Incentivizing Innovation

Promoting Technical Competency to Win Future Wars

James E. Bevins

Despite numerous studies and initiatives, most current Air Force efforts to add science and technology talent have been insufficient. This begs the question: How does the Air Force incentivize and promote the necessary technical competence required to win future competition, conflicts, and wars? Several key initiatives, grounded in behavioral economics, can incentivize innovation and pursue science and technology expertise. Developed in the context of peer adversaries' actions; global trends in technology, competition, and conflict; and the global competition for science and technology talent, these recommendations have the potential to reform institutional culture and unleash the creativity and talent of the officer corps, thereby strengthening the US military's technical competency to fight and win future wars.

"Learning and innovation go hand in hand. The arrogance of success is to think that what you did yesterday will be sufficient for tomorrow."

—C. William Pollard, *The Soul of the Firm* (1996)

The Air Force embodies this ethos of learning coupled with innovation through its commitment to real-world training and continuing and professional military education. For science and technology (S&T) competency, however, often the reverse is true: advanced education, innovation, and S&T professional engagement opportunities are limited and can be seen as an impediment to one's career.[1]

The military has a storied history of developing leaders, innovators, and entrepreneurs.[2] For example, S&P 500 CEOs are almost three times as likely to have been military officers as not, and companies led by former officers outperform their peers.[3] Unfortunately, many of these CEOs left the service early, along with a deluge of other talented officers. Surveys of current and former officers indicate a vast majority—93 percent—believe "half or more of 'the best officers leave the military early rather than serving a full career.'"[4]

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1. James Joyner, "Soldier-Scholar (Pick One): Anti-Intellectualism in the American Military," War on the Rocks, August 25, 2020, https://warontherocks.com/; Tim Kane, *Bleeding Talent* (New York: Palgrave Macmillan, 2012); and National Research Council (NRC), *Examination of the US Air Force's Science, Technology, Engineering, and Mathematics (STEM) Workforce Needs in the Future and Its Strategy to Meet Those Needs* (Washington, DC: The National Academies Press, 2010), 37.
2. Kane, *Bleeding Talent*, 59–84.
3. Tim Duffy, *Military Experience and CEOs: Is There a Link?* (Los Angeles: Korn Ferry International, 2006).
4. Tim Kane, "Why Our Best Officers Are Leaving," *Atlantic*, January–February 2011, https://www.theatlantic.com/.

This attrition is attributed to the military's perceived anti-intellectual bias, an anti-entrepreneurial career ladder that stifles innovation, and better opportunities to leverage an individual's talent outside of the military.[5]

Paradoxically, S&T innovation is consistently highlighted by senior leaders and strategic guidance alike as the key to winning future wars. Secretary of the Air Force Frank Kendall has stated we are facing peer competitors that demand attention to strategic and technical superiority.[6] In 2019, then-Secretary of the Air Force Heather Wilson launched the 2030 *Science and Technology Strategy* noting, "The advantage will go to those who create the best technologies and who integrate and field them in creative operational ways that provide military advantages."[7] In August 2020, newly appointed Chief of Staff of the Air Force General Charles Q. Brown Jr. published his directive to the Air Force to "accelerate change or lose."[8]

Importantly, these comments reflect existing formal, strategic guidance. For example, the unclassified *Summary of the 2018 National Defense Strategy* states "the drive to develop new technologies is relentless . . . and moving at accelerating speed . . . advanced computing, 'big data' analytics, artificial intelligence, autonomy, robotics, directed energy, hypersonics, and biotechnology . . . ensure we will be able to fight and win the wars of the future."

These Department of the Air Force and DoD strategies call for a stronger pipeline of technology-proficient Airmen capable of elevating S&T advocacy and rapidly adapting to the unpredictable nature of revolutionary or disruptive technologies.[9] As a former Air Force senior acquisition professional has highlighted, "The answer is not going to be airplanes, ships, [or] ground vehicles. The answer is going to be the fastest and most agile system, to build whatever. . . . The future is too uncertain to say, 'We know how to beat China in 2030, 2035'. . . . If you don't know what the future is, be agile."[10]

Rephrased, an agile Air Force will achieve the next offset in strategic advantage by requiring broad-based, rigorous, ongoing education to develop a concentration of officers

5. Joyner, "Soldier-Scholar"; Paul Yingling, "A Failure in Generalship," *Armed Forces Journal* (May 1, 2007); and Kane, *Bleeding Talent*.

6. Edie Williams, "Department of Defense Laboratories: Recalibrating the Culture," *Air & Space Power Journal* 35, no. 4 (Winter 2021): 23.

7. Heather Wilson, "Op-Ed: USAF Secretary on the Future of Science and Tech in the Air Force," *Popular Mechanics*, April 18, 2019, https://www.popularmechanics.com/; and Department of the Air Force (DAF), *Science and Technology Strategy: Strengthening USAF Science and Technology for 2030 and Beyond* (Washington, DC: DAF, April 2019), https://www.af.mil/.

8. Charles Q. Brown Jr., *Accelerate Change or Lose* (Washington, DC: DAF, August 2020).

9. DAF, *2030 and Beyond*; and James N. Mattis, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: Department of Defense, January 2018).

10. Greg Hadley, "Former Air Force Acquisition Chief: DOD Should Leverage 'Revolving Door' in New Ways," *Air Force Magazine*, October 7, 2021, https://www.airforcemag.com/.

with science, technology, engineering, and math (STEM) and critical thinking skills capable of addressing real-time emerging technological challenges.[11]

A former senior policy advisor to John McCain observed, "The irony is that much of what is said today is strikingly similar to what has been said for the past three decades."[12] Clearly, the translation of strategic guidance to action developing the expertise that "ensure[s] we will be able to fight and win the wars of the future" is mixed at best. On one hand, the recent Department management initiatives and action orders emphasize organic expertise to "accrue advantage in military-technological competition."[13] On the other hand, Department priorities do not specifically list innovation, agility, or developing S&T talent to maintain the Air Force's current technological edge.[14]

Similarly, one must strain to find strong advocacy for S&T talent and innovation in the Chief of Staff of the Air Force priorities or the Secretary of the Air Force imperatives.[15] This disconnect is important because, as the director of the Defense Innovation Unit said in 2021, for the most part, current efforts to add S&T talent are "insufficient," illustrated by the fact that the percentage of officers with STEM degrees has not appreciably increased since 1976, counter to global trends.[16] The lack of explicit prioritization and action has ensured the status quo, which has resulted in insufficient military officer S&T talent, poor retention, and a belief that the advanced education was not valued.[17]

Research has shown that serial innovators, companies consistently ranking in the top 50 for innovation, have a few common characteristics: innovation is a top-three priority, investments are made in innovation, and these investments are increased in times of financial constraints.[18] Currently, all three of these characteristics are lacking for Air Force officers, a shortcoming that will not be addressed overnight. As retired Army colonel Paul

11. National Intelligence Council (NIC), *Global Trends 2040: A More Contested World* (Washington, DC: Office of the Director of National Intelligence (ODNI), March, 2021); and Chad Bollmann et al., "Education Is the Next Offset," *Proceedings* 146, no. 11 (November 2020), https://www.usni.org/.

12. Christian Brose, *Kill Chain* (New York: Hatchette Book Group, 2020), 76.

13. Charles Q. Brown, *CSAF Action Orders: To Accelerate Change Across the Air Force* (Washington, DC: DAF, February 7, 2022), https://www.af.mil/.

14. DAF, *DAF Priorities* (Washington, DC: DAF, 2020), https://www.af.mil/.

15. Amy Hudson, "The Next CSAF Lays Out Top Priorities," *Air Force Magazine*, June 1, 2020, https://www.airforcemag.com/; and Charles Pope, "Kendall details 'Seven Operational Imperatives' & How They Forge the Future Force," *Secretary of the Air Force Public Affairs*, March 3, 2022, https://www.af.mil/.

16. Greg Hadley, "Pentagon's Push to Build Up Technology Talent 'Insufficient,' DIU Boss Says," *Air Force Magazine*, October 21, 2021, https://www.airforcemag.com/; and Air Force Personnel Center, data pull for the author, January 20, 2022.

17. NRC, *Review of Specialized Degree-Granting Graduate Programs of the Department of Defense in STEM and Management* (Washington, DC: National Academies Press, 2014), https://nap.nationalacademies.org/; Kane, *Bleeding Talent*; and Joyner, "Soldier-Scholar."

18. Michael Ringel et al., *The Most Innovative Companies 2020: The Serial Innovation Imperative* (Worldwide: Boston Consulting Group, June 2020), https://web-assets.bcg.com/.

Yingling said, it is "unreasonable to expect that an officer who spends 25 years conforming to institutional expectations will emerge as an innovator in his late forties."[19]

In contrast, the Chinese have been actively creating incentive structures and policies to "establish a complete, unified, efficient, and open system for military-civil collaborative innovation in S&T, promote breakthroughs in S&T innovation, [and] seek advantages in military S&T" through "increased emphasis on acquiring officers with an enhanced STEM background" that enables the "close integration of military theory and military science and technology."[20] These efforts directly threaten the US technological edge on the battlefield. How, then, does the Air Force incentivize and promote the technical competence required to maintain this edge and win future competition, conflicts, and wars?

The Innovation Landscape

Future Conflict and Warfare

While the United States has enjoyed a distinct technological advantage since the end of the Cold War, this is not a given in future conflicts where adversaries will be able to counter longstanding advantages, at least in some key domains, and may even have technological superiority in others.[21] To further complicate the strategic environment, the range of adversaries and risk of conflict are projected to increase due to the spread of lethal and disruptive technologies that will erode the US military's experience advantage.

Technology agility is increasingly seen as the key to competing in an environment where technology development timelines are shrinking rapidly, ensuring an unpredictable future and rapid capability obsolescence. The resulting outcome is clear: "the most successful states will be those with governments that encourage research and innovation; promote information sharing; [and] maintain high-quality education and lifelong learning in [STEM]."[22]

19. Yingling, "Generalship."

20. Peoples Republic of China (PRC) Ministry of Science and Technology, *The "13th Five-Year" Special Plan for S&T Military-Civil Fusion Development* (2017), 3; Roy D. Kamphausen, ed., *The People of the PLA 2.0* (Carlisle, PA: US Army War College Press, 2021), 156, https://press.armywarcollege.edu/; and Song Yan, "Xi Jinping Gave a Military Banner to the National Defense University of the Academy of Military Sciences and Gave a Lecture," Xinhua News Agency, July 19, 2017.

21. Defense Science Board, *Technology and Innovation Enablers for Superiority in 2030* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2013), vii.

22. NIC, *Global Trends: Paradox of Progress* (Washington, DC: ODNI, January 2017), 53, https://www.dni.gov/; and NIC, *Global Trends 2040*.

The Rise of China

Chinese president Xi Jinping recognizes this strategic imperative stating, "science and technology is [sic] the core fighting capacity in modern warfare."[23] According to Chinese strategists, the future of warfare is "informatized" and "intelligentized" warfare that "pits states' defense strategies, systems of systems, and degree of civil-military synergy against one another."[24] A 2021 DoD annual report to Congress indicates China is seeking to master advanced technologies to become a global innovation superpower, dominate the technologies associated with the Fourth Industrial Revolution, and become a world-class military capable of intelligentized warfare.[25]

These priorities are not significantly different than the *2018 National Defense Strategy* guidance, but the implementation, prioritization, force of conviction, and pace of the People's Liberation Army (PLA) S&T modernization is striking. In fact, many are raising alarm bells that the window is shrinking, or past, to adapt to keep pace.[26] China's sheer agility is increasingly evident. For example, in 2019, the Office of the Secretary of Defense projected that the Chinese intended on maintaining a limited, ~200 nuclear-weapon-deterrent stockpile. In 2021, this was projected to increase to 700 deliverable warheads by 2027 and 1,000 by 2030.[27]

This shift in policy is enabled by tremendous feats in engineering, innovation, and production that dwarf current US production capabilities and timelines for comparable programs such as the Sentinel missile and W87-1 warhead. The accelerated Chinese development cycle is paying dividends across multiple domains, not just nuclear weapons.

> The slowing US innovation time for new capability . . . does not compare favorably to our competitors. In 2018, Mike Griffin, the first Under Secretary for Research and Engineering, disclosed an innovation time comparison that it takes the US on average sixteen years to deliver an idea to operational capability, versus fewer than seven for China. . . . This sobering analysis implies that China accomplishes two and a quarter development and fielding cycles to every US turn. At this relative rate, any technological advantage that the US has would eventually be overcome; it is only a question of when.[28]

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23. Kamphausen, *PLA 2.0*, 163.

24. Alex Stone and Peter Wood, *China's Military-Civil Fusion Strategy: A View from Chinese Strategists* (Maxwell AFB, AL: China Aerospace Studies Institute, 2020), 6.

25. Office of the Secretary of Defense (OSD), *Military and Security Developments Involving the People's Republic of China 2021: Annual Report to Congress* (Washington, DC: OSD, November 2021), XI, https://media.defense.gov/.

26. Stacie L. Pettyjohn and Becca Wasser, "Don't Sweat the Small Stuff: Getting Force Design Right in the Next National Defense Strategy," War on the Rocks, October 12, 2021, https://warontherocks.com/; Elsa B. Kania and Emma Moore, "Great Power Rivalry Is Also a War for Talent," Defense One, May 19, 2019, https://www.defenseone.com/; and Anthony Tingle, "Army Generals Are Not Prepared for the Future," Defense One, May 22, 2021, https://www.defenseone.com/.

27. OSD, *Military and Security Developments Involving the People's Republic of China: Annual Report to Congress* (Washington, DC: OSD, 2019-2021 reports).

28. William Greenwalt, *Competing in Time: Ensuring Capability Advantage and Mission Success through Adaptable Resource Allocation* (Washington DC: Hudson Institute, 2021), 35.

This development cycle is enabled by the Chinese concept of civil-military fusion (军民融合), modeled in some respects after the US military-industrial complex. But the implementation is "more far-reaching and ambitious in scale than the US equivalent" reflecting a whole-of-government approach driven by strategic guidance.[29]

Of the six primary civil-military fusion thrusts, two focus on topics relevant to this discussion: integrating and leveraging S&T innovations across the military and civilian sectors, and cultivating talent and blending military and civilian expertise and knowledge.[30] These efforts are further supported by the fact that national defense education is imbedded by law at all levels, even down to primary education.[31] This makes the civil-military fusion goal of integrating universities, research institutes, and professional institutions into military research and development (R&D) relatively straightforward: they already are predisposed to thinking in a military context, unlike many US academicians, companies, and research institutes.

The civil-military fusion policy is further advanced by the strong People's Liberation Army emphasis on military S&T education. In the words of Jian Zemin, Chairman of the Chinese Military Commission, "The key to strengthening national defense . . . [is] bringing up a large batch of high quality, new-model, talented military personnel, and vigorously increasing the ability to make innovations in S&T."[32] Accordingly, the PLA started developing recruitment programs, ties to civilian institutions, and graduate programs in 1998 to "increase the emphasis on acquiring officers with enhanced STEM backgrounds."[33]

The emphasis on STEM education is not just academic, the goal is for them to "be able to use their knowledge on the battlefield, not in a classroom or laboratory."[34] This integration of STEM knowledge to achieve battlefield effects was accelerated in 2017 when Xi realigned the Academy of Military Sciences with a stated goal of ensuring "the close integration of military theory and military science and technology."[35]

Unsurprisingly, this focus has carried over to the PLA educational institutions. While the military has over 36 educational institutions, most of which award master and doctoral degrees, two are relevant for Air Force S&T comparison purposes: the PLA Air Force Engineering University and the PLA Rocket Force Engineering University. In total, this in-house graduate education capacity dwarfs the Air Force Institute of Technology (AFIT) with a combined student production of about three times that of AFIT. This doesn't include the multiservice National Defense University or quasi-military

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29. Lorand Laskai, "Civil-Military Fusion: The Missing Link between China's Technological and Military Rise," Council on Foreign Relations (blog), January 29, 2018, https://www.cfr.org/.
30. Stone and Wood, *Chinese Strategists*, 30–31.
31. PRC Ministry of Defense, *Law of the People's Republic of China on National Defense Education* (2021).
32. Kamphausen, *PLA 2.0*, 156.
33. Kamphausen.
34. Kamphausen.
35. Song, "Xi Jinping."

universities such as the National University of Defense Technology, which alone produces about three times as many graduate students as AFIT and the Naval Postgraduate School combined.[36]

These increased education opportunities have been coupled with increased promotion opportunities and emphasis. In 2021, the PLA announced officer reforms that simplified the officer corps to dual career tracks, increasing technical officer opportunities. Additionally, the PLA made a clear association between junior officer ranks and one's academic background, a concept similar to that currently employed for US Air Force medical officers.[37] Tellingly, it appears the PLA is "walking the walk" as 93 percent of brigade commanders, 75 percent of chiefs of staff, and 90 percent of chief engineers in the PLA Rocket Force were educated at the PLA Rocket Force Engineering University.[38]

Competition for Talent and Innovation

Globally, and in the United States in particular, the demand for S&T talent currently outpaces production, a gap that is expected to increase into the foreseeable future. The Chinese appear to have recognized that future competition and conflict success will be predicated on success in the global competition for talent, and they have completely reoriented their officer accession, education, and university structures to compete and intensify this competition.

This led to the Chinese producing more science and engineering degrees than the United States 20 years ago, and they currently produce twice the STEM graduates per capita, a gap that is widening. Exacerbating this trend is the fact that approximately 30 percent of the US STEM workforce, many graduates of US universities, are foreign born, with Chinese nationals constituting 11 percent of this group, the second leading nationality.[39]

This deficit in educational emphasis is starting to manifest itself as a deficit in innovation. While innovation is tricky to measure directly, science and engineering journal publications and patents are two important trackable metrics. By 2010, China had surpassed the United States in the total number of international patents. Currently China produces three times as many. In 2016, China surpassed the United States in total science and engineering journal publications, and China's rate of publication growth is currently 10 times that of the United States. Furthermore, US STEM research is skewed towards

36. Kamphausen, *PLA 2.0*, 181–87; and "About," National University of Defense Technology (website), accessed June 30, 2022, https://english.nudt.edu.cn/.

37. James Char, "What a Change in China's Officer Rank and Grade System Tells Us about PLA Reform," *Diplomat*, March 31, 2021, https://thediplomat.com/.

38. Kamphausen, *PLA 2.0*, 63.

39. Abigail Okrent and Amy Burke, *The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers* (Washington, DC: NSB, August 31, 2021), 71–77, https://ncses.nsf.gov/; and Burke, Okrent, and Katherine Hale, *The State of US Science & Engineering 2022* (Washington, DC: NSF, January 2022), 5–14, https://ncses.nsf.gov/.

health and social sciences, whereas China's output is dominated by engineering, physics, chemistry, and materials science.[40]

This widening gap with China comes at a time when the US government is no longer the driving factor in research and development funding. In the period following World War II, the US government was responsible for almost 70 percent of global research and development funding. Today, the US government is responsible for approximately 20 percent of domestic research and development funding.[41] Consequently, the US government and the Air Force by extension have a much smaller ability to drive the direction of innovation and ensure strong pipelines of national-security-relevant S&T expertise exist.

Unfortunately, it appears the Air Force has decided to ignore these trends when setting policies that affect the structure of the officer corps. Despite the rapid growth of STEM demand in China and across the United States, the percentage of officer accessions entering with a STEM degree has remained constant for the past 30 years, a trend replicated in the percentage of officers obtaining a STEM advanced degree. Tellingly, only about 25 percent of Air Force officer graduate degrees are in STEM fields. The number of positions coded for STEM graduate degrees has also generally been constant, although approximately 26 percent of the PhD-coded positions, mostly from operational units, have been lost in the past decade.[42]

In a one-way pipeline, these accessions and development requirements are determining the talent resources the United States will have to compete decades in the future, and the divergence of STEM emphasis in the Air Force from global trends does not bode well for maintaining technological superiority. When considering the rapidly decreasing half-life of STEM knowledge, the Air Force is faring even worse as opportunities to maintain or increase technical competency are few and far between for most Air Force officers.

For example, approximately 75 percent of the Air Force's officer STEM talent has not received additional STEM education since accession, a number that exceeds 90 percent when excluding the science and engineering career fields.[43] This is the equivalent of saying that all the military strategy necessary can be learned from commissioning sources—a premise flatly rejected based on the existence of professional military education programs. Moreover, STEM degrees are just a starting point. Those degrees must be exercised to develop innovation leaders, but few opportunities exist or are incentivized, a partial cause for irreplaceable talent bleed from the system.[44]

40. Karen White, *Publication Output: US Trends and International Comparisons* (Washington, DC: NSB, December 2019), https://ncses.nsf.gov/; and Burke, Okrent, and Hale, *Science & Engineering 2022*, 14–22.

41. Burke, Okrent, and Hale, *Science & Engineering*, 14–22; and Williams, "Recalibrating the Culture," 26.

42. Aleah M. Castrejon, "AFRL Team Works to Boost Number of Advanced Stem Degrees," Air Force Research Laboratory Public Affairs, August 15, 2022, https://www.afrl.af.mil/.

43. Air Force Personnel Center, data pull for the author, January 20, 2022.

44. Kane, *Bleeding Talent*.

Air Force Innovation Barriers

Organizational Inertia

Why has the Air Force decided not to meaningfully participate in the competition for S&T talent in its officer corps? Among the myriad of plausible reasons, behavioral economics and cognitive biases provide a useful framework to consider not only the challenges but also the solutions that turn vision into reality.

In many ways, the current predicament is entirely predictable, a perfect storm of cognitive biases and behavioral economics gone awry. Institutions are particularly vulnerable to the status quo bias that leads to system justification, a preference for the existing structure often at the expense of even considering alternatives. This is the root of Norman Dixon's "the psychology of military incompetence," which includes a "failure to use or tendency to misuse available technology," a "tendency to reject or ignore information which is unpalatable or which conflicts with preconceptions," and a "tendency to underestimate the enemy and overestimate the capabilities of one's own side."[45]

Strong shocks to the system that fundamentally challenge core beliefs are often needed to break this bias, and China's military reforms in response to the efficacy of the US military in Operation Desert Storm are an excellent example. For better or worse, the United States has not faced such a seminal moment since the 1957 Sputnik launch. This situation is compounded by the survivorship bias, "a cognitive shortcut that occurs when a visible successful subgroup is mistaken as an entire group, due to the failure subgroup not being visible."[46] Coupled with system justification, this leads to beliefs from those at the top that the system cannot have significant flaws, despite evidence to the contrary, the "after all, the system produced me" phenomenon.[47]

For example, in response to the 2021 resignation of Nicolas M. Chaillan, the Air Force's first chief software officer and subsequent critique of S&T management practices, then-Lieutenant General Duke Z. Richardson, who at the time was serving as military deputy, Office of the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics, summarily dismissed the concerns stating, "I don't know that I personally agree that we don't put the right people in charge that [don't] have the technical background. . . . We will always put people in those positions that are qualified."[48]

45. Brose, *Kill Chain*, 79.

46. "Why Do We Misjudge Groups by Only Looking at Specific Group Members?" The Decision Lab, n.d., accessed August 18, 2022, https://thedecisionlab.com/biases/survivorship-bias.

47. Ned Stark, "A Call for Senior Office Reform in the Air Force: An Insider's Perspective," War on the Rocks, May 14, 2018, https://warontherocks.com/.

48. Shaun Waterman, "Software Chief 'Dropped the Mic' as He Quit; Now Senior USAF Officials Say They're Looking into His Recommendations," *Air Force Magazine*, September 22, 2021, https://www.airforcemag.com/.

This resistance to change is fueled by a presumption that reforms will replace key "gates" in one's career: survivorship bias in action. Combined, these biases tend to ensure those most able to affect change are those most predisposed to not listen—the core of Admiral William Owens' warning that, "There are common causes for military disasters, and at the heart of them lie dangerous smugness, institutional constraints on innovation, and the tendency to avoid questioning conventional wisdom."[49]

This challenge is further complicated by the present bias where short-term payoffs are valued over future returns. The complete revamp of China's military S&T expertise and development structure has taken about 25 years to date, and there are still modifications being made to achieve their 100-year plan. To this author's knowledge, the Air Force has never embarked on a 25-year human capital reform, despite over two decades of warnings about the erosion of US technological advantage.

Recent, available experiences in Iraq, Afghanistan, and elsewhere often led to the prioritization of short term-payoffs that are unlikely to yield high returns in future near-peer conflict. Recent efforts to shift this focus have gained some traction, but S&T personnel reforms have lagged due to a combination of the previously described biases and the more immediate, high-visibility capability gaps that exist in areas such as hypersonics. In contrast, the S&T personnel structure reforms required are incremental and lack immediate, tangible warfighting impacts. But neglecting these reforms is the essence of the present bias and a root cause for the current technological challenges facing the service.

As Nobel prize-winning behavioral economist Daniel Kahneman explained, perhaps the most daunting factor to change is overcoming loss aversion, the finding that the perceived utility loss associated with giving up an object is higher than the perceived utility of acquiring that same object.[50] In this sense, this effort is worse than a zero-sum game. Funding officer corps S&T development requires a reallocation of funds and personnel time, and that allocation will be seen as painful by many. Implementing the required changes to promote the necessary STEM competency will require active cognition and use of the same biases and behavioral tendencies, while only requiring about 0.03 percent of the Air Force FY22 budget.[51]

Deincentivizing STEM Talent and Innovation

The military is paid based solely on rank and time in service. With major and lieutenant colonel promotion rates sitting at 95+ percent and 85+ percent respectively, this means a vast majority of officers serve an entire 20-year career with little distinction in economic rewards. To put this in perspective, a major with 13 years of active duty service stationed

49. William A. Owens and Edward Offley, *Lifting the Fog of War* (New York: Farrar, Straus and Giroux, 2000), 20.

50. Daniel Kahneman and Amos Tversky, "Prospect Theory: An Analysis of Decision under Risk," *Econometrica* 47, no. 2 (1979), https://doi.org/.

51. Author's calculations below and "Air Force President's Budget FY22," Air Force Financial Management and Comptroller (website), https://www.saffm.hq.af.mil/.

in Dayton, Ohio is in the top 10 percent of their respective occupational category if they are a nurse or public affairs officer. That same major is at or under the median if they are pilots, physicists, or aerospace engineers.[52]

Additionally, whereas pilots receive an additional $12,000 annually in aviation incentive pay to help close this gap, no technical proficiency pay is currently funded for S&T officers, despite being authorized since 2003.[53] As the Air Force has recognized with pilots, pure economic considerations would dictate that the Air Force should only be able to retain the average engineering officer—the top ones would leave for greener pastures.

In addition to lacking incentive pay structures for top STEM talent, there is currently no clear incentive structure for S&T innovation by Air Force officers, despite General Brown's action order to develop and incentivize the force required to "accrue advantage in military-technological competition."[54] The Chief of Staff of the Air Force guidance is consistent with industry practices that have shown that well-designed pay-for-innovation schemes increase innovation activity, and, consequently, technical proficiency of their workforce—a force multiplier that drives further innovation.[55]

In fact, 90 percent of US organizations use short-term performance incentives, the Air Force included, just not for active duty personnel.[56] Even intangible rewards, such as improved performance reports, are often missing. For most officers, any publications, patents, or other innovation products are often condensed into a single bullet on their annual performance report and carry little to no influence at promotion boards.

In contrast, China is in many ways the world leader in such incentives and has developed a sophisticated publication monetary reward system. The introduction of this system and the monetary funds allocated ($180 billion in 2013) correlate strongly with the growth in Chinese international publications and patents. This system was introduced in 1995, part of China's mid-1990s thrust to prepare for "informatized" and "intelligentized" warfare after watching the results of Operation Desert Storm, and continues to this day.[57]

52. US Bureau of Labor Statistics (BLS), *Occupational Outlook Handbook*, BLS (website), last modified July 1, 2022, https://www.bls.gov/ooh/.

53. A. J. Bosker, "Scientists, Engineers Vital to Air Force Mission," Air Force Print News, April 1, 2003, https://www.af.mil/News/.

54. Brown, *CSAF Action Orders*, 5–11.

55. Emir Kamenica, "Behavioral Economics and Psychology of Incentives," *Annual Review of Economics* 4, no. 13 (2012); Thomas Franklin, "Inventor Bonus Programs - How They Can Make or Break Your Patent Pipeline," The Future Shapers, March 23, 2021, https://thefutureshapers.com/; and Chidiebere Ogbonnaya, Kevin Daniels, and Karina Nielsen "How Incentive Pay Affects Employee Engagement, Satisfaction, and Trust," *Harvard Business Review*, March 15, 2017, https://hbr.org/.

56. Emily D. Campion, Michael C. Campion, and Michael A. Campion, "Best Practices in Incentive Compensation Bonus Administration Based on Research and Professional Advice," *Compensation & Benefits Review* 49, no. 3 (2017).

57. Wei Quan et al., "Publish or Impoverish: An Investigation of the Monetary Reward System of Science in China (1999-2016)," *Aslib Journal of Information Management* 69, no. 5 (2017).

In addition to better addressing extrinsic motivators such as money and promotion opportunities, the Air Force must address intrinsic motivators such as autonomy, mastery, and purpose, which have been shown to be significant drivers of human behavior in the twenty-first century.[58] While the Air Force provides a meaningful purpose for many, it generally provides few opportunities for intellectual creativity or autonomy and encourages generalization over mastery, resulting in less organic innovation and challenges in retaining top talent, especially when coupled with average or below-average compensation.

The resulting lack of focus on S&T innovation has led to the Department of Defense being

> repeatedly ambushed by many of the technological disruptions flowing out of Silicon Valley and the rest of the commercial world. It missed the commercial space revolution. It missed the move to cloud computing. It missed the advent of modern software development. It missed the centrality of data. And it missed the rise of artificial intelligence and machine learning.[59]

While many factors are at play, "it is hard to overstate" that these innovations were missed because the Department of Defense "simply did not understand them, or even that they were possible," mostly due to the cognitive biases and organizational inertia described above.[60] It is simply unsustainable to continue to be behind the proverbial eight ball on every major technological revolution in the past 20 years. At the same time, it is impossible to flip the narrative without empowering officers who do understand the realm of the possible and can recognize cutting-edge, game-changing technology in its infancy. The Air Force led the technological edge in the past, and it can do so again.

A Path Forward

Signaling Intent – Promotion Board Changes

To drive meaningful S&T officer human capital reforms, the stated senior-leader objectives need to be translated into strong signals that account for behavioral economics and cognitive biases to move the officer corps towards greater STEM proficiency. The first and most powerful of these signals is promotion board guidance. Given a constraint on monetary incentives, promotion guidance tends to be the single most impactful signal of senior-leader intent and driver of officer behavior.

Currently, all advanced academic degrees are masked at promotion boards below O-6 for all career fields—a clear signal opposite of the one necessary to increase the officer corps technical proficiency. The masking or unmasking of degrees has been the subject of significant debate, but this debate has missed a key component: making the type of degree matter.

58. Daniel Pink, *DRiVE* (Prestonpans, Scotland: Canongate Books, 2011).
59. Brose, *Kill Chain*, 71.
60. Brose, *Kill Chain*, 71–72.

In contrast to previous guidance, a graduate degree should not be a broad mandated requirement for promotion. In combination with unmasking of degrees at promotion boards, a floor should be set for the quantity of officers promoted with advanced STEM degrees. This floor should vary by developmental category but should be no less than the percentage of the eligible population in each development category with a graduate STEM degree, a desired long-term goal of 30 to 35 percent for major through general officers across the Air Force.

Accelerating Knowledge Development – Direct Bachelor-to-Doctorate Path

In analyzing the career development paths of 5 recent general officers with a STEM doctorate, there was one common theme: they all received their doctorate by year 9 of their careers.[61] Yet very few officers achieve their doctorate by this point as the master and doctorate developmental assignments are normally separated. Coupling increased opportunities with STEM graduate degree promotion floors provides strong incentives to increase technical proficiency while breaking the status quo.

One method to increase this pool is to formalize the direct bachelor-to-doctorate program. This direct approach, the predominant pathway to STEM doctorates in the civilian sector, accelerates the officer's transition from being a consumer of knowledge (bachelor) to a creator of knowledge (doctorate), thereby making innovation more likely. A key component to formalizing this program would be to ensure a fixed quota for each year targeted at junior officers. By fixing the quota in advance for each year as opposed to selecting near the end of the master degree program, the educational plans can be more thoughtfully managed to ensure student success while minimizing organizational churn with the assignment process.

Considering AFIT has about 50 percent excess capacity, together with the myriad of options for tuition-free S&T degrees at civilian universities, there would be no additional cost to the Air Force. In fact, the bachelor-to-doctorate program would save approximately 12 percent of the necessary education time and eliminate one move, reducing costs and time in an educational status.

If done early, this approach allows the officer to accomplish traditionally rewarded promotion criteria and hit important career gates necessary for promotion beyond lieutenant colonel. This avoids loss aversion by reducing the institutional bias that a doctorate requires an officer to choose between promotion opportunities and education. An important aspect to monitor is retention, and adjustments to timing and commitments may need to be made to ensure that a high percentage of the developed talent stays past the initial service commitment.

61. Castrejon, "STEM Degrees."

Lifelong STEM Learning – Conferences, Proficiency Pay, Edison Grants (total cost $36.5 million, of a total annual service budget of $156.3 billion)

Education is a baseline, but the half-life of technology and knowledge means that it must be exercised to maintain proficiency. This exercise of knowledge also drives innovation. Communicating these innovations improves the ability for STEM-competent officers to connect ideas to battlefield impact. In other words, actively using one's education creates a positive feedback loop for the Air Force.

Unfortunately, many officers feel they have little to no ability to directly use their degree, a key factor in retaining STEM talent. This situation is exacerbated for the STEM competency that exists beyond the science and engineering career fields.[62] As such, the Air Force should incentivize innovation through a combination of traditional monetary incentive structures and improvements in opportunities to exercise intellectual creativity, autonomy, and mastery.

First, the Air Force should develop a fund to support professional conference attendance for all officers with a STEM graduate degree. Conferences are a low-cost (~$3,000) method to maintain currency of degrees valued at $100,000–750,000. These opportunities broaden one's technical knowledge base and provide an opportunity to network with industry and academia to stay current with the latest research and development.

Currently, few Air Force organizations support professional conference attendance, even in the science and engineering communities. Setting an Air Force-funded priority to maintain technical proficiency would be a powerful signal in the right direction. At a proposed frequency of one conference per year for doctorates and one conference every other year for those with master degrees, the total annual cost would be $10 million, assuming a 50 percent participation rate.

Second, while many studies have recommended STEM proficiency pay, the general approach ignores retention data and incentivizes attainment of a degree, not actual innovation and proficiency. Instead, a model that couples STEM proficiency pay with continuing innovation requirements—a modification of the pay-for-innovation schemes used by industry and China—would help off-set pay differentials, incentivize continued development, increase the ties of service-funded graduate students to Air Force operational needs, and result in impactful innovation for the Air Force. Moreover, such a model would address a key retention complaint that officers are not able to use their degrees in meaningful ways.

The proposed STEM proficiency pay would be $3,000 for master degrees and $6,000 for doctorates. To maintain this pay, a biannual continuing innovation requirement would need to be met: 2 points for master degree holders and 3 points for doctorates. This would be more effective than pay-for-innovation schemes by leveraging the loss aversion bias, effectively increasing the value placed on the proficiency pay.

62. *Hearing on Military Personnel Talent Management Modernization and the Effects of Legacy Policies, Before the House Armed Services Subcommittee on Military Personnel*, 117th Cong. (February 8, 2022).

Points would be earned through scientific peer-reviewed journal publications (2 points for lead author; 1 point for coauthor), patents (3 points for lead; 2 points otherwise), and 1 point for professional society engagement through defined conference or society roles. Assuming a desired end state of 22 percent and 3 percent of Air Force officers with a STEM master and doctorates, respectively, the total program cost would be $24.5 million, assuming a 60 percent participation rate. In the case of 100 percent participation rate, the cost would be $41 million and would yield at least 6,500 technical products every year.

For reference, the Air Force currently only receives about 100 patents per year from both the military and civilian workforce. While the participation rate will likely be lower, the cost-benefit analysis is clear for what amounts to a fraction of the Air Force research and development budget. This level of production would enable classified and limited distribution communities of interest and journals to be established and thrive—a challenge in many domains—allowing for the communication of research and innovation, a driving force of exponential technology growth.

Finally, the Air Force needs to incentivize an Edisonian mindset. The story is told that a colleague of Thomas Edison's, upon learning the famed inventor had "made over nine thousand [unsuccessful] experiments" as he was developing the nickel-iron battery, said "'Isn't it a shame that with the tremendous amount of work you have done you haven't been able to get any results?'," to which Edison replied "'Results! Why, man, I have gotten a lot of results! I know several thousand things that won't work.'"[63]

A pilot effort aptly named Edison Grants, should be expanded and adequately resourced to support innovative high-risk, high-reward research. In the first year of the program, $2.5 million in proposals were received, despite relatively limited advertisement and a short lead time. This is expected to grow in coming years, and a minimum increase to $2 million (from $750,000) in funds should be set aside to support the program. Importantly, leadership must prioritize autonomy and provide time allocations for interested officers, perhaps even adopting an approach similar to Atlassian's ShipIt, a company-wide, 24-hour innovation challenge.[64]

Lifelong STEM Innovation – Journals and Software Access

Innovation often requires access to tools, resources, and the existing broader base of knowledge. But these enabling components are often missing. Although many items could be considered here, two key ones are access to scientific journals and access to computing software. Access to professional journals in Air Force assignments is intermittent; the Air Force Research Laboratory's D'Azzo Library restrictions should be removed to allow access to all officers regardless of location.

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63. Frank Lewis Dyer and Thomas Commerford Martin, *Edison: His Life and Inventions*, vol. 2 (New York: Harper & Brothers, 1910), 615–16.

64. Dominic Price and Philip Braddock, "'24 Hours of Opportunity': Behind the Scenes of ShipIt," *Inside Atlassian*, October 14, 2019, https://www.atlassian.com/.

Technically, scientific computing software is available at every base across multiple classification levels through the Defense Supercomputing Resource Center, but the resource is poorly understood and poorly utilized by many organizations. There is no simple solution, but a base-by-base, organization-by-organization road show would be useful to encourage adoption of the resources and solve technical challenges that often stymie adoption. A good starting point would be connecting through the network of organizational chief scientists, defense technical conferences, and strengthening ties with the Air Force Institute of Technology and the US Air Force Academy.

Conclusion

Organizational change is difficult, but a failure to adapt to the rising S&T challenges facing the Air Force could be fatal. Global trends and the return of great power competition have highlighted the need for increased technical competency in the Air Force officer corps to drive and manage innovation. Yet despite significant leadership assertions, numerous internal and external studies, and advocacy within the science and engineering community, little progress has been made.

In the meantime, China has made exponential progress in reforming their defense and civilian STEM educational institutions; increasing PLA Air Force and PLA Rocket Force officer, NCO, and enlisted STEM competency; and developing world-class and unique promotional and economic incentive structures. In doing so, China has overtaken the United States in most academic measures of innovation.

The lack of service progress is largely attributable to behavioral economics and cognitive biases that exist in an Air Force that has enjoyed few existential challenges in 60 years. Progress can only be made by recognizing these biases and instituting revolutionary programs to counter the status quo. These changes are not without cost but in direct program costs, this amounts to less than 0.03 percent of the annual Air Force budget of $156.3 billion. The larger cost is to institutional norms and preferences, a cost that must be born to maintain technological advantage in future conflicts.

In addition to identifying these institutional challenges in the context of the worldwide competition for STEM talent, the initiatives outlined in the article will shift the current paradigm, strongly signal that intent, and incentivize innovation. These initiatives have the potential to reduce pay differentials for STEM degree holders, dramatically increase the quantity and quality of Air Force internal innovation, and build a strong, collaborative internal community of interest, thereby accelerating further research and development. In total, these initiatives ensure a robust, vibrant pool of innovation-oriented S&T officers are available to accomplish the Department of the Air Force's vision, helping the service "accrue advantage in military-technological competition" to "fight and win the wars of the future."