keep sizes manageable while improving functionality, complex packaged electronics require similar components to be compressed together horizontally and vertically, and combined with dissimilar components providing complementary functions
- Significant challenges in heterogeneous integration include maintain reliability of connections, managing thermal cycling, and limiting damage from mechanical stress that can cause failures, etc.
- *Participating Universities:* Purdue, Georgia Tech, SUNY-Binghamton, **Arizona State University**

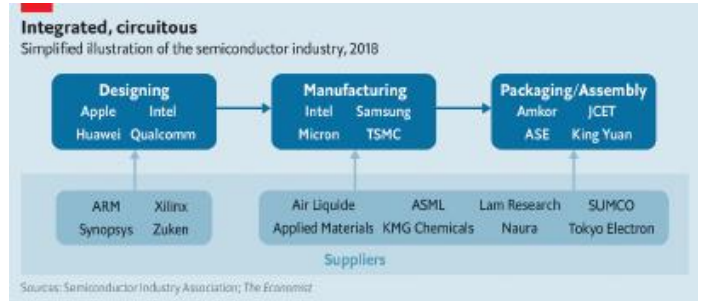


Trusted Artificial Intelligence (AI)

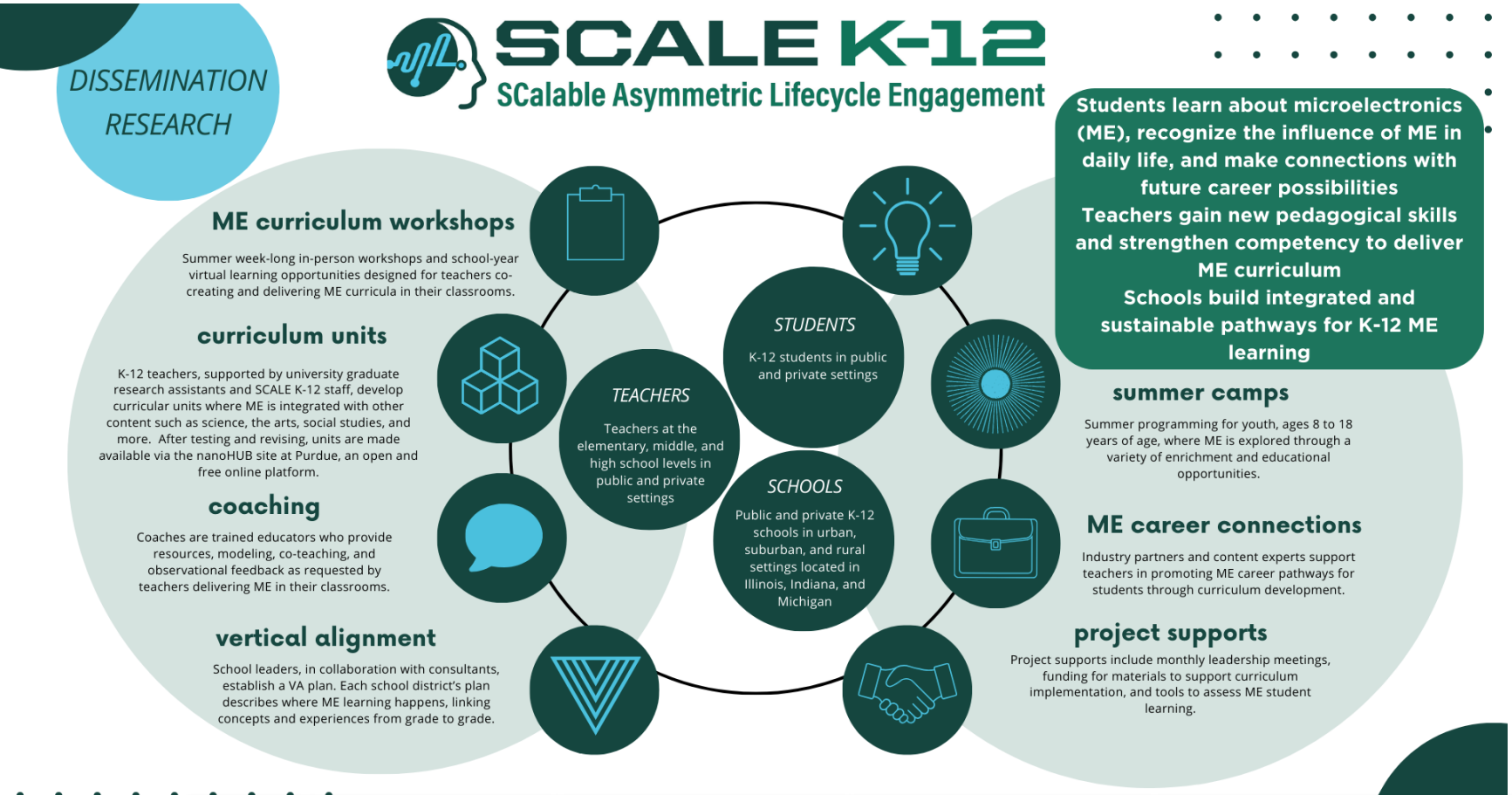
- Artificial intelligence (AI) provides a tremendous amount of sophisticated information analysis and decision making capabilities
- Trusted AI requires addressing hard challenges such as verifiability, bias, fairness, explainability, and human interaction and feedback
- *Participating Universities:* Indiana University, University of Notre Dame, IU-PU Indianapolis

Supply Chain Awareness

- With the increasingly central role of electronic hardware in a broad range of defense applications, securing supplies of electronics is more important than ever before.
- At the same time, exponential growth and complexity in semiconductor manufacturing creates potential supply chain disruption at all levels
- Challenges include understanding potential risks of IP security, measuring and detecting potential tampering with manufacturing and packaging, as well as improving supply chain resilience
- *Participating Universities:* Purdue, Univ of FL, Georgia Tech, NPS



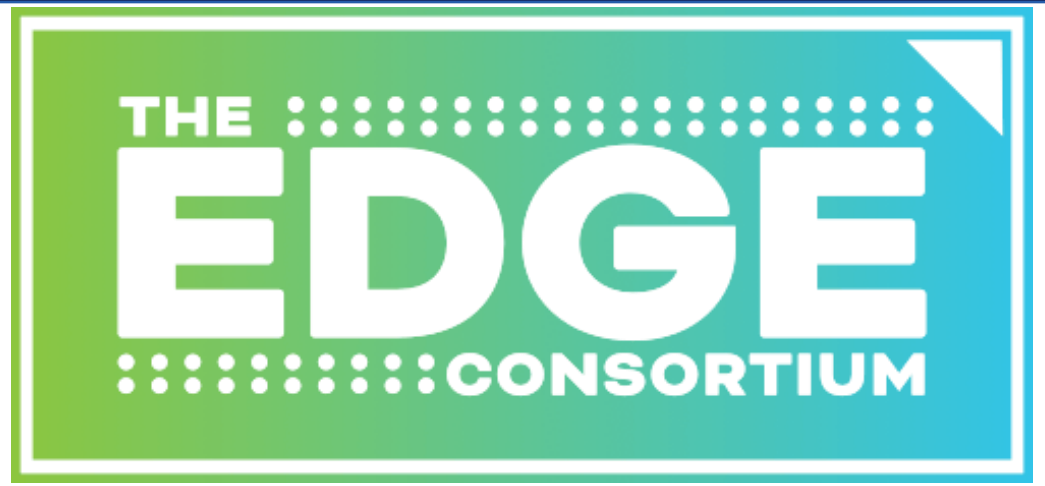
SCALE K-12 Pilot Overview



- Year 1
  - School Districts ~ 7
  - Teacher Fellows ~ 32
  - Students ~ 1,000
- Year 2
  - School Districts ~ 12
  - Teacher Fellows ~ 70+
  - Students ~ 12,000
- Year 3
  - School Districts ~ 12
  - Teacher Fellows ~ 90+
  - Students ~ 19,000

K-12 program reaches ~20,000 students and is self-sustaining after 3.5 years

SCALE / EDGE Consortium



The EDGE Consortium consists of seven top universities led by presidents and deans of engineering. Their goal is to expand the semiconductor workforce to meet economic and security needs.

BROWN DARTMOUTH INDIANA UNIVERSITY UNIVERSITY of WASHINGTON

Berkeley UNIVERSITY OF CALIFORNIA UNIVERSITY of ROCHESTER Olin College of Engineering

SCALE / EDGE Pilot

Mission and goals: In this 2-year pilot, the EDucation Group for Growth in Engineering (EDGE) will develop a national education program using evidence-based pedagogy and design to attract, educate, train, and retain a broad population in semiconductor sciences and technologies.

Target audiences

K-12 Students

Students often make decisions about their future careers by middle school.

Early undergraduate students

Students drop out of early STEM courses when they are made to feel they are not "smart enough."

College students near completion

Students may not start in the semiconductor workforce without adequate support.

Early/mid-career professionals

More than 50% of workforce entering microelectronics sector leave within 5 – 7 years.

Disengaged from higher ed

Most positions in the semiconductor industry don't require a college degree.

Increase the size of the talent pool - bringing more clearable,skilled talent into ME

Summary of new programs

EDGE X	EDGE X will attract K-12 students to the semiconductor workforce. We will work with local affiliates of PBS to develop videos and learning experience materials relevant to the semiconductor industry. *Target audience(s): K-12 students*
EDGE Academy	EDGE Academy will educate and retain college students and consist of comprehensive instructor support, including collaborative learning experience redesign, classroom climate evaluation, training, and evaluation. *Target audience(s): Early undergraduate students*
EDGE Scholars	EDGE Scholars will retain senior-level undergraduate and graduate students and early/mid-career professionals by providing professional development and mentorship. *Target audience(s): Students near completion; early/mid career professionals*
EDGE Works	EDGE Works will train non-college-bound populations in skills relevant to the semiconductor industry and will consist of industry-driven curriculum and will be disseminated via state-level economic development organizations. *Target audience(s): Disengaged from higher ed*

EDGE X – Chip Kids

- New web series being co-produced with East Tennessee PBS
  - working to go national in Year 2
- Program aims to ignite passion in **STEM disciplines related to the semiconductor industry** and motivate all children to see science as an exciting and attainable career path
- Seven episodes for season 1 are nearing completion
  - Season 2 planning in progress
- Host: Alia Pope
  - 4th grade math and science teacher at eSTEM Academy in Little Rock Arkansas
  - @thealiapope has **>1M followers** across Instagram, Tik tok, Facebook
- Episode 1: https://www.youtube.com/watch?v=c9bSoQgg0-c

Center for Secure ME Ecosystem (CSME)

SCALE
Scalable Asymmetric Lifecycle Engagement
Developing the U.S. Defense Microelectronics Workforce

- CSME fosters **collaboration between industry, academia, and the U.S. government** by investigating, designing and evaluating technologies that ensure the security principles of confidentiality, integrity and availability for Integrated Circuit (IC) design, fabrication and packaging **while developing the workforce**.

IC Design
IC Packaging
Reliability

- **RV1** Holistic approaches for zero-trust IC fabrication
- **RV2** Performance and cost tradeoffs of security techniques
- **RV3** Design, verification, testing and characterization of foundational secure circuit primitives
- **RV4** Unique opportunities for secure microelectronics with beyond-CMOS devices
- **RV5** Extended lifetime and behavior under extreme conditions for advanced technology nodes
- **RV6** Materials Assurance for Trusted Package Behavior

In collaboration with:

tsmc

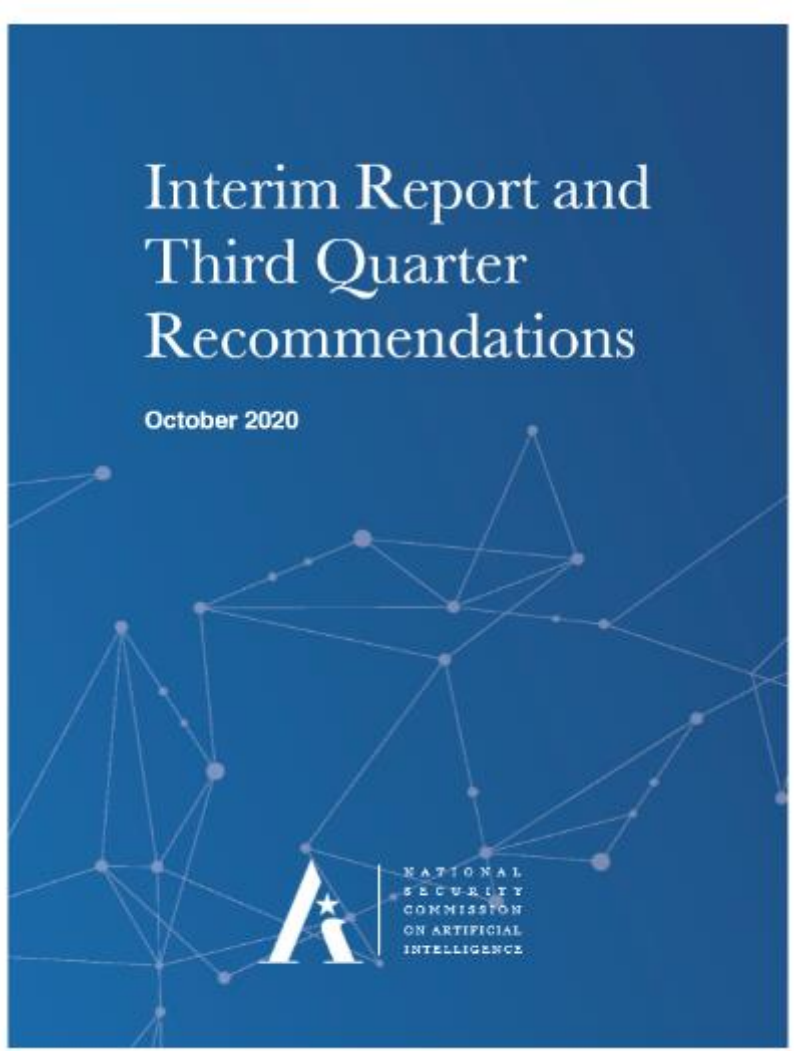
SYNOPSYS®

- Ongoing matching funds from Industry
- Governing Council selected research projects

Workforce Recommendations for the National Security Commission for Artificial Intelligence (NSCAI)

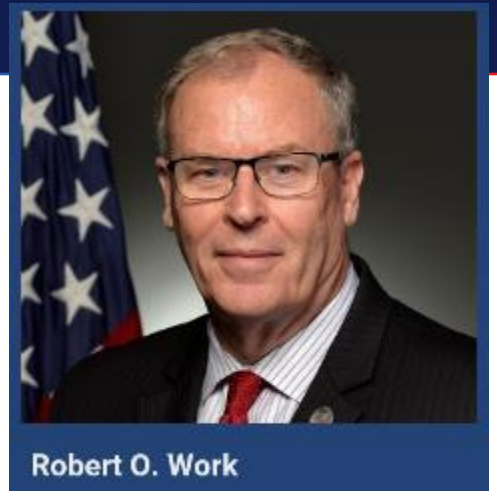
Recommendations will be incorporated in NSCAI's Q3 report (Sept 2020)

NSCAI 3rd Quarter Recommendations
October 2020




Dr. Eric Schmidt

Chairman


Robert O. Work

Vice Chairman

Recommendations for the Microelectronics Workforce Prototype, SCALE

"At minimum, **$24.7 million per year** over the next decade of additional funds are needed to address ***each*** critical technical area - $122.36 million per year over the next decade of additional funds are needed to initiate a parallel AI-specific consortium…"

https://www.nscai.gov/home

Pages 134-136

Projected Yield for 10-YR Investment

Year One

- 1,000 GOV Work Years, at minimum, completing the maximum service agreement of 4:1
- Assume equal number of graduates joining the DIB
- Total: 2,000 Work Years
- **Total/Vertical: 400 Work Years**

Year Ten

- 10,000 GOV Work Years, at minimum, completing the maximum service agreement of 4:1
- Assume equal number of graduates joining the DIB
- Total: 20,000 Work Years
- **Total/Vertical: 4,000 Work Years**

**Does not include personnel continuing to work after the 4-year service period.*

Year Thirty

- Assume 50% attrition rate after the 4 year service and total service of 30 years for remaining population: 42,500 GOV Work Years
- Assume equal number of graduates joining the DIB and same attrition rate
- Total: 85,000 Work Years
- **Total/Vertical: 17,000 Work Years**

Years 1 - 10

- Incoming employees familiar with applied research that aligns with DoD priorities
- Recruiting advantage through early (K-12) exposure to the program
- Security-policy savvy hires already trained in ITAR, EAR, CCL, and related regulations

Assumes Annual Investment Over 10-Years

Assumes 50 Students/Year Per Vertical with a Scholarship for Service