R&D Workforce Working Group Update and Recommendations

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Acknowledgements

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Updated Charge to Working Group

Given the portfolio of R&D programs
(NSTC, NAPMP, Manufacturing USA Institutes, NIST Metrology R&D)
and the $11B of resources available for those programs,

the R&D Workforce working group should examine and make recommendations on how these programs can be best leveraged to meet the workforce needs of the microelectronics industry for both R&D and manufacturing.

Invited Speakers

Name	Organization	Topic
Navid Asadi	University of Florida/IEEE Int'l Conference on Physical Assurance and Inspection of Electronics (PAINE)	WFD initiative for advanced packaging
Peter Bermel	Purdue University Scalable Asymmetric Lifecycle Engagement (SCALE) program	SCALE program
Oliver Brand	National Nanotechnology Coordinated Infrastructure (NNCI)	NNCI support for WFD
Robert Geer	SUNY Poly/American Institute for Manufacturing Integrated (AIM) Photonics	AIM Photonics WFD programs
Tracy Green	Lorain County Community College (LCCC)	Microelectronics manufacturing education programs
Raj Jammy	MITRE Engenuity	MITRE-Engenuity proposed NSTC WFD program
Barry Johnson	National Science Foundation (NSF)	NSF and Semiconductor WFD
Beth Keser	Intel Corp./International Microelectronics Assembly and Packaging Society (IMAPS)	IMAPS Academy
Shari Liss	SEMI Foundation	Holistic semiconductor WFD programs
Robert McClellan	Micron Technology, Inc.	Industry panel discussion
John Monk	Northrup Grumman Corp.	Industry panel discussion
Om Nalamasu	Applied Materials, Inc.	U.S. semiconductor talent shortage analysis
Shadi Sandvik	SUNY/American Semiconductor Innovation Coalition (ASIC)	ASIC proposed NSTC WFD program
Somnath Sengupta	My Life Learning Center / Powerhouse Consulting Group	Training of specially abled
Gaby Cruz Thompson	Intel Corp.	Industry panel discussion
Robert Weinman	National Institute for Innovation and Technology (NIIT)	Demo of National Talent Hub
Karen Wetzel	NIST National Initiative for Cybersecurity Education (NICE)	NICE Framework
Todd Younkin	Semiconductor Research Corporation (SRC)	Overview of SRC programs
Jared Zerbe	Apple Inc.	New Silicon Initiative

WG Meetings since previous IAC Meeting

Date	Topics of Discussion
12/16	CHIPS R&D Program team; WG membership & invited speakers
12/23	Questions from 12/8 IAC mtg; updated WG charge; meeting schedule & plan
1/6	NICE framework presentation and Q&A
1/13	Q&A with speakers (IMAPS, AIM Photonics, NIIT)
1/20	Q&A with speakers (SCALE, My Life Learning Center, PAINE)
1/27	Q&A with speakers (ASIC, SEMI Foundation, SRC, LCCC)
1/30	Discussion and drafting of initial recommendations
2/3	Industry panel (Intel, Micron, Northrup Grumman); R&D Gaps WG update

Outline

- Resources and programs examined – **key takeaways**
- Findings
- Initial recommendations
- Further work

Resources recommended by CHIPS R&D Program Team

- NIIT Semiconductor-Nanotechnology Manufacturing Competency Model
  Outlines competencies and skills needed for semiconductor manufacturing roles

- U.S. Census Bureau *From College to Jobs: Pathways in STEM* interactive chart
  Shows that less than half of STEM graduates work in STEM fields overall

- Eightfold AI 2021 whitepaper *How the U.S. Can Reshore the Semiconductor Industry*
  Asserts that up-/re-skilling individuals with the potential to move from declining roles to rising roles can dramatically increase the pool of potential semiconductor talent

- NASEM 2022 Report *Infusing Advanced Manufacturing into Undergraduate Engineering Education*
  Recommendations include incorporating more experiential learning opportunities

Research papers recommended by CHIPS R&D Program Team

- B.N. Geisinger and D. R. Raman. "Why they leave: Understanding student attrition from engineering majors" *International Journal of Engineering Education* 29,no.4 (2013): 914-925.
  Mentorship by engineering instructors helps to counteract issues: unwelcoming climate; conceptual difficulties with core courses; lack of self-efficacy or self-confidence; inadequate high-school preparation; insufficient interest in engineering; racism and/or sexism.

- M.A. Cannady *et al*. (2014). “Problematizing the STEM pipeline metaphor: Is the STEM pipeline metaphor serving our students and the STEM workforce?” *Science Education*, 98(3), 443-460.
  Interest in STEM career by 8th grade most strongly correlates to pursuing a STEM career.

- P. Gardner and K. Bartkus (2023). *An Analysis of U.S. Learn-and-Earn Programs*.
  Learn-and-earn programs (apprenticeships, internships, co-ops) work better when employers, education institutions, and government & NGOs work together.

- G. Ceyhan *et al*. (2019). The Socialization and Retention of Low-Income College Students: The Impact of a Wrap-Around Intervention. *International Journal of Higher Education*.
  Most-helpful interventions are faculty mentorship, research experiences, community building.

Additional Documents Reviewed

- SIA-Oxford Economics report (May 2021) *Chipping In: The U.S. Semiconductor Industry Workforce and How Federal Incentives will Increase Domestic Jobs*
  Analyzes U.S. semiconductor workforce and estimates impact of $50B federal investment in domestic chip production (including directly creating 42,000 new semiconductor jobs)
- Manufacturing USA Highlights Report (October 2022)
  Summary of technology innovation and WFD projects involving the institutes
- McKinsey report (September 2022) *How semiconductor makers can turn a talent challenge into a competitive advantage*
  Best practices to attract, retain and excite technologists
- National Science Foundation & Semiconductor Workforce Development (January 2022) – prepared by Dr. Barry Johnson, NSF TIP Directorate
  Overview of NSF-funded WFD programs aligned with CHIPS & Science Act goals for DOC (technician training, scholarships & fellowships, experiential learning, research experiences)

Established Workforce Development (WFD) Programs Examined

- Lorain County Community College microelectronics manufacturing program
  Certificate and Associate- & Bachelor-degree programs with embedded earn-and-learn
- Purdue University Scalable Asymmetric Lifecycle Engagement (SCALE) program
  Semiconductor WFD for the defense sector involving 17 universities + 27 defense industry companies: new curricular content & courses; internships; new K-12 program
- My Life Learning Center / Powerhouse Consulting Group
  STEM workforce training program for adults with autism, for U.S. Dept of Defense
- American Institute for Manufacturing Integrated (AIM) Photonics
  Courses, training and internships for CC students, undergrads, grads, incumbent workers and veterans to engage & prepare them to enter PIC fabrication & packaging workforce
  - **Online courses; in-person academy, boot camps and workshops; internships and co-ops**
  - **Open-source design, fab & validation program; educational consortium to deploy curricular content**

Established WFD Programs Examined (continued)

- Semiconductor Research Corporation
  Low-overhead research programs in partnership with industry & government sponsors, supporting ~1500 students (B.S., M.S., Ph.D.) – next-gen semiconductor innovators

- Apple Inc. New Silicon Initiative program
  Guest lectures, support for chip tapeout courses, scholar/fellowships & internships, curriculum sharing

- SEMI Foundation holistic WFD programs (from High Tech U to VetWorks)
  Hands-on learning for K-12 students, industry image & awareness campaign, apprenticeships, partnership with universities & colleges, SEMI-IEEE joint certification program, reskilling programs, new online learning program

Developed/Proposed WFD Programs Examined

- International Microelectronics Assembly and Packaging Society (IMAPS)
  - **Premier association representing the microelectronics packaging and assembly supply chain**
  - **Education & WFD via events, training (IMAPS Academy & on-site training), publications, networking**
- IEEE Int'l Conference on Physical Assurance and Inspection of Electronics (PAINE)

  Online workshops and videos on IC packaging, including advanced packaging (heterogeneous integration, 2.5D & 3D packaging), antenna in package, integrated silicon photonics, MEMS packaging, IC & PCB assurance (optical inspection, nano- and EO-probing, FIB + SEM imaging, X-ray tomography)
- American Semiconductor Innovation Coalition

  Proposes a national program as part of the NSTC (American Semiconductor Education and Training, AScENT) to invest in and support equitable education & training programs, and enable broad access to facilities
  - **Partner with stakeholders from high schools to research universities and national labs**
  - **Scale best-practice exemplar programs**
  - **Increase awareness of – and engagement with – semiconductor career pathways**
  - **Promote sustainable culture of DEI (core principle for all activities)**
- MITRE-Engenuity

  NSTC is proposed to coordinate with partners and run targeted solutions (summer program, internships, breakthrough-challenge learning materials, ROTC-like program, technician apprenticeships)

Additional WFD Resources Examined

- National Nanotechnology Coordinated Infrastructure (NNCI)
  NSF-funded research infrastructure (comprising 16 sites, 71 facilities, >2200 tools for micro- and nano-scale fabrication and characterization) that supports hands-on education & outreach

- National Initiative for Cybersecurity Education (NICE) Framework
  - **First published in 2017 (updated in Nov 2020) to describe & share information about cybersecurity work**
  - **Promotes Knowledge and Skill statements that are flexible, consistent, clear, affirmative, and discrete, to help students develop skills, job seekers to demonstrate competencies, and employees to accomplish tasks**
  - **Common, consistent lexicon: specialty areas, work roles, tasks, and KSAs required for tasks**

- National Institute for Innovation and Technology (NIIT) National Talent Hub
  - **NIIT** (a 501c3 org) **is deploying a national strategy & infrastructure to develop the talent pipeline for strategic industry sectors**
  - **National Talent Pipeline Development Initiative (TPDI): infrastructure, programs, and mechanisms**
    "Talent hubs" to fill regional WFD gaps via deployment and scaling of developed solutions
    New Growing Apprenticeships in Nanotechnology and Semiconductors (GAINS) program to increase apprenticeships
  - **NTH is an online portal for connecting industry & education programs with talent; supports TPDI**
    Currently includes programs at 21 community colleges, jobs at 26 employers

Findings

- Today microelectronics education and training, while well-intentioned, creative and largely effective locally, exist primarily in a very large number of silos (disciplinary, education level, industry segment and/or geographical) with little standardization, almost no sharing of curriculum, and pockets of proprietary information and training that limit the industry's ability to grow the diverse, multidisciplinary, highly skilled workforce needed.

  Microelectronics industry participation in WFD programs has been limited as well.

- A key challenge is that the depth and breadth of careers within the industry are largely invisible to job seekers and students, particularly at early decision points that determine subsequent career paths.

  A whole-of-nation effort is needed to address these challenges with speed and scale.

Microelectronics WFD Gaps

- Centralized mapping of existing workforce development (WFD) programs and capabilities to workforce needs across the microelectronics ecosystem is needed to identify gaps and opportunities for strategic and coordinated investments by the federal government, industry, and others.
  - Map information should also include WFD program connections to companies and other groups providing resources crucial for their success.
- The effectiveness of WFD programs should be measured by meaningful metrics for recruitment, education, retention, training and transitioning of students into careers in the microelectronics industry.

Guiding Principles for a CHIPS R&D WFD Program

- Strategic investments by the Department of Commerce should provide additional resources to grow the impact of existing successful microelectronics-related WFD programs to scale their impact, and also support new WFD programs that leverage proven-effective strategies.

- Both new and existing programs should coordinate efforts and resources and share best practices, integrating efforts and collaborating where possible for mutual and synergistic benefit.

Recommendation #1

- The CHIPS R&D programs should create a strong, coordinated, and inclusive workforce development and training program to address WFD needs across the microelectronics ecosystem

  through the NSTC, NAPMP, Manufacturing USA Institutes, and NIST metrology R&D program

  in collaboration with academia and industry to ensure best pedagogical practices for cultivating a diversity of R&D talent

  – human bridges for “lab-to-fab” transition of new innovations.

Recommendation #2

- The CHIPS R&D Program Office in conjunction with its component R&D programs should define metrics by which the success of semiconductor microelectronics WFD programs are to be measured, and

  support the mapping of existing programs and assessment of their effectiveness to guide new investments in existing and new WFD programs and infrastructure

    that address regional and national needs for technical talent – ranging from technicians to R&D personnel –

    and that leverage investments by the federal government, industry, and others.

Recommendation #3

- All post-secondary educational institutions which receive funding through CHIPS R&D programs should be incentivized to participate in and contribute to an inclusive and highly collaborative national network for microelectronics education

  that promotes sharing of curricular content and WFD program models, adoption of best practices, and standard frameworks,

  for maximum collective benefit.

  Likewise, companies which receive funding through CHIPS R&D programs should be expected to actively participate in the national network.

  NSTC COEs should offer experiential learning opportunities for students.

National Network for Microelectronics Education

- A national network for microelectronics education was authorized in the 2022 CHIPS and Science Act to enhance and broaden participation in microelectronics education in coordination with industry, led by a network coordination hub.

  Such a network must transcend competition that produces winners and losers (*e.g.*, programs run by SRC, NSF, DARPA), given the national scale of the WFD challenge.

- The national network should be run by a committed, independent organization capable of bringing together industry, academia, and government in transformational ways.

  Examples include SEMI, the Manufacturing USA Institutes and NIST.

- The SEMI-American Semiconductor Academy (ASA) initiative has published a vision paper that addresses these requirements.

Recommendation #3 subpoints

- The national network will be expected to facilitate access to hands-on learning opportunities (workshops, apprenticeships, internships) and infrastructure (labs for semiconductor processing, metrology, assembly/packaging and testing) to bolster the efficacy of WFD programs spanning the entire microelectronics ecosystem, including advanced packaging.

- The participants also should develop, implement and assess new pedagogical approaches, disseminate and adopt modern educational tools such as augmented reality/virtual reality and digital twins, ChatGPT - including for attracting and preparing a larger number and a greater diversity of new talent - to maximize the efficacy and benefit of their WFD programs for the Nation.

Recommendation #4

- The Department of Commerce should support coordinated efforts to increase awareness and excitement in K-12 students and their families and their communities about careers in microelectronics, perhaps as part of a broader STEM advocacy effort.

  Awareness must then be followed by authentic opportunities to learn and engage, for these efforts to be more than marketing.

Recommendation #4 subpoints

- The model that then-Governor Raimondo pioneered for comprehensive CS education in RI, to raise student awareness and to provide progressive training from elementary school through high school, can serve as a model, as it demonstrated the efficacy of a “whole-of-state” approach.

- Experiential microelectronics education for students in grades 9-12

  that includes engineering training, industry apprenticeships and internships in addition to Advanced Placement and other high-school courses

  has the potential to grow the microelectronics workforce pipeline for all technical career professional job types and educational attainment levels.

Recommendation #4 subpoints (continued)

- Mentorship programs, particularly beginning in early grades (middle school or earlier), have been found to be effective for attracting and increasing the retention and success of women, first-generation-college, low-income, and underrepresented minorities in STEM.

→ Companies which receive funding through CHIPS R&D programs should be expected to support their employees – and their retirees – to actively participate in such programs.

Further Work

- Weekly meetings
  - Q&A with speakers (NNCI, MITRE-Engenuity, Apple) on 2/10
  - Additional speakers to be (re)invited
- Topics of further discussion to include:
  - Programs to motivate and support a greater diversity of students to pursue STEM education and develop professional skills for success in microelectronics careers, from trades and technician to doctoral levels
  - Methodology for annually assessing and tracking evolving talent gaps for U.S. chip manufacturing, assembly, packaging, and testing.
    - Standard workforce framework, database and clearinghouse that maps KSAs for general and specific work roles to education and training programs and job types?