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AMERICAN SEMICONDUCTOR ACADEMY

FUELING AMERICAN INNOVATION & GROWTH

A NATIONAL NETWORK FOR MICROELECTRONICS EDUCATION AND WORKFORCE DEVELOPMENT

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AMERICAN SEMICONDUCTOR ACADEMY

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INTRODUCTION

EXECUTIVE SUMMARY

The semiconductor microelectronics industry[1] was born in the U.S. with the inventions of the transistor and the integrated circuit (IC, a.k.a. "chip") in 1947 and 1958, respectively. Through the early 1990s, the U.S. continued to lead innovation in microelectronics, resulting in the information technology revolution that has had a transformative impact on virtually every aspect of life in modern society. As the industry steadily advanced semiconductor manufacturing technology to enable greater chip functionality and/or to lower cost per function, the complexity — and hence the costs of construction and operation – of chip manufacturing facilities ("fabs") grew exponentially. Consequently, over the past three decades, more and more established semiconductor companies as well as new startups outsourced the fabrication of their chip designs to semiconductor foundries, giving the latter the economies of scale needed to sustain the rapid pace of technology advancement set by Moore's law.

Today the most advanced fabs cost roughly $20 billion to build [2], and only a small number of semiconductor companies (referred to as "integrated device manufacturers" or IDMs) can fabricate their own chip designs more cost-effectively than foundries. Lower construction and operating costs in Asia, as well as proximity to back-end and final assembly facilities, drove companies to build fabs in the region, and now roughly 80% of leading-edge fabs are in Asia.[3] Recognizing that the U.S. semiconductor industry's dependence on off-shore manufacturing poses a threat to the nation's long-term economic competitiveness and national security, the U.S. Congress passed the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act[4] in January 2021, authorizing new programs to promote the research, development, and fabrication of semiconductors within the United States. After much deliberation, the U.S. enacted the CHIPS and Science Act on August 9, 2022.

Even as the balance of chip manufacturing jobs moved overseas, the number of chip design jobs in the U.S. burgeoned due to the fabless-foundry business model. Also, the U.S. still dominates the wafer fabrication equipment (WFE) and electronic design automation (EDA) industry segments that have grown with the size of the semiconductor industry. The unparalleled complexity and sophistication of chip design and fabrication processes require a highly trained microelectronics workforce with knowledge and skills spanning multiple science, technology, engineering, and math (STEM) disciplines; almost two-thirds of workers in the semiconductor industry (including fabless chip companies, IDMs, WFE and EDA companies) have college or advanced degrees. A recent survey of SEMI member companies indicates that more than 5% of engineering positions are presently unfilled; that is, *the U.S. higher education system currently does not supply enough fresh talent to the semiconductor industry.* Furthermore, it has been conservatively estimated that the U.S. microelectronics workforce development (WFD) need will more than double as CHIPS Act programs create tens of thousands of new jobs, mostly highly skilled engineer, and technician roles, in the next few years.[5]

[1] Herein semiconductor microelectronics refers to integrated circuits of all types (digital/logic, analog, mixed-signal, memory, communications, power, optoelectronics, micro/nano-electro-mechanical systems, spintronics, quantum information systems, and others) comprising one or more semiconductor materials (silicon, germanium, compound semiconductors, etc.). The semiconductor industry includes integrated device manufacturers; semiconductor foundries; fabless chip design firms; assembly, testing, and packaging service providers; wafer fabrication equipment and metrology tool vendors; semiconductor wafer and chemical suppliers; electronic design methods and automation software providers. The broader microelectronics ecosystem includes electronics systems companies, researchers, and educators.

American Semiconductor Academy

INTRODUCTION

To address this urgent and large-scale WFD need — not only for CHIPS Act programs to succeed but also for the U.S. microelectronics ecosystem to thrive — we propose the establishment of a national network for microelectronics education, herein referred to as the American Semiconductor Academy (ASA), that is open to all U.S. universities and colleges to participate and to industry and government stakeholders to partner with. The ASA initiative brings together four-year universities and community colleges across the U.S. to collaborate with each other and to collectively partner with industry through the SEMI Foundation, the non-profit, public-benefit arm of SEMI which represents more than 2,500 member companies across the entire microelectronics ecosystem, over 1,400 of which are based in the U.S. Through a series of internal workshops, the ASA-SEMI partnership has identified the following key challenges for meeting the U.S. microelectronics industry's WFD needs:

1. A largely invisible (to most students and the public) microelectronics industry
2. Aging faculty/instructor population and infrastructure
3. Lack of alignment between industry needs and educational program outcomes
4. Outdated microelectronics curricula
5. Pipeline inequity, limiting the size and strength of the talent pool
6. Leaky talent pipeline

In this vision paper, we propose near-term (Years 1-3) and long-term (Years 3-5+) solutions to address each of these challenges, noting the resources that will be needed as well as expected outcomes and indicators of success. We also recommend a collaborative governance model to ensure the following objectives are met:

- Increase awareness of career opportunities and create excitement among students for microelectronics
- Align courses and student competencies with present and future industry needs
- Broadly engage, enable, and empower faculty in microelectronics-related fields
- Pave a variety of talent pathways, from K-12 to re-skilling/up-skilling workers
- Graduate knowledgeable and skilled talent, from technician to-Ph.D.-level

To achieve these objectives, new federal funding is needed to:

- Establish the national network and thereby drive and coordinate curriculum revitalization and sharing across institutions
- Empower faculty and instructors nationwide
- Develop and run regional coordinated training programs at "hub" universities equipped to offer to students from other institutions hands-on learning experiences in chip manufacturing, metrology, test, and packaging to motivate and prepare a large number and diversity of students for microelectronics careers.

INTRODUCTION

Educational laboratory facilities and equipment at universities and colleges across the country need to be modernized in order to offer learning experiences relevant to state-of-the-art chip design and manufacturing. Federal funding is also needed to incentivize institutions to hire new faculty and instructors in microelectronics; we estimate that 100 new hires are needed to increase the capacity of U.S. universities to produce an additional 5,000 graduates per year, and that 100 more new hires are needed to increase the capacity of U.S. community colleges to produce an additional 5,000 new skilled technicians annually for the semiconductor industry. Students also need to be incentivized and financially supported to pursue STEM degrees. We recommend at least 2,500 advanced microelectronics traineeships for graduate students and scholarships for undergraduate students at ASA universities, in addition to STEM scholarships for 3,000 students at community colleges in the ASA network.

Meeting the U.S. microelectronics WFD need with the necessary speed and scale requires federal investment exceeding $1 billion over 5 years. To leverage previous and other ongoing government investments, the ASA will adopt best practices and complement existing WFD programs focused on regional WFD needs and/or industry segments. Also, we are committed to fostering equity and inclusion and to enriching the diversity of the talent pool by including minority-serving institutions nationwide, sharing curricular resources and best practices, and offering hands-on learning, research experiences, and internship opportunities for their students. Our measures of success will include:

- the increase in number and diversity of students in microelectronics programs; and
- the increase in number of new graduates placed in semiconductor industry jobs.

The Semiconductor Industry Association has estimated that $50 billion invested by the federal government will result in 42,000 new jobs in chip manufacturing and design, leading to a total of 280,000 new jobs in the U.S. economy.[6] Only a broad, inclusive, and collaborative network of universities and colleges can meet this growing WFD need with the necessary speed and scale. The ASA-SEMI partnership aims to build sustainable and diversified talent pathways for the U.S. microelectronics industry to regain leadership in semiconductor manufacturing.

We welcome all solution-providers and stakeholders to join us in this endeavor!

Workforce Development — A Critical Need for the U.S. Microelectronics Industry

The microelectronics industry is growing (with annual global semiconductor sales as percentage of GDP doubling over the last three decades[7] and semiconductor market size projected to exceed $770 billion worldwide by 2030[8]) and evolving at an ever-increasing pace. Navigating the waters of an uncertain and fragmented business environment has become increasingly complex, with geopolitical, globalization, immigration, and economic issues creating a unique set of strategic challenges. At the same time, the technologies and processes required to design and manufacture semiconductor chips continue to become more sophisticated, requiring a workforce with a wider and more flexible range of STEM skills.

Today significant gaps exist between the industry-oriented skills in demand and the traditional skills being supplied. A 2017 survey conducted by Deloitte and SEMI[9] found that 82% of semiconductor industry executives reported a shortage of qualified job candidates, and the challenges of finding qualified workers have increased since then, with gaps at all skill and education levels — from technicians to doctoral-level engineers. Looking forward, the workforce needs of the industry are expected to more than double as CHIPS Act manufacturing incentives in the U.S. will create tens of thousands of new jobs within the next few years, concentrated in technical and engineering roles.

In order to meet the challenge of revitalizing the U.S semiconductor industry and building resiliency into the semiconductor supply chain, a highly skilled workforce will be essential. That workforce must meet short-term labor demand as new manufacturing facilities are built, as well as sustain long-term growth of the domestic industry. New talent will be required not only to design advanced products and advance research and development but also to build, equip, and run semiconductor manufacturing facilities. To grow domestic talent and innovation, students need to be nurtured for the industry, beginning in their K-12 years. These educational efforts must prepare new talent well to meet the industry's workforce needs.

Today many students enrolled in U.S. universities and colleges are not aware of the industry and don't have sufficient work experience to take on the technical and engineering positions in semiconductor fabs.[10] Together with the growing foundational STEM skills gap, this creates an urgent need to provide students with more hands-on training opportunities such as apprenticeships and internships. And because chip design and manufacturing technologies continue to advance at a rapid pace, investments in updated educational curricula, educator training, and refreshed university research and training facilities are critical.

While universities and community colleges offer degree-oriented educational programs, and the national labs and companies offer complementary experiential learning opportunities and practical hands-on skills training, a collaborative new approach to building pathways and strengthening pipelines is needed to attract, train, and retain a much larger and more diverse workforce.

Growing and Diversifying the Industry Talent Pool with Speed and Scale

To meet the urgent and growing microelectronics WFD need, a collaborative nationwide network of universities and community colleges — the American Semiconductor Academy– is proposed to increase access to education and training for technical careers in the microelectronics industry, particularly in semiconductor manufacturing and chip design. The ASA Initiative is focused on dramatically increasing the supply of diverse talent and innovation needed to grow the U.S. microelectronics industry, by broadly engaging and empowering faculty and by incentivizing undergraduate and graduate students enrolled at U.S. universities and colleges to pursue careers in the microelectronics industry.

Today jobs in design, manufacturing, testing, and research and development of semiconductor chips are distributed across 49 states in the U.S.[6], with the most resource-intensive semiconductor fabs concentrated in a smaller number of states (including Arizona, California, Colorado, Florida, Idaho, Maine, Massachusetts, Minnesota, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Texas, Utah, Vermont and Washington), each with a local ecosystem of equipment/tool suppliers and service providers. To meet the WFD needs of all the semiconductor fabs, IDMs, fabless chip design firms, and EDA companies which have operations distributed across the country, universities, and colleges in all states, ideally, need to be able to effectively educate and train new talent for the industry — and tap into the diversity of talent in our country. It should be noted that new graduates — particularly of community college and baccalaureate programs — usually do not choose jobs located far from their home and/or alma mater. For this reason, and to support their local communities, companies often focus their recruiting efforts on local universities and colleges. Therefore it is important for the ASA network to partner broadly with industry, to ensure inclusion of all postsecondary education institutions that are supplying talent to meet their WFD needs.

A novel aspect of the ASA Initiative is that it promotes nationwide collaboration between universities, community colleges, and companies to educate and train a broad range of students and provide hands-on learning experiences. That type of large-scale effort is made possible through its partnership with SEMI and its broad base of member companies across the global electronics design and manufacturing supply chain. Also, the SEMI Foundation provides experiential learning and training programs that complement degree-oriented education programs offered by universities and colleges and gives students greater visibility into rewarding professional careers in the industry. For example, High Tech U is a 3-day program for high-school students that builds connections from their math and science courses to career opportunities in the high-tech field, through hands-on workshops. This and other SEMI programs will be leveraged to bolster outreach, mentorship, and training activities across the ASA network.

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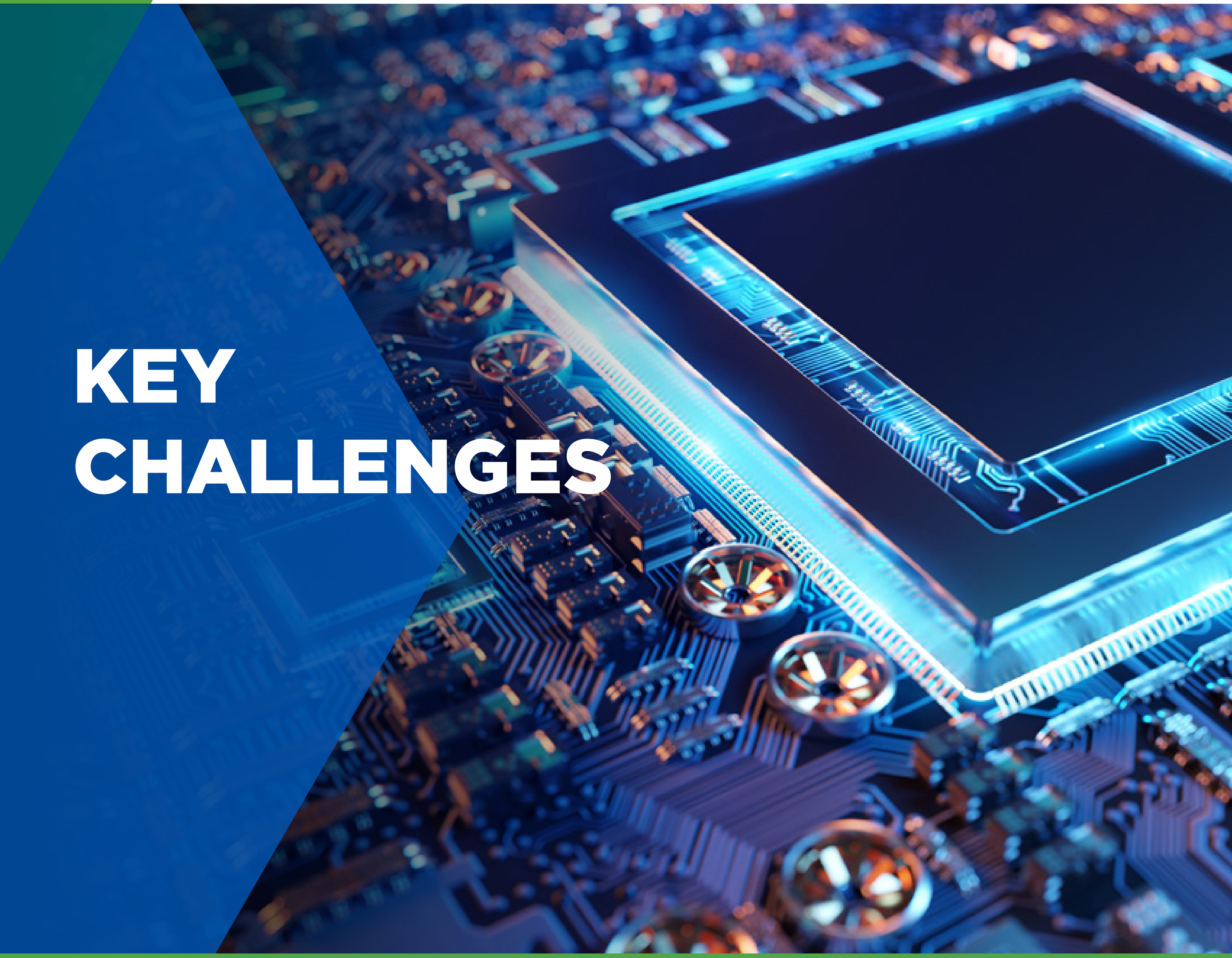
KEY CHALLENGES



Key Challenges and Solutions for Closing the Microelectronics Talent Gap

The ASA-SEMI planning team has identified the following key challenges in addressing the large and growing microelectronics workforce development gap.

An Invisible Industry Our industry is invisible to most students and the public. This lack of awareness already has resulted in a shortage of qualified job candidates and must be urgently addressed in order to fill the 42,000 new jobs that will be directly created by CHIPS Act incentives.	**Costly/ Inconsistent Training** Training programs are faced with an aging population of faculty and instructors and high cost of infrastructure (facilities and equipment, consumables, lab operation/ maintenance, simulation and design software).	**Industry and Academic Silos** Educators need to tailor their educational programs to align with current and future industry needs. Industry should help to support and advocate for microelectronics-related program growth or investment.
Dated Curriculum Updating of content, and modern multimedia teaching tools (e.g., simulations and AR/VR experiences) are needed to enhance curricula, build new skills, and engage students.	**Pipeline Inequity** The industry's student and workforce demographics don't reflect those of the U.S. population. Diversity, equity, and inclusion issues limit the size and strength of the talent pool.	**Talent Retention** The industry continues to see a leaky talent pipeline. There are retention issues as students complete internships and graduate, and even after they enter the workforce.

In the pages that follow, we describe near-term and long-term solutions to address each one of these key challenges, noting the resources needed for implementation, and their expected outcomes.

Key Challenge #1: An Invisible Industry

The microelectronics industry is invisible to most students and to the public. This lack of awareness already has resulted in a shortage of qualified job candidates and must be urgently addressed in order to fill the 42,000 new jobs that will be directly created by CHIPS Act incentives.

Near-Term Solutions for Increasing Semiconductor Microelectronics Visibility

- Conduct a high-visibility career advertising campaign that uses culturally relevant messaging and practices known to promote diversity, equity and inclusion (DEI) and that emphasizes the broader impacts of the field to address societal needs, including the role of industry innovations in healthcare devices (e.g., pacemakers and insulin pumps), electric vehicles, renewable energy, computing, space, etc.
- Raise the visibility of leaders & individual contributors; feature heroes & their contributions to society
- Increase visibility and promote industry careers in places like LinkedIn and Blind
- Assure students of the long-term availability of stable, good-paying jobs in the industry: track and communicate metrics of advertised job openings and salaries
- Implement cultural changes from within the industry that will help to attract and retain talent
- Build more intentional partnerships between universities, community colleges, industry, and K–12 schools that will increase student exposure to industry professionals through a variety of outreach, internship, mentoring and hands-on training programs, summer camps, guest lectures, etc.
- Develop a comprehensive career map resource for educators, guidance counselors, and students with information about a range of jobs that support the semiconductor industry and what training is required for those jobs
- Support efforts to advocate for education measures at the state and national governmental levels that will maintain and strengthen K–12 student preparation for STEM and semiconductor/microelectronics careers

Near-Term Solutions — Create More On-Ramps to Workforce

- Develop bridge programs that support the transition from K–12 to college programs; inform guidance counselors to act as advocates
- Strengthen community college relationships with industry and universities, especially to form pathway programs from 2–year community college to 4–year university programs
- Bolster existing university and community college technology programs that focus on more applied skills for jobs in e.g., manufacturing, construction, and equipment operation
- Develop targeted training programs (reskilling/upskilling) for groups such as veterans and tradespeople
- Develop short courses or micro-credential programs for people with transferable skills interested in moving from a different industry to the semiconductor industry

Long-Term Solutions

- Develop new educational materials - tutorials, demo kits, and other materials with modern and interactive content
- Develop "Entertain to Educate" resources like interactive demonstrations, games, AR/VR simulators, animations (a modern version of the video Silicon Run) and other engaging media in collaboration with relevant educational entertainment experts (such as Veritasium or 3Blue1Brown) and develop a course materials repository
- Train educators on how to incorporate modern resources in their classrooms
- Empower educators and guidance counselors as advocates for the semiconductor industry with info sessions and a teach-the-teachers program, which will 1) increase industry understanding and familiarity, 2) support teachers with new industry educational resources, 3) train educators on the materials, and 4) provide career maps that will help educators and guidance counselors advise students on how to pursue jobs in the industry
- Offer resources and guidance to expand industry capabilities in new and existing makerspaces (e.g., a list of recommended equipment, training materials, instructions for basic student projects, and competition ideas)

Required Resources

- Sustained financial support for students via scholarships, fellowships, loan forgiveness programs, paid internships
- Programs that facilitate engagement between students and industry professionals
- Support for educators and incentives to develop new educational resources
- Teach-the-teachers programs aimed at K–12 and community/technical college instructors
- Small equipment grants and project guides for makerspaces

Expected Outcomes

- Greater public awareness and understanding of the semiconductor industry and microelectronics jobs in the U.S.
- Growth of electronics infrastructure and activity in makerspaces
- Greater diversity in both student demographics and industry employees
- Scaling of reskilling/upskilling programs and engineering technology programs

Measures of Success

- Social media/survey analysis of the industry's public visibility and perceptions
- Increased number of students transferring from community college to 4-year university STEM programs
- Increased number of new programs (credited and micro credentials)
- Increased enrollment in programs that feed into semiconductor industry jobs, especially domestic students, women, and underrepresented minority students
- Increase in number of qualified applicants applying to jobs in semiconductor/microelectronics industry

Key Challenge #2: Costly/Inconsistent Training

Training programs are faced with an aging population of faculty and instructors and high cost of infrastructure (facilities and equipment, consumables, lab operation/maintenance, simulation and design software).

Near-Term Solutions

- Leverage existing fab facilities at colleges, universities, national labs, and industry for workforce development by broadening access for hands-on training in chip micro/nanofabrication, metrology, testing, packaging, etc.
- Catalyze collaborations to enhance the training and workforce development ecosystem
- Function as a central clearinghouse of information, resources, educational materials, open-source curriculum, guidance, best practices, and strategies to promote and facilitate diversity, equity, and inclusion
- Centralized network resources to include national database of facilities with sharable resources and their lab capabilities
- Form regional hubs and create processes to coordinate and lower the barrier for access to regional hub facilities
- Require ASA university members to partner with local community colleges and trade/technical schools
- Provide incentives for facilities to widen access and host training programs (like summer camps or student exchange programs) and to support trainees with temporary housing and stipends
- Help existing facilities acquire additional or duplicate equipment as well as appropriate staff support to accommodate more users
- Create a coordinated ecosystem to facilitate training access that will be able to readily integrate with and maximize the usefulness of the new infrastructure

Long-Term Solutions

- Devise incentives for colleges and universities to hire and retain more faculty and instructors in the semiconductor field
- Support existing teaching labs in securing modern equipment, supplies, access to software design tools, and long-term operations costs
- Identify recurring needs of network members and coordinate with industry and federal agency partners in securing appropriate support through gifts, at-cost or subsidized pricing, direct funding support, or other mechanisms
- Create more AR/VR simulations for training. Develop virtual interfaces to learn about cleanroom and fabrication equipment and alleviate access issues, especially with respect to the uneven geographic distribution of facilities.
- Explore opportunities to set up remote access training resources and integrate these activities with onsite visits
- Revitalize the teaching workforce by helping companies host train-the-trainer programs that bring instructors to fabs for “industry sabbaticals”
- Ensure sabbaticals provide instructors with experiences on state-of-the-art equipment to then integrate experience and knowledge into their classroom instruction

Required Resources

- Administrative support to coordinate access and use of fab facilities
- Financial resources to incentivize organizations to broaden access to their facilities; If needed, increase user capacity and support to acquire additional equipment
- Incentives for schools to hire more semiconductor faculty
- Supplemental funding for new faculty start-up packages
- Funding to outfit teaching labs with modern equipment, supplies, software tools and sustained operational support
- Support for the development of virtual interfaces for equipment training and AR/VR simulations
- Support or incentives for companies to develop train-the-trainer programs and support for instructors to participate

Expected Outcomes

- Greater facility access and resource sharing system for training
- Substantial growth of semiconductor teaching workforce
- Improved quality of training facilities and software resources available to students
- Development of virtual interfaces for remote instrument training

Measures of Success

- Increase in hourly usage of facilities for training courses
- Increased number of student projects that are taped out
- Increased number of university and college faculty with semiconductor specialization
- Increase in number of semiconductor-focused courses offered throughout the nationwide network

Key Challenge #3: Industry and Academic Silos

Educators need to tailor their educational programs to align with current and future industry needs. Industry should help to support and advocate for microelectronics-related program growth or investment.

Near-Term Solutions

- Build on existing networks to create a framework for bi-directional communication between educators and industry
- Develop a more durable model for re-integration of industry feedback to identify and incorporate trends, topics, courses, issues, and demands into the academic curriculum
- Survey member companies to quantify specific workforce needs and inform educational pipeline targets
- Show educators how many people are needed for what jobs and with what levels of training
- Show educators any skill deficits of graduating students that might be addressed in the curricula
- Equip educators to advocate for changes and growth of their programs or facilities in their home institutions

Long-Term Solutions

- Create and implement models for industry professionals to interact more with K-12 students and undergraduates
- Consider “industry-endorsed” certification to promote alignment of training programs with industry needs.
- Identify continuing education needs and provide resources to enable job and career growth
- Investigate micro-credentialing, nanodegrees, or skill-specific training, or single classes and micro-certs across schools
- Encourage members to consider cross-personnel appointments between industry and academia, giving industry personnel some release to teach at universities (teaching sabbaticals), and academic personnel some release to do hands-on training in fabs/industry (industry sabbaticals)
- Build a forum for educators and industry to share, identify, and spread best practices and successful programs for industry-academic partnerships where students take part in special programs, apprentice part time or complete a year-long industry internship
- Look for ways to create new innovative programs where industry experience is integrated with college coursework

Required Resources

- Administrative support to conduct workshops, meetings, task groups, surveys, and other measures to improve communication and alignment across academic and industry sectors
- Support to develop an industry endorsement process
- Support to identify continuing education needs and to develop and offer appropriate programs, certifications, or micro-credentials that address these needs
- Resources to run annual surveys to quantify industry workforce needs

Expected Outcomes

- Higher degree of collaboration, communication, and interaction between academic and industry sectors
- Defined workforce targets and evaluation mechanism to track progress toward goals
- Better alignment of education pipelines and skill training with industry workforce needs; possible development of soft accreditation process
- Greater interaction between students and industry professionals
- Development of strategic continuing education training opportunities

Measures of Success

- Increase in student recruitment, reflected in both program enrollment and graduation rates
- Increase in student placement into semiconductor industry jobs, and retention in the field
- Shorter times required to fill positions and to train new employees to proficiency

Key Challenge #4: Outdated Curriculum

Microelectronics textbooks and courses have evolved since the 1960's as SI technology has evolved and now contain a mixture of very relevant and outdated content. The curriculum needs to be updated and refreshed for a beyond Moore's Law era and in partnership with industry. Modern multimedia teaching tools (e.g., simulations and AR/VR experiences) are needed to enhance curricula, build new skills, and engage students.

Near-Term Solutions

- Develop and distribute new interactive teaching resources
- Support educator enthusiasm for new tools and help them dedicate the necessary time for development
- Require more training programs to include co-op internships in industry so students get exposure to work environments and hands-on experiences with state-of-the-art equipment
- Support universities to develop tailored chip-design curricula and acquire corresponding design tools for training
- Help educators share successes and best practices across the network to promote adoption and scale-up of pilot programs, such as Purdue University's SCALE program funded by the Department of Defense

Required Resources

- Faculty time to develop new teaching tools and resources, supported by funded sabbatical programs, partial summer salary, or course-buyouts
- Server/cloud infrastructure to run chip design flows
- Free/reduced-fee access to EDA software tools
- Free/low-cost access to multi-project wafer fabrication runs and Process Design Kits

Expected Outcomes

- Development of new, modernized, multimedia learning tools
- Greater availability of software design tools at low or no cost for students; strengthened software training resources
- Development and growth of special training programs at colleges and universities with a focus on semiconductors
- Growth in hands-on learning opportunities inside and outside the classroom to supplement traditional coursework
- Development of cloud resource to support design training activities

Measures of Success

- Growth of student enrollment and graduation rates; more hands-on engagement is expected to improve retention
- Feedback from industry indicating increased readiness of job applicants with applicable hands-on training

Hands-On Learning Solutions

Internship opportunities in industry need to target the full range of workforce needs and skill levels from technicians and tradespeople to advanced engineers. Greater numbers and variety of hands-on learning experiences is a key element to attract and retain more students to the industry as well as prepare them for industry jobs. Approaches to increase hands-on training in the following four technical specialties are described below. A national network (ASA) should coordinate these efforts and facilitate internship opportunities for students across the network, for greatest impact. Resources developed for hands-on learning experiences will be considered shared network resources and will be available through the network's central repository for ready adoption by any network instructor.

1 Materials, Processes, and Technology Computer Aided Design (TCAD)

Near-term: Increase affordable access to software tools and the availability of training resources for software tools; ASA should seek to negotiate student licenses

Long-term: Undergraduate programs for students to receive more multidisciplinary training that includes statistics, materials science, and physics

2 Heterogeneous Integration (HI) and Packaging

Near-term: Increase access to training programs/activities at facilities equipped with HI capabilities

Long-term:

- Support for academic programs. Provide mechanism to acquire tools for HI and packaging in existing facilities
- Fellowships should require internships/co-ops to ensure that students get experience with "full size" applications
- Support the creation of a national packaging institute that has a neuromorphic structure with regional distribution. Would serve as a highly valuable resource for both training and R&D innovation. (Access to packaging substrates is limited due to their overseas manufacturing. While not financially feasible to establish all advanced packaging supply capabilities in the U.S., it could be feasible to build manufacturing infrastructure for a few key targets that would strategically support the innovation pipeline)

3 Reliability and Testing

Near-term: Add training on reliability and testing to give students a holistic process view and teach them how to anticipate and forward plan for potential scaling and manufacturing problems

Long-term:

- Develop ideal training resources such as multi-physics simulators for reliability and testing
- Promote collaborations between educators and industry professionals to create training resources on reliability and testing. Can include modular lectures on topics including cost trade off and risk avoidance; case studies from real-world problems; realistic problems, challenges, or competitions for students to solve

4 Chip/System Design and Electronic Design Automation (EDA)

Near-term:

- Increase affordable access to software tools and training resources, including negotiating student licenses
- Work with both vendors and industry professionals to strengthen the EDA training ecosystem on modern chip/system design flows and methodologies
- Develop cloud infrastructure to support easy sharing and deployment of complex flows — a centrally hosted cloud environment to ease sharing and adoption of design environments, classroom teaching material and labs, with the actual computing done locally. Canada's CMC is offering this to Canadian research groups
- Help advertise and standardize practice. Though many EDA tools are overly complex for undergraduate training, this can be successfully overcome by reducing the degrees of freedom in the software

Long-term:

- Make "Professor of Practice" positions more commonplace for dedicated support to teach students at all levels how to use EDA tools
- Support external seminars/lectures on chip/system design through universities & colleges partner with industry
- Leverage ASA community to overcome challenges of proprietary tools limiting information and script sharing
- Help obtain funding/subsidies for actual fabrication, test and characterization (follow Canada/EU models) and help to develop a more efficient process for MPW submission (like CMC and EUROPRACTICE)

Key Challenge #5: Pipeline Inequality

The industry's student and workforce demographics don't reflect those of the U.S. population. Diversity, equity, and inclusion issues limit the size and strength of the talent pool.

Near-Term Solutions

- Create more on-ramps for non-traditional students, such as bridge programs or re-training programs for veterans
- Increase scholarship and fellowship funding. Scholarships should support both full and part-time students at universities/colleges, community colleges, and trade/technical schools
- To increase diversity, resources must be intentionally allocated to increase opportunities at minority-serving institutions, community colleges, and trade/technical schools
- Create loan forgiveness programs at every level of training
- Ensure abundance of paid internships that offer adequate compensation so that participating in an internship does not pose a financial risk or burden
- Offer resources to promote adoption of "Earn and Learn" models that lower time to employment, such as using models like subsidized wages, bootcamps, apprenticeships, paid research, and on-campus opportunities
- Enhance supportive services for students such as emergency grants, mental health, career development, confidence coaching, mentorship, transportation, and childcare
- Gather support for teaching facilities, especially at minority-serving institutions, with proper/modern equipment and consumables for teaching labs
- Increase low-barrier access to fab facilities and hands-on training experiences off campus where needed as well as develop rich virtual training resources
- Collect and share, train, and offer resources for educators to adopt more inclusive and equitable teaching practices
- Review pedagogical practices in electrical engineering and consider new ways of making key content accessible
- Make resources available, support, and incentivize companies to adopt strategies that promote diversity, equity, and inclusion. Offer DEI training and mentorship curriculum to shift company and industry culture
- Engage in discussions to understand and use evidence-based outreach techniques that would have the greatest traction with female and underrepresented minority students, making connections between the semiconductor industry and solutions to real-world societal problems (climate change, healthcare, and others)
- Ensure diversity is visible in all industry advertising so all students can see a place for themselves in these careers

Long-Term Solutions

- Target underrepresented and underserved communities in K-12 outreach; early awareness is key to recruitment
- Track equity and distribution of program funding because women and underrepresented minority populations traditionally receive less funding for ventures
- Work with instructors in programs where growth is slow, stagnant, or declining (such as some technical and community colleges) to revitalize programs that aren't exhibiting the same rate of growth. While the topline number of students entering STEM fields is growing, it is not increasing equally across educational institutions or student identity groups
- Use targeted recruitment, support of curriculum development and training infrastructure, strategic partnerships with universities and industry, and other approaches to catalyze growth

Required Resources

- Resources to develop special programs targeting untapped and underrepresented talent pools
- Scholarship, fellowship, loan forgiveness programs, internship, and supportive service funding
- Resources purposefully allocated to support training programs and infrastructure at institutions serving underserved and underrepresented students
- Employer commitment to a workplace culture that promotes diversity, equity, and inclusion and uses equitable practices during the interview, hiring, and training processes

Expected Outcomes

- Repository of resources available to support adoption of evidence-backed diversity, equity, and inclusion practices in colleges, universities, and industry
- Growth in workforce diversity, improved equity, and inclusivity
- Growth of funding supporting women, underrepresented minorities, and other underrepresented students in semiconductor training programs
- Growth of funding going to institutions that serve underrepresented students

Measures of Success

- Increase in enrollment, graduation rates, job placement, and retention rates of women and underrepresented minority students in semiconductor programs and industry jobs
- Improvement in job and academic program satisfaction reported in an annual industry-wide DEI survey.
- Reduced attrition of women and members of underrepresented groups in industry

Key Challenge #6: Talent Retention

The industry continues to see a leaky talent pipeline. There are retention issues as students complete internships and graduate, and even after they enter the workforce.

Near-Term Solutions

- Build a stronger sense of community, professional identity, and a culture of inclusion
- Extend student engagement beyond the classroom through participation in extracurricular team competitions, use of electronics-equipped makerspaces, mentorship opportunities, summer programs, REUs, apprenticeships, internships, externships, co-ops, and other industry-led programs
- Industry to collaborate with ASA, SEMI, and educators to evaluate and enhance their internship programs to ensure high quality, high impact of student experience, and subsequent retention
- Financially support students throughout their training with scholarships, fellowships, loan forgiveness programs, and competitively paid internships
- Broadcast assurance of the long-term availability of stable, good-paying jobs in the semiconductor industry to help with recruitment and retention
- Align student/trainee expectations with reality by painting a transparent representation of working conditions, expectations and career growth opportunities in the field
- Explore ways to overcome pay gap and work-life balance shortcomings compared to other industries
- Continue to develop, offer, and support programs that foster equity and inclusion, especially with partner minority-serving institutions and community colleges
- Gather and share resources and best practices to promote DEI within academic and industry organizations

Long-Term Solutions

- Promote and organize mentoring relationships, including near-peer mentoring especially at the college/university level between lower- and upper-level students, as well as between partnered community colleges and universities
- Develop Career Map resource to aid in recruitment and in education-workforce alignment. Will also help students to map out and envision meaningful career trajectories for themselves
- Investigate potential benefits of hosting an industry-wide job board to help applicants navigate their job searches and help to streamline the hiring process for managers
- Identify pool of exceptional “first experiences” comprising programs and mentors that are particularly adept at supporting students who are new to the field, cultivating positive experiences, and inspiring students to pursue the semiconductor/microelectronics field long term
- Identify and develop more opportunities for professional development and career advancement. Review opportunities to create strategic continuing education programs (like Google has started for Project Management, User Experience Design) to support skill development, diversification, leadership and advancement
- Conduct an annual survey of current students and recent graduates to gather quantifiable data about what motivates students to pursue the field, perceptions of

the field and available jobs, and what causes students to pursue other fields. Data helps benchmark impacts of advertising and other recruitment and retention efforts and to shape the direction of future programs and approaches to grow the field

- Support the industry with Technical Ethics classes and Cultural Change and Inclusion courses, educating corporations and employees

Required Resources

- Support to extend student engagement beyond the classroom through several types of programs
- Scholarships, fellowships, loan-forgiveness programs, and paid internships
- Identification, promotion, and adoption of proven DEI methods
- Support for organizing and facilitating a mentoring program
- Administrative support to develop an engaging and user-friendly career map resource for students and educators
- Support to identify and develop continuing education and professional development courses
- Support to administer an annual survey for current students and recent graduates to gauge interests, motivations, and perceptions of the field to evaluate impacts of ongoing ASA-SEMI programs and drive future directions

Expected Outcomes

- Stronger interest, excitement, outlook, and sense of professional identity reflected in student surveys
- Growth of participation in mentorship programs
- Growth in semiconductor job placement after graduation

Measures of Success

- Increase in graduation rates from relevant programs
- Increase in workforce retention (i.e., how long students remain in semiconductor industry jobs after graduation)
- Greater job satisfaction as measured through annual surveys
- Competitive salary levels of graduates compared to other fields

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LEVERAGING EXISTING PROGRAMS FOR LARGE-SCALE IMPACT

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LEVERAGING FOR IMPACT

The U.S. microelectronics education community comprises a broad diversity of baccalaureate- and graduate-degree-granting institutions and community colleges, a fraction of which work in partnership with industry to increase student participation in STEM fields and prepare them well for careers in the microelectronics industry. In fact, some of the solutions described above already are being implemented in a limited capacity. The ASA-SEMI partnership will connect with and leverage existing successful WFD programs to promote best practices and effective collaboration models for increasing the number and diversity of students, supporting faculty in teaching and mentorship, and coordinating development and sharing of curricular content aligned with industry needs. Examples of such programs are briefly described below.

- **California State Summer School for Mathematics and Science (COSMOS)** [11]
  The California state legislature established COSMOS in 1998 with the goal of engaging talented and motivated high school students in an intensive program of study, experimentation, and activities to further their interests and skills in STEM. COSMOS summer programs improve the linkage between high school, postsecondary education, and the workforce by connecting students to institutions of higher learning and research facilities.

- **NSF Advanced Technological Education (ATE)** [12] **and Industry-University Collaborative Research Centers (IUCRC)** [13]
  The National Science Foundation ATE program focuses on community college (CC) technical education programs that provide students a pathway to complete a CC degree and enter directly into the workforce. Two national ATE Centers relevant to microelectronics are the Micro Nano Technology Education Center (MNT-EC) and the National Center for Next Generation Manufacturing (NCNGM). In particular, MNT-EC has a Business Industry Leadership Team (BILT) consisting of 32 industry partners who meet three times a year to assess the knowledge, skills, and abilities needed and to share trends in the microsystems industry so that CC educators can tailor courses and programs for the future needs of the industry.

  The MNT-EC also updates curriculum and is creating an e-portfolio portal for students to complete challenges that they can share with industry when applying for jobs. The e-portfolio platform is part of the Micro Nano Technology Collaborative Undergraduate Research Network (MNT-CURN). MNT-CURN provides 50 students a year with a year-long internship, meeting weekly online with research university and industry professionals to share opportunities in micro/nanotechnology. Each MNT-CURN student is provided a summer internship with a university partner. CC students can tailor their summer internship to meet their needs. For instance, partnerships with Purdue University and Indiana University are completely online with no need to travel. The Support Center for Microsystems Education at the University of New Mexico provides a one- to two-week cleanroom experience where students design and fabricate their own micro pressure sensor.

In addition to the remote or shorter-term experiences described above, MNT-CURN students can obtain full-year internships through the Skills Training in Advanced Research & Technology (START) program which partners research university IUCRC sites and ATE programs with CCs. IUCRC sites foster research university and industry partnerships to accelerate the impact of basic research, leading to increased innovation in technology development. Currently, MNT-EC and IUCRC sites at CalTech and the University of Southern California provide internships to six community college students, focusing on micro- and nano-systems research. 90% of students in the MNT-CURN program are from underrepresented groups, including 40% African American.

- **NNSA Minority Serving Institute Partnership Program (MSIPP)** [14]
  The National Nuclear Security Administration MSIPP partners minority-serving educational institutions with Department of Energy National Laboratories to increase academic success of underrepresented minority (URM) students. The program has partner institutions focusing on additive Manufacturing, Advanced Manufacturing, Advanced Sensors, and Materials Science, all disciplines essential to microelectronics. Forty-six CCs and universities partner with eleven national labs and two non-profit organizations to develop educational pathways for URM students. One partnership, through the non-profit Growth Sector, has developed the STEM Core Network that provides CC students a summer bridge program to prepare them for advanced math courses. Students then take an Algebra course in the fall semester and a Trigonometry course in the spring semester, while simultaneously participating in research and a technical education course. Faculty mentors provide guidance for different academic and career pathways in STEM. At the conclusion of year one of the STEM Core program, students are given a summer internship opportunity at a national lab or research university.

- **The National GEM Consortium** [15]
  The GEM consortium began in the 1970s with the goal of creating an educational environment that increases participation of underrepresented groups at the master and doctoral levels in engineering and sciences. Over 4,000 students have graduated with degrees from the GEM consortium including over 200 with doctorate degrees. GEM Consortium opportunities include the GEM Fellowship Program that provides funding for master's and doctorate students at top science and engineering universities; the Inclusion In Innovation Initiative (I4) which supports academic researchers in launching tech startups through entrepreneurial training; the GRAD Lab which provides underrepresented undergraduate students exposure to the benefits of research and technology careers; and the Faculty and Professional Symposium (FFP) which is a career development program for future faculty members and industry professionals.

- **Project SCALE[16] and nanoHUB** [17]
  The Scalable Asymmetric Lifecycle Engagement (SCALE) program is a research and workforce development program, led by Purdue University and funded by the Department of Defense (DoD), that provides access to courses, mentoring, internships, and targeted research projects in microelectronics. Eighteen universities, 26 DoD organizations, and 26 companies partner in five microelectronic technical areas: radiation hardening, system on a chip, heterogeneous integration/advanced packaging, embedded system/AI design, and semiconductor supply chains. Through a community of practice, SCALE faculty and students collectively learn through an online environment, tech talks, design senior projects, multi-disciplinary cross-campus research, and conferences.

  The Network for Computational Nanotechnology (NCN) administers nanoHUB, an online repository of simulations and educational resources in the nanosciences. nanoHUB includes a dedicated space for semiconductor workforce development, which includes immersive learning through simulations and virtual reality with over 600 apps and open education textbooks. Each year, over 10,000 students use nanoHUB simulations for education. Over two million users make use of online simulation and open content educational resources on nanoHUB.org each year. Educators can also partner with nanoHUB to develop new simulation tools and open educational content that can be disseminated within the nanoHUB community.

The exemplary programs described above are all aimed to address the WFD needs of certain interest groups and are limited in scale — nowhere near the many thousands of new graduates per year that the microelectronics industry needs. The ASA-SEMI partnership aims to work with these programs and others to scale up their impact through expansion and/or replication across the country, in addition to implementing additional solutions noted above, in order to close the talent gap. By fostering collaboration over competition within the microelectronics education community, the whole can be greater than the sum of the parts, and all participants (students, faculty, industry professionals, educational institutions, industry and government) will benefit.

A Case Study in Educational Collaboration: The nanoHUB

The nanoHUB is a case study that shows why educational content development (i.e., curriculum development, online course development, virtual/augmented-reality experiences, interactive resources, etc.) and infrastructure development should be bundled together within the ASA network (and not independently funded) and managed with encouragement (or even requirement) to share resources through the network.

- During the first 10 years of NCN (Network for Computational Nanotechnology), research and education activities and the nanoHUB infrastructure were bundled into one program. As a result, 25 participating faculty across six universities collaborated and were committed to the success of the network.
- For the second 10 years of NCN, NSF chose to unbundle the research and education activities from the infrastructure network, to allow a larger number of universities to compete for the program. There is now a platform team that runs the infrastructure network and independent (separately funded and reviewed) university “hubs” that develop educational content for dissemination via the nanoHUB network.

Faculty connection to the network and connections between the participating universities are not as strong and synergistic today as they were during the first 10 years. Faculty tend to focus on their own priorities rather than the success of the network. In fact, nanoHUB activity data show that the number of annual contributions in the second (unbundled) model is about one-half that of the first (bundled) model. Key to the greater success of the first model was the ability of the network leadership to influence resource development activities so that they fit together into a coherent overall plan.

Today nanoHUB is a model for harvesting innovative research and educational approaches and translating them into widely usable, shared resources. The benefits of such translational work are not self-evident to most faculty; therefore, successful implementation requires formal structures and financial incentives.

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PRINCIPLED AND VALUES-BASED GOVERNANCE

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PRINCIPLED GOVERNANCE

To strengthen the nation's position in semiconductor R&D and manufacturing, a balanced and holistic approach to workforce development is needed, one that takes into consideration the needs and objectives of the stakeholders – specifically, the U.S. Government and Industry. Guiding principles must ensure equitable and unbiased evaluation of proposals and a fair decision-making process to direct and measure the success of investments. The governance structure and operations of the network also should reflect the values of equity and inclusion, transparency and accountability, and they should follow best practices to facilitate engagement of stakeholders and collective decision-making for effective stewardship of investments. SEMI has a successful track record of managing public-private partnerships with the following governance structure:

a. A Governing Council comprised of stakeholders and solution providers;

b. Elected Chair and Vice Chair of the Governing Council, each with term limits;

c. Advisory Council of subject matter experts that identify key gaps and weaknesses in the talent pipeline;

d. Management of the Councils by a neutral party, belonging to neither the stakeholder nor solution provider community, and

e. A fair and equitable process by which proposals are evaluated and selected for funding.

Accordingly, the ASA/SEMI partnership proposes a Governing Council comprising:

1. U.S. Government stakeholders,
2. Industry stakeholders representing a spectrum of supply chain disciplines,
3. The SEMI Foundation, a separate 501(c)3 organization and a solution provider which represents semiconductor industry interests in talent and workforce development,
4. Representatives from a diversity of U.S. institutions of higher education, geographically distributed across the U.S., and
5. SEMI, a 501(c)6, semiconductor industry association, chartered with a position of neutrality on the Governing Council.

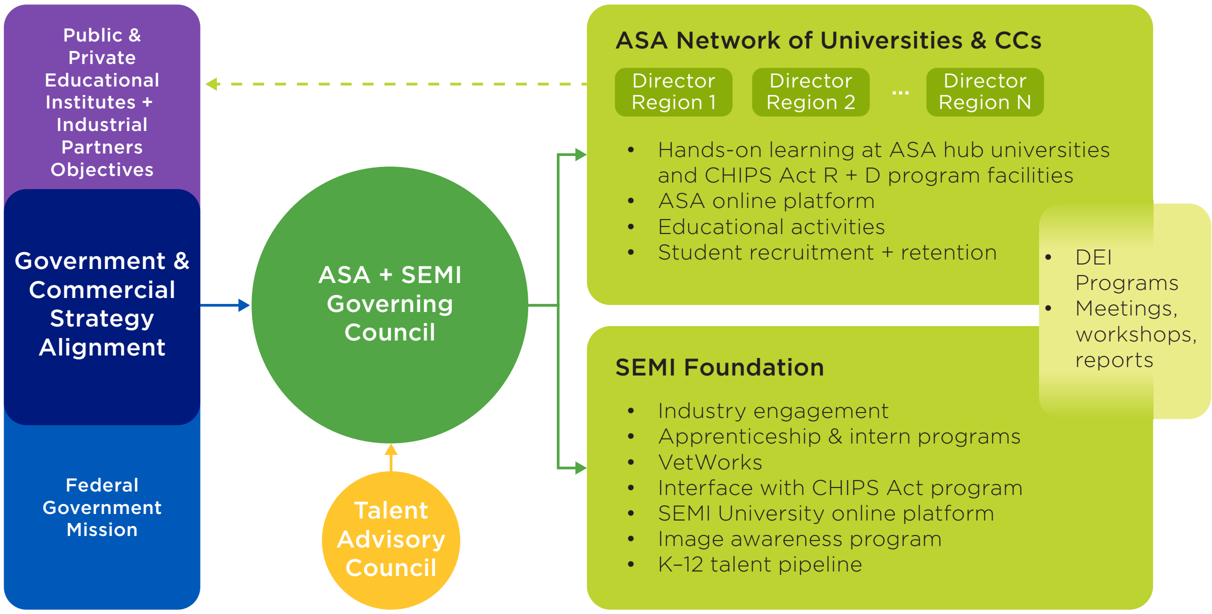
National objectives, represented by the U.S. Government participants, are defined and aligned with industry objectives within the Governing Council to drive dual-use solutions. The ASA Executive Committee represents the network of Universities and Community Colleges across the U.S. providing higher education solutions. The SEMI Foundation is a solution provider for talent development to serve the semiconductor industry, including the educational pipeline before college, technician skills, and up-skilling and re-skilling later in one's career. The Governing Council's roles and responsibilities include balancing the National, Industrial and Academic objectives, investment strategy, managing budget commitments, ensuring key performance indices are collected and reported, and management/consultation with the advisory level.

The Governing Council should be advised by a Talent Advisory Council (TAC) in carrying out its responsibilities. The membership of the TAC may include regional sponsors who represent State Government interests and subject matter experts. The Regional Committees' role is to assess regional objectives and identify gaps in the talent pipeline and opportunities within the educational process, facilities and curricula. In order to identify gaps, stakeholder forums may be conducted. In addition to the skills and educational gap analysis, the objectives will include proposing investments to close those gaps and request for proposal (RFP) development. The Governing Council will consider the TAC inputs, evaluate proposals and vote on investment decisions.

Figure 1 illustrates the governance and organization of activities within the ASA and SEMI Foundation. Education and training programs at U.S. institutions of higher education should be funded through a fair and transparent request-for-proposal (RFP) process. Proposals received will be evaluated using a scorecard methodology and the proposal review panels will include representatives from a diversity of universities and colleges, including minority-serving institutions and community colleges. Funded programs will be required to provide periodic reports and program reviews.

Figure 1: National Network for Semiconductor Microelectronics Education governance and operations

Public/Private Consortium Model



ASA + SEMI Governing Council's Role

- Investment strategy
- Budget commitment
- ROI analysis and KPIs

SEMI's Role

- Manage process of aligning industry objectives with academic solutions
- Federal contract management
- Marketing, membership and industry forums

ASA's Role

- Stage government missions and regional objectives alignment and execution
- Road mapping and educational gap analysis
- Investment proposal & RFP development

Division of Responsibilities

- **Universities and colleges** will carry out educational activities, recruiting and retaining a broad diversity of talent; regular meetings and topical workshops will be organized to ensure sharing of best practices to empower faculty at all participating universities and colleges to succeed in these endeavors. Hub universities (where hands-on learning and training take place) are expected to be geographically distributed across the country; regional directors will coordinate extended visits and apprenticeships for students from the nearby node universities and colleges. An online platform will be curated for sharing of curricular materials and best practices, and for facilitating access to industry-standard TCAD and EDA tools, across the national network.
- **The SEMI Foundation** will be responsible for building an image awareness program to reach a diverse group of students and promote the exciting opportunities the semiconductor industry has to offer. The Foundation will also facilitate industry engagement for modernization and revitalization of microelectronics curricula, as well as for industrial training (apprenticeship) programs for students. Mentoring programs as well as programs that provide transition training for existing workers and military veterans will be deliverables. Last but not least, the Foundation will promote sharing of ideas and industry + academic collaboration through networking events and workshops.
- **SEMI** will be responsible for managing external and internal communications, logistical support for network meetings and workshops, and grants & contracts administration — including negotiation and administration of the prime contract with funders and of subcontracts with universities and colleges, to ensure that compliance and reporting requirements are met. It will support the Governing Council in requesting proposals from higher-education institutions and conducting a fair and transparent evaluation process to select proposals for funding. Last but not least, it will be responsible for tracking of key performance indices, annual assessment of the network by a third party, and annual report to funders.
- **Universities/Colleges and SEMI Foundation** will collaborate synergistically in publicity, outreach and various initiatives to advance diversity, equity and inclusion (DEI) in the broad field of microelectronics and thereby expand the pool of talent for the industry.

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PROPOSED NATIONAL INVESTMENTS

National Network for Microelectronics Education — $500M over 5 years

To ensure that the industry has an adequate supply of talent and innovation to thrive and to regain global leadership in semiconductor design and manufacturing, we recommend new federal funding be allocated in a coordinated manner to establish a nationwide education and training network in partnership with the industry to meet its workforce development needs with speed and scale, at a level of $100M per year, broken down as follows:

- **$2M/year** (or $10M over five years) for administrative support for the network. This includes managing external and internal communications; logistical support for meetings and workshops; grants and contracts administration; compliance and reporting of contracts; supporting the Governing Council in requesting, coordinating, and evaluating proposals for funding; facilitating industry engagement for modernization and revitalization of microelectronics curricula and training programs; tracking key performance indicators; creation of annual reports; publicity, outreach, and initiatives to advance diversity, equity, and inclusion (DEI) within the industry to ensure a broad field of talent; and all human resources, information technology, finance, and other general administrative functions.
- **$3M/year** (or $15M over 5 years) for programs that support students to transition from K-12 to college STEM programs, and to transition from postsecondary school to the microelectronics workforce, for up to 1000 students per year countrywide.
- **$35M/year** (or $175M over 5 years) to support curriculum modernization and sharing across the nationwide network. This curriculum would include courses on chip design and prototyping of student-designed chips. A few university groups within the network will undertake this task to maintain the software tools and flows for chip design and prototyping.
- **$10M/year** (or $50M over 5 years) to support broad university and college access to industry-standard electronic design automation (EDA) and technology computer aided design (TCAD) software tools, design flows, and multi-project wafer fabrication runs in semiconductor foundries for teaching and research purposes. This funding would subsidize the cost of software tool licenses, cloud computing and chip fabrication for users across the nationwide network.
- **$50M/year** (or $250M over 5 years) to cover operational costs of hands-on learning and training programs in chip design, fabrication, metrology, packaging and/or testing at hub universities geographically distributed across the U.S. and including a diversity of institutions. This funding (averaging $1M/yr per hub) would cover student travel and local living expenses as well as instructional staffing, supplies and materials needed to continually offer programs to a broad diversity of students in the local region.

This level of federal investment is needed not only to modernize and align with industry needs microelectronics-related education and training programs at participating U.S. universities and colleges but also to attract and support a greater number and diversity of students, resulting in 10,000 additional new graduates per year for the microelectronics industry. The number of participating institutions and additional new graduates produced per year can be scaled up (or down) with the actual level of total funding appropriated.

Microelectronics Education Infrastructure — $600M over 5 years

In order to support the development of workers with modern skills needed for the U.S. to lead in semiconductor manufacturing and innovation, existing educational makerspaces, laboratory facilities and equipment also must be modernized. Therefore we also recommend **$100M per year** (or $500M over 5 years) in funding to modernize existing educational laboratory facilities and equipment at a diversity of universities and colleges geographically distributed across the network, including institutions participating in CHIPS Act R&D programs. Investments in hard infrastructure include new tools, equipment and infrastructure, and will vary from institution to institution and with the type of laboratory. For example, an instructional lab for testing and characterization of semiconductor devices, circuits and systems can cost up to $2M to modernize, whereas an instructional cleanroom facility for chip fabrication can cost up to $25M to modernize. (Since the operational and maintenance costs of cleanroom facilities and advanced test/characterization labs can be prohibitively high for a university to support in perpetuity, we do not recommend establishment of new instructional cleanroom facilities; rather, we recommend upgrading existing such facilities and making them accessible to students from other institutions in the region.)

There is also a need to incentivize universities and community colleges to prioritize the hiring and support of faculty and teaching staff in order to increase the annual output of the U.S. higher education system for the U.S. microelectronics industry. The NSF Quantum Computing & Information Science Faculty Fellows (QCIS-FF) program [7] provided funding to cover the salary and benefits of new faculty hires in QCIS. Therefore we also recommend an additional investment of **$100M over five years** to incentivize the hiring and support of up to 200 faculty and teaching staff to increase the total output of the U.S. higher education system by 10,000 new graduates (from technicians to Ph.D.-level) per year. This funding could be used to help cover the cost of salary and benefits for new faculty/staff hires for the first 3-5 years, and to provide startup funds for new faculty/staff hires. (It should be noted that faculty startup funds can easily exceed $1M for university faculty who are experimentally oriented researchers.) Salaries in the industry are much higher than in academia, so this financial support can help to incentivize professionals to transition to academia.

Microelectronics Talent — $200M per year

Careers in microelectronics research and development often require graduate-level training, [18] while careers in software engineering generally require a bachelor's degree or less and offer higher starting salaries. Therefore, financial incentives such as scholarships and fellowships, as well as paid internships, are necessary to attract students to careers in hardware engineering and grow the domestic pipeline of students in microelectronics-related graduate programs. Therefore, we also recommend the U.S. government offer advanced traineeships for graduate students and scholarships for undergraduate students, to incentivize pursuit and completion of degrees related to microelectronics at the network institutions, many (but not all) of which may be participating in CHIPS Act R&D programs. Some or all of these traineeships and scholarships could be offered in partnership with industry to guarantee internships and jobs and may be concentrated in geographical regions advancing U.S. competitiveness in semiconductor design and manufacturing. These additional costs are estimated to total **over $200M per year:** [19]

- $105M/year: microelectronics traineeships for 1000 M.S. students (at $60K/student) and 500 Ph.D. students (at $90K/student) per year
- $40M/year: microelectronics scholarships for 1000 undergraduate students (at $40K/student) per year
- $60M/year: STEM scholarships for 3000 community/junior college students (at $20K/student) per year

Summary of Recommended Federal Investments

The total amount of new funding required to attract, support, educate and train additional new talent for the U.S. semiconductor industry in order to secure the nation's future economic competitiveness and security is substantial. To maximize the return on this investment, we propose first the establishment of a coordinating national network for microelectronics education through the NSF (CHIPS for America Workforce and Education Fund), followed by coordinated funding of WFD activities (across the categories summarized below) through the NSF, Department of Commerce (CHIPS for America Fund), and Department of Defense (CHIPS for America Defense Fund), as well as industry. For example, earlier this year, Intel announced a $100 million investment over the next 10 years to support research collaborations with universities, community colleges and technical educators across the country.[20]

Investment Category	Recommended 5-year Investment Total
National Network for Microelectronics Education	**$500M**
Administration ($2M/yr)	$10M
Outreach and Bridge Programs ($3M/yr)	$15M
Curriculum Modernization ($35M/yr)	$175M
Hands-On Chip Design Infrastructure ($10M/yr)	$50M
Operational Costs of Hands-On Training ($50M/yr)	$250M
Microelectronics Education Infrastructure	**$600M**
Modernization of Facilities & Equipment ($100M/yr)	$500M
Support for New Microelectronics Faculty and Instructors	$100M
Microelectronics Talent	**$1.25B**
Traineeships — 1000 M.S. and 500 Ph.D. students per year ($105M/yr)	$525M
Undergraduate Scholarships — 1000 per year ($40M/yr)	$200M
Community & Junior College Scholarships — 3000 per year ($60M/yr)	$300M
Total ($470M/yr)	**$2.35B**

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CONCLUSION

Call to Action

To meet the urgent and growing need for new microelectronics talent, a collaborative and inclusive solution is needed, one that engages a diversity of universities and colleges across the country, companies across the entire supply chain, and government stakeholders. We propose that the ASA should serve as a national network for microelectronics education that partners with industry to empower and support faculty to attract and effectively develop a broad diversity of talent for the industry. Activities of the ASA will include coordination of practical, hands-on training at hub universities that are equipped and staffed to support this training. In partnership with SEMI, the ASA also will facilitate internships for students at government research labs and at industry R&D facilities, including those that are part of the funded CHIPS Act R&D programs.

In summary, the ASA-SEMI partnership will strengthen and broaden pathways to careers in the U.S. microelectronics industry with the speed and scale necessary to meet the industry's growing workforce development needs.

We welcome all solution-providers and stakeholders to join us!

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About the American Semiconductor Academy (ASA) Initiative

The ASA Initiative was launched in summer 2021 to address the shortage of talent for the U.S. semiconductor microelectronics industry, whose workforce development needs are projected to more than double with incentives authorized by the CHIPS for America Act. The ASA planning team comprises faculty and administrative leaders at universities and community colleges across the U.S. who are interested to work together to increase and broaden access to education and training leading to technical careers in the semiconductor industry, by coordinating curriculum development and hands-on training and by collectively partnering with industry to provide apprenticeships and internships. The Executive Committee of the ASA planning team are

- Prof. Tsu-Jae King Liu (Chair), University of California, Berkeley
- Prof. John Dallesasse, University of Illinois at Urbana-Champaign
- Prof. Stephen Goodnick, Arizona State University
- Prof. Quanxi Jia, State University of New York at Buffalo
- Prof. Mark Lundstrom, Purdue University
- Prof. Kang Wang, University of California, Los Angeles
- Prof. Albert Wang, University of California, Riverside (Ex Officio founding member)

About SEMI and the SEMI Foundation

The SEMI Foundation is a non-profit, public benefit arm of SEMI, the broadest tech-focused, global industry association in the world.

SEMI represents the electronics manufacturing and design supply chain, connecting over 2,400 member companies and 1.3 million professionals worldwide. Through its programs, communities, initiatives, market research, and advocacy, SEMI informs and coordinates its members and the industry, cultivates collaboration, drives action, and synchronizes innovation to speed business results. Regional and technology communities are connected in pre-competitive forums for global collective action.

The SEMI Foundation supports workforce development in the semiconductor industry. Our charge is to dramatically expand the pipeline of talented workers ready to fill the significant workforce deficits reported by companies worldwide. We are leveraging this critical need for new and more workers as an opportunity to diversify the talent pool, benefitting both the workers and their communities, as well as the companies who hire them.

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Each of the following corporate leaders has provided written endorsement of the American Semiconductor Academy Initiative and has expressed intention to collaborate with the ASA in areas of workforce training, curriculum development, student internships, and academic research initiatives to help ensure its success.

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