Department of the Air Force

# ASOR

## Air & Space Operations Review

Antifragile Air Force

Incentivizing Innovation

Air Mobility Intelligence

Forged at the Edge of Chaos

Contested Agile Combat Employment

Vol. 1, No. 3 - fall 2022

DEPARTMENT OF THE AIR FORCE

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AIR & SPACE OPERATIONS REVIEW



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# Air & Space Operations Review

FALL 2022 VOL. 1 NO. 3

## FROM THE EDITOR

Dear Reader,

Thank you for taking time out of your busy schedule to explore the Fall 2022 *Air & Space Operations Review*. Our issue begins with three articles focused on different aspects of **Talent Management** in the Air Force. In the first, a quad of researchers from RAND Corporation and the Air Force Institute of Technology—Joseph Hoecherl, David Schulker, Zachary Hornberger, and Matthew Walsh—argue the approach the service takes to retention and pay undercompensates those performing many of the Air Force's critical skills. They offer two policy proposals aimed at modernizing compensation based on quantifiable skillsets and broadening the retention-management outlook to include the Air Reserve Components.

In the second article in the forum, James Bevins asserts the Air Force has been unsuccessful thus far in properly incentivizing and promoting key technical competencies among its scientists and engineers. He offers recommendations to reform institutional culture and retain, reward, and promote individuals in these critical career fields. In the final article in the forum, Phillip Surrey contends the current rapid mobility intelligence architecture is insufficient for the demands of wars to come. He proposes expanding the participation of mobility intelligence in operational planning and establishing a mobility senior intelligence officer to serve as lead integrator in such an effort.

Our **Research and Operations** forum leads with an article by Michael Byrnes and Aubrey Olson who explain the concept of emergent function weapons, which operate as complex adaptive systems. They advocate for a tailored defense research program that leverages advances in behavioral robotics. The second article in the forum, and our final for the issue, considers agile combat employment (ACE) in a contested environment. Another quad of researchers—Zachary Moer, Christopher Chini, Peter Feng, and Steven Schuldt—present an ACE site-selection methodology that engages a multicriteria decision analysis framework to identify airports best suited for ACE employment in the event of a conflict with our pacing adversary.

The issue closes with a selection of recent book reviews covering a notable Air Force figure, air operations of the past, and international security. As always, the journal welcomes considered, well-researched responses to our articles, with a possibility of publication in future issues.

In closing, to the following peer reviewers, including journal contributors, each an expert in their field by virtue of a terminal degree, a long career, or both, thank you very much for your time—past, present, or promised—spent supporting the journals: Andrew Akin, Christian Anrig, Filomeno Arenas, Todd Arnold, David Benson, Louis René Beres, Robert Bettinger, Michelle Black, Todd Book, Molly Braun, Maria Burczynska, Stephen Burgess, Ryan Burke, Chris Cain, Garick Chamberlin, Andrea Charron, Stephen Cimbala, J. P. Clark, Andrew Clayton, Mark Clodfelter, Damon Coletta, Chris Colliver, Daniel Connelly, Conrad Crane, GK Cunningham, Chad Dacus, Jim Davitch, Melvin Deaile, Everett Dolman, Jared Donnelly, Scott Drylie, Charles Dunlap, Michael Dziedzic, Antulio Echevarria, Michael Eisenstadt, Ryan Engle, James Fergusson, David Finkelstein, Jim Forsyth, Brian Fry, Cristina Garafola, Billy Giannetti, Benjamin Gochman, Derrill Goldizen, Tim Goodroe, Christina Goulter, Heather Gregg, Kelly Grieco, Achala Gunasekara-Rockwell, Ernest Gunasekara-Rockwell, Lawrence Grinter, Stephen Hamilton, Michael Hankins, Dale Hayden, Peter Hays, Jordan Hayworth, Eric Heginbotham, Megan Hennessey, John Hinck, Paul Hoffman, Tim Hoyt, Tony Hughes, JP Hunerwadel, Jonathan Hunt, Wes Hutto, Mark Jacobsen, Benjamin Jamison, Thomas Keaney, James Keeley, Michael Kraig, Matthew Kroenig, Benjamin Lambeth, Brent Langhals, Wiley Larson, Brian Laslie, Sale Lilly, Adam Lowther, Steve Marrin, Richard Marsh, Steve Martinez, Kevin McCaskey, Jared McKinney, Phillip Meilinger, Ann Mezzell, Richard Muller, Brendan Mulvaney, Jason Newcomer, Richard Newton, Lana Obradovic, Galen Ojala, Christopher Paige, David Palkki, Ginta Palubinskas, Mike Pavelec, Joseph Piroch, Brian Price, Kyle Rassmussen, Robert Reardon, Edwin Redman, Christopher Rein, Dan Ritschel, James Rogers, Nick Sambaluk, Tony Sampson, Dan Sanders, Jorg Schimmelpfennig, Joshua Schwartz, Jorge Serafin, Mario Serna, John Shields, Dennis Skocz, Art Speyer, J. William Sutcliffe, Dick Szafranski, Brent Talbot, Michael Tate, Samantha Taylor, John G. Terino Jr., Mike Thomas, Teera Tony Tunyavongs, David Umphress, Gilles van Nederveen, Heather Venable, Mark Visger, James Walsh, Evelyn Watkins-Bean, Larry Weaver, Michael Weaver, Edward White, Wendy Whitman Cobb, Bishane Whitmore, Edie Williams, Michael Young, Michael Zmuda, and Ben Zweibelson.

~ The Editor

# Antifragile Air Force

## Building Talent for the High-End Fight

Joseph C. Hoecherl
David Schulker
Zachary T. Hornberger
Matthew Walsh

The US Air Force's approach to retention and pay creates an expensive force that undercompensates those performing many of its most critical skills. Also, by overly focusing on retention for active duty personnel, the Air Force accepts a larger than necessary disconnect between personnel and authorizations, forces Air Reserve Components to spend increased time and resources on training and recruiting, and leaves the service vulnerable to severe human capital disruptions in a conflict or crisis. A two-pronged approach would modernize compensation based on quantifiable skill sets and change the regular Air Force's retention-management outlook to encompass the Air Reserve Components. This quantitatively grounded cost-neutral or cost-saving solution will improve the system's functioning and increase the Air Force's ability to field appropriately experienced personnel during wartime.

The US Air Force is undergoing a significant transition in strategy and focus due partly to the shift from a period of dominance to one of aggressive competition with technologically capable adversaries.[1] This shift requires Airmen with more technical, in-demand skills, with technical defined in a general sense. While the shift includes skills such as programming, data literacy, and machine learning, the article uses this term to refer to the broader collection of quantifiable technical skills, including aircraft maintenance certifications, warrants for contracting personnel, continuous process improvement certifications, and others.

New operational concepts also call for "multicapable" Airmen with talent stacks that transcend traditional specialty structures.[2] As articulated by Chief of Staff of the Air

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*Dr. Matthew Walsh is a behavioral and policy scientist at RAND Corporation.*

1. James N. Mattis, *Unclassified 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 (DoD), January 2018), https://dod.defense.gov/.

2. Curtis E. LeMay Center for Doctrine Development and Education (LeMay Center), *Agile Combat Employment*, Air Force Doctrine Publication 1 (Maxwell AFB, AL: LeMay Center, December 1, 2021), https://www.doctrine.af.mil/.

Force General Charles Q. Brown Jr. in his December 2020 CSAF action orders, "the attributes of the Airmen we need, and how the USAF develops and manages them, may not be the same [in the high-end fight] as today; Airmen must be able to adapt, innovate, and apply lessons learned to enable a culture of continuous improvement."[3]

Senior leaders recognize the importance of a talent management system that fosters the development and retention of technical skills to achieve these aims outlined by Gen Brown. Yet the current talent management system may not be adaptable enough to develop a highly qualified workforce to compete with adversaries. The misalignment between officer capabilities and technical abilities was vividly illustrated in a viral 2021 LinkedIn post by Nicolas M. Chaillan when he abruptly resigned his post as the service's first chief software officer:

> Please stop putting a Major or Lt Col. (despite their devotion, exceptional attitude, and culture) in charge of ICAM [Identity, Credential, and Access Management], Zero Trust or Cloud for 1 to 4 million users when they have no previous experience in that field—we are setting up critical infrastructure to fail. We would not put a pilot in the cockpit without extensive flight training; why would we expect someone with no IT experience to be close to successful?[4]

The challenge of developing a highly qualified workforce is exacerbated by the difficulty of attracting talented individuals amid changing expectations, preferences among those who might serve in the military, and the difficulty of retaining qualified individuals given the strong commercial demand for their specialized skill sets.[5]

The competitiveness of military compensation for in-demand skill sets has also been at the forefront of DoD and congressional discussions of compensation reform; one of the charter issues for the *Thirteenth Quadrennial Review of Military Compensation* (*13th QRMC*) was to examine "whether an alternate compensation system, such as a salary system, would enhance readiness, recruiting, and retention."[6]

While the *13th QRMC* found that average compensation compares favorably with comparably educated civilians, the review acknowledged the current system might not be tailored enough to account for the market competitiveness of specialized skills. Therefore, one of the key recommendations of the review was to conduct a study that "examines a more expansive view of military compensation, including regular military compensation plus special and incentive pays targeted toward recruiting and retention."[7]

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3. Charles Q. Brown Jr., *CSAF Action Orders to Accelerate Change Across the Air Force* (Washington, DC: Headquarters, US Air Force (USAF), December 2020), https://www.af.mil/.

4. Nicholas M. Chaillan, "It Is Time to Say Goodbye!" LinkedIn, September 2, 2021, https://www.linkedin.com/.

5. National Academies of Sciences, Engineering, and Medicine, *Strengthening U.S. Air Force Human Capital Management: A Flight Plan for 2020-2030* (Washington, DC: National Academies Press, 2020), https://doi.org/.

6. Office of the Under Secretary of Defense for Personnel and Readiness (OUSDP&R), *Report of the Thirteenth Quadrennial Review of Military Compensation* (*13th QRMC*), vol. 1, Main Report (Washington, DC: DoD, December 2020), https://militarypay.defense.gov/.

7. OUSDP&R, *13th QRMC*, 21.

The Air Force must deal with these challenges in a fiscally constrained environment. At a cost of $35.04 billion, the active duty military personnel costs made up approximately 20 percent of the service's total FY 2021 budget.[8] Between FY 2000 and 2021, the average cost of an Airman increased by 106 percent, from $50,000 to $103,000. Comparatively, civilian pay grew by only 60 percent during the same period.[9] The continued growth in the average cost of an Airman above general inflation will create affordability and readiness challenges and could crowd out future efforts to modernize key military capabilities. Consequently, the service cannot simply pay more for the workforce it needs.

As the Air Force seeks to accelerate change, the primary driver of success will be having the right people in place to enable and lead that change. To field a highly qualified workforce in a fiscally responsible manner, the service must create a responsive talent management system that can recruit, develop, and retain the right people in times of calm and crisis.

This article proposes an approach to expand the technical depth and breadth of the active duty workforce without increasing military personnel costs. The approach has two key elements:

1. The Air Force needs flexibility to reduce the growth in base compensation and to increase the growth in skill-based pay. The pivot toward skill-based compensation is the only way for the service to retain the right skill mix without increasing overall costs.

2. The Air Force should shift to managing retention across the uniformed lifecycle, including time spent in the regular Air Force (RegAF), (consisting of active duty Airmen) and the Air Reserve Components (ARC).

Counterintuitively, this shift requires the RegAF to retain fewer people. Shifting toward skill-based compensation and lowering overall RegAF retention will create a much more dynamic personnel system where Airmen adapt to develop the talent stacks the service needs. It will also create a much-needed capacity to adapt to changes in requirements or increase capability during a crisis.

The Air Force is structured to develop specific talent sets systematically in a stable environment, but it can struggle to respond to rapid changes in required personnel and relies mostly on new accessions to respond to crises. This reliance is a worrisome source of fragility for a high-skill military service. The greater responsiveness resulting from these proposed changes will create a less fragile workforce with talent more tailored to the service's changing needs. While this proposal provides some savings, the primary benefits are nonfinancial.

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8. Office of the Under Secretary of Defense (Comptroller) (OUSD Comptroller), 2018 *National Defense Budget Estimates for FY 2022* (*Green Book*) (Washington, DC: OUSD Comptroller, May 2021), 45, https://comptroller.defense.gov/.

9. OUSD Comptroller, *Green Book*, 58–59, 64–65.

## Historical Context for Compensation Changes

The Air Force's limited flexibility to provide compensation commensurate with service members' skills relates to two factors: (1) the principle of "equal pay for equal work," or the idea that service members should be compensated at approximately the same rate regardless of occupation; and (2) a time-in-grade pay table that rewards years of service and grade, which only partially captures skill demands and technical merit. Each of these factors is discussed in turn.

In 1973, the US military transitioned from a draft to recruiting an all-volunteer force. Since then, the Air Force has attempted to balance attracting and retaining high-quality personnel with keeping personnel costs low enough to furnish those personnel with the opportunities and equipment needed to field a highly capable military. As the complexity of Air Force missions has risen and the workforce has grown smaller, the service has increased compensation levels so it can better compete with the private sector for high-value skill sets.

While the Air Force has used certain specialty pays—e.g. flight and language—and skill-specific retention incentives for similar skill sets, the service has continued providing the bulk of its compensation through a flat pay structure adjusted only for years of service and grade. In FY 2021, special and incentive pays accounted for only 6 and 2 percent of officer and enlisted standard composite pay rates.[10]

Because special and incentive pays include multiple entitlements, skill-based pay varies even less. In the fight to retain high-value skill sets, policymakers have resorted to elevating base pay, which raises the average compensation provided to service members relative to the average market demand for Airmen's skills. But this flat pay structure tends to undercompensate the most marketable skill sets.[11] Over time, such a structure is guaranteed to produce retention patterns that do not align with Air Force strategic goals for the high-end fight.

The policies that govern growth in pay further exacerbate the challenges inherent in delivering a highly technical workforce with a mostly flat pay structure. To ensure Airmen wages remain competitive with the private sector, year-to-year changes in basic pay are tied to the US Department of Labor's Employment Cost Index (ECI), which measures growth in the wages and salaries of private industry workers as a percentage.[12]

The problem with anchoring changes in basic pay to ECI is that this measurement is an average over a range of sector-specific salary growth patterns. Anchoring changes in basic pay to ECI is limiting in two ways. First, unlike the military, wages and salaries are highly differentiated in the civilian labor market (fig. 1, top panel). A specific percentage

10. Department of the Air Force (DAF), *Financial Management US Air Force Cost and Planning Factors*, Air Force Instruction (AFI) 65-503 (Washington, DC: DAF, July 13, 2018), https://static.e-publishing.af.mil/.

11. Beth J. Asch, *Setting Military Compensation to Support Recruitment, Retention, and Performance* (Washington, DC: RAND Corporation, 2019), https://www.rand.org/.

12. US Department of Labor Bureau of Labor Statistics (BLS), "National Compensation Survey," BLS (website), n.d., accessed August 15, 2022, https://www.bls.gov/.

increase in civilian wages, then, reflects very different growth patterns (depending on the sector) than the same percentage applied to the service's flat pay system.

Second, the ECI is an overall average of widely varying annual growth rates in different sectors. The sector-specific rates show that this average metric tends to be lower than the growth rate among knowledge workers and higher than the growth rates in less-skilled areas (fig. 1, bottom panel). The unfortunate result of both limitations is that the main policy intended to keep US Air Force compensation competitive with the private sector actually produces a larger misalignment between service compensation and market demand for skills. To keep US Air Force compensation competitive with the private sector, the department pays too much for low-growth occupations and too little for high-growth occupations.

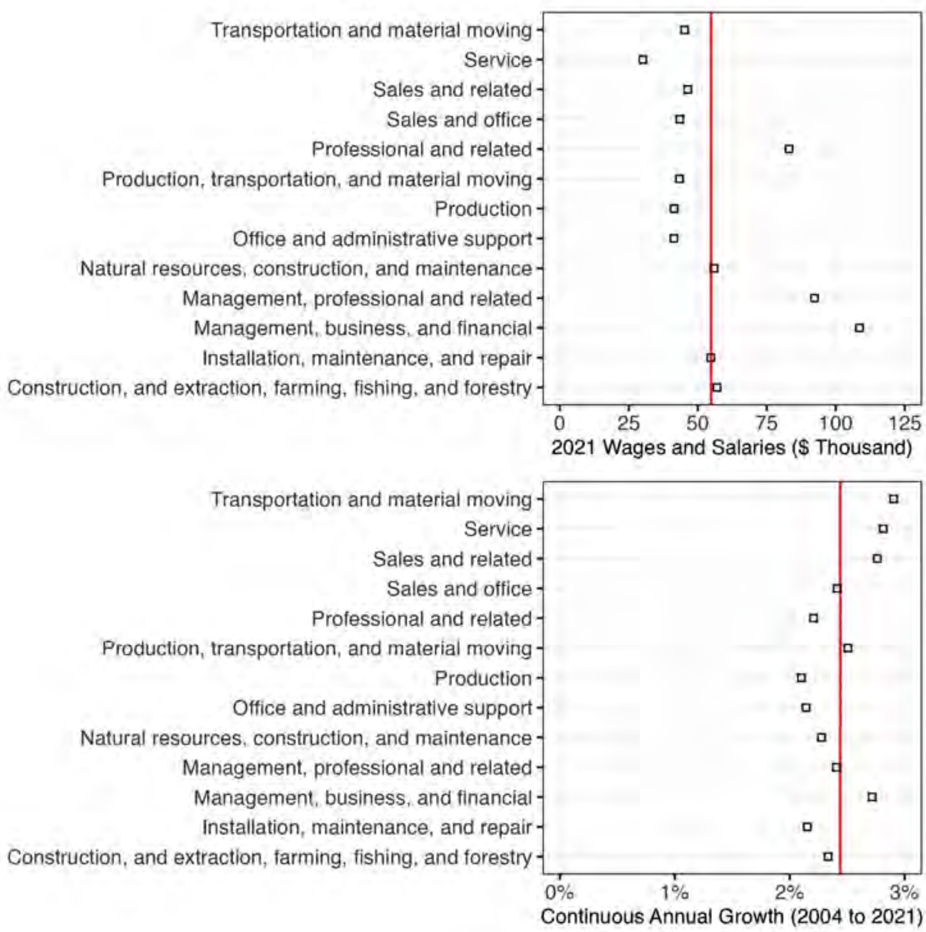


**Figure 1. Variations in wages and salaries (top) and continuous annual growth in wages in salaries (bottom) by occupational category**

Note: Red line denotes unweighted average across occupational categories

Advancement policy, another means of differentiating compensation, also fails as a mechanism for producing a more technically skilled workforce. As previously mentioned, basic pay is adjusted for years of service and rank. Years of service is a measure of longevity and not directly related to technical merit or demand. The biggest determinant for rank is time in service.

While the enlisted force is more dynamic in this regard, line Air Force officers currently meet a 100 percent opportunity for promotions to O-2 and O-3 and a 95 percent promotion opportunity to O-4. Except for differences in pin-on times for O-4, for the top 90 percent of officers, the first significant change in compensation based on skill set or performance quality occurs at the O-5 promotion board around 15 years of service. While job performance is a determining factor as promotion opportunities become more competitive, the Air Force primarily uses promotion to recognize leadership potential instead of technical merit or functional competency for officers and senior enlisted service members.

Together, these factors confirm the Air Force's talent management system is not designed to compensate the most technically proficient or functionally competent service members commensurate with their skills. The rates of compensation, based on the ECI, pay too much for low-growth occupations and too little for high-growth occupations relative to the private sector. Simultaneously, the Air Force tends to emphasize time in service and leadership potential more than technical merit when considering promotion opportunities, particularly for officers and senior enlisted service members.

Thus, incentives normally experienced in the private sector to upskill more rapidly and be compensated at a higher rate based on the market value do not exist in the Air Force. Further, pay differentials from the private sector may incentivize less skilled service members to remain in the service and more skilled ones to leave. For example, average regular military compensation is estimated to be at the 85th percentile of civilian wages for enlisted personnel and the 77th percentile for officers.[13]

While this might be a good sign for general retention, it leaves anyone with earning potential in the top 15 percent for enlisted and top 23 percent for officers financially better off as civilians. This observation is supported by previous research into the effect of military pay and benefits on recruitment and retention in different countries. In particular, the militaries of countries with liberal market economies, such as the United States, are expected to retain a higher proportion of their low-skilled employees and a lower proportion of their high-skilled employees.[14]

One example provides insight into how this structure may struggle to meet the Air Force's needs. The service invests in personnel to attain technical doctorates. But taking three years in the middle of a career, often in addition to one and a half years for a master's

13. OUSDP&R, *13th QRMC*.

14. Lindsay P. Cohn, "How Much Is Enough?," *Strategic Studies Quarterly* 9, no. 3 (September 2015), https://doi.org/.

program, requires a substantial opportunity cost in terms of operational experience. Partially for this reason, personnel with doctorates often do not promote well to senior ranks compared to their more operationally seasoned peers.

Many of these technical experts, receiving compensation at the same level as less-technical service members and facing perceived barriers to promotion, are incentivized to depart the service early. This mismatch between private-sector recognition and compensation for this skill set and diminished Air Force promotion opportunities is a tough problem in the current system; the opportunity cost in terms of operational experience is real, and a doctorate does not automatically qualify personnel to lead at a given level.

In the private sector, the talent management approach is not as limited. Personnel with rare technical skills can be compensated at higher levels for their technical talent while gaining valuable leadership experience and being promoted to roles as they achieve appropriate levels of experience.

Conversely, allowing personnel with doctorates to gain additional experience before promotion requires them to take a further pay cut compared to similarly qualified peers, even if stigmas associated with promotions later in a career are fully overcome. In response to congressional queries, researchers have suggested alternatives to the basic pay table that, like the private sector, adjust for the marketability of skills in addition to the level of responsibility. For example, a recent report notes that the pay model for civilian physicians and dentists in the Department of Defense is based on the Office of Personnel Management General Schedule (GS) system but includes a pay supplement that factors in labor market conditions.[15]

Historically, Congress has created various specialty and incentive pays to help the services with these compensation-related limitations affecting workforce segments that are difficult or costly to replace (e.g., pilots). But the expanding set of missions and skills required for effective personnel in many areas (including force support, cyber skills, maintenance, and many others) make the pace of upskilling across the workforce more critical than ever.

This becomes doubly important as the Air Force attempts to accelerate change and devise new ways of doing business, relying on the multidisciplinary skill sets of its Airmen to do so. The instinctual response to this reality might be to create more specialty and incentive pays for other in-demand areas. Still, statutory restrictions on how the service can use these pays combined with the need to constrain military personnel budget growth will limit the effectiveness of this tool, likely resulting in total compensation levels that remain out of step with private sector earnings.

15. Nancy M. Huff et al., Analysis of a Salary-Based Pay System for the Quadrennial Review of Military Compensation, IDA Document D-13204 (Alexandria, VA: Institute for Defense Analyses, September, 2020), https://apps.dtic.mil/.

## Historical Context for Retention

In the absence of alternative quantifications of competency across the Air Force, aggregate experience—measured as mean years of experience—is one proxy metric for how force-wide policies such as changing compensation drive changes in skill levels. While the desired amount of experience for service members to produce mission success is almost always "more," this desire is bounded by resource constraints and past accession policies. Decisionmakers also allow experience to shift incrementally to meet other policy goals, such as growing or shrinking the workforce.[16] Unbeknownst to many, the changing size of the RegAF over the Air Force's history has had large second-order effects on experience levels and on how personnel move in and out of the different components.

From the end of the Vietnam War until the Air Force began growing in FY 2016, the RegAF averaged a greater than 2 percent annual decline in the number of active duty personnel (end strength), even including the Reagan-era build-up in the 1980s.[17] The service can reduce personnel numbers in two ways: (1) train the same number of people but reduce retention of more experienced (and therefore more skilled) personnel; or (2) train fewer people but retain the same number of experienced personnel. Historically, the Air Force has used both to reduce the workforce's size. Since reductions in accessions are generally the more desirable policy, the prolonged decline from the end of the Vietnam War has resulted in a workforce that is consistently more senior than what could be achieved with the same retention in an environment with a steady end strength.

This dynamic changed beginning in FY 2016 as the Air Force began to grow the workforce.[18] The boom in recruiting new personnel to meet end-strength goals has necessarily reduced aggregate experience despite record-high retention rates among experienced personnel. Such high retention within the RegAF is beneficial in the short term because it allows the workforce to absorb more junior personnel while slowing the accompanying drop in experience.

But there are three negative second-order effects of maintaining such high retention into the future. First, the Air Reserve Component relies on high affiliation rates from the RegAF. While the RegAF has decreased in size by approximately 50 percent since the end of the Vietnam War and retention rates have risen, the ARC has remained roughly the same size. A decline in affiliations from RegAF to ARC creates gaps that the ARC must fill by recruiting and training an ever-larger share of its own personnel.

The inability to meet the target for RegAF affiliations drives changes to recruiting, training, and upskilling business processes that the ARC is not designed to manage.

16. Albert A. Robbert et al., " 'Muddling Through': The Revolutionary Potential of Evolutionary Officer Management Reform," RB-A416-2 (Santa Monica, CA: RAND Corporation, 2021), https://www.rand.org/.

17. USAF, Automated Budget Interactive Data Environment System (ABIDES) (Washington, DC: Secretary of the Air Force Financial Management and Budget Office [SAF/FMB] September 30, 2021), (ABIDES was replaced by the Program and Budget Enterprise System in January 2022).

18. SAF/FMB, ABIDES.

Aside from increasing costs, this detracts from the focus on maintaining proficiency in the ARC. While targeting a 70 percent rate for prior service gains, the Air Force Reserve averaged 54.5 percent over the last 5 years (an annual shortfall of 1,039). During the same period and while targeting a 55 percent rate for prior service gains, the Air National Guard averaged 41.4 percent of this target (an annual shortfall of 971).[19]

This is especially challenging because the ARC lacks the enterprise-level organizations and processes the regular Air Force uses to efficiently manage business functions such as analyzing skill sets (Air Force A1 Human Resources Data, Analytics, and Decision Support Division), recruiting (Air Force Recruiting Service), and moving personnel between locations at scale (Air Force Personnel Center). Starving the ARC of trained personnel increases costs and decreases the effectiveness of the ARC as they must increasingly focus on recruiting, training, and upskilling personnel instead of maintaining proficiency.

The second consequence of such high retention is that it limits flexibility to increase the workforce's size during a crisis. The Air Force can grow the workforce by boosting production, increasing the number of inexperienced personnel, or reducing separations (thereby increasing the number of experienced personnel).[20] Relying on retention during a crisis is attractive because it avoids the need to execute operations with a workforce that suddenly becomes more junior in composition, potentially requiring changes to procedures or training. Relying on retention during peacetime, however, diverts resources to retention incentives, higher pay, and retirement costs and away from building and maintaining training pipeline capacity—a strategic asset that takes years to build and allows the workforce to expand rapidly when needed.

Further, when retention is high, the Air Force has limited ability to reduce separations to expand the workforce. For example, when stop loss was enacted after 9/11, loss rates fell from roughly 12 to 9 percent, immediately boosting the number of people in separation-eligible year groups. But current retention rates are much closer to the stop loss rate in 2002 than the retention of the 1990s or early 2000s.[21] This exceptionally high retention means there is little room to boost retention further, especially as some portion of individuals leaving the workforce do so for medical or disciplinary reasons that the service may not wish to or cannot disregard.

In time, the Air Force will almost certainly need to increase end strength quickly to deter or respond to aggression. Given current retention levels, the service would rely almost entirely on increasing accessions to do so. The accompanying rapid increase in junior personnel could drive a potentially catastrophic shift in experience that will affect the Air Force's ability to conduct operations in the moment it can least afford it.

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19. Joseph C. Hoecherl, "Military Personnel Data System, AF/A1XD Extract," May 30, 2022..

20. Joseph C. Hoecherl, "Background Paper on Impacts of End Strength Changes on Service Experience and Training," white paper (Washington, DC: Air Force Human Resources Paper, June 25, 2018).

21. Hoecherl, "AF/A1XD Extract."

The final consequence of such high retention results from the set of policies for the enlisted force that are currently helping drive that retention higher. Historically, one of the types of policy levers the Air Force used to ensure the right mix of skill sets as measured by Air Force specialty codes (AFSCs) was involuntary retraining. These policies helped the service keep pace with changing manpower requirements as programmed in the collective unit manpower documents for different skill sets, which, in turn, reflected the changes in mission sets and programmatic changes authorized by Congress.

During the past two decades, the Air Force has averaged 10,000–12,000 RegAF enlisted specialty code shortages despite meeting end-strength goals.[22] In other words, the service is continually overmanned in some enlisted AFSCs and undermanned in others, though which AFSCs are over- or undermanned change. Historically, the programs that created "cross-train to reenlist" pressure could be used to fill specialty code shortages, though these programs increased separations.

For example, the career job reservation program used prior to 2014 only allows a certain number of Airmen in each career field to reenlist in their current AFSC. An alternative program with the acronym RRAP was developed in 2016 to solve some of the limitations of the career job reservation process but was never fielded. The cessation of policies like career job reservation has made it difficult for the Air Force to reduce shortages, especially in specialty codes that rely entirely on retraining to replace personnel.

The net effect of these recent policies has boosted retention, with the effects accelerated by the economic impacts of the COVID-19 pandemic. This retention has given the Air Force time to normalize this new, more junior experience level resulting from flattening the decline of RegAF end strength. But further efforts to sustain such high retention will increase the cost of the workforce while also making it less adaptable and less robust.

## Proposed Strategy

To expand the technical depth and breadth of the regular Air Force, this article presents a two-pronged strategy that seeks to retain and incentivize the right mix of skill sets without ballooning compensation costs. The strategy requires two broad policy changes with significant interactions.

First, the US Air Force must request Congressional support for an incremental, steady transformation of the service's approach to compensating talent to one that directly rewards Airmen based on the value of different skill sets. This could either be through a separate pay structure for the service or through providing these same pay flexibilities to the other services, which face the same challenge of recruiting, developing, and retaining high-value skill sets.

Second, the Air Force must establish policy structures to increase retraining to undermanned Air Force specialty codes for enlisted personnel and rates of affiliation

22. Hoecherl, "AF/A1XD Extract"; and Hoecherl, "Manpower Programming and Execution System—Unit Manpower Document, AF/A1XD Extract," May 30, 2022.

into the Air Reserve Component for both officers and enlisted personnel, resulting in higher turnover for the RegAF. Aside from allowing the Air Force to meet total force requirements better, a higher turnover will create a more resilient workforce in a time of crisis and will decrease military personnel costs.

## Policy Proposal 1: Compensation Transformation and a Skills-Based Organization

Future raises to base pay should be divided into two categories: 45 percent of growth would be dedicated to increasing base pay, and 55 percent of growth would be dedicated to a new category of competency-based pay. Over time, competency-based pay will grow from a small share of total pay to become a much larger share. Because competencies and competency-based pay will be held at higher rates by personnel with more experience, the competency-based pay should provide higher compensation for more experienced personnel.

Conversely, the base pay table should flatten over time, as pay increases based on grade and years of service are slowly replaced in part by competency-based pay. This would provide a floor for personnel to be compensated adequately as they enter the force, then provide increased compensation as they gain relevant skills.

A key driver of the effects of competency-based pay will be the specific skills the Air Force uses to set compensation levels. This can start with specialty pays for nonrated specialty codes, the primary skill-level qualifications for enlisted personnel, and skills such as language proficiency that are already defined and measured. The next logical steps are technical skills such as programming, data literacy, and specialty-specific technical skills as measured by degrees or certifications.

As the proportion of total pay for competencies increases over time, this process can mature to include a larger number of more specific competencies if additional granularity is needed. The slow rate of growth allows for some experimentation to find the right levels and structure of compensation (fig. 2). Since changes in compensation structure will occur slowly, retention effects will also manifest gradually.

Defining skills in this way confers additional benefits, such as the ability to measure and report different types of talent in the workforce and track changes over time. In an age of digital transformation, the Air Force will need a broader set of technical skills related to data literacy across all specialties. This type of approach creates a way to track and incentivize such skills without requiring overly broad restrictions based on coarse measures such as undergraduate major. Also, this puts the changes in compensation directly into service members' hands; this system could advertise in-demand skills, resources available to obtain those skills, and the monetary incentives for doing so.

To slow the exponential growth in personnel costs, the total rise in compensation should be capped at 0.5 percent below the Employment Cost Index rate of growth until 2035 while maintaining the ECI rate for junior enlisted grades (fig. 2). While aggregate compensation will not rise as fast as private sector aggregate compensation during this period, the competency-based pay will help retain high-quality technical talent and incentivize personnel to upskill in critical skills defined by the service.

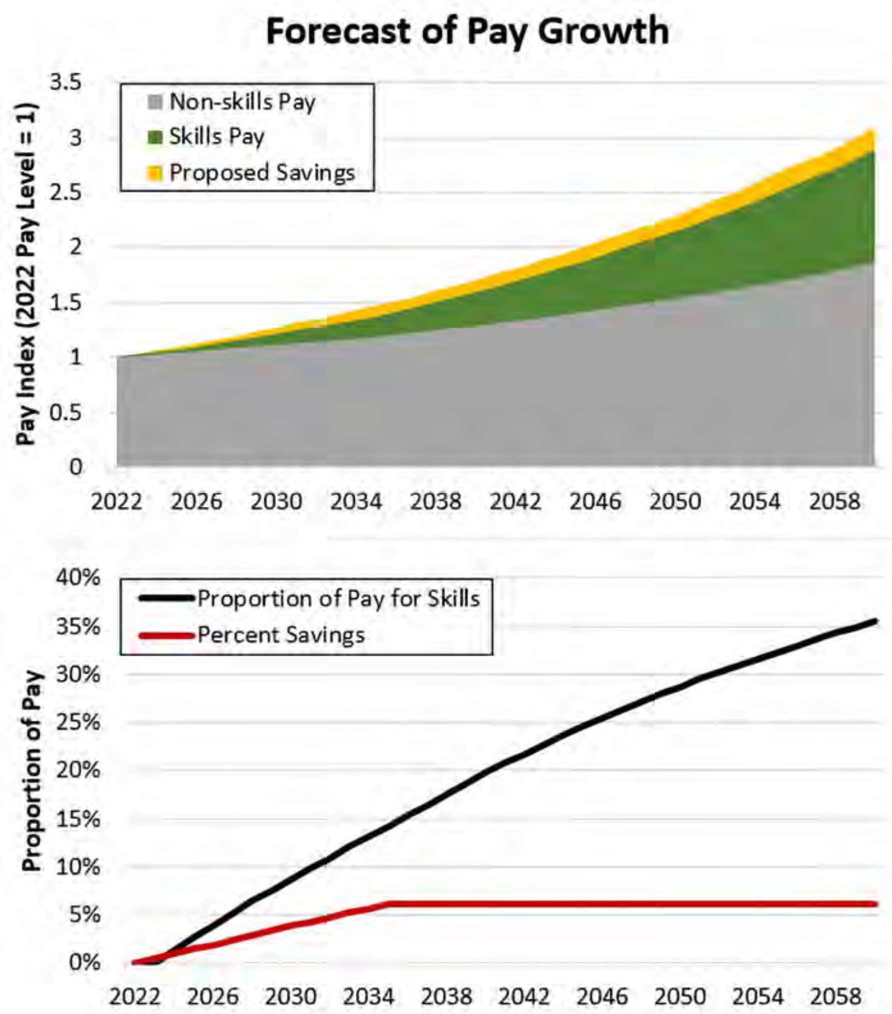


**Figure 2. Growth over time of base pay and competency-based pay (top) and proportional division of pay and savings level (bottom)**

## Policy Proposal 2: Manage Total Force Retention, Not Regular Air Force Retention

By maximizing regular Air Force retention, the service trades away the right RegAF skill mix, stable experience during future crises, and the healthy flow of individuals into the Air Reserve Components. To deal with these problems, this article proposes a shift to managing retention with a Total Force mindset, creating an intentional downward shift of RegAF retention while maintaining Total Force retention. This can be achieved by combining expanded Palace Chase programs with better marketing from the RegAF and a similar mechanism to the historical career job reservation process, allowing individuals without a career job reservation to transition to the ARC if they so desire.

Simply targeting additional affiliations to meet the current Air Force Reserve and Air National Guard enlisted affiliation shortfalls would create 2,010 additional transitions each year, requiring an additional 2,689 RegAF accessions (i.e., an 8.5 percent increase) once adjusting for retention patterns. In a crisis, this would establish the ability to grow end strength by an additional 2,000-plus experienced personnel per year without increasing accessions or by a significantly larger number of personnel per year without dramatically disrupting experience ratios if pipeline capacity is available.

The Air Force can gain a similar capability through voluntary or involuntary officer transitions as well, though existing voluntary mechanisms will require a greater concerted effort to create awareness of ARC opportunities among personnel in the regular Air Force. This increased awareness can also ameliorate the impact of additional separations caused by the career job reservation program if personnel who would have separated choose to instead transition to the ARC.

By exercising policy options like career job reservations and accepting lower retention levels within the regular Air Force, the service can right-size different specialties in the RegAF enlisted force. A rejuvenated retraining program would allow the regular Air Force to retrain people able and willing to bring their experience to address unfilled needs for different specialties.

At the same time, the Air Force could significantly expand opportunities to volunteer for the Palace Chase program for officers and enlisted personnel; this would help meet Air Force Reserve and National Guard requirements while normalizing higher turnover in the RegAF. A greater flow of fully qualified, skilled Airmen into the Reserve would also reduce fragility by improving reserve readiness in a conflict. This policy would offset the costs of a larger training pipeline by reducing the proportion of the RegAF who will collect senior pay and, eventually, retirement compensation.

Implementing this course of action will directly cause average experience (as measured by years of service) to decrease in the RegAF, though not necessarily in the Total Force. While this will require creative efforts to train and upskill junior RegAF personnel more rapidly, the alternative is considerably more dangerous—upskilling more junior personnel during a crisis. It will be much easier to adapt to such experience levels in peacetime with the time and resources to iterate and develop ways to upskill personnel more rapidly. Maintaining the status quo risks paying for peacetime savings with service members' lives during a conflict.

Also, while career job reservations affect only first-term reenlistment, this type of policy can shift some portion of the retention change to more senior levels via either the noncommissioned officer retraining program or other mechanisms. While this policy can be implemented in many ways, the key is to ensure the RegAF can meet its requirements and increase retention to grow in a time of crisis, and the ARC can increase its level of affiliations from the RegAF. The changes implemented in the blended retirement system also help ensure personnel separated at earlier stages of their career are receiving retirement compensation.

## Potential Criticisms

Notwithstanding the widespread benefits to skill mix, resiliency, and cost, the policy proposals are challenging to implement for various reasons. Some potential critiques are discussed below.

### *Critique: Competencies are hard to catalog, verify, and set compensation levels.*

For the strategy to be workable, the personnel and pay systems need a catalog of valuable skills, credible ways of verifying which members possess them, and a method to determine their monetary value. Past successes in these areas show Department of the Air Force personnel and pay systems are equipped to handle these implementation challenges.

The department already assesses and adjusts special and incentive pays for more technical and varied skill sets, including, for example, oral and written proficiency in foreign languages and the ability to be a test pilot for experimental fighter aircraft. Also, the department can incrementally refine skill-based pays year-over-year, learning from how the personnel with various skill sets respond. Further, the department's need to define and assess competencies is not unique to this proposal. Any viable strategy to achieve the Air Force chief of staff's aims to develop attributes for the high-end fight must first define and assess those attributes.

### *Critique: Skills-based pay will increase military personnel costs.*

The addition of new pay and the cost of conducting additional assessment and compensation analysis may not appear to be viable, especially when all services are focused on containing growth in the military personnel budget. If a new skills-based pay system was naively layered atop the current compensation system, this would increase costs. Still, given that the current policy of anchoring base pay to the ECI is counterproductive, diverting future increases in base pay to skills-based compensation would further talent management goals in a cost-neutral or cost-saving manner, depending on implementation choices.

### *Critique: Reducing base pay may hurt certain workforce segments, such as junior members of the enlisted force.*

Modifying the linkage between base pay and ECI and creating a new category of compensation requires statutory change, and in the political domain, discussions often rightly focus on the lowest-earning Airmen. Slowing the growth of base pay in favor of skills-based pay could raise objections that some individuals at the bottom of the base pay scale who have not yet obtained skills that would increase compensation would fall below a living wage. Increases in base pay, however, do not need to be flatly applied across the existing pay structure. Over time, the base pay structure should flatten considerably to provide a solid, livable wage, while much of the increased compensation provided to senior personnel would be tied to their competencies.

### *Critique: The Air Force must maintain the principle of equal pay for equal work.*

Would a compensation system that is vastly more differentiated based on member skills violate the cultural value of equality? The reality is that the current pay system is already significantly differentiated because of special and incentive pays. Still, these payments are reserved for the concentrated subsets of the workforce, such as pilots. This approach instead provides many more Airmen the ability to gain such types of additional pay as they gain new skills.

### *Critique: Personnel may acquire but not routinely use skills that they are compensated for.*

A critique of this policy is that it might compensate members for marketable skills irrelevant to their jobs, which again reflects a challenge for existing special and incentive pays. To remain competitive with the commercial market while maintaining relatively similar pay across occupations, the Department of the Air Force is already overcompensating some service members, so the risk given the alternate system may be no worse.

Also, even if a skill is not relevant for an individual in a particular job, it may increase depth and flexibility in the workforce. Lastly, certain skills like digital competency may unexpectedly transform how service members perform in certain positions. The high rate of change in these digital skills and their interaction with war fighting and support functions are evolving incredibly rapidly; planners cannot possibly anticipate all the combinations of skill sets that will unlock the innovation the Air Force seeks. These fortuitous advances are only possible given a highly skilled workforce.

### *Critique: Allowing RegAF retention to decrease will increase the required recruiting quota.*

Recruiting individuals for military service is a nontrivial problem in America today. But the Air Force must be ready to meet this challenge during a conflict anyway. While Air Force Recruiting Service is having difficulty making its current recruiting goals, the ability to recruit to a required level is a strategic resource that must be managed carefully.[23] Hoping a crisis will result in increased volunteerism is not a wise strategy. Also, reducing

23. David Roza, "Air Force Recruiting Is in the Toilet and Senior Leaders Are Sounding the Alarm," Task and Purpose, January 12, 2022, https://taskandpurpose.com/.

ARC accession requirements will reduce competition for RegAF recruiters. Addressing the challenge in peacetime gives us the luxury to try different policies and incentives with lower stakes than after a crisis erupts. Moreover, emphasizing how the Air Force invests in the development of valuable skill sets in its members may increase interest in service among America's best and brightest potential recruits.

## A Holistic View of the Future Workforce

The list below summarizes areas touched by the policy proposals and links them to existing fragilities and intended changes. By simultaneously implementing the these proposals, the Air Force can manage skill sets more directly through compensation and workforce management policies, ensuring a better skill mix for the RegAF and the ARC.

Also, by investing the time to quantify skill sets, the service creates a way to measure what shortfalls cannot be met by existing policy mechanisms and enables a framework that could one day enable better permeability. As the Air Force begins to develop multi-capable Airmen, these approaches create structures to incentivize Airmen to invest in needed skill sets across the force and avoid simply demanding that Airmen "do more with less."[24] Finally, the RegAF can grow quickly in a crisis without immediately compromising normative experience levels.

### *Recruiting*

- Fragility: Sized to meet minimum accession requirements given high retention rates
- Design Change: Expand RegAF recruiting capacity to exceed minimum accession requirements

### *Training Capacity*

- Fragility: Sized to meet minimum production requirement given high retention rates
- Design Change: Expand training pipeline capacity to exceed minimum production requirements

### *Compensation*

- Fragility: Anchored to average wages and salaries across private sector occupations
- Design Change: Shift compensation from base pay to skill-based pay

24. David Roza, "Air Force Leaders Love the Phrase 'Multi-Capable Airmen.' Here's Why Airmen Hate It," Task and Purpose, April 14, 2022, https://taskandpurpose.com/.

### *RegAF Career Field Manning*

- Fragility: Large problems caused by changes in requirements or lack of volunteers to cross-flow into certain Air Force specialty codes
- Design Change: More dynamic policies create a closer match between personnel and requirements

### *ARC Recruiting*

- Fragility: ARC manning is dependent on the local recruiting of nonprior service trainees to meet shortfalls in RegAF affiliation
- Design Change: Increase the number of RegAF personnel available for affiliation

### *Experience/Competency*

- Fragility: Dependent on historically high retention rates and low production
- Design Change: Decouple experience from retention in RegAF; increase experience in ARC

### *Military Personnel Budget*

- Fragility: Limited ability to change the average cost of an Airman, forcing reductions in end strength to control the military personnel budget
- Design Change: Limit growth in the average cost of an Airman

One can imagine a future where Airmen log into an Air Force application that provides a comprehensive view of their current skill sets and performance assessments. As they select personal goals, they are provided with suggested skill sets or certifications, along with the programs to help them gain these skills. They can see estimates of how these skill sets would increase their take-home pay, increase their odds of promotion, create cross-training opportunities, and prepare for private-sector careers. Lastly, they can see which Air Force Reserve and Air National Guard bases have openings for such a skill set. As the Air Force invests in its people's skill sets, it creates the skilled personnel needed for today's problems and tomorrow's crises. ✈

# 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

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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]

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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

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]

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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]

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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

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/.

Force Research Laboratory's D'Azzo Library restrictions should be removed to allow access to all officers regardless of location.

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."

# Air Mobility Intelligence

## Survivability in the Contested Environment

Phillip Surrey

The intelligence enterprise supporting air mobility operations must evolve to meet the demands of the future fight. The rapid global mobility intelligence architecture should provide mobility-focused intelligence at tempo; however, it currently exhibits a structure more suited to a set-piece Cold War than the next war. To adequately protect rapid global mobility in a high-end conflict and deliver the Joint Force to its destination, the Air Force must accelerate change in the intelligence architecture in three ways. The service must update its force development, expand the participation of rapid global mobility intelligence in operational planning, and establish a rapid global mobility senior intelligence officer who can operate across service and Joint boundaries to ensure air mobility Airmen have the situational awareness to optimize their decisions in a crisis.

Students of great power competition recognize the vital contribution Air Mobility Command (AMC) delivers through rapid global mobility (RGM) to deploy and sustain the Joint Force at the time and place of the nation's choosing. Rapid global mobility encompasses the entire range of AMC-delivered capacities, namely airlift, air refueling, aeromedical evacuation, and air mobility support.[1] Now more than ever, the command requires dedicated intelligence processes to protect these capabilities in the future contested environment.[2]

Unfortunately, the RGM intelligence enterprise has not evolved to meet this new era, prompting the need to streamline how intelligence supports air mobility. This restructure will require (1) deliberate force development within the AMC intelligence force, (2) the provision of AMC intelligence liaisons for air mobility planning, and (3) the designation of an RGM senior intelligence officer responsible for synchronizing processes across the global enterprise.

The rapid global mobility intelligence architecture is disjointed and lacks process discipline from planning to execution. While some intelligence support exists at AMC and its 618th Air Operations Center (AOC), the Air Force persists in splitting RGM intelligence capabilities into geographic commands rather than deploying them as part of a functional intelligence organization. Meanwhile, almost no RGM intelligence-trained

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1. US Air Force (USAF), Air Force Doctrine Publication (AFDP) 3-36, *Air Mobility Operations* (Maxwell AFB, AL: Curtis E. LeMay Center for Doctrine Development and Education (LeMay Center)), 1, https://www.doctrine.af.mil/.

2. Mike Minihan, *Air Mobility Command Strategy* (Scott AFB, IL: Headquarters, Air Mobility Command (HQAMC), March 29, 2022), 4, https://www.amc.af.mil/.

Airmen sit on air component or Joint staffs outside transportation organizations. This results in what the US Air Force *Operating Concept for Information Warfare* describes as a fragmented approach to integrating key information capabilities across war-fighting echelons.[3]

Because of this construct, small teams of RGM intelligence personnel at the theater air operations centers must rely on nonmobility Airmen for intelligence support. Airmen at the unit level develop their intelligence products based on what they happen to know. This model is deficient as it defeats the purpose of a necessary "unity of effort" in the execution of intelligence operations for RGM customers and lacks the depth of analysis that would be gained from an experienced intelligence staff focused on their core mobility mission.[4] As a result, quality intelligence is not reaching all its RGM stakeholders.

In response, the service should functionally align its rapid global mobility intelligence at all echelons, linking AMC headquarters to theater air operations centers and unit-level activities to provide the optimum intelligence available. This will require an intelligence force seasoned in the RGM ecosystem, liaisons across planning staffs, and, most importantly, a single RGM intelligence officer overseeing the enterprise. This transformation will allow the Air Force to leverage one voice on RGM intelligence matters unencumbered by command boundaries while maintaining the forward force necessary to conduct analysis at the tactical level when operating in a contested environment.

To understand why now, more than ever, an inflection point exists in how the Air Force should harmonize mobility intelligence requires a discussion of how the Joint Force is imagining employing air mobility in a near-peer fight across multiple geographic commands and theaters. During combat operations, a commander might yield partial air superiority or cede key terrain and plan to come back another day. In contrast, the worldwide logistics chain is only as strong as its weakest link, and a break incurs immediate strategic risk. In this environment, an antiquated RGM intelligence architecture will fail to provide relevant intelligence. This reality should drive the service to explore why and how RGM intelligence should transform to meet the demands of the future fight.

## Failure to Adapt

Despite AMC's recent success when it extracted 124,000 personnel from Afghanistan and then rapidly flew weapons to Eastern Europe in support of Ukraine, it is becoming more feasible for adversaries to contest air mobility from the point of departure, requiring what the unclassified summary of the *2022 National Defense Strategy* describes as the

3. USAF, *United States Air Force Operating Concept for Information Warfare* (Washington, DC: USAF, March 2022), 6.

4. Chairman of the Joint Chiefs of Staff (CJCS), Joint Publication (JP) 2-0, *Joint Intelligence* (Washington, DC: CJCS May 26, 2022), https://www.jcs.mil/.

ability to "withstand, fight through, and recover quickly from disruption."[5] The historical treatment of air mobility as a guaranteed resource is outdated, and the new environment is driving AMC to develop concepts and capabilities to survive in the contested environment. But RGM intelligence has fundamentally failed to innovate in the same manner as Air Mobility Command's operational side, even though there are examples of functional integration within other military intelligence organizations.

The military often inadequately plans for RGM effects. During the Operation Desert Storm build-up, the planners did not initiate mobility planning until after the deployment order was issued, leading to infeasible airlift requirements.[6] When the pace of operations accelerated during Operation Allied Force, the understaffed planning cell was nearly overwhelmed.[7] During Operation Unified Response, a lack of RGM and intelligence resources within the geographic command delayed the US response to the Haiti earthquake.[8] These cases represent an indifferent approach to RGM planning that senior DoD and Air Force officials have stated will no longer be acceptable.[9]

New threats, including hypersonic weapons and information warfare, underscore the reality that the battlefield now starts at home. Air Force operating concepts advise that "adversaries will aggressively target and attack vulnerable US and allied information and logistics networks to prevent our advanced weapon systems from engaging in any consequential kinetic fight."[10] In April 2022, US Transportation Command (USTRANSCOM) commander General Jacqueline Van Ovost summed up the situation by warning that "the complex contested environment that is emerging will test the future readiness of our enterprise and challenge USTRANSCOM's ability to deliver a decisive force when needed."[11] As the air component to USTRANSCOM, Air Mobility Command is investing in capabilities to improve situational awareness and survivability. The command

5. Department of Defense (DoD), "Fact Sheet: 2022 National Defense Strategy," DoD News (website), March 2022, https://media.defense.gov/.

6. James A. Winnefield, Preston Niblack, and Dana J. Johnson, *A League of Airmen: U.S. Air Power in the Gulf War* (Washington, DC: RAND Corporation, January 1, 1994), https://www.rand.org/.

7. D. Richard Simpson, "Command of Theater Air Mobility Forces during the Air War over Serbia: A New Standard or A New Data Point?," *Air & Space Power Journal,* Chronicles (online Journal), October 11, 2000, https://www.airuniversity.af.edu/.

8. Joseph Vanoni, "From Strategic to Tactical and Nowhere In Between: The USAF at the Operational Level" (master's thesis, School of Advanced Air and Space Studies, Maxwell AFB, AL, June 1, 2012), https://apps.dtic.mil/, 127.

9. Valerie Insinna, "EXCLUSIVE: Even with Ukraine Operations Ongoing, Air Mobility Commander Focused on China," Breaking Defense, April 1, 2022, https://breakingdefense.com/.

10. USAF*, Information Warfare*, 1.

11. US Transportation Command Public Affairs, "Van Ovost Delivers Command Posture Statement to Senate Armed Services Committee," National Defense Transportation Association (website), April 1, 2022, https://www.ndtahq.com/.

is fundamentally transforming the way it conducts operations through agile combat employment.[12]

The agile combat employment concept replaces traditional linear methods of airlift that have been the hallmark of mobility since the advent of Air Transport Command in World War II. This concept injects flexibility and adversarial dilemmas through a proactive scheme of maneuver but requires "sufficient coordination of intertheater and intratheater transportation to move the force at the proper time and with sufficient tempo to achieve desired effects."[13] These efforts inherently complicate coordination between air, maritime, and surface logistics, requiring real-time intelligence for risk-informed decisions during mission execution.

## Obstacles to Reliability

Despite this paradigm shift, the intelligence apparatus supporting RGM operations does not reflect the new intertwined, fast-paced environment. There is no intelligence synchronizer to pull and push intelligence and drive activities across all mobility intelligence units, which often operate under different command relationships and environments. Additionally, Joint and air component staffs do not have dedicated RGM intelligence planners that advocate for the intelligence needs of air mobility. Consequently, if the Air Force faces a near-peer fight, intelligence support to air mobility will be ill-prepared and reactive. Instead, it should have a unifying voice that collaborates across the Joint Force to represent RGM intelligence equities.

A case study of where change is needed can be found within the theater air operations center construct, the Air Force's command-and-control center for a combatant command. While Air Mobility Command's 618th AOC conducts global air mobility operations and is dedicated to RGM requirements, a theater AOC is much different. A theater AOC has only a small RGM intelligence support team functionally separate from the center's intelligence, surveillance, and reconnaissance division. Per service doctrine, this team is beholden to this intelligence division for all its intelligence needs.[14]

Rather than reaching back to AMC experts to provide additive mobility intelligence, the rapid global mobility intelligence team is simply one of many customers clamoring for the intelligence division's support. Even in that aspect, it is at a disadvantage because the intelligence division will not prioritize mobility needs. Instead, the division's priority

12. US Government Accountability Office (USGAO), *Defense Transportation: DoD Can Better Leverage Existing Contested Mobility Studies and Improve Training*, Report to Congressional Committees, GAO-21-125 (Washington, DC: USGAO, February 2021), 29, https://www.gao.gov/.

13. Curtis E. LeMay Center for Doctrine Development and Education (LeMay Center) Air Force Doctrine Publication (AFDP) 1-21, *Agile Combat Employment* (Maxwell AFB, AL: LeMay Center, December 1, 2021), 8, https://www.doctrine.af.mil/.

14. Department of the Air Force (DAF), DAF Manual 13-1 AOC, vol. 3, *Operational Procedures–Air Operations Center (AOC) Operations Center (OC)* (Washington, DC: DAF, December 18, 2020), https://static.e-publishing.af.mil/.

is combat air force equities such as threats against Air Force and Joint combat sorties, theater intelligence collection operations, and targeting for local air operations.[15] This leaves the theater RGM intelligence support team without adequate or consistent support.

Because of this structure, the isolated RGM intelligence team at the center must conduct independent research and raise different, important questions for mobility operations that the rest of the AOC overlooks. This outcome is unfortunate and inefficient but predictable since the fundamental purpose of the air operations center is to plan and direct activities of assigned and attached forces. Even if the theater AOC tries to support its own local RGM forces adequately, it lacks the expertise and depth that resides at Air Mobility Command and the 618th AOC.[16] (Incidentally, the 2019 AOC Intelligence, Surveillance, and Reconnaissance Initial Qualification Training made no mention of RMG intelligence other than making the observation that some intelligence existed within the Air Mobility Division, but they were independent.)

In addition to these obstacles to reliability at the theater AOC, there is no forcing mechanism to ensure a common intelligence picture is consistent across the RGM enterprise. Because RGM intelligence is split among commands, when an air mobility aircraft flies a mission with one enroute stop, the crew might receive three different intelligence briefings based on the peculiarities of the unit-level intelligence shops they encounter. By continuing to disperse RGM intelligence Airmen across geographic commands when their customers operate globally and deserve intelligence products aligned across command borders, the Air Force accepts clear disadvantages and fails to present a common intelligence picture for RGM Airmen.

## Functional Alignment

By comparison, other DoD and Air Force intelligence organizations functionally align their intelligence activities. The 44,000 Airman-strong Sixteenth Air Force provides "multisource intelligence, surveillance, and reconnaissance, cyber warfare, electronic warfare, and information operations."[17] With a single commander, the Sixteenth Air Force can integrate efforts while simultaneously providing tailored support to diverse customers.

Similarly, the US Space Force concentrates its operational intelligence in Space Delta 7, whose squadrons provide a central hub to forces across its service and to Joint Force commanders worldwide.[18] Perhaps most directly analogous to AMC, the functionally organized Air Force Special Operations Command (AFSOC) consolidates its intelli-

15. DAF, *Operational Procedures*, para 6.1.

16. DAF, *Operational Procedures*, para 2.1; and AMC, Air Mobility Command Instruction (AMCI) 10-2102v1, *Roles, Responsibilities, Relationships, and Authorities* (Scott AFB, IL: AMC, April 11, 2020), 3.3.2.

17. Sixteenth Air Force (Air Forces Cyber), "U.S. Air Force Factsheet," n.d., accessed July 24, 2022, https://www.16af.af.mil/.

18. US Space Force Space Delta 1, "Space Delta 7," n.d., accessed July 24, 2022, https://www.spacebasedelta1.spaceforce.mil/.

gence capabilities under one umbrella to better present intelligence support to its command as it performs a worldwide mission.[19]

While the missions of Sixteenth Air Force, Space Force, and AFSOC differ, there are some relevant comparisons. All three organizations are based around a functional mission, they are agnostic to command boundaries, and they are vital contributors to a particular core mission or capability. These examples should inspire the Air Force to think about how to better structure RGM intelligence.

In short, the fault lines described above create an intelligence problem for RGM forces endeavoring to become more formidable in the face of contested operations. Despite the signs that concepts such as agile combat employment influence how the Air Force will employ air mobility, the supporting intelligence architecture has not evolved. Yet before exploring potential solutions, it is important to examine the principles of RGM intelligence. These principles contribute to the overall ability of the service to plan and execute air mobility operations.

## Principles of RGM Intelligence

Three key principles highlight why RGM intelligence is functionally unique and how those tenets should impact Air Force planning and execution: unity of effort, operational relevance, and responsiveness to leadership. When appropriately applied, these principles enable effective RGM preparation during planning and employment during execution.

The first principle is unity of effort, in that the service must ensure the intelligence supplied to all mobility Airman—from the AMC commander to the pilot in command—is analytically sound across time zones and units. Disconnected and independently developed threat briefings provide no value to wing deployments and sortie executions. Clearly, situations will occur when unit Airmen must respond to fresh intelligence or cannot communicate in a denied environment. But these production anomalies should be the exceptions to consistency and standardization among RGM intelligence products and assessments regardless of which mission or AOC they support.[20]

The second principle is operational relevance. Air mobility leadership needs an intelligence staff that describes threats in operationally relevant terms incorporating air mobility standards and employment parameters. This may cause friction with other analysts that do not understand threats to rapid global mobility. For example, in the early days of Operation Enduring Freedom, assessments differed regarding the antiair threat in southern Afghanistan.[21]

19. 1st Special Operations Wing Public Affairs, "361st Intelligence, Surveillance, Reconnaissance Group," Hurlburt Field (website), n.d., accessed July 24, 2022, https://www.hurlburt.af.mil/.

20. LeMay Center, *Agile Combat Employment*, 10.

21. Nathan Lowrey, *U.S. Marines in Afghanistan 2001–2002: From the Sea* (Washington, DC: US Marine Corps (USMC) History Division, 2011), 101.

This disagreement illustrates that without a dedicated intelligence staff to inform air mobility commanders and pilots, external stakeholders will place aircraft in jeopardy either through ignorance or moral hazard. Mobility-tailored threat assessments underpin the ability to make effective risk decisions for mobility air forces, applying a mobility-sophisticated lens to threat assessments for operational planning and execution.

The third RGM principle is responsiveness to air mobility leadership. In major combat operations, multiple commanders with different priorities will compete for limited resources. The engaged combat forces striving to maximize tactical successes often garner the most attention. Air mobility leaders, whether at headquarters, AMC or in the theater, must have a clear picture of threats to aircraft, airfields, and supporting activities to ensure the Joint Force strikes a deliberate balance in the allocation of counterair, air and missile defense, and force protection. Along with outlining threats to rapid global mobility missions, RGM intelligence experts must craft intelligence requirements that inform the selection of mission location, the timing of operations, and synchronization with combat forces or theater logistics.

By proactively applying these principles at the inception of operational planning, RGM intelligence experts will produce analysis that will inform logistics schemes and set expectations for force protection. Working in collaboration with the Intelligence Community and theater intelligence staffs, RGM intelligence analysts should examine adversary courses of action to determine threats to airfields and airspace while creating associated priority intelligence requirements. These actions will ensure air mobility's risk-to-force and risk-to-mission are accurately evaluated in parallel with other stakeholders and adequately represented during wargaming and course-of-action evaluation.

Applying RGM principles at the outset of operational planning is important because once logistics infrastructure is set, it becomes a herculean effort to reset port locations and reallocate air and missile defenses. Moreover, it is unacceptable to put aircraft and Airmen in harm's way because of avoidable miscalculations during planning. This error has occurred not only during exercises where the theater command plans in isolation but also in real-world operations where planners applied "pixie dust" to air mobility concerns by planning as if it was a limitless resource in a dynamic battlespace.[22]

After operational planning and transition to execution, RGM intelligence must provide a threat picture that takes advantage of all available intelligence and analytical resources. During execution, air mobility assets may transit multiple theaters of war with different command relationships. In this setting, intelligence personnel at command and control nodes are analysts and knowledge brokers; they must coordinate with multiple intelligence and operational entities to monitor the changing battlefield in real time and inform their aircrews.

In summary, RGM intelligence is most effective during planning and execution if it integrates the three principles of RGM intelligence: unity of effort, operational relevance,

22. Based on author's firsthand experience.

and responsiveness to leadership. These principles form the foundation that keeps mobility intelligence relevant; further, they inspire key recommendations to modernize the intelligence enterprise for air mobility.

## Modernizing the Enterprise

To achieve the goal of a functionally aligned RGM intelligence enterprise ready for a near-peer fight, the Air Force must innovate. This requires a model that standardizes RGM intelligence assessments across the force and ensures those assessments support operational planning and execution. This will occur through three lines of effort: (1) investing in force development, (2) providing liaisons to provide RGM intelligence support to planning, and (3) assigning functional responsibility to a single mobility intelligence Airman.

The first line of effort requires the Air Force to commit Airmen to develop their intelligence capabilities within the RGM enterprise. This process would pipeline Airman from unit-level intelligence to become intelligence staff officers ready to serve on the AMC staff or other air component staffs. This career path would avoid an atrophy of expertise that currently occurs when Airmen rotate out of the mobility world after only one assignment, and it would provide Airmen the time to grow staff skills as intelligence analysts and planners. The service should reinforce this priority by creating a special experience identifier for career-field development and designate some AMC assignments as milestone assignments within its talent management framework.

In tandem with this effort, the Air Force must grow RGM intelligence skills at the operational level of war—where operational art is used to link military actions to national strategic objectives.[23] The existing curriculum for RGM intelligence personnel—at the initial schoolhouses, command and control courses, and weapons school—focuses on performance at the tactical level. For intelligence Airmen expected to contribute to AOCs, staffs, and planning teams, the service should prepare them for such work by sending them to additional courses covering the Joint planning process and advanced command and control, including hosting intelligence officers within the Advanced Study of Air Mobility program.

Under the second line of effort, the Air Force should designate some intelligence officers as liaisons to provide intelligence insight during air mobility planning. These individuals could deploy to external staffs on short notice to work directly with Joint logisticians to analyze options for operating inside a threat's decision cycle.[24] This compliments the Air Force's intent to assign intelligence Airmen to the staffs where they will have the most impact.[25]

23. CJCS, JP 3-0, *Joint Operations* (Washington, DC: CJCS, May 15, 2018), I-13.
24. CJCS, JP 4-0, *Joint Logistics* (Washington, DC: CJCS, February 4, 2019), IV-15, https://www.jcs.mil/.
25. USAF, *Information Warfare*, 8.

These liaisons are somewhat akin to Air Force intelligence, surveillance, and reconnaissance liaison officers who integrate intelligence into ground schemes of maneuver and air mobility liaison officers who create feasible mobility requirements. [26] Rapid global mobility intelligence liaisons would identify threats to mobility operations during mission analysis and articulate the need for theater-provided force protection. They are particularly relevant when the supported staff lacks mobility know-how but is creating requirements that AMC will execute with organic forces.

To illustrate the value of a RGM intelligence liaison, consider the following scenario: a combatant command's emerging operational plan envisions multiple AMC C-17s delivering the Army's High Mobility Artillery Rocket System to an austere location held by a Marine littoral regiment inside an adversary's weapons engagement zone.[27] The liaison would work across organizations to ensure a complete threat picture, establishing intelligence-sharing relationships with the embedded Marines.

The liaison would ensure intelligence operations included collection required by the C-17 mission planning cell and would participate in the planning team responsible for the overall operation. In this scenario, the liaison would harmonize the natural seams between functional and geographic organizations at multiple echelons within the Joint Force and would provide a robust threat evaluation to the RGM commander with operational control of the C-17s.

The third and most important line of effort is designating a senior intelligence leader, most likely at AMC, as the RGM senior intelligence officer responsible for the orchestration and direction of the RGM intelligence enterprise, regardless of what customer or command relationships exist.[28] This individual would set standards on analysis and production applicable to all mobility intelligence Airmen. Moreover, they would actively oversee the entire enterprise to ensure effective force disposition of intelligence resources and synchronizing intelligence assessments across the force. This officer would also be responsible for setting the right force balance between meeting the requirements for theater intelligence support and AMC priorities as set by US Transportation Command.

Aligning under a single air mobility senior intelligence officer brings RGM intelligence into compliance with how AMC leads the overall RGM enterprise, which must comply with AMC's standards for air mobility forces' interoperability and efficient employment regardless of assignment.[29] This would also fundamentally realign RGM intelligence within theater AOCs by linking all the RGM intelligence personnel worldwide

26. Mike Snelgrove and Jaylan Haley, Ricochets and Replies, *Air & Space Power Journal* 29, no.2 (March–April 2015), 166–69, https://www.airuniversity.af.edu/.

27. USMC, *Tentative Manual for Expeditionary Advanced Base Operations* (Quantico, VA: USMC Warfighting Laboratory Futures Directorate, February 2021), https://www.mcwl.marines.mil/.

28. USAF, Air Force Instruction 13-103, *Command and Control: AFFOR Staff Operations, Readiness, and Structures* (Washington, DC: USAF, April 12, 2019), https://static.e-publishing.af.mil/.

29. AMC, *Roles, Responsibilities, Relationships*, 2.4.2.

into a singular intelligence structure and possibly require those forces to be in a direct support relationship versus attached to the theater.

As a result, the value of RGM intelligence deployed to the theater AOC would improve by harnessing the analytical power of a global air mobility intelligence enterprise. This translates to more robust support when planning and executing operations such as escorted airdrop missions or air refueling combat sorties.

Implementing these lines of effort does not assume RGM intelligence resources will increase; instead the Air Force can accomplish this by more effectively employing existing capabilities. Accordingly, there is a risk that some stakeholders will believe these changes deplete their capabilities or move processes outside their control. As these concerns become known, subsequent research should incorporate these perspectives to ensure the service includes customer needs when optimizing the RGM intelligence enterprise.

## Conclusion

These three recommendations represent a needed starting point, and their implementation will evolve as they demonstrate value. They are rooted in military and civilian experiences in US Transportation Command, Air Mobility Command, and AOC combat operations. More importantly, they reinforce the Air Force's global approach to integrating capabilities across strategic, operational, and tactical warfighting intent.[30]

As the Air Force seeks to maintain its ability to project and sustain the Joint Force under all-domain persistent attack, it must mature air mobility intelligence for the contested environment. Doing so will ensure the underlying intelligence architecture meets the demand of the mobility maneuver force at tempo in a near-peer fight. With a reinvigorated force, key touchpoints across the Joint Force, and an air mobility intelligence senior intelligence officer at the helm, rapid global mobility intelligence will be a critical capability that enables AMC and air mobility forces to project "decisive strength across contested domains."[31] This is the cost of entry to ensure the Air Force can provide decisive contributions to Joint warfighting and preserve the competitive advantage of rapid global mobility.

30. USAF, *Information Warfare*, 6–8.
31. AMC, "About Us," AMC (website), n.d., accessed July 24, 2022, https://www.amc.af.mil/.

# Forged at the Edge of Chaos

## Emergent Function Weapons

Michael W. Byrnes
Aubrey L. Olson

A specific class of weapons is appropriately categorized under the moniker *emergent function weapons*. The devices in this category include not only swarming and flocking systems, but a host of system types that have in common the idea that they operate as complex adaptive systems whose battlefield functions manifest only from emergent behavior at scale. Emergence is the underlying phenomenon that enables flocking, swarming, clustering, patterned diffusion, and other self-organizing system behaviors. The concept of an emergent function weapon invites the military to establish a defense research program that moves beyond the endless quest for better sensors and more processing power and instead leverages contemporary advances in behavioral robotics.

A first-rate warship slowly drifts toward Okinawa and crosses into Japanese territorial waters. The Coast Guard tries to establish communications, but the ship does not respond to hails or interrogation. A patrol vessel approaches but finds no human activity visible on the ship. The engines appear active at a low idle, standard systems seem to be operating, and there is no evidence of external damage. Eventually, the patroller receives orders to send a boarding party to investigate and prevent the distressed vessel from running aground. A small, elite security team transfers to the distressed warship and finds the upper deck abandoned. Live audio and video from the tactical team's gear beamed back to the patrol vessel paint an increasingly confusing picture.

As the team members initially explore, they observe the normal hum of ship systems but no sign of human life. As they search deeper into the ship, the picture turns grim. The normal hum is still present, along with mutilated corpses. Body positions suggest the victims were running from something, but no obvious battle reconstruction makes sense. None of the wound patterns conform to conventional combat methods one would expect from projectiles or hand-to-hand fighting. Instead, the bodies look like they received innumerable slashes from fine razor blades. Now on high alert and with backup teams on

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standby, the tactical team executes a systematic search with orders to secure the ship and drop anchor.

The unexplainable carnage continues to materialize throughout the ship. As the team approaches the engine room, broken profanity underscores statements of incredulity—the density of casualties and heinousness of the conditions of the bodies increases markedly. Upon opening the hatch to the engine room, a team member reports that they see movement on a battery bank and hear intensifying buzzing and clicking sounds.

Leaders aboard the patrol vessel observe in horror as screams fill the audio channels, and the body cameras show frantic movements as the team runs from what looks like a large swarm of mosquitoes. Some team members open fire as they retreat, hitting nothing but bulkheads. One camera, either knocked to the ground in the chaos of retreat or still attached to a now-deceased team member, shows a swarm returning to the battery bank. The clicking stops. Only the quiet humming of the ship remains.

## Complex Behaviors from Simple Machines

This gruesome vignette illustrates one potential outcome of militarizing a crossdisciplinary pool of knowledge that stretches from theories about complex systems to leading developments in behavioral robotics. It is far from the only potential outcome of such mastery, but it is a realistic use-case of a class of weapons practitioners might label as swarming devices. This article's position, however, is that a missing intermediate concept is needed to categorize a host of complex system behaviors, only one of which is swarming. For example, should swarming and flocking systems be regarded as fully distinct concepts? Intuitively, something relates them but what?

This article proposes partitioning the universe of weapons design into two general branches: (1) direct function weapons (DFWs), covering classical theories of operation for platforms, payloads, and munitions; and (2) emergent function weapons (EFWs). Further, the article argues that swarming, flocking, and related approaches to design belong to this superset of *emergent function* devices. This small ontological adjustment provides theorists, industry, and defense practitioners with a unifying framework to study these approaches to weapons design.

This article defines EFWs, distinguishing them from their more familiar direct function counterparts and highlighting the theoretical underpinnings of the emergent variety. It observes a disconnect between design philosophies at the leading edge of behavioral robotics versus those guiding the development and acquisition of advanced weapons systems. It identifies the desirable properties of EFWs and discusses the tradeoffs between direct and emergent designs. Finally, the article highlights how these weapons might extend existing approaches to dynamic targeting in highly contested combat environments, proposing a concept called hypervelocity targeting.

## Defining Emergent Function Weapons

Concisely stated, an emergent function weapon is one with operational functions that rely on the emergent properties of complex systems. Such emergences generally appear at scale and are difficult to predict from an evaluation of raw components that comprise a system. Many "agents" (instances of the software program or physical device that follows some behavioral repertoire) operating as part of what scholars label a *complex adaptive system* compose an EFW ensemble.[1]

These ensembles feature high degrees of interaction between agents and, under the right conditions, generate emergent properties such as self-organization.[2] Operational performance is only apparent at runtime (simulated or actual) because designers seek aggregate behavior from the system's dynamics rather than from encoding explicit repertoires of behavior into a centralized hardware or software controller.

Understanding how an EFW operates on the battlefield and how to design one requires oblique thinking. In an emergent function design, creators purposefully disaggregate the weapon's operational function. Typically, a single instance of the device would not be sufficient to perform a useful task on the battlefield. Instead, multiple devices aggregate into an ensemble (whether multiple copies of the same design or an array of heterogeneous devices) that adopts the formal properties of a complex adaptive system at scale.

Devices *appear to cooperate* to fulfill the weapon's overall function, but the devices have no concept of that overall function in their programming. Picture a terrarium with ants: four ants wander with little interaction, but past a certain threshold—perhaps 40 or 400 ants—they exhibit what scholars of complex systems call self-organizing behaviors.[3] Those behaviors are emergent properties that appear at scale; the object of EFW design is to exploit this phenomenon for tactical advantage.

By contrast, one might label traditional weapon designs as direct function weapons. These weapons explicitly do all the work of action without the weapon design itself leveraging emergent system behaviors. Operational users of direct function weapons certainly consider cascade effects, such as when seeking to cripple enemy logistical systems through efficient targeting behaviors. Still, nothing in the weapon's technical specifications requires an emergent property to appear for the weapon to function. The distinction between emergent and direct function weapons lies in where designers encode the governing logic of the weapon.

In a pure direct-function design, designers encode control logic into devices such as bombs or missiles or delivery vehicles such as aircraft. Practically, the work involves programming computers or fashioning electromechanical assemblies. When the job is com-

1. John H. Miller and Scott Page, *Complex Adaptive Systems: An Introduction to Computational Models of Social Life* (Princeton, NJ: Princeton University Press, 2009), 3.

2. Melanie Mitchell, *Complexity: A Guided Tour* (New York: Oxford University Press, 2011), 13.

3. Miller and Page, *Complex Adaptive Systems*, 214.

plete, the device contains all the logic necessary to perform operationally within published employment parameters.

Impressionistically, these devices reflect how mankind solves battlefield problems through step-by-step logical deduction. On the other hand, EFWs reflect how natural systems might solve that problem given time, space, opportunity, and pressure to adapt. The EFW design, which will likely require techniques ranging from genetic algorithms to reinforcement learning, will present at least as many technical and ethical challenges as opportunities.

Nevertheless, exploiting emergent properties in weapons design does not automatically correlate to vicious devices such as the vignette's robotic mosquitos. Emergence is a feature that regularly appears in complex systems from microscopic to cosmological and in natural and synthetic systems. In some cases, the elements of an EFW might not manifest as physical assets, such as flying robots, but rather ensembles of interacting software packages hosted on terrestrial, seaborne, airborne, and spaceborne computing environments. The ability to encode logic into the dynamics of a system and leverage emergent properties provides additional trade space in hardware and software for designers facing challenging operational requirements. Still, the approach is a departure from current practices in the defense industry, even where robotic and autonomous systems are concerned.

## Advances in Robotics

Over the past 8 decades, the field of robotics underwent several iterations of what Thomas Kuhn called "normal science."[4] Academics and industry leaders pursued one avenue until finding intractable problems and pivoted to another avenue of research. Before the 1950s, society's grasp on the topic consisted of various fictional representations, prototypes, and industrial precursors. Only when key technologies existed simultaneously could experts in the field develop actual robotic systems. Enabling technologies included programmable multifunction processors based on the Von Neumann architecture, foundational artificial intelligence work of the kind Alan Turning accomplished, and the transistor (leading, in turn, to integrated circuits).[5]

In this milieu of robotics and computer science advances, initial progress enticed some early proponents to proclaim computers would solve any definable problem.[6] Some

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4. Thomas S. Kuhn, *The Structure of Scientific Revolutions: 50th Anniversary Edition* (Chicago: Chicago University Press, 2012), 24.

5. J. von Neumann, "First Draft of a Report on the EDVAC," *IEEE Annals of the History of Computing* 15, no. 4 (1993), https://doi.org/; and A. M. Turing, "Computing Machinery and Intelligence," *Mind* 49 (1950), https://www.jstor.org/.

6. H. A. Simon and Allen Newell, "Heuristic Problem Solving: The Next Advance in Operations Research," *Operations Research* 6 (1958), https://www.jstor.org/; and Marvin Minsky, *Computation: Finite and Infinite Machines* (Hoboken, NJ: Prentice-Hall, 1967).

imagined robots would soon do any work that a human could.[7] After initial successes in applying robotics to factory-scale manufacturing processes and besting the vast majority of the population in relatively simple games such as checkers, the euphoria quickly died away.[8] It became clear that achieving the robotic vision of the day required significant research, material improvement, and processing capabilities that technology of the time simply could not deliver.

From the 1970s, the next wave of research sought to solve the key problems of robotics with a two-pronged approach. First, researchers leveraged increased computational power.[9] Second, they sought to create better sensors that presented more consistently accurate data to the computers (reducing the "noise" with which the computer would have to contend).[10]

But as this wave unfolded, researchers correctly deduced that some problems remained unsolvable even with near-perfect information. Simply put, the tasks for robots to solve still contained irreducible error factors, and the scale of even simple tasks proved computationally intractable.[11] The key insight this generation of roboticists deduced was that one could ask for near-infinite amounts of computing power and accurate data streams and yet still fail to solve the challenge. Something about the fundamental approach itself had to change.

The next epoch for robotics research appeared in the 1990s as the study of behavioral robotics. In this research program, roboticists pursued self-organizing systems to solve relevant problems.[12] Robots navigating physical environments is a classic example. In the 1970s, roboticists would have sought better information and processing power to try to preemptively calculate an optimal path through a crowded city square. On the other hand, behavioral robotics approached the task knowing that a predetermined perfect solution was unrealistic. Instead, a robot might move in a general direction and perform specific behaviors given small scenarios such as: avoid obstacles, wait for people or vehicles to clear out, look for open areas, and so forth.

In this line of thinking, researchers hoped that behavioral patterns would emerge to accomplish the overall task (i.e., cross the crowded square) by piecemeal actions without ever processing a completed, optimal answer. This approach enjoyed some success but proved insufficient to complete complex tasks. Particularly, it was difficult to tell which

7. H. A. Simon, *The Shape of Automation for Men and Management* (New York: Harper & Row, 1965).

8. Paul Mickle, "1961: A Peep into the Automated Future," *The Trentonian*, 1961, http://www.capitalcentury.com/.

9. Hans Moravec, "The Role of Raw Power in Intelligence," unpublished manuscript, May 12, 1976, pdf, https://stacks.stanford.edu/.

10. Hans Moravec, *Mind Children* (Boston: Harvard University Press, 1990).

11. L. Stephen Coles et al., "Decision Analysis for an Experimental Robot with Unreliable Sensors" (paper presented at the 1975 International Joint Conferences on Artificial Intelligence, 1975), 749–57, https://citeseerx.ist.psu.edu/.

12. Ronald C. Arkin, *Behavior-Based Robotics* (Cambridge, MA: MIT Press, 1998).

behavior would emerge from the series of human-created rules and situations that might exist.[13]

Contemporary robotics research addresses shortcomings in the behavior-based approach by integrating reward-based machine-learning techniques. The novelty here is that the agent can modify its own behaviors given the initial stimuli, mimicking underlying processes that seem fundamental to how living organisms achieve complex behavioral repertoires.[14]

## Behavioral Robotics and Defense Aerospace

Unfortunately, the transfer of learning from high-end robotics research to defense aerospace development has been exceptionally slow moving. The developmental activities of contractors working on advanced aircraft and autonomous systems today reflect activities roboticists pursued in the 1970s. Military services still pursue development of increasingly capable sensors to cover wider swaths of the electromagnetic spectrum with greater resolution. In parallel, they seek better processing capacity to push a higher volume and quality of data to classical algorithms for exploitation.[15]

Whatever automation exists in these projects still reflects an attempt to find optimal solutions by breaking the overall task into well-defined phases of execution and maximizing the volume of high-quality sensor inputs. Furthermore, the input to these few automated system functions generally involves a prerequisite step of human "wetware" manually interpreting and annotating sensor data.[16]

The gap between the leading edge of robotics research and the weight of effort within defense aerospace developmental activities leaves potential capability unexplored and unexploited. Today's applications of machine-learning algorithms are relatively piecemeal.[17] Even the literature within defense and security studies—the body of work reflecting the ideas by which scholars and practitioners evaluate potential futures—is mixed concerning ideas that behavioral robotics embraces. Some sources explicitly claim swarming

13. Maja J. Mataric, "Integration of Representation into Goal-Driven Behavior-Based Robot," *IEEE Transactions on Robotics and Automation* 8, no. 3 (June 1992), http://web.mit.edu/.

14. Leslie Pack Kaelbling, Michael L. Littman, and Andrew W. Moore, "Reinforcement Learning: A Survey," *Journal of Artificial Intelligence Research* 4 (1996), https://www.jair.org/.

15. Colville McFee, "Opening Doors to the Future 427th Reconnaissance Squadron Ribbon Cutting Ceremony," 9th Reconnaissance Wing Public Affairs, April 26, 2019, https://www.beale.af.mil/.

16. Ridge R. Flick, "Winning the Counterland Battle by Enabling Sensor-to-Shooter Automation," Air Land Sea Application (ALSA) Center (website), November 1, 2021, https://www.alsa.mil/.

17. Sydney J. Freedberg, "Culture, Not Tech, Is Obstacle to JADC2: JAIC," Breaking Defense, February 11, 2021, https://breakingdefense.com/.

weapons cannot replicate the self-organization found in nature's examples.[18] Others see no clear theoretical obstacle to doing exactly that.[19]

Leading minds and leading breakthroughs in the field of robotics continue to leverage behavior-based approaches as a framework for exploiting machine learning and related artificial intelligence techniques. This observation suggests further investigation of behavioral methods holds promise for the maturation of applied machine learning in military weapon systems. The emergent function weapon conceptual category is an ontological placeholder that invites importation of behavioral robotics into defense research and development programs. Implementing a behaviorally based project might invoke swarming, flocking, or another form of emergent behavior.

## Leveraging Emergence Now

The Air Force is only now beginning to support ideas and demand new capabilities that make this discussion about EFWs institutionally relevant. For example, "digital engineering" is a process by which creators use computer-aided design software to create blueprints of weapon systems and build, test, model, simulate, and refine prototypes in virtual environments.[20]

This practice of high-fidelity digital modeling is an enabler for EFWs because finding desirable emergent properties requires either prescient creativity or extensive simulation support. Designing systems to exploit emergence requires shifts in thinking and practice but offers many potential benefits. In particular, four stand out: (1) extended capabilities for power- and compute-density-constrained devices; (2) the ability to invert employment -planning principles; (3) a design methodology inherently focused on scaling properties; and (4) disaggregation of the sensitive data that makes the weapon function in combat.

Though computing efficiency and power storage capabilities improve annually, an enduring lesson from the 1970s robotics research program is to be skeptical that these improvements will provide breakthroughs in capability.[21] The approach of an EFW is, therefore, to recast a computationally intensive task into one that a distributed aperture of potentially low-power, low-bandwidth, and low-processing power devices solve in the aggregate.

This approach leverages what scholars call "computation in the large," wherein no device in a complex adaptive system attempts to solve the overall problem.[22] Instead, the

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18. John Arquilla and David Ronfeldt, *Swarming and the Future of Conflict*, Documented Briefing DB-311-OSD (Santa Monica, CA: RAND Corporation, 2000), https://www.rand.org/.

19. Paul Scharre, "How Swarming Will Change Warfare," *Bulletin of the Atomic Scientists* 74, no. 6 (2018), https://doi.org/.

20. Air Force Materiel Command (AFMC), "Digital Campaign: One Team . . . One Digital Lifecycle Enterprise," AFMC (website), n.d., accessed May 30, 2022, https://www.afmc.af.mil/.

21. John Shalf, "The Future of Computing beyond Moore's Law," *Philosophical Transactions of the Royal Society A* 378, no. 2166 (March 2020), https://doi.org/.

22. Mitchell, *Complexity*, 143–58.

microlevel actions of individual devices aggregate in such a way that the entire system produces the solution through emergence.

Complexity theorists regard systems such as economies as essentially giant distributed computers. Each buyer and seller in a market has neither the capability nor the information required to set global prices. Yet through the interactions of buyers and sellers, the economy continuously calculates the prices of commodities, stocks, and so forth.[23] Emergent function weapon design seeks to operationalize this phenomenon.

Consequently, EFWs invert some portion of operational employment planning principles, favoring self-organizing system behaviors instead of a top-down operational direction. For example, missions such as reconnaissance or search and rescue generally involve allocating sensors to search large areas for objects of interest. Coordinating such an activity requires logical plans for sensor distribution and information reporting. Using a direct function methodology, humans think through the problem of where to point which sensors and when, create a primary plan, and then develop a series of contingency plans.

An emergent function methodology features little preplanning and requires no centralized control to achieve the mission objective. Instead, the search path is an artifact of the emergent behaviors of the EFW interacting with the operating environment.

Emergent function weapons only achieve these interesting outcomes by operating as complex adaptive systems at some level of scale. Estimating the specific scale required for each application likely varies significantly enough to require dynamics simulations. Scaling is a requirement, but the consistent presence of that requirement forces the entire design methodology to optimize for scaling from the outset.

The distribution of costs for the development of an EFW is likely front-loaded: a large effort to find a design that will produce the right emergent behaviors at runtime; a significant effort to produce factory tooling to create the devices of the complex adaptive system; and a lower intensity but longer-running optimization, tuning, and testing effort throughout the lifecycle of the system. That distribution suggests building additional devices in production would be relatively inexpensive, contrasted with other program budget elements. Thus, when researchers find one of those rare, winning combinations of parameters that creates a desirable emergent system behavior, program managers can exploit the finding and build larger inventories of devices.

Lastly, the peculiar development lifecycle disaggregates the weapon from the shared knowledge of why the weapon works as it does in any configuration. The data loaded in the robotic device would consist of some low-level control logic (e.g., to actuate flight control surfaces) but mostly parameterized data that, to a third-party observer, lacks context.

The rationale behind the settings for dozens to thousands of unlabeled parameters on the device exists only in the laboratory. Even if an adversary recovered copies of the device, they would have no obvious means of ascertaining why these parameters were effective in one context but not others. Reverse engineering EFWs might be inherently

23. Mitchell, 9–10.

difficult, depending on the depth of parameterization. Their true lethality resides in the simulation and testing environments that discover unique combinations of parameter values that create particular emergent behaviors.

## Maintaining Healthy Skepticism

If a research and development program in EFWs does gain traction, the first risk to success will be institutional misunderstanding, misuse, or misrepresentation of the concept. Labels for concepts become popular, then, as leaders wrestle with the ideas or early pilot projects fail to produce results worth the hype of the new buzz-phrase, the labels fall out of fashion, and the ideas become altered and repackaged with new acronyms.

For example, attrition-tolerant aircraft and command-and-control methodologies linking manned and unmanned systems have both undergone such fashion trend upheavals. The term low cost attrittable aircraft technology (LCAAT) peaked in popularity between 2017 and 2020, but as prototype vehicle losses mounted and the reaction from the combatant commands was less than enthusiastic, its vocabulary waned in popularity. Similar vocabulary shift patterns occurred where the term manned-unmanned teaming (MUM-T) fell out use in favor of collaborative combat aircraft (CCA).[24]

In one sense, this cycle is simply an artifact of the social system of the Pentagon engaging in collective thinking and creativity. In another sense, the cycle becomes connected to notions such as social status associated with so-called "staying on trend." A socially motivated pursuit of intellectually fashionable vocabulary detracts from rather than adds to the organization's ability to think collaboratively and collegially. Instead of applying effort to rigorous ontological designs of future fighting concepts, a corrosive, pathological trend of pseudointellectualism tempts the Pentagon to mill through buzz-phrases. The concept of emergent function weapons might easily be lost in the noise of such an environment.

Humility is part of the price of admission for something as ambitious as a defense research program on weapons that harness emergence from complexity. That requirement runs in two directions. First, scholars, researchers, and industry leaders who must secure resources in order to work on exploiting emergence must avoid the trap of overselling the idea.

Second, while moving from the familiar toward the unfamiliar is natural, senior leaders and headquarters staff challenged to think about future force design must resist the temptation to interpret EFWs entirely through familiar lenses of yesterday's doctrines. Furthermore, they must avoid the collective social pathology that will tempt them to think about EFWs and the idea of emergent system behaviors as though they were fodder for just another short-lived round of buzz-phrases. Emergence, like many fascinating properties of the physical universe, operates whether or not humans choose to study it or harness it for advantage. But if they do pursue it, they should not expect quick results or

24. Thomas Hamilton and David A. Ochmanek, *Operating Low-Cost, Reusable Unmanned Aerial Vehicles in Contested Environments: Preliminary Evaluation of Operational Concepts*, RAND Report 4407 (Santa Monica, CA: RAND Corporation, 2020), https://www.rand.org/.

for the encounter to leave their original patterns of thinking—or their warfighting doctrines—undisturbed.

Instead, those exploring EFWs should be clear about the scope of utility and the limitations of the concept. As with any design effort in any engineering discipline, the theoretical basis for EFWs represents an adjustment of tradeoffs, not a panacea. A good research and development program will achieve favorable trades that expand a designer's toolkit in helpful ways. Understanding this trade-space requires a fair appraisal of the costs of the EFW approach. The tradeoffs between direct and emergent functional design extend from the practical to the social and ethical.

## Tradeoffs

First, the preponderance of weapons designs will likely remain direct function, owing to the eminent practicality of such approaches and the inherent difficulty in designing for elusive emergent functions. There is little motive to replace proven air-delivered precision munitions with an alternative based on a complex system, for example, when the added complexity might not result in any corresponding gain in battlefield performance.

Emergent function weapons are likely to appear first as special-use tools for focused operational scenarios. When further matured, they will probably maximize return on investment as enablers that tackle difficult tactical and operational tasks when integrated with existing fleets of classically designed weapon systems. But building EFWs to counter specific adversary systems on their own (such as the ship in the vignette) may require extensive intelligence on details of the foreign weapon system.

Second, until someone designs sufficiently advanced software development packages that support rapid scripting of interactive behavioral repertoires and embedded systems dynamics simulations, the practical act of EFW design will likely be taxing, manual labor. Designing EFWs from scratch may require significant research support. Constructing a complex adaptive system that will meet specific war-fighting requirements through an emergent behavior may even drive live combat test, evaluation, and optimization work across the lifecycle of the weapon. Emergent function weapons would likely occupy a point on the spectrum of generalizability halfway between conventional weapons and tailored cyber exploits.

Third, the concept of an EFW originates from subject matter in a crossdisciplinary field that few if any educational programs through the undergraduate level tend to cover as a core curriculum. While by no means too difficult for students or professionals to grasp, the notion of emergence from complexity may be unfamiliar to many audiences and evoke wild ideas that exceed the true scope of the subject.

Mass unfamiliarity with the conceptual basis of a proposed weapon design is a significant messaging challenge for a public institution that is accountable to citizens who fund it. It is likely, even more than the military experienced with remotely piloted aircraft programs, society's collective mental processing of EFWs may generate a host of critiques about "killer robots" and "playing God with robotics."[25] If the Pentagon must spend significant political capital managing the domestic narrative, it may be less patient with fledgling EFW projects.

## Supporting Dynamic Targeting

With a balanced view of the opportunities, costs, and tradeoffs associated with EFWs, it is reasonable to ask what application of this concept would yield a significant return on investment and thereby drive a productive defense research program. In one sense, the history of the Air Force is a history of targeting theories.

From the earliest days of industrial webs to Operation Desert Storm to modern targeting constructs, two simple but important ideas predominate: prioritizing *what* to target and ascertaining *how much* one can successfully target simultaneously.[26] The modern concept for satisfying these properties is to focus on the performance of the dynamic targeting cycle, sometimes called a kill chain, the steps of which are: find, fix, track, target, engage, and assess (F2T2EA).[27] But the US military did not arrive at this elegant formulation overnight, nor did it arrive at the idea independently.

In the 1970s and 1980s, the United States pursued development programs in precision-guided munitions and digitization of command and control, including airborne data networking.[28] Beyond improving tactical performance on the battlefield, these projects aided the Western powers in offsetting Soviet numerical advantages and battle strategies in Europe.

At the time, however, Americans tended to view each project analytically and independently. They paid less attention to the holistic implications of how the projects, when brought together, would radically alter major combat operations.[29] Soviet Marshal Nikolai Ogarkov saw the convergence of trends and sounded the alarm among his colleagues. He and other Soviet thought leaders claimed that the Americans were building Рекогносцировочно-ударный комплекс (Рук, or RUK in the Latin alphabet), a

25. Amie Haven, "Killer Robots in the US Military: Ethics as an Afterthought," Towards Data Science, October 25, 2019, https://towardsdatascience.com/; and Joseph O. Chapa, *Is Remote Warfare Moral? Weighing Issues of Life and Death from 7000 Miles* (New York: PublicAffairs, 2022).

26. Scott D. West, *Warden and the Air Corps Tactical School: Déjà Vu?* (Maxwell AFB, AL: Air University, October 1999), https://media.defense.gov/.

27. ALSA Center, Air Force Techniques, Tactics, and Procedures 3-2.72, *Multi-Service Tactics, Techniques, and Procedures for Strike Coordination and Reconnaissance* (Hampton, VA: ALSA Center, January 2022), 43–54, https://www.alsa.mil/.

28. Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Stanford, CA: Stanford University Press, 2010), 1–5, 33–34.

29. Adamsky, *Military Innovation,* 28–55.

"reconnaissance-strike complex" linking long-range precision fires with long-range reconnaissance.[30]

The massive air campaign of Operation Desert Storm, with its air operations center closing the loop between intelligence findings and sortie generation via an air tasking order cycle, essentially embodied the RUK. The exceptional performance of that air campaign seemed to validate Soviet concerns about American capabilities. The early 1990s marked a stepwise change in the velocity of prioritized targeting cycles. But air tasking order-based deliberate targeting operates on a time horizon marked in days. If applied as the sole targeting construct, it would perform exceptionally well against predictably located targets such as infrastructure and less spectacularly against elusive and highly mobile targets.

The complementary construct became dynamic targeting. Then, in the early twenty-first century, a doctrine called strike coordination and reconnaissance (SCAR) extended dynamic targeting.[31] In this model, the air tasking order designates an aircraft or formation to assume SCAR leadership over a specified geographic area. The aircrew utilizes the theater commander's prioritized target list to sift the sensor data they collect from the battlefield. As other strike aircraft arrive, the SCAR crew simultaneously directs those aircraft to attack discovered targets in prioritized order, destroying as many targets as quickly as possible.

In essence, SCAR represents another stepwise change in the velocity of prioritized targeting capability. Subdividing the battlespace and appointing a SCAR lead for each section permits highly parallel operations and impressive rates of target destruction. Much to the chagrin of senior Air Force leaders who want to liquidate the asset, the MQ-9 Reaper, with its remote cockpit that permits access to multiple intelligence sources while remaining connected to the battlespace, is a top-performing asset for SCAR leadership duties.[32]

But consider a complex and highly contested battlespace like the Donbas region of eastern Ukraine. Even an asset such as the MQ-9, which can accept more risk than a human-inhabited vehicle, might not attain a favorable ratio of enemy targets destroyed per aircraft lost. Direct-function thinking might pursue either of two methods to restore a functioning reconnaissance-strike complex in such an environment.

With their deep investments in low-observable aircraft, Americans might put a stealthier remotely piloted aircraft over the battlefield and resume the same model they used with the MQ-9. With more modest means but impressive creativity and resolve, as

30. Barry D. Watts, *The Maturing Revolution in Military Affairs*, Center for Strategic and Budgetary Assessment (CSBA) Report (Washington DC: CSBA, 2011), 1–4, https://csbaonline.org/.

31. ALSA Center, *Multi-Service Tactics*, 1–13.

32. Rachel S. Karas, "As Contested Battlespace Grows, MQ-9 Explores New Roles," *Inside the Air Force* 28, no. 26 (June 30, 2017), https://www.jstor.org/; and Lawrence A. Stutzriem, "Reimagining the MQ-9 Reaper," Mitchell Institute Policy Paper, vol. 30 (Arlington, VA: The Mitchell Institute, November 18, 2021), https://mitchellaerospacepower.org/.

their Аеророзвідка (Aerorozvidka) team exemplifies, Ukrainians employ small unmanned systems to find-fix-track while artillery or aircraft target-engage-assess to close the kill chain.[33] Emergent-function thinking, however, would pursue a completely different path.

Consider a change from the "killer mosquito" vignette. Instead of developing a swarm of robots that conduct the entire kill chain autonomously, imagine designing a distributed aperture, emergent function sensing system and deploying it over vast areas of the battlespace. The devices, perhaps numbering in the thousands or tens of thousands, make no attempt to engage enemies.

Instead, they remain largely out of sight, preferring to perch in treetops when possible. If the targeting objective were enemy equipment, designers might equip the devices with low-power detectors tuned to "sniff" compounds from engine exhaust. If the targeting objective were adversary troops, the detectors might instead target ketones associated with human perspiration.[34] The emergent behavior required, in this case, is for the devices to change their spatial concentration, marking clusters of interest by being collectively attracted to targets of interest.

The concentration would not be a frenzy, either. Instead, the change in the field density of devices nearest the enemy would look unremarkable from the ground yet be high enough to correspond to a reporting threshold. Once reaching the threshold, the devices might collectively emit signals that a persistent air asset, such as an MQ-9 orbiting farther from enemy air defenses, would collect. The simple but detailed data in the signals (phase angles, modulation patterns, etc.), combined with the collecting aircraft's known position and time at receipt, would create a heat map of enemy target activity. The specificity of that data would depend on the cleverness of the designers in choosing detectors and communication schemes.

At a minimum, a heat map would provide cueing information for other sensors to identify enemy targets positively. At its best, the map might differentiate targets consistently and accurately, enabling US forces to find, fix, and track massive arrays of targets in parallel, without manual sensor allocation planning, thus accelerating the SCAR model. In some future iteration, the ambient field of detector devices might also recognize inbound friendly munitions and provide terminal guidance to targets. In this kind of *hypervelocity targeting*, the SCAR would direct all attacking aircraft to send munitions into tracked hotspots, allowing the devices to take control of the weapons during the terminal phase of flight.

33. Alia Shoaib, "Inside the Elite Ukrainian Drone Unit Founded by Volunteer IT Experts: 'We Are All Soldiers Now,'" *Business Insider*, April 9, 2022, https://www.businessinsider.com/.

34. Sara Nilsson et al., "Behavioral Responses to Mammalian Blood Odor and a Blood Odor Component in Four Species of Large Carnivores," *PLoS ONE* 9, no. 11 (October 2014), https://doi.org/.

## Conclusions

This example of a hyperscale reconnaissance-strike complex illustrates why a conceptual holding category for emergent function weapons is helpful and appropriate. The devices envisioned are not exactly swarming or precisely flocking, yet they operate together as a complex adaptive system with battlefield functions that manifest only from emergent behavior at scale. Emergence is the underlying phenomenon that enables flocking, swarming, clustering, patterned diffusion, and other self-organizing system behaviors. The need to complete targeting cycles successfully in increasingly dynamic and dangerous battlespaces, and the as-yet untapped potential of emergence, provide compelling reasons to investigate these approaches.

The concept of an EFW invites the military to establish a defense research program that moves beyond the endless quest for better sensors and more processing power and instead leverages contemporary advances in behavioral robotics. Supporting constructs such as digital engineering are becoming part of the Air Force's institutional vocabulary. The combination of battlefield necessity, a clear research opportunity, and the presence of enabling mechanisms suggest now is an appropriate time to explore this design concept.

Researchers and defense leaders should approach EFW design with conservative expectations, however, because the task of shaping complex adaptive systems to force particular patterns of emergent behavior is intensely difficult. Even successful attempts are likely to have severe scope limits with the design working in some environments but not others, requiring continual adjustment during the lifecycle of the weapon system. The toolsets needed to craft weapons that follow this theory of operation might partially exist in piecemeal software packages today.

Still, designers need time to build an integrated development environment, symbolic languages, and an understanding of principles for achieving various desirable emergences from ensembles of devices operating in a complex adaptive system. Emergent function weapons are unlikely to become the singularly defining weapons of the future, but they are probably part of a wild future of advanced military capabilities.

More importantly, the conceptual category of an emergent function weapon provides a unifying construct for scholars, researchers, war fighters, and defense leaders to effectively categorize swarming, flocking, clustering, patterned diffusion, and many other complex system behaviors whose underlying commonality is leveraging emergent effects. ✈

# Contested Agile Combat Employment

## A Site-Selection Methodology

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The Agile Combat Employment concept relies on foreign country access and infrastructure to generate airpower. Yet numerous factors complicate site-selection decisions including peer-to-peer threats, complex geopolitics, and resource requirements. Multicriteria decision analysis can help strategists appropriately account for competing objectives and maintain a competitive advantage with theater adversaries. This paper presents a site-selection decision framework that evaluates agile combat employment basing alternatives using a geographic information system, analytic hierarchy process, and unclassified, publicly available data. This framework identifies existing airports best suited for strategic utilization. The methodology could support combatant commands as they optimize agile combat employment infrastructure, preserve resources, and minimize risk to US Armed Forces.

*Adapt or perish, now as ever, is nature's inexorable imperative.*
H. G. Wells, *Mind at the End of Its Tether*

Civilization's survival has hinged on humans' capacity to innovate and evolve amid difficult circumstances. Today, the sentiment rings true for the US Air Force and its pacing adversary. The People's Republic of China (PRC) continues to develop its military capabilities considerably, driving the Air Force to "accelerate change or lose."[1] Complex geopolitical landscapes, resource limitations, and other competing objectives require the service to adapt its strategy, policy, and forces to deter factions threatening global peace and prepare for future global conflict.

Accordingly, the Air Force developed a modernized power-projection approach, agile combat employment (ACE). The foundation of this concept, adaptive basing, utilizes "alternate basing options to enable flying operations" and "calls for forces to disaggregate

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1. Charles Q. Brown Jr., *CSAF Action Orders: To Accelerate Change across the Air Force* (Washington, DC: Department of the Air Force (DAF), December 2020), https://www.af.mil/.

capabilities from a single base and disperse forces and capabilities to many locations for operational maneuver."[2] But the US military is predominately postured at large main operating bases, which is detrimental to ACE strategy.[3] Therefore, barring any major force changes, the service must leverage strategic infrastructure in foreign countries to support ACE.[4]

Efforts to establish strategic ACE operating sites are underway in the Pacific Air Forces and the US Air Forces in Europe.[5] Yet, what happens if these operating sites become compromised at the onset of conflict? The People's Liberation Army recognizes foreign country access, resource logistics, and limited defensibility as vulnerabilities to the agile combat employment concept.[6] China may undermine ACE by denying the Air Force access to these locations through diplomatic, economic, or kinetic action, thereby reducing the survivability of air operations. These factors prompt the question: how can the service adapt ACE if its access to predetermined hubs and spokes becomes compromised?

This article proposes the ACE site-selection framework, a selection methodology that, with existing airport infrastructure, evaluates decision criteria and facilitates rapid decision making for ACE site selection. The methodology can be applied to post-attack scenarios to provide reactionary decision-making capabilities for adaptive basing. Additionally, the framework is suitable to help guide strategic or just-in-time decision making, including in wargaming or as a way to increase political-military engagement at strong candidate locations.

The ACE site-selection framework combines geographic information system analysis and decision analysis to provide a flexible, scalable, expedient, and reproducible framework offering planning capabilities at multiple strategic levels by evaluating prospective sites and informing decisionmakers. The proposed framework methodology uses the Pacific Air Forces area of responsibility to demonstrate its utility.

## DoD, US Air Force, and ACE Doctrine

Great power competition, a principal priority outlined in the unclassified *Summary of the 2018 National Defense Strategy*, has been a catalyst for modern-day military doctrine and strategy. The Department of Defense recognizes China's ambition to fulfill the "great

2. Patrick Mills et al., *Estimating Air Force Deployment Requirements for Lean Force Packages: A Methodology and Decision Support Tool Prototype* (Santa Monica, CA: RAND Corporation, 2017), 22, https://www.rand.org/.

3. Patrick Mills et al., *Building Agile Combat Support Competencies to Enable Evolving Adaptive Basing Concepts* (Santa Monica, CA: RAND Corporation, 2020), https://www.rand.org/.

4. Miranda Priebe et al., *Distributed Operations in a Contested Environment: Implications for USAF Force Presentation* (Santa Monica, CA: RAND, 2019), https://www.rand.org/.

5. Brian W. Everstine, "PACAF Surveyed Every 'Piece of Concrete' in the Pacific for Agile Combat Employment," *Air Force Magazine*, November 25, 2020, https://www.airforcemag.com/.

6. Derek Solen, "The PLA's Critical Assessment of the Agile Combat Employment Concept," China Brief 21, no. 14, Jamestown Foundation (website), July 16, 2021, https://jamestown.org/.

rejuvenation of the Chinese nation," including the unprecedented expansion and modernization of the People's Liberation Army.[7] China's military development spans numerous domains, but the rapid growth of its nuclear forces and long-range precision strike capabilities are of particular concern to the US Air Force.

These advancements pose a significant threat to the service's conventional basing strategy that currently relies on large main operating bases to sustain airpower in contested, degraded, and operationally limited environments. Accordingly, the *2018 National Defense Strategy* calls for investments in forces "that can deploy, survive, operate, maneuver, and regenerate in all domains while under attack" and a transition from "large, centralized, unhardened infrastructure to smaller, dispersed, resilient, adaptive basing."[8]

These realities prompted the Air Force to adopt agile combat employment.[9] Missiles, and to a lesser extent, aircraft, represent the most significant risk to Air Force installations, particularly in the Pacific theater.[10] ACE helps mitigate these threats by dispersing forces throughout the theater using hub-and-spoke basing configurations, offering the service unpredictability and requiring the People's Liberation Army to expend more missiles to reduce US Air Force airpower effects.[11]

Several significant challenges accompany the ACE concept and site selection. First, due to the hub-and-spoke structure, dispersed operations will inevitably increase operational costs and complicate agile combat support activities.[12] Thus, a balance must be struck between optimally disaggregating aircraft operations and effectively supporting these sites with resources.

Second, foreign country access is an essential enabler to ACE operations.[13] This factor is particularly challenging since peacetime partnerships and agreements could be negated at the onset of conflict. Therefore, establishing overt and covert agreements that support ACE is prudent, provided planners recognize their unpredictability and posture contingency plans.

Finally, the current agile combat employment concept relies on prepositioned assets.[14] Should the People's Republic of China conduct anti-access/area-denial (A2/AD) at these locations, ACE operations would require repositioning to under-resourced operating

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7. Office of the Secretary of Defense (OSD), *Military and Security Developments Involving the People's Republic of China: Annual Report to Congress* (Washington, DC: OSD, November 3, 2021), 1, https://media.defense.gov/.

8. 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: OSD, January 2018), 6, https://dod.defense.gov/.

9. DAF, Air Force Doctrine Publication (AFDP) 3-99, *The Department of the Air Force Role In Joint All-Domain Operations* (Maxwell AFB, AL: LeMay Center for Doctrine Development and Education (LeMay Center), October 8, 2020), Appendix B, https://www.doctrine.af.mil/.

10. Priebe et al., *Distributed Operations*.

11. Mills et al., *Adaptive Basing Concepts*.

12. Priebe et al., *Distributed Operations*.

13. Priebe et al.

14. DAF, AFDP 3-99, Appendix B.

sites. Planners would have to obtain assets from the host nation because airlift capabilities will be preoccupied, and traditional combat support will be unpredictable.[15] The proposed ACE site-selection framework simplifies the decision-making process and supplies leaders with a flexible, scalable, expedient, and reproducible framework to support data-driven site-selection decisions.

## Methodologies, Tools, and Techniques

Multicriteria decision analysis (MCDA) can simplify complicated decisions by combining user preferences with decision alternatives, criteria, and constraints to meet a defined objective.[16] Analytic hierarchy process (AHP) is a prevalent MCDA technique in literature.[17] Analytic hierarchy process utilizes a simple and flexible system of scoring and weighting parameters based on a criterion's relative significance compared to other criteria through pairwise comparison.[18] This process is the most applied MCDA method to construction disciplines and the study of site-selection optimization and has been proven effective in former military site-selection frameworks.[19]

GIS can be an essential enabler for site-selection methodologies. A 2018 MCDA site-selection review highly recommended integrating GIS software and spatial data in site-selection analysis because complex geographic constraints are a significant factor for this type of optimization.[20] Site-selection methods are primarily concerned with geospatial data, and GIS-based methods provide a reliable and pragmatic tool for integrating constraints, analyzing data, and producing visualizations.[21] The prevalence of GIS-based

15. DAF.

16. Gilberto Montibeller and L. Alberto Franco, "Multicriteria Decision Analysis for Strategic Decision Making," in *Handbook of Multicriteria Analysis*, ed. Constantin Zopounidis and Panos Pardalos (Berlin: Springer, 2010), 25–48.

17. Ernest H. Forman and Saul I. Gass, "The Analytic Hierarchy Process—an Exposition," *Operations Research* 49, no. 4 (July–August 2001), https://www.jstor.org/.

18. Ali Jozaghi et al., "A Comparative Study of the AHP and TOPSIS Techniques for Dam Site Selection Using GIS: A Case Study of Sistan and Baluchestan Province, Iran," *Geosciences* 8, no. 12 (December 2018), https://www.mdpi.com/.

19. Daniel Jato-Espino et al., "A Review of Application of Multi-Criteria Decision Making Methods in Construction," *Automation in Construction* 45 (September 2014), https://www.sciencedirect.com/; Jeremy Yee Li Yap, Chiung Chiung Ho, and Choo-Yee Ting, "A Systematic Review of the Applications of Multi-Criteria Decision-Making Methods in Site Selection Problems," *Built Environment Project and Asset Management* 9, no. 4 (2019), https://www.emerald.com/; and Bahar Sennaroglu and Gulsay Varlik Celebi, "A Military Airport Location Selection by AHP Integrated PROMETHEE and VIKOR Methods," *Transportation Research Part D: Transport and Environment* 59 (March 2018), https://www.emerald.com/.

20. Yap, Ho, and Ting, "Site Selection."

21. Jato-Espino et al., "Construction"; and Aleksandar Rikalovic, Ilija Cosic, and Djordje Lazarevic, "GIS Based Multi-Criteria Analysis for Industrial Site Selection," *Procedia Engineering* 69 (2014), https://www.sciencedirect.com/.

MCDA varies across construction disciplines, with the majority applied to energy and logistics facility site selection.[22]

ACE and adaptive basing aim to project airpower from alternate locations, which requires a runway, taxiways, apron space, and supporting infrastructure. Case studies of airport site-selection methodologies provide best practices and selection criteria due to the similarities between airports and US Air Force bases. In 2019, researchers provided an overview of airport site selection, confirming AHP as the most frequently applied method of siting airport infrastructure.[23] Moreover, GIS played a pivotal role in the optimization process, particularly when organizations had inadequate data and financial constraints.

Selection criteria recurrence varied across studies, but accessibility, economic, and environmental considerations were the most common among the literature.[24] Many airport site-selection studies demonstrate the effectiveness of combining AHP and GIS, and provide a breadth of selection criteria and constraints to consider for future decision frameworks.[25] An additional study developed an AHP methodology for a military airport in Turkey, analyzing nine criteria for an objective function, including military-centric parameters.[26] Finally, one recently developed model assesses the utility of four aircraft systems in a distributed basing environment. Notably, the authors used runway characteristics such as runway parameters, parking, munitions, fuel, and warehouse storage to quantify aircraft efficacy at military and civilian airfields.[27]

Despite the significance of the aforementioned site-selection methodologies, no studies address ACE site-selection processes when A2/AD prevents access to established ACE operating sites. Moreover, the nature of ACE and adaptive basing necessitates the integration of DoD- and Air Force-specific criteria. A few studies provide sample criteria to meet military goals, but none concentrate on service needs and DoD objectives.[28]

Contemporary adaptive basing requirements and considerations are necessary to determine the best solutions. Site selection often consists of dynamic variables, competing interests, varying risks, and limited data to support decision making. Accordingly, the proposed ACE site selection framework, based on risk and utility metrics and

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22. Yap, Ho, and Ting, "Site Selection."

23. Turan Erman Erkan and Wael Mohamed Elsharida, "Overview of Airport Location Selection Methods" *International Journal of Applied Engineering Research* 14, no. 7 (2019), https://www.researchgate.net/.

24. Erkan and Elsharida, "Selection Methods."

25. Cláudio Jorge Pinto Alves et al., "Towards an Objective Decision-Making Framework for Regional Airport Site Selection," *Journal of Air Transport Management* 89 (October 2020), https://www.sciencedirect.com/.

26. Sennaroglu and Celebi, "PROMETHEE and VIKOR."

27. Patrick Kelly, "Methodology for Including Base Infrastructure in Conceptual System Analysis" (master's thesis, Air Force Institute of Technology, 2019), https://apps.dtic.mil/.

28. Ghassan K. Al-Chaar et al., "Construction Material-Based Methodology for Contingency Base Selection," *The Open Construction & Building Technology Journal* 11 (2017), https://openconstructionbuildingtechnologyjournal.com/; Kelly, "Conceptual System Analysis"; and Sennaroglu and Celebi, "PROMETHEE and VIKOR."

considering a breadth of criteria, applies GIS and AHP to analyze airport alternatives and inform decisionmakers.

## Data

GIS-based AHP models require multiple data sources to perform geospatial analysis and evaluate decision variables. An ideal ACE site-selection framework would incorporate open-source and classified data sources to ensure conclusions integrate defense factors appropriately. For instance, data regarding airport coordinates and runway lengths are readily available in open-source environments, while accurate data on peer-to-peer missile threats, state agreements, theater posture plans, and operational plans are stored in classified environments, requiring analysis in controlled areas.

The proposed ACE site-selection framework uses solely open-source data to simplify the analysis, simulate inaccessible variables, and demonstrate the methodology's utility. The proposed ACE site-selection framework uses six data sources to produce geospatial indicators.

The method's principal data source is a global airport dataset.[29] The dataset contains information about medium and large airports, including, but not limited to, location, runway length, and aviation attributes. Airport characteristics are vital for the decision framework because existing runway infrastructure is essential for ACE in a right-of-boom (post-attack) environment. Furthermore, each airport offers varying risk and utility tradeoffs based on multiple factors such as the aircraft utilized, runway length, apron space, and fuel availability. This research utilizes airport location and runway length in the decision framework.

Opportunity exists to add additional decision variables from this dataset such as runway width, surface type, and lighting. For this research, runway length is a primary consideration because it dictates which aircraft can operate at a location and how much risk aviators assume during takeoff and landing. The global dataset includes 576 airports from 26 countries relevant to a Pacific Air Forces-level analysis.

Host-country attributes are integral to ACE effectiveness. Historically, the US Air Force postures its main operating bases in countries with strong diplomatic ties, stable governments, and robust economies such as Germany, Japan, and the Republic of Korea. Accordingly, overt and covert state agreements greatly influence ACE site feasibility. But incorporating and scaling this variable (overt and covert agreements) for the ACE site selection framework is challenging due to its uncertainty and confidentiality.

As a surrogate, the ACE site-selection framework applies the Fragile States Index to simulate accessibility and quantify country viability based on each state's peace and fragility

29. Environmental Systems Research Institute (Esri) Deutschland, "World Airports," dataset, info on May 5, 2020, https://hub.arcgis.com/.

environment.[30] The Fragile States Index scores and ranks 178 countries based on 12 indicators encompassing cohesive, economic, political, and social conditions.[31] But several prospective states (e.g., Palau and New Caledonia) do not have scores because the Fund For Peace only evaluates countries that are members of the United Nations and capable of generating the necessary data to perform its analysis.[32]

The final data subgroup includes 26 Pacific countries with their respective index score and contributing indicators. Incidentally, the use of the Fragile States Index as a surrogate is not infallible. For example, a stable regime does not necessarily imply willingness to provide basing in a peer-to-peer conflict especially in the Pacific theater.[33] Therefore, future iterations of the framework should include the latest information about political willingness to partner and not just a notional stability index.

The distance an aircraft will need to fly to accomplish its mission is an integral variable to ACE operations. Agile combat employment sited further from threats is exposed to less risk but could require refueling support, allowing adversaries additional time to prepare and respond when aircraft scramble. Conversely, ACE sited closer to adversaries enables a swifter and less predictable strategy but is more exposed to various risks such as short-range ballistic missiles.

Therefore, a sortie distance decision variable must strike a delicate balance between risk and utility. The proposed ACE site-selection framework facilitates adaptability by including an expected sortie distance variable, allowing planners to customize results based on known or probable mission requirements. For this analysis, an arbitrary coordinate in China was selected for sortie distance calculations.

Should ACE strategy require a shift to undetermined airfields, support assets will require airlift to these sites. Some materials and equipment are more manageable to airlift than others, but heavy construction equipment needed to assemble structures, perform repairs, or move assets would be impractical. Therefore, the proposed ACE site-selection framework includes access to construction equipment as a decision-making component.

When a contingency requires heavy equipment, crisis managers often use Air Force assets, such as war reserve materiel, to prepare, respond, and recover, which is prospectively impracticable in a right-of-boom ACE environment. Alternatively, ACE planners could acquire necessary equipment from construction vendors within the host nation's footprint. Accordingly, the framework uses dealer and rental locations for Caterpillar,

30. Fund for Peace (FFP), *Fragile States Index: Annual Report 2021* (Washington, DC: FFP, 2021), https://fragilestatesindex.org/.

31. FFP, *Fragile States Index Methodology and CAST Framework* (Washington, DC: FFP, 2017), https://fragilestatesindex.org/.

32. FFP, "Annual Report 2021."

33. Bonny Lin et al., *Regional Responses to U.S.-China Competition in the Indo-Pacific* (Santa Monica, CA: RAND Corporation, 2020), https://www.rand.org/; and Stacie L. Pettyjohn et al., *Access Granted: Political Challenges to the U.S. Overseas Military Presence, 1945–2014* (Santa Monica, CA: RAND Corporation, 2016), https://www.rand.org/.

Komatsu, Hitachi, and Volvo to quantify construction equipment proximity and availability.[34] A multistep data-collection process was exercised to collect construction equipment dealer geographic coordinates, yielding 565 construction equipment dealers across 26 countries.

The ACE site-selection framework includes water access in the decision framework because it is a high-priority resource in military operations. Presumably, potable water sources are readily available at medium and large airports, but military planners assume a degree of risk relying on host nations for this resource in contingency environments. Reverse osmosis water purification units can mitigate this risk and provide potable drinking water to forces if engineers can access a water source within a reasonable distance from their operating site. The World Water Bodies dataset provides the geospatial components needed to balance this tradeoff, and the methodology uses each of the dataset's water resource categories subset to the 26 countries included in the analysis.[35]

Finally, peer military capabilities represent a strategic risk for ACE because proximity to these threats can limit the service's ability to counteract and jeopardize mission execution. China's missile capabilities are particularly concerning in the theater because they control one of the world's largest, most far-reaching missile arsenals. Since the research is limited to unclassified sources, the methodology uses a generalized missile threat variable in its approach.

In 2020, researchers developed a spatial representation of the PRC's missile capabilities based on declassified Central Intelligence Agency documentation, DoD reports, and various research publications.[36] This data source acts as a surrogate data set to more accurate, classified intelligence. Rather than speculating missile capabilities at each location, the framework utilizes three missile risk profiles assuming each launch site has either short-range ballistic missiles, medium-range ballistic missiles, or intermediate-range ballistic missiles.[37] Should the Air Force adopt the proposed framework, ACE planners could improve the missile threat decision variable by incorporating more accurate coordinates, armament types, and estimated ranges.

34. "Caterpillar - Rental Store Locations," The Cat Rental Store (website), 2021, https://www.catrentalstore.com/; "Hitachi - Dealer Locator," Hitachi, Hitachi Construction Machinery Global (website), 2021, https://www.hitachicm.com/; "Komatsu - Dealer Locator," Komatsu (website), 2021, https://www.komatsu.jp/; "Volvo - Global Dealer Locator," Volvo Construction Equipment Global (website), 2021, https://www.volvogroup.com/.

35. Esri, "World Water Bodies," dataset, data on October 15, 2021, https://hub.arcgis.com/.

36. Decker Eveleth, "Mapping the People's Liberation Army Rocket Force," A Boy and His Blog, March 29, 2020, https://www.aboyandhis.blog/.

37. Missile Threat: Center for Strategic and International Studies (CSIS) Missile Defense Project, "Missiles of China," "Missiles of the World," CSIS (website), last updated April 12, 2021, https://missilethreat.csis.org/.

## Methods

While the proposed ACE site-selection framework requires a variety of geospatial analysis tools to perform the analysis, it employs two primary tools to collect spatial indicators: distance and buffer. Three indicators (sortie distance, construction equipment, and water sources) are predicated upon distance from an airport to another location. Two indicators (runway length and the Fragile States Index) are inherent to each airport's location. The remaining indicator, missile threat, was evaluated utilizing a buffer around missile locations at three threat levels: short-range (1,500 km), medium-range (3,000 km), and long-range (5,500 km).[38] The chosen GIS includes built-in tools to calculate these distances and aggregate/subset the data based on these and other conditions.

Like many optimization problems, the case study's decision variables have different units or scales. Multi-attribute utility theory provides a way to modify these variables and present them on the same scale prior to analysis. Put simply, utility functions convert the statistics to a score between 0 and 1. Higher scores (1) represent qualities beneficial or desirable for the objective, and lower scores (0) represent qualities unfavorable or undesirable for the objective. Utility values are beneficial to the framework because Air Force leaders and planners can customize them based on mission needs, mission limitations, and leadership preferences.

For example, each airport's runway length does not produce constant utility to ACE operations: F-16 aircraft and B-52 aircraft have distinct takeoff and landing requirements and a 7,000-foot runway would be sufficient for the former and not the latter. Utility functions allow practitioners to define these scales, which is beneficial for strategies involving unique aircraft, resource requirements, and geospatial factors. The case study develops the utility functions based on background information, research committee input, and general intuition.

Additionally, not all ACE site-selection factors are equally important. For instance, although water accessibility is vital for troop sustainability, an inadequate runway will completely undermine ACE site operability. Analytic hierarchy process enables the model to form a hierarchy among the decision criteria by performing a pairwise comparison of each variable.

In practice, AHP pairwise comparison as an organization is preferable because it usually moderates selection bias. Group brainstorm sessions or surveys involving subject matter experts are both excellent means to gather these inputs. The case study forms pairwise comparison inputs from the research's primary stakeholders including Air Force civil engineers and 800th RED HORSE Group leadership (RED HORSE is the Air Force's heavy construction unit tasked with building in remote environments).

While a few pairwise comparisons deviate from the trend, the general priority consensus was (1) runway length, (2) Fragile States Index, (3) sortie distance, and a tie: (4) distance from construction equipment dealers and (5) distance from water. Using these

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38. CSIS, "Missiles of China."

priorities, the primary stakeholders determined weighted values for each indicator for the initial analysis:

1. Runway length: 40 percent
2. Fragile States Index: 25 percent
3. Distance from China (sortie distance): 16 percent
4. Distance from construction equipment dealers: 10 percent
5. Distance from water sources: 10 percent

The final step applied these weights to the utility values of airport alternatives. This process scales the utility values based on established preferences and then aggregates weighted decision criteria to generate efficacy scores for each airport. The equation that follows shows the aggregation equation for the model's AHP scores. Sorting the data by this metric exhibits a ranked catalog of airport alternatives based on the risk and utility they offer ACE operations.

$$Ax = (u1 \times w1) + (u2 \times w2) + (u3 \times w3) + (u4 \times w4) + (u5 \times w5)$$

Where: $A$x is the combined efficacy score for each airport $x$; $w$n is the determined AHP weight for each selection criteria $n$; and $u$n is the utility score for each of the five selection criteria.

## Results

The ACE site-selection framework results can be represented visually based on each airport's combined efficacy score. Figure 1 illustrates the spatial distribution of each airport's score by quartile. The most suitable airports are green, while the most unfit airports are red. This method highlights the airports, countries, and regions that present the most utility to ACE operations. Additionally, ACE planners can interpret each airport's utility more holistically by adding missile threat rings to the map. For example, leaders could define projected missile ranges as high, medium, moderate, or low risk and reduce alternatives based on their risk appetite and an airport's inclusion within the rings.

Additionally, geospatial presentation of the results lends additional inferences such as countries the US Air Force would not otherwise consider. For example, based on intuition, the Philippines seems like a candidate country that would present advantages to Air Force ACE operations. But the GIS score representations suggest the Philippines would not be ideal since fewer airports scored highly (green: ≥ 0.62 AHP score). Alternatively, several countries outside the short-range ballistic missile range possess airports with surprising high utility such as India, Indonesia, and Malaysia. The map indicates Japan and South Korea have the highest concentration of high-utility airports, and Australia, New Zealand, and Papua New Guinea have the lowest concentration.

Furthermore, decisionmakers could combine airport identification and missile threat rings to guide decisions. For instance, if ACE planners intend to avoid short-range ballistic missile threats yet are willing to accept medium-range ballistic missile risk, airports between the red and orange threat rings would likely have the most benefits to ACE operations. Alternatively, a more risk-averse strategy could avoid medium-range ballistic missile threats and search for alternatives between the orange and yellow rings. In this case, the northeast coastline of Australia would likely provide the most benefits to ACE operations. This approach could be beneficial to strategists and planners because it is tailorable to preferential inputs and could be altered based on acceptable risk levels at the time of analysis.

Finally, viewing the results spatially allows planners to assess hypothetical basing clusters based on the parameters and additional constraints. For example, one method could involve gauging regions with dense "green" airports. These regions would benefit ACE operations since they would provide planners with the most alternatives to pick from for a basing cluster. Alternatively, ACE planners could add additional data to the visualization to further subset or evaluate base clusters.

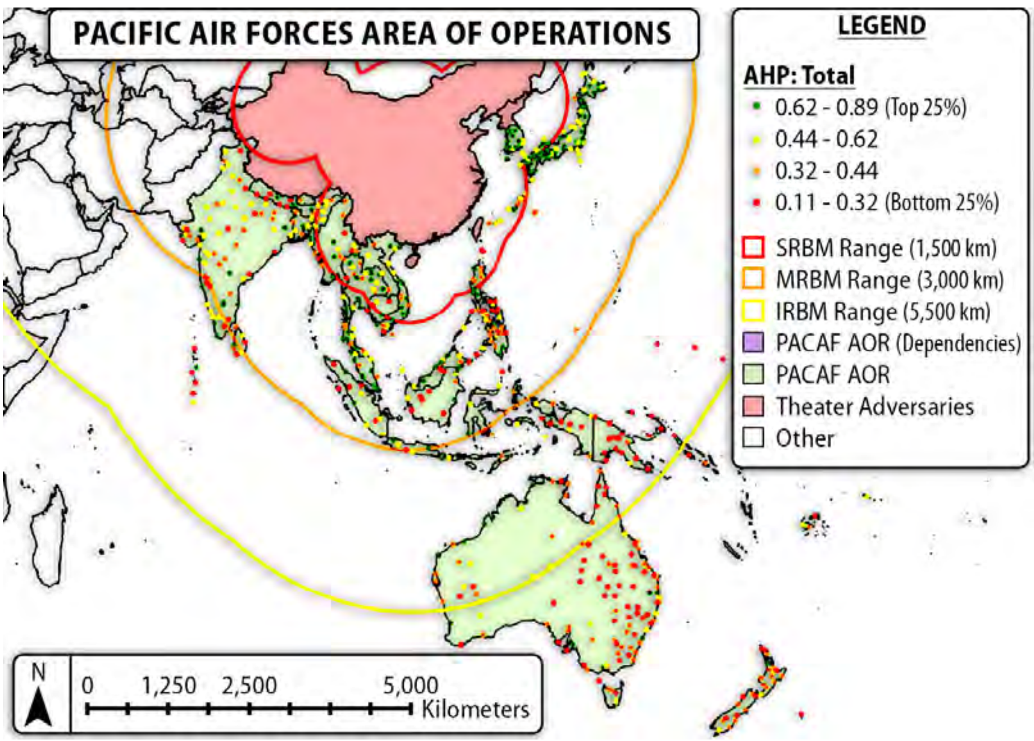



**Figure 1: ACE site-selection framework AHP results (Pacific Air Forces area of operations)**

GIS representation of the results furthers the methodology by allowing users to perceive ideal alternatives. Furthermore, analytic hierarchy process results can be challenging to assimilate; GIS helps bridge this gap by representing results in a more approachable manner. Most importantly, the technique aligns with the research's goals: to produce a flexible, scalable, expedient, and reproducible framework to conduct ACE site selection analysis.

Using the outputs from the geospatial analysis, a closer examination of the top quartile of identified airfields shows the large influence that missile threat has on the results. There are fewer viable basing options with a lower risk tolerance from missiles. Figure 2 depicts the combined efficacy score of each airfield, iteratively removing locations by missile range and the corresponding breakdown of the top quartile of airfields. The illustration demonstrates the influence missile constraints—the vulnerability of those locations to short- and medium-range ballistic missile attack—assert on the alternatives. The left side of the diagram reflects airport AHP scores, with high-scoring airports on the left and low-scoring airports on the right. The right side of the diagram reflects each country's count of airports in the top quartile of the results.

Unsurprisingly, these results show fewer airport alternatives remain as the model is constrained by longer-range missile threats. Moreover, the figure implies the highest-scoring airports begin to disappear noticeably from the model under medium- and intermediate-range ballistic missile (not shown) constraints. At these ranges, only six countries have airports that scored higher than 0.62, which indicates a significant loss of quality alternatives.

The short-range ballistic missile constraint retains 82.3 percent of the analyzed airports with a comparable mean analytic hierarchy process to the overall dataset (0.446 versus 0.467). On the other hand, the medium- and intermediate-range ballistic missile constraints significantly reduce the quantity and quality of the airports, retaining 36.5 percent and 20.1 percent of the alternatives, respectively. The mean AHP score decreases for each of these alternatives to 0.361 and 0.357, respectively. These observations suggest that using the short-range ballistic missile range as a model constraint could help ACE planners reduce risk without losing too many ideal alternatives.

Figure 2 also highlights the important countries within the framework. The ACE site-selection framework indicates Japan, India, Indonesia, and Malaysia have the most high-scoring airports under the short-range ballistic missile constraint. But these alternatives reduce significantly under the medium-range ballistic missile constraint, with India, Indonesia, and Australia representing the majority in that scenario.

Interestingly, the mean AHP score of the top-quartile airports is relatively unchanged as the progressive missile scenarios constrain the model. Each scenario's average AHP score is approximately 0.7. This observation indicates that despite missile constraints removing alternatives, quality airport options that meet the framework's criteria exist further from China (e.g., Australia). Should ACE planners assume a risk-averse strategy to avoid missile threats, several viable options remain based on the selection criteria.

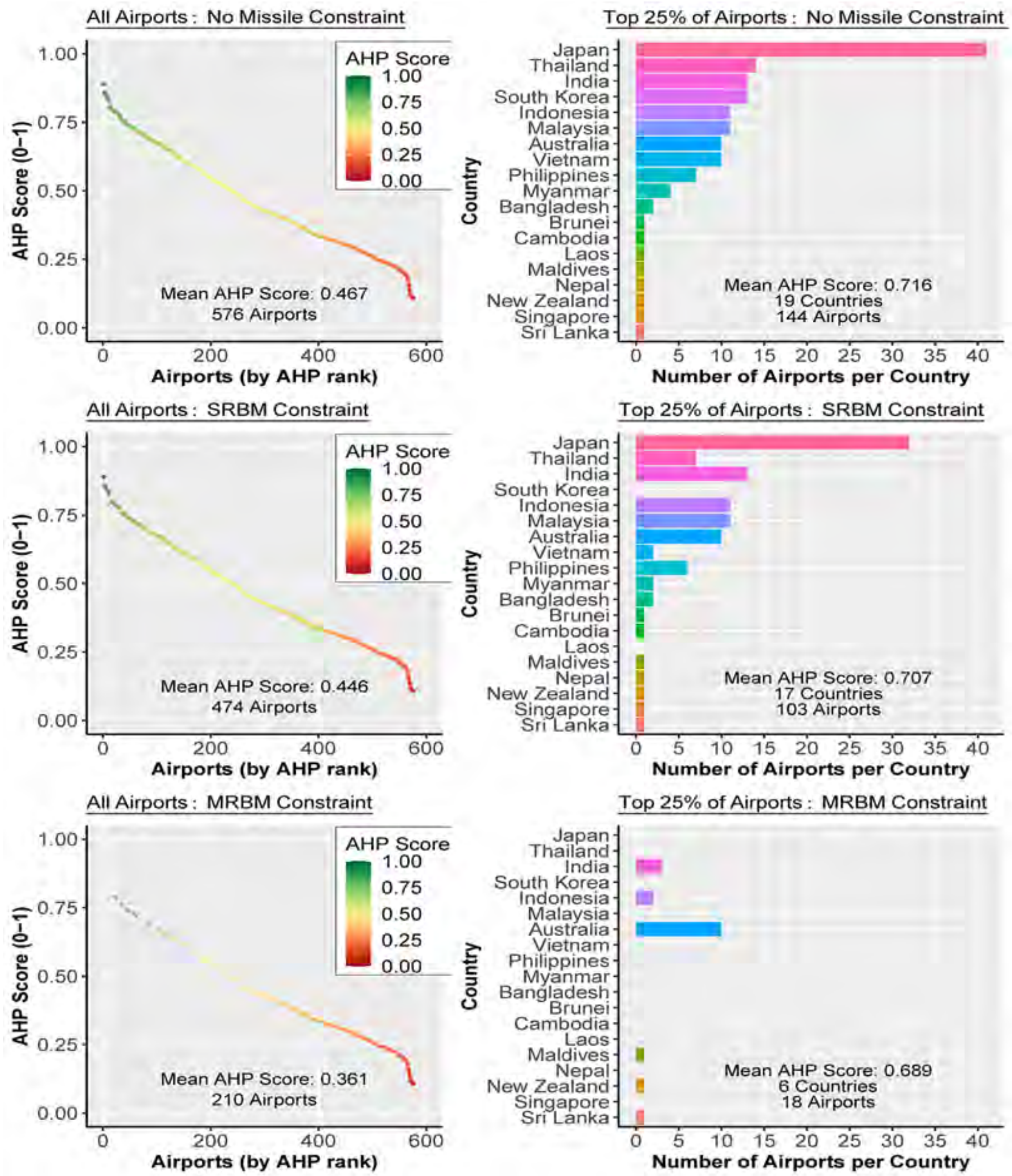



**Figure 2: PACAF ACE site selection analysis (missile threat constraint)**

## Framework Utility and Opportunities

The proposed ACE site-selection framework methodology could benefit strategists and planners significantly in an A2/AD environment. These decisionmakers will be extraordinarily tasked in a right-of-boom scenario and will be required to make frequent life and death decisions with little to no turnaround. The ACE site-selection framework could be an effective tool as the framework is scalable, flexible, expedient, and generates informative results and visualizations.

Several features make the framework scalable. First, the framework could be applied to any area of responsibility, despite the research concentrating on Pacific theater. Besides the missile and construction equipment decision variables, each data source extends across the globe and could be incorporated into other AOR-specific analyses. Pending data availability concerning the alternatives, criteria, and constraints, the proposed framework can be applied based on the needs of the service.

Second, the framework could incorporate additional selection criteria to balance a more comprehensive mission profile. This research concentrates on more general ACE requirements and assesses criteria based on five broader requirement categories. But these categories could be broken down further into subcategories to assess the airports further within the hierarchy.

For instance, the airport requirements category could include multiple criteria, such as runway length, runway width, apron space, lighting systems, and more. In this case, repeating the AHP process within the hierarchy would ensure holistic aviation requirements are met. Adding hierarchies within some or all the criteria categories will require further effort from users due to the additional pairwise comparisons, but these efforts would provide users more certainty that the airports will meet ACE requirements and maximize suitability to operations.

Use of analytic hierarchy process and geographic information systems by the proposed ACE site-selection framework provides significant flexibility for ACE planners. Planners might disagree with the criteria chosen for this research and wish to analyze other criteria. Alternatively, different base functions could require different requirements and constraints, which are easily retooled inside the AHP process. The framework can adapt to these considerations by adding, removing, or substituting criteria or constraints as needed.

Additionally, ACE planners might want to adjust utility functions and AHP criteria weights based on emerging knowledge or changes in resource availability. The framework can facilitate modifications if leaders and planners reach a consensus that satisfies AHP consistency ratio requirements.

Furthermore, the methodology's expedient nature would benefit ACE planners in right-of-boom environments. For example, before a conflict, ACE planners could prepare criteria, weights, and scores and utilize them when country access becomes more apparent. This practice would allow planners to make minor changes to the criteria and constraints and support site choices based on predetermined decision preferences.

Lastly, the proposed framework could aid ACE planners by providing informative results and visualizations to help guide strategic or just-in-time decision making. For instance, planners could run a simulation during peacetime to determine the countries with high-scoring airports. Planners could use this knowledge to posture diplomatic engagements and develop host-nation agreements.

Alternatively, combatant commanders or planners could use the results to inform just-in-time decisions. ACE planners will better understand which countries will allow US Air Force operations when conflict begins. This knowledge could be used to constrain the proposed ACE site-selection framework results and select ACE operating sites that optimally support ACE requirements and strategic outcomes.

## Limitations and Future Work

This article does not identify where to go for ACE after an A2/AD incident. Instead, the methodology proposes how to decide where to go if the requirement arises. Should combatant commands choose to employ the decision framework, several improvements are recommended to maximize the proposed ACE site-selection framework potential and accuracy.

First, a fully enabled ACE site-selection framework should analyze alternatives on a classified network to incorporate classified criteria, constraints, and site alternatives. While this paper demonstrates the framework's utility using unclassified data sources, classified information such as missile quantities and coordinates, overt and covert state agreements, ACE infrastructure requirements, and proposed resource storage locations would enhance the results significantly.

Implementing classified features ensures the framework optimizes and accounts for critical national security factors. For example, an expanded construction parameter could include specific equipment and building material if infrastructure requirements were known. The thought process could be applied to many data sources, including the airport alternatives. In general, a mix of classified and unclassified data will provide ACE planners with the ideal information to support site-selection decisions.

Second, the proposed ACE site-selection framework does not include a cost component in its selection criteria. A cost parameter would be advantageous for ACE site selection because the service is subject to budget constraints and aspires to implement fiscally responsible strategies. (This research could not produce this variable due to time and resource constraints.) Traditionally, the Air Force conducts site visits to estimate cost and resource requirements for aircraft beddowns, which is time-consuming and probably unfeasible in a right-of-boom scenario.

Alternatively, area cost factors are a way to compare relative construction costs between regions or countries, and the Air Force could implement a similar metric to quantify the cost. The US Army Corp of Engineers produces area cost-factor data, but the data is currently not comprehensive for the Pacific theater. Should cost be a parameter the service desires for A2/AD ACE site selection analysis, the Air Force could generate or invest in data sources that derive area cost factors for countries of interest.

As previously mentioned, performing an analysis in a classified environment would be a fruitful endeavor for ACE site selection. Planners could incorporate additional or higher-quality criteria not considered in this study, which would significantly improve the quality of the results. A host-nation agreement constraint could simplify analysis by removing unfeasible airports based on country accessibility. A more accurate missile threat constraint would give ACE planners confidence the model mitigates missile ranges appropriately.

A list of site requirements for ACE operations, including fuel availability, could add additional grading points for airfield alternatives and ensure optimal supply-chain management throughout adaptive basing. These examples and more are possible when an ACE site-selection framework integrates classified data sources; as ACE planners perform most of their planning on classified networks, this should be a viable course of action.

## Conclusion

While ACE strategy matures, Air Force leaders, strategists, and planners must develop contingency plans that confront worst-case outcomes. The proposed ACE site selection framework, a geographic information system-based analytic hierarchy process methodology, can help mitigate right-of-boom operational risks by incorporating leadership preferences and balancing the risk and utility of prospective operating sites. This framework supports adaptive basing and allows for preplanning through data collection and initial site identification. The application demonstrates the framework is flexible, scalable, expedient, and reproducible, allowing planners to evaluate prospective sites and inform decisionmakers. Moreover, planners can include additional relevant factors when those are or become available.

As the US Air Force navigates ACE development, America's adversaries continue to make unprecedented advances in military strength. Further, these nations' involvement in disputed territories challenges global stability and could compel the United States to engage in armed conflict in the near future. If necessary, the service must adapt its strategies and leverage advanced decision-making methods to navigate complicated scenarios. The proposed ACE site-selection framework can provide these necessary tools to the warfighter and ensure the Air Force maintains strategic advantages throughout conflict.

***Dark Horse: General Larry O. Spencer and His Journey from the Horseshoe to the Pentagon***
General Larry O. Spencer. Naval Institute Press, 2021, 182 pp.

Diving into *Dark Horse: General Larry O. Spencer and His Journey from the Horseshoe to the Pentagon,* it is imperative to first state what this book is not. It is not a boilerplate book on leadership, filled with lists of tips and tricks or tired adages that seem to be prevalent in many books written by military leaders. It is not a how-to guide about going from enlisted to officer or how to become a four-star general. Instead, this book is an honest, humble, and often raw firsthand account of one man's journey from a rough neighborhood in southeast Washington, DC, to become the US Air Force vice chief of staff.

The author writes this memoir-style book in a direct, down-to-earth manner. One thing that sets *Dark Horse* apart from other memoirs is the seemingly genuine account of his life. Throughout the book, the author does not appear to embellish or "clean up" certain life events or experiences. Instead, he simply writes them as he lived and perceived them.

The book's chronology is seamless as Spencer starts in his childhood and walks the reader through the important events at various stages of his life, including his appointment as the Air Force vice chief of staff and his early retired days after 44 years of active-duty service. Readers can easily follow the narrative without confusion or a break in continuity.

In a connected but almost separate final chapter, Spencer provides readers with a list of what he refers to as "life lessons." A person could read this chapter as a standalone, but the reasoning and credibility on why these life lessons matter are woven throughout the book. Because of the emotional depth and life experiences tied to these life lessons, readers could benefit from reading the entire book instead of simply skipping to the list of these lessons.

Throughout the book, a couple of key themes emerge and reemerge, two of which seem to shine the brightest. The first, introduced early in the book and prevalent throughout Spencer's life, is his deep belief in God. In the book's early pages, readers are introduced to his story of finding God and being baptized. In subsequent chapters, the author reiterates the importance of his faith in his life's decisions and successes. While this theme is clear throughout the book, the author does not alienate potential readers who may not share the same religious beliefs. Instead, as with the rest of the book, he simply writes his story, of which faith is a large part.

The second predominant theme is the adversities he faced throughout his life because of racism. A gut-wrenching aspect of the book is how he discusses with brutal honesty the racism he faced. Spencer provides several blunt examples of specific times racism impacted him. As readers, we are shown instances of deliberate racism and the effects on him, both directly and indirectly. The reader may need to pause for reflection after reading about a few events because of their power and rawness.

But even with the multiple examples of racism and its adverse effects, this is not a story fueled by negativity or self-pity. Instead, it is one of overcoming adversity and using that adversity and life experiences as building blocks to achieve more than most people think possible. The overwhelming theme and feel of this memoir are positivity and gratitude.

The author's curriculum vitae speaks for itself. He enlisted as an Airman basic and was eventually selected for Officer Training School. After he became a commissioned officer, Spencer was progressively promoted with his career culminating as the vice chief of staff. He is one of only nine African American four-star generals in Air Force history and one of only two who were not pilots. He is also the only person in Air Force history from the primary financial management career field to be promoted to four-star general. Also, he has the distinction of having two Air Force awards named in his honor, the *General Larry O. Spencer Innovation Award* and the *General Larry Spencer Special Acts and Services Award.* Even with this pedigree, the author still writes with incredible humility.

Overall, I would recommend *Dark Horse*. It gives the reader an inside glimpse into the life of an incredibly successful leader and the lessons learned from that life. Unlike the memoirs of many former military leaders in which the authors seem to inflate aspects of their life artificially, this book is written in a humble and down-to-earth way. This humility gives extraordinarily credibility to the book's life lessons.

The book also reminds us how far our nation and military have come regarding racism while pointing out that progress can still be made. General Spencer enlisted in 1971 and dealt with racial slurs from other Airmen at his first duty station. He retired from the Air Force in 2015 as the vice chief of staff and as someone who had seen the election of and met the first African-American US president. This memoir provides readers an insight into a leader's upbringing and life while giving life lessons that can be used in the military and our civilian lives.

**Technical Sergeant Tyler B. Trusty, USAF**

***Rise of the War Machines: The Birth of Precision Bombing in World War II***
Raymond O'Mara. Naval Institute Press, 2022, 352 pp.

Raymond O'Mara's *Rise of the War Machines: The Birth of Precision Bombing in World War II* covers the development of air warfare doctrine and the human-machine evolution for conducting aerial bombing until the end of World War II.

O'Mara retired from the US Air Force in 2016 as a colonel, having flown the F-15 in operations and operational test assignments. After his retirement, he worked in commercial aerospace and advanced technology startup companies and is an independent defense and technology consultant. He earned his doctorate in technology, policy, and engineering systems from the Massachusetts Institute of Technology.

The author focuses on the development of aerial bombing and the systems required to execute that mission. The systems are analyzed beginning with the relationship between the pilot and aircraft and working upward to doctrinal employment. O'Mara covers the inner workings of crew relationships in depth and how each member contributed to the systems of bomber employment. Each compartment is covered in depth and expands upon the specific relationship of its role and the equipment necessary to achieve bombs on target.

The book opens with the coverage of early bombing and explores the integration of machine-driven automation into flying. The early attempts at producing machine integration were difficult due to technological limitations. Because of the pilot aircraft system limitation, the role of bombing expanded into dedicated crew positions, and the people in those positions—bombadiers—became became experts in aerial bombing. The early methods of bombing required a system in which the bombardier directed the pilot to actuate the aircraft to achieve the desired results. This laid the foundational relationship between doctrinal bombing and crew interdependency.

During World War II, the relationship between the bomber and aircrew changed from the start to the end of the war. In the early portions of the war, the bombardier had independent control of the aircraft with the Norden bomb site. This allowed the bombardier to control the aircraft during the most critical phase of the mission, the bombing run. The pilot and other crewmembers existed to get the bombardier to the mission objective. This system inside the aircraft in which everyone worked toward the bombardiers' goals provided a unique dynamic not seen in other aircraft.

In the beginning of World War II, each aircrew had the bombardier as a specialist, but this was later changed due to a doctrinal shift. Wings would now fly in combat formations and required only one lead crew to get the entire formation to the target. This changed the dynamic for the whole US Army Air Force. The new system required only one group of individuals to be experts in their machinery while the other bombers followed along. The new system created an environment where the specialists were selected to lead a mass group of people instead of each crew acting individually during the bomb run.

This doctrinal shift emerged from accuracy constraints due to technological limitations. The combat box and lead crews allowed massed airpower to deliver weapons on strategic targets and to work together to increase the entire systems' effectiveness. By the war's end, the system's entirety rested on a few individuals working in sync with their machine. Most of the aircrew were "toggle pushers," meaning they simply performed a switch when ordered.

The profound and intriguing parts of the book are the manner in which systems evolved. As a need arose, the system itself changed to fulfill the needs of the operator and war fighter. The system evolved from using a human-human operator to a human-machine operator relationship. This relationship required a specialist and a crew of specialized operators. Finally, doctrine shaped the system on a macro level where a single specialized crew fulfilled the role of an individual specialist. This well-written historical evaluation provides insight into the development of aerial bombing.

The author demonstrated the evolution of the relationship between the aircrew members and their machines. The argument falls short with the analysis of the pilot's employment capabilities, highlighting the remotely piloted aircraft, the F-111, and F-117. None of these aircraft are categorized as bombers or are required to fulfill a strategic role akin to World War II bombers. Their mission sets fall within the tactical realm and are not designed to affect the operational level of warfare.

The B-52 is a relevant comparison of the system's evolution and employment practices. The long-range, all-weather bomber has been the backbone of US strategic operations since the early 1960s. The B-52 crew complement has remained consistent since its inception with a pilot, copilot, radar navigator (bombardier), navigator, and electronic warfare officer. Only the gunner has been removed from the original crew compliment.

The author postulates that the autopilot from an F-117 can replace the bombardier's job. This is incorrect because the other airframes must strike few tactical targets for an operation and fly a limited range for only a few hours. The bombardier must be capable of striking large operational-level targets across great ranges. Typical bomber sorties require 20-plus hours of mission employment, and the F-117 is capable of only a few hours due to fuel and system limitations. The comparison is not fully developed. Also, the increased automation the author suggests does not account for the dynamic and degraded environment operations must employ in current and future warfare.

This book is worth reading for those who would appreciate a thorough historical breakdown of early bombing practices through World War II. The bombing practices and problems go beyond dropping a weapon off an aircraft. O'Mara does a great job exploring the intricate workings of the systems required to accomplish the bombing mission. This exploration includes the aircraft, bomb sight, crew members, and doctrinal practices. The social dynamics of the crewed bomber have not changed much since World War II, and this work highlights the uniqueness of bomber airframes.

**Captain Thomas J. Urbanek, USAF**

***Ghostriders 1968–1975: "Mors de Caelis" Combat History of the AC-130 Spectre Gunship, Vietnam, Laos, Cambodia***
William Walter. Knox Press, 2022, 352 pp.

William Walter's *Ghostriders 1968–1975* is an excellent history of AC-130 gunships and the combat operations conducted in Vietnam, Laos, and Cambodia.

*Ghostriders* is compiled from historical accounts of declassified material and information gained from interviews with Special Operations Forces (SOF) veterans. It provides a fascinating perspective of the missions conducted by aircrew members and the challenges of employing a newly modified aircraft. For example, Walter stated that modifications to the aircraft did not come with technical data, leaving crews and maintainers to deal with complex problems requiring troubleshooting (86).

Walter is a retired US Air Force chief master sergeant and was an AC-130 Gunship aerial gunner. He participated in every AC-130 combat operation from 1980 to 1994. In 2001, Walter was inducted into the Air Commando Hall of Fame and the US Special Operations Command Hall of Honor in 2011. *Ghostriders* provides detailed accounts of AC-130s hunting trucks on the Ho Chi Minh Trail and supporting ground forces in the area. These operations proved to be very successful, saving countless lives and destroying thousands of tons of supplies. But that did not come without a cost: 6 AC-130 gunships were destroyed, and 52 crewmembers lost their lives (286).

Walter does a terrific job of telling the stories of crew members who flew on the AC-130 Gunships. A great level of detail exists on the specific missions executed and offers a unique point of view from those who were there. He also does an excellent job of explaining in detail each crewmember's position on the aircraft as well as their roles and responsibilities. Readers do not have to be familiar with gunships to understand the book. Walter additionally takes the reader through a chronological order of the operations adding to the ease of readability and allowing the reader to effortlessly keep track of the timeline.

A minor shortcoming of the book is a few missing perspectives. It offers references from the opposing side and some perspectives of the maintainers and ground forces. Still, more accounts from the People's Army of Vietnam and the aircraft maintainers could add to the content offering the reader more angles of the story. Even without these accounts, *Ghostriders* places the reader inside an AC-130 receiving effective enemy fire while performing evasive and emergency actions, thus keeping the reader engaged. At times, the book places the reader on the edge of their seat with adrenaline pumping. In these sections, the book is difficult to put down.

*Ghostriders* is a fantastic read for anyone interested in AC-130s in general or for those studying the conflicts in Vietnam, Laos, and Cambodia. This book offers a perspective that some may not have heard before. Special Operations Forces personnel could also benefit by gaining a better understanding of where gunships started, and the lessons learned early during employment that are still just as applicable today. These lessons should be passed down to future gunship aviators.

**Master Sergeant Daniel Christenson, USAF**

***Air Power in the Falklands Conflict: An Operational Level Insight into Air Warfare in the South Atlantic***
John Shields. Air World, 2021, 384 pp.

The Falklands War suffers from no shortage of literature. What the current body of work lacks, however, is an objective and data-based approach to analyzing the course of the conflict. It is here that John Shields' *Air Power in the Falklands Conflict* makes its contribution. Far from being another narrative account or personal memoir, Shields combines the practical knowledge of a serving Royal Air Force aviator with the historian's training. *Air Power in the Falklands War* is a deeply researched addition to understanding the role of airpower in the South-Atlantic conflict.

Shields' work can be divided up into four major sections. The first two chapters outline his motivation for the work, a review of the existing literature, and a summary of the methodology used in the rest of the book. This methodology section describes Shields' major contribution to the existing literature: a day-by-day, sortie-by-sortie breakdown of how each side employed (or, as we come to learn, did not employ) airpower in the pursuit of their objectives. To further refine his analysis, Shields also develops a framework for analyzing what each side's targets should have been for a given phase of operation, that is, their opponent's centers of gravity.

The next section, consisting of three chapters, describes Argentinean efforts to attack British centers of gravity over three distinct phases of the conflict: the preinvasion, invasion, and postinvasion ground campaign. In the first phase, the British required some semblance of local air and naval superiority to enable the amphibious assault's success. Shields convincingly argues the British center of gravity during this phase were the two aircraft carriers and their embarked air wings. In the second phase—the invasion—the British center of gravity shifted to the British amphibious force necessary to transport and land ground forces. Finally, in the ground campaign, the British center of gravity was the ground force necessary to take back the islands. It is against these centers of gravity that Shields judges the effectiveness of Argentine airpower.

In the campaign's first phase, no Argentine weapons struck the British center of gravity. Shields identifies several reasons for this failure, including a failure to find the target (44 percent of the weapons), soft kills by Sea Harriers (16 percent), and missions canceled (12 percent), among others. The second phase of the campaign, during which British forces landed in the Falklands, continues the trend of Argentina failing to employ airpower against its enemy's center of gravity. The book shows the largest causal factors for this failure were canceled missions (23 percent), missing the target (23 percent), air aborts (13 percent), and not dropping ordnance (13 percent).

In the campaign's final phase—the British ground force operation— Shields again highlights the failure of the Argentine Air Force to apportion its assets against the British center of gravity.

From postinvasion until the end of the conflict, the Argentines allocated 38 percent of their aircraft against maritime targets—primarily British aircraft carriers—and only 62 percent against the more critical land targets. Again, the biggest causal factors for the Argentine inability to get weapons on target were all within Argentina's control: missing the target, failing to drop weapons, and air aborts.

After covering Argentine airpower, the next two chapters cover British efforts to defend their centers of gravity and prosecute the Argentine center of gravity. Here, Shields appears somewhat iconoclast in his assessment of British defensive efforts. His analysis shows that British defenses—air, land, and sea—accounted for the destruction or deterrence of only 13 percent of Argentine weapons. In other words, it was not that British forces were particularly effective but that Argentine forces were particularly ineffective at their theoretical task.

On the offensive front, Shields defines the Argentine center of gravity as their land forces in the Falklands, without which the Argentines would be unable to hold the islands. Instead of striking this center of gravity, the British allocated some 67 percent of their air weapons to counterair-type missions, with 51 percent of weapons targeting Argentina's airfield on the island. The British allocated only 28 percent of their weapons to ground-force targets. Thus, like the Argentine air forces, the British air arms do not appear to effectively use their assets.

The final two chapters provide a summary and concluding thoughts. Shields identifies four major operational level lessons:

(1) The importance of generating and distributing a coherent joint air campaign plan

(2) The importance of understanding the theatre through reconnaissance and other activities

(3) The need to integrate and understand capabilities across services

(4) The peril of focusing on outputs (sorties, bombs dropped, etc.) instead of outcomes (Did those strikes meaningfully contribute to victory?)

Shields also explicitly outlines and debunks several myths from the conflict, such as the decisiveness of the Sea Harrier and the lethality of the new Sidewinder variant. These final chapters offer a useful summary of the work and much food for thought for current air planners.

While Shields' work is an effective contribution to Falklands War literature and airpower literature writ large, it is not without its faults. Principally, Shields does not include any narrative overview of the air campaign and only provides a few tactical vignettes in the text. Thus, the book is largely inaccessible to those without an understanding of the course of the conflict. While the book's intended audience is likely already familiar with the subject, the omission is still puzzling.

Additionally, readers are sometimes left wondering about alternative hypotheses or interpretations of the data. For example, Shields does not explicitly tackle the question of whether Argentine pilots may have missed their targets because of Sea Harrier patrols, thereby understating the impact of the Sea Harrier in the data. While these omissions do not change the overall conclusions, they may leave the reader with additional questions. Despite these faults, Shields' work is a must-read for any student of operational-level airpower, particularly for those interested in the Falklands conflict.

**Second Lieutenant David Alman, ANG**

***Spymaster's Prism: The Fight against Russian Aggression***
Jack Devine. Potomac Books, 2021, 304 pp.

*Spymaster's Prism: The Fight against Russian Aggression* stands out for its relevance and applicability in the growing field of literature on countering Russia.

Jack Devine's experience with the clandestine conflicts against the Soviet Union is invaluable for present-day intelligence personnel, military leaders, and policy makers. Devine explicitly wrote this book to help leaders choose "how to effectively respond in light of Russia and others' ongoing intelligence assaults on the United States" (xx). His hard-earned lessons from the Cold War will make American decisionmakers more successful today.

*Spymaster's Prism*, Devine's second book, is a passing of the flag between generations of those dedicated to preserving America and our way of life. His first book, *Good Hunting*, is an autobiography detailing his time at the Central Intelligence Agency (CIA). While *Spymaster's Prism* describes some of his life, it emphasizes choices available to the US national security establishment.

In this book, Devine distills 32 years of experience as a CIA officer, solidifying his position to speak as an authority on American efforts against Russia. His career covered such notable events as the Aldrich Ames scandal, the Iran-Contra affair, and the US arming of mujahidin forces in Afghanistan. He ended his career as the CIA's acting deputy director for overseas operations.

*Spymaster's Prism* fits with similar books on US and Russian competition, such as Michael McFaul's *From Cold War to Hot Peace: An American Ambassador in Putin's Russia*, Richard Stengel's *Information Wars: How We Lost the Global War Against Disinformation and What We Can Do About It*, Stephen F. Cohen's *War with Russia: From Putin and Ukraine to Trump and Russiagate*, and Ion Mihai Pacepa and Ronald J. Rychlak's *Disinformation: Former Spy Chief Reveals Secret Strategies for Undermining Freedom, Attacking Religion, and Promoting Terrorism*. But Devine adds a unique perspective, from his time within the US Intelligence Community. His prescriptions aim at countering Russia in a domain where that nation traditionally excels.

Devine's experience is crucial at this moment since "Russia's assault on Western democracy has primarily been predicated on what can traditionally be considered intelligence actions" (xviii). This is natural for a nation led by a former intelligence officer and a close association of the so-called "Siloviki," or members of Russia's security services. Moscow's most recent actions toward the West, including assassinations, election interference, planting illegal agents, or corrupting Western officials, all illustrate this point.

Yet, these are not new steps for Russia. As Devine states in the introduction, the "current contest with Russia is very much a continuation of our intelligence dueling with Moscow since the end of World War II" (xxi). For most of that time, the difference was an informal, mutually agreed-upon intelligence competition framework that existed between the United States and Soviet Union—the Moscow Rules. Devine describes how this framework was abandoned after the fall of the Soviet Union in 1991. Without it, the United States and the West lack a common language to deter or mitigate Russian aggression.

The bulk of *Spymaster's Prism* is dedicated to 13 axioms to use in creating a new set of "Moscow Rules." These observations (called "lessons") center on the human dimension of intelligence, including descriptions of Russia's leadership and goals, suggestions for gaining sources within Russia, or counterintelligence actions to be taken within the United States. These recommendations appear effective because they narrowly focus on the Intelligence Community. Relatively little discussion of technical methods, including cyber, happen. Devine is less interested in the means to act than he is in the ends they seek.

While a strength, Devine's focus can also be *Spymaster's Prism's* greatest weakness. His book is a product of the US Intelligence Community, written for the members of the same group, especially human intelligence practitioners. His recommendations will be less applicable to those in other fields. Similarly, Devine perceives Russia exclusively through the lens of intelligence competition. Thus, his lessons are all symmetric to Russian actions, founded on the assumption that Russia will respond in kind.

This last assumption is where perhaps Devine is most vulnerable. His understanding of Russia as a revanchist Cold War power might not accurately represent Russia after 2000, with the ascension of Vladimir Putin to the presidency. Events since the Russian invasion of Ukraine on February 24, 2022, show that Putin and his Siloviki might not be interested in creating a shared framework.

The Soviet Union at least understood that it needed to compete cooperatively with the United States; naked aggression would lead to catastrophe. In contrast, modern Russian leaders seem willing to cut their country off from the West and the entire liberal, democratic global community. Russian leadership's collective policy shrug toward spiraling sanctions indicates a willingness to take measures the Soviet Union would never have. Western leaders today may need to reevaluate what levers of influence are truly available to the United States to alter Russian behavior.

By contrast, Devine's vision of America is compelling. Although he witnessed moral failures in US leadership, such as Aldrich Ames' spy activities or the Iran-Contra investigation, he retains an unshakable faith in America's moral superiority and historical exceptionalism. As he describes it, this "combination of freedom, quality of life, and aspirational wish for a more fair and just world" (220) is the source of America's ultimate success. The need to live by these values is woven throughout his lessons. Devine dedicates two chapters to the requirement to fight a just conflict without stooping to the immoral practices that ultimately form a cancer in our adversaries.

*Spymaster's Prism* is a useful read for members of the US Intelligence Community, military leaders, and policy makers. It adds texture to a rich field of applying Cold War principles to the ongoing, overt conflict with Russia. More than that, Devine builds a credible structure to use when evaluating Russian actions or determining the appropriate American response. It is a reminder that all conflicts must follow our beliefs and values to succeed; otherwise, we fall into the moral trap Russian leaders set. While clear-eyed, Devine insists we can prevail if we hold true to our mission and integrity.

**Lieutenant Colonel J. Alexander Ippoliti, ANG**

***Klimat: Russia in the Age of Climate Change***

Thane Gustafson. Harvard University Press, 2021, 336 pp.

Climate change will be the defining issue in this century's international politics. It will shift international trade, drive conflicts, and—at least for some low-lying Pacific islands—be an existential threat.

Thane Gustafson's *Klimat: Russia in the Age of Climate Change* seeks to predict the effects on Russia. The book charts a perilous course for the Russian economy and society in the next 30 years, a course beset by the storms of shifting international markets and the shoal waters of poor domestic economic management. That course is only possible without any surprise, world-changing events beyond the COVID-19 pandemic that began as Gustafson completed his book. We are now beset by another world-altering event: Russia's February 2022 invasion of Ukraine. *Klimat* has only become more compelling as a result.

Gustafson argues that climate change's net effects on Russia will be negative (6). There will be benefits, such as marginal improvements in agricultural productivity in parts of Russia and greater access to Arctic waterways, but the costs will surpass these. Melting permafrost will degrade infrastructure across 70 percent of Russia's landmass (210). Droughts, floods, and extreme weather events will make parts of Russia less habitable and economically productive. This will drive economic migration, pushing rural populations into already crowded cities.

Compounding this problem for Russian policymakers, Gustafson argues that external actors control the economic impact of climate change on Russia. (7) Russian export revenue comes overwhelmingly from hydrocarbons, precisely those resources the world must wean itself from to limit the impact of climate change. Russia's economic output and its tax revenue are at the whim of governments actively seeking to move their economies away from oil and gas (15, 52). Changes in European policy toward fossil fuels, such as a carbon border tax, would strongly affect Russian exports. Similarly, any change in Chinese demand could radically change Russia's economic fortunes.

Gustafson predicts Russia will continue to benefit from its hydrocarbon resources in the short term as the global energy transition slowly builds speed. By the early 2030s, the global demand for fossil fuels will continue to increase, and Russia will remain in a strong economic position (13). But from the 2030s to 2050, the global energy transition will gain steam, and Russian exports of oil, gas, and coal will fall precipitously (13). The result will be a Russian economy short of export revenues, a state short of tax incomes, and a society struggling to cope with the effects of climate change.

All told, Gustafson paints a grim picture of Russia's economic future. This future has grown bleaker in the wake of Russia's 2022 invasion of Ukraine. Sanctions on Russia's central bank have obliterated the currency reserves that Russia developed during the last 20 years. This will reduce Russia's ability to offset the costs of climate change. Shell and BP—major British oil companies—withdrew their Russian investments. The four largest international oilfield servicing firms also left Russia.

With these departures, Russia loses the capital to finance the development of its fossil fuel reserves and the technical knowledge to exploit them. This will seriously constrain Russia's ability to benefit from its natural resources even to the early 2030s horizon that Gustafson predicts. Furthermore, Europe plans to cut Russian gas imports by 66 percent this year and intends to have complete energy independence from Moscow well before 2030. The 10 years of strong fossil fuel exports that Gustafson predicts seem to have burned up, leaving Russia in a much weaker position.

This is not to criticize Gustafson's work, which provides a sober analysis of the structural factors that will govern Russia's experience of and ability to respond to climate change. The point is to highlight the precarity of Russia's economic position until 2050 and its vulnerability to Kremlin mismanagement and outside events. Few predicted Russia would invade Ukraine in 2022, and fewer still predicted the unprecedented scale of economic sanctions the United States, European Union, and others enacted in response.

Russia could only overcome the structural problems that Gustafson highlighted if incredibly skilled and lucky political leaders in the Kremlin worked with all parts of Russian civil society and coordinated with their counterparts in other countries. Instead, Russian President Vladimir Putin launched his country into a war that puts Russia in opposition to its primary hydrocarbon customers and the source of the high technology the future Russian economy needs.

As we work to understand the world that will emerge after the Russo-Ukraine War, I strongly recommend *Klimat* for the insights it provides on Russia's future, climate change, and the future of international relations.

**Ian T. Sundstrom**

***America's Wars: Interventions, Regime Change, and Insurgencies after the Cold War***
Thomas H. Henriksen. Cambridge University Press, 2022, 324 pp.

Documenting America's military actions since the fall of the Soviet Union, Thomas Henriksen provides a compact and succinct outline of US intervention in Panama, the Balkans, Somalia, Haiti, the wars in Iraq, Afghanistan, and efforts throughout the continent of Africa.

Henriksen, an academic and senior fellow emeritus at the Hoover Institution, provides a temperate historical overview of these conflicts with elements of international relations theory embedded throughout the analysis. In examining conflict during America's unipolar moment, Henriksen portrays the United States as a liberal hegemon using its unrivaled power to project Wilsonian-like internationalism across the globe.

Henriksen's evaluation appears heavily influenced by mainstream liberal internationalist thought, accepting America's role as the enforcement arm of the liberal or "rules-based" international order. Despite this, he occasionally references international relations scholars and theorists with realist inclinations. While this work focuses primarily on the conflicts mentioned above, the brief conclusion offers an estimation of America's power projection capabilities in the imminent world of great power competition.

The author's views remain relatively absent during the book's first chapters. Still, the more nuanced analysis dissipates as the more recent and politically charged conflicts in Iraq, Afghanistan, and throughout Africa take center stage in the latter half of the work. While he is willing to concede misjudgment in some instances, Henriksen strongly suggests that any misfortunes seen in our recent foreign policy prescriptions are due to a lack of escalation, even in the face of repeated failure.

We have all heard the aphorism, "No plan survives first contact with the enemy." Yet, time and time again, Henriksen cannot seem to accept the practical application of this maxim, which is the reality of unintended consequences. Instead, when policies fail to materialize, every setback, complication, and frustration is met with the same passive refrain. All would have been well had we just executed said plan even more.

The subtle implications throughout the work echo the tired cliches of the armchair interventionists, who appear convinced that our actions in no way influence our adversaries. Thus, any policy out of Washington is necessarily a good policy, and the true motivations of critics are questioned. While remaining fairly mild, Henriksen says that a commander who continues down the path of past mistakes shows "a profile in courage," but one who scales back is *retreating*. Those who support intervention are *patriotic* and show "altruism," while skeptics "trivialize the sacrifice" of our service members. Though he briefly notes the cost of the past two decades of continued warfare, both in American lives and resources, legitimate concerns about the direction of US foreign policy are usually dismissed. Critics who oppose prolonged entanglements, he says, "have no realistic plan" as an alternative.

The logical conundrums the author finds himself in to justify his bias toward intervention are evident in his overview of intervention in Libya and the second-order effects this had on conflicts throughout Africa. He notes in earnest the "fire spread" throughout the region when Tuareg militants, formerly loyal to the deposed dictator Qaddafi, returned to Mali from Libya. The militants seized control of the northern portion of the country, unleashing a wave of violence and terror that spread though the region.

The destabilization of northern Africa empowered terrorism and militancy, with Henriksen specifically noting numerous subsequent military coups, the rise of Al Qaeda in the Lands of the Islamic Maghreb (AQIM), Ansar Dine, Boko Haram, and the terror of other violent extremist organizations who conducted mass murder, kidnapping, and terrorism throughout Nigeria, Niger, Cameroon, Chad, Somalia, Ethiopia, Uganda, and others.

Yet, somehow, the chapter concludes with the assertion that the "interventionist response" in Northern Africa was a "prominent victory" in deterring terrorist attacks. The problem with Libya, he reasons, was that there was not a firm enough commitment in the aftermath of intervention. There was "no follow-on treatment to stabilize the chaotic nation." The prescription always supports more escalation, more involvement and more intervention, no matter the cost.

Thus, blowback only flows in one direction, where the hand is not heavy enough. This refusal to acknowledge unintended consequences, or to selectively assess them in accordance with a preconceived agenda, is certainly a mistake that any policymaker or military theorist should avoid as we anticipate and plan for future conflicts, at the very least because it opens policy makers to the risk of making avoidable mistakes.

For example, he concedes "Iraq stands out in many ways as the exception" due to the "higher costs in lives and money" after the "strategic miscalculation" of removing a regional counterbalance to Iran. But he clarifies this admonition by stating the mistake was in the withdrawal, not the intervention itself. In this way, we see why his evaluation of second-order effects in Libya appears disordered. If those who do not learn history are doomed to repeat it, it stands to reason that those who learn the wrong lessons are also doomed to repeat them.

This point cannot be overstated. The rising threats we face as a nation are of vital importance as we see a return to superpower politics. Assessing the consequences of our actions so we can effectively plan for contingencies, is essential to mission accomplishment. So, too, is assessing the rational calculus of our adversaries to consider how they will respond to our actions.

These two points make up the facets of Sun Tzu's famous proverb, "If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle." Unfortunately, in this book, the focus is on neither.

**Second Lieutenant Micah Mudlaff, USAF**

***Illicit Money: Financing Terrorism in the 21st Century***
Jessica Davis. Lynne Rienner, 2021, 240 pp.

*Illicit Money* by Jessica Davis is a critical pillar of financial terrorism research and may become a foundational text for the field. Its use of data strikes a perfect balance between being evidence-based while not blindly following what out-of-context numbers say in an area almost defined by incomplete information. If the author had chosen to go in-depth in some case studies instead of brief descriptions of how capital was used, the book would also have been excellent for those outside of the field. *Illicit Money* is effective in showing how terrorists raise and deploy funds, but it falls short of being a text capable of generating more interest in a field unjustly written off as merely academic.

Davis discusses how terrorist organizations and actors acquire capital and use it to achieve various objectives. The book is broken down into three main parts—raising money (how groups collect resources), using money (how groups use, store, and obscure funds), and new frontiers (an analysis on financing methods and emerging tactics). It draws statistical evidence from 55 terrorist organizations, 18 plots, 32 attacks, and the authors' experience working on terrorism funding.

Multiple sections provide incredible insight into how money affects the operations of a terrorist group. One excellent example is the ransoming of hostages. As a summary, terrorist groups sometimes take people hostage to demand money for their release. While this traditionally happens to locals, the author's analysis shows that the big bucks (and high-profile incidents) are when foreigners are traded. She discusses how nation-states are put in awkward positions, wanting to spend money to free their citizens while also needing to avoid breaking international laws. Sometimes, individual family members make the payments themselves, even if that means funding a terrorist group.

The author does an excellent job discussing the "overhead" costs associated with ransoming: setting up communications, keeping the hostage alive, and paying the appropriate middlemen to transfer the prisoners and payment back and forth. The whole system is much more complex than it first appears. Learning about how this prohibitive cost could turn less organized groups away from ransoming was an absolute joy to read.

Another fascinating chapter was managing, storing, and investing funds. The author describes how the Palestinian Liberation Organization (PLO) invested in banks, businesses, factories, and all sorts of legitimate business activities (144). These investments provided more than half of the funding for the organization in 1987. It was a bit surreal comparing how action-packed one would expect terrorist activities to be with the duller dimensions of generating a return on investment high enough to beat inflation.

While some authors rely too heavily on their data, Davis expertly avoids this trap. Data is used to back it up when a claim is made, along with the author's expectation of it being over or underestimated. She explains her reasoning for her expectations. Given the lack of reliable data on terrorist funding, failing this crucial step would have compromised the entire text. Instead, the book goes above and beyond illuminating what the data suggests but never simply letting the numbers speak for themselves. The context she provides is critical to the conclusions which are drawn.

While many aspects of *Illicit Money* reconfirm preconceived notions about terrorist funding, the analysis also highlights truths that seem counterintuitive. One example is hawala, an informal method of money transfer that was vilified after the 9/11 attacks. A false raid against such an operation led to the seizure of immigrant remittances to families abroad. No one targeted in the raid was prosecuted for terrorist-related financing. Hawala can be used to fund terrorism but no more than any other source.

Another counterintuitive result is the volume of legitimate institutions which are used for the transfer of capital. To this day, traditional banking remains the dominant method by which money is moved for terrorist activities. New technologies, such as crowd sourcing through social media, can be adopted, but this is not always the case as cryptocurrency remains a small and niche corner of terrorism funding.

Furthermore, capital is used to provide social services with the goal of breaking state legitimacy through winning hearts and minds versus mere intimidation. At one point, Hamas was estimated to use up to 95 percent of its resources on social welfare programs. Some groups even have rudimentary taxation policies to track who has "contributed." It is difficult to ascertain if people paying the tax are merely being extorted, truly believe in the organization's mission, or some combination of the two. While it seems easy to say that providing money to a terrorist group ought to be sufficient grounds for terrorism financing charges, this book paints a more accurate but less crystal-clear world. These examples show how commonly held assumptions about terrorist financing can be false.

The book serves as an excellent foundational text for understanding the world of financial terrorism. Unfortunately, many elements of the book can be a bit dull to read that seems difficult to believe given the espionage involved in moving large amounts of money around the world. Davis could have dropped in more interesting case studies in multiple places.

It is strange that this phenomenon is treated as an afterthought, considering the prevalence of state-funded terrorism. For example, the role of the Central Intelligence Agency in providing funds to the Mujahedeen is essentially a part of the public discourse. American-funded Islamist proxies in the Soviet-Afghan War could have been an excellent concrete case study for how states provide resources to terrorist groups. The way the capital was transferred, the nature of the relationships, and the conflicting interests of the two parties would have been fascinating to read through the financial lens. This could have flowed perfectly into today's modern analysis of the modus operandi of Iranian-backed groups in the Middle East.

Another missed opportunity was when the author discussed legitimate political activities. Multiple groups attempted to use lobbying to achieve strategic objectives. For example, Davis mentions a law firm that the Liberation Tigers of Tamil Eelam (LTTE) hired to get its name off the State Department's terrorist list. But there is no follow-up to such an interesting relationship. Not only would it have been an illuminating example, given that the book lists multiple other groups who have pursued similar strategies, but it would have generated much more interest in the terrorist financing field. Since terrorism is violence pursued in hopes of political change, directly spending capital on lobbying is crucial to such movements. Why dedicate so little time to what might be the most interesting and unexpected way terrorist groups deploy funds?

A final area worth exploring would have been the chance and impact of collateral damage from counterterrorism operations in the financial domain. While drones striking the wrong target is obviously terrible, one can imagine how angry an individual would feel if their bank accounts were frozen with no ability to appeal. The author briefly mentions this possibility and provides an example of laws being misused concerning hawala. While terrorist financing laws could be helpful in retrospect to prosecute a terrorist or terrorist sympathizer, the impact of unilaterally seizing capital, which can be moved internationally almost instantly, was not explored to the extent necessary.

*Illicit Money* ended up doing exactly what the author intended to do, but nothing more. Still, given that Davis acknowledges the need for interest in financing terrorism, it is disappointing that more in-depth case studies were not explored. Individual name drops and brief descriptions of incidents do occur but are insufficient to generate the desperately needed interest from those outside the field.

The flows of capital dominate our world. From the outsourcing of jobs to access to healthcare and even how marriage has become as much of a contract as an intimately personal choice, almost every aspect of the human condition has been captured by economics. Thus, any discussion that highlights the role of capital in political struggle is critical to understanding how such activities take place, even if terrorism seems to "break" the logic of calculated self-interest.

Readers looking for intimate case studies of how finances flow may find *Illicit Money* sorely lacking in those examples. Given that part of the problem is a lack of interest in terrorist financing, the author missed a major opportunity to develop that interest outside of the traditional terrorist financing community. Still, the book serves its function well, providing an unparalleled foundation for those who want to pursue this area more vigorously.

**Vivek Thangam**

***From Berkeley to Berlin: How the Rad Lab Helped Avert Nuclear War***
Tom Ramos. Naval Institute Press, 2022, 288 pp.

While no longer owning a seat at the forefront of Americans' minds as was the case during the Cold War, nuclear weapons still hold a commanding seat at the table as policymakers develop national defense policy. Tom Ramos delves into the history of the founding of Lawrence Livermore National Labs (LLNL), a decades-long employee there himself. Though the book is historical, a great effort was put forth in capturing the leadership and management necessary to bring the national lab from a University of California outpost to the institution it is today.

The book does a fantastic job of contextualizing events as they occur. Ramos does this from the genesis of the Manhattan Project to the need for a second nuclear weapons lab to the need for a submarine-launched ballistic missile (which led to the modern intercontinental ballistic missile)to Kennedy going to Berlin and giving his "Ich bin ein Berliner" speech. He works through these major events that he argues were enabled by the LLNL. But there is a bias toward the LLNL vice Los Alamos (LANL), given his background. Ramos is fair in his treatment of the other weapons lab, and he reasonably explains why the governing philosophies of the two labs enabled the LLNL to expand into technology development while the LANL remained focused on technology refinement.

Ramos spends most of the first half of the book building up to the first years of the LLNL, giving historical accounts focusing on E. O. Lawrence and the work needed to develop a fusion bomb. He sets the stage, including a discussion of the personalities of the various scientists involved. The second half of the book focuses on nuclear weapon testing. He goes into details about atomic device naming, why they were testing, and the struggles. While the chapters are discrete, each one builds upon the next, and the theme that resonates is the leadership that was required by each scientist, senior military officer, and engineer and the sheer amount of willpower that was needed in the first two decades of the lab's existence to bring it to the prominence it knows today.

This book is a must read for any technical officer or government scientist/engineer who deals with nuclear weapons or manages highly technical problems. For anyone who has been able to visit the LLNL, you would undoubtedly recognize the names of his main characters whom he puts into focus. Ramos keeps the book technical enough to keep the scientist reading while offering enough policy and Cold War history to keep everyone interested.

*From Berkeley to Berlin* would have made past visits to the lab more impactful and put the lab's goals into great context. But the book only focuses on the infancy of the lab until about 1962. While that is the main intent, given how Ramos contextualized the first 20 years of the lab, writing a longer epilogue about its impacts would have added value. It was appreciated how he closed the loop on many of the characters in the epilogue, but he suggests things the lab contributed to throughout the 1970s and 19080s that leave the reader wanting slightly more.

Ramos' effort is an overall, thorough, and quick read on the lives of the scientists and engineers who helped found the Lawrence Livermore National Laboratory and how they contributed to preventing nuclear war during the Cuban Missile Crisis.

**Captain Glenn R. Peterson, USAF**

***Risk: A User's Guide***

General Stanley McChrystal and Anna Butrico. Penguin Books, 2021, 368 pp.

Having spent the better part of the latter half of my 30-year Air Force career as a strategist and a fan of retired General Stanley A. McChrystal's postmilitary transition and work, I was excited to see the title of this book as it was coming out.

*Risk: A User's Guide*, as a component of strategy and strategic planning, is vital as it reconciles an organization's ever-expensive requirements and appetites with its coffers' budgetary reality. Yet, at a deeper level, the understanding of risk and the science of "buying it down" through the art of the numerous and methodical approaches outlined in this user's guide will go a long way in conserving precious resources—people, monetary or other. The work and its analysis of risk will also help reduce, mitigate, or eliminate surprise and concern from the planning equation.

Risk is the perfect topic to discuss today. As McChrystal and coauthor Anna Butrico note early in the work, they wrote *Risk* during the pandemic when the world was fumbling with what to do about it, mitigate its spread, develop a vaccine, and respond to myriad other cascading events. Admittedly, and as McChrystal observes, after a military career in combat dealing with risks, many would think he has mastered the subject, yet the opposite is true. As he faced risk, dealt with it, and watched others contend with similar risks under roughly similar circumstances, he was intrigued by the many divergent approaches taken to deal with risk.

Thus, he set about to understand it in order to manage it better. *Risk* is not really a work on different types of risk, but an explanation of "the factors by which we can strengthen our ability to respond to risk, and how we can turn the dials up and down to make our responses more effective" (xix). And while McChrystal could have simply cataloged and cast his military experiences throughout the entirety of the book (which might have been a bit self-incriminating in some circumstances), they constitute but a small portion. A big strength of the book is that it covers examples across military, government, civil society, and business—ensuring a broad and appealing applicability to numerous audiences. The thesis is tackled in three parts.

Part one constructs a paradigm around a concept he describes as a risk immune system. Part two builds on this foundation by introducing 10 risk control factors (communication, narrative, structure, technology, diversity, bias, action, timing, adaptability, and leadership) "in identifying, analyzing, and ultimately controlling risk" (xxi). Part three takes these factors and offers proven tools and exercises through plausible scenarios with a fictitious airline—FlyVA—to tease out the germane takeaways. This is another strength of the book in that rather than telling stories and providing tools, the reader can visualize through the various scenarios how those tools are used, which is something of great comfort to those unaccustomed to managing and dealing with risk.

One of the aspects of this book that makes it a page-turner a reader will not want to put down is the breadth and variety of stories and how they are woven into the DNA of the thesis. For example, not only do the authors draw examples from Pearl Harbor, the 9/11 attacks, and COVID 19, but they also discuss Apple, the Alamo, Boston's Big Dig, the Cuban Missile Crisis, Google, Hurricane Katrina, Microsoft, pandemics writ large, Operation Eagle Claw, Overstock.com, Ponzi schemes, China, Russia, Greta Thunberg, the World Wars, military services, and of course, special operations—just to name a handful! With uncanny pertinence, the authors weave many of these topics throughout, applying the various tools in different circumstances so that the reader can evaluate them through multiple lenses.

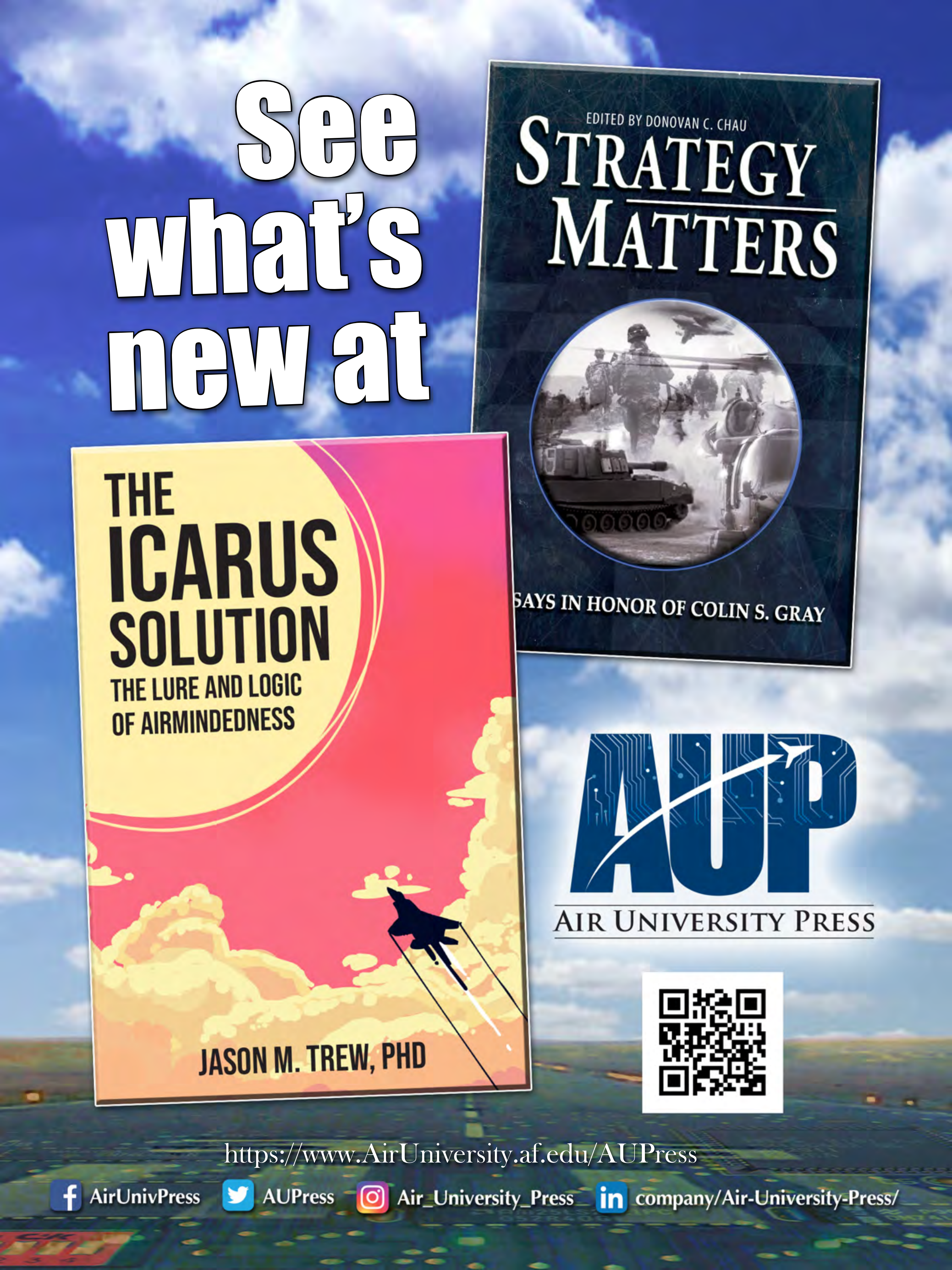
Ultimately, in this reviewer's humble estimation, the authors support their thesis. They narrowly define their task and deliver a readable and practical guide for all to better understand and deal with risk. Buying down and understanding this risk, whether it be when lives are at stake, profit and loss are on the line, or organizational reputation hangs in the balance, the authors show readers that despite the greatest risk to us, we must understand the inputs and factors inherent in a given situation. Then we can apply tools and measures and not be surprised by outcomes we wish to avoid but can roll with them because of sufficiently adept planning and forethought.

But there is a big elephant in the room that is neither addressed in this book nor considered in passing. And so, all readers considering the context for reading a book should first reflect on the author's credibility in writing it. The elephant is the author's error of developing and signing off on an unrealistic strategy for Afghanistan that flew in the face of certainty his troops faced on the ground. Risk, and a bit of hubris, conspired to create battlefield outcomes that led to the deaths of the likes of Pat Tillman. But of greater unmentioned are the colossal strategic shortcomings leading to the unfortunate deaths of numerous civilians—some even bordering on war crimes.

The book is chock full of platitudinous bromides sprinkled liberally throughout, diluting the meaning behind many exceptional suggestions and useful tools. Readers see right through this filler. Still, if these issues do not knock your conscience, and you can separate them from the pure content of the book, it is most useful. No stone has been left unturned in that pursuit.

Yet, the reviewer is still troubled a bit as a commander at the highest levels; McChrystal personally risked nothing while enabling stalemate at best on the battlefield, if not contributing to losses on a grand scale.

**Brigadier General Chad T. Manske, USAF, Retired**



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