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# POLICY OPTIONS TO PROMOTE DOD-DEFENSE INDUSTRY COLLABORATION IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION AND WORKFORCE DEVELOPMENT PROGRAMS, ACTIVITIES, AND OUTREACH

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# EXECUTIVE SUMMARY

The need to build and sustain a clearable STEM-competent workforce to support defense missions now and in the future is undeniably important, and across the defense enterprise there are many activities underway aimed at doing so. But the collective impact of these activities is currently unknowable.

More broadly, across the nation there exists a plethora of STEM education-related initiatives, programs, and organizations of all types that individually address aspects of the STEM educational lifecycle from pre-kindergarten through post-secondary education and extending to re-skilling and up-skilling of workers to meet evolving needs. In addition, new STEM initiatives are routinely announced at national, state, and local levels to address perceived gaps in current educational systems and pathways.

Even so, this study concluded that there is a **compelling case for action** by the Department of Defense (DoD) and the Defense Industrial Base (DIB), and an urgent need to **bring coherence to activities already underway** while building a **joint strategy to shape future initiatives**.

## A CASE FOR ACTION BY DOD AND ITS INDUSTRIAL BASE

A skilled STEM workforce is especially critical in a defense-focused industrial strategy, which requires innovative and bold solutions together with production and integration of complex systems.

DoD and the DIB have a common mission and shared strategic risks stemming from projected shortfalls in the clearable technical talent needed to support defense missions.

DoD and DIB technical personnel are uniquely qualified to engage, inspire, and attract future generations of talent to pursue careers in support of defense missions.

DoD and the DIB, working together, can create the educational pathways required to develop the technical skills needed to support evolving defense mission needs.

DoD and the DIB, working together, can establish a sustainable system that improves outcomes, amplifies impacts, and enables ongoing assessment of their collective efforts toward developing and sustaining the clearable STEM-competent workforce required to support defense missions now and in the future.

## SETTING THE CONDITIONS FOR SUCCESS—COLLECTIVE IMPACT

This study emphasizes DoD-DIB collaborative partnerships as a means to achieve synergies while amplifying the impacts of their STEM education-related activities. This approach is well-aligned with the Collective Impact model, first articulated in the

Stanford Social Innovation Review in 2011.[1] The Collective Impact Model is comprised of five conditions, as shown in Table ES.1.[2]

**Table ES.1. The Five Conditions of Collective Impact**

| THE FIVE CONDITIONS OF COLLECTIVE IMPACT | |
|---|---|
| **COMMON AGENDA** | All participants have a shared vision for change including a common understanding of the problem and a joint approach to solving it through agreed upon actions. |
| **SHARED MEASUREMENT** | Collecting data and measuring results consistently across all participants ensures efforts remain aligned and participants hold each other accountable. |
| **MUTUALLY REINFORCING ACTIVITIES** | Participant activities must be differentiated while still being coordinated through a mutually reinforcing plan of action. |
| **CONTINUOUS COMMUNICATION** | Consistent and open communications is needed across the many players to build trust, assure mutual objectives, and create common motivation. |
| **BACKBONE SUPPORT** | Creating and managing collective impact requires a separate organization(s) with staff and a specific set of skills to serve as the backbone for the entire initiative and coordinate participating organizations and agencies. |

There also are three preconditions that must be in place prior to launch of a "*collective impact initiative—an influential champion, adequate financial resources, and a sense of urgency for change*. ***The most critical factor by far is an influential champion (or small group of champions) who commands the respect necessary to bring CEO-level cross-sector leaders together and keep their active engagement over time***."[3]

The recommendations from this study, taken together, address both the three preconditions and the five conditions needed to deliver **Collective Impact**.

## ABOUT THIS STUDY

This research project resulted from language in the FY2020 NDAA, which directed the USD(R&E) to commission a study for the purpose of *"…developing collaborative DoD-industry activities relevant to: creating a clearable technical workforce to meet defense missions, supporting educational opportunities for defense sector personnel in both government and industry, and increasing educational opportunities for veterans and military dependents. Further, the study should focus on activities which are based on*

[1] J. Kania and M. Kramer (2011). *Collective Impact*. Stanford Social Innovation Review. https://ssir.org/articles/entry/collective_impact# Accessed 2 July 2022.
[2] IBID.
[3] IBID.

*metrics and education best practices to ensure maximum effectiveness."*[4]

The study was conducted in two parts. An Interim Report, delivered in February 2022, provided an overview of the existing STEM education-related activities underway within the DoD and across the Defense Industrial Base (DIB), and offered recommendations intended to improve the collective understanding of STEM talent needs, to motivate DoD-DIB collaborative partnerships, and to leverage existing DoD programs to accomplish some portions of the tasking. This final report builds on previous recommendations in addition to exploring in greater depth the issues of building a clearable technical workforce, specific ways to incentivize DoD-DIB collaborative partnerships, and leveraging existing STEM ecosystems to help attain DoD-DIB objectives.

### INFORMATION-GATHERING

Information-gathering efforts during phase one of the project included an online survey supplemented by web-based research on a sample population of 906 DIB organizations (including sizes ranging from tens of billions to millions in annual revenue; publicly-traded, privately-owned, employee-owned, and nonprofit corporations; both U.S.-owned and foreign-owned entities) to understand their STEM education-related activities; discussion with leadership of STEM programs supported by the DoD and selected external organizations to better understand the scope and motivations for their activities; and a literature review to establish a baseline understanding of the importance of a STEM-competent workforce to defense missions.

That baseline understanding was augmented during phase two by more targeted discussions with key DoD leadership and program managers; discussions with stakeholders in existing STEM ecosystems and other public-private partnership efforts focused on STEM education; discussions with DIB leadership; outreach to defense-related professional associations; discussions with subject matter experts in areas including evaluation and assessment of STEM education-related activities; and a more in-depth literature review augmented by a workshop focused on the Skilled Technical Workforce[5] (STW).

### KEY TAKE-AWAYS FROM RESEARCH

DoD-DIB collaboration on STEM education-related activities is rare, even though the scope and scale of STEM interventions underway by DoD and DIB organizations is vast.

- DoD-DIB collaborations do exist in the area of manufacturing/industrial workforce development; but more broadly, incentives must be aligned to create an environment conducive to meaningful collaboration.

[4] House Report 116-333. https://www.govinfo.gov/content/pkg/CRPT-116hrpt333/pdf/CRPT-116hrpt333.pdf p. 1327-1328.
[5] The Skilled Technical Workforce is comprised of individuals with a high level of technical expertise but less than a bachelor's degree in technical education.

The Skilled Technical Workforce is of growing importance to defense missions but its characteristics are not well understood.

- Nascent efforts are underway to better characterize the manufacturing-related STW, but needs for STW talent extend beyond that domain.

Few existing STEM education-related activities directly target building a clearable technical workforce; although both DoD and DIB organizations do emphasize engagement with military-connected families.

Opportunities exist to leverage ongoing activities within existing STEM ecosystems, but DoD and its industrial base have a differentiated role that cannot be ceded to those efforts.

- DoD and DIB technical personnel are uniquely qualified to engage, inspire, and attract future generations of talent to pursue careers in support of defense missions.

Evaluation/assessment methodologies identified during information-gathering for this report are inadequate for measuring collective impact.

### IN THIS REPORT

Chapter 1 addresses the broad issue of building a diverse and **clearable** technical workforce for defense missions, while also emphasizing educational opportunities for veterans and military dependents. Recommendations are provided in four areas: Retention of the Existing STEM Workforce; Prioritize Programs Most Likely to Engage U.S. Citizens; Raise awareness of national security STEM opportunities; and Increase Skilled Technical Workforce Engagement.

| **Building a Clearable Technical Workforce** | |
|---|---|
| **Retain Cleared Talent** | |
| **Key Points** | **Recommendation** |
| Cost of replacing an employee can range from one-half to two times the employee's annual salary.<br><br>Retention of the current cleared workforce must be a clear priority. | ***The DoD (and DIB) should invest in cleared-workforce retention through leadership training, promotion of flexible work environments, up-skilling and re-skilling efforts, and competitive compensation.*** |

| Prioritize Programs with Strong Links to U.S. Citizens | |
|---|---|
| **Key Points** | **Recommendations** |
| **JROTC**<br>Instructor eligibility restrictions and compensation challenges have contributed to a critical shortage of instructors.<br>JROTC is budget- and resource-constrained.<br>Increased coordination would enable JROTC units to leverage existing STEM resources. | ***DoD should support JROTC proposals for pay and eligibility to facilitate recruitment and retention of STEM-competent instructors.***<br>***DoD and the DIB should jointly establish a collaborative nonprofit to support ongoing STEM engagement efforts as well as enable program expansion.***<br>***DoD STEM should support and enable increased inter- and intra-service coordination to amplify the Department's overall STEM engagement with JROTC programs.*** |
| **Veterans Programs**<br>DIB engagement could provide GI Bill beneficiaries with valuable work-based training and professional experiences.<br>VET TECH, which supports educational pathways to the STW, would benefit from additional DIB engagement. | ***The DoD, in collaboration with the DIB, should seek to increase and facilitate internship opportunities for GI Bill beneficiaries in STEM/STW fields.***<br>***The DoD should seek to support the VET TEC program by fostering increased DIB involvement in the program's employer consortium.*** |
| **DoD Military Academies**<br>Collectively, wide reach to potential employees.<br>Additional STEM resources, e.g., providing guest lecturers, sponsoring STEM competitions, would be beneficial. | ***DoD STEM should prioritize partnerships with College Prep Military Schools, Senior Military Academies, Federal Service Academies, and DoD Postgraduate Schools as a means to expand the clearable technical workforce.*** |
| **Military Dependent Programs**<br>DoDEA system has limitations with regard to its ability to benefit from industry engagement. | ***DoD STEM should seek ways to support DoDEA STEM through activities such as internships, competitions, and guest speakers (both in-person and virtual).*** |
| **HBCU/MSI Engagement**<br>HBCUs and MSIs tend to attract a higher ratio of U.S. citizens.<br>HBCUs and MSIs are already a priority for DoD STEM. | ***STEM Program Managers and DoD agencies should continue to prioritize investments in HBCUs and MSIs through research funding, internships, and partnerships.*** |

| Build Bridges to the Potential National Security STEM Workforce | |
|---|---|
| **Key Points** | **Recommendations** |
| **Internships**<br>Current recruiting and hiring systems are fragmented across DoD, Services, and Defense Agencies.<br>DoD would benefit from having a consistent way to engage with the entire population.<br>Prospective interns would benefit from better awareness of the array of opportunities available. | ***DoD STEM should lead a collaborative effort to build an Intern Portal that communicates all available opportunities; provides a single application process; supports tracking of interns; and enables communications to the entire intern pool to expand awareness of career opportunities within DoD.*** |
| **Advocacy Networks**<br>Advocates work with students to increase awareness of career opportunities.<br>Experienced advocates include retired military and civilian defense leaders. | ***Stewards of STEM programs should support and expand advocacy networks (e.g., between university students and experienced advocates) as a way to grow the pipeline of cleared workers for defense missions.*** |
| **Public-Facing Strategic Partnerships**<br>Work that goes on inside defense installations is opaque to the general public (including prospective employees). | ***DoD should increase efforts to build a public-facing presence outside of security perimeters to engage with the public on innovative R&D topics and other aspects of defense missions.*** |
| **Increase Engagement of the Skilled Technical Workforce** | |
| **Key Points** | **Recommendations** |
| STW is more diverse than the remainder of the STEM workforce.<br>STW is poorly understood from a workforce planning perspective.<br>STW development programs sponsored by DoD emphasize manufacturing skills; needs exist across defense missions more broadly.<br>Veterans and transitioning service members would benefit from a more coherent way to translate their experience to civilian workforce opportunities. | ***DoD and DIB should jointly develop a comprehensive dataset describing the defense-related STW (current state, future projections, pathways, skills, competencies) to inform policies that support increasing STW engagement.***<br>***DoD and DIB should work jointly to establish pilot programs, in collaboration with Community Colleges and Technical Institutes, for high-priority emerging fields underserved by existing workforce development efforts.***<br>***DoD should lead a coordination effort to address skills/competencies classification and translation challenges for transitioning service members seeking to join the STW.*** |

Chapter 2 discusses incentives to promote DoD-DIB collaboration and provides recommendations in four areas: Executive Messaging; Financial Incentives; Branding Incentives; and Small Business Incentives.

| Creating Incentives for DoD-DIB Collaboration | |
|---|---|
| **Executive Messaging—'Tone at the Top** | |
| **Key Points** | **Recommendation** |
| There is no more powerful force for motivating collaboration than an explicit statement from the highest organizational levels about its importance. | ***Senior DoD leadership should publicly state a desire to see DoD-DIB collaborative partnerships formed to advance STEM-education related activities.*** |
| **Financial Incentives to Drive Behaviors** | |
| **Key Points** | **Recommendations** |
| Participation in DoD-DIB collaborative partnerships should be financially attractive to industry as well as in the best budgetary interest of DoD STEM offices. | ***DIB investments in approved collaborative partnerships for STEM education-related activities should be enumerated in the FAR as an allowable expense for reimbursement in contract rates.***<br>***DoD STEM budgets should prioritize engaging in approved collaborative partnerships with the DIB.*** |
| **Branding Incentives to Drive Behaviors** | |
| **Key Points** | **Recommendations** |
| Awards programs can heighten brand visibility both locally and nationally.<br>Example programs include Baldridge Awards, Program Excellence Awards.<br>Awards program should recognize successful DoD-DIB collaborative partnerships. | ***DoD and the DIB should establish a national awards program for excellence in DoD-DIB collaborative partnerships advancing STEM in support of defense missions.*** |
| **Small Business Incentives** | |
| **Key Points** | **Recommendations** |
| Small businesses rely heavily on STEM/STW talent, but are resource and budget-constrained. | ***DoD should build on existing programs and structures (e.g., Mentor-Protégé and Procurement Technical Assistance Centers) to reduce the barriers to Small Business participation in STEM education activities.*** |

Chapter 3 builds on the interim report from this project through deeper exploration of ways to advance STEM ecosystems through DoD-DIB collaborative partnerships—emphasizing pilot programs to lay the foundation for broader efforts—and provides recommendations in five areas: DoD-DIB Collaborative Partnerships; Evaluation/Assessment Framework; Leveraging Nonprofit Corporations; Leveraging P-TECH to Build the Skilled Technical Workforce; and Exploiting the Virtual Environment.

| **Advancing STEM/STW Ecosystems** | |
|---|---|
| **DoD-DIB Collaboration in STEM/STW Ecosystems** | |
| **Key Points** | **Recommendation** |
| Platform is needed to enable DoD-DIB collaborative partnerships in which the two parties jointly set priorities and then plan, implement, and assess STEM education-related interventions.<br><br>Report recommends the use of a nonprofit organization. | ***DoD/DIB should jointly establish a 3-year (at least) pilot collaborative partnership within in an existing STEM ecosystem in which both are heavily invested as a way to determine the benefits of joint planning and implementation of STEM activities.*** |
| **Evaluating Collective Impact** | |
| **Key Points** | **Recommendation** |
| Existing evaluation/assessment methodologies are inadequate.<br><br>An opportunity exists to work with partners on-the-ground to pilot the evaluation/assessment framework provided in this report. | ***DoD STEM should pilot the Collective Impact-aligned evaluation/ assessment framework within one (or more) of its existing hubs.*** |
| **Leveraging Nonprofit Organizations** | |
| **Key Points** | **Recommendation** |
| Nonprofit organizations can provide differentiated value in STEM ecosystems; many such organizations exist.<br><br>Decision criteria should include alignment with DoD-DIB priorities as well as financial outlook and organizational sustainability. | ***Standard criteria should be used to inform the decisions of DoD-DIB collaborative partnerships regarding selection of nonprofit partner organizations; this report suggests criteria for use in selection of nonprofits that implement STEM interventions.*** |
| **Models for Systemic Change** | |
| **Key Points** | **Recommendation** |
| The P-TECH 9-14 model provides an opportunity to bridge high school students seamlessly into 2-year post-secondary education.<br><br>The model is widely used and proven effective. | ***DoD STEM should, in collaboration with the DIB, leverage its partnerships with Community Colleges and Technical Institutes to implement the P-TECH 9-14 model to expand STW offerings of particular interest to the DoD and its industry base.*** |

| Exploiting the Virtual Environment | |
|---|---|
| **Key Points** | **Recommendation** |
| A collective virtual environment would bring coherence to existing information and provide a valuable means to engage, inspire, and expand the STEM talent pool for defense missions. | ***DoD STEM should lead the design and development of a Student/ Families portal based on existing information and activities implemented by the DoD, Military Branches, and Defense Agencies, as a pilot program.*** |

These recommendations, together with those provided in the interim report address both the three preconditions and the five conditions required to deliver Collective Impact. Acknowledging the immensity of the proposed initiative, however, pilot projects are offered as a way to get started, hoping to catalyze broader action. Pilot efforts also provide opportunities to test and refine the recommended approaches.

### BEYOND THIS STUDY

Although discussed at length in this report, additional work is needed to develop more specific engagement strategies arising from the need for a **clearable** technical workforce, particularly for PreK-8 populations. While still challenging, it is somewhat simpler to conceive of engagement opportunities for secondary and post-secondary populations as described in this report. **But the need remains to inspire and engage the PreK-8 population that feeds those populations.**

Further, while recommendations have emphasized engagement with existing STEM ecosystems, issues of prioritization remain. Existing ecosystems exhibit varying degrees of maturity and cohesion and offer opportunities to connect to differing demographic populations. Additional work is needed both to identify the existing ecosystems most likely to be well-aligned with DoD-DIB priorities as well as to develop criteria that might inform future decisions regarding engagement.

Additionally, parts of rural America are unlikely to be engaged by STEM ecosystems, and the same is true for military-connected families living abroad. Concerted efforts are needed to engage these populations—leveraging virtual means to supplement sparse options for in-person engagement.

Finally, while both reports recommended joint DoD-DIB development of STEM workforce-related strategies, the study team recognizes the immensity of the challenge. While essential for efficient prioritization of workforce development investments, it may be necessary to adopt more incremental approaches (e.g., efforts underway relating to advanced manufacturing and emerging technologies). But in doing so, it will be crucial to develop a common lexicon that supports overall workforce planning. It is unclear if there are mechanisms in place to drive the convergence of such activities.

# INTRODUCTION

This is the final report from a research project stemming from Conference Report language accompanying the National Defense Authorization Act (NDAA) for Fiscal Year 2020, which directed the Under Secretary of Defense for Research and Engineering (USD(R&E)) to commission a study to develop policy options and recommendations to promote DoD-defense industry collaborations in STEM-education activities. The focus of the study was defined as:

> *"… developing collaborative DoD-industry activities relevant to: creating a clearable technical workforce to meet defense missions, supporting educational opportunities for defense sector personnel in both government and industry, and increasing educational opportunities for veterans and military dependents. Further, the study should focus on activities which are based on metrics and education best practices to ensure maximum effectiveness."*[6]

An interim report[7], delivered in February 2022, focused on first understanding the existing landscape of STEM education-related activities currently underway by both the Department of Defense (DoD) and the Defense Industrial Base (DIB) and identifying existing collaborative efforts. From that baseline, recommendations were developed to lay the groundwork needed to motivate and enable collaborative DoD-DIB activities.

This final report, which includes three major chapters, provides further exploration of key elements of the project tasking. The first chapter provides a deeper dive into creating a clearable technical workforce to meet defense missions, supporting educational opportunities for defense sector personnel, and increasing educational opportunities for veterans and military dependents. The second chapter discusses potential incentives to motivate DoD-DIB collaboration in STEM education-related activities. The third chapter emphasizes activities that are based on metrics and education best practices to ensure maximum effectiveness and provides an expanded discussion of DoD-DIB collaborative partnerships within STEM/STW ecosystems.

## KEY MESSAGES FROM THE INTERIM REPORT

In describing the existing landscape of STEM education-related activities currently underway, the study team concluded that:

> *"While the scope and scale of STEM interventions underway by both DoD and the DIB is vast, collaboration is rare. The landscape is best characterized as a thousand points of light—each meritorious but failing to deliver synergistic impacts."*[8]

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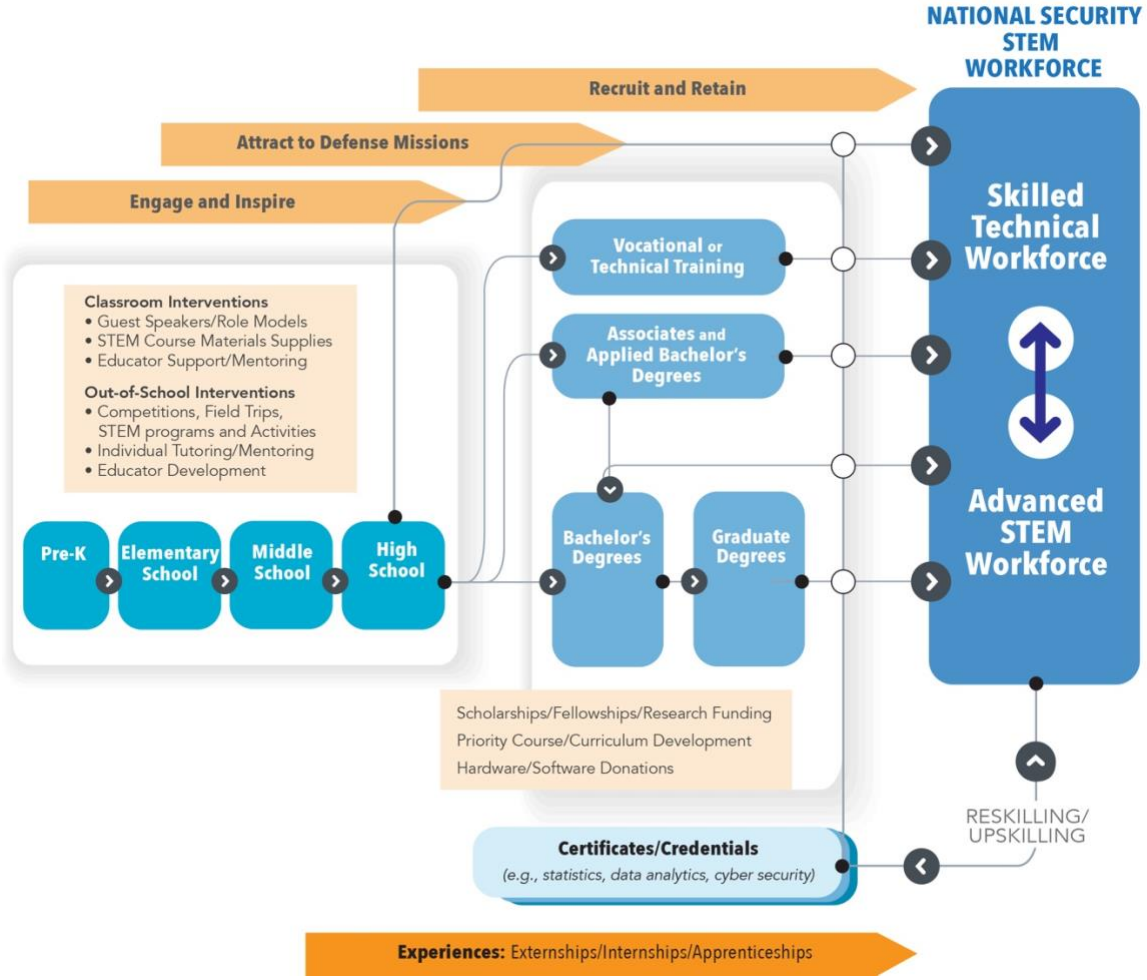
[6] House Report 116-333. https://www.govinfo.gov/content/pkg/CRPT-116hrpt333/pdf/CRPT-116hrpt333.pdf p. 1327-1328.
[7] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). p. 66. https://sercuarc.org/serc-programs-projects/project/119
[8] IBID. p. 8.

This conclusion motivated exploration of various types of collaboration and led to an emphasis throughout the report on the need for **collaborative partnerships** in which the DoD and the DIB work together to identify needs and then jointly develop and implement programs in order realize the full benefits.

While mapping STEM interventions to the various phases of the educational process, the team concluded that a linear pipeline model of student progression failed to capture the complexities that exist in building the STEM workforce. There is growing recognition of the importance of the Skilled Technical Workforce[9] (STW), a subset of the overall STEM talent pool which has a high level of technical expertise but less than a bachelor's degree in terms of educational credentials. The team therefore developed an expanded model to portray the differentiated pathways that exist for student progression into the overall STEM workforce. While the Pre-K through secondary school pathway remains linear, post-secondary options are diverse. This model, shown below, includes not only pathways for the STW, but also acknowledges the inevitable need for re-skilling and up-skilling of employees already in the workforce.




[9] National Center for Science and Engineering Statistics (2020). *Skilled Technical Workforce Initiative*. https://www.nsf.gov/statistics/stw/skilled-technical-workforce.cfm.

The study team also found, both by reviewing data collected on STEM interventions by DoD and DIB organizations as well as through conversations with key stakeholders, that there was varying support for some phases of interventions. In particular, some questioned the value of DoD/DIB investment in STEM interventions for K-12 populations, while others felt a clear value proposition existed. Similarly, the study found much less support for STW pathways, with interventions primarily supporting progression from high school to four-year educational institutions.

The study concluded that early interventions contributed to expansion and diversification of the prospective STEM talent pool, which is of broad interest, as well as to **engaging, inspiring, and attracting youth to defense missions**, which is of critical importance to both the DoD and its industrial base. This conclusion is corroborated by the fact that many of the DoD/DIB STEM interventions in the PreK-12 phase involve problem-based activities relating to defense missions (at age-appropriate levels of complexity) together with professional role models who serve as speakers, tutors, mentors, coaches, and educators. Offering work-based experiences (e.g., externships, internships, apprenticeships) for secondary and post-secondary students also helps attract students to defense missions. While acknowledging that there are many other organizations implementing STEM education-related activities along the various pathways, the study concluded that the **DoD and its industrial base have strategic interests at all stages and across diverse pathways.**

Although the study team found **no accessible projections specific to the technical workforce to support defense missions**, it did find that concerns about the overall state of the U.S. STEM workforce are well-documented[10] and corroborated by both government and industry leaders who are already finding it difficult to hire critical skills. Additionally, STEM workforce needs are projected to grow at a pace greater than that for non-STEM workers in the coming years.[11]

There also is growing recognition of the need to **broaden participation in STEM in order to gain the benefits of a diverse workforce**.[12,13] Additionally, alignment of STEM talent and STEM jobs remains a perpetual problem as "***new jobs and entirely new fields are being created daily***."[14] These are critical challenges confronting the DoD and its industrial base, which share needs for STEM talent in specialized domains as well as in domains that are of high interest to commercial industry, both now and in

[10] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2007). *Rising Above the Gathering Storm.* https://doi.org/10.17226/11463.
[11] U.S. Bureau of Labor Statistics. Employment Projections program. https://www.bls.gov/emp/tables/stem-employment.htm.
[12] *Participation of Demographic Groups in STEM*. https://ncses.nsf.gov/pubs/nsb20212/participation-of-demographic-groups-in-stem Accessed 24 June 2022.
[13] STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity. https://www.pewresearch.org/science/2021/04/01/stem-jobs-see-uneven-progress-in-increasing-gender-racial-and-ethnic-diversity/ Accessed 24 June 2022.
[14] E. White and A. Shakibnia (2019). *State of STEM: Defining the Landscape to Determine High-Impact Pathways for the Future Workforce.* Proceedings of the Interdisciplinary STEM Teaching and Learning Conference, Volume 3, Article 4. https://digitalcommons.georgiasouthern.edu/stem_proceedings/vol3/iss1/4

the future. In short, defense missions are in competition for a dynamic, and often limited, STEM talent pool.

**Recommendations from the Interim Report** are summarized below; a more complete overview is provided in Appendix C.

### *DEVELOP JOINT STRATEGY AND MOBILIZE PARTNERSHIPS*

**Address Shared Strategic Risk**

*DoD should, in coordination with Congress, acknowledge Technical Workforce Availability as a strategic risk to defense missions and mobilize an effort to update the DIB Sector-Specific Plan accordingly.*

This recommendation is intended to mobilize an effort to develop a joint DoD-DIB strategy to characterize their collective risks relating to technical workforce availability for various time horizons, and to identify actions needed to mitigate those risks in order to develop and sustain the clearable technical workforce needed to meet defense missions. The National Infrastructure Protection Plan[15] provides an available mechanism to enable this endeavor, which could be implemented under the leadership of the USD(R&E) as the DoD's Chief Technology Officer (CTO).

In examining existing STEM education-related activities across DoD and the DIB, few examples of collaboration, and even fewer instances of collaborative partnerships, in which DoD and DIB organizations work together to identify needs and then jointly develop and implement programs, were identified. STEM Ecosystems, which are increasingly used by communities in an effort to bolster their STEM-capable talent pools, provide platforms that could foster such collaborative partnerships—particularly given that both DoD and DIB organizations are already participating in a number of existing ecosystems.

**Build Collaborative Ecosystems**

*DoD should, in collaboration with the DIB, establish a system of local STEM/STW ecosystems that directly supports military-connected families and other high-priority populations.*

The primary area in which DoD-DIB collaborative partnerships are evident is in Manufacturing USA Institutes, which have workforce development initiatives underway that prioritize development of the STW.[16] This recommendation is intended to expand such collaborative activities to the entire STEM population within the context of local STEM ecosystems, establishing a system-level overlay to coordinate the DoD-DIB collaborative efforts and ensure alignment with joint objectives and strategies.

[15] National Infrastructure Protection Plan: NIPP outlines how government and private sector participants in the critical infrastructure community work together to manage risks and achieve security and resilience outcomes. https://www.cisa.gov/national-infrastructure-protection-plan

[16] Manufacturing USA. https://www.manufacturingusa.com/search?k=workforce+development Accessed 24 June 2022.

### *INCREASE EMPHASIS ON THE SKILLED TECHNICAL WORKFORCE*

**Expand STW Initiatives**

*DoD STEM should, in collaboration with the DIB, develop an alliance of Community Colleges and Technical Institutes to expand STW offerings of particular interest to the DoD and its industry base.*

DoD-DIB collaborative activities relating to the STW currently emphasize manufacturing-related skills. STW workers also provide essential support to other areas including research, development, test and evaluation (RDT&E) and operations and maintenance (O&M). This recommendation is intended to expand the availability of high-priority STW pathways while also leveraging the broader demographic participation often accessible via two-year educational institutions.

**Financial Aid for STW**

*A new scholarship program should be established under the National Defense Education program to provide scholarships for Community College/Technical Institute students pursuing STW careers in fields of high priority to the DoD and the DIB.*

While both DoD and the DIB have efforts in place to expand post-secondary educational opportunities for high-priority populations, few of those efforts directly support attainment of credentials needed to join the STW for defense missions. This recommendation addresses that gap, and further recommends that either DoD or DIB employment should be sufficient to discharge any service requirements stemming from such scholarships.

### *LEVERAGE EXISTING PROGRAMS*

**Leverage Existing Programs**

*DoD should examine SkillBridge and JROTC, and seek expansion to explicitly incorporate high-priority technical pathways.*

The interim study found that well-established DoD programs that today do not emphasize development of the STEM/STW workforce could be expanded to do so. This recommendation would expand SkillBridge[17] to enable transitioning service members to pursue a Certificate or Micro-Credentialing[18] program in a DoD-DIB career pathway either in lieu of, or in addition to, an internship opportunity, and would expand JROTC[19] to include an extracurricular technical track to inspire Cadets to pursue STEM/STW career paths.

[17] SkillBridge: DoD program that enables transitioning military to gain civilian work experience during their last 180 days of service via internship in industry. https://skillbridge.osd.mil

[18] Micro-credentials are like mini-degrees or certifications in a specific topic area. https://study.com/academy/popular/what-is-micro-credentialing.html#:~:text=Micro%2Dcredentialing%20is%20the%20process,Differentiate%20Instruction%20for%20ELL%20Students.https://study.com/

[19] JROTC: The Junior Reserve Officers' Training Corps is a federal program operated in high schools and some middle schools focusing on character development and citizenship.

**Build Collaborative Partnership**

*DoD should seek to move STARBASE to a full DoD-DIB collaborative partnership to enable ongoing program expansion.*

The study team observed that STARBASE[20] is a well-established STEM-development program with an in-place infrastructure in that allows for combination of government and private sector resources (via a nonprofit organization). DIB organizations are, in some cases, providing resources to support STARBASE implementation; but the examples found were relatively small in scale and appeared to derive from fortuitous connections rather than programmatic strategy. Given that the program appears to be resource-constrained, the study team concluded that a DoD-DIB collaborative partnership might motivate a broader base of DIB support including in-kind support, financial support, and coordinated volunteerism.

### *INCENTIVIZE DOD-DIB COLLABORATION*

**Celebrate Success**

*DoD should work with the DIB to create an annual awards program celebrating "excellence in DoD-Industry STEM/STW collaborations."*

As noted above, while both DoD and DIB organizations are implementing a broad spectrum of STEM education-related activities, few examples of collaboration were identified. Celebration of partnerships that work provides powerful motivation to transition the culture away from implementation of stove-piped portfolios and toward collaborative partnerships that deliver mutually-reinforcing STEM interventions to amplify collective impacts. This final recommendation from the interim report therefore emphasizes public celebration of success both at the local ecosystem level and at the broader system level. And given the importance of employee volunteers who support implementation of STEM outreach, the awards program should include a component that explicitly recognizes individuals (and teams) whose volunteer efforts contributed substantially to that success.

The interim report ended with identification of topics related to the original tasking that would benefit from deeper exploration. Those topics are the focus of this final report.

### OVERVIEW OF THE FINAL REPORT

This report is divided into three major chapters: (1) Expanding the National Security STEM Workforce; (2) Creating Incentives for DoD-DIB Collaboration; and (3) Advancing STEM/STW Ecosystems. Each chapter includes a summary and recommendations.

Chapter 1 takes an expansive view of building the clearable technical workforce for defense missions and includes discussion of:

- the importance of focusing on **retention** of the existing (cleared) workforce;

[20] STARBASE is a DoD Youth Outreach Program in which students participate in challenging "hands-on, minds-on" STEM activities. https://dodstarbase.org/about/

- **prioritization of existing programs** most likely to produce future national security workers;
- **building bridges to the potential National Security STEM workforce** through internship opportunities, advocacy, and outreach; and
- **increasing STW engagement** for defense missions.

Chapter 2 describes potential incentives in four areas:

- **executive messaging**, emphasizing the need to set the tone at the top;
- **financial incentives** to motivate true DoD-DIB collaborative partnerships;
- **brand-related incentives**, including an awards program; and
- **small business incentives** to engage the large population of DIB organizations that individually are capacity-limited in terms of their ability to participate in STEM-related initiatives.

Chapter 3 begins by overlaying the DoD-DIB collaborative System of Local STEM/STW ecosystems model recommended in the interim report onto existing STEM ecosystems and then discusses various opportunities for DoD-DIB collaboration. Topics include:

- **assessment/evaluation of Collective Impact** for ecosystems;
- **leveraging nonprofit organizations** within ecosystems;
- **fostering systemic change** to improve sustainability of STEM interventions; and
- **exploiting the virtual environment** to improve the efficiency and effectiveness of STEM ecosystems.

The report ends with concluding observations that suggest opportunities for future work aligned with developing collaborative DoD-industry activities relevant to creating a clearable technical workforce to meet defense missions.

# 1 EXPANDING THE NATIONAL SECURITY STEM WORKFORCE

The role played by technology in promoting and protecting the nation's security and prosperity is well-documented back to the earliest days of the republic. As early as Alexander Hamilton's "Report on Manufactures"[21] in 1791, national leadership has understood the importance of building the workforce and infrastructure needed to keep this wellspring of innovation thriving.

Concerns about the capacity and capabilities of the U.S. workforce to secure the benefits of this opportunity also are well-documented. The seminal report on the subject, "Rising above the Gathering Storm" (RAGS)[22] was released in 1989 by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, and the discussion has continued ever since. RAGS and its follow-up, "Approaching Category 5"[23] make the case that without intervention the U.S. workforce will not long be able to provide the requisite capacity in the skillsets necessary to unleash the innovation potential of the nation's economy.

While the STEM workforce skills-mismatch is an issue for the entire U.S. industrial base, the problem is particularly acute for the national security workforce as it has several constraints that don't exist—or exist to a lesser extent—in the non-defense segments of the economic landscape. For example:

- **Defense work is largely limited to U.S. citizens**. Outside of the defense industrial base, organizations are largely free to leverage foreign national talent through programs like the H-1B visa process.

  > *"Foreign-born workers also make up a substantial portion (26%) of STEM workers at all educational levels in knowledge- and technology-intensive (KTI) industries, but they are more concentrated among the pharmaceutical; computer, electronic and optical products; scientific R&D; software publishing; and information technology (IT) service industries. Among foreign-born STEM workers in KTI industries, a little over half of them are U.S. Citizens."*[24]

  Skilled foreign national STEM workers are able to work alongside U.S. citizens in support of commercial missions; the defense sector does not have that option.

[21] https://founders.archives.gov/documents/Hamilton/01-10-02-0001-0007
[22] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2007). *Rising Above the Gathering Storm.* https://doi.org/10.17226/11463.
[23] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2010). *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12999.
[24] The State of U.S. Science and Engineering 2022. https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force Accessed 1 July 2022.

- **Defense production is largely limited to U.S. national boundaries.** Commercial firms are free to outsource manufacturing to labor abroad while optimally matching labor costs with the competencies required. For example, Apple manufactures the iPhone largely in East and Southeast Asia.[25]

- **Defense contract rates trend lower than commercial salaries in high-demand skillsets**. Defense contractors typically are limited to certain rates at various experience levels in order to be reimbursed by the government. In discussions among the study team and other stakeholders, it was agreed that—particularly for high-demand skillsets—the defense sector has a difficult time meeting commercial industry salaries.

- **Defense work environments offer less flexibility than non-defense workplaces.** While the industry did heroic work in responding to the COVID-19 pandemic, and work-from-home flexibility increased greatly, classified work must be performed in settings in which materials can be protected. Commercial industries have much more flexibility as to where and how their work is accomplished and are therefore able to offer employees more flexible work environments.

The motivating concern behind this congressionally-directed study is that the national security STEM workforce might not have the capacity in key skillsets to meet future defense missions. This chapter provides a more holistic exploration of ways to ensure that the clearable technical workforce meets the needs of defense missions both now and in the future.

## 1.1 CHAPTER OVERVIEW

The interim report described the STEM engagement landscape for both DoD and the DIB and discussed existing and potential collaborative efforts to increase the number of students who choose a STEM career. While there was some discussion of reaching military-connected families and other targeted populations, for the most part that report was not specific to partnerships focused on building a clearable workforce (which is taken to mean U.S. citizens).

The purpose of this chapter is to specifically address STEM investments focused on expanding the size of the **clearable** and **cleared** workforce. In this chapter, four focus areas describe how the DoD and the DIB can mitigate the risk of falling short of national security STEM talent:

1) **Retain existing STEM workforce**: In Section 1.2 the topic of retention of the existing workforce is addressed with the goal of limiting the loss of capacity and capabilities within the current national security STEM workforce.

2) **Prioritize STEM investments**: Section 1.3 explores prioritization of those STEM

[25] https://u.osu.edu/iphone/3-the-manufacture-of-the-iphone/

investments most likely to result in STEM workers entering the national security workforce. These investments are focused on STEM interventions with U.S. citizens who have already demonstrated an interest in national security service. Specific programs addressed are:

- JROTC
- Veterans Programs
- Military Academies and DoD Affiliated Educational Institutions
- HBCUs and MSIs

3) **Raise awareness of national security STEM opportunities**: In Section 1.4, bridge-building efforts to improve awareness within existing pathways of what it looks like to work in national security are discussed. These efforts include creating internship opportunities, educating potential employees about work on the national security missions, providing on-ramps to security clearances, and forming public-facing partnerships to better engage the broader STEM community.

4) **Increase engagement of the skilled technical workforce**: Section 1.5 explores opportunities to expand the skilled technical workforce (STW) specifically for defense missions. The STW consists of occupations that require high-level knowledge in a technical domain but do not require a bachelor's degree.

## 1.2 FOCUS ON RETENTION OF THE CLEARED WORKFORCE

While not explicitly a part of this study's tasking, focusing exclusively on bringing new participants into the national security workforce risks neglecting an important way to maintain a robust workforce, which is to retain current STEM talent. According to Gallup, "*the cost of replacing an individual employee can range from one-half to two times the employee's annual salary—and that's a conservative estimate*."[26] That estimate also does not include the time and expense of clearing a new employee.

Anecdotal data from study team members' experiences suggests that turnover in the defense industry has increased significantly from pre-covid to the present day. While this study did not seek to validate this perception or explore causal factors, it does seem that the pool of STEM workers is shrinking more rapidly than normal attrition; if true, this exacerbates the challenge of ensuring sufficient workforce capacity to support defense missions. There have been many reports in the wake of the COVID shutdown of employees quitting their jobs in large numbers, and there is no reason to believe this trend is not impacting the national security workforce.

A recent Harvard Business Review article suggests that the massive resignation numbers reported over the past two years are, in fact, a continuing trend rather than having been caused by the pandemic. It attributes the steady growth in resignations (data from 2009-2021) to these factors:

- "*Workers are **retiring** in greater numbers but aren't **relocating** in large numbers;*
- *they're **reconsidering** their work-life balance and care roles;*
- *they're **reshuffling**, rather than exiting the labor market entirely; and*
- *because of pandemic-related fears, they're demonstrating a **reluctance** to return to in-person jobs."*[27]

A focused effort to build the defense STEM workforce must include actions to counter voluntary attrition and invest accordingly; provided below are suggested actions:

- Studies indicate[28] that most people leave their jobs because they either have issues with their supervisor (feel disrespected) or they do not see a path forward within the organization. In interviews conducted under Chatham House Rules, multiple senior leaders said their organizations did not provide first-level leader training that extends beyond compliance training. **Organizations should put in**

[26] S. McFeely and B. Wigert (2019) *This Fixable Problem Costs U.S. Businesses $1 Trillion*. https://www.gallup.com/workplace/247391/fixable-problem-costs-businesses-trillion. Accessed 1 July 2022.
[27] J. Fuller, W. Kerr. *The Great Resignation Didn't Start with the Pandemic*. https://hbr.org/2022/03/the-great-resignation-didnt-start-with-the-pandemic. Accessed 1 July 2021.
[28] https://www.pewresearch.org/fact-tank/2022/03/09/majority-of-workers-who-quit-a-job-in-2021-cite-low-pay-no-opportunities-for-advancement-feeling-disrespected/

**place programs that teach new leaders how to be effective; and senior leaders should make a concerted effort to communicate pathways for advancement within their organizations.**

- **Leaders should do all they can to promote flexible work arrangements for employees.** While classified work still must be done in a secure environment, it may be possible to provide opportunities to work from home on relevant unclassified work (for example, reading up on technological advances in the field of the employee's work) for some portion of the work week.

- Organizations may also have the flexibility to provide employees with opportunities to explore other pathways without leaving the employer. For example, some Science and Technology Reinvention Laboratories (STRLs) have implemented programs such as paid sabbaticals that permit employees *"to engage in study or uncompensated work experience that will contribute to their development and effectiveness*."[29] Additionally, **investing in employee up-skilling or re-skilling, as discussed in the interim report, will support retention of the cleared workforce**.

- Organizations should leverage workers planning to retire through programs that permit them to **work part time as they transition into retirement**.

- Organizations should have in-place **knowledge continuity programs** in which less experienced workers learn alongside of those planning to retire to transfer knowledge and experience.

- Finally, both DoD and DIB organizations should exercise existing flexibility (and seek new authorities if needed) to ensure that **compensation for high-demand skills is competitive** with the commercial sector.

Leadership within both the DoD and the DIB should make retention of the current cleared workforce a priority. For every employee who can be retained, there is less disruption to workflow and less investment needed to recruit and train a new worker.

***Retention of Cleared Talent***

*DoD (and DIB) should invest in cleared-workforce retention through leadership development, promotion of flexible work environments, up-skilling and re-skilling efforts, and competitive compensation.*

[29] Federal Register Notice 15 May 2020. Science and Technology Reinvention Laboratory (STRL) Personnel Management Demonstration Project in the Joint Warfare Analysis Center (JWC) of the United States Strategic Command (USSTRATCOM). Section H.2 Employee Development/Sabbaticals.

## 1.3 PRIORITIZE PROGRAMS MOST LIKELY TO PRODUCE FUTURE NATIONAL-SECURITY WORKERS

STEM interventions (particularly secondary and post-secondary) should focus on programs/pathways likely to produce a pool of U.S. citizens inclined towards national service.

In most learning communities, U.S. citizens, foreign nationals, and permanent residents learn alongside each other. STEM interventions in such communities will expand the STEM workforce, but will do so across all demographic groups. There are learning communities in which there likely is a disproportionate percentage of U.S. citizens including those serving veterans, military dependents, JROTC programs, and communities with a strong military presence. These communities of learners represent high-value targets for prioritization of DoD and DIB STEM interventions, and were specifically identified in the original tasking for this study.

**DoD and DIB STEM managers should prioritize investments in pathways and learning communities most likely to engage clearable learners who are predisposed to serving in the national security community.**

While this section does not emphasize partnerships between DoD and the DIB, STEM investments in this class of learning communities will likely provide meaningful collaborative partnership opportunities:

- From the perspective of the industrial base, these programs offer opportunities to work with public-sector counterparts while presumably raising the impact of their investment on individuals likely to join their workforce. Additionally, as noted in the interim report, DIB stem investments are made in part to build the brand of the entity with their customers and with the communities in which they serve. Partnerships would help build relationships with their customers while enhancing their brand and also building a pool of future STEM workers.

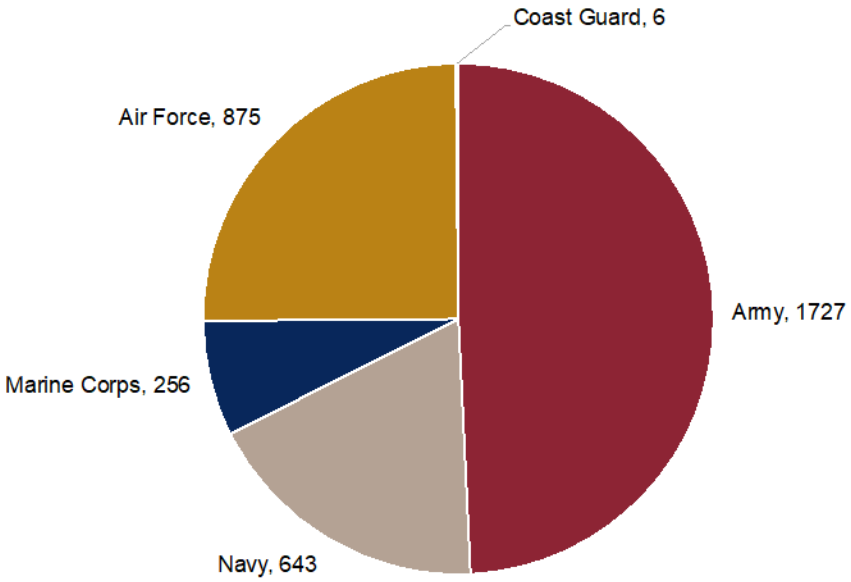
- From the perspective of the DoD, these programs are already well-supported as they have a natural foothold in these communities. By forming or enhancing industry partnerships, programs could scale more rapidly and resources such as industry speakers, laboratory facilities, and funding could be applied to stabilize and/or grow the programs. For example, the JROTC program is limited by the available teaching resources and STEM curriculum availability. Industry could augment the program, enabling it to reach more young people who will likely be part of the clearable workforce.

In the remainder of this section some successful efforts underway are discussed and recommendations are made to scale or enhance these programs. For the most part, this chapter does not specifically address partnerships, however the Chapter 2 on incentivizing partnerships will apply to the opportunities that follow.

### 1.3.1 JUNIOR RESERVE OFFICERS' TRAINING CORPS (JROTC)

JROTC is a voluntary high school program intended "*to instill in students in United States secondary educational institutions the values of citizenship, service to the United States (including an introduction to service opportunities in military, national, and public service), and personal responsibility and a sense of accomplishment*.[30]" Originally established as an Army program by the National Defense Act of 1916, JROTC now includes units operated by the Air Force, Navy, Marine Corps, and the Coast Guard (see Figure 1.1). General policy and guidance for the JROTC program is set at the OSD level, however the service JROTC offices have wide latitude in program implementation.

**Figure 1.1 JROTC Units[31,32] (as of June 2022)**




Although there is some variation across services, the JROTC curriculum typically includes up to four years of coursework in leadership; civics; U.S. history; geography and global awareness; health and wellness; and life skills. In addition, units offer extracurricular activities such as color guard/drill team, marksmanship, and field trips to military installations. JROTC units have a minimum of two instructors; instructors are retired officers or non-commissioned officers, certified by the respective branch of the service as qualified to serve as JROTC instructors. The 2007 NDAA allowed retirement-eligible reservists and guard members to also be certified as JROTC instructors. JROTC units are administered cooperatively by the services and the high schools. Specifically, the military services subsidize instructor salaries, the cost of uniforms, equipment, curricular materials, and some travel costs necessary for participation in co-

[30] United States Code Title 10 (10 U.S. Code § 2031 - Junior Reserve Officers' Training Corps)
[31] Defense Primer: Junior Reserve Officers' Training Corps (JROTC) https://sgp.fas.org/crs/natsec/IF11313.pdf. Accessed 15 June 2022.
[32] Coast Guard - https://www.uscg.mil/Community/JROTC/JROTC-Units/. Accessed 15 June 2022.

curricular activities (including drill competitions and academic bowls). Schools agree to contribute to salaries, provide facilities for the program, and schedule times for JROTC programming.

In FY 2021, there were over 3,500 JROTC units in the United States and abroad serving over half a million cadets[33]. JROTC enjoys tremendous support among leadership in Congress as well as in the DoD. The program is viewed favorably by political leadership as well as by local communities. In 2020, the National Commission on Military, National, and Public Service recommended expanding the number of JROTC units to 6,000 by 2031.[34] However, the number of units operated by the services is currently constrained by budget allocations.

#### 1.3.1.1 Existing STEM engagement within the JROTC program

Over the past several years, there has been growing interest in including STEM curriculum and activities within the JROTC program. Discussions with the leadership of the service JROTC programs—Air Force, Army, Navy, and Marine Corps—highlighted several STEM initiatives currently underway (due to the nascency of the Coast Guard JROTC program, these units do not yet include STEM activities). However, the scope and scale of STEM programming varies significantly between services and often between individual units within a service.

STEM activities are typically held after school, on weekends, or even during the summer months. Air Force JROTC is the only service program that specifically covers STEM instruction (Aerospace Sciences) in its core curriculum during the school day. Due to the extra-curricular and co-curricular nature of STEM activities, JROTC principals observed that it often is easier to carry out activities during the summer months when the JROTC program does not compete with other high-priority activities during the school year. However, similar to challenges faced by other after-school programs, the lack of reliable transportation options can be a barrier to participation—further hindering involvement by underserved and underrepresented students in particular.

In many instances, the STEM interventions are administered by individual instructors. While the JROTC program allows instructors to engage other resources (e.g., external organizations) for their STEM activities, this flexibility also creates a reliance on individual instructor motivation and ability to build relationships with local stakeholders. Some efforts to conduct larger-scale programs that span multiple JROTC units are underway. For example, the Air Force and Marine Corps JROTC programs are working with CS4All, a nonprofit, on a demonstration project to increase computer science and cybersecurity education for cadets. Participating JROTC schools receive training and

[33] Defense Primer: Junior Reserve Officers' Training Corps (JROTC) https://sgp.fas.org/crs/natsec/IF11313.pdf. Accessed 15 June 2022.
[34] Report to Congress of the National Commission on Military, National, and Public Service (March 2020). https://www.volckeralliance.org/sites/default/files/attachments/Final%20Report%20-%20National%20Commission.pdf p. 126. Accessed 1 July 2022.

professional development for teachers, counselors, and additional school staff. In particular, JROTC instructors receive training and resources from the National Center for Women & Information Technology (NCWIT) to support cadets as advisors in pursuing computer science and cybersecurity career pathways.[35,36]

Recent JROTC efforts are also exploring ways to leverage the program to support workforce readiness—for example, credits for summer STEM activities that can be used to bolster college applications or even to obtain credentials. For example, the Army JROTC Cyber Program, launched in April 2022 with 12 units, aims to provide cadets with cyber-related classes over four years, leading to industry-recognized certifications by the time they graduate high school. This pilot program is being conducted in partnership with the University of Alabama, Huntsville, which developed the cyber curriculum. A unique feature of the program is a partnership with local FBI field offices in proximity to the units; staff augment instruction and provide real-world application contexts to the cadets. Similarly, some Marine Corps and Navy JROTC units also partner with external institutions to provide credentialing support to their cadets.

Some JROTC service leadership teams are also exploring ways to engage their respective K-12 STEM offices as well as broader service STEM-related opportunities. For instance, the Naval Science and Engineering Apprenticeship Program (SEAP) has experienced increases in application rates through specific outreach to the Navy and Marine Corps JROTC programs.

Despite the well-meaning interest in increasing STEM interventions, the overall scale and impact of these efforts remains limited. The JROTC program faces serious challenges in strategic STEM outreach and engagement.

**Instructor eligibility restrictions and compensation challenges have contributed to a critical shortage of JROTC instructors**, especially at Title 1 schools. Some established JROTC programs have been discontinued due to challenges with hiring of instructors[37,38]. Part of the challenge stems from issues with calculation of instructor salaries, which currently includes retirement pay—making these positions less competitive relative to other parts of the market. In addition, strict instructor eligibility criteria reduce the pool of available talent for these positions. There also is widespread concern that additional STEM instruction requirements could hinder instructor recruitment and retention. This is particularly true of instructors who are unfamiliar/ uncomfortable with the latest technologies and scientific concepts. Conversely, in the case of instructor candidates with strong STEM competencies, JROTC faces competition from the private sector for this skilled, readily clearable talent. To address the pay issue, the JROTC services have collectively developed a proposal that revises

[35] https://www.csforall.org/projects_and_programs/jrotc/
[36] https://www.csforall.org/projects_and_programs/marines-jrotc-cs-cohort/
[37] https://www.coastalpoint.com/news/education/lack-of-instructors-could-end-tech-s-jrotc-program/article_bc837948-5427-11ea-b196-835e0557d8eb.html
[38] https://www.delawareonline.com/story/news/local/2020/03/04/update-sussex-tech-jrotc-program-canceled/112103598/

instructor pay. The Instructor Pay Legislative Proposal[39] calls for instructors to be compensated using the Joint Service Instructor Pay Scale (JSIPS) developed by the JROTC community rather than through the Blended Retirement System.

The **JROTC program is budget- and resource-constrained**. Supplemental funding for the program is determined on an annual basis, which hampers multi-year planning. While some STEM programs have been established through additional funds provided by Congress, sustainability of these programs is not guaranteed due to their reliance on the annual budget process. There are numerous grants available, both within the federal government as well as through external entities, for high school STEM initiatives; however, JROTC instructors typically do not have the training or resources to support grant writing. There is anecdotal evidence of schools supporting instructors with grant-writing resources, but these are rare occurrences.

According to service JROTC leadership, private sector organizations have indicated interest in supporting JROTC programs with both in-kind and monetary assistance. For example, an airplane manufacturer approached the Air Force JROTC program, eager to assist with its Flight Academy. Industry support would be particularly beneficial in providing STEM resources (kits, hardware, speakers, mentors) which would make available more JROTC funds to support cadet participation (transportation, logistics, facilities). Stewards of the JROTC program stated they had no resistance to collaborating with the private sector given the funds and other resources that the industrial base could contribute. However, industry involvement has been quite limited as accepting funds and donations through the current gifting process is cumbersome and administratively prohibitive. To address this issue, a recent Air Force JROTC proposal[40] aims to make the donation process less onerous through the establishment of a nonprofit titled Junior ROTC Education and Training Association (JET-A) specifically to facilitate acceptance of equipment, supplies, and other resources.

JROTC program implementation at the unit level is highly instructor dependent. As mentioned previously, while this approach provides opportunities for STEM interventions, the potential for increased burden on instructors results in recruitment/retention challenges. It also leads to nonuniform availability of programs across the various JROTC units even within school districts. As a result, **STEM activities in the JROTC program lack a common operational framework** that would support and enable collaboration among the JROTC units (or with the industrial base). It is difficult, for example, to ascertain all existing JROTC activities within a given community and/or region, which could enable identification of mutually reinforcing programs and opportunities to collaborate, thus leveraging limited resources.

#### 1.3.1.2 Opportunities to increase STEM engagement through JROTC

Due to the nature and reach of the program, JROTC has the potential to play a key role in strategic development of a clearable technical workforce. The core curriculum of the

[39] Based on information provided by Air Force JROTC leadership
[40] Based on information provided by Air Force JROTC leadership

program fosters the importance of citizenship and responsibility while also familiarizing cadets with public service. The four-year term of the program provides opportunities for ongoing access to STEM activities to inspire and subsequently sustain interest in STEM domains. Unlike single-touch programs, a thoughtfully developed STEM track within JROTC could allow for continued awareness and engagement mechanisms for students, particularly those from underserved and underrepresented populations. For instance, leveraging the demographics of the JROTC program, a recent DoD study recommended STEM internships as part of JROTC to improve racial and ethnic diversity and inclusion in the U.S. Military[41].

While the core competencies fostered by the JROTC program must remain strong, there are valuable opportunities to support and scale existing STEM efforts as well as to establish new ones. JROTC could serve as a catalyst to drive cadet interest in exploring STEM/STW pathways to higher education and/or employment. **This study strongly endorses supporting, sustaining, and growing the availability of STEM interventions in JROTC units.**

**DoD should support the service JROTC-led proposal that aims to update instructor pay** with the goal to increase recruitment and retention. **DoD also should actively support JROTC leadership efforts to expand instructor eligibility** to non-retired military members, thereby widening the pool of candidates. These efforts will enable the programs to attract and retain high-quality STEM instructors.

**The DoD should, in collaboration with the DIB, establish a JROTC-specific nonprofit to enable expansion via in-kind support, financial support, spreading of awareness, and coordinated volunteerism.** While supporting the previously mentioned Air Force JROTC proposal to use a nonprofit entity to accept funds and resources, this recommendation proposes leveraging a nonprofit entity to harness a wider range of benefits stemming from a DoD-DIB collaborative partnership. In addition to the anticipated purpose of enabling private sector contributions, the nonprofit also could include aid in both synchronizing academic and federal calendars and serving as a ‘clearing house’ to match needs to resources.

From the private sector standpoint, contributions are likely given the mission overlap, the branding opportunity, and the chance to support efforts important to their primary customer (i.e., the DoD). By forming or enhancing industry partnerships, JROTC STEM programs could scale more rapidly, and resources such as industry speakers, laboratory facilities, and funding could be applied to sustain and grow STEM engagement. Further, the nonprofit also could engage higher education institutions and STEM nonprofits for summer camps and college credits. Such a partnership also would alleviate instructor workload, and perhaps spur additional action by facilitating access to information, opportunities, and resources for the cadets. The public-private nonprofit partnership would augment the JROTC program and help it reach more young people,

[41] Department of Defense (2020). *Recommendations to Improve Racial and Ethnic Diversity and Inclusion in the U.S. Military*. DoD Board on Diversity and Inclusion Report. https://media.defense.gov/2020/Dec/18/2002554852/-1/-1/0/DOD-DIVERSITY-AND-INCLUSION-FINAL-BOARD-REPORT.PDF

attracting them to become a part of the clearable workforce.

As noted in this study's interim report, most of the DoD's STEM engagement and outreach activities are funded and executed at the Component-level, including at individual facilities (military installations and DoD laboratories and centers). Increased inter- and intra-service coordination would enable JROTC units to leverage existing STEM resources, curriculum materials, and opportunities for cadets, thereby also amplifying the reach, visibility, and outcomes of the individual DoD STEM activities and interventions.

***STEM Engagement through JROTC***

*DoD should support JROTC proposals for pay and eligibility to facilitate recruitment and retention of STEM-competent instructors.*

*DoD and the DIB should jointly establish a collaborative nonprofit to support ongoing STEM engagement efforts as well as to enable program expansion.*

*DoD STEM should support and enable increased inter- and intra-service coordination to amplify the Department's overall STEM engagement with JROTC programs*.

### 1.3.2 VETERANS PROGRAMS

Veterans present unique opportunities to increase the clearable technical workforce by leveraging DoD's investment in training its military members for technical occupations. Every year, more than 200,000 soldiers retire from active duty and transition back into civilian life. Of these, a significant number have worked in highly technical fields and are qualified to excel in STEM jobs. As noted by a recent National Science and Technology Council (NSTC) report[42], "*many [v]eterans have knowledge, skills, and abilities relevant to STEM occupations and careers resulting from their STEM-intensive military training and experience*." Among its recommendations in supporting STEM careers for veterans and military spouses, the NSTC report called for enhancing non-governmental STEM partnerships. In particular, the study encouraged "*efforts to leverage local partnerships, particularly those near military installations*" as these can help create pipelines from military training to STEM careers through work-based training opportunities or higher education.

The Department of Veterans Affairs has programs that provide veterans, service members, reservists, and certain military family members with education and training resources to assist in the transition to civilian life. Some of these programs have a particular STEM/STW emphasis. This section provides an overview of selected veterans education benefits related to STEM and presents opportunities for enhanced DIB engagement to support the scalability and impact of these efforts.

[42] Strategic Plan to Support Veterans and Military Spouses in STEM Careers https://www.whitehouse.gov/wp-content/uploads/2021/12/12-21_CoSTEM-STEM-Vets-Plan.pdf

#### 1.3.2.1 GI Bill and Rogers scholarship

Since 1944, the GI Bill has provided financial support to qualifying veterans and their family members for college, graduate school, and training programs. Financial support through the GI Bill includes tuition and fees, housing allowances, and funding for textbooks and supplies. In 2017, the Harry W. Colmery Veterans Educational Assistance Act, also known as the 'Forever GI Bill', transformed the GI Bill to a lifetime entitlement by removing certain time-based eligibility requirements thereby significantly expanding the educational benefits for beneficiaries. As part of the Forever GI Bill, the Edith Nourse Rogers STEM Scholarship was established to support veterans and military dependents in high-demand STEM fields to extend their GI Bill benefits when pursuing a STEM/STW degree. Recognizing the need for additional time for STEM/STW education compared to most other fields of study, the Rogers scholarship provides an extension of up to 9 months (or $30,000, whichever comes first) and at present can be applied toward an undergraduate degree program[43], a teaching certification, or a covered training program for health care professionals.

Despite the importance and benefits of on-the-job experiences (e.g., internships, apprenticeships, co-ops), discussions with the Veterans Benefits Administration (VBA) leadership indicated that only 0.5% of GI Bill students participate in such training during their course of study. The issue is partly due to challenges with housing allowances as the participant receives lower allowances due to anticipated higher wages during the internship period. Further, there is no real incentive for employers to support students as the administrative burden stemming from employment of students on the GI Bill is currently prohibitive. **Given the well-documented importance of work-based training and professional experiences, the DoD should identify and mitigate barriers to DIB engagement with GI Bill beneficiaries** and leverage its industrial base to connect service members with industry partners in real-world job experiences, particularly in STEM/STW fields.

#### 1.3.2.2 Veterans Employment Through Technology Education Courses (VET TEC)

In 2019, the VA launched a five-year pilot program to provide tuition and other financial support to eligible veterans who enroll in select high technology education programs through certain training providers. During this pilot phase, five courses of study are supported—computer programming, computer software, media application, data processing, and information sciences. The program uses an incentive-based approach featuring statutory performance targets for payments and oversight of training providers[44]. The payment structure provides 25% when a veteran enrolls and attends, 25% when the veteran completes their training program and the remaining 50% when the veteran secures employment related to the completed program of study. As part of

[43] List of study programs includes traditional science and engineering degrees as well as STW-related fields of study. https://benefits.va.gov/gibill/docs/fgib/STEM_Program_List.pdf. Accessed 12 June 2022.
[44] Department of Veterans Affairs FY 2023 Budget Submission. https://www.va.gov/budget/docs/summary/fy2023-va-budget-volume-iii-burial-and-benefits-programs-and-deptmental-administration.pdf. Accessed 15 June 2022.

the program, an employer consortium was developed to provide VET TEC students with employment, mentoring, and networking opportunities. Conversations with VA education leadership indicated that at present approximately 18-19 companies participate in the consortium.

Despite the nascency of the program and preliminary concerns around measuring and evaluating outcomes[45], the VET TEC program presents an important opportunity to support educational pathways to STW careers for veterans. VET TEC directly benefits both veterans and industry partners. For veterans, the program provides an opportunity to build technical skills in high-demand fields. For industry partners, the program is an opportunity to access competent technical talent, a large segment of which is presumably clearable, without incurring training costs. **The DoD should seek to support the VET TEC program and amplify its impacts by fostering DIB involvement.** Greater engagement with the private sector also could help drive enhanced or additional training programs tailored to defense industry needs.

***Leverage Veterans Programs***

*The DoD, in collaboration with the DIB, should seek to increase and facilitate internship opportunities for GI Bill beneficiaries in STEM/STW fields.*

*The DoD should seek to support the VET TEC program by fostering increased DIB involvement in the program's employer consortium.*

### 1.3.3 DoD Military Academies

DoD operates, or is affiliated with, a number of military academies providing high school through post-graduate programs. Students in these programs are largely U.S. citizens and have already demonstrated a commitment to national service by choosing this type of learning community. **Prioritizing STEM engagements within these academies would be an effective way to increase the size of the clearable technical workforce.** Traditionally, each of the Service Academies has placed emphasis on producing pilots (Air Force Academy); Sailors (Naval Academy); Infantry Soldiers (West Point). The Services should place greater emphasis on the value of STEM skills as an addendum to every career field in today's technology era. Below are some examples of learning communities in which the STEM workforce could be expanded through such engagements.

#### 1.3.3.1 College Prep Military Schools

Private military academies represent a learning community with youth who have demonstrated interest in national service and the national security mission. There are approximately 50 in the United States, primarily focused on middle and high school

[45] Government Accountability Office (2022). *Preliminary Observations on VA's Technology Education Pilot Program*. https://www.gao.gov/assets/gao-22-105720.pdf. Accessed 5 June 2022.

students. High school students are typically enrolled in a JROTC program and so learn the values of citizenship and leadership taught by this program as described previously.

Like their non-military counterparts, these schools have active STEM programs. By focusing STEM investments on programs within these schools, DoD and the DIB could potentially increase the size of the clearable national security STEM workforce with greater return than comparable investments in non-military schools.

**DoD and DIB STEM programs should consider prioritizing investments with these schools either through making resources available, providing guest lecturers, sponsoring STEM competitions, or by making contributions where appropriate to organizations like the Falcon Foundation**. (The Falcon Foundation[46] is a non-profit group that works to sponsor students into military academies with the goal of supporting their desire to ultimately enter the Air Force Academy.)

#### 1.3.3.2 Senior Military Academies

There are 6 federally-designated senior military academies that operate cadet programs, each with a long history of engagement with the national security community. In some cases, all enrolled students are in the ROTC program and part of the cadet corps. In others (Virginia Tech and Texas A&M), the cadet corps is part of a larger public university.

The student bodies of these academies are predominantly U.S. citizens (for example, about 99% of students at the Citadel.) Non-military colleges and universities have a lower percentage of U.S. citizens in their student body; but precise statistics are difficult find. The National Center for Education Statistics (NCES) indicates nearly 16% of all STEM degrees and certificates went to non-resident aliens (2019-2020).[47] But NCES does not separate US Citizens from Permanent Residents, so the actual percentage of U.S. citizens obtaining STEM degrees would be less than 84%. In addition, students who choose to attend senior military academies have already expressed an interest in national security service by applying. Each offers well-regarded STEM degree programs.

**By prioritizing STEM engagements with these universities there is a higher likelihood of building a national security STEM pipeline.** One recent example is a partnership between DIB-member Boeing and the Virginia Polytechnic Institute to build a STEM workforce development center for returning veterans in Northern Virginia.[48]

#### 1.3.3.3 Federal Service Academies

Engaging with the DoD-operated Federal Service Academies (U.S. Military Academy

[46] Falcon Foundation. https://www.falconfoundation.org/About Accessed 1 July 2022.
[47] National Center for Education Statistics. *Science, Technology, Engineering, and Mathematics (STEM) education, by gender*. https://nces.ed.gov/fastfacts/display.asp?id=899
[48] https://www.washingtonpost.com/dc-md-va/2022/06/13/veterans-virginia-tech-boeing-hub/

(USMA), U.S. Naval Academy, Air Force Academy) offers another existing pathway to building the clearable workforce as the vast majority of cadets are U.S. citizens (a small number of international cadets are enrolled) and are committed to the national security mission. These academies already have strong STEM programs, and their efforts are augmented by the DIB in some cases.

For example, the DIB is already engaged with the academies through senior capstone projects at the USMA. In these cases, DIB members develop real-world challenges and provide support to the cadet teams working on solutions. Cadets are offered tours of defense facilities and a chance to interact with DIB scientists and engineers. One example program run by Lockheed Martin involved a competition to improve the company's helicopter logistics operation; a team from West Point won the competition.[49]

**Such STEM partnerships should be encouraged and broadened where possible to foster an understanding of STEM work in the national security space.**

#### 1.3.3.4 Postgraduate Schools

One particular challenge in the STEM pipeline is finding and hiring U.S. citizens with advanced degrees (Masters or PhD) in STEM fields. International students are heavily represented in U.S. STEM graduate programs. According to the NCES[50], non-resident aliens earned nearly 47% of U.S. STEM master's degrees and 46% of U.S. STEM Doctor's degrees in 2019-2020. Finding and hiring U.S. citizens with advanced STEM degrees is a growing challenge for both DoD and the DIB. For this reason, **engaging with DoD-operated postgraduate schools (the Naval Postgraduate School (NPS) and the Air Force Institute of Technology) has the potential to stimulate growth in this important STEM pathway.**

DoD and the DIB should seek opportunities to partner and increase resources for these important programs. Guest lecturer opportunities should be expanded, and an emphasis should be placed on CRADAs between these schools and industry to support joint research. One example of this type of arrangement is a CRADA between General Atomics and the NPS to perform classified and unclassified research on advanced space technologies.[51] Such partnerships could expand the capacity of these graduate institutions to grow the clearable STEM workforce with the advanced degrees needed to meet the nation's most challenging technical needs.

***DoD Military Academies***

*DoD STEM should prioritize partnerships with College Prep Military Schools, Senior Military Academies, Federal Service Academies, and DoD Postgraduate Schools as a means to expand the clearable technical workforce.*

[49] https://www.army.mil/article/235581/west_point_cadets_win_lockheed_martin_engineering_competition
[50] National Center for Education Statistics. *Science, Technology, Engineering, and Mathematics (STEM) education, by gender*. https://nces.ed.gov/fastfacts/display.asp?id=899
[51] https://nps.edu/-/new-crada-between-nps-general-atomics-focused-on-advanced-space-technologies

### 1.3.4 MILITARY DEPENDENT PROGRAMS

DoDEA is one of only two Federally operated school systems that is responsible for planning, directing, coordinating, and managing Pre-K through 12th grade educational programs on behalf of the DoD. Under the direction and authority of the Office of the Under Secretary of Defense for Personnel and Readiness (OUSD (P&R)), DoDEA operates roughly 160 accredited schools in 8 districts located in 11 foreign countries, 7 states, Guam, and Puerto Rico.

The DoDEA system has an active STEM program both in the curriculum as well as through extra-curricular activities such as FIRST Robotics and STARBASE. Due to regulatory limitations associated with accepting any material support, there appears to be little to no industry engagement with DoDEA at this time. While it is challenging for outside entities to engage with DoDEA, STEM engagements should be possible through internship opportunities, funding of competitions through non-profits, and making available guest speakers for virtual or in-person appearances to discuss STEM fields.

This community of learners represents a large pool of potential national security STEM workers as most are U.S. citizens. With family members serving the nation, these students are already familiar with the mission and have role models for serving in the community. **STEM program managers should seek ways to support DoDEA STEM activities inside the system.**

***Military Dependent Programs***

*DoD STEM should seek ways to support DoDEA STEM through activities such as internships, competitions, and guest speakers (both in-person and virtual).*

### 1.3.5 HBCU/MSI ENGAGEMENTS

Partnerships or other investments with higher education have been a very effective means of building the national security STEM talent pool. Both DoD and industry maintain robust outreach efforts to college systems with the goal of both fostering research and recruiting potential workers upon graduation.

Some colleges are more fertile ground for national security workers; STEM program managers (as well as R&D leaders) should focus more energy on those schools. For example, Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) have strong STEM programs and student bodies made up of a greater percentage of U.S. citizens than typical universities. While data are difficult to come by and varies by type of Minority Serving Institution (MSI), the team noted that only 2.5% of undergraduates at both HBCUs and Hispanic Serving Institutions (HSI) were international students in 2016.[52] A focus on HBCUs and other MSIs is already called out in the DoD STEM Strategy.[53]

[52] American Council on Education. *Spotlight on Minority Serving Institutions*. https://www.equityinhighered.org/indicators/spotlight-on-minority-serving-institutions/
[53] DoD STEM. *The Department of Defense STEM Strategic Plan FY2021-FY2025*. https://dodstem-assets.dodstem.us/files/DoD_STEM_Strategic_Plan_2021.pdf

**STEM program managers and DoD agencies should prioritize investments in HBCUs and MSIs through research funding, internships, scholarships, and partnerships.** These actions are specifically recommended in a NASEM study released earlier this year titled "Defense Research Capacity at HBCUs and MSIs: Transitioning from Good Intentions to Measurable Outcomes".[54] The study recommends that the DoD establish "true partnerships" with these institutions to help address the department's STEM workforce needs, including creating a diverse pool of future military and civilian technology leaders.

As an example, the U. S. Space Force established a University Partnership Program with both major educational institutions, and HBCUs/MSIs, to "*provide a consistent pipeline of talent through internship, mentorship, scholarship, fellowship*", noting that HBCUs (e.g., Howard University) "*can help us develop future Guardians who can bring the technical expertise and diversity of thought and experience we need to serve the nation's security interests in space*."[55]

In another example, the Air Force Institute of Technology (AFIT) and the Air Force Research Laboratory (AFRL) recently held an "Air Force - HBCU Digital Literacy Summit"[56] with 25 of the nation's HBCUs and MSIs. The objective was to "*establish channels that will strengthen collaborative agreements and research efforts in digital engineering, digital acquisitions, and big data research to address DAF challenges.*"[57]

Finally, Air Force recently announced plans to create the first University Affiliated Research Center led by a Historically Black College or University.[58]

***HBCU/MSI Engagements***

*STEM Program Managers and DoD agencies should continue to prioritize investments in HBCUs and MSIs through research funding, internships, and partnerships.*

### 1.3.6 PRIORITIZE STEM INVESTMENTS: SUMMARY

This section observes that DoD and DIB STEM managers should prioritize investments

[54] National Academies of Science, Engineering and Medicine (2022). *Defense Research Capacity at Historically Black Colleges and Universities and Other Minority Institutions: Transitioning from Good Intentions to Measurable Outcomes*. https://www.nationalacademies.org/our-work/defense-research-at-historically-black-colleges-and-universities-and-other-minority-serving-institutions Accessed 1 July 2022.
[55] *Space Force signs partnership with Howard University* (13 April 2022). SPACE FORCE NEWS. https://www.spaceforce.mil/News/Article/2998611/space-force-signs-partnership-with-howard-university/ Accessed 2 July 2022.
[56] *Digital Literacy Summit brings together HBCUs, DAF science, technology communities* (28 June 2022). https://www.afrl.af.mil/News/Article-Display/Article/3070874/digital-literacy-summit-brings-together-hbcus-daf-science-technology-communities/ Accessed 2 July 2022.
[57] IBID.
[58] *DAF seeking science research partnerships with HBCUs*. Washington (AFNS): Secretary of the Air Force Public Affairs. 27 June 2022. https://www.af.mil/News/Article-Display/Article/3075257/daf-seeking-science-research-partnerships-with-hbcus/

in pathways and learning communities most likely to engage clearable learners who are predisposed to serving in the national security community.

Specific recommendations are offered for bolstering STEM engagement through JROTC programs; leveraging existing Veterans Programs (including GI Bill and Vet Tech); partnering with DoD Military Academies (including College Prep Military Schools, Senior Military Academies, Federal Service Academies, DoD Postgraduate Schools); support for Military Dependents via DoDEA schools, and continued emphasis on support for HBCU/MSI STEM programs.

## 1.4 BUILD BRIDGES TO THE POTENTIAL NATIONAL SECURITY STEM WORKFORCE

The nature of defense work as well as the environment within which that work is performed, are not well understood by the general public. The study team spoke with a number of DoD/DIB leaders who observed that many prospective workers believe you must wear a uniform to participate in defense missions and that most are unaware of the large civilian STEM workforce serving inside of DoD, and the history of accomplishments of this group.

While working in the private sector for a DIB organization is somewhat more visible, the nature of defense work is still largely misunderstood. The study team believes DoD and the DIB should work together to expand visibility by highlighting career opportunities, the tremendous resources (e.g., supercomputers, hypersonic test facilities, etc.) available, and the size, scope, and accomplishments of the STEM professionals serving defense missions as a means to attract new STEM talent.

**DoD and the broader national security workforce should build bridges to potential employees by de-mystifying the work done by the community.** In this section we describe several ways to do this including:

- Internships
- Advocacy Networks
- Public-Facing Strategic Partnerships

### 1.4.1 INTERNSHIPS

In the course of data-gathering for this study the team was impressed by the work underway within DoD to attract potential STEM recruits through internships. While the team did not conduct an exhaustive survey of the scale of these efforts, it was clear that every branch of the service (typically within their R&D elements) is working to create internship opportunities and bring young people in to work alongside established STEM professionals. Internships are a powerful bridge from learning communities into the national security STEM workforce.

Programs like the DoD SMART[59] scholarship program and the DCPAS Pathways[60] program make it possible for learners to pursue their studies with a stipend and the guarantee of a summer internship within the DoD laboratory community. The ability to grant interim secret clearances was noted as helpful in bringing students more fully into the work of the sponsoring agency.

It was clear from the leaders of the various internship programs that obtaining security clearances for interns was a somewhat ad hoc process, in that various mechanisms and

[59] https://www.smartscholarship.org/smart
[60] https://www.dcpas.osd.mil/policy/employment/dodpathwaysprograms

justifications had to be employed. Talented, passionate, and creative leaders can always make the system work, but it would be helpful if there were a streamlined and standardized process for getting interns into the flow of obtaining a security clearance.

Analysis of DIB programs during the first phase of this study made it clear that DIB companies also place emphasis on recruiting interns and then converting them into full time employees. The survey conducted for the interim report found that internships were common for more than 80% of corporations with estimated revenues exceeding $1 billion.[61]

While there is some effort made to track intern applications and engagements, the fragmented nature of the outreach from the various service components likely means that there are opportunities lost to ideally match candidates with opportunities within the DoD workforce. This is true both across DoD and within DIB organizations, in which individual lines of business in large corporations typically do not share information relating to their intern applicant pool with others in the enterprise.

Every program element within DoD appears to have their own process and systems for recruiting, onboarding, and tracking interns. This makes it challenging for students desiring DoD internships to know where to apply and requires multiple applications for applying to the various service branches. Determined students can make this work, and the department has developed web portals to aid their efforts, but friction could be further reduced with a centralized application process.

Once onboarded, there is an opportunity to showcase full-time opportunities to the interns through regular webinars and other platforms. DoD should explore ways to engage the entire intern pool to expand awareness of the breadth of career opportunities available across defense missions.

In general, centralizing the application and tracking of interns might improve onboarding and ultimately improve the rate at which interns are converted to full-time employees. Such a central platform would also provide improved visibility for hiring managers as they would have access to all candidate resumes. Also, a central DoD platform for managing the intern programs would improve communications to the intern cohort and provide them broader visibility into full time jobs upon graduation.

***Building Bridges: Internships***

*DoD STEM should lead a collaborative effort to build an Intern Portal that communicates all available opportunities; provides a single application process; supports tracking of interns; and enables communications to the entire intern pool to expand awareness of career opportunities within DoD.*

[61] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). p.50. https://sercuarc.org/serc-programs-projects/project/119

### 1.4.2 ADVOCACY NETWORKS

Expanding the clearable workforce can be enabled by building advocacy networks within and between different learning communities. These advocates (for example, retired military or civilian defense leaders) work with students to increase awareness of career opportunities in the national security sector. Additionally, they can help students understand the clearance process. Anecdotal evidence suggests some students do not consider work in national security because they do not believe they could obtain a security clearance (based on drug use or disciplinary issues, for example). A knowledgeable advocate could explain the process and how, in many cases, these students could obtain a clearance despite marks against them from their past. A sampling of programs that leverage advocacy networks is described below.

Catholic University: One university with an on-campus advocate for helping students find a path into national security work is Catholic University in Washington, DC. In this case, retired Navy Admiral Mel Williams serves in such a role. As someone who has served in the military, he is familiar with the national security community and related career opportunities. Admiral Williams educates the students and faculty on the process for obtaining a security clearance. He invites guest speakers in from industry and/or the national security community. He arranges tours of bases and other facilities for both students and faculty.

New Mexico State University (NMSU): Another platform is the Classified-Ready Employee Workforce (CREW) program run by NMSU. It is a one-year program for college seniors with sponsorship from local DIB members. Students accepted into the program are submitted for a security clearance; most are approved by the end of the fall semester. Students also have co-op internships with corporations. The CREW program is another good example of a platform for building bridges between learning communities and the national security STEM workforce. DIB members serve on the advisory board and are helping shape the program.

The study team is aware of other university programs (e.g., University of Alabama at Huntsville, Virginia Polytechnic Institute) in which both DIB members and the DoD provide resources and a platform for obtaining security clearances. In most cases these universities have existing contracts or CRADAs that enable the granting of security clearances to students.

***Building Bridges: Advocacy Networks***

*Stewards of STEM programs should support and expand advocacy networks (e.g., between university students and experienced advocates) as a way to grow the pipeline of cleared workers for defense missions.*

### 1.4.3 INCREASING AWARENESS AND ENGAGEMENT WITH THE PUBLIC

Defense installations are imposing places, typically surrounded by fences and patrolled

by armed guards. The work that goes on inside the fence is often opaque to the general public. Obviously, these installations are potential targets and must be protected, and the work that goes on inside is often classified, which limits entry to those with appropriate security clearances. Still, the default often is to put everything out of sight, when in reality there is usually some subset of work that can be done in less secure facilities, allowing prospective employees to better understand what is being done and who is doing it—thereby de-mystifying the activities. The study team identified several efforts underway with this intent, but more should be done to increase awareness and engagement with the public.

Army Research Laboratory. Initially this program was called the Open Campus Initiative but it now is a broad set of activities that fall under the Strategic Partnerships Office in the ARL Futures Division. This type of program can be very effective at building bridges through mechanisms such as:

- Focusing on engaging with universities and small businesses through CRADAs (Cooperative Research And Development Agreements) or EPAs (educational partnership agreements). These mechanisms do not require funding but provide the opportunity for public and private sector entities to share resources such as computing resources or test facilities.

- Giving tours of Army facilities to build “bench-level” researcher partnerships.

- Using layered security so more people can get past the front door and experience the work underway in the Army labs. ARL runs a network of buildings which are more ‘open’ than traditional bases in places like Boston, MA and Austin, TX.

Air Force Research Laboratory (AFRL). An initiative called AFWRX operates out of Las Vegas, NV and works to open the doors of the AFRL community to innovators and students in the private sector.

Oak Ridge National Laboratory (ORNL). Another ‘bridging platform’ is the Material Development Facility (MDF) operated by ORNL. While not a DoD effort, the example is a useful one in demonstrating how a highly classified facility can engage with the private sector. The MDF sits outside the gates of ONRL and requires minimal paperwork to enter. Inside the MDF are state-of-the-art manufacturing systems such as advanced 3D printers. Researchers from the private sector can use this equipment; the MDF even opens its doors to students working on robotics competitions. The facility also hosts open-houses of various sorts to engage the public.

Gains in the Education of Mathematics and Sciences (GEMS). There also are STEM intervention programs operated by the services focused on bringing awareness to the work they do while building bridges to young people. One example is the U.S. Army Educational Outreach Program’s GEMS program. GEMS brings high school and middle school students into Army Research Laboratory facilities to work alongside researchers

addressing national security challenges. GEMS is limited to U.S. citizens, thus directly engaging a potentially clearable workforce.

Hack-a-Sat. Open Innovation Challenges are another mechanism for building bridges to a prospective national security workforce while also building awareness of national security work. One example is the Hack-a-Sat program run jointly by the U.S. Air Force and U.S. Space Force. Hack-a-Sat is a cybersecurity competition in which players work to penetrate satellites and, in doing so, learn about the national security space mission.

***Building Bridges: Public Engagement***

*DoD should increase efforts to build a public-facing presence outside of security perimeters to engage with the public on innovative R&D topics and other aspects of defense missions.*

### 1.4.4 BUILD BRIDGES: SUMMARY

The study team concluded that DoD and the broader national security workforce should work to build bridges to potential employees by de-mystifying both the work and work environments. While a number of high-value efforts are underway, much more is needed. There are opportunities to better serve (and leverage) the intern population; opportunities to expand advocacy networks to engage students on-campus, helping them understand and navigate the clearance process; and opportunities to increase awareness and engagement with the general public by creating open facilities that invite visitation and participation.

## 1.5 INCREASE ENGAGEMENT OF THE SKILLED TECHNICAL WORKFORCE

In recent years, there has been increasing recognition[62,63,64] that workers with less than a bachelor's degree who have science and engineering skills and technical expertise are integral to the overall STEM capabilities of the nation. This is the skilled technical workforce (STW) consisting of occupations that require a high level of knowledge in a technical domain but do not require a bachelor's degree.

As noted in the interim report, a recent National Science Board report[65] estimated that there were nearly 36 million workers employed in STEM occupations in 2019, representing 23% of the total U.S. workforce. **Within this STEM workforce, 55% of workers do not have a bachelor's degree**, and 45% of workers have a bachelor's degree or more. Further, federal data shows that the **STW is the most diverse segment of the STEM-competent workforce**; its racial and ethnic composition is similar to the overall U.S. workforce aged 25 and older.[66] However, less than 28% of the STW workers are female.[67] While gender discrepancies remain, and must be addressed, racial and ethnic groups are reasonably well-represented in the STW.

Given the size and diversity of the STW, the interim report recommended that DoD, in collaboration with the DIB, expand the availability of high-priority STW pathways through an alliance of Community Colleges and Technical Institutes. Such engagement provides additional benefits in that these institutions often reach underserved/ underrepresented populations (including females) that are a priority for diversification of the STEM talent pool. The report also advocated for the creation of a new Community College/Technical Institute scholarship program specifically for students pursuing careers in fields of high priority to both DoD and the DIB.

Building on the discussion of the STW in the interim report, the sub-sections below provide a deeper understanding of STW development efforts as they relate to the national security community, note key challenges with engagement, and provide additional intervention opportunities to expand the defense-related skilled technical workforce.

### 1.5.1 CURRENT STATE OF STW DEVELOPMENT AS IT RELATES TO NATIONAL SECURITY

A patchwork of efforts—federal, state, and private sector—are implementing programs

[62] National Academies of Sciences, Engineering, and Medicine (2017). *Building the Skilled Technical Workforce*. Washington, DC: National Academies Press. https://doi.org/10.17226/23472
[63] National Science Foundation. *Skilled Technical Workforce Initiative*. https://www.nsf.gov/statistics/stw/skilled-technical-workforce.cfm.
[64] National Science Board (2021). *The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers.* https://ncses.nsf.gov/pubs/nsb20212
[65] National Science Board (2020). *The State of U.S. Science & Engineering 2020.* https://ncses.nsf.gov/pubs/nsb20201
[66] National Science Board (2019). *The Skilled Technical Workforce: Crafting America's Science & Engineering Enterprise*. https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf
[67] Ibid

with the goal of increasing the STW within the national security domain. For example, Manufacturing USA is a network of public-private partnerships, referred to as Institutes, organized around a set of technologies seen as key to U.S. manufacturing competitiveness. Each of these 16 institutes (typically formed by a nonprofit through a competitive process) leverages funds and in-kind resources contributed by the federal government, large and small corporations, and learning communities such as community colleges as well as both public and private universities. The DoD, specifically the OUSD (R&E), is responsible for funding and overseeing 9 of these Institutes. Workforce development is a key initiative for Manufacturing USA with specific interests in:

- *defining the skills and training needed for new careers in advanced manufacturing (e.g., automation, robotics, and artificial intelligence);*
- *retraining and upskilling the current workforce; and*
- *attracting STEM talent*[68].

The Institutes engage with educational institutions (including community colleges and Historically Black Colleges and Universities) and industry on a range of education, training, and development programs.

A separate initiative of the Office of the Under Secretary for Acquisition and Sustainment (OUSD (A&S)), is the Industrial Base Analysis and Sustainment (IBAS) program. IBAS partners with industry and academia to help improve and scale the workforce centered around the skilled manufacturing trades[69] including welding, advanced machining, electronics, precision optics, metrology, and digital/additive manufacturing.

In addition to the DoD, other departments also have efforts aimed at expanding the STW. Some of these target populations of interest to the DoD such as veterans and military-connected family members. For instance, as noted in Section 1.3.2.2, the Department of Veterans Affairs' VET TEC program provides pathways to STW careers for veterans in select courses of study—computer programming, computer software, media application, data processing, and information sciences. At the federal level, STW education and preparation is administered by 43 different government programs across nine different agencies, with some initiatives having an impact on the defense-related STW pool while others support the broader development of the nation's STW talent.[70]

States are also involved in STW efforts related to defense missions. For example, Connecticut has a structured governance model to manage its skilled technical

[68] https://www.manufacturingusa.com/key-iniatives/manufacturing-workforce-development
[69] Office of the Secretary for Acquisition and Sustainment (OSD (A&S) Industrial Policy (2020). *Fiscal Year 2019 Industrial Capabilities Report to Congress*. https://www.businessdefense.gov/docs/resources/USA000954-20_RPT_Subj_FY19_ICR_07092020.pdf
[70] National Science Board (2019). *The Skilled Technical Workforce: Crafting America's Science & Engineering Enterprise*. https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf

workforce programs particularly driven by the needs of defense contractors.[71] All of Connecticut's efforts for a STW are codified in state statutes. In 2014 the Connecticut Legislature established a recurring $75 million Manufacturing Innovation Fund to support education and training of a skilled workforce for defense contractors. Statute defines the use and accountability for the funds that have been leveraged with federal and private support totaling more than $200 million. The Statute also created a *Coordinating Board* for education and training for careers in manufacturing. This board includes representatives from the following constituencies: Department of Economic and Community Development, Labor Department, Connecticut Center for Advanced Technology, technical high school system, independent higher education institutions offering training in manufacturing, Connecticut Employment and Training Commission, manufacturing companies and the employee organizations (collective bargaining) representing manufacturing workers, community colleges, and middle and high school teachers and guidance counselors. State Statute created an *Advisory Board* consisting of appointed state Senate and House of Representative members to ensure recurring funding for manufacturing training and education and to ensure that the funds are dedicated to advancing manufacturing workforce needs.

A review of the private sector's engagement with the STW, through web research as well as in conversations with selected DIB companies, indicated that DIB organizations are directly involved in growing this workforce. Companies work closely with Community Colleges and Technical Institutes for, among other activities, internships, apprenticeships, curriculum development, and certifications/credentials. In some cases, private sector employers have engaged high schools, particularly through the growing P-TECH model (see Section 3.4.1 for additional detail). However, these are often local, disaggregated efforts with limited organization and reach.

In summary, while there are a number of efforts underway to develop and expand the national security STW, most of these efforts are uncoordinated from a defense mission perspective. DoD-DIB collaborative activities relating to the STW currently emphasize manufacturing-related skills and cybersecurity. However, STW workers also provide essential support to other areas including research, development, test and evaluation (RDT&E) and operations and maintenance (O&M). Smaller scale efforts exist to engage some of these domains, but the initiatives are not widespread.

### 1.5.2 Challenges with Growing the Defense-Related STW

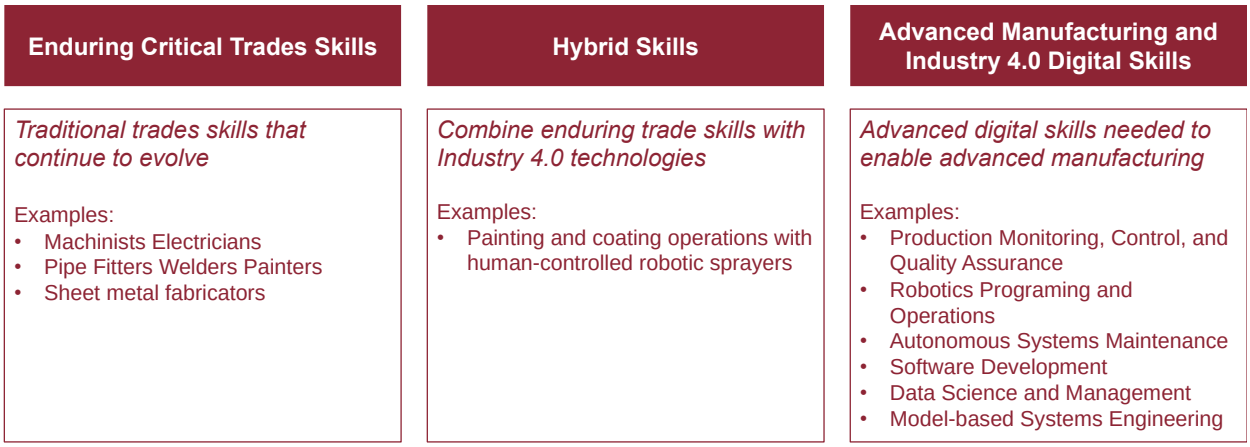
As indicated in previous sub-sections, there is consensus among stakeholder groups about the need for greater STW engagement within the national security space, but key challenges remain.

While there is a general acknowledgment and understanding of the importance of the STW, this study found no accessible, comprehensive information on the state of the

[71] Report. Gargano, M., Lombardi, J., and Rouse, W. (2022). *Developing A Skilled Technical Workforce*. Policy Innovations to Enhance the STEM Talent Pipeline, Systems Engineering Research Center WRT 1042.

STW as it relates to national security (or defense missions). Discussions with government officials, private sector employers and researchers highlighted **insufficient data needed to clearly assess workforce supply and demand** (both current labor and future projections) within the DoD and the DIB. Some organizations have attempted to create classification systems. For instance, IBAS views the manufacturing related STW as a continuum of needs spanning three major categories as shown in Figure 1.2.

**Figure 1.2 STW Needs for Manufacturing[72]**




The NSF's Advanced Technological Education (ATE) program also provides some information on the role of the STW in emerging fields. The ATE program funds pilot partnership initiatives between academic institutions (high schools; post-secondary 2-year institutions) and industry to promote improvement in the education of the STW specifically in advanced technology fields. Currently, these STW development efforts span numerous fields including nanotechnology, optics, biotechnology, information technology, digital building control systems, fault detection and diagnostics, autonomous technologies, and maritime technologies.[73]

In addition to classification efforts, there also are data collection programs underway to better understand the state of the STW (numbers, qualifications, pathways)—for example, through the IBAS and NSF programs—but at present these are not coordinated efforts and likely will not produce a comprehensive dataset covering all fields of interest to national security.

Representative data is particularly important to guiding policy- and decision-making relating to financial and resource investments. Despite the growing recognition of the importance of expanding the STW, most large-scale efforts related to defense missions have been focused on two domains: advanced manufacturing and cybersecurity. While manufacturing comprises a significant proportion of the skilled technical workforce, the

[72] Industrial Base Analysis and Sustainment (2021). *Training of Skilled Technicians for the DIB, Pilot Program Strategy, Briefing to Senate Armed Services*. https://www.businessdefense.gov/ai/ibas/docs/opportunities/SASC_WFD_Master_Briefing_20211029.pdf
[73] NSF Advanced Technological Education Impact Report (2020). https://atecentral.net/downloads/10867/ATE-Impacts-2020-2021.pdf

STW also plays a role in other parts of the defense apparatus. Unfortunately, the study team was unable to locate a comprehensive list of defense-specific STW occupations, particularly in high-priority and emerging industries. A wide-ranging and actionable dataset is crucial to understanding the current STW workforce, creating projections of future occupations and requirements, and understanding the rapidly evolving skill and competency requirements.

*Considerations: Addressing data gaps and silos is imperative to maximize the effectiveness of DoD-DIB collaborative initiatives around STW development. Specific information useful to support policymaking might include:*

1. *Current state of the STW within the DoD and the DIB today*
2. *Characterization of the skills and competencies used in various defense-related STW occupations*
3. *Information on how employers are investing in STW education and skill-building*
4. *Links among post-secondary credentials (degrees, certificates, certifications, badges, micro-credentials), training, and wages*
5. *Longitudinal measurements of how people move from education and workforce preparation programs to their first job, and subsequent jobs and/or additional education*

Part of the challenge stems from the **rapidly evolving nature of the skilled technical workforce**. This is not just true of emerging, high-tech fields; many of the traditional trades now require digital expertise. As employers increasingly automate tasks and incorporate artificial intelligence in standard operating procedures and decision-making processes, the capability of workers to use these tools to manage tasks is becoming essential in most occupations and jobs. This changing skill set "*spans design to service, production to operations. Skills like programming, critical thinking, and knowledge of computers are becoming table stakes for many production-floor jobs…Robot teaming coordinators, digital twin engineers, and predictive supply network analysts are examples of the new roles cropping up in manufacturing facilities*."[74]

Rapid technological changes complicate efforts to project future STW requirements. These forces also impact workforce development efforts and skills training, demanding that both organizations and workers quickly adapt. Markow and Hughes (2018)[75] noted

[74] Wellener, P., Umbenhauer, B., Dollar, B., Zale, J, and Ashton, H. (2020). *Navigating Disruption: Five trends influencing tomorrow's manufacturing industry.* Deloitte Insights. https://www2.deloitte.com/content/dam/insights/us/articles/6493_navigating-disruption/DI_Navigating-disruption.pdf. Accessed 25 June 2022.

[75] Markow, W. and Hughes, D. (2018) *The New Foundational Skills of the Digital Economy: Developing the Professionals of the Future*, Burning Glass/Business Higher Education Forum.https://www.bhef.com/sites/default/files/BHEF_2018_New_Foundational_Skills.pdf

that as "*jobs come to be redefined by new modes of work, the result is a hybridization that mashes together skills from disparate domains and demands greater breadth and flexibility of the workforce*."

**Current occupation-based military job classification systems do not cleanly map to the civilian STW**. This is particularly challenging for the transitioning military and veteran workforce. Recent research[76] found that existing crosswalks that connect Military Occupational Specialties (MOSs) to the Standard Occupation Classification (SOC) system developed for the private sector by the Department of Labor have several shortcomings. For instance, the available crosswalks based on skill equivalencies have been computationally expensive to develop and maintain and thus include a limited number of MOSs. This can limit the number of veterans who find the use of crosswalks beneficial. Also, these platforms are not particularly useful to veterans who do not want jobs related to their MOS after exiting the military. Further, because crosswalks are rigidly based on acquired technical skills and job tasks, they do not expose veterans to the entirety of jobs they may qualified for, or can become qualified for with further education.

The existing institutional support structures for military to civilian career transition tend to focus on resume development and skills translation as a primary driver of civilian workforce success. Greater emphasis is needed on career development, education, and credential acquisition, rather than only job placement. Programs should also work to encourage veterans to explore a more diverse set of STW career pathways, including opportunities for skill acquisition outside of their MOS. Further, instead of preparing veterans for a narrow set of roles analogous to their current position, transition programs should also emphasize the soft skills that prepare veterans for a variety of roles and are of critical importance to employers.

Another major challenge with STW development efforts arises from the **confusing education and training requirements** for skilled technical occupations. There are a variety of training programs to produce a skilled technical workforce, including up-skilling and re-skilling of current workers. Some are clear occupational training systems managed by federal or state agencies via collaborative arrangements with industries. These efforts are guided and supported by a complex and often uncoordinated set of policies and funds at the local, state, and federal government levels. Most resources are allocated by formulas based on demographic factors, which serve as a proxy for need, rather than on performance, outcomes, or evidence of what works best in workforce development.[77] Other programs with similar purpose are operated by industries themselves as well as community and technical colleges; private for-profit organizations; and not-for-profit institutions. Additionally, collective bargaining unions often provide skilled technical workforce training as a benefit of membership.

Despite the availability of numerous education and training programs, there is limited

[76] In conversation with leadership of the University of Virginia Biocomplexity Institute and Initiative Social and Decision Analytics Division

[77] National Academies of Sciences, Engineering, and Medicine (2017). *Building the Skilled Technical Workforce*. Washington, DC: National Academies Press. https://doi.org/10.17226/23472

clarity about the usefulness, acceptance, and reliability of education/training providers of post-secondary credentials (degrees, certificates, certifications, badges, micro-credentials). This adds to the confusion of occupational choice, education, and training. Potential STW workers may find these complexities too daunting to enter the field.

### 1.5.3 INCREASING STW ENGAGEMENT: SUMMARY AND RECOMMENDATIONS

The STW plays a crucial role in the overall STEM competency of the national security apparatus, and increased engagement with this talent pool facilitates expansion and diversification of the defense technical workforce. STW development efforts tend to be viewed favorably by local community stakeholders, especially DIB organizations, as these initiatives support the building and retaining of skilled regional workforces.

**The DoD, its industrial base, and the broader research community should seek to develop a comprehensive understanding of the existing STW labor force, future requirements, emerging high-priority fields, skills and competencies, and qualifications.** This effort should also establish a framework and organizational structure for certificates and credentials that are/will be recognized by both the DoD and the DIB, thereby creating education and training guidance for the various STW career pathways specific to defense missions. Collecting and disseminating robust data on the STW will admittedly be a large-scale and potentially multi-year effort. However, this initiative is crucially needed so that policymakers, employers, and individuals considering STW education and career pathways have high-quality data and information on the characteristics, educational needs, skills, competencies, and career opportunities of the STW.

The interim report recommended engaging Community Colleges and Technical Institutes to develop high-priority pathways for STW careers in national security by expanding offerings of particular interest to the DoD and DIB communities. As a specific initial step toward this broader effort, **the DoD, in coordination with the DIB and educational institutions, should develop pilot programs specific to high-priority emerging areas that are currently underserved by existing workforce development programs.** Such a DoD-DIB collaborative effort, particularly in regions with significant DoD and DIB presence, will:

1) allow both entities to pro-actively shape the direction of STW programs for key areas of strategic importance, and

2) increase engagement of 2-year institutions and support their ability to anchor regional workforce development efforts.

**The DoD should lead a coordination effort with federal agencies (e.g., Department of Labor and the Department of Veterans Affairs) and the research community to understand and improve ways to translate service member skills and competencies into the civilian skilled technical workforce.** For instance, the NSB recommends that the DoD should "*further integrate skills transition into military training rather than treating it as a separate component at the end of the service member's*

*career*". [78] Efforts to improve veterans' transitions into the civilian workforce have focused on actions taken immediately prior to their leaving the military at the point of transition into the civilian workforce. A seamless transition may require that planning to begin earlier in—perhaps even at the start of—service members' military careers. This will enable the DoD to pursue more fluid employment models that meet its workforce needs while allowing for easier transitions between the civilian and military workforces.

The recommendations below identify specific steps that could be taken to increase DoD engagement with the STW workforce—identifying the needs, building pathways, and easing service member transitions.

***Increase STW Engagement***

*DoD and DIB should jointly develop a comprehensive dataset describing the defense-related STW (current state, future projections, pathways, skills, competencies) to inform policies that support increasing STW engagement.*

*DoD and DIB should work jointly to establish pilot programs, in collaboration with Community Colleges and Technical Institutes, for high-priority emerging fields underserved by existing workforce development efforts.*

*DoD should lead a coordination effort to address skills/competencies classification and translation challenges for transitioning service members seeking to join the STW.*

[78] National Academies of Sciences, Engineering, and Medicine (2017). *Building the Skilled Technical Workforce*. Washington, DC: National Academies Press. https://doi.org/10.17226/23472

## 1.6 SUMMARY AND RECOMMENDATIONS

This chapter presented opportunities for STEM investments that focus on expanding the size of the clearable and cleared workforce. These recommendations centered around four key areas:

1) Retention of existing STEM workforce: Leadership within both the DoD and the DIB should explore—and implement—options that make retention of the current cleared workforce a clear priority; specific areas to be addressed include leadership development, flexible work environments, upskilling/reskilling support, and competitive compensation.

> ***Retention of Cleared Talent***
>
> *The DoD (and DIB) should invest in cleared-workforce retention through leadership training, promotion of flexible work environments, upskilling and reskilling efforts, and competitive compensation.*

2) Prioritization of STEM investments: The DoD should explore prioritizing those STEM investments most likely to result in STEM workers entering the national security workforce. These investments are focused on STEM interventions with U.S. citizens who have already demonstrated an interest in national security service. Specific programs addressed are:

- **JROTC**: Due to the nature and reach of the program, JROTC has the potential to play a key role in the strategic development of a clearable technical workforce. While the core competencies taught and fostered by the JROTC program must remain strong, there are valuable opportunities to support and scale existing STEM efforts as well as to establish new ones. JROTC can serve as a catalyst to drive cadet interest in exploring pathways to STEM/STW higher education or employment. This study strongly endorses supporting, sustaining, and growing the availability of STEM interventions in JROTC units.

> ***STEM Engagement through JROTC***
>
> *DoD should support JROTC proposals for pay and eligibility to facilitate recruitment and retention of STEM-competent instructors.*
>
> *DoD and the DIB should jointly establish a collaborative nonprofit to support ongoing STEM engagement efforts as well as enable program expansion.*
>
> *DoD STEM should support and enable increased inter- and intra-service coordination to amplify the Department's overall STEM engagement with JROTC programs.*

- **Veterans Programs**: The Department of Veterans Affairs has programs that provide veterans, servicemembers, reservists, and certain military family members with education and training resources to assist in the transition to civilian life. Some of these programs have a particular STEM/STW emphasis. This section provides an overview of selected veterans' education benefits related to STEM and presents opportunities for enhanced DIB engagement to support the scalability and impact of these efforts. The DoD should seek to support the VET TEC program and amplify its impacts by fostering DIB involvement. Greater engagement with the private sector will also help drive enhanced or additional training programs tailored to the defense industry needs.

  ***Leverage Veterans Programs***

  *DoD, in collaboration with the DIB, should seek to increase and facilitate internship opportunities for GI Bill beneficiaries in STEM/STW fields.*

  *DoD should seek to support the VET TEC program by fostering increased DIB involvement in the program's employer consortium.*

- **Military Academies and DoD Affiliated Educational Institutions:** The DoD runs, or is affiliated with, a number of military academies operating from high school through post-graduate programs. Students in these programs are largely U.S. citizens and have already demonstrated a commitment to national service by choosing this type of learning community. Prioritizing STEM engagements within these academies would be an effective way to increase the size of the clearable workforce. Additionally, opportunities exist to better support DoDEA STEM activities.

  ***DoD Military Academies***

  *DoD STEM should prioritize partnerships with College Prep Military Schools, Senior Military Academies, Federal Service Academies, and DoD Postgraduate Schools as a means to expand the clearable technical workforce.*

  ***Military Dependent Programs***

  *DoD STEM should seek ways to support DoDEA STEM through activities such as internships, competitions, and guest speakers (both in-person and virtual).*

- **HBCUs and MSIs:** Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) have strong STEM programs and student bodies made up of a greater percentage of U.S. citizens than typical universities. A focus on establishing "true partnerships" with these institutions can help address the department's STEM workforce needs, including creating a diverse

pool of future military and civilian technology leaders.

> ***HBCUs and MSIs***
>
> *STEM Program Managers and DoD agencies should continue to prioritize investments in HBCUs and MSIs through research funding, internships, and partnerships.*

3) Raising awareness of national security STEM opportunities: The nature of defense missions is such that the type of work, and the environment within which people perform that work, is not well understood by the general population. The DoD and the DIB could expand their visibility with the clearable workforce by shining a light on the opportunities and tremendous resources available to STEM workers. DoD and the broader national security workforce should build bridges to potential employees by de-mystifying the work done by the community

> ***Building Bridges***
>
> *DoD STEM should lead a collaborative effort to build an Intern Portal that communicates all available opportunities; provides a single application process; supports tracking of interns; and enables communications to the entire intern pool to expand awareness of career opportunities within DoD.*
>
> *Stewards of STEM programs should support and expand advocacy networks (e.g., between university students and experienced advocates) as a way to grow the pipeline of cleared workers for defense missions.*
>
> *DoD should increase efforts to build a public-facing presence outside of security perimeters to engage with the public on innovative R&D topics and other aspects of defense missions.*

4) Increase STW engagement: The STW plays a crucial role in the overall STEM competency of the national security apparatus and increased engagement of this talent pool facilitates expansion and diversification of the defense technical workforce. STW development efforts tend to be viewed favorably by local community stakeholders, especially DIB organizations, as these initiatives support the building and retaining of skilled regional workforces. Many of the challenges associated with increasing the STW pool center around a shortage of actionable data. The DoD and the DIB should jointly seek to develop a comprehensive understanding of the existing STW labor force, future requirements, emerging high-priority fields, skills and competencies, and qualifications (certificates, credentials, etc.). This initiative is crucially needed so that policymakers, employers, and individuals considering STW education and career pathways have high-quality data and information on the characteristics, educational needs, skills, competencies, and career opportunities. This large-scale data collection and synthesis effort should be leveraged to support pilot programs and curriculum development as well as opportunities to support

transitioning service members and veterans.

***Increase STW Engagement***

*DoD and DIB should jointly develop a comprehensive dataset describing the defense-related STW (current state, future projections, pathways, skills, competencies) to inform policies that support increasing STW engagement.*

*DoD and DIB should work jointly to establish pilot programs, in collaboration with Community Colleges and Technical Institutes, for high-priority emerging fields underserved by existing workforce development efforts.*

*DoD should lead a coordination effort to address skills/competencies classification and translation challenges for transitioning service members seeking to join the STW.*

# 2 CREATING INCENTIVES FOR DOD-DIB COLLABORATION

In its interim report the study team found that while both DoD and DIB organizations are actively engaged in STEM education-related activities, collaboration across organizational boundaries is rare.

If expanding the national security STEM workforce through DoD-DIB partnerships is important to the department, then incentives are needed to align the interests of the public and private sector. In this section, consideration is given to means of incentivizing collaborative partnerships in order to make them a viable and valuable platform from which to secure the nation's national security STEM workforce now and in the future.

## 2.1 THE CASE FOR DOD/DIB STEM PARTNERSHIPS

In the 2020 NDAA (HR 166-333), while discussing the importance of the STEM workforce to the national security mission, the conferees stated that they:

> *"...believe that a strong partnership between the defense industry and the Department of Defense can stimulate efforts to increase that pool of STEM talent."*[79]

As noted in the interim report:

> "…*both DoD and the DIB invest significant resources in pursuit of STEM education activities, and those programs are largely stove-piped by organization with minimal collaborative activity. The operating assumption is that by working together, the DoD and DIB can yield synergies and create more effective and/or efficient interventions.*
>
> *The conferees' belief that there is value in DoD-DIB collaboration appears to be based on the opportunity to capitalize on their common mission and the shared risk of a STEM worker shortage. Presupposing that there exists latent synergy, that might be based on a value proposition of:*
>
> - *Common articulation of STEM workforce shortfalls: For the most part, the workforce needs of the DoD and the DIB are identical in that both are working in tandem to develop systems and services. Given that, the risks to the DIB and DoD in terms of ensuring a clearable, technical workforce with the capacity and the capabilities to meet future needs are the same. It would seem to be of value to create a common understanding of those risks rather than have that be a collection of various assessments of the national security STEM workforce challenge. Agreeing on the future needs and necessary interventions would enable the community to speak with one voice, giving clarity to the various learning communities that serve to build the needed*

[79] House Report 116-333. https://www.govinfo.gov/content/pkg/CRPT-116hrpt333/pdf/CRPT-116hrpt333.pdf p. 1327-1328.

*workforce. The most common complaint from learning communities is a lack of clarity on what, exactly, employers need from graduates. Building a common vision would serve to improve the effectiveness of STEM education activities.*

- *Common approach to collecting metrics and evaluating programs: Every steward of a STEM portfolio right now has their own approach to defining and collecting success metrics. This leads to a patchwork understanding of program effectiveness. A common platform for collecting metrics would help reduce duplicative and confusing efforts.*

- *Sharing of best practices: Nobody has all the answers, yet STEM program managers do not appear to actively seek out and apply best practices from other programs. This is not to say they are not willing (even eager) to adopt best practices; they simply do not have the time to seek them out and evaluate them. One common denominator of offices that fund STEM portfolios seems to be that they are stretched thin to respond to the need in the communities they serve. A platform that allowed for best practice sharing would make everyone more effective.*

- *Communicating opportunities to serve: Every organization that seeks to encourage students to enter the national security STEM workforce has a story for the opportunities available to contribute to the mission. This is most true in high school and beyond, but even K-8 activities seek to convey the excitement of high-demand fields including, for example, aerospace, robotics, and cybersecurity. If the community partnered on the national security STEM challenge, an impactful common story could be developed and shared widely, helping to draw learners in a more effective way than the current piecemeal approach."*[80]

The study team agrees that there is value to be unlocked through collaborative partnerships between the DoD and its industrial base, and that efforts should be made to create conditions conducive to such partnering.

[80] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). p. 71-72. https://sercuarc.org/serc-programs-projects/project/119.

## 2.2 THE CHALLENGES OF PARTNERING

Stewards of STEM programs all take tremendous pride in their work and their service to the nation's learning communities (especially America's youth and veterans), "*but manage their portfolios without apparent structured efforts to seek out force multipliers through partnerships. This seems to be due to a number of factors:*

- *Lack of awareness: The STEM landscape of programs is made up of hundreds (if not thousands) of islands of varying size that focus on serving distinct regions, populations, and disciplines. These islands have little ability (without investing significant time in research) to see what is going on in other portfolios. Within the DoD, there is a platform to coordinate work through the STEM office by bringing together the leaders of the various programs in the Components. As a public sector effort, these programs are identifiable. The condition in the private sector is much more challenging as there is no common platform to bring visibility to the collective efforts.*

- *Differing incentives: While the public sector incentives are clear and flow from budget authority channels, the private sector is (by and large) making investments from operating funds, in some cases directly and in others through foundations. Because these companies are making investment decisions for stakeholders, the value proposition for STEM investments must be compelling to these stakeholders. While in part that value proposition can be workforce development related (for interventions in more advanced pathways such as high school and college), it is hard for companies to draw a line between investments in K-8 and their workforce. Instead, the primary value proposition seems to be brand awareness and building community support in regions where they operate.*

- *Competitive barriers: All DIB and DoD STEM programs are focused on the same set of needs, and at some point, the organizations are competing for the same set of workers. This is not really an issue in K-8, but graduates of training programs for robotics technicians, for example, will be sought after by all and so they may be at cross purposes in sharing investments. Also, for the DIB in particular, the STEM program serves as branding in the communities they serve, so they will want to ensure their investments burnish their brands and not those of their competitors."*[81]

[81] IBID. pp. 77-78

## 2.3 LEVEL 4 PARTNERSHIPS: TRUE COLLABORATION

In the Interim Report the study team categorized collaborative activities into four different levels. These are:

- "*Level 1: Parallel Engagements: There are STEM-education activities that are supported both by DIB members and by the DoD, usually through a nonprofit entity that runs the program, but where there is no intentional coordination of effort or communication between the DIB and DoD. Some of these are through a common platform (for example the Air Force Association) that has a specific goal of serving the national security mission, while others are mission-agnostic (e.g., FIRST Robotics).*

- *Level 2: Service-member Support Engagements: In these partnerships, the DIB engages directly with DoD constituents (e.g., Veterans or Military Dependents) to serve their STEM-education needs, but the DoD is not an active partner.*

- *Level 3: DoD Program Engagements: In these activities, the DIB engages directly with DoD programs to support STEM-education activities (e.g., JROTC). We consider these programs to not meet the definition of true collaborations as industry is participating in a STEM-education program run by DoD but is not an equal partner in setting strategy and shaping the program.*

- *Level 4: Collaborative Partnerships: These are true partnerships where the DoD and DIB work together to identify needs and then develop and implement programs."*[82]

The study team recommended that the focus of building DoD/DIB partnerships should be on Level 4 collaborative partnerships as defined above. In this chapter on the incentivization of partnerships, the definition of a partnership should be assumed to be a true collaboration in which the **parties <u>jointly</u> define the vision, build objectives, implement programs, and collect metrics to a common framework**. The sections that follow discuss four areas in which action could motivate and incentivize DoD-DIB collaboration in STEM education-related activities: Executive Messaging; Financial Incentives, Branding Incentives; and Small Business Incentives.

[82] IBID. p.75

## 2.4 EXECUTIVE MESSAGING—*'TONE AT THE TOP'*

There is no more powerful force for bringing the DIB and DoD together than an explicit statement from the highest levels of the DoD that the department is committed to prioritizing the establishment of collaborative partnerships for the purpose of securing the national security STEM workforce. In fact, if this messaging is not delivered, other recommendations in this report are unlikely to be fully effective, and improvements in the national security STEM workforce will be made at the margins, at best.

### 2.4.1 DIB LEADERSHIP MOTIVATION FOR PARTNERING

The defense industrial base is intimately connected to its national security customers, and their financial health and value in the eyes of shareholders are tightly coupled to how they are perceived by these customers. Accordingly, DIB senior leaders are incentivized to understand what their customers value and expect of them; and they respond in kind. If senior DoD leaders publicly state that they want to foster STEM partnerships with the DIB and request regular updates on progress in establishing and growing these partnerships, then the leaders responsible for investing STEM budgets in both DoD and the DIB will prioritize those partnerships.

In the case of the DIB, CEOs of companies will respond by directing their functional leaders in Human Resources, Engineering, Community Relations, and Government Relations to evaluate how their STEM budgets are being spent and will likely direct them to seek out opportunities to partner with DoD and to prioritize those partnerships. They will do this in order to be responsive when their customer asks them to describe STEM-related activities done in collaboration with the department.

### 2.4.2 DOD LEADERSHIP MOTIVATION FOR PARTNERING

In the case of DoD, STEM program leaders will likely respond by initiating contacts with their DIB counterparts with the goal of initiating or expanding partnerships. They will do this in order to be responsive to their leadership, and to be able to report positively when asked to describe their STEM collaboration with the DIB. A likely outcome of such a directive would be to enhance communications between the DoD STEM programs the DIB STEM programs.

As currently structured, DoD program managers have little incentive to engage with the DIB or to share their work. Conversations with industry during the first phase of this study made it clear they had little idea what STEM-related work was being done by the DoD or how that work was organized. With the proper 'tone-at-the-top' it is likely that STEM leaders in both sectors would work to make their efforts more visible, with the goal of fostering collaborative partnerships. At a minimum, DoD and DIB STEM program managers would learn about counterpart organizations and their STEM-related priorities. There currently is no motivation to make that happen.

### 2.4.3 THE IMPORTANCE OF METRICS AND REPORTING

While a public statement of support from DoD leadership is a necessary condition to incentivize DIB participation, it is not sufficient. It is important that goals be established and tracked for discussion during senior-level exchanges on a regular basis. By putting partnership goals in place and creating a framework for reporting against those goals, the DoD will be able to communicate its interest in measurable terms, and DIB executives will have a mechanism by which they can steer their enterprises.

### 2.4.4 EXECUTIVE MESSAGING: RECOMMENDATION

Public messaging must make it clear that the SECDEF believes the STEM workforce constitutes a critical infrastructure for defense missions while calling for the public and private sectors to join together in a common cause.

***Executive Messaging***

*Senior DoD leadership should publicly state a desire to see DoD-DIB collaborative partnerships formed to advance STEM-education related activities.*

At the highest levels of the department, collaboration goals and metrics should be established and senior leaders from industry and the department should be regularly asked to report progress against those goals.

## 2.5 FINANCIAL INCENTIVES TO DRIVE BEHAVIORS

### 2.5.1 FINANCIAL INCENTIVES FOR INDUSTRY

In articulating the importance of STEM partnerships to the department, DoD leadership should also make clear that they are open to making these partnerships financially beneficial to industry through appropriate means. One example might involve addressing how the cost accounting is treated for STEM-related collaborative partnerships done in concert with DoD.

The landscape of how the industrial base accounts for their STEM investment expenses is complex. At one end of the spectrum, such investments can be characterized as part of workforce development. Workforce development expenses, for the most part, are allowable contract charges; corporations build these expenses into their rates. An example of this type of investment might be joining one of the Manufacturing USA Institutes to promote skilled workforce training.

At the other end of the spectrum, these investments can be considered advertising, which is expressly not allowable as a contract charge. An example of this type of expense would be buying naming rights to a planetarium. While this type of investment promotes STEM to the public, it is primarily done as a philanthropic contribution to the community. In fact, because most advertising costs are expressly unallowable, there are penalties for companies who claim them if the costs are subsequently disallowed by the Defense Contract Auditing Agency (DCAA).

Between these two extremes lies a space in which industry and the DoD (through the DCAA) negotiate the type of expense and whether/how it can be reimbursed according to the Federal Acquisition Regulations (FAR). The study team's understanding of how defense contractors allocate STEM costs is that the majority are considered allowable workforce development, recruiting, or public-relations expenses. DIB organizations, however, indicate that they spend significant resources defending these expenses to DCAA because they are not enumerated in the FAR as specifically allowable.

Because STEM investments come in all types from allowable workforce development expenses to expressly unallowable advertising costs, and since STEM investments as a cost category are not well-defined, making a blanket statement that all STEM investments are allowable risks opening the department to significant unanticipated costs. However, **DoD should explore creation of a category of STEM investments done in partnership with DoD—and specifically approved by DoD as a valid partnership**. This category of expenses could then be enumerated in the FAR as allowable, making it easier for defense contractors to be reimbursed for participating in DoD-DIB collaborative partnerships.

The study group recognizes the complexity of this issue, and this recommendation would need significant study by appropriate authorities. A change of this sort, however, would create an incentive for DIB members to prioritize STEM partnerships with DoD over other types of STEM investments and could drive investment dollars into these

partnerships, thereby increasing their scale and impact.

### 2.5.2 Financial Incentives for DoD STEM Programs

As a public sector organization, DoD does not operate under the same financial incentive structure as industry, however there are ways to use the budget allocation process to encourage partnerships. DoD STEM program funds are allocated by the various DoD organizations based on the needs and priorities of those organizations. The landscape of DoD STEM programs is described on the DoD STEM website.[83] If the goal of Department leadership is to foster STEM collaborative partnerships with industry, then prioritizing requests that work their way up the planning process that are tied to partnerships might drive behavior in the direction of seeking out partnerships.

### 2.5.3 Financial Force Multiplier Incentive

Financial incentives also can take the form of less explicit benefits than funding considerations. As discussed in the interim report, most STEM programs operate in isolation with minimal support from a network that might provide things like access to metrics, best practices, resources such as teaching kits, and so forth. While many such resources are available via web searches, making sense of the vast quantity of available information is time-consuming.

DoD-DIB partnerships would be fostered if both parties believed that working together provided them access to curated resources that they would not otherwise have at their fingertips. (This topic is addressed more fully in Section 3.5 of this report.) As collaborative partnerships are implemented and scaled, these implicit financial benefits should be enumerated and communicated as a means of furthering interest and supporting partnership growth.

### 2.5.4 Financial Incentives: Recommendations

Participation in **DoD-DIB collaborative partnerships should be financially attractive to industry** as well as in the best budgetary interest of DoD STEM program offices.

Creation of an explicit category within the FAR to make approved DoD-DIB collaborative partnerships for STEM activities is not a simple task, but the study team believes it would serve to incentivize (and catalyze) DIB interest in such partnerships.

**Financial Incentives**

DIB investments in approved collaborative partnerships for STEM education-related activities should be enumerated in the FAR as an allowable expense for reimbursement in contract rates.

DoD STEM budgets should prioritize engaging in approved collaborative partnerships with the DIB.

[83] DoD STEM. https://dodstem.us/ Accessed 25 June 2022.

## 2.6 BRANDING INCENTIVES

Within the private sector, STEM investments are made for a variety of reasons. It is difficult to prioritize them as a whole since the decision-making process (and the identity of the decision-makers themselves) is opaque to outside study. It is, however, safe to assume that one reason for investing discretionary budget is to build the brand of the organization within the communities they wish to reach. Accordingly, if entering into a STEM partnership with the DoD improves the brand of the corporation disproportionately as compared to a non-partnering STEM investment, that would incentivize entering into such a partnership.

Key to branding success is the ability to showcase successful contributions and partnerships. This can be thought of in two ways: improving the corporation's visibility with clients, and improving brand visibility in the community at large.

### 2.6.1 FAVORABLE 'OPTICS' WITH CUSTOMERS AND POTENTIAL CUSTOMERS

DoD often uses metrics of contractor performance when considering new contract opportunities. Most familiar is the Contractor Performance Assessment Reporting System (CPARS) which is used by procurement managers to report, "*the contractor's record of conforming to requirements and to standards of good workmanship; forecasting and controlling costs; adherence to schedules, including the administrative aspects of performance; reasonable and cooperative behavior and commitment to customer satisfaction; reporting into databases; integrity and business ethics; and business-like concern for the interest of the customer*."[84] Other metrics include areas like compliance with Small Business subcontracting responsibilities.

DoD contractors are rightfully concerned with their reputations and how they are represented in various reports related to their performance. If DoD wishes to incentivize partnerships with the DIB, developing and disseminating (or posting) a list of partnerships underway and the resources committed to those partnerships would be one way to use 'optics' to drive behavior.

### 2.6.2 HEIGHTENED BRAND VISIBILITY IN THE COMMUNITY—AWARDS

Award programs can serve as a galvanizing force to bring the public and private sectors together around a common objective. These programs serve to structure the objectives of the partnerships (necessary for making awards), celebrate successful partnerships, serve as valuable branding for winning entities, and energize the individuals working in the field. If the department publicly recognizes the national security STEM workforce as critical infrastructure and prioritizes DoD-DIB collaborative partnerships as a means to secure this workforce, then structuring an awards program is an effective means of moving the community toward the goal of a sustainable STEM pipeline for defense missions.

[84] Contractor Performance Assessment Reporting System. https://cpars.gov/.

## The Baldridge Award

Perhaps the most famous awards program of this type is the Malcom Baldrige Award. The Baldrige award was founded in an era during which the nation's leaders were concerned that U.S. industry had lost its edge in terms of quality management and that other countries (specifically Japan at the time) would overtake the nation economically. Following the work of a presidential commission on industrial competitiveness, a bill was introduced in the House of Representatives to, "*establish a National Quality Improvement Award, with the objective of encouraging American business and industrial enterprises to practice effective quality control in the provision of their goods and services*."[85] On August 20, 1987, President Reagan signed the Malcolm Baldrige National Quality Improvement Act of 1987 into law.

The Baldrige Award continues to be a sought-after form of recognition within industry for its emphasis on quality management and other fields (the original scope of the award has expanded over the years). More than just serving as a public-relations goal, the award program itself set the framework for how industry and the government think about quality and pursue its benefits. While the federal government structures the nature of the program (through the National Institute of Standards and Technology) and gives it the imprimatur of a national award, funding for the program comes from the private sector through contributions made by industry to a 501(c)3 nonprofit known as the Baldrige Foundation. **This public-private partnership is a useful framework for thinking about the STEM workforce challenge, which is as critical today as the quality challenge was in the 1980s.** Congress and the Executive Branch should consider implementing a similar program to meet the STEM challenge.

## The Program Excellence Awards

Another example of an award program that brings together the public and private sector (in this case largely DoD and the DIB) is the Aviation Week and Space Technology Program Excellence Awards[86]. This program is run by a publishing company that brings together judges from industry to select programs of varying scale and type that are successful examples of partnerships between contractors and the program offices responsible for meeting mission needs.

This program is cited as an example of how public relations goals can drive industry participation in programs. This particular example is not endorsed by the DoD, but program managers from the department are honored together with their contractor counterparts during an annual banquet. Programs like this serve to declare the importance of a topic, to establish a framework for evaluating success in meeting the goals of that topic, and in generating goodwill for the winners.

85 https://baldrigefoundationorg.presencehost.net/file_download/3947a16d-ad22-4a67-83ec-c8493fca15c3

86 https://adprograms.aviationweek.com/en/program-excellence/program-excellence.html

### *2.6.3* BRANDING INCENTIVES: RECOMMENDATION

DoD and the DIB should work together to establish a national STEM partnership awards program to establish a framework for defining what a successful STEM partnership looks like, and to recognize successful partnerships.

***Branding Incentives***

*DoD and the DIB should establish a national awards program for excellence in DoD-DIB collaborative partnerships advancing STEM in support of defense missions.*

In its interim report, the study team made a similar recommendation; this repeat is accompanied by exploration of potential models for such a program.

## 2.7 SMALL BUSINESS INCENTIVES

Small businesses are a critical component of the defense industrial base. These firms produce specialty components for prime contractors, sell spare parts directly to the DoD, and are a source of innovation and productivity in the weapon system production process. In FY 2020, DoD obligated $80.5 billion to small businesses[87], 77 percent of which was received by three industries—professional services, manufacturing, and construction.

**Professional services are the largest and fastest growing industry for small businesses contracting with the DoD.** While these services span a range of professional capabilities, three categories comprise the bulk of DoD's expenditures with respect to small businesses (see Figure 2.1): architectural and engineering services, computer systems design services, and scientific research and development services—notably **services that rely on a competent STEM/STW workforce**.

Anecdotal evidence, including through discussions with DIB survey participants (from the survey conducted during phase 1 of this study) as well as subject matter experts, suggests that small businesses are challenged to find skilled technical talent. These discussions, supported by web-based research, indicate that many small businesses are addressing these technical labor issues by supporting local STEM education activities through initiatives including employee volunteerism in local communities, internship and apprenticeship programs, and partnerships with regional public-private education models like P-TECH and NAF (see Section 3.4). These outreach and engagement programs appear to be individual efforts (largely uncoordinated). Given the critical role played by STEM expertise in the small businesses that contribute to the DoD's industrial base, a potential value proposition is to encourage DoD-small business collaborative partnerships to support the strategic development of a skilled technical workforce:

- Leveraging a section of the industrial base that has wide geographic distribution and a vested interest in growth of the local technical workforce**.** Small businesses located in rural areas, near military installations, and even in mid-sized cities are challenged to attract technical talent.

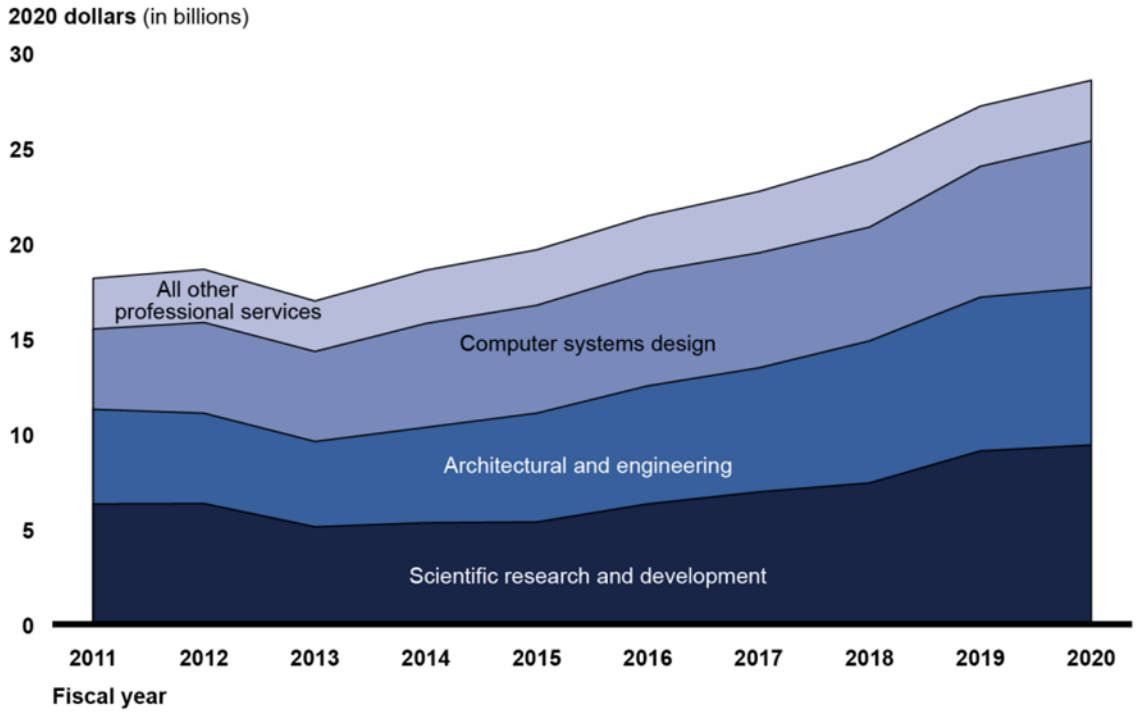
- Partnering with the portion of the industrial base that is often more agile and responsive to DoD needs. Small businesses, especially those that provide cutting-edge R&D and manufacturing expertise, are particularly sensitive to evolving skills and capabilities, and have a strong motivation to respond quickly to changing talent needs.

- The DIB includes a large number of 8(a) corporations that have unique access to underserved/underrepresented populations. Examples include small businesses owned by Alaska Native Corporations, Native Hawaiian organizations, Indian

[87] Government Accountability Office (2021). *Small Business Contracting: Actions Needed to Implement and Monitor DOD's Small Business Strategy*. https://www.gao.gov/assets/gao-22-104621.pdf

Tribes, and Community Development Corporations; HUBZone businesses and other minority-owned businesses should be considered as well. At present, these entities rarely participate in STEM outreach activities, however, they offer opportunities to expand and diversify the STEM/STW talent pool.

**Figure 2.1 DoD Contract Obligations to Small Businesses for Professional, Scientific, and Technical Services, Fiscal Years 2011–2020**




Source: Government Accountability Office, "Small Business Contracting Actions Needed to Implement and Monitor DOD's Small Business Strategy", October 2021

Historically, the challenges faced by small businesses in participating in the defense procurement process have similarly hindered their ability to engage in STEM outreach more broadly. Notable obstacles involve (1) complex and inefficient contracting processes[88] and (2) administrative difficulties including burdensome cybersecurity requirements[89]. The need to navigate complex DoD contracting processes with limited manpower and resources leaves small businesses with inadequate capacity to engage in activities such as STEM outreach and workforce development. This limited bandwidth also hinders their ability to apply for grants from external entities that support education and outreach efforts. These headwinds can reduce motivation for even the most innovative businesses and undermine crucial workforce development efforts needed to supply the DoD with services and technology vital to defense missions.

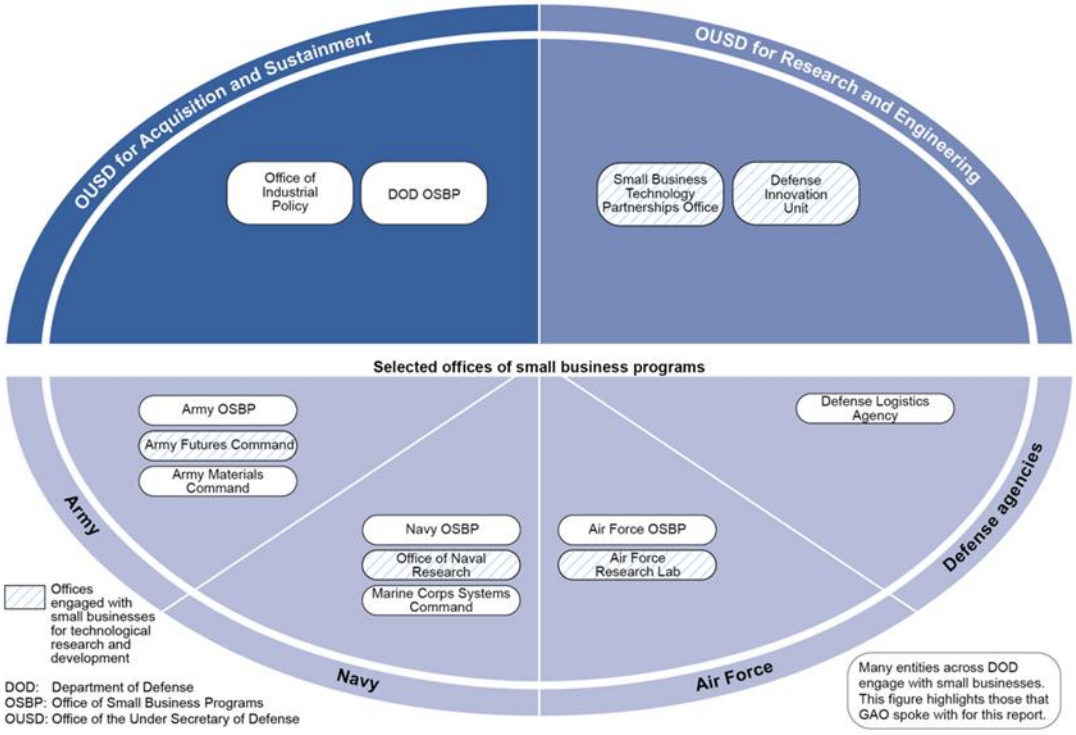
DoD has several activities in place to support the development of contracting processes

[88] https://thehill.com/opinion/national-security/573377-if-dod-wants-small-business-contracts-it-has-to-cut-the-red-tape/
[89] https://business.defense.gov/Portals/57/Documents/Small%20Business%20Strategy.pdf?ver=2019-11-19-115847-510

specifically for small businesses, including various forms of management, technical, financial, and procurement assistance. Participating businesses receive training and technical assistance designed to strengthen their ability to compete effectively in the U.S. economy.

DoD's small business engagement efforts are distributed across the military services and within different parts of the Office of the Secretary of Defense, as shown in Figure 2.2. The Office of Small Business Programs (OSBP) is responsible for negotiating DoD's small business contracting goals with the Small Business Administration and for developing policy to ensure maximum practicable opportunity for small businesses in defense procurement. The OSBP is housed within the Office of Industrial Policy and falls under the Office of the Under Secretary of Defense (OUSD) for Acquisition and Sustainment (A&S). This office also manages key programs such as the Mentor-Protégé Program (MPP) and the Indian Incentive Program (IIP) that support increased participation by small businesses.

**Figure 2.2 Examples of the Variety of DoD Organizations That Engage Small Businesses**




Source: Government Accountability Office, "Small Business Contracting Actions Needed to Implement and Monitor DOD's Small Business Strategy", October 2021

The OUSD for Research and Engineering (R&E) as well as the service branches also have offices that engage that administer innovation-focused programs designed to leverage small businesses. For instance, the OUSD(R&E)'s Small Business and Technology Partnerships Office administers the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs for DoD. Similarly, the services have offices that provide resources and opportunities for increased access

to innovation from small businesses.

Broadly, the DoD's OSBP (and related organizations) aims to maximize small business participation, monitor progress toward SBA goals, conduct outreach to small businesses, and advise on small business policy. While STEM /STW outreach and workforce development are not the primary purposes of these programs, they may serve as gateways to small business engagement on this topic.

Discussions with the leadership of OSBP indicated interest in engaging small businesses on STEM/STW outreach and workforce development; the office previously supported STEM initiatives and is actively considering future engagement opportunities. Recently, OSBP collaborated with the National Security Agency (NSA) to support small businesses in their need to be cyber-compliant by facilitating student internships from computer science programs in HBCUs; some internships led to full-time employment upon graduation. OSBP leadership also indicated interest in engaging with other entities across the DoD to identify opportunities for which department resources could be leveraged. As an example, OSBP seeks greater coordination with the Industrial Base Analysis and Sustainment (IBAS) program which also falls within the A&S organization. However, budget restrictions have resulted in staffing and resource constraints, hindering OSBP's ability to undertake a wider range of STEM/STW outreach efforts.

Given the previously mentioned challenges, increasing small business STEM engagement will best be achieved in the near term by making the participation process easier through means such as (1) **building on existing programs and operational structures**, and (2) **reducing barriers to participation**.

For instance, the DoD could leverage the Mentor-Protégé Program (MPP)—an existing program—for increased STEM outreach and engagement. This program provides incentives, through directly reimbursed and credit agreements[90], for major defense contractors (mentors) to pair with small, disadvantaged firms (protégés) in an effort to enhance their capability to compete for federal and commercial contracts. The MPP benefits both the protégé and the mentor:

- protégés receive guidance from established defense contractors on navigating processes such as cost accounting standards and security clearance processes; and
- mentors gain opportunities to leverage the nimble and agile nature of small businesses and their technologies, services, and cutting-edge products.

[90] Directly reimbursed agreements are those in which a mentor receives reimbursement for allowable costs of developmental assistance provided to a protégé. Credit agreements are those in which a mentor receives a multiple of credit toward their Small Disadvantaged Business (SDB) subcontracting goal based on the cost of developmental assistance provided to a protégé.

Informal discussions with small businesses owners and stakeholders indicate that the program is viewed favorably[91]. **The DoD should seek to expand the mentor-protégé program to include credits for mentors that work with small business protégés on STEM/STW engagement activities, specifically those efforts that advance approved DoD-DIB collaborative partnerships.** Such efforts might leverage the mentor's experience in supporting and facilitating STEM/STW interventions and drive application in the protégé's local/regional community. This is also in the mentor's interest as such efforts will enable the protégé to build the long-term workforce to support sustained contributions to defense contracts.

For small businesses that are particularly resource-constrained, structured associations can support greater participation by reducing barriers, especially around awareness (engagement opportunities and partnership-building) and coordination (resource-sharing and eliminating parallel efforts). The DoD should **draw on the existing reach and organizational network available through the Procurement Technical Assistance Centers** (PTAC). PTACs identify and engage with small companies on contracting opportunities with DoD, other federal agencies, state and local governments, and government prime contractors[92]. PTACs serve as a resource for businesses to obtain information and training related to the contracting process. These centers also work directly with private sector, university, non-profit and local partners to conduct outreach activities necessary to develop long-term relationships with the small business community and the larger defense industry. According to OSBP officials, there are currently 95 PTAC centers, of which 6 PTACs exclusively serve Native American-owned businesses. In terms of STEM outreach, the PTAC network can provide the organizational structure and communication channels to engage small businesses, particularly for target populations that are of interest to the DoD. **Based on the PTAC infrastructure and reach, these centers can collectively facilitate awareness, coordination, collaboration, and potentially create involvement opportunities and mechanisms to encourage STEM-related collaborative partnerships**. In addition, their proximity to and connections with the local/regional small business communities can inform DoD's understanding of future workforce requirements in terms of occupations, skills, and competencies.

[91] U.S. Small Business Administration (2020). *Report to Congress on Mentor-Protégé Programs for Fiscal Year 2019*. https://www.sba.gov/sites/default/files/2021-01/Final%20FY19%20MPP%20Report%20to%20Congress%20with%20Agency%20Reports-508.pdf

[92] Government Accountability Office (2021). *Procurement Technical Assistance Program: Opportunities Exist for DOD to Enhance Training and Collaboration*. https://www.gao.gov/assets/gao-21-287.pdf

### 2.7.1 SMALL BUSINESS INCENTIVES: RECOMMENDATION

Partnering with small businesses has always been a priority for DoD as it works to leverage the innovation capacity of this segment of the industrial base. Small businesses have much to offer to STEM partnerships, but they also have challenges and constraints that larger companies do not have.

***Small Businesses***

*DoD should build on existing programs and structures (e.g., Mentor-Protégé and Procurement Technical Assistance Centers) to reduce the barriers to Small Business participation in STEM education activities.*

## 2.8 SUMMARY AND RECOMMENDATIONS

This section recommends incentives to promote DoD-DIB collaborative partnerships in four areas:

1. Executive Messaging: There is a need to '**set the tone at the top'**, calling for the public and private sectors to join together to build and sustain the clearable technical workforce needed to support defense missions.

***Executive Messaging***

*Senior DoD leadership should publicly state a desire to see DoD-DIB collaborative partnerships formed to advance STEM-education related activities.*

2. Financial Incentives: Participation in DoD-DIB collaborative partnerships should be **financially attractive to industry as well as in the best budgetary interest of DoD STEM program offices**. In addition to the explicit financial incentive recommendations, **financial force multipliers** (e.g., access to information and other resources not otherwise readily available) should be promoted as direct benefits (reducing resource requirements) to stakeholders in both government and industry.

***Financial Incentives***

*DIB investments in approved collaborative partnerships for STEM education-related activities should be enumerated in the FAR as an allowable expense for reimbursement in contract rates.*

*DoD STEM budgets should prioritize engaging in approved collaborative partnerships with the DIB.*

3. Brand-related Incentives: DoD and the DIB should work together to **establish a framework for defining what a successful STEM collaborative partnership looks like, and to recognize successful partnerships** at regional as well as national levels.

***Branding Incentives***

*DoD and the DIB should establish a national awards program for excellence in DoD-DIB collaborative partnerships advancing STEM in support of defense missions.*

4. Small Business Incentives: Small businesses provide essential products and services to defense missions and are growing rapidly in domains that require STEM expertise. Collectively, this population represents a relatively untapped resource in terms of engagement in STEM education-

***Small Businesses***

*DoD should build on existing programs and structures (e.g., Mentor-Protégé and Procurement Technical Assistance Centers) to reduce the barriers to Small Business participation in STEM education activities.*

related activities, due to their limited capacity. DoD should **take steps to mitigate/reduce the barriers that limit their participation.**

The study team notes that creation of a platform for fostering partnerships, publicizing opportunities, celebrating accomplishments, promulgating best practices, and connecting interested parties in government, industry, and academia is a necessary precondition for building partnerships. The recommendations above are meant to build on such platforms. Chapter 3 addresses more directly the creation of such platforms.

# 3 ADVANCING STEM/STW ECOSYSTEMS

This chapter emphasizes the motivation and prospective role(s) for DoD-DIB collaboration within STEM/STW ecosystems and offers recommendations in several areas in which near term action could lay the groundwork for a more strategic DoD-DIB collaborative partnership effort.

- Section 3.1 provides a brief recap describing STEM ecosystems, pulling from the interim report and related research, together with a fuller description of how DoD-DIB collaborative partnerships could serve as valuable components within existing ecosystems while also delivering measurable benefits to defense missions.

- Section 3.2 provides an updated framework for evaluation and assessment based on the Collective Impact model and also introduces an evaluation overlay specific to DoD-DIB strategic priorities.

- Section 3.3 suggests decision criteria to inform choices regarding partnering with STEM nonprofits to advance DoD-DIB priorities.

- Section 3.4 discusses two models for systemic change within educational institutions, both of which are in widespread use, that are designed to deliver more sustainable results.

- Section 3.5 discusses exploitation of the virtual environment as an enabler for STEM ecosystems, with initial emphasis on development of user-centric portals to boost efficiency and effectiveness.

- Section 3.6 provides a brief summary of the recommendations from this section of the report.

## 3.1 ABOUT STEM ECOSYSTEMS—*AND PROMOTING DOD-DIB COLLABORATION*

Work relating ecological models to ecosystems for STEM education dates back more than a decade, with the concepts gaining significant traction more recently. A 2010 paper by the University of Cincinnati FUSION (Furthering Urban STEM Innovation, Outreach, and New Research) Center describes an ecological model of STEM education, "*which provides a mechanism for understanding the interconnected and complex interactions that occur across multiple systems (e.g., policy makers, curriculum developers, teachers, and students) within current STEM education infrastructures*."[93]

In a 2015 report, the National Research Council (NRC) observed that the ecosystem perspective of learning was gaining traction and noted that "*this systemic view of learning includes multiple parties in a community who collectively seek to expand opportunities for STEM Learning.*"[94]

Also in 2015, STEM Learning Ecosystems, a global Community of Practice (SLECoP) "*with extensive sharing of resources and expertise among leaders from education, business, and industry, nonprofits, philanthropy and others*" was launched by the Teaching Institute for Excellence in STEM (TIES) during an international conference held in Denver.[95] Today the SLECoP website reports 100 active STEM Learning Ecosystems that engage 1,980 school districts (rural, urban and suburban) and impact more than 42 million PreK-12 children in the U.S., Canada, Mexico, Israel, and Kenya.[96]

Interest in the ecosystem model for STEM education extends well beyond the countries identified on the SLECoP website, as is illustrated by research papers including:

- *Ecosystem-based Theoretical Models for Learning in Environments of the 21st Century,* written by researchers from Austria and Australia, which explores "*how ecosystem-based models are applicable for E-learning 2.0 approaches."*[97]

- *Versatile Learning Ecosystem: A Conceptual Framework,* written by researchers from India, which proposes "*a supplementary architecture to reinforce the traditional learning ecosystem by leveraging the ubiquitous presence of technology-enabled learning atmosphere*."[98]

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[93] J. D. Basham, M. Israel, & K. Maynard (2010). *An Ecological Model of STEM Education: Operationalizing STEM FOR ALL*. Journal of Special Education Technology. Volume 25, Number 3. p. 9.
[94] National Research Council (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21740 p. 26
[95] STEM Learning Ecosystems Overview. https://stemecosystems.org/about/ Accessed 14 June 2022
[96] Participating STEM Learning Ecosystems. https://stemecosystems.org/ Accessed 14 June 2022
[97] C. Gutl, V. Chang (2008). E*cosystem-based Theoretical Models for Learning in Environments of the 21st Century*. International Journal of Emerging Technologies in Learning. https://doi.org/10.3991/ijet.v3i1.742
[98] K. R. Pillai, P. Upadhyaya, A. Balachandran, J. Nidadavolu (2018). *Versatile Learning Ecosystem: A Conceptual Framework*. The Kerala State Higher Education Council. https://doi.org/10.1177/2347631118802653

- *Transforming Higher Education Learning Ecosystem: Teachers' Perspective,* written by Estonian researchers, which "*presents a case study of transformation challenges of the institution during COVID-19 from the perspective of teaching staff*."[99]

- *A Territorial Learning Ecosystem for Parents' Participation and Cooperation,* written by a researcher from Chile, which "*describes the implementation of a territorial learning ecosystem that provides K12 parents with the facilities to support their children's learning at home, track progress against the national curriculum, and network and share their experience with other parents.*"[100]

The evolving model provides a powerful framework for identifying the complex interactions that occur among the various stakeholders within a vibrant STEM ecosystem. But related research, including conversations with stakeholders in several existing STEM ecosystems, suggests there is much work to be done to align stakeholder objectives and to develop the effective collaborative partnerships needed to more fully realize the potential benefits of the model.

### 3.1.1 ATTRIBUTES OF ROBUST STEM ECOSYSTEMS

A primary purpose of a STEM ecosystem is to act as a force multiplier—amplifying the reach, visibility, and outcomes of individual initiatives. Robust ecosystems generally share common attributes, including:

- alignment with community needs and interests (for example, STEM talent needed by local businesses);

- mutually-reinforcing programs that assist with learning (e.g., extracurricular activities that reinforce what is being taught in the classroom; museum exhibits tailored to classroom materials);

- a continuum of STEM exposure via interventions beginning Pre-K, continuing into adolescence and early adulthood;

- activities spanning a broad range of topics and technical domains at all ages, designed to engage and inspire students with differing interests;

- cross-pollination of ideas enabled by effective communications networks both within and among STEM ecosystems;

- willingness to pilot and evaluate innovative ideas—and share outcomes within and among STEM ecosystems;

[99] T. Valjataga, K. Ppp,-Valickis, K. Rumma, K. Aus (2020). *Transforming Higher Education Learning Ecosystem: Teachers' Perspective*. Interaction Design and Architecture(s) Journal, N.46, pp. 47-69.
[100] R. Araya (2021). *A Territorial Learning Ecosystem for Parents' Participation and Cooperation*. Center for Advanced Research in Education, Institute of Education, Universidad de Chile.

- effective means to reach targeted populations to deliver culturally-relevant STEM interventions as well as to provide access to wrap-around services[101] if needed;
- assessment and evaluation methodologies that reveal the impact of STEM interventions (individually and collectively); and
- engaged and diverse role models who embody STEM-related career options, inspiring students of all ages.

A scan of ecosystems within the SLECoP network indicates that while many existing ecosystems exhibit a number of these attributes, few exhibit the full array (based on publicly available information). In particular, it appears there is no comprehensive framework for assessment and evaluation of ecosystem performance and impact in widespread use. There are, however, efforts underway within some existing STEM ecosystems to address this gap.[102,103]

### 3.1.2 A CONCEPTUAL MODEL OF STEM ECOSYSTEMS

As indicated in the graphic in Figure 3.1, essential *design* elements for STEM/STW ecosystems include building strong connections among partners and stakeholders in the ecosystem, who leverage a wide array of available resources and exploit best practices to prioritize and develop/access the needed STEM interventions.

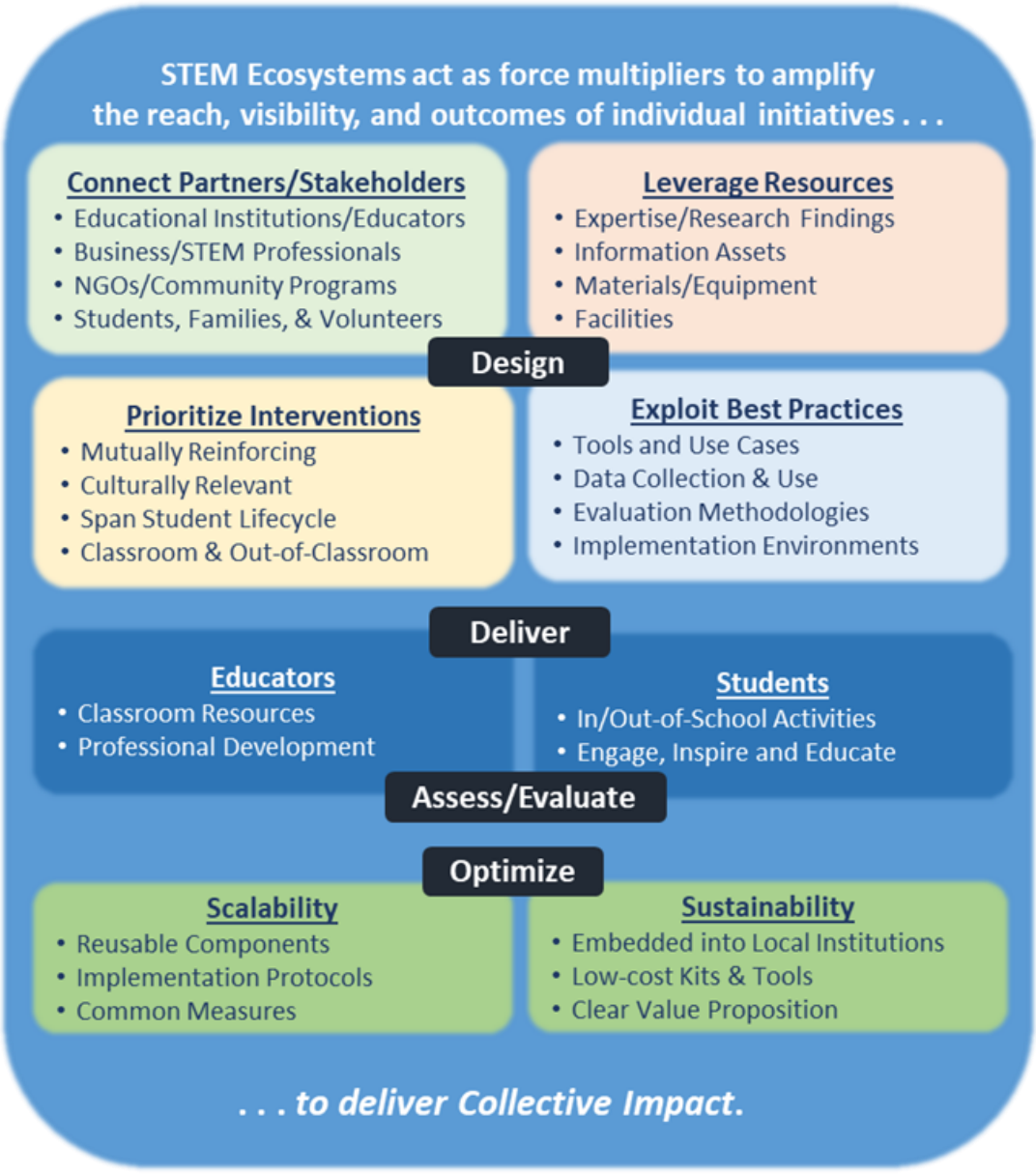
STEM Interventions are *delivered* to both educators and students over time, enabling the growth and development of both stakeholder communities. The *assess/evaluate* cycle is intended to identify the level of performance demonstrated as well as the degree to which goals are attained.

Finally, there are ongoing needs to optimize the ecosystem in terms of both scalability and sustainability. Both are intended to maximize the value delivered relative to costs incurred—enhancing both efficiency and effectiveness.

While portrayed as a serial process in the graphic, there are ongoing cycles at each stage. Implementation requires committed and fully engaged partners/stakeholders.

[101] Eber, L. (2008). *Wraparound: A Key Component of School-Wide Systems of Positive Behavior* Supports. In E. J. Bruns & J. S. Walker (Eds), The resource guide to wraparound. Portland, OR: National Wraparound Initiative, Research and Training Center for Family Support and Children's Mental Health. https://nwi.pdx.edu/NWI-book/Chapters/Eber-5e.3-(school-wide-support-systems).pdf 23 June 2022.
[102] K. Lewis-Warner, P. Allen, G. Noam (2019). *Partnerships to Transform STEM Learning: A case Study of Tulsa, Oklahoma's Ecosystem.* Partnerships in Education and Resilience (PEAR). https://www.pearinc.org/tulsa-case-study-short Accessed 23 June 2022.
[103] P. Allen, G. Noam (2016) STEM Learning Ecosystem: *Evaluation and Assessment Findings. Partnerships in Education and Resilience* (PEAR). http://stemecosystems.org/wp-content/uploads/2017/01/STEMEcosystems_Final_120616.pdf Accessed 23 June 2022.

**Figure 3.1 Conceptual Model for STEM Ecosystems**




### 3.1.3 AN UPDATED VISION FOR FUTURE DOD-DIB COLLABORATION

The interim report from this project set forth a vision for DoD-DIB collaboration built around:

> "…*a collaboratively operated system of local STEM/STW ecosystems, each of which prioritizes military-connected families while also reaching the community's underserved/underrepresented populations. Each local ecosystem addresses a*

> *full spectrum of STEM/STW pathways tailored to the needs of the community. Additional programmatic elements support nation-wide initiatives*."[104]

This vision failed to fully account for existing ecosystems with governance structures and partnerships already in place (or forming). This *system-of-systems* approach was intended to provide a platform for DoD-DIB collaborative partnerships at the system level as well as within (and among) individual STEM ecosystems. Coordinating entities (nonprofit organizations) were to be established to facilitate joint planning and implementation, as well as to enable combined public-private sector funding.

**The updated vision explicitly acknowledges that, in practice, collaborative activities implemented by DoD and its industrial partners will coexist with related activities implemented by many other partners and stakeholders in a given STEM ecosystem**. This is an advantage in that DoD and its partners reap benefits from these related activities which also contribute to expansion of the STEM-capable talent pool; but visibility into programmatic specifics and outcomes of these related activities may be limited, thus making it difficult to discern the relative value of individual programs within the ecosystem. Fortunately, a number of existing STEM ecosystems have efforts underway to develop assessment/evaluation processes, so this gap may be alleviated over time.

In developing the future vision, two key elements derived from the study tasking were emphasized: **develop collaborative DoD-industry activities** and focus on **activities which are based on metrics and education best practices to ensure maximum effectiveness**.

In phase one of this study, the team concluded that some mechanism was needed to enable true **DoD-DIB collaborative partnerships**—**partnerships in which the DoD and DIB work together to identify needs and then jointly develop and implement programs in order to realize the full benefits**—and noted that the Manufacturing USA public-private partnership provides one such model.

The interim report recommended a networked system of nonprofit organizations, with each established as a collaborative DoD-DIB partnership. The nonprofit model was selected as the basis for the public-private partnership largely because it can benefit from both direct funding (public and private) and philanthropic contributions (many private sector organizations fund STEM education-related activities via foundations and/or philanthropy). The team noted that nonprofits are already in use by some DoD STEM programs (e.g., STARBASE), although not for the purpose of building collaborative partnerships with DIB organizations.

[104] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). p.86. https://sercuarc.org/serc-programs-projects/project/119

The study team continues to believe that establishment of a networked system of nonprofit DoD-DIB collaborative partnerships is the most effective way to maximize the benefits from DoD-DIB collaboration on STEM education-related activities. But such organizations would, in many cases, be better-positioned as ***partners within existing ecosystems***, while operating in alignment with DoD-DIB jointly established strategic priorities. Thus, the ***updated vision*** for DoD-DIB collaboration is re-framed as:

> ***…a DoD-DIB collaboratively-operated system of local DoD-DIB nonprofit organizations, each of which is a fully-participating partner within an existing STEM ecosystem. The DoD-DIB partnership would emphasize outreach to priority populations; engaging, inspiring and attracting students to defense missions; introduction of high-priority STW pathways as needed; and other jointly-established strategic priorities***.

**At the system level, it is envisioned that a small nonprofit would be established for the purpose of motivating, coordinating and evaluating the distributed DoD-DIB collaborative efforts.** It would be governed by a Board of Directors including representation by senior defense officials together with senior DIB representatives. Key functions would include:

- Screen candidates for placement of local DoD-DIB nonprofit organizations—based on proximity to targeted populations (e.g., military-connected families and other underserved/underrepresented groups); DoD and DIB organizational presence; and evidence of community support (e.g., either an existing STEM ecosystem or a strong desire to develop one).

- Provide core funding to support establishment and sustainment of local DoD-DIB nonprofits; intervene and/or cease support for a local nonprofit if warranted.

- Establish and periodically review/update DoD-DIB strategic priorities both at the system level and at the local level.

- Develop and manage a grant process to distribute, on a competitive basis, funds to support high-priority DoD-DIB needs identified by local DoD-DIB nonprofits.

- Establish a web presence and maintain an information/resource-sharing network to support and enable the DoD-DIB network of local nonprofits, and to support sharing of best practices across the network.

- Establish/maintain an assessment/evaluation framework to be used by the local DoD-DIB nonprofits. Annually evaluate the overall network to determine progress against established priorities (synthesize assessments/evaluations received from each local nonprofit).

- Develop and administer a system-wide awards/recognition program for exemplary volunteers (individuals and teams) as well as DIB and DoD organizations that make significant contributions to collaborative activities.

At the local level, the DoD-DIB nonprofit is expected to be an engaged and active partner within the local ecosystem—contributing to the slate of STEM interventions implemented; sharing of best practices and available resources, etc. It also should develop a comprehensive understanding of the overall objectives and challenges confronting the ecosystem to help inform DoD-DIB priorities. **But primarily, the local nonprofit is charged with being the voice for DoD-DIB strategic priorities and implementation of initiatives intended to inspire, engage, and attract youth to defense missions**.

Duties would include: prioritization and coordination of DoD-DIB collaborative engagements and activities; coordination of volunteer efforts specific to DoD-DIB collaborative activities; identification of potentially high-value interventions that would benefit from a pilot effort (and application for system-directed grant funding if appropriate); submission of an annual assessment/evaluation of DoD-DIB collaborative activities aligned with the system-provided framework together with relevant locally-captured assessments; and administration of a local awards/recognition program aligned with the program established at the system level.

Note that this **structure assumes ecosystem-level assessment/evaluation processes as well as a specific system-wide DoD-DIB evaluation that addresses alignment with joint DoD-DIB strategic priorities**. Such priorities might include: increase public/community awareness of defense missions, related workforce development initiatives, and career opportunities; implement out-of-school STEM interventions (K-12) designed to engage and inspire students to pursue defense-related career opportunities; enable DoD/DIB STEM professionals to serve as role models and mentors to help attract students to defense missions; attract students to defense missions through internships and related work-based opportunities; develop/support high-priority DoD-DIB STW workforce development initiatives; and reach military-connected families and other underserved/underrepresented populations with DoD-DIB STEM interventions.

### 3.1.4 DoD-DIB Collaboration in STEM/STW Ecosystems: Summary and Recommendation

Section 3.1 offers a vision for a system of DoD-DIB collaborative partnerships that operate within existing STEM ecosystems. While operating as an engaged and contributing partner within an ecosystem, the primary emphasis for DoD-DIB participation would be to inspire, engage, and attract STEM talent to defense missions through targeted interventions.

The system would be instantiated as a network of small nonprofit organizations, each established to motivate and enable DoD-DIB collaboration within a specific local ecosystem, together with system-level oversight provided by a small nonprofit (also a DoD-DIB collaborative partnership) that provides strategic guidance and evaluates the impact of the network over time.

Section 3.2 provides an evaluation/assessment framework applicable to collaboration

with other ecosystem partners as well as informing the DoD-DIB collaborative partnership. If an existing STEM ecosystem of interest to DoD-DIB has no in-place evaluation/assessment framework, it could be used by the local DoD-DIB nonprofit to open a dialog with other partners who are interested in developing such a tool. It also might be of interest in instances wherein evaluation/assessment processes are in place but partners are interested in exploring alternative approaches. It would be beneficial to the system-level DoD-DIB collaborative partnership as it enables local DoD-DIB nonprofits to evaluate their portfolio of STEM interventions via a common framework to support synthesis of results at the system level. It also would inform a local DoD-DIB nonprofit as it prioritizes STEM interventions and/or justifies the need for new interventions.

A useful first step toward establishing a broader DoD-DIB collaborative partnership would be to jointly select an existing STEM ecosystem in which both DoD and DIB organizations are well-represented and establish a pilot collaborative partnership. The pilot should operate (excludes up-front planning) for at least 3 years in order to provide meaningful results (5 years would be preferable).

The evaluation/assessment framework noted above (and described in more detail in Section 3.2) could be used to guide the activities within the pilot while also serving as a means to evaluate its impact over time.

***DoD-DIB Collaborative Partnership***

*DoD/DIB should jointly establish a 3-year (at least) pilot collaborative partnership within in an existing STEM ecosystem in which both are heavily invested as a way to determine the benefits of joint planning and implementation of STEM activities.*

## 3.2 A FRAMEWORK FOR EVALUATING THE COLLECTIVE IMPACT OF DOD-DIB COLLABORATION IN STEM/STW ECOSYSTEMS.

In spring 2022 the study team held numerous conversations with individuals and organizations that regularly assess and evaluate STEM/STW activities, and conducted an in-depth review of literature related to the evaluation of out-of-school STEM activities, with the goal of refining and expanding the preliminary evaluation framework described in the interim report from this study. This section presents a revised framework for evaluating the collective impact of DoD-DIB collaboration in STEM/STW ecosystems. Throughout this discussion, **it is assumed that a local DoD-DIB nonprofit organization is participating as a partner in the STEM/STW ecosystem while also engaging with a system of counterpart DoD-DIB collaborative partnerships.**

This revised model incorporates previously identified measures related to the health, efficiency, and effectiveness into an overall evaluation framework based on research related to Collective Impact, a process often used to help public- and private-sector organizations commit to a common agenda for solving complex social problems.[105] The revised framework—described in the following pages—is strongly aligned with Goal 4.0 of DoD's STEM Strategic Plan,[106] as it advances the efficiency and effectiveness of STEM education and workforce development programs, activities, and outreach through evaluation and assessment.

### 3.2.1 CONSIDERATIONS FOR EVALUATING STEM/STW ECOSYSTEMS

As the National Research Council writes, "*Evaluation is key to improving the overall quality of out-of-school STEM programs and to understanding how they contribute to the learning ecosystem*."[107] Yet measuring success in STEM/STW ecosystems is challenging in several ways. Two of these challenges—changing partner objectives and measuring an accumulation of experiences—are particularly important considerations in the development of a framework for evaluating STEM/STW ecosystems.

First, STEM/STW ecosystems necessarily include a range of community, industry, non-profit, and education partners, each of whom has their own reasons for participating in STEM education activities and each who may change its objectives, organizational structures, established policies, or dollars committed for any number of reasons.

Successful STEM/STW ecosystems must account for this type of change over time, and evaluations of STEM/STW activities must be similarly flexible, as well as tailored to

[105] Tamarack Institute. (2017). *Five Conditions of Collective Impact.* Waterloo, Ontario, CAN: Author. https://www.tamarackcommunity.ca/hubfs/Collective%20Impact/Tools/Five%20Conditions%20Tools%20April%202017.pdf. Accessed 17 June 2022.
[106] *The Department of Defense STEM Strategic Plan FY2021 – FY2025*, p. 5. https://dodstem-assets.dodstem.us/files/DoD_STEM_Strategic_Plan_2021.pdf Accessed 15 June 2022.
[107] National Research Council. (2015). *Identifying and supporting productive STEM programs in out-of-school settings.* Washington, DC: The National Academies Press, p. 33.

ecosystem partners and geographic contexts. However, this makes the development of common and/or longitudinal measures for assessing impact or outcomes—both within and across ecosystems—extremely challenging.

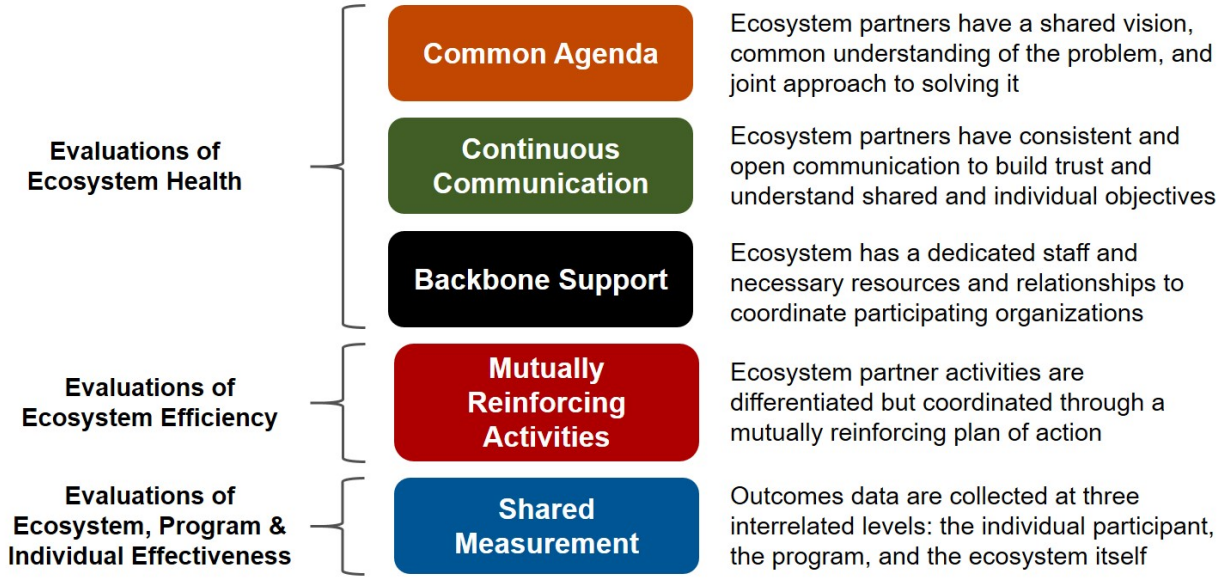
Similarly, STEM/STW ecosystems typically follow a 'dosage' model or assumption that an accumulation of learning opportunities over time will lead to the development of STEM expertise and further interest. Indeed, as the National Research Council states, "*A single experience may not have an immediately recognizable or detectable effect on knowledge or interest, but it may have a relatively profound effect if it serves to orient, inspire, or motivate a young person to be open to new STEM learning opportunities*."[108] Thus, any evaluations of ecosystem effectiveness must utilize a broad range of assessment approaches that capture participation and interest development over time and in numerous settings, as well as measures that help evaluators understand how learners make connections between experiences and how those connections may contribute to sustained learning and engagement. In other words, STEM/STW ecosystem assessments must consider both the short- and long-term outcomes of individual programs, as well as how each program "*diversifies, deepens, or enhances possibilities for STEM learning in a given community*."[109]

### 3.2.2 EVALUATING THE COLLECTIVE IMPACT OF STEM/STW ECOSYSTEMS

The following is a framework for evaluating STEM/STW ecosystems which incorporates measures related to the health, efficiency, and effectiveness into an overall framework based on research related to Collective Impact. In 2011, an article published in the Stanford Social Innovation Review identified **five conditions that allow public- and private-sector organizations to collaborate around a clearly defined goal: a common agenda, continuous communication, backbone support, mutually reinforcing activities, and shared measurement**.[110] Figure 3.2 illustrates how evaluations of the health, efficiency, and effectiveness of STEM/STW ecosystems can be considered in the context of these five conditions of Collective Impact.

[108] National Research Council, p. 33.
[109] National Research Council, p. 35.
[110] Kania, J., & Kramer, M. (2011). *Collective impact.* Stanford Social Innovation Review (1), 36-41.

**Figure 3.2 STEM/STW Ecosystem Evaluation in Context of the Five Conditions of Collective Impact[111]**




### 3.2.2.1 Evaluations of Ecosystem Health: A Common Agenda

Three of the five conditions of Collective Impact—understood in the context of STEM/STW ecosystems—relate to the health of local/regional STEM/STW ecosystems. The first of these is Common Agenda. Research shows that when several organizations work together on a common social issue, they often have slightly different definitions of the problem and the ultimate goal. As the Tamarack Institute writes, "*These differences are easily ignored when organizations work independently on isolated initiatives, yet [they] splinter the efforts and undermine the impact of the field as a whole*."[112] By discussing and resolving their differences, ecosystem partners can come to a shared vision, a common understanding of the problem, and a joint approach to solving it.

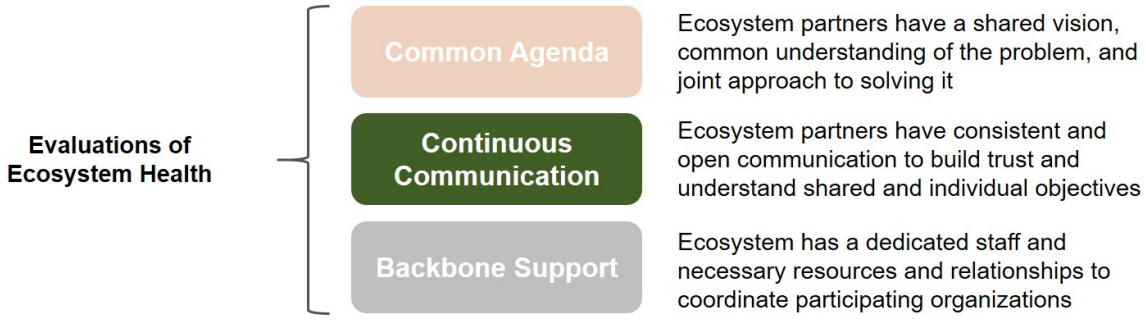
[111] Figure adapted from Tamarack Institute. (2017). *Five Conditions of Collective Impact.* Waterloo, Ontario, CAN: Author.
[112] Tamarack Institute, p. 1

Evaluations related to the extent to which STEM/STW ecosystem partners agree on a common agenda might include the measures shown in Table 3.1 (several of which have been adapted from the NSF INCLUDES Shared Measures project[113])

**Table 3.1 Evaluation Relating to Common Agenda**

| Common Agenda | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Are STEM/STW ecosystem goals clearly articulated and informed by an assessment of the participant population's needs? Are each project's goals similarly informed?<br>Do the STEM/STW ecosystem goals address systemic barriers to broadening participation in STEM or the STW? Does each project have a plan to address one or more of these barriers?<br>Are STEM/STW ecosystem partners involved in developing goals? | *Are DoD-DIB priorities congruent with those of other ecosystem partners?* |

### 3.2.2.2 Evaluations of Ecosystem Health: Continuous Communication




The second of the five conditions of Collective Impact related to the health of local/regional STEM/STW ecosystems is Continuous Communication. As the Tamarack Institute writes, "*developing trust among nonprofits, corporations, and government agencies is a monumental challenge*."[114] Ecosystem partners may require months or years of consistent and open communication in order to understand shared and individual objectives, see that their own interests will be treated fairly, and believe that decisions will be made on the basis of objective evidence rather than the priorities of certain organizations or individuals.

Evaluations related to the extent to which STEM/STW ecosystem partners engage in clear and continuous communication might include the measures shown in Table 3.2

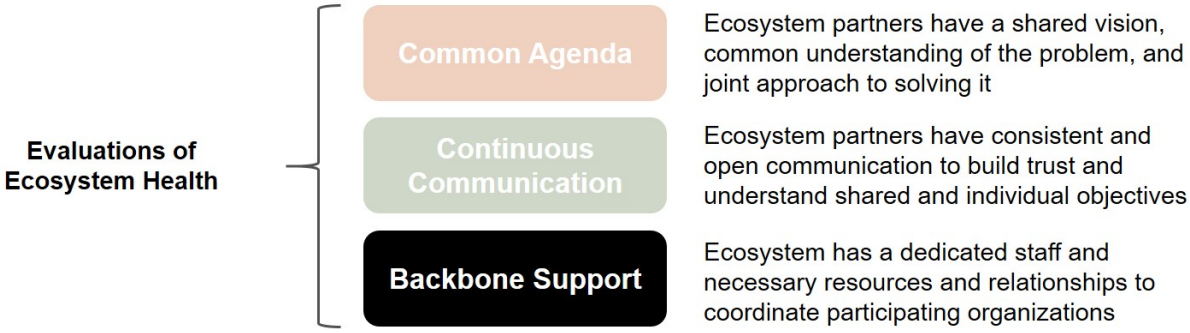
[113] https://networksharedmeasures.org/index.html. Accessed 20 June 2022.
[114] Tamarack Institute, p. 2.

(many of which have been adapted from the NSF INCLUDES Shared Measures project).

**Table 3.2 Evaluation Relating to Continuous Communication**

| Continuous Communication | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Are key stakeholder groups represented in the STEM/STW ecosystem, and are the benefits of participation clear?<br><br>Do STEM/STW ecosystem partners display mutual understanding, trust, and respect for one another?<br><br>Are procedures and expectations for participating in the STEM/STW ecosystem clear to ecosystem partners?<br><br>Are methods of communication among STEM/STW ecosystem partners frequent and productive?<br><br>Are there channels for information and data sharing among STEM/STW ecosystem partners?<br><br>Are partners willing to engage in frank and open discussions when areas of disagreement exist? | *Does the DoD-DIB nonprofit work to minimize potential power imbalances among partners? Build effective relationships with partners? Provide transparency with regard to decisions impacting other partners?*<br><br>*Several measures could also apply to communications between the system and local level DoD-DIB partnerships. More specific measures might include:*<br><br>*Are top-level strategic priorities effectively communicated to the local DOD-DIB collaborative partnerships?*<br><br>*Is the network fully informed about available funds, grants, non-monetary awards, etc., and are there mechanisms in place to ensure the smooth transfer of funding and awards?*<br><br>*Does the assessment framework that specifies annual reporting requirements for local nonprofits allow for some local control over specific metrics and evaluation techniques?*<br><br>*Does the DoD-DIB system provide a platform for communication, collaboration, and data sharing across the network in addition to connecting with other local ecosystems?* |

### 3.2.2.3 Evaluations of Ecosystem Health: Backbone Support




The third of the five conditions of Collective Impact related to the health of local/regional STEM/STW ecosystems is Backbone Support. As the Tamarack Institute writes:

> *"Creating and managing Collective Impact requires a separate organization and staff with a very specific set of skills to serve as the backbone for the entire initiative. Coordination takes time, and none of the participating organizations has any to spare. The expectation that collaboration can occur without a supporting infrastructure is one of the most frequent reasons why it fails".*[115]

**Within local/regional STEM/STW ecosystems, partners must agree to and support establishment of, an Ecosystem Support (ES) organization if one does not already exist.** Evaluations related the extent to which ES provides effective backbone support might include the measures shown in Table 3.3 (some of which have been adapted from the NSF INCLUDES Shared Measures project).

**Table 3.3 Evaluation related to Backbone Support**

| Backbone (Ecosystem) Support | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Does the Ecosystem Support (ES) organization have legitimacy in the community (e.g., is it viewed as a leader in STEM/STW education, and does it represent the cultural diversity of the surrounding area)?<br><br>Do ES staff have the human resources necessary to carry out organizational goals?<br><br>Do ES staff display organizational and relationship-building skills? Do they have relationships with key stakeholder groups?<br><br>Does the ES leverage the collective knowledge of ecosystem partners and other stakeholders? | *Several of these measures could also apply to the extent to which the system-level DoD-DIB partnership provides effective backbone support to its network of local DoD-DIB nonprofits.* |

[115] Tamarack Institute, p. 2.

| | |
|---|---|
| Does the ES have structures in place to encourage full participation by all ecosystem partners?<br>Does the ES have the necessary resources to operate the STEM/STW ecosystem?<br>Are STEM/STW ecosystem partners' resources effectively identified, coordinated, and shared? | |

### 3.2.2.4 Evaluations of Ecosystem Efficiency: Mutually Reinforcing Activities

As noted in Section 3.2.1, STEM/STW ecosystems are premised on a 'dosage' model: the assumption that an accumulation of learning opportunities over time will lead to the development of STEM expertise and further interest. There is some evidence that repeated exposure to STEM/STW education and activities may be especially important for students from races and ethnicities underrepresented in the STEM/STW workforce.[116] Thus, in the context of Collective Impact, the efficiency of regional STEM/STW ecosystems can be considered in terms of how well each program, initiative or activity mutually reinforces others within the ecosystem. The idea of Mutually Reinforcing Activities is does not mean that all ecosystem partners must act in the same ways, but "*encourages each participant to undertake the specific set of activities at which it excels in a way that supports and is coordinated with the actions of others*."[117]

Evaluations regarding the extent to which STEM/STW ecosystems engage in mutually-reinforcing activities might include the measures shown in Table 3.4 (some of which have been adapted from the NSF INCLUDES Shared Measures project).

[116] Bright, M. (2017). *The importance of early, consistent exposure to STEM fields*. Diverse Issues in Higher Education. www.diverseeducation.com/demographics/african-american/article/15100458/the-importance-of-early-consistent-exposure-to-stem-fields. Accessed 20 June 2022.
[117] Tamarack Institute, p. 2.

**Table 3.4 Evaluation of Mutually Reinforcing Activities**

| Mutually Reinforcing Activities | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Within the STEM/STW ecosystem, is there a continuum of STEM exposure from early childhood through professional careers?<br>Within the STEM/STW ecosystem, do existing partners represent the range of institutions necessary to achieve ecosystem goals?<br>Within the STEM/STW ecosystem, do existing partners reflect the diversity of participant and/or target populations?<br>Within the STEM/STW ecosystem, do a variety of STEM opportunities or interventions exist, and do they collectively inform and engage learners in a diversity of career pathways (i.e., the STW through the advanced STEM workforce)?<br>Within the STEM/STW ecosystem, is each partner's role clearly specified?<br>Do STEM/STW ecosystem partners collaborate with one another to align their actions?<br>Is there an easily accessible online platform for data and information sharing among STEM/STW ecosystem partners?<br>Do STEM/STW ecosystem partners leverage and share resources related to STEM activities, intervention models, lesson plans, etc.?<br>Do STEM/STW ecosystem partners regularly seek advice from one another (e.g., about effective strategies for addressing a given challenge)?<br>Do STEM/STW ecosystem partners share challenges, setbacks, and lessons-learned with other organizations in the ecosystem? | *Several of these measures could also apply to the extent to which the system-level DoD-DIB partnership encourages and enables mutually-reinforcing activities among its network of local DoD-DIB nonprofits.* |

### 3.2.2.5 Evaluations of Ecosystem Effectiveness: Shared Measurement

In an ideal world, mechanisms would exist to empirically assess the impact of STEM/STW ecosystems—including their diverse array of STEM/STW programs and education activities—on the development of the STEM/STW talent pool. However, with

**Evaluations of Ecosystem, Program & Individual Effectiveness** → **Shared Measurement**: Outcomes data are collected at three interrelated levels: the individual participant, the program, and the ecosystem itself

few exceptions (e.g., AEOP, 4-H Science, and FIRST), few organizations or ecosystems can longitudinally track students participating in STEM activities through their education/training and/or into the workforce. Furthermore, because the value of a STEM/STW ecosystem is largely dependent upon an accumulation of STEM learning experiences over time, determining the relative impact of any one STEM/STW program or activity is challenging at best. Nonetheless, assessing the effectiveness of these activities and collaborations is critical to determining best practices, setting priorities, and justifying future investment in STEM education activities.

The final condition of Collective Impact—Shared Measurement—provides a framework for assessing effectiveness, as it involves collecting data and measuring results consistently at the ecosystem level and across all ecosystem partners. According to the National Research Council, shared measures should be considered at three inter-related levels: the STEM/STW ecosystem, the STEM program or education activity, and the outcomes of individual participants.[118] This three-level approach allows for a comprehensive examination of the effectiveness and reach of each STEM/STW ecosystem and its respective programs and activities, yet provides the autonomy necessary for ecosystem partners to develop individual and programmatic assessments that reflect their unique contexts and priorities.

Indeed, the Shared Measurement condition does not mean that every STEM program or education activity assesses its effects on participants in exactly the same ways; the formative (process) and summative (outcome) measures utilized by rural 4-H programs may be substantially different than those prioritized in FIRST robotics competitions or incorporated into collaborative P-TECH programs. Yet when STEM/STW ecosystems encourage the collection of data in certain areas or on a short list of common indicators, they ensure that ecosystem partners' efforts are aligned, that they can hold one another accountable, and that they can learn from their collective successes and failures.

**At the level of STEM/STW ecosystems**, effectiveness is considered in terms of the cumulative impact of all STEM/STW programs or education activities in which ecosystem partners are engaged. As such, evaluations may include the measures shown in Table 3.5 (some of which have been adapted from the NSF INCLUDES Shared Measures project).

[118] National Research Council, p. 35.

**Table 3.5 Evaluation of Shared Measurement—Ecosystem-Level**

| Shared Measurement at Ecosystem-Level | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Does the STEM/STW ecosystem have participatory processes to identify local needs and gaps in the delivery of STEM education activities (in terms of the number of participants and the variety of education or training opportunities provided) and does it collaborate with ecosystem partners to introduce new or expand the scope of existing interventions?<br><br>Does the STEM/STW ecosystem reach its target populations (including females, underrepresented minorities, veterans, military dependents, etc.), and does it provide needed wraparound services to ensure effective engagement?<br><br>Where possible, does the STEM/STW ecosystem track data on participants longitudinally and/or across programs or STEM education activities?<br><br>Does the STEM/STW ecosystem have participatory processes to refine the measures, indicators, metrics, and/or data collection methods utilized by ecosystem partners?<br><br>Does the STEM/STW ecosystem have the capacity to track progress across all partners (e.g., protocols, data sharing agreements, common metrics)?<br><br>Does the STEM/STW ecosystem use data to make regular improvements?<br><br>Are all major STEM/STW ecosystem partners involved in the process of making sense of findings that emerge from analyses of shared data?<br><br>Does the ES work closely with local school districts to ensure that out-of-school STEM/STW ecosystem programs and activities are aligned with state education standards and required curricula? | *Several of these Shared Measures also could be implemented at the DoD-DIB system-level to assess the effectiveness of the system of local/regional STEM/STW ecosystems, as well as its ability to broaden and diversify a technical workforce able to receive the security clearances needed to support defense missions.* |

Evaluations related to the **effectiveness of various STEM programs or education activities led by ecosystem partners** may include the measures shown in Table 3.6 (some of which have been adapted from the NSF INCLUDES Shared Measures project).

**Table 3.6 Evaluation of Shared Measurement—Program/Activity-Level**

| Shared Measurement at Program/Activity-Level | |
|---|---|
| **Evaluation** | **DoD-DIB Considerations** |
| Does the STEM program or education activity routinely collect demographic data on participants to ensure that it reaches its target populations (including females, underrepresented minorities, veterans, military dependents, etc.)?<br><br>Does the STEM program or education activity routinely collect data related to the outcomes or impact of the program or activity on participants' intellectual development in STEM, positive STEM identity, and/or expansion of their awareness, connections, or choices in the context of academic or career engagement with STEM?<br><br>Does the STEM program or education activity routinely collect data related to participants' interests and/or experiences in the program?<br><br>Does the STEM program or education activity have participatory processes to refine its measures, indicators, metrics, and/or data collection methods?<br><br>Does the STEM program or education activity use data to make regular programmatic improvements?<br><br>Is the STEM program or education activity involved in the process of making sense of its and other ecosystem partners' shared data?<br><br>Is the STEM program or education activity involved in the process of identifying local needs and gaps in the delivery of STEM education activities across the STEM/STW ecosystem, and does it collaborate with ecosystem partners to introduce new or expand the scope of existing interventions?<br><br>Does the STEM program or education activity provide opportunities for educators/ facilitators/volunteers to enhance their STEM education skillset?<br><br>Does the STEM program or education activity routinely collect data related to educators'/ facilitators'/volunteers' experiences in the program? | *Common evaluation at program/activity level.* |

| | |
|---|---|
| Do employers or other partners in the STEM program or education activity have mechanisms to reward volunteer time and effort? | |

Assessments related to the **outcomes or impact of STEM programs or education activities on individual learners** are highly context-specific and thus should be developed by ecosystem partners in collaboration with their ES organization. Where possible, longitudinal assessments that follow learners over time or assess growth before and after participation in STEM programs/activities are preferrable to cross-sectional or one-time surveys. Possible topics for assessment are shown in Table 3.7.

**Table 3.7 Assessment of Shared Measurement—Impact on Individual Learners**

| Continuous Communication | |
|---|---|
| **Assessment** | **DoD-DIB Considerations** |
| Levels of learners' interest and/or experiences in the STEM program or education activity.<br>Growth in learners' intellectual development related to STEM.<br>Development of learners' positive STEM identity.<br>Expansion of learners' horizons (e.g., awareness, connections, and/or choices) in the context of academic or career opportunities in STEM/STW. | *DoD-DIB may wish to include assessment of learner's interest in defense missions before and after interventions.* |

### 3.2.3 Evaluation/Assessment Framework: Summary and Recommendation

Section 3.1.3 reframes the vision for future DoD-DIB collaboration in STEM activities as:

> *…a DoD-DIB collaboratively-operated system of local DoD-DIB nonprofit organizations, each of which is a fully-participating partner within an existing STEM ecosystem.* ***The DoD-DIB partnership would emphasize outreach to priority populations; engaging, inspiring and attracting students to defense missions; introduction of high-priority STW pathways as needed; and other jointly-established strategic priorities.***

The framework described in this section—which incorporates measures related to the health, efficiency, and effectiveness of STEM/STW ecosystems into a framework based on research related to Collective Impact—provides a roadmap for evaluating these collaborations, as well as the cumulative impact of individual STEM programs and education activities, at regional and national levels. Included are considerations relating to evaluation and assessment activities specific to DoD-DIB collaborative partnerships.

Given that DoD STEM is underway in establishing regional hubs in cooperation with existing STEM ecosystems, an **opportunity exists to work with partners *on-the-ground* to pilot the framework described in this section**, adapting/refining it as needed over time to ensure that it provides information useful to local decision-making while also informing future investment decisions.

***Evaluation/Assessment Framework***

*DoD STEM should pilot the Collective Impact-aligned evaluation/ assessment framework within one (or more) of its existing hubs.*

## 3.3 LEVERAGING NONPROFIT CORPORATIONS

Both DoD and DIB organizations already partner with a wide array of nonprofit corporations that support activities including both extracurricular and classroom-based interventions, workforce development programs, and administration of scholarships/ fellowships.

The Defense Science, Technology, Engineering, and Mathematics Education Consortium (DSEC) portfolio of partnerships[119] includes educational institutions, organizations that implement STEM competitions and other interventions, existing STEM ecosystems, and organizations that emphasize networking and outreach to specific populations. The Services also partner with nonprofits, particularly in the areas of competitions and domain-specific STEM interventions.

DIB organizations partner with a broader array of nonprofits in the same categories as those in the DSEC portfolio, but also include organizations that provide more individualized support such as internships, apprenticeships, scholarships, and fellowships. Additionally, DIB organizations often emphasize engagement with Youth Clubs and Professional Societies, many of which have implemented STEM-specific strategies. A more robust discussion of DIB engagement with nonprofit organizations is contained in the interim report.[120]

This section addresses the top-level benefits as well as some potential risks of engaging nonprofits as part of an institutional STEM strategy and suggests decision criteria that could aid in selection of prospective partners. It also highlights illustrative examples derived from ongoing DoD and DIB nonprofit partner portfolios.

### 3.3.1 BENEFITS OF ENGAGING NONPROFIT ORGANIZATIONS

Many nonprofit organizations have years or even decades of experience and demonstrated success in working with local communities, schools, teachers, parents, and students to advance STEM education. Their impact is often demonstrated through measurable results that include meaningful outcomes. Partnering with such organizations provides tangible benefits including reducing the resources needed to develop, implement, and sustain equivalent STEM interventions.

Many nonprofit organizations operate at scale with a nationwide (or beyond) geographic footprint. This model supports development and sharing of best practices across their networks, enabling them to operate more efficiently and effectively. It also suggests that the organizations are supported by a broad donor/sponsor base, providing high leverage for incremental investments. Additionally, such organizations could be engaged at the system-level to support multiple DoD-DIB collaborative partnerships.

[119] https://dodstem.us/about/partners/ Accessed 14 June 2022
[120] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). Section 3.3.7. https://sercuarc.org/serc-programs-projects/project/119

Conversely, some nonprofit organizations are established to operate locally, targeting specific challenges. These organizations, too, may deliver partner benefits given their knowledge and connection to local conditions.

A growing number of nonprofit organizations are chartered to support specific underserved/underrepresented populations. Some emphasize specific interventions while others provide a broader array of services to create pathways to successful STEM careers. Partnering with such organizations may provide access to relatively untapped talent pools.

One caveat is that while many existing nonprofits deliver programs of high value in terms of expanding and diversifying the STEM competency pool, their interventions are not typically designed *to inspire and engage students to pursue careers in defense missions.* **While nonprofit programs are valuable contributors to STEM ecosystems, they do not preempt the need for direct DoD-DIB engagement**.

A broader observation is that nonprofit organizations in general operate for specific (chartered) purposes, and answer to their own governance structure which typically includes a Board of Directors that sets and/or confirms organizational goals and priorities. **Those priorities may—or may not—be aligned with those of a DoD-DIB collaborative partnership**.

### 3.3.2 SUGGESTED DECISION CRITERIA

Given the vast landscape of STEM-focused nonprofits as well as the fact that both the DoD and the DIB are already partnering with many such organizations, this report emphasizes development of decision criteria that could be used when assessing the potential value of forging a new partnership—or re-assessing the continuation of an existing partnership. Decision criteria are focused in two areas: alignment with strategic goals, and organizational financial outlook and sustainability.

While most criteria require qualitative assessment, some provide quantifiable results. Many of the decision criteria are relevant both at the system-level and for individual ecosystems, while others are ecosystem-specific.

#### 3.3.2.1 Alignment with Strategic Goals

Absent a joint DoD-DIB STEM Strategic Plan, goals taken from the Department of Defense STEM Strategic Plan[121] are used in this discussion. (A joint plan is needed to support DoD-DIB collaborative partnerships.) Perfect alignment is unlikely, but the goals of the nonprofit should not be incompatible with those of the DoD/DIB. Suggested decision criteria are shown in Table 3.8.

[121] *The Department of Defense STEM Strategic Plan FY2021 – FY2025.* https://dodstem-assets.dodstem.us/files/DoD_STEM_Strategic_Plan_2021.pdf. Accessed 15 June 2021.

**Table 3.8 Decision Criteria for Alignment with Strategic Goals**

| Alignment with Strategic Goals |
|---|
| DoD STEM Strategic Plan Goal 1.0: Inspire community engagement in DoD STEM education programs and activities to provide meaningful STEM learning opportunities for students and educators. |
| • *Does the nonprofit have a demonstrated track record of working productively with local communities, including schools, educators, and students?*<br>• *Are the nonprofit's programs designed to be complementary and synergistic with other ongoing activities (both in-school and out-of-school)?*<br>• *Are there opportunities for DoD/DIB personnel/volunteers to directly engage with the communities in support of the nonprofit's programs?*<br>• *Are the nonprofit's operating procedures sufficiently sensitive to youth protection in design and implementation of interventions?* |
| DoD STEM Strategic Plan Goal 2.0: Attract the Nation's and DoD's current and future STEM workforce through multiple pathways to educational and career opportunities. |
| • *Does the nonprofit provide—or bolster—a STEM/STW pathway that is critical to defense missions?* |
| DoD STEM Strategic Plan Goal 3.0: Increase participation of underserved and underrepresented groups in STEM education and workforce development programs, activities, and outreach. |
| • *Does the nonprofit design and implement culturally relevant programs that target specific populations?*<br>• *Does the nonprofit measure its ability to reach and impact specific groups? Does it provide wraparound services if needed?* |
| DoD STEM Strategic Plan Goal 4.0: Advance the efficiency and effectiveness of STEM education and workforce development programs, activities, and outreach through evaluation and assessment. |
| • *Does the nonprofit have an evaluation/assessment program in place that includes measurable outcomes?*<br>• *Does the nonprofit make its assessment results available to the public?* |

### 3.3.2.2 Financial Outlook and Sustainability

Many STEM-focused nonprofits rely heavily on contributions from individual donors and corporate sponsors to support their work. Successful nonprofits typically have a diverse, strong, and deeply committed base of support. Savvy donors often rely on independent organizations such as Charity Navigator[122], which provides free access to data to inform

[122] Charity Navigator. https://www.charitynavigator.org/ Accessed 15 June 2022

their decision-making. Metrics in Financial Performance as well as Accountability & Transparency are generally available, as are historical ratings for the organization. (GuideStar[123] is another source of relevant information for vetting prospective partners.)

STEM-focused nonprofits often rely heavily on the efforts of volunteers for local program implementation. As a result, program sustainability and outcomes can be highly variable.

Decision criteria for Financial Outlook and Sustainability are shown in Table 3.9.

**Table 3.9 Decision criteria for Financial Outlook and Sustainability**

| Financial Outlook and Sustainability |
|---|
| Financial Outlook *(based on Charity Navigator indicators)* |
| • *Does the nonprofit have a high "Give with Confidence" rating?*<br>• *Are its Financial and Accountability & Transparency ratings favorable?*<br>  ○ *Is the Program Expense Ratio reasonable in comparison to similar organizations?* |
| Sustainability |
| • *Does the nonprofit have mechanisms in place to develop, grow, and support committed communities of volunteers?* |

#### 3.3.2.3 Decision Criteria Summary

The decision criteria above were developed to inform choices regarding direct partnering with nonprofit organizations for the purpose of augmenting STEM interventions within individual ecosystems and/or at the system level. These criteria are not intended to apply in every circumstance as there are other reasons for engaging nonprofits within STEM ecosystems. For example, a nonprofit organization may provide hard-to-find expertise in an area which is critical to ecosystem operations. Or a nonprofit organization may be useful in providing an independent review or assessment of elements within an ecosystem. In such cases, due diligence aligned with the specific requirements is necessary.

### 3.3.3 Illustrative Examples of Beneficial Partnerships with Nonprofits

The sections above described some potential benefits of partnering with STEM-related nonprofits. This section highlights three examples of existing DoD/DIB STEM partners to show how the suggested criteria could be used to inform decision-making. The examples were selected to illustrate applicability to organizations with distinctly different

[123] GuideStar. https://guidestar.org/ Accessed 15 June 2022

operating models.

### 3.3.3.1 STEM Competitions

STEM competitions are a popular intervention for students of all ages across the U.S. as well as abroad. Nonprofit organizations implement a variety of competitions that primarily engage students in the PreK-12 populations, although some extend to post-secondary students. Both DoD and DIB organizations support a variety of STEM competitions, many of which are implemented via nonprofit organizations.

Research indicates that students' participation in STEM competitions increases their interest in STEM careers. A 2018 research paper found that:

- "*First, students who participate in STEM competitions are more likely to express interest in a STEM-related career at the end of high school than are students who do not participate; even when students' prior career interest in STEM is controlled for.*

- *Second, the relationship between competition participation and interest in a STEM career appears to be domain specific.*

- *Third, the impact of competition participation on the pursuit of a STEM career is three times stronger when students compete in more than one competition*."[124]

This research suggests not only that STEM competitions are beneficial within ecosystems, but that a diversity of STEM competitions (i.e., differing domains of emphasis) that extends throughout the student lifecycle is of even greater value in terms of inspiring students to pursue STEM careers.

For Inspiration and Recognition of Science and Technology (FIRST)[125] is a DSEC partner and also was the most often cited DIB partner in the STEM Competitions category.[126] It therefore provides a high value and relevant model to illustrate the utility of the decision criteria described in the previous section. As indicated in Table 3.10, FIRST performs quite well against the criteria.

**FIRST Mission**

To inspire young people to be science and technology leaders and innovators, by engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership.

[124] K. Miller, G. Sonnert, & P. Sadler (2018) The influence of students' participation ion STEM competitions on their interest in STEM careers, International Journal of Science Education, Part B, 8:2, 95-114, DOI: 10.1080/21548455.2017.1397298.
[125] https://firstinspires.org/ Accessed 15 June 2022
[126] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). Section 3.3.7.1. https://sercuarc.org/serc-programs-projects/project/119

**Table 3.10 FIRST: DoD STEM Strategic Goals Alignment; Financial Outlook & Sustainability**

| Alignment with DoD Strategic Goals | FIRST |
|---|---|
| Does the nonprofit have a demonstrated track record of working productively with local communities, including schools, educators, and students? | ✓ *FIRST was incorporated in 1989 and hosted its inaugural event in 1992. Programs have evolved and expanded over time. During the 2019-2020 season, FIRST engaged more than 679 thousand students in approximately 110 countries, more than 320 thousand mentor, coach, and volunteer roles, and exhibited 18% year-over-year growth. FIRST directly engages educators as well as students.* |
| Are the nonprofit's programs designed to be complementary and synergistic with other ongoing activities (both in-school and out-of-school)? | ✓ *FIRST Class Pack provides implementation options for classrooms and structured after-school programs. FIRST also offers Certified Professional Development opportunities (continuing education or professional development) for educators.* |
| Are there opportunities for DoD/DIB personnel/volunteers to directly engage with the communities in support of the nonprofit's programs? | ✓ *DoD and DIB personnel are already serving as coaches, mentors, and volunteers for FIRST teams.* |
| Are the nonprofit's operating procedures sufficiently sensitive to youth protection in design and implementation of interventions? | ✓ *FIRST has both a Privacy Program and a Youth Protection Program*[127] |
| Does the nonprofit provide—or bolster—a STEM pathway that is critical to defense missions? | ✓ *FIRST Programs build engineering and coding skills of high value to defense missions.* |
| Does the nonprofit design and implement culturally relevant programs that target specific populations? | ✓ *"FIRST Equity, Diversity, & Inclusion is a concerted, organized effort to develop strategies to make its programs more accessible and inclusive."*[128] *Specific initiatives are described on their website.* |
| Does the nonprofit measure its ability to reach and impact specific groups? | ✓ *FIRST demonstrates lasting impact on girls and young women.* |
| Does the nonprofit have an assessment/ evaluation program in place that includes measurable outcomes? | ✓ *FIRST works with research and academic organizations to provide evidence of impact on students' education and career choices.* |
| Does the nonprofit make its assessment results available to the public? | ✓ *FIRST Impact includes research, longitudinal studies, peer-reviewed publications, and evaluations.*[129] |

[127] Youth Protection Program. https://www.firstinspires.org/resource-library/youth-protection-policy Accessed 15 June 2022.
[128] Equity, Diversity, and Inclusion Statement. https://www.firstinspires.org/resource-library/training-equity-diversity-inclusion Accessed 15 June 2022.
[129] FIRST Impact. https://www.firstinspires.org/about/impact Accessed 15 June 2022

| Financial Outlook and Sustainability | FIRST |
|---|---|
| Does the nonprofit have a high "Give with Confidence" rating? | ✓ *4 Star (Exceptional), 95.87 out of 100* |
| Are its Financial and Accountability & Transparency ratings favorable? | ✓ *Financial = 95/100*<br>✓ *Accountability & Transparency = 97/100* |
| Is the Program Expense Ratio reasonable in comparison to similar organizations? | ✓ *Score 10/10* |
| Does the nonprofit have mechanisms in place to develop, grow, and support committed communities of volunteers? | ✓ *FIRST provides volunteer training as well as periodic newsletters to sustain engagement. It also provides a "General Volunteer Resources" repository containing policies and procedures, role descriptions, required forms, and other volunteer resources.*[130] |

### 3.3.3.2 Educator Development

DoD and DIB organizations are both directly and indirectly supporting activities focused on STEM educator development and support. Direct activities range from in-class activities such as curriculum development and classroom participation to dedicated educator development sessions (often summer activities). Indirect activities include partnerships with various nonprofit organizations that also target educator development.

National Math + Science Initiative (NMSI)[131] is a DSEC partner that also is supported by a number of DIB organizations. NMSI provides teacher training, including both professional development and curriculum support, as well as student support with a focus on Advanced Placement students. In addition, the organization supports school administration in development of sustainable plans together with the policies and practices needed for implementation. NMSI's operating model is quite different from that of FIRST, but the organization also performs well against the suggested decision criteria as shown in Table 3.11.

**NMSI Mission**

We strive to advance STEM education to ensure all students, especially those furthest from opportunity, thrive and reach their highest potential as problem solvers and lifelong learners who pursue their passions and tackle the world's toughest challenges. We promote and provide high quality STEM education at the local, school system and national levels.

[130] FIRST General Volunteer Resources. https://www.firstinspires.org/resource-library/volunteer/general-volunteer-resources Accessed 15 June 2022.
[131] NMSI. https://www.nms.org/About-Us.aspx Accessed 13 June 2022.

**Table 3.11 NMSI: DoD STEM Strategic Goals Alignment; Financial Outlook & Sustainability**

| Alignment with DoD Strategic Goals | NMSI |
|---|---|
| Does the nonprofit have a demonstrated track record of working productively with local communities, including schools, educators, and students? | ✓ *NMSI traces its roots back to the 1990s but was officially launched as a 501(c)(3) in 2007. Their work emphasizes partnerships with communities, school leaders, teachers, parents and students.* |
| Are the nonprofit's programs designed to be complementary and synergistic with other ongoing activities (both in-school and out-of-school)? | ✓ *NMSI works within existing school systems, emphasizing cultural change and sustainable solutions. They partner with organizations that are similarly motivated.* |
| Are there opportunities for DoD/DIB personnel/volunteers to directly engage with the communities in support of the nonprofit's programs? | ✓ *NMSI invites community members to engage by advocating to bring NMSI to local schools (Let's Connect). NMSI also invites other organizations to partner with them to work with military-impacted communities.* |
| Are the nonprofit's operating procedures sufficiently sensitive to youth protection in design and implementation of interventions? | ✓ *NMSI programs focus on educator support and working within school systems. Student support focuses on AP study support/course access, much of which is online.* |
| Does the nonprofit provide—or bolster—a STEM pathway that is critical to defense missions? | ✓ *NMSI emphasizes high-quality STEM education PreK-12, including a College Readiness Program.* |
| Does the nonprofit design and implement culturally relevant programs that target specific populations? | ✓ *Via their Laying the Foundation program for teachers, "NMSI provides hands-on training, vertical teaming strategies, culturally responsive classroom resources and small-group support through a blend of in-person and virtual delivery."*[132] |
| Does the nonprofit measure its ability to reach and impact specific groups? | ✓ *NMSI tracks metrics for its AP enrollment to demonstrate engagement of non-white, female, and FRL (free or reduced-price lunch) students. They also track postsecondary success for NMSI students in ethnic and FRL groups, demonstrating success above the national average.* |
| Does the nonprofit have an assessment/ evaluation program in place that includes measurable outcomes? | ✓ *NMSI uses National Student Clearinghouse Data and explores outcomes including Postsecondary Enrollment Rates, Postsecondary Persistence Rates, and Degree Completion Rates. They also have metrics specific to their AP offerings.* |
| Does the nonprofit make its assessment results available to the public? | ✓ NMSI provides a number of reports relating to program impact on its website. |

[132] NMSI. https://www.nms.org/Our-Programs/Teachers/Grades-3-12/Laying-the-Foundation.aspx Accessed 13 June 2022

| Financial Outlook and Sustainability | NMSI |
|---|---|
| Does the nonprofit have a high "Give with Confidence" rating? | ✓ *4 Star (Exceptional), 94.68 out of 100* |
| Are its Financial and Accountability & Transparency ratings favorable? | ✓ *Financial = 93.64/100*<br>✓ *Accountability & Transparency = 96/100* |
| Is the Program Expense Ratio reasonable in comparison to similar organizations? | ✓ *Score 10/10* |
| Does the nonprofit have mechanisms in place to develop, grow, and support committed communities of volunteers? | ✓ *NMSI does not rely on volunteers to implement its programs.* |

### 3.3.3.3 Youth Clubs

As indicated in the interim report[133], DIB organizations partner with a wide variety of youth organizations in community-based settings. Many such organizations have incorporated STEM-related activities into their programs (e.g., hands-on activities plus interactions with mentors).

One of the most often cited youth organizations was Boys and Girls Clubs of America (BGCA), a nation-wide network of local clubs committed to providing safe, positive, and inclusive environments.

**BGCA Mission**
To enable all young people, especially those who need us most, to reach their full potential as productive, caring, responsible citizens.

BGCA provides STEM-related Academic Success Programs such as Computer Science Pathway (all ages), Digital Literacy Essentials (ages 8-18), DIY STEM (ages 9-12) as well as a number of other supportive programs (e.g., diplomas2Degrees – a college readiness program). BGCA reports that STEM programming is valued, and that a majority of Club members express interest in STEM. BCGA's reach is significant and includes **direct access to military-connected families**. According to their "At a Glance" fact sheet:[134]

> "*In a typical year, Boys & Girls Clubs serve 4.3 million young people—2 million through membership and 2.3 million through community outreach—in more than 4,700 Club facilities, including: 1,955 school-based Clubs; 497 BGCA-affiliated Youth Centers on U.S. military installations worldwide; 1,082 Clubs in rural areas; 278 Clubs in public housing; 208 Clubs on Native lands, making the Boys & Girls Clubs the largest youth development provider to Native communities*."

As indicated in Table 3.12, BGCA performs well against the suggested decision criteria.

[133] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). Section 3.3.7.8. https://sercuarc.org/serc-programs-projects/project/119
[134] BGCA 2020 At a Glance Factsheet. https://bgca.org/about-us/club-impact Accessed 16 June 2020.

**Table 3.12 BGCA: DoD STEM Strategic Goals alignment; Financial Outlook & Sustainability**

| Alignment with DoD Strategic Goals | BGCA |
|---|---|
| Does the nonprofit have a demonstrated track record of working productively with local communities, including schools, educators, and students? | ✓ *BGCA traces its roots to 1860, and received a U.S. Congressional Charter in 1956. That charter was amended and renewed in 1990, changing the name to Boys and Girls Clubs of America. BGCA is community-based; nearly half of its clubs are school-based.* |
| Are the nonprofit's programs designed to be complementary and synergistic with other ongoing activities (both in-school and out-of-school)? | ✓ *Local, community-based Clubs are autonomous organizations; most offer a mix of national and locally-developed programs. While not directly affiliated with schools, BCGA reports that 97% of Club teens expect to graduate from high school.* |
| Are there opportunities for DoD/DIB personnel/volunteers to directly engage with the communities in support of the nonprofit's programs? | ✓ *Local Clubs rely heavily on volunteers for support including assistance with homework, coaching, and teaching. Volunteers may also advocate implementation of programs (e.g., STEM-related activities).* |
| Are the nonprofit's operating procedures sufficiently sensitive to youth protection in design and implementation of interventions? | ✓ *BGCA provides local clubs with comprehensive child safety resources to protect youth and position Boys & Girls Clubs as catalysts for child protection.*[135] |
| Does the nonprofit provide—or bolster—a STEM pathway that is critical to defense missions? | ✓ *BGCA provides several programs designed to increase STEM competencies; specific implementations are left to local clubs. BGCA report that 52% of 12th grade Club members express an interest in a STEM career, compared with 27% of 12th graders nationally.*[136] |
| Does the nonprofit design and implement culturally relevant programs that target specific populations? | ✓ *BGCA offers inclusive and culturally relevant programs and resources. They also build Club leaders and staff to support DE&I at all levels of the Club and serve as supportive allies for youth leaders.*[137] |
| Does the nonprofit measure its ability to reach and impact specific groups? | ✓ *BGCA tracks Race & Ethnicity, Sex & Gender Identity and ages for its members, demonstrating broad engagement of non-white populations (30% white).* |
| Does the nonprofit have an assessment/ evaluation program in place that includes measurable outcomes? | ✓ *BGCA launched a National Youth Outcomes Initiative in 2011, using a common set of research-informed indicators of outcomes.*[138] |

[135] BGCA. https://www.bgca.org/about-us/faqs#fourteen Accessed 16 June 2022
[136] BGCA. https://www.bgca.org/about-us/club-impact Accessed 16 June 2022
[137] BGCA. https://www.bgca.org/empowering-kids/diversity-equity-and-inclusion Accessed 16 June 2022
[138] BGCA. 2020 National Outcomes Report.

| | |
|---|---|
| Does the nonprofit make its assessment results available to the public? | ✓ *BGCA provides National Outcomes reports and other assessment information online.*[139] |
| **Financial Outlook and Sustainability** | **BGCA** |
| Does the nonprofit have a high "Give with Confidence" rating? | ✓ *3 Star (Good), 88.62 out of 100* |
| Are its Financial and Accountability & Transparency ratings favorable? | ✓ *Financial = 84.2/100*<br>✓ *Accountability & Transparency = 97/100* |
| Is the Program Expense Ratio reasonable in comparison to similar organizations? | ✓ *Score 8.68/10* |
| Does the nonprofit have mechanisms in place to develop, grow, and support committed communities of volunteers? | ✓ *Volunteers are coordinated at the local level; BGCA seeks support from individuals, groups, and corporations for various types of activities. Some clubs provide application forms to express interest in volunteerism.* |

### 3.3.4 LEVERAGING NONPROFIT CORPORATIONS: RECOMMENDATION

Nonprofit organizations make high-value contributions to STEM ecosystems. DoD-DIB engagement with such organizations occurs both at the system-level (i.e., with the central/parent organization) and at the ecosystem level (i.e., with community-based implementations). Given the wide array of nonprofits operating in the STEM space, it will be helpful to understand their contributions in the context of both the system and local ecosystems. Thus, criteria are suggested to support decisions regarding **direct partnering with nonprofits by a DoD-DIB collaborative partnership**. Examples selected from existing DoD/DIB partnerships are provided to illustrate how the criteria could be used. Note that these criteria focus on organizations implementing STEM interventions and may not apply to other types of organizations.

***Leveraging Nonprofit Corporations***

*Standard criteria should be used to inform the decisions of DoD-DIB collaborative partnerships regarding selection of nonprofit partner organizations; this report suggests criteria for use in selection of nonprofits that implement STEM interventions.*

[139] BGCA. https://www.bgca.org/about-us/annual-report/annual-report-supporters Accessed 16 June 2022

## 3.4 MODELS FOR SYSTEMIC CHANGE

In the interim report from this project, it was noted that multiple DIB organizations cited engagement with two public-private models developed to drive systemic change in education systems—P-TECH (Pathways in Technology Early College High School) and NAF (National Academy Foundation). Those two models are explored further in this section. While other models were identified, for example, the I-BEST[140] model developed by the Washington State Board for Community and Technical Colleges, none had the existing footprint or DIB support base of P-TECH and NAF.

### 3.4.1 P-TECH 9-14

IBM, in partnership with the New York City Department of Education, and the City University of New York established the first P-TECH school in Brooklyn, New York, in September 2011. The P-TECH model was designed with two goals:[141]

- **Address the global "skills gap" and strengthen regional economies by building a workforce with the academic, technical and professional skills required for new-collar jobs.**
- **Provide underserved youth with an innovative education opportunity—with a direct pathway to college attainment and career readiness.**

P-TECH schools now exist in 27 countries around the world. In the U.S. alone there are 210 school partners, 98 college partners, and 421 industry partners providing 82 education pathways.

IBM established ptech.org as a separate nonprofit organization to sustain the P-TECH model and provide implementation guidance—including pre-planning and year-by-year stakeholder guidance. Also provided are curated resources including suggested techniques for skills-mapping and techniques for garnering commitment and financial support from state legislatures.[142]

#### 3.4.1.1 P-TECH 9-14 Model

P-TECH is a public-private partnership emphasizing public education reform focused on college attainment and career readiness.

> "*P-TECH schools span grades 9-14 and enable students to earn both a high school diploma and a no-cost, two-year postsecondary degree in a STEM field. Students can participate in a range of workplace experiences, including mentorship, worksite visits and paid internships. Upon graduation, students have*

[140] I-BEST (Integrated Basic Education Skills and Training). https://www.sbctc.edu/colleges-staff/programs-services/i-best/ Accessed 12 June 2022.
[141] P-TECH History. https://www.ptech.org/about/history/ Accessed 13 June 2022
[142] P-TECH Blueprint. https://www.ptech.org/getting-started/blueprint/ Accessed 13 June 2022

*the academic and professional skills required to either continue their education in a four-year postsecondary institution or enter into entry-level careers in IT, healthcare, advanced manufacturing and other competitive fields. While the P-TECH Model encompasses six years, students are able to move at their own pace, enabling some to accelerate through the model in as little as four years. P-TECH serves students from primarily underserved backgrounds, with no testing or grade requirements*."[143]

P-TECH is a school-within-a-school model, and relies upon smaller cohorts of students which enables students to get the attention and resources needed to succeed.

Critical partners include secondary school leadership, community college leadership, and industry leadership. The roles of each are summarized below.[144]

- High School Partner: Provide resources afforded to other public schools and ensure successful start-up and ongoing implementation.
- Community College Partner: Ensure adequate administrative and faculty resources to support student learning at the college level.
- Industry Partner(s): Identify critical workplace skills and provide experiences for students to graduate career-ready.

A formal steering group, with representation from each partner, drives the strategic direction of the P-TECH school. Planning committees address specific issues—including curriculum development—and support shared decision-making.

The P-TECH model also relies upon partnerships with state governments/education agencies, which make policy and operational decisions that impact success.

#### 3.4.1.2 P-TECH Impact[145]

P-TECH schools are expected to assess impact across a number of different measures, which are reviewed by the Steering Committee. Measures include indicators for success across the program pipeline and include: attendance; retention; high school performance; high school graduation; college readiness; college performance; college degree attainment; internships; job attainment; and ongoing college pursuit.

- MRDC, a nonprofit social policy research organization, is assessing the benefits of the P-TECH model and published a paper summarizing interim results; findings on high school graduation and postsecondary education outcomes are anticipated in 2023. The interim report concluded that the "*P-TECH 9-14 model*

[143] P-TECH Mission. https://www.ptech.org/about Accessed 13 June 2022.
[144] P-TECH Partnership. https://www.ptech.org/how-it-works/the-model/partnership/ Accessed 13 June 2022.
[145] P-TECH Impact. https://www.ptech.org/how-it-works/impact Accessed 14 June 2022.

*appears to have had positive effects on student outcomes*."[146] Specific findings included the results that follow. "*By the end of the second and third years of high school, P-TECH 9-14 students earned more total credits than students in other schools. Students in P-TECH 9-14 schools were much more likely to earn nonacademic credits in work-based learning, technology, engineering, and human service subjects. P-TECH 9-14 students attempted more Regents exams than the comparison students in other schools, and a higher percentage of them passed the ELA Regents exam with a score qualifying them for enrollment in CUNY coursework in each of the first three years of high school. The CUNY-qualifying-score pass rates in ELA indicate that more P-TECH 9-14 students were eligible to dual enroll in CUNY coursework in earlier years than their comparison group counterparts."*[147] Note that these results were achieved in New York City's P-TECH schools, which explicitly prioritizes students who are academically at-risk.

#### 3.4.1.3 Industry Partner Commitment

Strong industry partnerships are crucial to success of the P-TECH model. Summarized below is a list of the types of investments industry partners need to make to support a P-TECH School:[148]

- *"Industry liaison—an employee at the school full-time to implement commitments*
- *Work experiences that include mentoring, site visits, speakers, project days, paid internships*
- *Commitment to "first in line for jobs" (guaranteed interview, but not guaranteed hiring)*
- *Collaboration with high school and college partner to ensure that work experiences are integrated"*

#### 3.4.1.4 Case Studies

Two in-depth case studies are provided on the P-TECH website.[149] The first case study is for The Institute of Technology at Syracuse Central (ITC), which offered two P-TECH pathways—Electrical technology and Mechanical technology. TTM Technologies, which is a member of the DIB, is one of the industry partners. The second case study is for the

[146] M. Dixon, and R. Rosen (2022). *On Ramp to College: Dual Enrollment Impacts from the Evaluation of New York City's P-TECH 9-14 Schools.* https://www.mdrc.org/sites/default/files/P-TECH_Dual_Enrollment.pdf. Accessed 16 June 2022.
[147] R. Rosen, D. Byndloss, L. Parise, E. Alterman, M. Dixon, with F. Medina (2020). *Bridging the School-to-Work Divide. Interim Implementation and Impact Findings from New York City's P-TECH 9-14 Schools*. https://www.mdrc.org/sites/default/files/P-TECH_Report_ES.pdf. Accessed 18 June 2022.
[148] What is the Industry Partner Commitment? https://www.ptech.org/getting-started/faqs/. Accessed 16 June 2022.
[149] PTECH Case Studies. https://www.ptech.org/case-study/. Accessed 16 June 2022.

Greater Southern Tier STEM Academy (GSTSA), which offered four pathways—Advanced Technical Education, Health Care, Clean Energy, and Information Technology. Corning Inc., also a member of the DIB, is one of the industry partners.

The case studies provide background on P-TECH program implementation, school data and results, academic results and stories from participants (including alumni, students, educators, and industry partners).

#### 3.4.1.5 Perspectives from Stakeholders

**In 2015, the Governor of Colorado signed the Pathways in Technology Early College High Schools (P-TECH) bill into law.**[150] The Colorado Department of Higher Education and the Colorado Department of Education jointly approve new P-TECH schools in Colorado. There are now 20 P-TECH Schools in Colorado; several have industry partners who are members of the DIB.[151] The Colorado P-TECH program is open to all students, but strongly encourages enrollment of students who are socio-economically and racially diverse, first-generation college students, English language learners, and students with disabilities.[152]

> A DIB organization based in Colorado identified ongoing needs for manufacturing-related technical talent not readily available in their labor market; for many years the corporation maintained its own internal training programs. They were attracted to the P-TECH model not only for the training it provided but also because of the credentials earned by students, and observed that the administrative overhead was far lower than that required for in-house training. **An additional motivation was described as the need to '*rebrand*' manufacturing—for both parents and students—in order to attract more talent.**
>
> The corporation donated capital to buy equipment for the school and maintains access to do their own training as needed. The corporation also provides subject-matter-expert speakers, topical presentations, and TechEd equipment. At present, feeder populations are diverse, but mostly male; they hope to improve the gender balance over time (a female Tech Ed teacher was recently hired and they intend to reach out to her for assistance). **While pleased with the talent being generated via the program, concern was expressed regarding its scalability to meet workforce needs.** (This corporation currently has 12 interns in the program and needs to hire hundreds of new employees this year.)
>
> An experienced high school shop teacher in Colorado expressed excitement about participation in the P-TECH program. Although the school's program is relatively new (first cohort this year), this educator engaged in the early planning

[150] Colorado P-TECH. https://www.cde.state.co.us/postsecondary/p-tech Accessed 16 June 2022.
[151] Approved P-TECH Schools/Programs.
[152] P-TECH Fact Sheet. https://www.cde.state.co.us/postsecondary/p-techfactsheet Accessed 16 June 2022.

phases to prepare for the launch. The educator noted that state support was invaluable, including hosting of quarterly statewide Zoom meetings to share best practices and help new programs get started. The individual also noted that it was helpful to have a Community College partner that had already helped launch 8-10 programs across the state and a strong industry partner as well. **One of this educator's major objectives is to sell the 'trades' as both valued and valuable.**

**The New York State Education Department oversees the NYS P-TECH program; their map[153] shows 42 P-TECH schools, with the first cohort of schools having been established in 2013.** The NYS P-TECH program prioritizes partnerships that demonstrate the willingness and capacity to serve students who are academically at-risk; have historically not had access to or success in higher education; may be identified as early as grade 6 to receive extensive support to achieve college-readiness by grades 9-12; do not have the financial resources to fully fund an associate degree without tuition assistance; and are in attendance in a school district with Focus status as most recently determined by the State Education Department.[154]

A DIB corporation based in New York State with a long history of supporting STEM education, first in K-5 and then in middle school, acknowledged that they had gained little traction in terms of producing STEM graduates. After being introduced to the P-TECH model by a New York State Commissioner, representatives visited the P-TECH school in Brooklyn and returned excited about the potential impact. The corporation recruited nine industry partners and collaboratively developed a curriculum that included not only technical skills, but also professional skills including teamwork, communications, discretion, etc. Their intent is to develop job-ready graduates, noting that the existing educational system is not building the requisite skills.

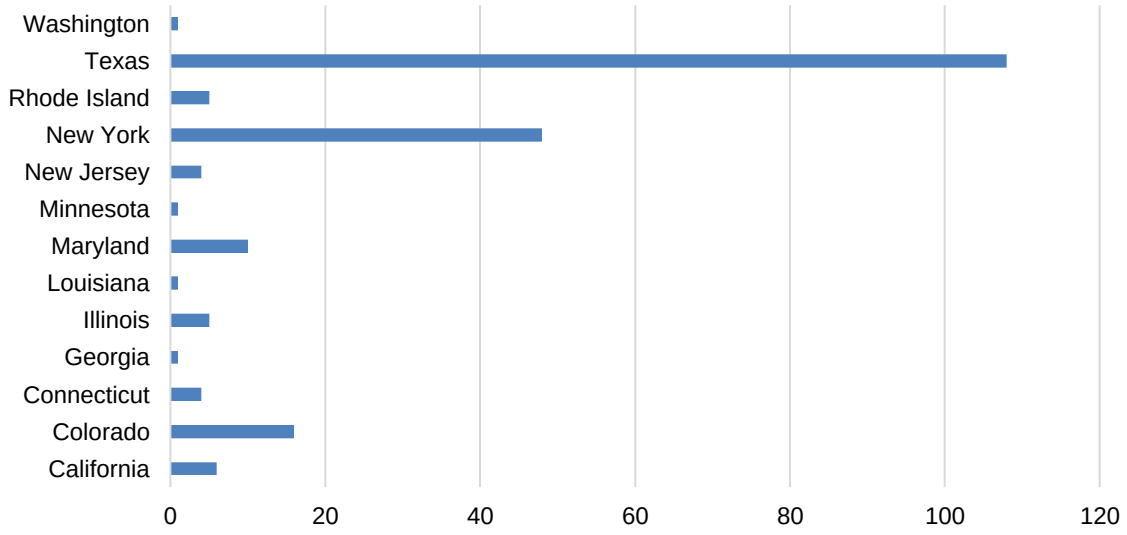
Industry roles include serving as mentors, job shadows, internships, and 'shark tank' reviewers for actual industry problems. **All of the industry partners recognize the value of the program but acknowledge that it is resource-intensive and requires commitment by the industry partners.** While the initial 7-year program grant ends this year, the program is expected to expand in the future, perhaps to include industry credentials/certifications. **This representative believes that the P-TECH model has changed the image of vocational skills.**

#### 3.4.1.6 P-TECH Summary

The P-TECH website indicates that P-TECH schools currently operate in 13 states as shown in Figure 3.3.

[153] P-TECH Map of Projects. http://www.nysed.gov/postsecondary-services/pathways-technology-nys-p-tech-program Accessed 16 June 2022.
[154] Questions on NYS P-TECH. http://www.nysed.gov/common/nysed/files/programs/postsecondary-services/nys-p-tech-2013-20-faq.pdf Accessed 16 June 2022.

**Figure 3.3 Number of P-TECH Schools by State**




Technical pathways[155] span a diverse range of topics as shown in Table 3.13. While a number of the schools implement a single pathway, some implement up to five pathways. **Discussions with stakeholders indicated that as programs mature additional pathways of importance to industry partners are likely to be added. Note that a majority of the pathways already in place are of interest to both DoD and its industrial base.**

**Table 3.13 P-TECH Pathways Implemented**

| | |
|---|---|
| Manufacturing<br>• Advanced Manufacturing<br>• Advanced Robotics & Manufacturing<br>• Computer Numerical Controls Tech<br>Engineering & Technology<br>• Electrical Engineering Technology<br>• Electronic Technology<br>• Energy Management<br>• Engineering & Mechatronics<br>• Instrumentation & Electrical Technology<br>• Intelligent Automation Engineering<br>• Mechanical Engineering<br>• Mechatronics<br>• Welding Technology<br>• Process Technology<br>• Machining<br>• Automotive Technology<br>• Corrosion Technology<br>• Basic CADD & Solidworks Certifications | Operations<br>• Aviation Management & Operations<br>• Logistics & Management<br>Business<br>• Business<br>• Business Accounting<br>• Business Administration<br>• Business Management<br>• Business & Industry<br>• Marketing & Finance<br>Architecture & Construction<br>• Architectural Design<br>• Architectural Design & Construction<br>• Construction Technology<br>Health<br>• Health Professions<br>• Health Science<br>• Health Information Technology<br>• Healthcare |

[155] P-TECH Schools in the United States/Pathways. https://www.ptech.org/p-tech-network/our-schools/usa/more-schools Accessed 17 June 2022.

| | |
|---|---|
| • Modern Design & Entrepreneurship<br>Digital Media & Gaming<br>• Digital Media<br>• Digital Media & Technology<br>• Gaming & Animation<br>• Simulation Game & Technology<br>• Design & Visual Communications<br>• UX Design<br>Computer/Cyber/IT<br>• Computer Information Systems<br>• Computer Network System<br>• Computer Programming<br>• Computer Science<br>• Computer System Networking<br>• Computer & Informational Sciences<br>• Cybersecurity<br>• Information Technology<br>• IT Cybersecurity Specialist<br>• Network Administration<br>• Networking Technology<br>• Software Development | • Histologic Technology<br>• Nursing<br>• Nursing & Medical<br>• Pharmacy<br>• PreMed /PreDental<br>• Registered Nursing<br>• Life Sciences<br>Education<br>• Early Childhood Education<br>• Education<br>• STEM Education & Management<br>• Teacher Prep<br>Hospitality<br>• Hospitality & Food Industry<br>• Hospitality Administration/Management<br>Legal<br>• Criminal Justice<br>• Paralegal<br>Other<br>• Interdisciplinary Studies/General Studies<br>• Liberal Arts |

The P-TECH 9-14 model has gained significant traction in many states (as well as in many other countries) since its introduction just over a decade ago. The model as designed targets underserved populations and has demonstrated benefits in rural areas as well as in urban and suburban settings. **The P-TECH 9-14 model is directly relevant to the DoD-DIB need to build a Skilled Technical Workforce in high priority pathways**; a number of DIB corporations are already engaged in doing so. Additionally, the model also has been demonstrated to motivate some students to pursue four-year STEM degrees. Opportunities exist for DoD-DIB to further diversify available pathways in existing schools as well as to expand P-TECH implementation into additional school systems.

### 3.4.2 NAF

The origin[156] of the NAF model dates back to 1982 when the first Academy of Finance opened in Brooklyn, New York, under the leadership of Sanford I. Weill and the American Express Company. The model was expanded in 1987 to offer an Academy of Travel & Tourism. The National Academy Foundation was established as a nonprofit organization in 1989 to oversee the quality and expansion of programs nationwide. The model was expanded into the technology space in 2000, with the launch of the Academy of Information Technology.

[156] What is the National Academy Foundation? https://www.naf-education.org/theacademies/PlanningGuide/NAF Accessed 15 June 2022.

According to their 2021-2022 data[157] NAF now has 618 Academies in 384 schools, located in 35 states and territories, covering the following domains: Finance (180); Information Technology (120); Engineering (96); Hospitality & Tourism (87); Health Sciences (85); Other (50). Of the student population, 89% are females and/or ethnic minorities; 67% are eligible for free/reduced price lunch, and 17% are English Language Learners; 53% are male and 47% are female.

DIB corporations are represented on the NAF Board of Directors[158] as well as on their STEM Advisory Committee, which "*meets periodically to share major industry trends, inform NAF's approach to STEM-enabling strategies in curriculum, work-based learning, advisory board development, college access, and professional development.*"[159]

#### 3.4.2.1 NAF Model

The NAF model is essentially that of a school-within-a-school. "*Academies are structured as small, focused learning communities that fit within and enhance high school systems.*"[160] NAF supports teachers through career-focused curricula that incorporate current industry standards and practices, project-based learning, and performance-based assessment. NAF also exposes students to real-world issues in career-focused industries through connections with industry professionals.

> "*NAF's Program of Study embraces the U.S. Department of Education's 16 Career Clusters[161] and provides curricular options for students to achieve NAFTrack Certification, NAF's employability credential that serves as NAF's seal of college and career readiness. NAF academies offer multiple career pathways and enhance the academic rigor of their program of study by applying for dual enrollment/early college and state-approved, career cluster courses to meet the curricular requirements of NAFTrack Certification."*[162]

At the local level, NAF Advisory Boards provide linkage between the school and the workplace. Comprised of industry professionals and local community leaders, these Boards work with educators to inform curricula and help organize work-based learning activities. They also provide students with opportunities to build relationships with mentors.

NAF's model for work-based learning provides a continuum of experiences starting with

[157] NAF Impact by the Numbers. https://naf.org/wp-content/uploads/2022/05/Data-Sheet_National.pdf Accessed 17 June 2022.
[158] NAF Board of Directors. https://naf.org/about/board-of-directors Accessed 17 June 2022.
[159] NAF STEM Advisory Committee. https://naf.org/about/stem-advisory-committee Accessed 17 June 2022.
[160] NAF Academy Development & Structure. https://naf.org/our-approach/educational-design Accessed 17 June 2022.
[161] Department of Education Career Clusters. https://www.exploring.org/activity-library-category/us-department-of-education-career-clusters/ Accessed 12 June 2022.
[162] NAF Curriculum & Instruction. https://naf.org/our-approach/educational-design Accessed 18 June 2022.

career awareness, progressing to career exploration, and culminating with career preparation. Business professionals speak in classrooms, host skills workshops, and take part in mock interviews. Students are afforded opportunities to tour worksites and shadow professionals. The experience culminates in an internship opportunity that allows students to apply their classroom skills and learn more about what it takes to succeed.[163]

#### 3.4.2.2 NAFTrack Certification

The NAF model assesses student performance through career-focused courses, internships, and high school graduation. NAFTrack Certification is an employability credential that serves as NAF's seal of college and career readiness.[164] Certification components include:[165]

1. *"Career-Focused Courses: Four-semesters of NAFTrack approved career-cluster courses and a required performance-based assessment.*

2. *Qualifying Internship: A paid, compensated, or volunteer experience of 80+ hours (or two 40-hour sessions) under the direct supervision of an accountable adult who completes an internship assessment.*

3. *High School Graduation: Students must complete all school and district requirements for high school graduation."*

In addition to NAF's curricula for programs of study, NAF approves third-party curricula that meet NAF's standards. Current approved curriculum providers include: Cisco, Intelitek, Odysseyware, Paxton-Patterson, Project Lead the Way (PLTW), and STEM 101.[166] NAF also accepts selected courses that are aligned with designated career-cluster content from designated providers.

NAF academies must apply for NAFTrack Certification approval of career-cluster courses in order to meet the certification requirement.

#### 3.4.2.3 NAF Network Benefits

NAF provides a broad range of information/resources to support development of new academies together with ongoing information/resources to help sustain established academies. Examples include NAF-sponsored professional learning experiences to support academy development; virtual and in-person support from NAF academy portfolio managers to ensure development of high-quality academies; industry-validated and career-focused curricula; data-driven support to track student outcomes, academy goals, and strategic action steps for continuous improvement; national scholarship

[163]NAF Work-Based Learning. https://naf.org/our-approach/educational-design Accessed 17 June 2022.
[164] NAFTrack Certification. https://naf.org/our-approach/naftrack Accessed 17 June 2022.
[165] IBID.
[166] IBID. Third-Party Curriculum.

opportunities; and national awards and recognition.[167]

### 3.4.2.4 NAF Results

NAF commissioned a 4-year research project conducted by ICF that examined the effect of the NAF design on high school student graduation rates. The report, titled *Transforming the American High School Experience: NAF's Cohort Graduation Rates from 2011-2015*[168], compared results from NAF students against equivalent non-NAF students (i.e., those with comparable Grade 9 on-track/at-risk status). Key findings included:[169]

- ***"Overall NAF Students**: Students enrolled in a NAF academy in Grade 9 are 3 percentage points more likely to graduate than their non-NAF counterparts.*
- ***At-risk NAF Students**: Students enrolled in a NAF program in Grade 9 and were identified as at-risk of not graduating are 5 percentage points more likely to graduate from high school than their non-NAF counterparts.*
- ***NAF Students with Full Program Participation**: NAF students who completed the NAF program of study are 6 percentage points more likely to graduate from high school than their non-NAF counterparts.*
- ***At-Risk NAF Students with Full Program Participation**: Students who were identified as at-risk AND participated in a high-quality NAF academy program through their senior year are 10 percentage points more likely to graduate than their non-NAF counterparts."*

More current data indicates that "*as of 2020, 60% of NAF academy students receive free/reduced price lunch, 80% are students of color, and nearly half are female. Last year 99% of seniors graduated, 87% were college-bound, and 39% of seniors had an internship*."[170]

### 3.4.2.5 NAF Summary

For 2021-2022, NAF reports that their footprint includes 618 academies in 150 districts, 209 cities, and 35 states/territories including:[171]

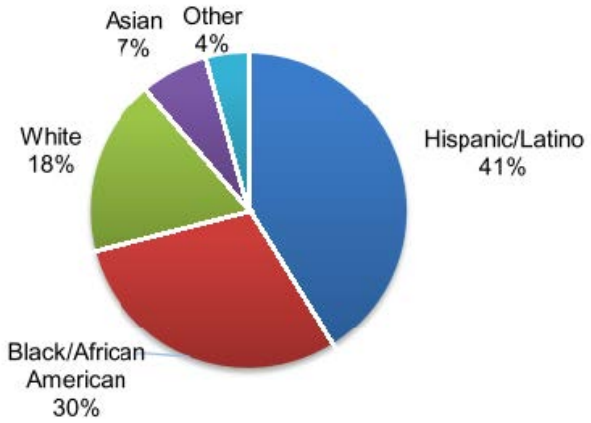
---

[167] NAF's network of over 600 academies has access to the following benefits. https://naf.org/our-approach/naftrack Accessed 18 June 2022.
[168] J Sun, S. Spinney (2017*) Transforming the American High School Experience: NAF's Cohort Graduation Rates from 2011-2015*. ICF. https://www.icf.com/-/media/files/icf/reports/2017 /nafs-cohort-graduation-rates-from-2011-to-2015.pdf Accessed 17 June 2022.
[169] IBID. p.8
[170] NAF Results. Education has the power to change everything. https://naf.org/our-approach/results Accessed 17 June 2022.
[171] NAF – Our Cities (2021-2022). https://naf.org/wp-content/uploads/2022/05/NAF-Cities-Landscape-2022.pdf Accessed 17 June 2022.

| | | |
|---|---|---|
| Alabama | Louisiana | Pennsylvania |
| Arizona | Massachusetts | Puerto Rico |
| California | Maryland | Rhode Island |
| Colorado | Michigan | South Carolina |
| Connecticut | Minnesota | South Dakota |
| Washington DC | Missouri | Tennessee |
| Delaware | North Carolina | Texas |
| Florida | Nebraska | Virginia |
| Hawaii | New Hampshire | Virgin Islands |
| Idaho | New Jersey | Washington |
| Indiana | Nevada | Wisconsin |
| Kansas | New York | |

As of May 2022, NAF reported STEM-related pathways (Engineering, Information Technology, Health Sciences, Other: STEM) engaging 69,530 students across 325 NAF Academies in 227 high schools. Student demographics are shown in Figure 3.4. Of the students, 56% are male and 44% are female. The reported senior graduation rate was 97%, with 91% of the students college-bound.[172]

**Figure 3.4 Race/Ethnicity – NAF STEM Students**




**The NAF model has a broad footprint across the nation and is demonstrating positive impacts, particularly for underserved/underrepresented populations.** Some DIB organizations are already engaged at leadership levels (Board of Directors, STEM Advisory Committee) as well as in implementation of academies at the local level.

The NAF organization provides substantial experience, information, and ongoing support to establish and sustain NAF Academies. **There may be opportunities for a DoD-DIB collaborative partnership to leverage this model as a component in STEM ecosystems.**

[172] NAF. Find an Academy. STEM Data. https://naf.org/naf-network/find-an-academy Accessed 17 June 2022.

### 3.4.3 MODELS FOR SYSTEMIC CHANGE: RECOMMENDATION

The two models explored in this section (P-TECH and NAF) have garnered significant nationwide buy-in from educators as well as industry partners; both have demonstrated positive results in terms of student outcomes. Additionally, umbrella organizations fostering both models provide substantial assistance to support establishment and sustainment of programs, enabling new-starts to learn from more than a decade of experience. Some DIB organizations are already partnering to implement these models. **Looking to the future, both NAF and P-TECH 9-14 could play important roles in STEM Ecosystems, serving as new platforms for DoD-DIB collaborative partnerships.**

The interim report for this project recommended that "*DoD STEM should, in collaboration with the DIB, develop an alliance of Community Colleges and Technical Institutes to expand Skilled Technical Workforce (STW) offerings of particular interest to the DoD and its industry base*."[173]

The P-TECH 9-14 model provides an opportunity to reach back into high schools to strengthen the incoming pipeline, engaging students earlier with relevant courses and work experiences. Since a number of Community Colleges are already engaged with high schools via this model, which has proven effective, it would be beneficial for DoD to leverage the model in its efforts to develop the STW needed for defense missions.

***Leveraging P-TECH to Build the STW***

*DoD STEM should, in collaboration with the DIB, leverage its partnerships with Community Colleges and Technical Institutes to implement the P-TECH 9-14 model to expand STW offerings of particular interest to the DoD and its industry base.*

[173] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). Recommendation 3. https://sercuarc.org/serc-programs-projects/project/119

## 3.5 EFFECTIVE EXPLOITATION OF THE VIRTUAL ENVIRONMENT

The term 'virtual environment' is defined in various ways. For the purpose of this report, the term refers to a networked common operating space that allows users to interact with the computing environment as well as other users and their work. Over the past few decades virtual environments have progressed in many dimensions—from asynchronous email to synchronous chat; from phone calls to video conferencing; from presentation platforms to collaboration platforms; from web presence to virtual worlds, and so forth.

Emerging capabilities suggest that in the future the 'metaverse' will provide a common operating space. Once again, there are many different definitions for the term, including "*a virtual-reality space in which users can interact with a computer-generated environment and other users*"[174]. A more expansive description is provided by: "*the metaverse refers to a virtual environment that incorporates different internet functions and services, such as socializing, gaming, and business opportunities, all within an immersive virtual reality universe*."[175] Although metaverse instantiations exist today, there appears to be general agreement that these are the early days of the concept, which will continue to mature and evolve over the coming years. In fact, according to Reuters, on 21 June 2022, "*Meta, Microsoft, and other tech giants racing to build the emerging metaverse concept have formed a group to foster development of industry standards that would make the companies' nascent digital worlds compatible with each other*."[176] **The emerging STEM City USA metaverse[177], which is already garnering attention from both DoD and the DIB, should be tracked for potential future applicability.**

The sub-sections below take an expansive view, focusing not on a single ecosystem, but rather on how the national security community (including DoD, DIB organizations, other governmental agencies, and many nongovernmental organizations (NGOs)) could establish a ***collective virtual environment to engage, inspire, and expand the STEM talent pool for defense missions***. This virtual environment could serve local STEM ecosystems as well as the over-arching DoD-DIB system of collaborative partnerships embedded in existing ecosystems—and even the public at large. Benefits of such an approach would include:

- **Providing user communities coherent access to vast amounts of already available STEM education-related information designed/developed to engage, inspire, and attract users to defense (or national security more broadly) mission opportunities**. For example, classroom materials for use by educators, STEM activities/experiments for use at home, videos featuring STEM professionals as role models, internship/apprenticeship opportunities, scholarships/financial aid available—these types of materials and more already

[174] Oxford Languages Dictionary.
[175] https://cyberscrilla.com/metaverse-pros-and-cons-the-top-benefits-and-drawbacks/
[176] Reuters. https://www.reuters.com/technology/meta-other-tech-giants-form-metaverse-standards-body-without-apple-2022-06-21/ Accessed 24 June 2022.
[177] STEM CITY USA. https://stemcityusa.com/ Accessed 18 June 2022.

exist, but are distributed across hundreds of individual organizational websites.

- **Extending mission outreach to rural and remote communities that are not adjacent to STEM ecosystems, making connections that could provide new pathways for underserved communities.** Significant effort is currently devoted to reaching underserved and underrepresented communities within/adjacent to existing STEM ecosystems across the nation, but parts of the U.S. remain untouched; this also would extend mission outreach to families living abroad.

- **Creating a platform for more dynamic engagement with current and prospective STEM/STW workers for defense/national security missions.** A well-designed and informative virtual environment, kept current with changing needs and opportunities, would deliver a collective voice to increase public awareness of the vital role(s) of defense/national security missions.

### 3.5.1 CURRENT STATE OF VIRTUAL ENVIRONMENTS RELATING TO DEFENSE MISSIONS

At present, organizations throughout the DoD and the Services; individual DIB organizations; military/defense-connected NGOs; and other defense-related agencies maintain individual web presences delineating STEM interventions and other related activities including availability of internships, scholarships, etc. Some activities have national (or beyond) applicability, while others are geographically anchored. While individually well-intentioned and well-designed, there is no simple way for students, parents, or educators to efficiently navigate the vast landscape of resources/ opportunities available that relate directly to building the STEM talent pool for defense missions. Nor is there an easy way for a volunteer, who wishes to support such activities, to fully understand the opportunities to do so (either locally or virtually).

In the interim report from this project, it was observed that: *"A vast array of online resources was described by DIB participants, including educational resources for teachers, parents, and students at all levels; videos featuring projects and/or role models; virtual tours; webinars; digital libraries; and an eMentoring platform."*[178]

Other organizations in the defense/national security mission space provide similar types of resources that could be made more readily accessible via a collective/collaborative approach.

The sections that follow advocate development of user-centered portals to bring coherence to available information—while enabling individual organizations to retain branding links—as well as to establish bi-directional links that are responsive to user queries. This report discusses three user communities: Students/Families; Educators; and Volunteers. (Note that a single individual may embody multiple roles.)

[178] Interim Report: *Policy Options to Promote DoD-Defense Industry Collaboration in Science, Technology, Engineering and Mathematics (STEM) Education and Workforce Development Programs, Activities, and Outreach*. (2022). p. 66. https://sercuarc.org/serc-programs-projects/project/119

### 3.5.2 PRINCIPLES OF USER-CENTERED DESIGN

User-Centered design is a conceptually simple but extremely powerful approach for developing web portals. In short,

> *"User-centered design (UCD) is an iterative design process in which designers focus on the users and their needs in each phase of the design process. In UCD, design teams involve users throughout the design process via a variety of research and design techniques, to create highly usable and accessible products for them."*[179]

User engagement throughout the design/development/implementation lifecycle is the key ingredient to success. What this means in practice, is that designers must have a clearly identified target audience/community—and ways to include representatives of that community in the design process (including usability testing).

A number of lists of User-Centered Design Principles exist, but most include some variation of the following:

- **"*Users are involved in the design process from the very beginning***. *Critical design decisions are evaluated based on how they work for end-users.*
- ***Importance of requirement clarification.*** *The product team always tries to align business requirements with user's needs.*
- ***Introducing user feedback loop in the product life cycle.*** *The product team collects and analyzes feedback from users regularly. This information helps the team to make more user-focused decisions.*
- ***Iterative design process***. *The product team constantly works on improving user experience; it introduces changes gradually as it gains more understanding about their target audience*."[180]

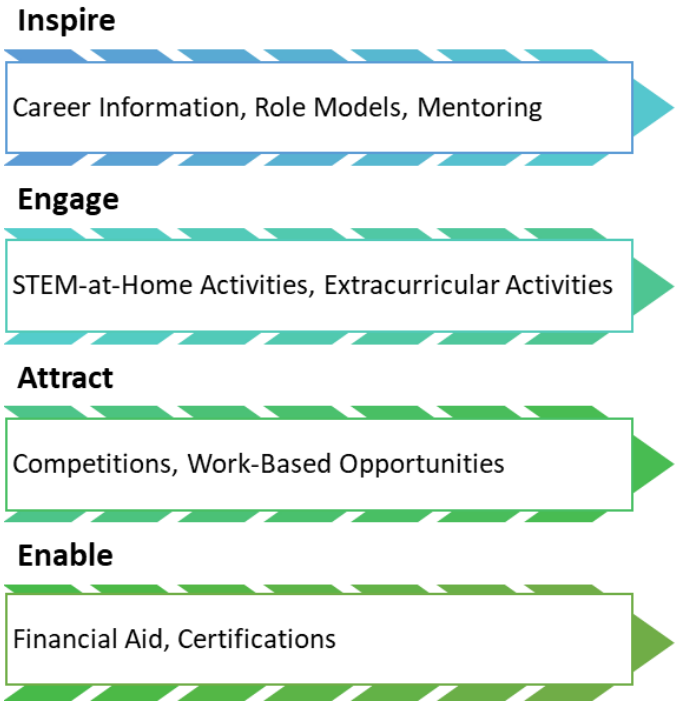
In the context of this study, this means that efforts to engage different stakeholder communities will more likely be successful if: 1) differentiated communities are clearly identified up front; and 2) representatives from each community are engaged during design/development/implementation of the user portal for that community. In short, a student (or parent) has different interests and needs for information than does an educator seeking materials available for use in a classroom, and so forth. While making a broad array of information available to the general public is of value, streamlining access to information and enabling bi-directional communications to particular user communities is of even greater value in establishing and sustaining engagement.

[179] Interaction Design Foundation. https://www.interaction-design.org/literature/topics/user-centered-design#:~:text=User-centered%20design%20(UCD),and%20accessible%20products%20for%20them Accessed 27 June 2022.
[180] Adobe: User-Centered Design Principles. https://xd.adobe.com/ideas/principles/human-computer-interaction/user-centered-design/ Accessed 27 June 2022.

### 3.5.3 USER COMMUNITY: STUDENTS/FAMILIES

The ultimate reason for building connections to students and their families is to develop and motivate STEM talent to seek defense-related career opportunities. **Figure 3.5 illustrates the types of information that would be of value when working to inspire, engage, attract, and enable students to pursue careers in defense missions.**

**Figure 3.5 User Community: Students/Families**




Defense-related organizations have already amassed a great deal of information regarding potential career opportunities and portraying role models (short stories, brief videos) intended to ***inspire*** and inform both students and their parents. Such information is useful independent of geographic location. Additionally, many organizations provide mentors (largely through volunteers); this service is most effective when done via in-person interactions, but a number of organizations are implementing eMentoring platforms that are both convenient and effective across geography and time zones.

Similarly, many defense-related organizations have developed age-appropriate STEM-at-Home activities for use by parents to **engage** their children with hands-on learning opportunities that relate in varying ways to defense missions. These resources are also of value independent of geography. Related extracurricular activities may be either in-person or virtual, and include after-school/weekend activities as well as summer camps.

A growing number of defense-related organizations are devising student competitions with local to national reach that are intended to **attract** students to defense missions (e.g., CyberPatriot, American Rocketry Challenge). Organizations also offer job shadowing, internships, and apprenticeships to provide students with a first-hand view of work in support of defense missions; while mostly in-person opportunities, a number of organizations are experimenting with virtual internships.

Scholarships/Fellowships and Co-Op programs are provided by governmental organizations, NGOs, and some DIB corporations; such opportunities **enable** students to pursue post-secondary STEM education—particularly in fields of relevance to defense missions. Additionally, some corporations provide Certifications/Credentials that qualify students for high-value job opportunities.

By making information including (but not limited to) that described above more readily accessible to students and families, the **impact of existing resources could be amplified**. In developing the portal, it will be important to enable users to easily find age-appropriate and geographically-relevant information. It also will be important to support transactional queries (i.e., applying for scholarships or internships; requesting a mentor; registering for extracurricular activities, etc.). Finally, given that the prospective partners who have developed the information need to maintain ownership, it will be important to retain brand linkages within the portal.

### 3.5.4 USER COMMUNITY: EDUCATORS

Defense-related organizations also have recognized the value of supporting and enabling educators via a variety of classroom resources and growth opportunities. **Figure 3.6 shows some of the types of information available to support and enable educators.**

**Figure 3.6 User Community: Educators**

Many defense organizations **support** educators by making available lesson-plans and standards-aligned curricula for use in classrooms. Such materials are often accompanied by short videos that illustrate STEM concepts in a mission context. Organizations also provide guest speakers who reinforce key concepts while also serving as role models for the students. While historically an in-person activity, some organizations are making use of virtual classroom engagement, which both reduces resource requirements and eliminates geographic constraints.

Defense organizations also provide educators with coaching and professional development opportunities (often with Continuing Education Credits) to **enable** them to more effectively convey STEM topics.

**While there are many general resources available to educators, the resource categories above are intended to equip them to use defense mission-relevant examples and activities as they educate students.** Once again, in addition to providing information, the portal should support educator requests for Guest Speakers as well as registration for enabling activities.

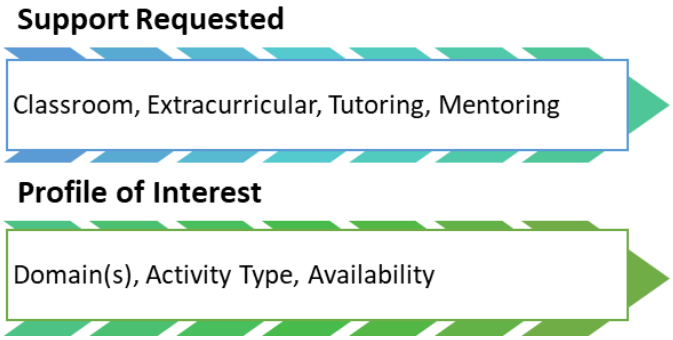
### 3.5.5 USER COMMUNITY: VOLUNTEERS

A review of the STEM-related engagement and outreach activities of both industry and government clearly demonstrates the vital role(s) played by volunteers—from supporting classroom activities to coaching robotics teams for competitions—to tutoring

or mentoring individual students, and more. Most often, it appears that **matching needs to assets occurs largely via personal networks**. Effective use of a volunteer portal has the potential both to make more effective use of local assets and also to tap into geographically-distant assets via virtual engagement. **Figure 3.7 illustrates some of the considerations for more effectively engaging the volunteer community by matching needs to available assets.**

This portal is intended to broker requests between those who need assistance (e.g., educators; organizations implementing extracurricular activities; parents/families) and volunteers. Interested individuals would maintain a profile describing their personal expertise and interests together with their availability (including geographic information or virtual engagement).

**Figure 3.7 User Community: Volunteers**




If such a portal were readily accessible (and highly visible) it might expand the volunteer network in local communities through outreach to defense-related organizations that do not today support STEM outreach. It might also serve to connect virtual assets to local communities in need. (Note that implementation would require privacy protections as well as attention to Child Protection Policies.)

### 3.5.6 Exploiting the Virtual Environment: Summary and Recommendation

This section makes no attempt to lay out all of the options for exploitation of the virtual environment in implementing the DoD-DIB system of collaborative partnerships. Rather, it suggests a starting point—making available assets and activities more coherent to prospective beneficiaries in an attempt to amplify impacts.

The portals described above require thoughtful design as well as willing collaborative partners. While the portals are intended to interact, particularly in support of queries and matching needs to available assets, an opportunity exists to begin with a pilot effort focusing on students/families. Outreach to the broader defense community is essential in the long term, but a 'proof-of-concept' pilot involving the DoD, Military Branches, and Defense Agencies would be a useful starting point.

The portal then should be expanded through engagement with DIB partners, defense-related NGOs, and other government agencies in the national security mission space.

***Exploiting the Virtual Environment***

*DoD STEM should lead the design and development of a Student/ Families portal based on existing information and activities implemented by the DoD, Military Branches, and Defense Agencies, as a pilot program.*

## 3.6 SUMMARY AND RECOMMENDATIONS

Section 3 builds on the interim report from this project through deeper exploration of ways to advance STEM ecosystems through DoD-DIB Collaborative partnerships.

Section 3.1 offers a vision for a system of DoD-DIB collaborative partnerships that operate within existing STEM ecosystems. While operating as an engaged and contributing partner within the ecosystem, **the primary emphasis for DoD-DIB participation would be to inspire, engage, and attract STEM talent to defense missions through targeted interventions.**

***DoD-DIB Collaborative Partnership***

*DoD/DIB should jointly establish a 3-year (at least) pilot collaborative partnership within in an existing STEM ecosystem in which both are heavily invested as a way to determine the benefits of joint planning and implementation of STEM activities.*

Section 3.2 provides an updated framework for evaluation/ assessment aligned with the Collective Impact model, which identifies conditions that allow public- and private-sector organizations to collaborate around a clearly defined goal. The framework considers both **ecosystem-wide and DoD-DIB-specific measures.**

***Evaluation/Assessment Framework***

*DoD STEM should pilot the Collective Impact-aligned evaluation/assessment framework within one (or more) of its existing hubs.*

Section 3.3 acknowledges the value nonprofit organizations already bring to STEM ecosystems as well as to DoD and DIB partnerships and offers decision criteria that could be used to inform choices about selection of nonprofit partners by DoD-DIB collaborative partnerships. Examples are provided to illustrate the application of the criteria.

***Leveraging Nonprofit Corporations***

*Standard criteria should be used to inform the decisions of DoD-DIB collaborative partnerships regarding selection of nonprofit partner organizations; this report suggests criteria for use in selection of nonprofits that implement STEM interventions.*

Section 3.4 explores the P-TECH 9-14 and NAF models identified in the interim report as having been of interest to multiple DIB organizations. Both of these public-private models have gained wide-spread application and have demonstrated positive performance impacts. The study team opted to emphasize the P-TECH model due to its direct applicability to building the Skilled Technical Workforce.

***Leveraging P-TECH to Build the STW***

*DoD STEM should, in collaboration with the DIB, leverage its partnerships with Community Colleges and Technical Institutes to implement the P-TECH 9-14 model to expand STW offerings of particular interest to the DoD and its industry base.*

Section 3.5 takes an expansive view of the need to fully exploit the virtual environment not only in developing STEM ecosystems, but also in engaging differentiated user communities nation-wide via user-centered portals. **While the discussion is broad-based, potentially engaging the entire national security apparatus, this report recommends a pilot program as a starting point for the broader initiative.**

***Exploiting the Virtual Environment***

*DoD STEM should lead the design and development of a Student/Families portal based on existing information and activities implemented by the DoD, Military Branches, and Defense Agencies, as a pilot program.*

# 4 CONCLUSION

This study was charged with a formidable challenge—ensuring availability of a clearable technical workforce to meet the needs of defense missions now and in the future. This report, together with the interim report from this study, offers an array of recommendations intended to 'move the needle' toward bringing coherence to the vast array of STEM education-related activities already being sponsored by DoD and DIB organizations. The intent is to better align such activities going forward in order to amplify impacts—exploiting synergies and realizing efficiencies. But implementation of these recommendations represents an equally formidable challenge.

## 4.1 SETTING THE CONDITIONS FOR SUCCESS—COLLECTIVE IMPACT

The Collective Impact model was introduced in Section 3.2 as a framework for use in evaluation and assessment of STEM ecosystems, but the model has broader applicability. In *Channeling Change: Making Collective Impact Work*[181] the authors contrasted 'Isolated Impact' and 'Collective Impact' in the context of paradigms for social progress as shown in Table 4.1.

**Table 4.1 Isolated Impact vs. Collective Impact**

| ISOLATED IMPACT VS. COLLECTIVE IMPACT | |
|---|---|
| **ISOLATED IMPACT** | **COLLECTIVE IMPACT** |
| • FUNDERS SELECT INDIVIDUAL GRANTEES THAT OFFER THE MOST PROMISING SOLUTIONS.<br>• NONPROFITS WORK SEPARATELY AND COMPETE TO PRODUCE THE GREATEST INDEPENDENT IMPACT.<br>• EVALUATION ATTEMPTS TO ISOLATE A PARTICULAR ORGANIZATION'S IMPACT.<br>• LARGE SCALE CHANGE IS ASSUMED TO DEPEND ON SCALING A SINGLE ORGANIZATION.<br>• CORPORATE AND GOVERNMENT SECTORS ARE OFTEN DISCONNECTED FROM THE EFFORTS OF FOUNDATIONS AND NONPROFITS. | • FUNDERS AND IMPLEMENTERS UNDERSTAND THAT SOCIAL PROBLEMS, AND THEIR SOLUTIONS, ARISE FROM THE INTERACTION OF MANY ORGANIZATIONS WITHIN A LARGER SYSTEM.<br>• PROGRESS DEPENDS ON WORKING TOWARD THE SAME GOAL AND MEASURING THE SAME THINGS.<br>• LARGE SCALE IMPACT DEPENDS ON INCREASING CROSS-SECTOR ALIGNMENT AND LEARNING AMONG MANY ORGANIZATIONS.<br>• CORPORATE AND GOVERNMENT SECTORS ARE ESSENTIAL PARTNERS.<br>• ORGANIZATIONS ACTIVELY COORDINATE THEIR ACTION AND SHARE LESSONS LEARNED. |

[181] F. Hanleybrown, J. Kania, M. Kramer (2012). *Channeling Change: Making Collective Impact Work.* Stanford Social Innovation Review. https://ssir.org/articles/entry/channeling_change_making_collective_impact_work. Accessed 2 July 2022.

The Collective Impact Model is comprised of five conditions, as shown in Table 4.2.[182]

**Table 4.2 The Five Conditions of Collective Impact**

| THE FIVE CONDITIONS OF COLLECTIVE IMPACT | |
|---|---|
| **COMMON AGENDA** | All participants have a shared vision for change including a common understanding of the problem and a joint approach to solving it through agreed upon actions. |
| **SHARED MEASUREMENT** | Collecting data and measuring results consistently across all participants ensures efforts remain aligned and participants hold each other accountable. |
| **MUTUALLY REINFORCING ACTIVITIES** | Participant activities must be differentiated while still being coordinated through a mutually reinforcing plan of action. |
| **CONTINUOUS COMMUNICATION** | Consistent and open communications is needed across the many players to build trust, assure mutual objectives, and create common motivation. |
| **BACKBONE SUPPORT** | Creating and managing collective impact requires a separate organization(s) with staff and a specific set of skills to serve as the backbone for the entire initiative and coordinate participating organizations and agencies. |

There also are three preconditions that must be in place prior to launch of a "*collective impact initiative—an influential champion, adequate financial resources, and a sense of urgency for change*. ***The most critical factor by far is an influential champion (or small group of champions) who commands the respect necessary to bring CEO-level cross-sector leaders together and keep their active engagement over time***.*"*[183]

## 4.2 STUDY RECOMMENDATIONS IN THE CONTEXT OF COLLECTIVE IMPACT

Recommendations from this study address the five conditions of Collective Impact as well as the three preconditions in various ways.

- Both the interim report and this final report emphasize the need for jointly-developed strategies to establish priorities relating to STEM/STW workforce development, together with collaborative partnerships in which the DoD and DIB work together to identify needs and then develop and implement programs—**building a Common Agenda**.

- Similarly, both reports emphasize a framework for evaluation and assessment of the impacts of STEM-related activities that includes **Shared Measures**. This report adopts the Collective Impact model as its framework for development of

[182] IBID.
[183] IBID.

evaluation and assessment of the recommended system of DoD-DIB collaborative partnerships operating within existing STEM ecosystems.

- The need for **Mutually Reinforcing Activities** is explicitly identified in both reports as a key attribute of successful STEM Ecosystems. For example, it has been shown that coupling between curricular and extra-curricular activities enhances learning.

- **Continuous Communication** is similarly emphasized in the context of building robust STEM ecosystems, as well as across the recommended DoD-DIB system of collaborative partnerships to be embedded within existing STEM ecosystems.

- The recommended DoD-DIB system of collaborative partnerships as envisioned provides the requisite **Backbone Support** to coordinate participation among DoD and DIB organizations.

In terms of the preconditions, the interim report recommended that the DoD CTO, together with DIB counterparts, serve as **champions** through development of a joint strategy to drive collaboration. This report similarly recommends clear executive-level messaging to set the 'tone at the top'—conveying the importance of DoD-DIB collaboration in building the clearable technical workforce needed for defense missions now and in the future. **Financial resources** were discussed largely in the context of establishing the Backbone Support organizations (the network of nonprofit organizations envisioned to coordinate STEM education-related activities). And both reports attempted to instill a **sense of urgency for change** describing the perceived benefits of DoD-DIB collaboration and developing a case for action.

### 4.3 THE PATH AHEAD

This report recommends several 'pilot' efforts intended to **lay the groundwork** for a major DoD-DIB collaborative initiative and to **catalyze broader action**. Additionally, this study identified opportunities to engage the broader national security community, which also needs a STEM-competent clearable technical workforce to support current and future missions—opening the door to additional collaborative partners in the future.

Although discussed at length in this report, additional work is needed to develop more specific engagement strategies arising from the need for a **clearable** technical workforce, particularly for PreK-8 populations. While still challenging, it is somewhat simpler to conceive of engagement opportunities for secondary and post-secondary populations as described in this report. **But the need remains to inspire and engage the PreK-8 population that feeds those populations.**

Further, while recommendations have emphasized engagement with existing STEM ecosystems, issues of prioritization remain. Existing ecosystems exhibit varying degrees of maturity and cohesion and offer opportunities to connect to differing demographic populations. Additional work is needed both to identify the existing ecosystems most likely to be well-aligned with DoD-DIB priorities as well as to develop criteria that might

inform future decisions regarding engagement.

Additionally, as noted earlier in this report, parts of rural America are unlikely to be engaged by STEM ecosystems, and the same is true for military-connected families living abroad. Concerted efforts are needed to engage these populations—leveraging virtual means to supplement sparse options for in-person engagement.

Finally, while both reports recommended joint DoD-DIB development of STEM workforce-related strategies, the study team recognizes the immensity of the challenge. While essential for efficient prioritization of workforce development investments, it may be necessary to adopt more incremental approaches (e.g., efforts underway relating to advanced manufacturing and emerging technologies). But in doing so, it will be crucial to develop a common lexicon that supports overall workforce planning. It is unclear if there are mechanisms in place to drive the convergence of such activities.

# APPENDIX A: ABBREVIATIONS

| | |
|---|---|
| A&S | Acquisition and Sustainment |
| AEOP | Army Education Outreach Program |
| AFRL | Air Force Research Laboratory |
| ASD (M&RA) | Assistant Secretary of Defense for Manpower and Reserve Affairs |
| ATE | Advanced Technological Education |
| BGCA | Boys and Girls Clubs of America |
| CEO | Chief Executive Officer |
| CREW | Classified Ready Employee Workforce |
| CTO | Chief Technology Officer |
| DE&I | Diversity, Equity and Inclusion |
| DIB | Defense Industrial Base |
| DoD | Department of Defense |
| DoDEA | Department of Defense Education Activity |
| DSEC | Defense Science, Technology, Engineering, and Mathematics Education Consortium |
| FIRST | For Inspiration and Recognition of Science and Technology |
| GEMS | Gains in the Education of Mathematics and Sciences |
| GSTSA | Greater Southern Tier STEM Academy |
| HBCU | Historically Black Colleges and Universities |
| HSI | Hispanic Serving Institutions |
| IBAS | Industrial Base Analysis and Sustainment |
| ITC | Institute of Technology at Syracuse Central |
| JROTC | Junior Reserve Officers' Training Corps |
| MOS | Military Occupational Specialty |
| MPP | Mentor-Protégé Program |
| MSI | Minority Serving Institutions |
| NAF | National Academy Foundation |
| NAICS | North American Industry Classification System |
| NCES | National Center for Education Statistics |
| NDAA | National Defense Authorization Act |
| NGO | Nongovernmental Organization |
| NMSI | National Math and Science Initiative |
| NPS | Naval Postgraduate School |
| NSF | National Science Foundation |
| NSTC | National Science and Technology Council |
| O&M | Operations & Maintenance |
| ORNL | Oak Ridge National Laboratory |
| OSBP | Office of Small Business Programs |

| | |
|---|---|
| OSD | Office of the Secretary of Defense |
| P-TECH | Pathways in Technology Early College High School |
| PTAC | Procurement Technical Assistance Centers |
| R&E | Research and Development |
| S&E | Science and Engineering |
| SBIR | Small Business Innovation Research |
| SEAP | Science and Engineering Apprenticeship Program |
| SLECoP | STEM Learning Ecosystems Community of Practice |
| STEM | Science, Technology, Engineering, and Mathematics |
| STTR | Small Business Technology Transfer |
| STW | Skilled Technical Workforce |
| TIES | Teaching Institute for Excellence in STEM |
| USD(R&E) | Under Secretary of Defense for Research and Engineering |
| USMA | U.S. Military Academy |
| VET TEC | Veterans Employment Through Technology Education Courses |

# APPENDIX B: GLOSSARY

| Term | Definition |
|---|---|
| Defense Industrial Base (DIB) | The DIB is the worldwide industrial complex that provides products and services that are essential to mobilize, deploy, and sustain military operations. The DIB consists of more than 100,000 companies and their subcontractors. |
| DoD Components | Tri-Services /Services plus the Fourth Estate (DoD Agencies) |
| DoD STEM[184] | All forms of education, training, and outreach about the natural, physical, mathematical, and social environments and the use and transfer of tools, technologies, processes, and mechanisms to better preserve national security and support the mission of U.S. warfighters. |
| Educational Institutions[184] | Educational agencies, colleges, universities and any other nonprofit institutions that are dedicated to improving science, technology, mathematics, and engineering education. |
| Facilities | Military installations and DoD laboratories and centers |
| Internship[184] | An official or formal program that provides practical experience (paid or unpaid) in an occupation or profession to a student at the secondary through post graduate level for a specified period of time at a location within the Defense enterprise. |
| Military installation | Military base |
| Outreach | Efforts designed to build awareness, develop relationships, and promote education products and services that support formal or classroom-based education, as well as informal education that occurs outside the classroom including the providing of services to people who might not otherwise have access to those services. |
| Program evaluation[184] | A systematic study using research methods to collect and analyze data to assess program operations and outcomes. Program evaluation results may be used to assess a program's effectiveness, identify how to improve performance, or guide resource allocation. |
| Skilled Technical Workforce[185] | Occupations that require a high-level of knowledge in a technical domain but do not require a bachelor's degree. |

[184] DoD Instruction 1025.11 DoD STEM Education Programs and Activities. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/102511p.pdf?ver=2020-08-26-102256-227

[185] National Science Board (2021). *The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers.* https://ncses.nsf.gov/pubs/nsb20212

| | |
|---|---|
| STEM education programs and activities[186] | Formal or informal education that is primarily focused on physical and natural sciences, technology, engineering, social sciences, and mathematics disciplines, topics, or issues (including environmental science education or stewardship). STEM education includes one or more of the following as the primary objective:<br>• Develop learners' knowledge, skill, or interest in STEM.<br>• Attract students to pursue certifications, licenses, or degrees (two- year degrees through post-doctoral degrees) or careers in STEM fields.<br>• Provide growth and research opportunities for post-secondary, college and graduate students in STEM fields, such as working with researchers or conducting research that is primarily intended to further education.<br>• Improve mentor/educator (K-12 pre-service or in-service, post- secondary, and informal) quality in STEM areas.<br>• Improve or expand the capacity of institutions to promote or foster STEM fields.<br>• Support research on effective STEM teaching and learning practices. |

[186] DoD Instruction 1025.11 DoD STEM Education Programs and Activities. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/102511p.pdf?ver=2020-08-26-102256-227

# APPENDIX C: INTERIM REPORT FINDINGS AND RECOMMENDATIONS

The sections that follow provide findings drawn from earlier observations together with recommendations that lay the groundwork to enable effective DoD-DIB collaboration on STEM/STW activities needed to expand and diversify the STEM talent pool and develop the clearable technical workforce needed to support future defense missions.

The Findings and Recommendations provided in this report are incomplete in that there are a number of topics that will benefit from more in-depth exploration; those topics are summarized in Chapter 7 and will be addressed in the final report from this study.

### Recommendation 1 - Address Shared Risks via DoD-DIB Collaboration

**Finding 1**

***DoD and the DIB share common risks regarding the availability of a clearable technical workforce to meet defense missions, but there is no plan in place to mitigate those risks.***

As noted in Chapter 1, concerns regarding projected shortfalls in the U.S. STEM/STW workforce are growing. While projections specific to the technical workforce required to support defense missions over the coming years are not available, it seems evident that this sector, too, will increasingly confront tight labor markets, particularly for clearable talent and technical skills that are in high demand in commercial markets. In House Report 16-333, which recommended this study, the conferees noted their belief that "*a strong partnership between the defense industry and the Department of Defense can stimulate efforts to increase that pool of STEM talent*."

This study found that although the DoD and its industrial base share common risks stemming from projected shortfalls in the STEM/STW workforce, there is no mechanism in place to support collaborative efforts to address those risks. Additionally, while both DoD and DIB organizations are implementing diverse arrays of STEM/STW interventions, there is no way to assess the impact of their individual or collective efforts on the available talent pool.

The Defense Industrial Base is designated as one of 16 critical infrastructures under the National Infrastructure Protection Plan. Presidential Policy Directive 21: Critical Infrastructure and Resilience "*calls on the Federal Government to advance a unified national effort to strengthen and maintain secure, functioning, and resilient critical infrastructure.*"[187]

A recent report by the President's National Infrastructure Advisory Council, titled "Workforce and Talent Management Study", found that: "***Lack of coordination between the public and private sectors and across all levels of government hampers critical infrastructure workforce development***."[188] This study provides

[187] Cybersecurity & Infrastructure Security Agency. https://www.cisa.gov/supporting-policy-and-doctrine

[188] "Workforce and Talent Management Study", NIAC, September 2021. https://www.cisa.gov/publication/national-infrastructure-advisory-council-workforce-and-talent-management-study Accessed 23 December 2021.

additional support for this finding, and emphasizes the urgent need to address public/private sector coordination specific to development of the technical workforce needed to support defense missions now and in the future.

The Department of Defense is the Sector Risk Management Agency for the DIB Sector. The most recent DIB Sector-Specific Plan was published in 2010 (2015 Defense Industrial Base Sector-Specific Plan is pending)[189], and includes a letter of acknowledgement signed by the Chairman of the DIB Sector Coordinating Council indicating their support for plan implementation. That plan update was motivated in large measure by mutual concerns regarding cybersecurity issues, and addresses training and education only in terms of plan implementation, with an emphasis on anti-terrorism awareness, computer security awareness, and cyber investigations training.

The DoD should employ a similar approach now and engage the DIB Sector Coordinating Council to address strategic risks stemming from technical workforce availability. Doing so also would also support **identification of specific points of contact for the DIB organizations that "opted in" to the effort, thus enabling development of more robust ways to collaborate to build the needed STEM/STW talent pool**.

**Recommendation 1**

***DoD should, in coordination with Congress, acknowledge Technical Workforce Availability as a strategic risk to defense missions and mobilize an effort to update the DIB Sector-Specific Plan accordingly.***

The Under Secretary of Defense for Research and Engineering (USD(R&E)), as the DoD's Chief Technology Officer (CTO), should be designated to lead this effort, which should both characterize the risks for various time horizons and identify actions needed to mitigate those risks and promote resiliency. This effort should be initiated in the near term; acknowledging that it will take some time to complete, action on other recommendations in this study should proceed as soon as DIB partners are identified.

**Recommendation 2 - Amplify Impacts via System of STEM/STW Ecosystems**

**Finding 2**

***There exists no operational framework to create linkages, share resources, or coordinate activities in ways that would amplify impacts and support outcome-based assessments.***

As observed in Chapters 2 and 3, both DoD and the DIB are sponsoring and/or implementing a wide array of STEM/STW-related activities. Although a few DoD-DIB collaborative efforts were identified, the study found that **the current landscape could best be characterized as a thousand points of light – each activity individually meritorious, but with the collective failing to deliver synergistic impacts**.

[189] https://www.cisa.gov/2015-sector-specific-plans

This study also found that in order to develop true collaborative partnerships, those in which DoD and DIB partners work together to identify needs and to address those needs, an operational construct is needed that supports collaboration while respecting the distinct roles of public and private sector entities. Such a construct does not today exist.

The development of local and regional STEM ecosystems is underway across the country; both DoD and DIB organizations are engaged in a number of these initiatives, which are delivering value to local communities. These efforts do not, in general, provide targeted support for military-connected families[190]; they do not effectively enable DoD-DIB collaborative efforts; and they do not support holistic assessments of the impacts from DoD-DIB collaborative efforts. This study therefore recommends adoption of the approach outlined in Section 5.2 A Vision for Future DoD-DIB Collaboration. **This effort should be led by USD(R&E), as DoD's CTO, in collaboration with DIB CTOs (or their designated representatives).**

**Recommendation 2**

***DoD should, in collaboration with the DIB, establish a system of local STEM/STW ecosystems that directly supports military-connected families and other high-priority populations.***

Establishment of the DoD-DIB Central Coordination Organization[191] (CCO) is a necessary first step as it is instrumental in setting priorities and developing the system-level collaborative agreements between the DoD and the DIB partners that opt to participate.

Early actions should include identification of several military installations that have in the surrounding community significant representation by DIB partner organizations. Based on observations from this study, it is likely that both DoD and DIB organizations will already be engaged in STEM outreach activities that can be leveraged to mobilize a collaborative effort. This study recommends starting with 4 to 6 geographically distributed installations with diverse mission emphasis, and thus diverse workforce needs; the DSEC regional hubs should be considered for inclusion in this first phase. Initial evaluations should characterize what already exists in each locale, including potential partner institutions and community organizations, and determine the optimal path forward to establish the collaboratively-operated system of local STEM/STW ecosystems described in Section 5.2. It is envisioned that the system would be built out over time, initiating the development of several additional STEM/STW ecosystems each year while also guiding and assessing the maturation of the existing local ecosystems.

A Local Coordinating Organization (LCO) would be established for each local STEM ecosystem to provide local governance and promote local collaboration among DoD and DIB organizations in that region. The LCO is also envisioned to be a small nonprofit

[190] The DSEC regional hubs do provide targeted support for military-connected families; these hubs would provide valuable platforms to accelerate the launch of a more robust collaborative partnership.
[191] As indicated in Section 5.2, the CCO is envisioned as a small 501(c)(3) nonprofit organization whose Board includes executive-level representatives from both DoD and DIB organizations.

organization whose Board includes representatives from local DoD and DIB organizations as well as local educational institutions to ensure that focus on local community needs is maintained.

**Early attention to an information-sharing backbone is of vital importance** as it not only enables efficient operations through resource sharing (potential cost-savings for both DoD and DIB partners), but also affords opportunities to capture lessons-learned and assessment information.

The CCO also should establish the top-level assessment framework as well as the awards program for the system (see Recommendation 6). Finally, **provision of core funding to support both the CCO and LCOs is vital to success**, and a grants program to support high-priority local initiatives on a competitive basis is strongly recommended.

**Recommendations 3 and 4 - Increase Focus on the STW**

The growing importance of the STW was highlighted in Chapter 1, yet in reviewing both DoD activities (Chapter 2) and assessing DIB activities (Chapter 3) it was noted that few efforts are underway that directly focus on building the STW. There are, however, several public-private partnerships that are implementing initiatives that help address this shortfall; Manufacturing USA (See Section 2.2.4) provides one set of examples, and the P-TECH 9-14 School Model (Section 3.3.7.11) provides another.

**Recommendation 3**

***DoD STEM should, in collaboration with the DIB, develop an alliance of Community Colleges and Technical Institutes to expand STW offerings of particular interest to the DoD and its industry base.***

Opportunities exist to more effectively engage Community Colleges/Technical Institutes in building the STW needed for defense missions. Engagement with such institutions provides additional value in that they often reach underserved/ underrepresented populations that are a priority for diversification of the talent pool.

This study recommends development of an alliance with Community Colleges and Technical Institutes, with emphasis on institutions reaching underserved/ underrepresented populations and military-connected families. **Ideally, such institutions would be partners in a local DoD-DIB STEM ecosystem**; when this is not feasible, attention is needed to establish and sustain a strong connection to defense missions. Offerings should include 2-year degree programs, certificate programs, and micro-credential programs suitable for

**Finding 3**

***Current STEM outreach activities of both DoD and the DIB emphasize College/ University engagement significantly more than Community College/ Technical Institute engagement.***

workforce development. Career path priorities should be developed in collaboration with the DIB, targeting near- and mid-term STW needs. DoD-DIB should work collaboratively with the educational institutions, providing financial support, materiel support, and technical support as needed, to develop high-priority curriculum and course materials as well as pathways to employment.

While creating robust career pathways for the STW targeting defense missions is an important first step, financial assistance is needed for prospective students who wish to pursue such pathways. The DoD and DIB fund a variety of scholarship programs, but few support students pursuing STW careers.

**Finding 4**

***Scholarships available via the DoD and DIB disproportionately emphasize College/University programs at the undergraduate/graduate levels.***

The DoD and the DIB have targeted efforts underway to expand post-secondary educational opportunities for underserved/underrepresented populations as well as military-connected students, but few of those efforts directly support attainment of Community College/Technical Institute Degrees and/or Credentials needed to join the STW for defense missions.

This study recommends creation of a new scholarship program that supports development of the STW. This program should be in addition to the existing DoD scholarship funding rather than diminishing the current program, which remains of vital importance.

**Recommendation 4**

***A new scholarship program should be established under the National Defense Education Program to provide scholarships for Community College/ Technical Institute students pursuing STW careers in fields of high priority to DoD and the DIB.***

**Scholarships should be available for students pursuing DoD-DIB STW career pathways at one of the alliance partner institutions**. Applicants could include high school seniors who engaged in DoD-DIB STEM activities, including those who had summer internships as well as community college/ technical institute students from priority populations who demonstrate interest and commitment to pursue a high priority STW pathway leading to a degree, certificate, or other recognized credential. **Service requirements stemming from scholarships awarded could be satisfied with either DoD or DIB employment.**

Additionally, a dedicated scholarship pool should be established to support reskilling/upskilling of veterans.

**Recommendation 5 - Expand Existing Programs to Emphasize STEM/STW**

Well-established DoD programs that today do not directly emphasize the STEM/STW

workforce could be expanded to do so, adding new opportunities for important populations already engaged by the DoD.

Programs identified during this study included SkillBridge and JROTC, both of which are integral to workforce development in support of defense missions and also were mentioned by DIB organizations as collaborative opportunities.

**Finding 5**

***There are DoD-funded, education-related programs in place that today do not emphasize STEM/STW skills, which are increasing in importance.***

SkillBridge currently supports 180-day internships/apprenticeships for transitioning service members in partnership with DIB organizations. **DoD should consider expanding SkillBridge to enable transitioning service members to pursue a Certificate or Micro-Credential program in a DoD-DIB career pathway either in lieu of, or in addition to, the internship opportunity.** This could be accomplished through the Community College/Technical Institute alliance described in Recommendation 3, and also could leverage DoD educational institutions that offer Certificate programs.

JROTC programs exist both nation-wide and internationally and deliver a high-value, well-established curriculum that includes coursework on leadership, civics, geography and global awareness, health and wellness, language arts, life skills, and U.S. history. **The Army and Air Force should consider expanding JROTC to include an extracurricular technical track to inspire Cadets to pursue STEM/STW career paths**. This might, for example, include a DoD-funded internship for high school students at a local DIB facility in addition to other extracurricular STEM-related activities (which could be adapted from other existing DoD STEM interventions). The ongoing demonstration program between the Air Force JROTC Headquarters and the nonprofit, “CS4ALL” that is working to bring Computer Science education into the JROTC curriculum at several pilot schools might also be leveraged. Lessons learned from this process could inform the development of a more holistic extracurricular STEM track for Cadets.

**Recommendation 5**

***DoD should examine SkillBridge and JROTC, and seek expansion to explicitly incorporate high-priority technical pathways.***

**Recommendation 6 - Expand STARBASE via DoD-DIB Collaboration**

STARBASE (see Section 2.2.1) is a well-established DoD program with an infrastructure (including nonprofit organizations) in place that allows for combination of government and private sector resources. Evidence that this is occurring was provided by survey results and corroborated by DoD, but the examples were relatively small in scale

**Finding 6**

***While the DIB sometimes participates in STARBASE activities, it has no role in shaping the program.***

and seemed to derive from fortuitous connections rather than programmatic strategy.

STARBASE has evolved since inception and now includes interventions that are a part of a local school's curriculum as well as extracurricular activities and summer programs. STARBASE conducts an annual review of its activities and employs an evidence-based approach to assess the effectiveness of its programs. **This program would be of high value in the envisioned local STEM/STW ecosystems, and already has a presence in many military-connected communities.** While a list of potential new-start locations exists, the program is currently resource-limited and not well-positioned to plan for ongoing expansion. A collaborative partnership with the DIB might enable expansion via in-kind support, financial support, and coordinated volunteerism.

**Recommendation 6**

***DoD should seek to move STARBASE to a full DoD-DIB collaborative partnership to enable ongoing program expansion.***

DoD should emphasize collaboration with industry in the STARBASE program as a way to encourage a culture of partnerships, while also opening the door to new opportunities for program expansion. Metrics and other indicators should be collected to evaluate progress in building the collaboration as well as impacts on program effectiveness.

**Recommendation 7 - Create Awards Program to Incentivize Collaboration**

**Finding 7**

***Private sector organizations often link STEM outreach activities to corporate brand, for example "giving back" or "corporate citizenship."***

There is a truism attributed to Frank Blake, former CEO of Home Depot, that "*you get what you celebrate*."[192] Given that the top-level goal derived from the study mandate is to diversify and expand the pool of STEM/STW talent for defense missions through collaborative partnerships between DoD and the DIB, then **celebrating partnerships that work is a powerful path to transitioning the culture from implementation of stove-piped portfolios to collaborative partnerships** that provide mutually-reinforcing interventions and amplify collective impacts.

One driver for private sector organizations to fund STEM-related activities, as observed in Chapters 3 and 4, is to burnish their brand - in their communities, among their employees, and in the eyes of their customers.

A corresponding way to incentivize DIB collaboration with DoD on STEM/STW activities is to publicly recognize and celebrate successful collaborative partnerships (Level 4), thus further raising the profile of DIB philanthropy.

[192] https://jhsfocus.org/2018/07/09/you-get-what-you-celebrate/

**Recommendation 7**

***DoD should work with the DIB to create an annual awards program celebrating "excellence in DoD-Industry STEM/STW collaborations."***

The awards program should be sponsored and hosted at the highest possible level of DoD in order to generate the greatest incentive for industry participation. For example, an annual awards program held at the White House with senior civilian and military leaders involved in the presentation would encourage leaders in industry to prioritize DoD-DIB collaborative partnerships in their STEM programs throughout the year.

The program could be structured as a series of regional award events leading to a national event. Awards should be given in broad categories to encourage different types of partnerships. For example, there should be categories of awards for large and small corporations, perhaps one for "best regional partnership" or one focused on "best training partnership for manufacturing skills".

Additionally, given the importance of volunteers who support implementation of STEM outreach activities (both DoD and DIB), the awards program should include a component that recognizes individuals (and teams) whose volunteer efforts contributed substantially to the success of DoD-DIB collaborative partnerships. Both government and DIB personnel should be eligible for this type of recognition.

This awards program should provide the structure for the awards program described in Recommendation 2 regarding the system of local STEM/STW ecosystems.

**Summary**

The recommendations provided in this report do not comprehensively acknowledge the many excellent STEM outreach activities already underway in both the DoD and DIB organizations. The intent of this report is to lay the groundwork to motivate and enable a transition to DoD-DIB collaborative partnerships in an effort to scale up exceptional programs, amplify collective impacts, focus more clearly on high-priority populations, and provide a path to system-level assessments that lets both DoD and the DIB better understand the return on their investments over time.

# APPENDIX D: STUDY GROUP MEMBERS

## Dinesh Verma

Dinesh Verma is the Executive Director of the Systems Engineering Research Center (SERC), the first University Affiliated Research Center established by the DoD for Systems Engineering Research. He is also a Professor in Systems Engineering at Stevens Institute of Technology as well as the Scientific Advisor to the Director of the Embedded Systems Institute in Eindhoven, Holland. Prior to this role, he served as the Dean of the School of Systems and Enterprises at Stevens institute of Technology (2007 -2017), as well as the Technical Director at Lockheed Martin Undersea Systems, in Manassas, Virginia, in the area of adapted systems and supportability engineering processes, methods and tools for complex system development and integration.

Before joining Lockheed Martin, Verma worked as a Research Scientist at Virginia Tech and managed the University's Systems Engineering Design Laboratory. While at Virginia Tech and afterwards, Verma continues to serve numerous companies in a consulting capacity, to include Eastman Kodak, Lockheed Martin Corporation, L3 Communications, United Defense, Raytheon, IBM Corporation, Sun Microsystems, SAIC, VOLVO Car Corporation (Sweden), NOKIA (Finland), RAMSE (Finland), TU Delft (Holland), Johnson Controls, Ericsson-SAAB Avionics (Sweden), Varian Medical Systems (Finland), and Motorola. He served as an Invited Lecturer from 1995 through 2000 at the University of Exeter, United Kingdom. His professional and research activities emphasize systems engineering and design with a focus on conceptual design evaluation, preliminary design and system architecture, design decision-making, life cycle costing, and supportability engineering. In addition to his publications, Verma has received one patent and has two pending in the areas of life-cycle costing and fuzzy logic techniques for evaluating design concepts.

Dr. Verma has authored over 100 technical papers, book reviews, technical monographs, and co-authored two textbooks: Maintainability: A Key to Effective Serviceability and Maintenance Management (Wiley, 1995), and Economic Decision Analysis (Prentice Hall, 1998). He is a Fellow of the International Council on Systems Engineering (INCOSE), a senior member of SOLE, and was elected to Sigma Xi, the honorary research society of America. He serves as a member of the External Advisory Board on Systems Engineering at SAIC, on the Systems Engineering Advisory Council (SEAC) of the Systems and Software Consortium, and the Advisory Board of the Center for Systems Engineering at the Air Force Institute of Technology

## Ruth David

Dr. Ruth A. David is a private consultant and currently serves as Secretary/Treasurer for the International Council of Academies of Engineering and Technological Sciences (CAETS). She also serves on an advisory committee for the Systems Engineering Research Center (SERC), a DoD-sponsored UARC.

She previously served on the Defense Science Board and the National Science Board,

and also has served on technical advisory bodies for Lockheed Martin Corporation, Lucent Technologies, the Jet Propulsion Laboratory, the Institute for Defense Analysis, the Lawrence Livermore National Laboratory, the Senate Select Committee on Intelligence, the Department of Energy's Nonproliferation and National Security program, the Securities and Exchange Commission, the Council on Competitiveness, and several universities.

She retired in 2015 after serving as President and Chief Executive Officer of Analytic Services Inc. (ANSER) since 1998. ANSER is an independent, nonprofit corporation that provides research and analytic support to the national security, intelligence, and homeland security communities.

From 1995 to 1998, Dr. David was Deputy Director for Science and Technology (DDS&T) at the Central Intelligence Agency. As technical advisor to the Director of Central Intelligence, she was responsible for research, development, and deployment of technologies in support of all phases of the intelligence process. During her tenure as DDS&T she conceptualized a new nonprofit corporation that could speed CIA's adoption of commercially viable technologies; In-Q-Tel was subsequently established to fulfill this role.

Previously, Dr. David served in several leadership positions at the Sandia National Laboratories, where she began her professional career in 1975.

Dr. David was elected to the National Academy of Engineering (NAE) in 2002 and was designated a lifetime National Associate of the National Research Council (NRC) in 2008. She was elected to a four-year term as NAE Foreign Secretary in 2015; as an officer of the NAE she also served on the NAE Council. She was the founding chair of the NRC Board on Global Science and Technology as well as the NRC Technology Insight Gauge Evaluate Review (TIGER) Standing Committee, and has served on numerous study committees.

Dr. David holds a B.S. in Electrical Engineering from Wichita State University and both M.S. and PhD degrees in Electrical Engineering from Stanford University.

**Jeff Wilcox**

Jeffrey (Jeff) Wilcox is a retired aerospace executive with 32 years of industry experience, culminating in the position of Vice President for Digital Futures at Lockheed Mar- tin. In that role he was responsible for the future-of-work portfolio and served as the champion for catalyzing change across the Lockheed Martin enterprise. His team was chartered with building and casting the Lockheed Martin transformation vision and creating the space for change to take hold and flourish across the corporation.

Previously, Mr. Wilcox served as Lockheed Martin's Founding Vice President for Digital Transformation, where he was responsible for the design, development, and implementation of Lockheed Martin's strategy for entering Industry 4.0. He led the effort to rethink how the organization could leverage emerging digital technologies to transform systems design, production, and sustainment. Delivering unique and

innovative strategies, he also worked to ensure the workforce and systems were in place to enable successful transformation.

Mr. Wilcox has also served as the Vice President for Engineering and Program Operations for Lockheed Martin where he was responsible for the effectiveness and efficiency of the engineering, program management, production operations and sustainment functions across the enterprise. Mr. Wilcox also served as Vice President for Corporate Engineering at Lockheed Martin, and, prior to joining Lockheed Martin, he served for 17 years with Science Applications International Corporation (SAIC).

Mr. Wilcox earned his Bachelor of Science degree in biomedical engineering from Case Western Reserve University and his Master of Science degree in electrical engineering from Drexel University. He holds an honorary doctorate of engineering from Stevens Institute of Technology.

**Lester Lyles**

General Lester L. Lyles received his B.S., in mechanical engineering from Howard University in 1968, his M.S. in mechanical / nuclear engineering from New Mexico State University in 1969, and Honorary Doctorate of Laws degrees from New Mexico State University in 2002, and Urbana University in 2009. He is a graduate of the Defense Systems Management College (1980), the Armed Forces Staff College

(1981), the National War College (1985), and the National and International Security Management Course at Harvard University (1991).

General Lyles entered the United States Air Force in 1968 as a distinguished graduate of the Air Force ROTC program. He served in various assignments, including Special Assistant and Aide- De-Camp to the Commander of Air Force Systems Command; and, Avionics Division Chief in the F-16 Systems Program Office. He served as Program Director of the Medium-Launch Vehicles Program and Space-Launch Systems offices in 1997 during the recovery from the Challenger Space Shuttle accident.

General Lyles became Vice Commander of Ogden Air Logistics Center, Hill AFB, Utah. He served as Commander of the center from 1993 until 1994, then commanded the Space and Missile Systems Center at Los Angeles AFB, Calif., until 1996. General Lyles became the Director of the Ballistic Missile Defense Organization in 1996. In May 1999, he was assigned as Vice Chief of Staff at Headquarters U.S. Air Force. In April 2000, he became the Commander, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio. The command conducts research, development, test and evaluation, acquisition management services and logistics support for the Air Force. He retired in October 2003.

The General has received many awards and decorations including the Defense Distinguished Service Medal, the Distinguished Service Medal, the Defense Superior Service Medal, and the Legion of Merit with oak leaf cluster. He was named Astronautics Engineer of the Year by the National Space Club in 1990, and received the Roy Wilkins Renown Service Award for outstanding contributions to military equal

opportunity policies and programs from the NAACP in 1994. He was named Black Engineer of the Year / Lifetime Achievement in 2003. Gen. Lyles received the “General Thomas D. White Award” for distinguished service in national security, from the U.S. Air Force Academy in 2012.

He serves on the Board of Directors for several corporations, including General Dynamics Corp., KBR Corp., Battelle Labs. (Battelle Memorial Institute), and United Service Automobile Association (USAA). General Lyles is currently Chairman of the Board of USAA

General Lyles served on the Augustine Space Committee in 2009 developing the agenda for the Human Space Flight missions of NASA. He also chaired the National Research Council’s ‘Roles and Rationale Study of the U.S. Civil Space Programs’ in 2009. General Lyles was appointed to the Defense Science Board from 2009 to 2016, and, appointed by the White House to the President’s Intelligence Advisory Board from December 2009 to May 2013. General

Lyles was elected to the National Academy of Engineers in March of 2011. From 2013-2017 General Lyles served as a member of the State Department’s International Security Advisory Board. He served as chair of the Aeronautics and Space Engineering Board for the National Academy of Engineering from 2012 to 2016. He was named the Chairman of the NASA Advisory Council in 2016. In June 2018 General Lyles was appointed as a member of the Users Advisory Group to the National Space Council.

General Lester L. Lyles was born in Washington, DC on 20 April 1946. He currently lives in Vienna, Virginia

**Carrie Kisker**

Dr. Carrie B. Kisker is an education research and policy specialist with Kisker Education Consulting in Los Angeles, California. Drawing from her own and others' research, she regularly consults with college leaders on issues related to entrepreneurship and innovation, program and policy development, strategic planning and accountability, civic learning and democratic engagement.

In addition to her consulting work, Dr. Kisker runs the Center for the Study of Community Colleges, a nonprofit organization that engages in and supports research related to community college practice and policy. Working through the Center, Dr. Kisker has conducted several national investigations of transfer and articulation reform, civic learning and democratic engagement, and deliberative practices in community colleges.

Dr. Kisker is author of numerous books, chapters, research reports, journal articles, and other publications on issues related to community college practice and policy. Her most recent book is Creating Entrepreneurial Community Colleges, A Design Thinking Approach (Harvard Education Press, 2021). Previous books include The American Community College (Jossey-Bass, 6th ed., 2014) with Arthur M. Cohen and Florence B. Brawer and The Shaping of American Higher Education: Emergence and Growth of the

Contemporary System (Jossey-Bass, 2nd ed., 2010) with Arthur M. Cohen. She has also co-edited two volumes of New Directions for Community Colleges (Jossey-Bass, 2013 and 2016).

Dr. Kisker holds a B.A. in psychology and education from Dartmouth College, and an M.A. and Ph.D. in higher education from the University of California, Los Angeles. She sits on the board of the Council for the Study of Community Colleges, a scholarly association comprised of university-based researchers and community college practitioners dedicated to furthering community college scholarship.

**Michael Gazarik**

As the vice president of Engineering at Ball Aerospace, Dr. Mike Gazarik is responsible for overall strategic and operational leadership of the organization, which includes all disciplines of engineering, as well as program and project execution, capital investments, internal research and development and intellectual property.

Prior to this position, he served as Technical Director, where he worked to align Ball's technology development with business development and growth strategies. Gazarik brings more than 25 years of experience in the design, development and deployment of spaceflight systems. He joined Ball from NASA Headquarters, where he held the position of Associate Administrator for the Space Technology Mission Directorate.

He has contributed to the development of technology with application to NASA's exploration, space operations and science missions. In standing up the Space Technology Mission Directorate at NASA Headquarters, he led NASA's rapid development and incorporation of transformative technologies that enable the agency's missions and address the nation's most difficult challenges.

Prior to joining NASA, Gazarik served as project manager for the Geosynchronous Imaging Fourier Transform Spectrometer project at the Massachusetts Institute of Technology's Lincoln Laboratory. He also led the development of the Airborne Sounder Testbed-Interferometer, an instrument that helps scientists understand temperature and water vapor profiles of the Earth's atmosphere. Gazarik has worked in the private sector on software and firmware development for commercial and government applications including telecommunications and signal processing.

For his contributions, Gazarik has received numerous awards, including NASA's Outstanding Leadership Medal and a Silver Snoopy Award, one of NASA's highest honors. He is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a member of various university advisory boards. He also serves on the NASA Advisory Council (NAC) Technology, Innovation and Engineering Committee.

Gazarik received a B.S. in electrical engineering from the University of Pittsburgh, a M.S. in electrical engineering from the Georgia Institute of Technology, and a Ph.D. in electrical engineering from the Georgia Institute of Technology.

### Heather Bulk

Heather Bulk is the chief executive officer and co-founder of Special Aerospace Services, SAS Flight Factory, and Rocket Apparel. She is also a co-founder of the Who Dreams Wins foundation.

Since 2007, Ms. Bulk has overseen the strategic direction and business performance of these aerospace and space/aviation companies and non-profit. Her focus is on strategy, leadership, and impact for all entities.

SAS, a woman-owned, Certified 8(a), small business and its wholly owned subsidiary, SAS Flight Factory, have roughly 100 employees across the United States. SAS engages in long term partnerships with its clients by providing critical guidance, tactical engineering, precision manufacturing, and assembly and testing for mission-essential hardware. The Companies provide innovative aerospace solutions to the aerospace industry, NASA, the U.S. Department of Defense, and the emerging commercial spaceflight sector.

Prior to her leadership at SAS, Heather spent over 17 years as a senior executive in financial and estate planning to some of the country's most affluent families and business owners. She completed her Executive Juris Doctorate degree in 2007, and holds a Masters in Taxation (LLM) from the University Of Denver, and a Bachelor of Science degree (Finance) from CSU, Chico. She maintains her Certified Financial Planner Designation and compliance.

In 2018, Ms. Bulk and her daughter launched Rocket Apparel, a clothing and accoutrement company that lends a fashion sense to the wardrobes of aerospace professionals and enthusiasts.

As a leader in the business community, Ms. Bulk represents SAS in the space and aviation community through advocacy and the voice of a small business. One of her key representations is her critical role as an Executive Board Member of the Aerospace Industries Association. She is also a member of YPO, representing a global community of executives committed to the shared mission of becoming "Better Leaders through Lifelong Learning and Idea Exchange." Ms. Bulk also sits on the MSU Denver Foundation Executive Board and focuses her emphasis on STEM and classroom to career. She is a passionate STEM supporter and is actively engaged in bringing science and education together through direct interaction in Boulder County and Denver schools.

Ms. Bulk and her family have created the Who Dreams Wins Foundation, which fosters STEM education and provides scholarships and technology to those in need.

### Payuna Uday

Dr. Payuna Uday is a Research Scientist at the Systems Engineering Research Center (SERC). Her research in systems engineering aims to improve decision-making within

the context of designing and operating large-scale, complex systems. She is particularly interested in exploring interdisciplinary approaches to develop tools and metrics that better inform strategies and policies.

She received her Ph.D. and master's degrees from the School of Aeronautics and Astronautics at Purdue University. She also holds B. Tech. in electronics and communication engineering from the National Institute of Technology in Trichy, India. Prior to her current position, she was a Senior Consultant at Landrum & Brown working on air transportation systems, specifically airfield and airspace planning for major U.S. airports.