OverSTEMulated

The Science and Art of Space Power Leadership

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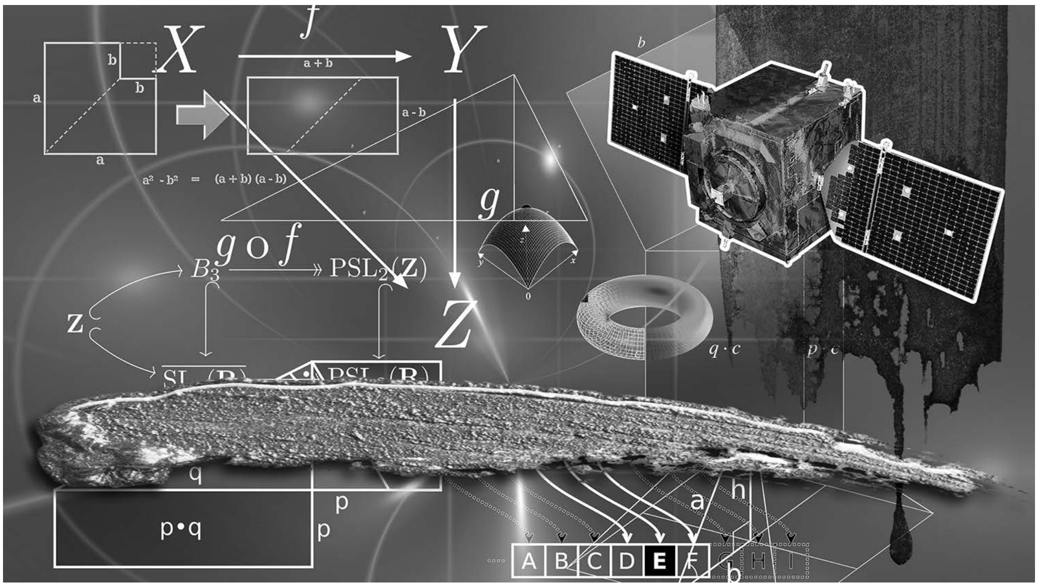
No one can select from the bottom those who will be the leaders at the top because unmeasured and unknown factors enter into scientific, or any, leadership. There are brains and character, strength and health, happiness and spiritual vitality, interest and motivation, and no one knows what else, that must need enter into this supra-mathematical calculus. We think it much the best plan, in this constitutional Republic, that opportunity be held out to all kinds of conditions of men whereby they can better themselves.

Vannevar Bush,
Science, The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research, 141



Introduction

In this article, we examine the US Air Force (USAF) and United States Space Force's (USSF) decision to require science, technology, engineering, and math (STEM) degrees for the space operations officer career field, as well as whether STEM-degreed space officers historically rise to the top of their respective peer group, evidenced by being selected for squadron command. A decision to place educational quotas on officer accessions excludes a large and diverse group of potential officers, so it is imperative that the requirements align with a desired outcome. To evaluate STEM requirements empirically, we examine two multiyear studies conducted by *Google*, the RAND Corporation's findings on Air Force STEM requirements, and our own cursory analysis of space operations officer performance data. We find that STEM degrees are not useful predictors of competitive selection for space operations command positions, nor are they useful for predicting performance within peer groups.[1] Aside from not predicting success in the space operations career field, two significant risks emerge as a result of overemphasis on STEM:

1. Diversity (Demographic and Cognitive). Demographically, women and some minorities (primarily Black and Hispanic populations) are underrepresented in STEM fields; STEM requirements also preclude a greater diversity of thought and experience. Diversity enhances the formulation of soft skills, leads to greater innovation, and enhances overall team performance.

2. Supply. Initial analysis suggests that the space operations career field is not meeting target accession numbers specified in the *Air Force Officer Classification Directory*, and the available pool of eligible officers will continue to shrink as the Air Force's cyber career field has now instituted STEM requirements as well.[2]

Background

During the last 20 years, the US has been barraged by reports that American students are falling behind global competitors in education, specifically in the production of STEM graduates. US students have also performed poorly in the last several decades on administered standardized tests that measure STEM skills compared to students around the world.[3] With the emergence of China, India, and others as global powers, the disparity in STEM education can appear to be a significant weakness for the US, compared to its potential competitors. The Department of Education has allocated tens of millions of dollars toward STEM education in the last 20 years and maintains that "if we want a nation where our future leaders, neighbors, and workers have the ability to understand and solve some of the complex challenges of today and tomorrow, and to meet the demands of the dynamic and evolving workforce, building students' skills, content knowledge, and fluency in STEM fields is essential."[4] As a result, STEM education has captured the attention of national security decision-makers and has fostered a sense of urgency for corrective action; however, research suggests that United States' obsession with STEM might have gone too far and potentially sacrifices qualities that have been integral to the US' growth as a global superpower in the last 100 years.[5] The USAF has similarly prioritized STEM—and several officer career fields, including space operations—and have implemented STEM requirements for their new accessions.[6] The USSF has inherited these STEM requirements and, as a result, could be in danger of losing its greatest strength—diverse and agile leadership. All of these efforts and expenditures appear to be in the best interest of national defense and the continued prosperity of the US, yet the far-reaching and long-lasting implications of these decisions deserve to further scrutiny.

At face value, STEM requirements seem entirely logical, particularly when considering the highly technical nature of space operations. It is reasonable to assume that technically minded college graduates would not only excel but be necessary to lead the growing number of complex space mission sets. In fact, the 2001 Space Commission made this recommendation explicitly, citing similar requirements in the Navy nuclear officer career field.[7] At least part of this logic is based on an Air Force artifact where officers, not enlisted, are the primary operators of military systems (i.e., airplanes). Shortly after the Air Force's creation, enlisted pilots were converted to officers and warrant officer ranks were removed from the service entirely. In the space operations community, however, it is common practice for officers and enlisted members to perform the same or similar crew functions, despite STEM requirements only applying to officer operators. If the USSF intends to carry this practice forward into its new service, where officers will continue to be both technical and tactical experts, the advancing nature of emerging space technology may necessitate a technical education. Currently, it is unclear whether baccalaureate degree programs are the best source of that education, nor does this address the enlisted crew members who have no such accession requirement. The Air Force space operations career field management team did not put mechanisms in place to assess past and present performance of non-STEM graduates in the career field, nor were assessments made on the most critical factors that determine optimal utility, so there are no existing data to indicate whether a STEM education is indeed fundamental to effective space operations leadership. For reference, other highly technical operations career fields within the Air Force specifically chose not to impose STEM requirements as their analyses showed STEM education was not causal or even positively related to performance in those career fields.[8]

Before 2012, the Air Force's space operations officer career field, usually referred to by its specialty code of "13S," accepted officers with any undergraduate degree specialization. However, with the emergence of competition between nation states—particularly in the space domain—along with increasing complexity of systems and threats, many senior leaders believed that 13S officers of the future would need to be far more technically competent than their mostly non-STEM educated predecessors. To address this perceived gap, the 13S career field management team added STEM constraints for officers entering their field in 2012. The restrictions mandated that new accessions would need to meet STEM prerequisites through their baccalaureate or graduate degree programs to access into the 13S career specialty. Specifically, the guidance mandated that greater than or equal to 80 percent of new accessions *should* be sourced from a selection of particularly useful STEM degrees (identified as Tier 1 and 2), and less than or equal to 20 percent *could* come from any bachelor or master of science degree (Tier 3).[9] Any officer candidates outside these STEM thresholds would be placed elsewhere in the service. If similar constraints apply to the USSF, candidates falling outside these thresholds would not be considered for employment.

Significant Risk, Questionable Return

At this point, it is important to revisit the risks incurred by continuing to focus on STEM at the exclusion of other degrees: diversity and supply. The value of diversity is now widely acknowledged in the military and society. Diversity fuels innovation, enhances performance, empowers the collective, and raises our moral standard, enabling organizations to avoid common pitfalls like groupthink and overconfidence.[10] While commonly assessed against demographic data, it is also relevant to consider diversity of thought, beliefs, and experience. Unfortunately, STEM requirements cull diversity in all of its many forms. Women, as well as Black and Hispanic students, are underrepresented in the STEM fields, while Asian/Pacific Islanders are overrepresented from a demographic standpoint.[11] As a result, any restrictions on hiring STEM graduates inherently limits diversity simply as a result of participation. A valid argument against STEM restrictions could be made on that fact alone. While many efforts are underway to increase minority interest and participation in STEM fields, ultimately, the numbers still reflect that certain demographic groups are more likely to pursue STEM education. Instead of the USSF hoping that this trend will change, recognition of the current environment is crucial to efforts of recruiting and retaining a more diverse service. In addition to demographic constraints, STEM policies also inhibit the diversity of thought, experience, and beliefs that candidates outside of STEM have to offer. This type of diversity can be enhanced by selecting officers from a variety of different majors, regions, schools, commissioning sources, and so forth.

Another factor to consider is whether the supply actually exists to continue enforcing STEM requirements for new accessions. Figure 1 (below) compares actual accessions by tier to Air Force target accession percentages. Over the three years of available data, actual accessions were substantially behind target. Moving forward, the Air Force's cyber operations career field now requires STEM degrees for 90 percent of their accessions, and that will eat into the available pool for 13S in the future. Additionally, other science and engineering career fields in the USAF and USSF (developmental engineers, scientists, statisticians, etc.) require

STEM degrees. Combined with the already low number of STEM graduates in America (thinking back to the original crisis), the ability to meet target accession numbers for STEM in the 13S career field is tenuous at best.

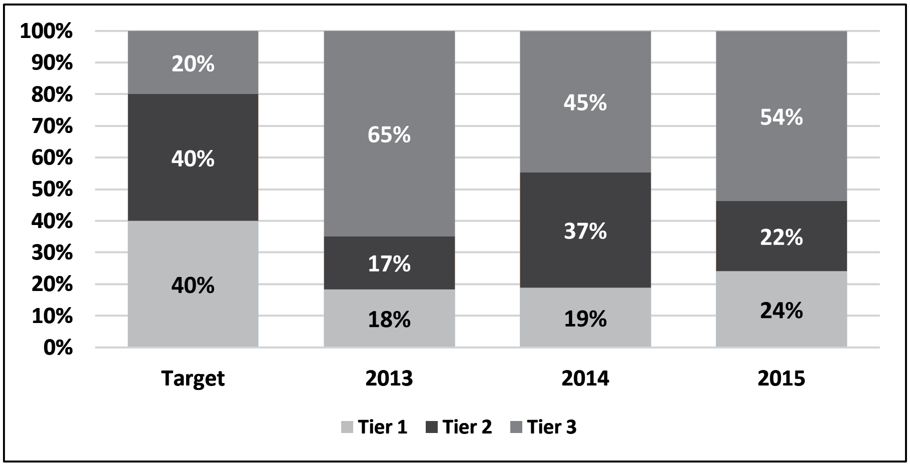


Figure 1. Accession goals versus actual accessions for 2013–15 year groups

There are certainly mechanisms that could be put in place to meet accession numbers, if required, such as diverting STEM graduates exclusively to career fields with STEM requirements or mandating higher numbers of STEM majors for college scholarship recipients or US Air Force Academy students. However, the real question is whether the data supports such a requirement to begin with, and the answer is no. It is also unlikely that the future will change that fact. On the contrary, future conflicts will add pressure on kill chains to operate at machine speed and many of the tasks performed by human space operators today will be automated.[12] Machine learning and artificial intelligence are already changing the way we collect, interpret, and act upon data. In addition to reducing cognitive load and human error, this will be a requirement due to the evolution in the speed and conduct of warfare. In an increasingly computerized and automated environment, the importance of leadership and other nontechnical skills will be magnified. The ability to perform calculations on the fly without computer aid is not only improbable, but a terrible use of a human operator's limited cognitive processing ability. Instead, the humans that occupy operations floors of the future must be strong communicators, they must be calm under pressure, creative, empathetic, and decisive. These are not skills intrinsically linked to STEM education.

The recent Congressional *Future of Defense Task Force Report 2020* identified both the issues with diversity in STEM education and the limits on STEM supply and applied the findings to the US security apparatus' ability to develop a twenty-first century workforce. The task force ultimately concluded that "when gaming out the future of defense, the US must seek to leverage the capabilities of all of its citizens," which is a clear call to action to recognize strengths from a variety of demographic and educational backgrounds.[13]

Research Data on STEM Requirements

The RAND Corporation conducted a study in 2014 that focused on STEM requirements across Air Force career fields. The report states that career field managers generally "value officers with STEM degrees," and this preference is based upon a belief that these officers excel in critical thinking and problem-solving. However, the report goes on to say that "this preference may be unfounded since the evidence of a difference in critical thinking and problem-solving skills between science graduates and graduates in the social sciences/humanities is not conclusive (see, e.g., Arum and Roska, 2011)."[14] Additionally, RAND did not find a preference for STEM in other operations career fields. For example, the rated community (flyers) that includes pilots, combat systems operators, and air battle managers, from which the vast majority of the Air Force's senior leaders have ascended, "observed that a STEM degree is not necessary for effective performance as a rated officer." Instead, they found that "while a STEM degree may provide some advantage in the academic portions of initial training, problem-solving, multitasking, and stress-management skills are more important for performance and progression."[15] The RAND STEM report concluded with a recommendation that the Air Force "develop evidence-based methods to assist Career Field Managers in refining academic degree requirements for their functional areas" and "develop a more precise and visible framework. . . to know more precisely whom it needs to recruit, access, and classify."[16] It is unclear if this was ever accomplished for the 13S career field, but this article could be the first step toward rectifying that issue.

The findings of the rated community are also supported by several studies from the private sector, academia, and prior experiments with this type of narrow focus. The studies demonstrate that STEM requirements alone are not useful for predicting future success, even in technical career fields or organizations. Instead, these studies show that STEM requirements limit diversity, tamper innovation, and can hinder overall performance. In his recent book *Range: Why Generalists Triumph in a Specialized World*, David Epstein demonstrates how our obsession with specialization is unfounded, and that diversity of thought, experience, and beliefs allow generalists to "triumph in a specialized world."[17]

These challenges are not new for military leadership, nor are they specific to the United States. The Royal Navy made a push toward "technocrat" leaders before World War I and one admiral "almost lost the war through his obdurate quest for technical solutions to the U-boat problem."[18] The technocrat leaders of the Royal

Navy proved incapable of decisive leadership in battle and instead grasped for technical safety nets, which are what they knew best. Critics for this period of misguided naval force management warned the late twentieth century Royal Air Force against committing the same errors by conflating the technical nature of their work with the importance of broader leadership ability and perspective.[19] Now it's time for the USSF to appreciate and heed this warning.

The private sector has experienced similar challenges with too narrow a focus on STEM requirements, including one of the most tech savvy organizations on the planet, Google. Since its inception, Google has placed a premium on hiring the best possible candidates and selecting individuals capable not just of evolution, but revolution. Fittingly, Google initially used algorithms to identify and hire the best computer science graduates in the world, but as the company grew, cooperation and communication proved to be as valuable to success as coding. In a robust analysis of more than 15 years' worth of hiring and performance data, Google's Project Oxygen showed that out of the top eight traits that led to success at Google, STEM skills came in last. The skills that were most important were actually "communicating and listening well; possessing insights into others; being a good critical thinker and problem solver; and being able to make connections across complex ideas." The most important factor to success will not come as a surprise, being a good coach or leader.[20] As a result of the findings, Google expanded their hiring to include more liberal arts, humanities, and business graduates.

A skeptical reader might say that it is obvious that in a company full of STEM graduates, the defining characteristics for success must be soft skills as they would be most differentiated. However, that line of thinking still concedes that tech savvy alone is not sufficient to effectively lead large and complex technical organizations, nor optimally effective teams. Additionally, Google did not stop with the results of Project Oxygen and instead sought greater insight into the characteristics of their highest performing teams. Project Aristotle examined Google's most innovative and successful teams, as well as decades worth of academic literature on team performance. The results showed that teams filled with the top-performing individuals who excelled in STEM actually performed worse than "B-teams" filled with a mixed bag of performers that also tended to be more soft-skill dominant. The researchers cited numerous reasons for this outcome, but, in general, A-teams were filled with individuals that sought to optimize efficiency and output while continuing to operate as individuals even when working as a collective. As a result, the net intelligence of the group was no higher than the individual members. On the B-teams, though, information exchange and empathy were key tenets, which contributed to improved performance overall.[21]

The aforementioned studies enabled Google to adjust hiring practices, leadership selection, and team composition, but that is not to say that Google suffered nothing during their STEM-blinded period. One of Google's most elite teams, Product Management, had a firm requirement that all employees needed a computer science degree. Three notable employees tried to join the team to bring forward good ideas while working for Google but were barred admittance due to not meeting the hard-coded computer science requirement. Frustrated by the erroneous prohibition, these employees chose to leave Google to pursue their good ideas elsewhere; Biz Stone went on to cofound Twitter, Ben Silbermann founded Pinterest, and Kevin Systrom cofounded Instagram.[22] Who has the 13S community turned away in the last eight years? Who will be turned away in the future?

To assess the performance of space operations officers by degree, we were given access to personnel rankings for the 2013–15 year groups. These groups fall after the STEM requirements were implemented, so our analysis has limitations. However, the data allowed us to examine personnel by specific degrees, which could be bucketed into the tiers established by the Air Force Officer Classification Directory for the 13S career field. The Tier 3 degrees serve as a sort of proxy for non-STEM in this analysis, despite the fact that all tiers have to meet basic STEM coursework requirements, even if their degrees were not STEM. To evaluate performance of graduates with no STEM requirements, we also looked at command selection in the space operations career field for 2017, as all of these officers entered the career field many years before STEM requirements were implemented. Unfortunately, the data is flawed for a different reason, as we do not have a sense of the total inventory of STEM vs. non-STEM for the year groups eligible for command in this selection. Regardless, we believe the data is convincing enough to overcome some of these limitations, and at the very least demand further analysis with more complete databases.

The board scores for space operations officers in the 2013–15 year are roughly distributed equally across year groups and across degree tier and major (see fig. 2). Additionally, all year groups have non-STEM graduates in the top third of performers and STEM graduates in the bottom third and vice-versa (see fig. 3). No significant advantage or performance improvement exists for any tier, which at the very least demonstrates that the tiered accession targets are not meaningful in the space operations career field.

When digging deeper into individual performance, the success of non-STEM majors is evident across all year groups. All year groups have non-STEM graduates in the top 10 officers and also Tier 1 graduates in the bottom 10 officers by ranking.[23] The key takeaway from all of the performance data is that people can be successful (or not) regardless of what they studied in college. What many have failed to consider is that majoring in non-STEM fields is not necessarily indicative of any lack of ability in learning and understanding STEM.

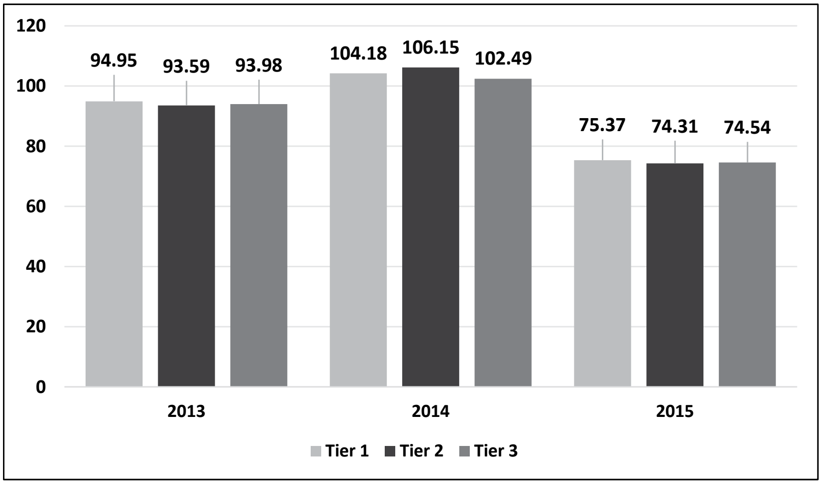


Figure 2. Average board score by degree tier and year group

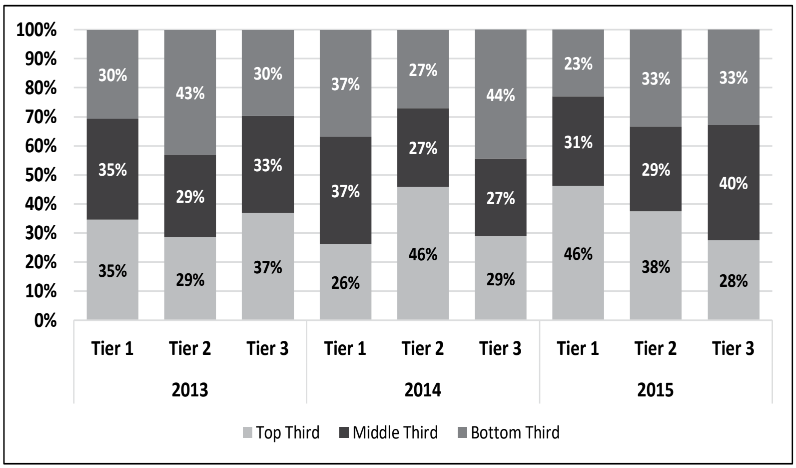


Figure 3. Percentage of education tier in each ranking third, by year group

The Vigilant Eagle board is the process used by the space community to select its squadron commanders, which is arguably the most pivotal leadership position in the USAF and USSF. If ever there was an indicator of success in a given career field, and the community's confidence in the competence, potential, and effectiveness of an individual, squadron command is that litmus test. The 2017 Vigilant Eagle board selected 24 people for command; only four out of the 24 commanders selected had STEM degrees, and only one of the four STEM majors started their career as a 13S. Said differently, one officer out of 21 who entered the service as a 13S and was selected for command had a STEM degree. The other three selected for command began their careers as engineers and/or program managers in the acquisition career field. These officers and their peers are the ones who are currently on the frontlines of space operations. They are leading the transformation that we believe is so demanding of STEM education, yet they are doing it without STEM degrees. Either the supply of STEM in the 13S career field for these year groups was so low that there simply were not STEM graduates to select for command, or there is more to leadership in space operations than a STEM degree.

The argument being made here is not that non-STEM grads are more effective leaders, because that claim is equally erroneous. Rather, the data show that non-STEM officers can not only survive but thrive as 13S leaders, as well as in virtually any other USAF or USSF career field. Artificially limiting the potential diversity, innovation, and performance of future space operations units based on assumptions about the inferiority or incapability of non-STEM graduates not only limits the potential to include more diversity of thought and experience, but it also potentially weakens joint power projection. It is incumbent upon all leaders to be willing to continuously evaluate assumptions and adjust fires if needed.[24]

Conclusion

Leadership is both an art and science, and the future USSF officer corps would be most effective as a diverse and balanced team trained and educated to lead across all areas. Ten years from now, the people making these decisions will be retired and counting on the rest of us to continue to lead and succeed. To do so, we need to recruit and retain the best possible people, who embody not only the science of leadership but the art as well. Leadership is essential to continued military power projection and its relationship to deterring conflict. The USSF needs a diverse team of leaders who are motivated and willing to work hard but, even more so, are skilled at leading diverse teams to address dynamic challenges at a pace that outmatches the competition. To ensure success across this diverse team, we should focus on rigorous initial training and continuous education. There are no data that support an argument that a STEM major will be more successful in military technical training programs than a non-STEM major. Even if that were the case, leadership ability is mostly linked to the successful employment of soft skills that are frequently a focus of non-STEM education. ✪

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Notes

1. The transition of space operations officers from the Air Force to the newly established Space Force is currently in progress, but the Space Force will likely continue the STEM requirements for new space operations officer accessions.

2. The military already competes with commercial and other entities for STEM graduates in the US. This competition affects the supply of STEM officers to all services. Our assessment is based on the number of STEM graduates who are entering the Air and Space Forces.

3. National Center for Education Statistics, *International Data Explorer* (Washington, DC: Department of Education, accessed 20 July 2020), https://nces.ed.gov/.

4. US Department of Education, *Science, Technology, Engineering, and Math, Including Computer Science* (Washington, DC: Department of Education, accessed 29 June 2020), https://www.ed.gov/.

5. Alexandra Ossola, "Is the U.S. Focusing Too Much on STEM?" *Atlantic,* 3 December 2014, https://www.theatlantic.com/; Fareed Zakaria, "Why America's Obsession with STEM Education is Dangerous," *Washington Post,* 26 March 2015, https://www.washingtonpost.com/; Laura McInerney, "A Misguided Obsession with STEM Subjects Is to Blame for the Decline in English A-Levels," *Guardian,* 16 July 2019, https://www.theguardian.com/; and Colin Seale, "A Perfect Time To End Our STEM Obsession: 3 Ideas for Teaching Critical Thinking at Home During (and after) The Coronavirus Pandemic," *Forbes,* 15 March 2020, https://www.forbes.com/.

6. National Research Council, *Examination of the U.S. Air Force's Science, Technology, Engineering, and Mathematics (STEM) Workforce Needs in the Future and Its Strategy to Meet Those Needs* (Washington, DC: National Academies Press, 2010); and Lisa M. Harrington et al., *Air Force-Wide Needs for Science, Technology, Engineering, and Mathematics (STEM) Academic Degrees* (Santa Monica, CA: RAND Corporation, 2014), 113.

7. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington DC: US Government Printing Office, 2001), 45.

8. There are no STEM requirements for pilots, combat systems operators, air battle managers, special operations officers, or intelligence officers. The intelligence community actually prioritizes liberal arts (45 percent) over STEM (30 percent), though they still allow any degree to join the career field. Cyber operations have recently added STEM requirements with 90 percent supposed to be sourced from STEM, while 10 percent can come from any degree. Air Force Personnel

Center (AFPC), *Air Force Officer Classification Directory (AFOCD)* (Randolph AFB, TX: United States Air Force, 2017), 244–49.

9. AFPC, *AFOCD,* 246–47.

10. Toyah Miller and Maria Del Carmen Triana, "Demographic Diversity in the Boardroom: Mediators of the Board Diversity–Firm Performance Relationship," *Journal of Management Studies* 46, no. 5 (July 2009): 755–86; Christian R. Østergaard, Bram Timmermans, and Kari Kristinsson, "Does a Different View Create Something New? The Effect of Employee Diversity on Innovation," *Research Policy,* April 2011, 500–09; and Irving L. Janis, *Victims of Groupthink: A Psychological Study of Foreign-Policy Decisions and Fiascoes* (Boston: Houghton Mifflin, 1972).

11. Amanda L. Griffith, "Persistence of Women and Minorities in STEM Field Majors: Is It the School That Matters?" *Economics of Education Review* 29, no. 6 (December 2010): 911-22; and Eugene Anderson and Dongbin Kim, *Increasing the Success of Minority Students in Science and Technology* (Washington, DC: American Council on Education, March 2006).

12. Mady Mayfield, "Air Force Envisions AI Automating Satellite Operations," *National Defense Magazine,* 4 December 2019, https://www.nationaldefensemagazine.org/; and US Small Business Administration (SBA), *Autonomous Satellite Ground Operations* (Washington, DC: SBA, 2016), https://www.sbir.gov/.

13. US House of Representatives, House Armed Services Committee, *Future of Defense Task Force 2020* (Washington, DC: US House of Representatives, 23 September 2020), 55.

14. Harrington et al., *Air Force-Wide Needs,* xiii.

15. Harrington et al., *Air Force-Wide Needs,* xiii.

16. Harrington et al., *Air Force-Wide Needs,* xiv.

17. David Epstein, *Range: Why Generalists Triumph in a Specialized World* (New York: Penguin, 28 May 2019).

18. Andrew Gordon, *Military Transformation in Long Periods of Peace: The Victorian Royal Navy* (Cambridge, UK: Cambridge University Press, 2006), 161.

19. Gordon, *Military Transformation,* 161.

20. Valerie Strauss, "The Surprising Thing Google Learned about Its Employees—and What It Means for Today's Students," *Washington Post,* 20 December 2017, https://www.washingtonpost.com/.

21. Charles Duhigg, "What Google Learned From Its Quest to Build the Perfect Team," *New York Times,* 25 February 2016, https://www.nytimes.com/.

22. Kim Scott, *Radical Candor: Be a Kick-Ass Boss without Losing Your Humanity* (New York: St. Martin's Press, 2017).

23. For example, three of the top 10 officers in the 2013 year group have business management (non-STEM) degrees, while two of the bottom five have aerospace engineering (Tier-1 STEM) degrees.

24. Academic literature is filled with examples of seemingly valid indicators of success that do not withstand the gauntlet of real-world application. Famously, Kahneman and Tversky's work on predicting the success of officer candidates in Israeli Defense Force training programs and repeatedly failing led them to identify, publish, and popularize the bias of the "illusion of validity" (Kahneman [2016]; Lewis [2013]; etc.). From a US perspective, Angela Duckworth's best-selling book *Grit: The Power of Passion and Perseverance* details her analysis of indicators of success for candidates of the United States Military Academy. She, too, found that measures that might seem relevant at face-value often do not play out as expected (Duckworth [2016]). These examples

highlight the fact that decisions are often made by well-meaning and entirely capable leaders based on logical assumptions that ultimately do not pan out in reality. Daniel Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus, and Giroux, 2013); Michael Lewis, *The Undoing Project: A Friendship That Changed Our Minds* (New York: W. W. Norton and Company, 2016); and Angela Duckworth, *Grit: The Power of Passion and Perseverance* (New York: Scribner, 2016).