Every Airman and Guardian a Technologist

Reinvigorating a Disruptive Technology Culture

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The US Air Force (USAF) and Space Force (USSF) face an era of fierce technological competition against rapidly modernizing great-power competitors. Sustaining war-fighting advantages in the twenty-first century will require a dramatic increase in technological innovation at all levels. As articulated by Gen Charles Q. Brown Jr., Air Force chief of staff, the mandate is clear: accelerate change or lose.[1]

Recent reforms led by Dr. Will Roper, the assistant secretary for acquisition, technology, and logistics, and other senior Air Force leaders helped the Department of the Air Force accelerate acquisition processes and bring more commercial technologies into the acquisition pipeline. These processes include embracing digital engineering to shorten product development times, expanding agile non-Federal Acquisition Regulation procurement mechanisms, and creating new innovation cells that connect commercial innovators with Air Force needs. The USSF has moved early to embrace rapid acquisition practices as its standard for future space systems.

Accelerating acquisition processes is only part of what is needed. Many other processes and functions should be aligned to create military services that are optimized to prevail in an environment of disruptive technological change. True disruption is painful, and imposing it voluntarily on one's organization is hard. Past disruptive changes in military technology were controversial and required difficult changes to military traditions and institutions. Those disruptive changes were pivotal to maintaining a technological advantage in earlier eras, and future victories may depend on reinvigorating the USAF and USSF's ability to foster, embrace, and institutionalize disruptive technology faster and more effectively than our competitors.

Fortunately, the shared heritage of the USAF and USSF was built on disruptive technological change. In this article, we briefly review the successful practices of earlier eras to illuminate how they supported the efficient advancement of disruptive change during those periods. We then reconsider those enabling practices in the current context and make recommendations for reinvigorating institutional service cultures that are postured to accelerate a new era of technological warfighting dominance.

A Heritage of Disruption and Reinvention

Air and space forces have experienced an unusual period of relative technological stability since the end of the Cold War and during the Global War on Terror. Many frontline systems today are upgraded versions of those that fought during the Gulf War 30 years ago. As a result, today's servicemembers and organizations have not experienced the dramatic level of change experienced by previous generations of Airmen.

The USAF had its origins in the desire to use an emerging technology—the airplane—to conduct warfare in a new and decisive way. The new technology enabled military operations against the enemy that were very different from the established ways of conducting war in the early twentieth century. The pro-innovation practices of the era enabled a rapid cycle of disruptive technological innovation, followed by the substantial reinvention of equipment, doctrine, and organization that made transformational change almost routine.

For example, the first military flight demonstrations in the US were performed by the Wright Brothers at Fort Myer near Washington, DC in 1909.[2] Within less than 10 years, the Army Air Service was conducting large-scale operations in World War I as a scout (reconnaissance) and pursuit (air-to-air fighter) force with all the required training, maintenance, and supporting functions in place. Comprehensive doctrinal changes were developed after the war, leading to the rise of strategic bombing theory and the demand for long-range heavy bombers. As a result, the Army Air Forces went to World War II primarily as a bomber force, with other operations such as pursuit working in support to thousands of heavy bombers. Ten years after World War II, the USAF had converted its frontline bomber and fighter units to jets, with all the changes that entailed. Within another 10 years, intercontinental ballistic missiles had become a core weapon system. By 1965, the first generation of nuclear missiles, Atlas, was already being phased out in favor of the newer Titan II, and the USAF was operating its first orbiting satellites.

This pace and breadth of technological change seem almost inconceivable today. This process didn't happen only with the engagement of a few innovators. The ability of the service to reinvent itself continuously as technology advanced relied upon the service culture—the way we collectively perceive ourselves. Doctrine preceded and anticipated technology in many cases. Logisticians, maintainers, personnelists, and trainers rapidly accepted change and adapted their methods as new technologies replaced old, sometimes in just a few years. Senior service leaders and budget specialists planned for the next generation of technology, often while the current generation was just reaching the field.

Certainly, the competitive pressures of the world wars and the Cold War provided a strong demand and sense of urgency. However, strong demand alone didn't account for the service's repeated success in meeting that demand. Several core cultural practices helped account for the early Air Force's ability to develop and adopt disruptive innovations and reinvent itself quickly.

Technologists and Operators as a Team

Civilian inventors such as the Wright Brothers, Glenn Curtiss, and their peers in Europe worked to design better airplanes, but they were not primary drivers for the adoption of airpower by the militaries of the great powers. Technology-minded military thinkers and operators were central in adopting the airplane, which had no existing role in military operations. Junior and midgrade officers in the US Army's Signal Corps were instrumental in bringing the Wright Brothers to demonstrate their aircraft at Fort Myer.[3] Many early combat pilots had learned to fly in the prewar days when pilots built their planes from kits and served as their own mechanics. They saw themselves as tinkerers and were active participants in developing new methods of air combat, sometimes designing and building equipment themselves. Innovative military scout pilots first used firearms to attack enemy aircraft during their patrols and carried grenades and specially made bombs to drop on the advancing enemy and supply areas as they passed overhead.[4]

Military innovators routinely moved back and forth between technical and operational roles in the junior and middle grades. For instance, the future Gen Henry "Hap" Arnold spent his early years in the cockpit helping to test early air-to-ground radio communications and, in addition to leading flying units, served as a major and colonel in the Aeronautical Division overseeing new aircraft and weapon development. His personal experiences with emerging technology were important to his later work to build the Army Air Forces and the early Air Force. Gen Jimmy Doolittle started his career as an engineering officer and test pilot and was sent by the military to get master's and doctorate degrees in aeronautical engineering at the Massachusetts Institute of Technology. He credited this kind of technical training with solidifying the relationship between flyers and technologists. Later in World War II, as the commander of the Eighth Air Force, Doolittle established an Operational Engineering Division in Europe to keep engineers close to his combat squadrons.

The close relationship between technologists and operations endured in the Vietnam era. For example, Col Joe Davis, a former F-84 attack pilot, served as the vice commander of the Armament Development and Test Center at Eglin AFB, Florida, in 1965. He developed the idea of using newly invented lasers to guide bombs to ground targets.[5] Davis sponsored laser engineers at Texas Instruments to design and build the first prototype laser-guided bombs and personally flew the live-fire test missions with the weapon in Southeast Asia.

In short, science and technology (S&T) was close to operations; and operators, if not technically trained themselves, were familiar with research and development (R&D) and understood what was in development and technically feasible. The relatively small size of the early Air Force R&D enterprise helped to naturally create the melding of operational and technical competencies, sometimes in the same individual. Such close working relationships at the junior and field grades are cited as a key factor in modern Israel's small but highly efficient defense R&D establishment.[6]

Technologists as Leaders in Doctrine and Future Force Design

After World War I, technically astute aviators codified new theories about employing airplanes in warfare. The early airpower theorists such as Gen Giulio Douhet in Italy, Air Marshal Hugh Trenchard and B. H. Liddell Hart in the United Kingdom, and Gen William "Billy" Mitchell in the United States focused their arguments on how the inherent capabilities of aircraft could impact future warfare. Because the aircraft of the 1920s only offered a foreshadowing of what the theorists envisioned, they focused on the potential of future systems.

For example, in 1925, Liddell Hart wrote:

> The air has introduced a third dimension into warfare. . . Aircraft enable us to jump over the army which shields the enemy government, industry, and people, and so strike direct and immediately at the seat of the opposing will and policy. A nation's nerve system, no longer covered by the flesh of its troops, is now laid bare to attack.[7]

In the US, technically trained military theorists at the Air Corps Tactical School further refined the idea of striking at the heart of the enemy through the third dimension, yielding precision bombing theory. This doctrinal refinement furthered the argument that bombing vital enemy targets from the air could be strategically decisive. This refinement was a dramatic departure from previously accepted concepts of victory. As many Airmen know, this eagerness to pursue heretical doctrinal concepts got some of the advocates of precision bombing theory, including General Mitchell and the young Colonel Arnold, into trouble with their superiors.

The buildup of US airpower before World War II was guided by the doctrine developed in the interwar period. Technologists and theorists drove the vision for future force design. For instance, theorists as early as Douhet had envisioned the "battle plane," a long-range aircraft capable of carrying a heavy bomb load into an enemy's heartland and bristling with defensive armament to protect itself.[8] Fleets of battle planes would form the core of offensive airpower. The four-engine B-17 Flying Fortress was conceived and championed as the US's battle plane and was a faithful incarnation of the doctrinal concept.[9]

The emergence of ballistic missiles precipitated another doctrinal revolution. Military innovators such as Gen Bernard Schriever saw the potential for ballistic missiles to provide a potentially superior means to carry nuclear warheads into the vital centers of the enemy, and the improvement of Soviet surface-to-air missiles threatened the credibility of existing bombers as a strategic deterrent.[10] Just as the long-range bomber had provided the means to bypass enemy ground forces, the ballistic missile provided a way to bypass the enemy's improving air defenses. General Schriever drove the development of the Air Force's ballistic missile and space forces during the 1950s and 1960s. Holding an advanced degree in aerospace engineering and experienced in R&D leadership, General Schriever aligned the new technology of ballistic missiles with future force design and the concurrent development of strategic deterrence theory.

Leadership and Training Support for Technological Preeminence

After World War II, an assessment of the role of military scientists and engineers in the war predicted that "any future war will require within the services a large group of technically trained officers of high skill to function in research, planning, and operations."[11] General Arnold sponsored Dr. Theodore von Kármán to produce the landmark report *Toward New Horizons*, assessing the future of the Air Force. The summary volume stated that "the first essential of air power is preeminence in research."[12] This short but powerful observation established that S&T would provide the foundation of USAF combat effectiveness and help solidify a culture of technical skill and innovation readiness for the newly independent Air Force.

The men in charge of the future Air Forces should always remember that problems never have final or universal solutions, and only a constant inquisitive attitude toward science and a ceaseless and swift adaptation to new developments can maintain the security of this nation.[13]

This principle was matched with initiatives to embed technological excellence further into institutional DNA. High levels of investment in S&T were typical for the young USAF. The Air Corps Engineering School was expanded to create the Air Force Institute of Technology, offering advanced technical degrees to officers. At the base level, initiatives encouraged technical competence for all ranks.

For example, Gen Curtis E. LeMay, Strategic Air Command commander, encouraged mechanical and electrical skills among Airmen by establishing auto hobby shops at air bases.[14]

Getting Off Track

If the Air Force had continued the disruption-embracing practices of its earlier decades, it would be well positioned for today's new era of technological competition. However, toward the end of the Cold War, the cycle of technology-driven reinvention slowed dramatically.

As the US military absorbed the experience of Vietnam, the concept of airpower solidified around a single primary technological implementation, the high-performance jet fighter. The "fighter generals" assumed predominance in the Air Force's top leadership.[15] As Carl Builder observed in his influential 1994 book *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force*, the centrality of the jet fighter remained essentially unchanged during the 20 years post-Vietnam, and indeed it has remained largely intact through the almost 30 years since he wrote. The rise of the jet fighter made sense because it is a versatile and capable weapon system. Technologically, new fourth-generation multirole fighters provided much of the striking power that had previously required dedicated bombers. Precision guided weapons, such as laser-guided bombs, provided greater potency with smaller bomb loads, and the growing use of aerial refueling provided jet fighters with intercontinental range.

Unfortunately, Builder argued, this initiated a period of doctrinal stasis as new airpower theory lost its central role in driving the future direction of the USAF to be replaced by a focus on incremental improvements in the tactical and operational art of flying jet aircraft.

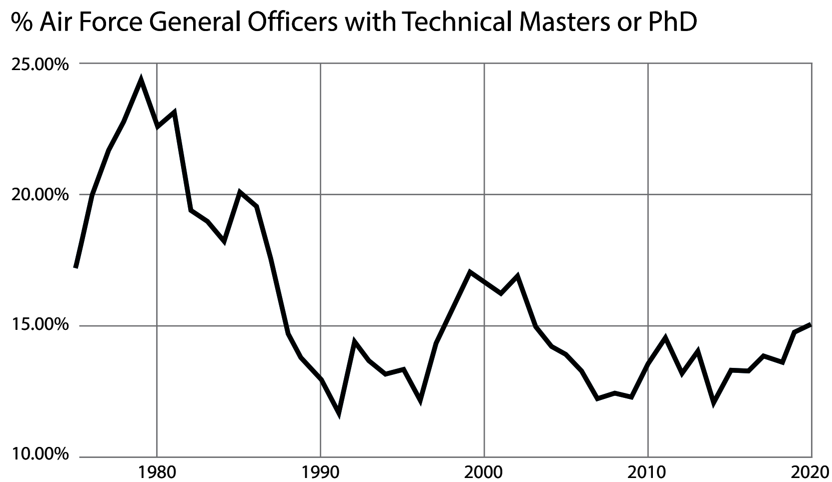
Instead of advocating new war-fighting doctrines, Air Force leaders devoted their energies to pushing for the next incremental airplane development program.[16] As Builder put it, "Somewhere during this time, the institutional Air Force was shifting its compass from a guiding theory of air power to a devotion to the symbols or means of air power—to the airplanes themselves."[17]

This shift might have been a temporary state of affairs, but the fall of the Soviet Union removed the main source of competition for the US military. Then, starting in 2001, the US military spent two decades engaged in conflicts against difficult but relatively low-tech terrorist and insurgent forces over whom US technological supremacy was never in question.

Consequently, S&T became a more isolated subfield within the acquisition function, less connected to operations and to strategic decision-making within the Air Force. It also became more civilian in nature, with uniformed military presence reduced to a minimum and more focused on administration. Instead of shaping the future, the priority for S&T shifted to addressing "technology gaps" within existing operational constructs as communicated by operational commands. This incremental focus was strengthened further by grading Air Force S&T, using metrics like technology transition percentages and quantifiable return-on-investment. In short, instead of helping drive the strategic agenda regarding the character of the future USAF, S&T became a specialized support function tasked with maturing technology for desired but optional improvements to current capabilities.

To be sure, there were some dramatic advances by USAF S&T during the past few decades. However, the most visible of them, stealth technology and unmanned air vehicles, had to overcome significant skepticism from the institutional USAF of their time because the status quo doctrine did not call for them. Early development programs in those new areas, such as the F-117 Nighthawk and the MQ-1 Predator, had champions within the USAF but faced reluctance from institutional leaders who perceived that they competed for resources against more conventional aircraft programs.[18]

This relative decline in the perceived importance of S&T was reflected in a decline in the percentage of general officers holding advanced degrees in technical fields. As shown in figure 1, since the late 1970s the percentage decreased from almost 25 percent to a current value of less than 15 percent. Only a single USAF general officer billet currently requires an advanced STEM (science, technology, engineering, and math) degree as a qualification.



Source: Air Force Personnel Center

Figure 1. Relative decline of Air Force general officers holding advanced technical degrees, 1970–present

The decline in emphasis on technological change and reinvention was also reflected in a relative decline in resources for S&T. As shown in figure 2, S&T resources fell from an average of 2.5 to 3.0 percent of the USAF's total budget during the Cold War period of the 1960s and 1970s to less than 1.9 percent today, a relative decline of about a third.[19]

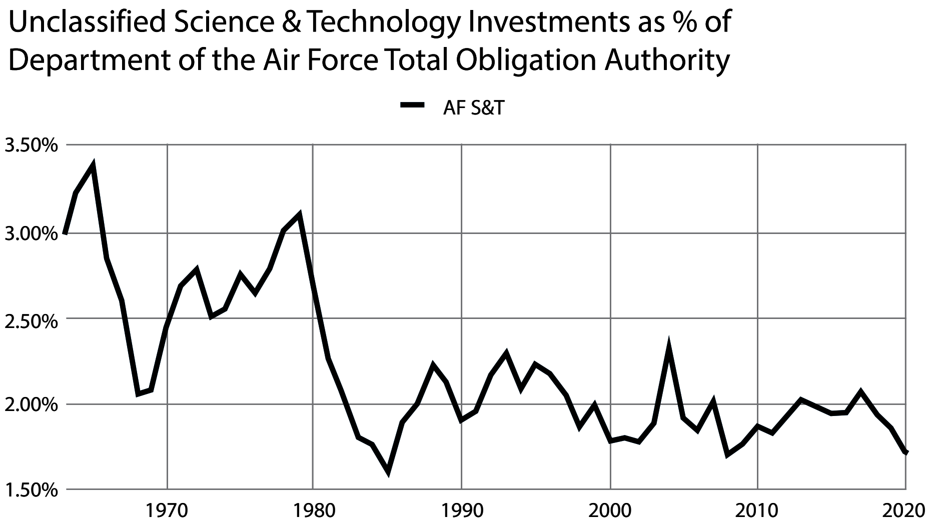


Figure 2. Data from President's Budget submission 1963–2021 by fiscal year, includes civilian pay and Space Force funding

New Competitive Challenges

The level of military technological competition today may be greater than at any time in the past 100 years, not only because of the re-emergence of peer competitors but because the US military has largely lost the budgetary advantage it historically enjoyed over its rivals. During World War II, the US gross domestic product (GDP) easily surpassed that of all the Axis powers combined.[20] During the Cold War, the Soviet Union's GDP reached only about 26 percent that of the US.[21] Today, China's GDP alone is two-thirds that of the US, and in terms of local currency purchasing power, may exceed the US GDP.[22] On a purchasing power basis, Chinese military spending in 2017 may have reached 87 percent that of the US.[23]

In particular, the US defense sector no longer dominates the investment landscape for S&T. In 1960, the US accounted for 69 percent of global R&D expenditures. US federal defense R&D alone accounted for 36 percent of global R&D.[24] In 2016, by contrast, US federal defense R&D spending accounted for less than 4 percent of global R&D. Approximately 93 percent of global R&D was funded by either commercial or foreign sources.[25]

Foreign and commercial investment is especially pronounced in many areas of emerging technology that will be critical to future military advantage, such as artificial intelligence, microelectronics, and robotics. As the unclassified *Summary of the 2018 National Defense Strategy* says:

> New commercial technology will change society and, ultimately, the character of war. The fact that many technological developments will come from the commercial sector means that state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which our Nation has grown accustomed.[26]

The US military can no longer outspend its rivals or rely on uniquely US sources of technology. American advantage will depend on superior efficiency in developing disruptive military technologies and translating them into revolutionary war-fighting capabilities and quickly seizing their benefits through institutional reinvention.

Recommendations for Reinvigorating a Disruptive Innovation Culture

Fortunately, there are abundant signs that the posture toward S&T and doctrinal evolution in the Air Force is starting to change. For instance, the secretary of the Air Force and the Air Force chief of staff published a new *Air Force Science and Technology Strategy* in 2019 that explicitly calls for shifting a substantial portion of Air Force S&T investment toward "transformational" innovations that can deliver sustainable technological advantages over fast-moving adversaries.[27]

Innovation cells like AFWERX have made progress in promoting "innovation" across the USAF and USSF, helping generate excitement about technological change. Their activities are generally associated with activities like "Spark Tanks" and interactions with startup companies. However, bringing innovation from the margins back to the core war-fighting practices of the services requires reinventing the practices that enabled rapid technological change in earlier eras. This reinvention includes restoring a close relationship between technological innovation and operations, reestablishing a strong role for technologists in future force planning and building new training and leadership practices to help reinvigorate a culture where "every Airman and Guardian is a technologist."

Reconnect technologists and operators. In earlier eras, military technologists and operators had shared experience at the "tactical edge" and a close relationship that gave them a personal understanding of each other's specialties. This relationship was built by cross-training and working together at the junior and midgrades. In today's more specialized world, it may be more challenging for individual service members to be fully cross-qualified, but they can be brought back into closer rapport. For example, the Air Force's Advanced Battle Management System field exercises and the Army's Project Convergence have shown the future combat necessity to do software coding at the tactical edge to respond to technical challenges in real time.[28] The work can't be delegated to civilians or contractors in rear areas—it requires uniformed technologists who can work "under fire." New initiatives could place military technologists in, or in close cooperation with, operational units with the mission of engineering technical solutions in peacetime and times of conflict. One option would be to establish operationally integrated engineering cells at the wing, delta, or other unit levels. They would provide operational connection to the service's larger technological community, identifying and solving technical challenges in real time, and mentoring units through the process of adopting and integrating disruptive new technologies. Also, wargames and exercises should include unanticipated technological moves by potential adversaries that impose "technological surprise" on friendly forces. This tactic can build the ability of operators and technologists to work together to quickly develop and deploy solutions at the tactical edge.

Restore technologists as leaders in future force design. Earlier eras utilized military technologists, including technically educated operators, to help create new theory and doctrine and cocreate the vision for the shape of the future force. The establishment of the Air Force Warfighting Integration Capability, now known as AF Futures, and the Space Warfighting Analysis Center has created strong new centers for future force planning. These offices should embrace the role of the old Air Corps Tactical School to foster and develop future war-fighting theory and doctrine that can guide emerging technology development and target capabilities that go beyond what current systems and forces can deliver. These organizations have welcomed the early involvement of technologists by inviting detailees from the S&T community. This good start should be expanded to emphasize technological expertise and vision as a core competency in future force design. This expansion will also require military technologists to rebuild competencies in doctrine development and future force design, areas where they have not been substantially involved for decades. Collaborative planning activities like those in the new Warfighter-Technologist (WARTECH) process coled by AF Futures and the Air Force Research Laboratory are a good first step.

Establish foundational training. Air, space, and cyber systems are increasingly based on digital microelectronics, software, and robotics. Competence in these areas will be an almost universal requirement, whether in a maintenance facility, the cockpit, or a space operations center. Also, effective innovation must arise from a foundation of technical competence. "Innovative" ideas that are not anchored in physics, and a solid technical understanding can be impractical. The danger of disconnected "innovators" has been lampooned via characters such as Michael Keaton's eccentric brainstorming "idea man" in the movie *Night Shift*, who suggests providing mayonnaise right in the can with tuna fish before proposing the even "better idea" of feeding live tuna fish mayonnaise.[29] Every servicemember needs some level of foundational technical competence to be effective. This level of competence includes an informed understanding of emerging technical possibilities and a mentality of constantly looking ahead for new technological means that can change the ways we go to war. To make this point, former Air Force Secretary Heather Wilson said in many of her speeches to Airmen, "We're all bicycle mechanics at heart."[30] All Marines receive two weeks of marksmanship training whether they will serve as infantry or not. In the same way, Airmen and space professionals should receive initial skills training in technical concepts that enable war-fighting effectiveness. The USSF's move to establish Space Warfighting Discipline training for all incoming members is a good model. This practice should be followed up by providing additional training in technical subjects, using modern mechanisms such as online training portals. For instance, the National Security Commission on Artificial Intelligence has recommended establishing emerging technology certifications that are similar to today's joint qualification certification, to qualify military members for service in positions that will demand competence in emerging technologies.[31] General LeMay's initiative for encouraging technical hobbies should be modernized to provide base facilities for members to pursue projects in software, robotics, and similar fields.

Develop military science and engineering leaders. To out-innovate fast-moving adversaries, the services must restore a stronger community of empowered uniformed science and engineering leaders. This restoration involves better using the technical competence of science and engineering officers entering the USAF and USSF and providing more opportunities for them to develop their technical and leadership talents. Early career experiences for military scientists and engineers should go beyond the current focus on administering standard DOD acquisition contracts to include training in integrating with operations and deploying solutions in real time. More opportunities to lead other military members, such as within operationally integrated engineering cells, can provide these officers with development opportunities that also use their technical skills. Military scientists and engineers should have access to resources to apply their skills to inventing solutions. For instance, competitive grants could be made available to fund inventions with operational impact and develop the intellectual property themselves instead of relying on contractors. The Air Force Research Laboratory-managed Edison Grant pilot is a promising start. The pilot could be connected with the current Squadron Innovation Fund, which has provided $64 million in funding for hundreds of projects to "kick start squadron-level innovation at the tactical edge."[32] Lastly, more general officer positions should favor candidates with advanced degrees and experience in science and engineering, in keeping with the technological nature of future war fighting.

Provide senior leader messaging and example. Changing culture requires a strong example from leadership. As part of his campaign to reform Marine Corps culture, esprit de corps, and doctrine after the Vietnam War, Marine Corps Commandant Gen Alfred M. Gray established the dictum "every Marine a rifleman" and insisted that every incoming Marine receives marksmanship training regardless of what operational specialty they enter.[33] His phrase articulated the core cultural value instilled within the Corps that every Marine is, at heart, a disciplined warrior ready to take up a rifle and engage in close combat if called upon to do so. Similar messaging from USAF and USSF leaders is important for focusing their service members on the technical nature of future war fighting in their domains, placing priority on the need for every Airman and space professional to be a technologist, regardless of their specific role. Senior leadership roles themselves are important indicators of an organization's priorities. The USSF has established the chief technology and innovation officer (CTIO) as a key military position at the service headquarters, much as the chief technology officer is a key strategic role at large tech companies. This move clearly broadcasts the strategic importance of technology to the USSF's war-fighting mission. It also provides the CTIO with the breadth and authority to take action in accordance with that reality. Similar top positions dedicated to Air Force technology could send a similar message. Lastly, there is no doubt that resource allocation is a strong indicator of organizational priorities. To compete effectively, the USAF and USSF should strive to restore S&T funding to at least the fraction of the overall service budgets that was commonplace during the Cold War.

Conclusion

To prevail in the current era of fierce competition for military technological advantage and future conflicts with innovative adversaries, the USAF and USSF must revive the readiness to embrace disruptive new technologies and reinvent themselves. For more than a century, Airmen have identified, matured, and employed the latest technology to bring bold visions to reality and change the rules of warfare. Technological innovation must once again be part of the core cultural "DNA" of both services, present not only within specialized acquisition functions and innovation programs but in operations, doctrine development, training, and elsewhere. The recommendations outlined here create a framework for reinvigorating such a disruptive innovation culture. At their core is restoring the role of military scientists and engineers as the essential link between S&T, operations, and future force design. They aim to reaffirm an institutional principle that technology is the key to combat advantage in our war-fighting domains, and therefore all USAF and USSF members must be, to some degree, technologists. ✪

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