The Competitive Etch: Addressing the talent gap in the semiconductor industry

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Each developed economy is in a race to develop its own domestic semiconductor ecosystem

Since 2018, a confluence of factors has constricted semiconductor supply: The evolving geopolitical environment, unforeseen climate catastrophes, raw material shortages, and unexpected spikes in demand prompted by evolving consumer behaviors throughout the COVID-19 pandemic. Amid the ongoing chip shortage, chip makers across the world remain in a tight race to increase capacity and spur domestic chip production to hedge against future supply chain vulnerabilities. Momentum to build more localized and resilient semiconductor ecosystems is growing, with governments across the world publicly committing to multi-billion dollar spending packages to enable semiconductor self-sufficiency (see Figure 1). Investment has been matched and multiplied in the private sector, with Intel, Samsung, TSMC, Texas Instruments, GLOBALFOUNDRIES, SK Hynix, and Micron pledging to break ground on new fabs and R&D innovation centers.

Drive for Self-Sufficiency by Country

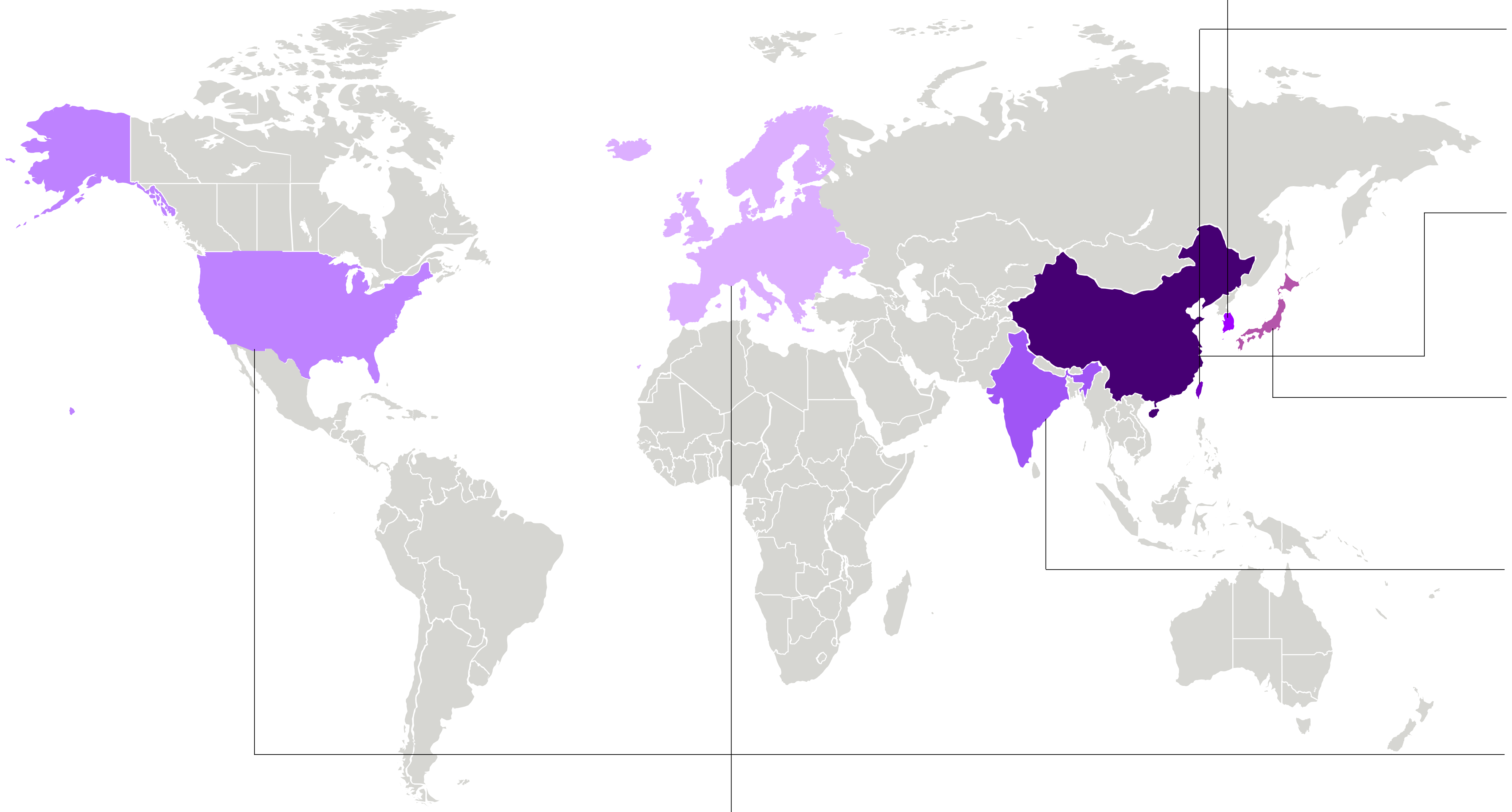


Figure 1
The US is the global laggard in public sector investment into the semiconductor industry[1]

*Legislation proposed, not yet passed

SOUTH KOREA

Build the World's Largest & Most Advanced Semi Supply Chain by 2030[1]
$452B K-Semiconductor Belt strategy unveiled to double the semiconductor workforce, enable a 20% tax credit for new fabs, and provide up to a 50% R&D tax credit

TAIWAN

Strengthen Taiwan's Position in the Global Semiconductor Ecosystem[2]
$260M+ earmarked for semiconductor subsidies (incl. 15% R&D tax credit, income tax exemptions for royalties on imported production technologies) and $300M+ invested into graduate R&D programs

CHINA

Achieve Chip Self-Sufficiency by 2030[3]
$150B in semiconductor investment through Made in China 2025, incl. corporate income exemptions, import duty exemptions on imported materials / equipment, and state financing for R&D

JAPAN

Double Japanese Chip Revenue to $114B by 2030[4]
~$6.8B in funding passed, 80% of which will go towards domestic manufacturing at the leading node, 14% to R&D, and 6% to domestic manufacturing at the trailing node

INDIA

Diversify and Deepen India's Semiconductor Footprint[5]
$10B Semiconductor India Program enacted to attract foreign semiconductor players into the region, with companies eligible to receive 50% of set-up and run costs for new fabs built in India

UNITED STATES

Bring Semiconductor Manufacturing Back to America*[6]
$52B US Chips Act, pending House approval as of June 2021. 75% allocation towards construction/modernization of US fabs and 25% towards critical R&D through creation of NSTC center of excellence

EUROPE

Double the EU's Share of Global Semi Market to 20% by 2030*[7]
$43B EU Chips Act proposed in September 2021 to fund R&D, design, manufacturing, post-graduate scholarships, apprenticeships in advanced labs, and growth of EU-based semiconductor startups

The talent gap in semiconductor emerges as a major obstacle to growth

The effort to strengthen domestic semiconductor capacity is complicated by an acute talent shortage across the entire value chain. For the US alone to become self-sufficient in the semiconductor sector, the US would need to capture an additional 20% of global chip production, translating into 74-80 net new fabs and 300,000 total semiconductor fabrication (fab) positions created. Should the US focus on meeting domestic demand for just critical semiconductor applications (e.g., automotive, home appliances, aerospace, defense), 18-20 additional fabs staffed by 70,000 – 90,000 highly skilled personnel would still be required.[9] Aside from the colossal public and private sector investment needed to operationalize these fabs, finding the right talent to run the fabs on a global scale continues to surface as a key challenge.

Despite growing efforts to invest in science, technology, engineering, and mathematics (STEM) education, the talent pipeline remains narrow. While supply shortages are currently the largest bottleneck in the production process, once the supply chain resets there is a significant risk of going directly from a material shortage into a talent shortage if significant action is not taken. Semiconductor companies are clamoring against players across the technology ecosystem to secure a limited supply of chemical, electrical, computer, mechanical, and materials science engineers. Compounding this talent shortage is the allure of opportunity within hyperscalers (e.g., Meta, Google, Amazon), automotive companies (e.g., Tesla, BMW, Ford), consumer electronics manufacturers (e.g., Apple, SONY, LG), and professional services firms who are all attracting qualified semiconductor talent with competitive compensation packages and brand promises to change the world. Semiconductor companies, with less defined brand equity and fewer market-competitive perks, continue to struggle in building the diverse, premier workforces needed to meet near-term demand and pioneer the next frontier of innovation. Companies are racing to add jobs and connect with rising generations. Intel, as an example, has aired Sunday night football ads to lure new technical talent and has announced $2.4B in cash and stock incentives to retain key personnel.[10] But by and large, semiconductor companies are losing the talent war – severely impeding the movement to re-shore semiconductor manufacturing.

No one country has the labor force needed to support domestic semiconductor self-sufficiency, with each country relying on an interconnected web of highly specialized semiconductor talent dispersed across the US, APAC, and EMEA. The US has particularly benefitted from this inflow of global talent in growing its local semiconductor ecosystem since the 1950s. However, as China and Taiwan catalyze growth of their own domestic semiconductor industries, the US is likely to face increased difficulty as more competitive recruiting tactics are used to fill the 250,000 – 400,000 unfilled semiconductor positions in China and at least 34,000 vacancies in Taiwan.[11] As part of the Made in China 2025 agenda, for example, Chinese legislators have implemented a 1-5-3 recruiting strategy, whereby South Korean semiconductor industry veterans and new college graduates are offered five times the salary in exchange for a three-year commitment to work in China.

What we'll cover in this report

With plans to strengthen domestic foundry and Integrated Device Manufacturing (IDM) capacity, the US is striving to be an all-encompassing semiconductor powerhouse. However, with comparatively less state-sponsored support to accelerate growth of the US semiconductor ecosystem, semiconductor companies stand to continue losing ground in the talent war in the absence of a thoughtful strategy to fill critical engineering talent gaps. In this paper, we explore three tactical levers companies should consider in evolving their workforces and their applicability across the semiconductor value-chain:

Section 1

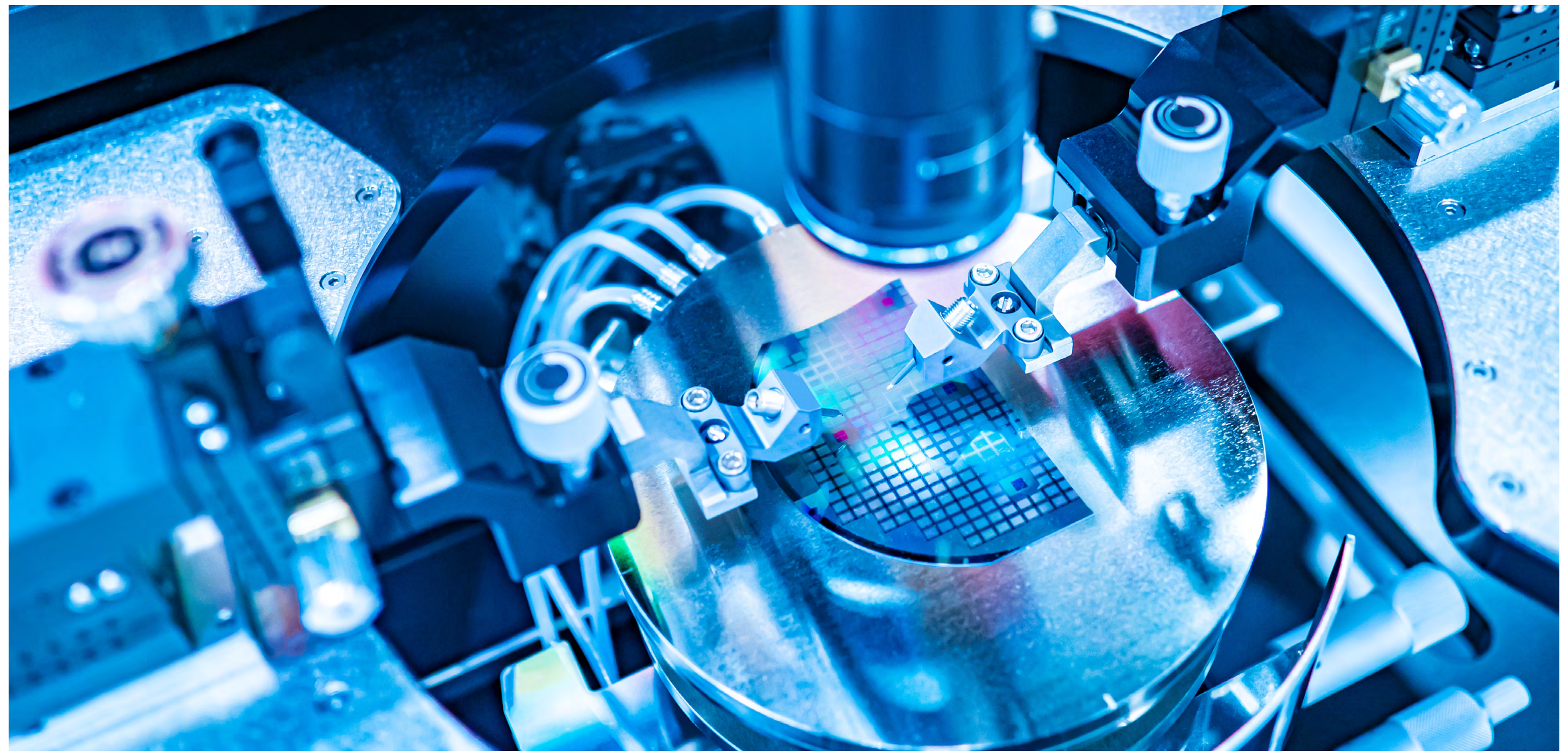
Automate
describes automation opportunities and why they will be essential to scaling the domestic manufacturing footprint

Section 2

Reskill
offers an original perspective on reskilling that is unique to the semiconductor industry

Section 3

Grow Pipeline
outlines specific strategies semiconductor companies can use to grow their pipeline and be more competitive with hyperscalers in the talent war



LEVER 1

Reveal hidden value: Automate where you can

Leading semiconductor companies have yet to embrace the full potential of automation

Many semiconductor powerhouses lag other technology players in implementing core automation solutions, limiting their ability to free up employees to focus on higher value-add activities. This, coupled with rising costs to source, hire, onboard and retain semiconductor talent amid an increasingly competitive cross-sector talent war makes automation an appealing mechanism to help semiconductor companies re-envision their workforce. Embedded appropriately, automation should alleviate demand for hard-to-reach engineering talent – which must be done in parallel to increasing the supply of skilled resources to better position the semiconductor industry to meet the urgent need for qualified STEM professionals.

Moore's Law has supercharged industry innovation, motivating semiconductor companies to continually push the boundaries of computing power while decreasing the cost of chips. Automation has been essential to sustaining pace with Moore's Law, enabling semiconductor companies to double the number of transistors every 18 – 24 months. Historically, automation-powered advancements within Electronic Design and Automation (EDA) have turbocharged semiconductor innovation without necessitating a marked increase in the semiconductor workforce. However, automation has yet to reach its full potential in other segments of the value chain. Today, there are promising automation use cases that have yet to be embraced by the industry (see Figure 2) but are sure to bring further efficiency gains.

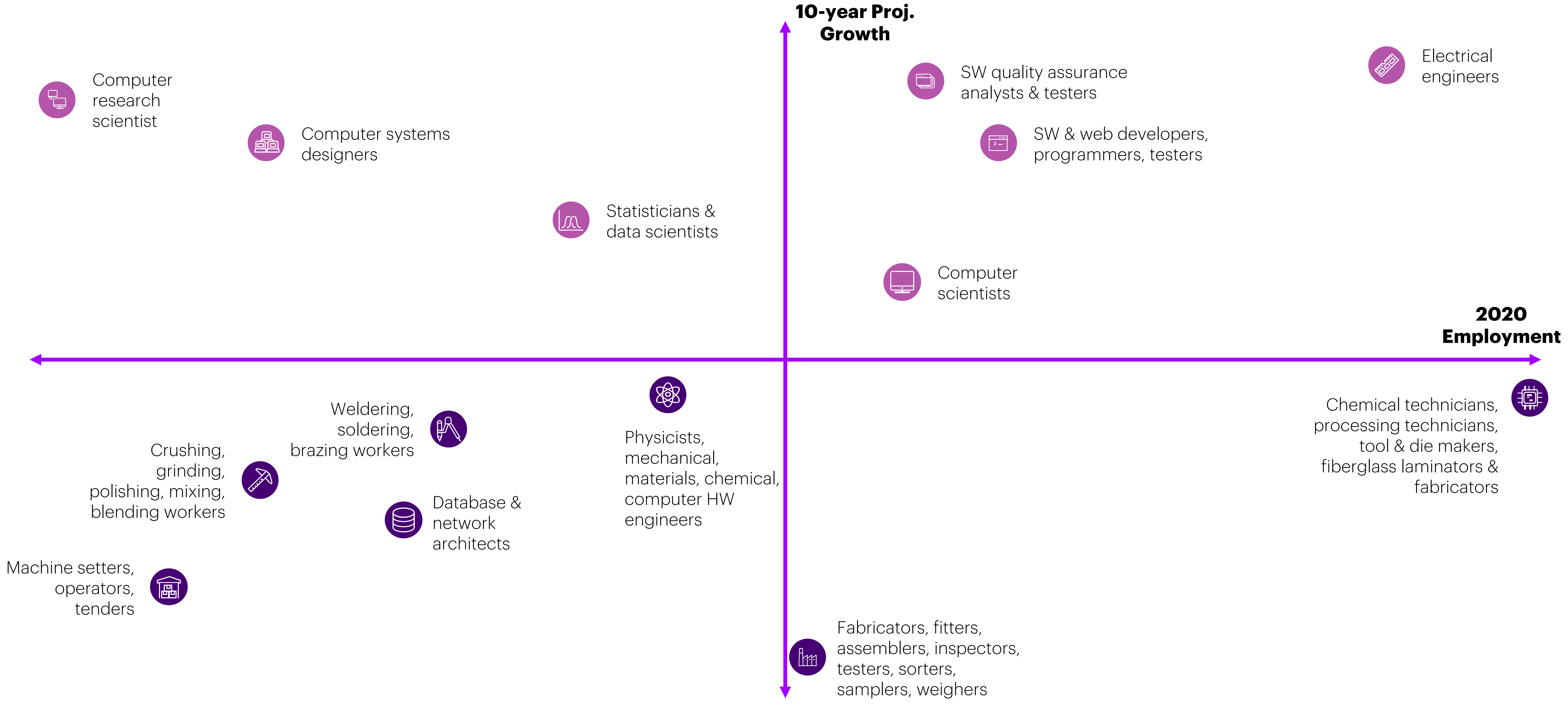
Automation Opportunity Across the Value Chainmation

Automation Use Cases	IP	EDA	Design	Foundry	IDM	Equipment	OSAT	Materials
IP Integration & Reuse | SoC assembly solutions to boost design team productivity and lower costs	■	■	■					
TCAD (Tech Computer-Aided Design) | Verify that mfg. process delivers required performance & density		■	■					■
DFM (Design for Manufacturability) | Validate that design meets requirements of manufacturing process		■	■					
SLM (Silicon Lifecycle Mgmt.) | Assess device performance from post-mfg. test through deployment		■	■					
Tool / Process Parameter Adjustment | Optimized process times per wafer or batch to improve yield				■	■			
Fab Layout Planning | Optimized manufacturing line layout (incl. tool layout, process separation)				■	■		■	■
Automated Material Handling | Transport material from one place to another in manufacturing area				■	■		■	
Preventive Maintenance | Optimized equipment availability through planned unproductive downtime				■	■	■	■	
Predictive Maintenance | Visibility into current state of equipment based on IoT-powered anomaly detection				■	■	■	■	
Automated Robotic Systems | Reduce particle contamination; improve process control & throughput				■	■	■		■
Automated Testing | Verification that device functionalities match end use application expectation				■	■		■	
Virtual Engineering | Remote Engineers-in-Charge (EICs) enabled by AR/VR				■	■	■	■	■
Defect Detection | Computer vision-enabled defect classification to signal process / tool deviations				■	■	■	■	■
Big Data Analytics | Actionable insights to identify root cause of issues and propose corrective actions		■	■	■	■	■	■	■
Value Chain Stage	**IP**	**EDA**	**Design**	**Foundry**	**IDM**	**Equipment**	**OSAT**	**Materials**

Figure 2
Across the semiconductor value chain, automation remains an under-leveraged source of value

Bureau of Labor Statistics (BLS), Job Growth 2020-2030

Figure 3
Projected Change Semiconductor Roles by 2030 (Bureau of Labor Statistics)



As shown in Figure 2, foundries, IDMs, and OSATs have the most to gain with increased use of automation. Within these three stages of the value chain, highly valued engineers remain bogged down in manual, time-consuming fabrication and assembly activities that have the potential to be significantly heightened through automation. Broader use of automation within these stages is critical, particularly as all sectors of the modern global economy drive up demand for an ever-limited pool of STEM talent and the appeal for new engineering graduates to join these areas of the semiconductor sector declines accordingly.

Slowly but surely, the semiconductor industry is embracing automation to fill this delta.

Semiconductor manufacturers worldwide began construction on 19 new high-volume fabs in 2021 and will break ground on another 10 by the end of 2022 to meet accelerating demand for chips.[10] This near-term explosive growth in the number of newly constructed fabs puts steep demand for new fab roles. However, the US Bureau of Labor Statistics (BLS) expects the number of certain lower-level fab roles to reduce by 2030 (see Figure 3). What helps to explain this apparent discrepancy? Automation – the key to enabling this shift of talent away from highly manual process-oriented fab roles towards value driving data science and analytics activities in the fabs.

LEVER 2

Debunking the myth: The complexity of reskilling in semi

Reskilling is an increasingly popular phenomenon...

Across industries, reskilling emerges as a thought-provoking lever to mitigate ongoing talent shortages. The semiconductor industry is no exception, as momentum around reskilling and its potential to fill key talent gaps has only surged with time. Leading IDMs have made significant investments into reskilling, education, and leadership development initiatives (see Figure 4) to enable employees to adopt in-demand data science and coding skills. Some portion of the engineering workforce has the potential to be reskilled, but this has yet to make a tangible dent in the talent gap.

Figure 4
Reskilling Case Studies

Intel nurtures talent to remain at the forefront of innovation...[13]

- **AI for the Current & Future Workforce:** Strengthen coding, data science, computer vision and NLP skills
- **Intel AI for Youth:** Enable 100K+ youth across the world to solve social impact problems using AI
- **Relaunch Your Career:** Provide 16-week paid internship for experienced hires ready to return to work
- **Gig:** Support rotation within Intel to gain ex posure to new areas of the org and learn new skills

Micron invests in ongoing learning to retain premier tech talent...[14]

- **Pledge to America's Workers:** Enhance 10K career opportunities within five years through reskilling
- **Rotation:** Empower new hires to rotate across functions to build core technical & business skills
- **Micron Leadership Accelerated:** Build the next generation of semiconductor leaders
- **Micron University:** Augment digital skills in AI, cloud computing, data science, and digital security

TI accelerates career growth through cutting-edge programming...[15]

- **Make an impact:** Prepare new grads to problem solve through 1-year case-based learning program
- **Early Career Pivotal Learning Roles:** Offer 10-month program for employees to learn new technical skills
- **TI Tech Ladder:** Supercharge diversity technical career development for engineers
- **Leadership Matters & Business Leader Development:** Transition managers into new leadership roles

...But poses unique challenges in the context of the semiconductor industry

Many semiconductor engineers share a common physics, electrical engineering, and computer science academic background. However, each semiconductor role is highly specialized and requires a niche level of expertise that limits immediate skillset transferability in a way that is not apparent in other industries. Hypothetically, an experienced design engineer with a background in mechanical engineering could be retrained to work in a fab. However, from an employer's perspective, this requires a significant investment in capital and time that will not pay off in the time needed to operationalize new fabs.

Reskilling is a complicated reality in the semiconductor sector for three key reasons:

1

There is a dearth of reskilling in areas that matter most

Existing reskilling programs are over-indexed on equipping back-office/business operations employees with incremental engineering, mathematical computation, and data modeling expertise. There is not enough emphasis on providing ex-isting employees, community college students, or new graduates with the skills required to work in a fab, which is where the most acute talent shortage is.

2

Reskilling at scale takes time that our industry doesn't have

Semiconductor companies will need to fill several hundred thousand fab positions to meet global consumer electronics demand within the next decade. Even for seasoned semiconductor veterans, there is likely to be high activation energy to properly learn and safely execute intricate, complex fabrication sub-processes in high-pressure fab environments.

3

Pushing engineers to move downstream in the value chain creates major flight risk

Design engineers are higher paid than their peers operating in fabs and are largely insulated from the stress of potentially making a costly and expensive mistake directly handling chemicals or machinery (Figure 5). Additionally, semiconductor executives have increasing concerns that hybrid/remote work has become an increasing priority for their engineering talent. One company even expressed concern for upward mobility if certain engineers chose a hybrid work model that leaned too far into work from home, and fab roles are inherently less flexible than those on the design part of the value chain. The industry cannot afford to lose in-demand engineers – and expecting employees within early stages of the val-ue chain to give up higher paying, lower stress, flexible desk jobs for demanding fab positions is unreasonable. This will create discontent and open the door for higher attrition.

More transferable roles are also the most desirable

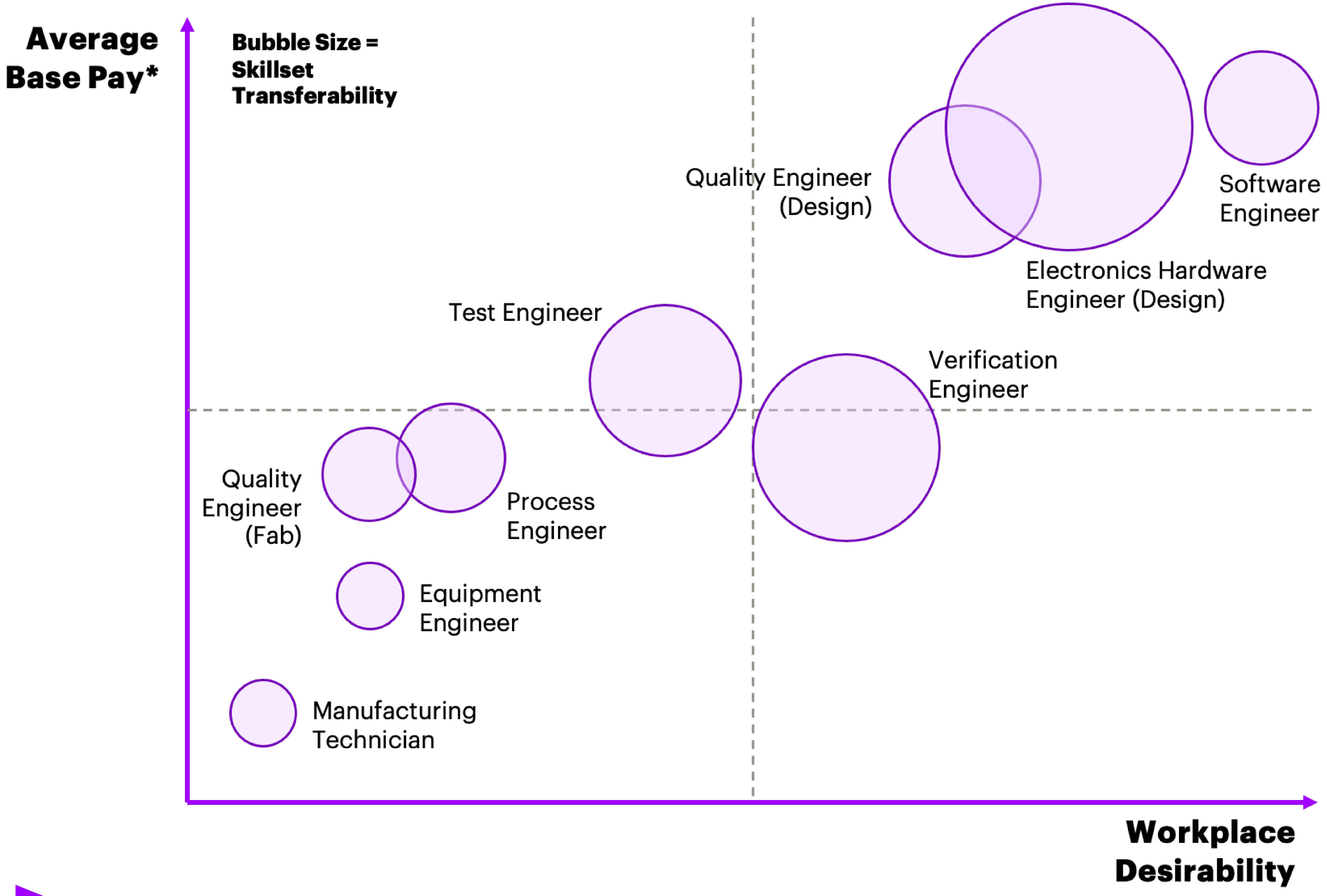


Figure 5
There is a trade-off between role transferability and desirability

Note on Workplace Desirability Axis: *This axis represents a perspective formed by Accenture based on interviews with experts and employees in the semiconductor industry. The spectrum represented is intended to reflect the non-compensation related factors that influence the desirability of a workplace environment. Fab roles typically demand longer hours, higher on-the-job stress, greater physical discomfort, and less job flexibility. These variables disincentivize employees to reskilling into these roles.*

*Based on data from Glassdoor

It's time to get real about the practicality of reskilling in semi

Semiconductor companies can reap greater reward by reframing the solution from "reskilling" to "skilling". As GLOBALFOUNDRIES has done in launching an apprenticeship program with Hudson Valley Community College, foundries and IDMs may wish to reconsider who they recruit and who they upskill. Semiconductor companies that adapt their recruiting profiles in favor of more diverse and alternative skillsets are likely to bring a needed edge to the STEM recruiting war. Rather than reskill PhD graduates from design roles to fab roles, semiconductor companies may wish to follow GLOBALFOUNDRIES' example and train new community college / traditional four-year college graduates to fill open technician and process engineering roles and upskill them to fill demand – a strategy that is both cost-effective and feasible in the near-term.[16]

Illustrative Role Structure by Degree Requirements

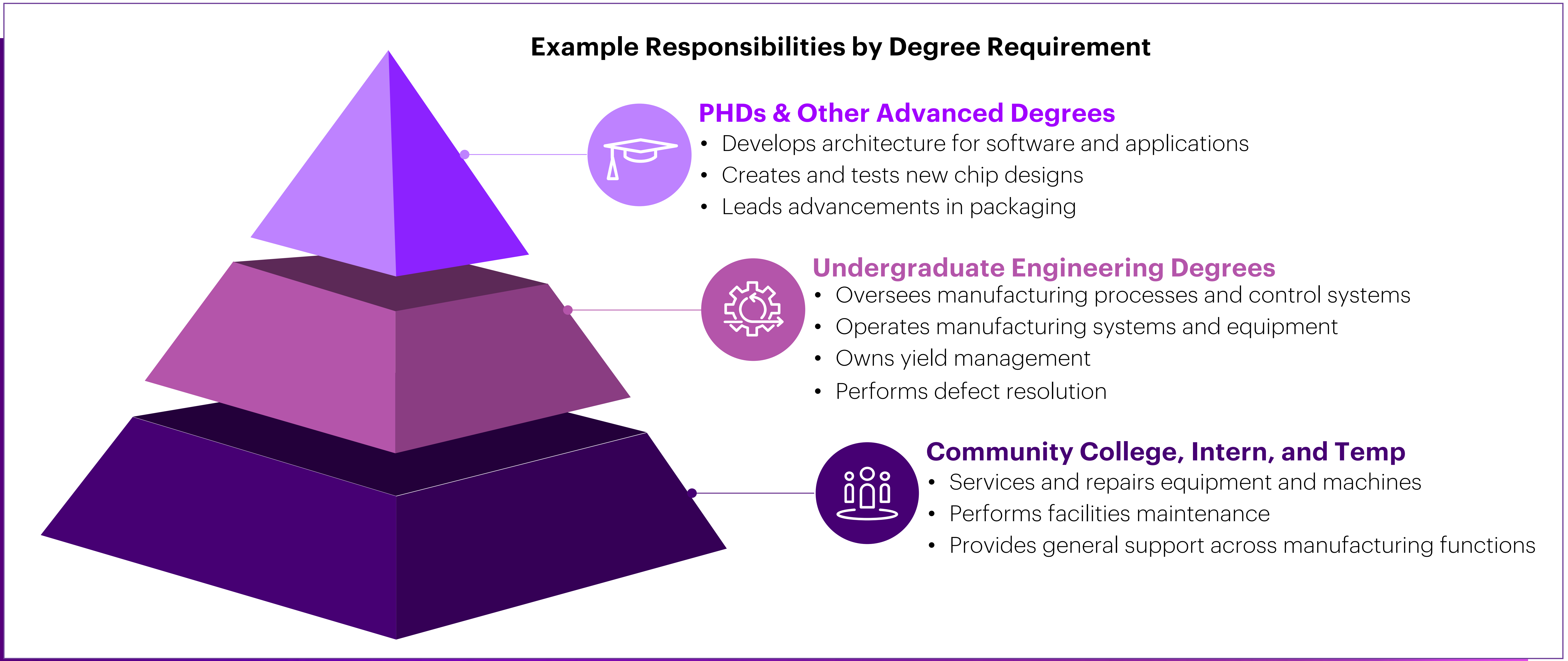


Figure 6
The most in demand talent is the least available

LEVER 3

Grow the pipeline: Attract & retain talent

The semiconductor industry is losing ground not only to hyperscalers, but also to aerospace and automotive in the prestige war

COVID-19 spurred explosive demand for semiconductor products and by extension, semiconductor talent. However, the industry struggled with the talent battle long before the pandemic. A 2021 survey of engineering students revealed that most undergraduates prefer to work at software and services pioneers (Google, Apple, Microsoft, Amazon), aerospace players (Lockheed, Boeing, Northrup Grumman, Raytheon, GE, and NASA), and automotive leaders (Tesla, General Motors, Ford) above the highest ranked semiconductor leaders.[10] Before high-potential STEM students even reach their college campuses, they have already developed strong perceptions of prestigious tech companies. This reaffirms how disadvantaged semiconductor companies are in brand equity, meaning standard university recruiting tactics will continue to fail to draw highly valued STEM talent.

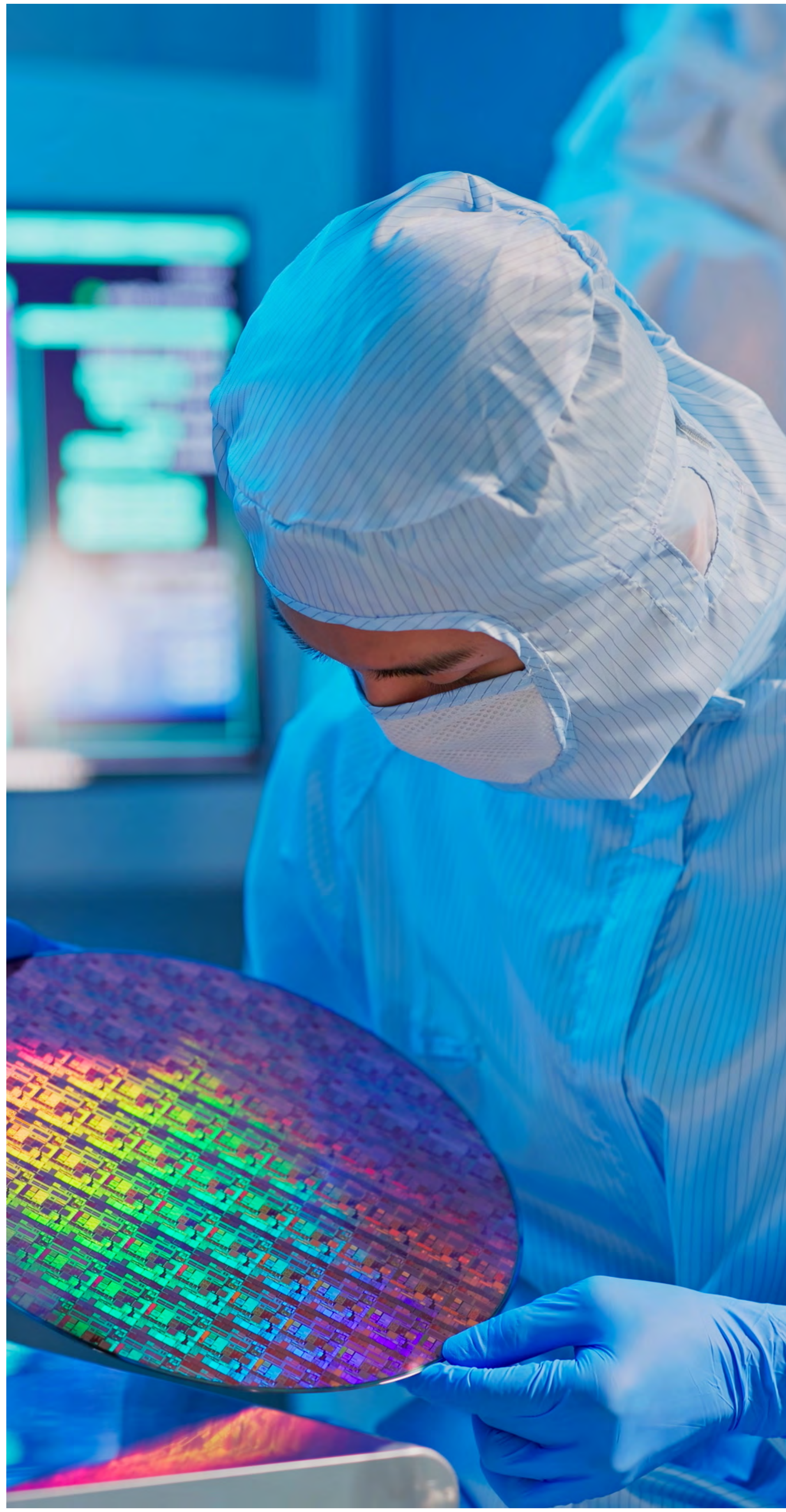
To deploy a one-size-fits-all recruiting approach is to vastly underestimate the complexity of the STEM talent war.

A More Targeted Approach

Semiconductor companies should tailor their approach based on where they sit in the value chain, the talent they are targeting and with whom they compete. As semiconductor IP and EDA companies embrace cloud, a growing number of semiconductor leaders are forced to compete for the same talent that software hyperscalers are successfully poaching. Across the rest of the semiconductor value chain, semiconductor companies are losing critical talent to hyperscalers as they further develop their core software business and deepen their footprint in hardware. This talent needs to be targeted differently than slightly lower skilled materials or back-end manufacturing talent where IDMs have been able to leverage temps, interns, technical skill graduates, and vocational training.

A More Sophisticated Recruiting & Retention Strategy

Semiconductor companies are long overdue in implementing more market-competitive recruiting and retention practices. Those that broaden their recruiting influence by offering stronger compensation / benefits packages, designing more flexible and desirable work environments, and carving out clearer upward mobility pathways for employees are likelier to attract and retain access to top-tier STEM talent.



From Meta's investment in local STEM and robotics lab programs[16] to Alphabet's *Code with Google*[17] and *Amazon's Future Engineer*[18], hyperscalers establish a strong track record with STEM talent as early as middle school. This investment matters, as empirical research shows that students who do not become interested in STEM by middle school are significantly less likely to choose STEM education pathways or careers.[19]

By and large, the semiconductor industry leads the charge in far fewer early education STEM initiatives. Qualcomm's Thinkabit Lab is a leading example in the industry, engaging more than 78,000 students nationwide in Internet of Things (IoT)-themed summer projects across their 16 innovation campuses.[20] Applied Materials has taken a different approach, funneling investment into local STEM education programs in central Texas to community STEM grants in Montana.[21] SEMI sponsors *High Tech U* [23], a three-day long program for highschoolers to develop hands-on experience within microelectronics and semiconductor.

However, many other semiconductor companies and industry consortia fall short in comparison, sponsoring occasional STEM competitions and science fairs without cultivating meaningful relationships with our nation's youth. The average American high school curriculum fails to expose high-potential STEM students to engineering disciplines beyond computer science, meaning many students are unfamiliar with the core subject knowledge or exposure needed to want to work in the semiconductor sector.

There are clear opportunities for semiconductor companies to extend their reach among middle and high school students, namely:

- **Innovation for Social Good:** Coding solutions to real-world problems
- **Site Visits:** Broadening exposure to workplace cultures and career trajectories in semi
- **Week-Long Camps/Immersion Experiences:** Building relationships with fellow STEM enthusiasts and turning ca reer explorations into future goals
- **Extracurricular Programs:** Sponsored opportunities associated with the schools to learn STEM topics specific to semiconductor
- **Sponsoring STEM Programs:** Furnishing local schools with state-of-the-art technologies, lab equipment, and teaching personnel

These investments in early academia can help tip the recruiting scales in favor of the semiconductor industry.

Likewise, university partnerships are key to offering exposure to the semiconductor industry before undergraduates settle on their desired fields (see Figure 6). Semiconductor hubs from Silicon Valley to Austin have emerged due in large part to their proximity to world-class research institutions.

International talent retention is key to sustainable growth

American universities are a magnet for the world's brightest STEM talent and are the primary channel by which foreign-born semiconductor talent come to the US. International students account for two-thirds of graduate students in electrical engineering and computer science and have been the primary source of growth of semiconductor talent over the last three decades.[22] However, once these highly skilled individuals receive their diplomas, they face difficulties in remaining in the US within the context of the current immigration law landscape.[23]

Every stage of the semiconductor value chain is extremely dependent upon international STEM talent (see Figure 7). As each country races to develop its own semiconductor ecosystem and elevate pay for STEM talent, the US is at risk of losing access to a significant portion of the world's STEM pipeline. Isolated efforts have taken place to strengthen STEM talent pathways, but not at a pace that matches desired growth of the US semiconductor ecosystem.

Dependence on International Talent Pipeline

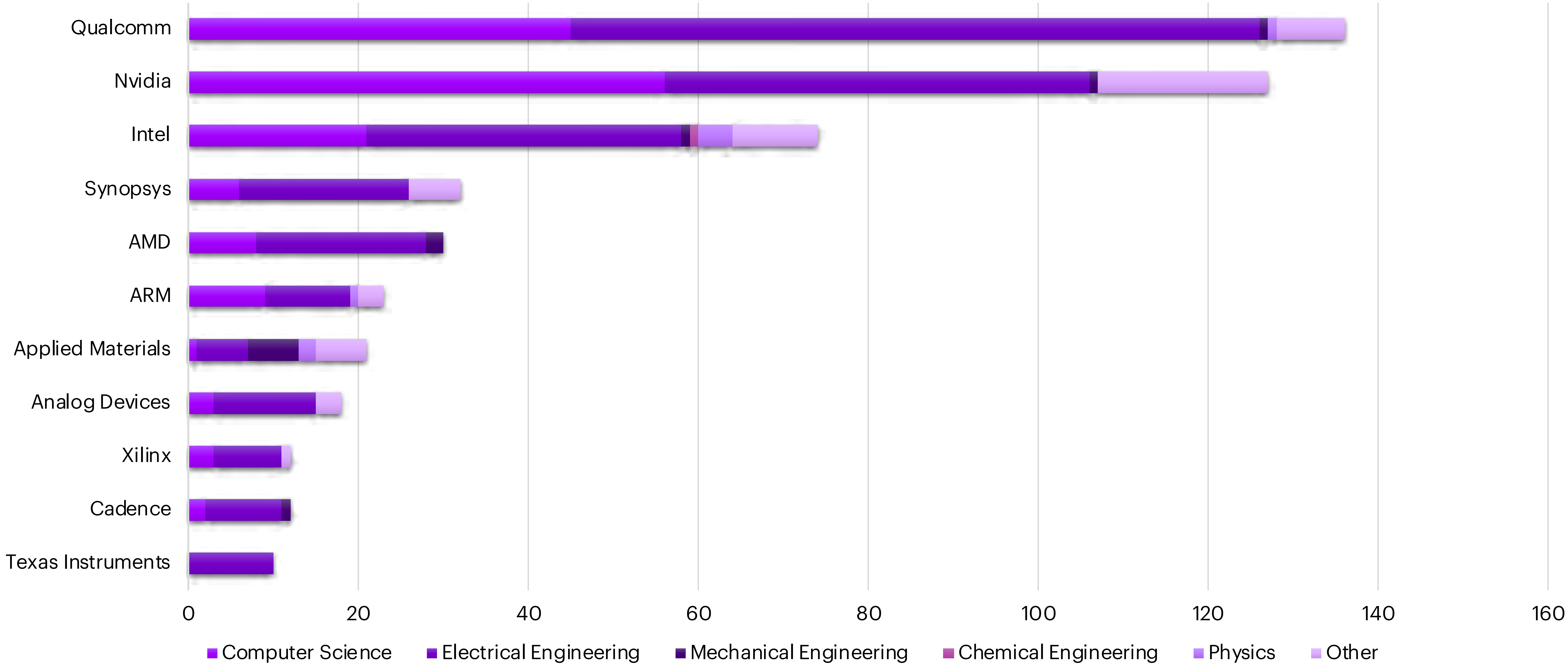


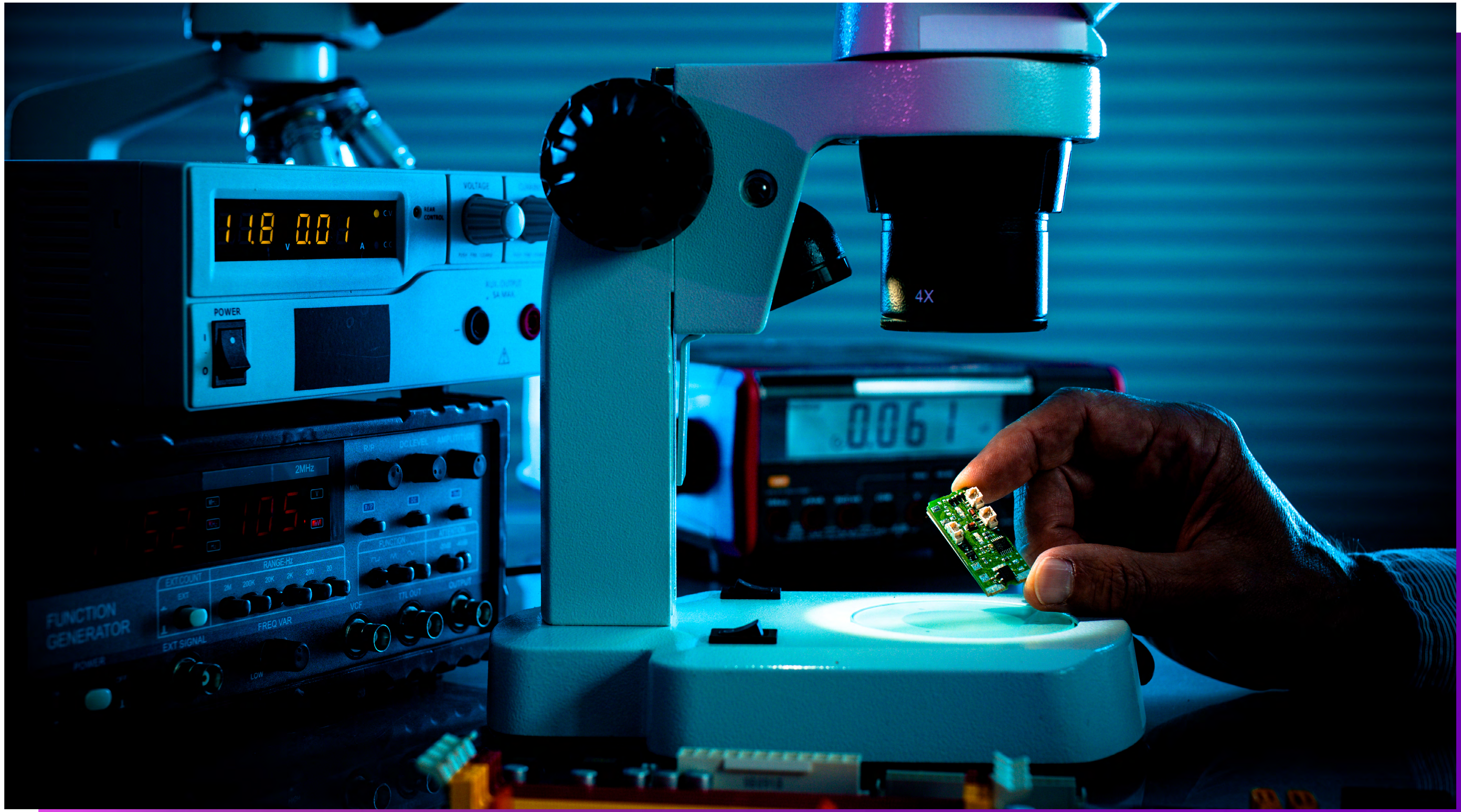
Figure 7
The semiconductor ecosystem is a deeply complex, interconnected ecosystem that depends on a mix of highly specialized talent from across the globe. Fabless players and IDMs emerge with the highest number of green card applicants across the value chain

Note: "Other" in the above graph refers to a combination related majors that are of interest to leading semiconductor companies (e.g., Mathematics, Operations, Graphic Design, and assorted Sciences)

Talent, the next big distruption threat

This is not the first time the semiconductor industry has undergone a major disruption. Over the course of history, the industry has endured both supply and demand side shocks. In 1994,there were aggressive rollouts of CDMA networks[25] as well supply shortages due to a series of natural disasters such as an earthquake affecting output at TSMC in 1999, or floods halting production at Western Digital facilities in Thailand in 2011.[26] Vulnerabilities exacerbated by the COVID-19 pandemic paired with exploding demand for work from home technologies, automobiles, advanced medical devices, and 5G mobile networks have elevated the semiconductor Supply Chain to the global stage.

However, it cannot be lost that all of this is occurring during a historic surge in demand for STEM talent, and if the talent discussion is not elevated it will become the next big disruptor. To mitigate talent shortages and prevent future downtime due to missed opportunities, semiconductor companies must deploy a combination of strategies outlined in this report to become magnets for the world's leading STEM talent.



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