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Features

Departments

78 | Commentary

Improving Resource Management in the Afghan Air Force

Lt Col Jonathan D. Ritschel, USAF
Ms. Tamiko L. Ritschel

Significant change is occurring in the Afghan Air Force (AAF). Dramatic change has already occurred on the operational side as the AAF has significantly expanded and modernized in the past seven years. The air force added C-208s, C-130s, and MD-530s to the fleet, and in 2016 the first four A-29s arrived.[1] These platforms provide the AAF with airlift, search and rescue, and attack capability as coalition forces have transitioned to a train, advise, and assist role and relegated combat operations to Afghan forces. Change is also on the horizon for support functions of the AAF. Specifically, a transition of financial responsibility from US to Afghan processes is underway. The current AAF construct, however, is ill-suited to facilitate this transition. No mechanism exists to effectively transition aviation unique requirements from coalition to Afghan control under the extant financial construct. Additionally, the lack of authorities in the resource allocation process is a significant problem for the AAF as it resides under the Afghanistan National Army (ANA). Thus, this article examines the current resource allocation problems the AAF is experiencing and subsequently provides a road map to ameliorate these issues through organizational change.

We analyze the AAF through extensive interviews of coalition advisors and Headquarters (HQ) AAF personnel. In conjunction with the information acquired from these interviews, we utilize the accumulated knowledge gained from one year of field work training, advising, and assisting at HQ AAF. The research is scoped to the AAF's financial and procurement processes and encompasses a thorough examination of the ongoing resource allocation problems they face today. Additionally, we analyze how widespread corruption in Afghanistan is adversely impacting the resource allocation process.[2] Thus, this article seeks to determine solutions to the resource allocation problems the AAF is currently experiencing.

Afghanistan National Army Force Structure

There are several components that encompass the force structure for the ANA. The Ministry of Defense (MoD) is one of 24 ministries in the Afghan government.[3] The MoD, along with the general staff, are responsible for those functions necessary to ensure operational readiness for the ANA.[4] ANA combat forces are divided into six geographically numbered corps (201st, 203rd, 205th, 207th, 209th, and 215th) plus a capital region division in Kabul. (see Figure 1)[5] This corps construct resulted from the reestablishment of the ANA after the fall of the Taliban in 2002 and stabilized to its current six corps plus capital region form in 2009. Each of the six regional corps manages one to four brigades which are comprised of multiple battalions (called *kandaks* in Afghanistan). As of March 2016, the ANA had 203,000 people with approximately 7,400 of those personnel designated as AAF.[6]

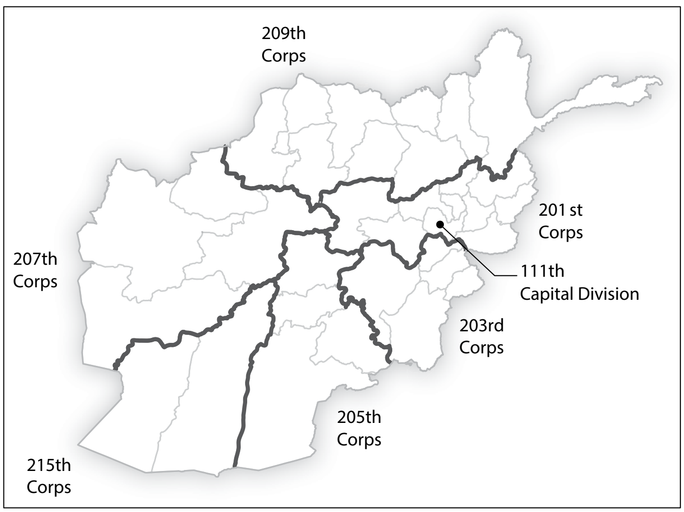

Figure 1. Afghan Army Corps (reproduced from GAO)[7]

The Afghan Air Force resides within the ANA and not as a separate component. The AAF is comprised of three wings (Kabul, Kandahar, and Shindand), an AAF headquarters, and an Air Academy (Pohantoon-e-Hawayee, dubbed PeH). In total, there are 34 units attached to the three AAF wings. It is important to understand that these units are geographically dispersed throughout the country and reside within the ANA corps construct. As a result, control resides with the corps. The ANA corps manage the AAF units that fall within their purview like a typical army unit (i.e. like an infantry brigade). This ANA–AAF relationship and its implications for allocating resources will be explored in subsequent sections.

The Ministry of Defense Budget Landscape

Afghanistan is one of the poorest countries in the world. As a war-torn country with a literacy rate of only 31 percent,[8] Afghanistan has struggled to generate a sustainable economy. In 2015, Afghanistan's gross domestic product (GDP) per capita was $672 US dollars (USD), compared to that of the US GDP per capita of $56,596 USD and the world GDP per capital of $15,800 USD. Using this metric, Afghanistan ranks as the 16th poorest country in the world.[9] Afghanistan levies a progressive income tax system, with the top tax bracket at 20 percent.[10] However, the generation of revenue remains low. Corruption in income and sales tax collection remains problematic as the collection system lacks the necessary checks and balances. Afghanistan's Ministry of Finance (MoF) states that "systematic corruption of tax officials is a serious threat to future tax collection."[11] As a result, much of Afghanistan's revenue comes from international donor nations.

The MoD budget mirrors the economic reality in Afghanistan. The majority of the funding supporting the MoD is a result of donor nations. Seventy–three percent of MoD funding (as shown in Figure 2) comes from the United States. Almost 10 percent is provided by other donor nations through the NATO Trust Fund, with 8.6 percent coming from the United Nations Development Program. The Government of the Islamic Republic of Afghanistan (GIRoA) only directly contributes 8.6 percent of the total MoD budget.

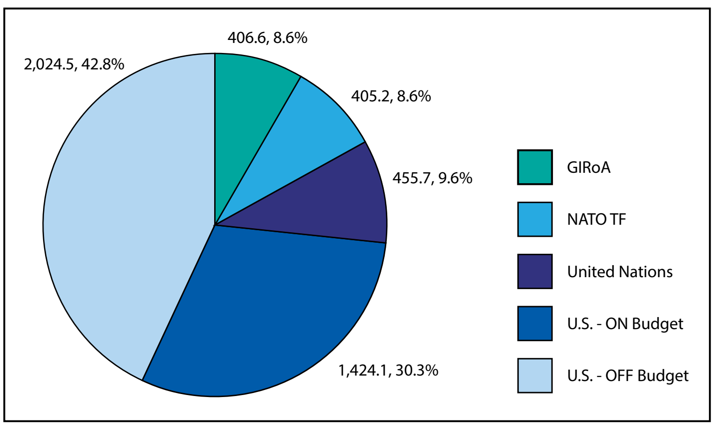

Figure 2. MoD fiscal year 2017 budget commitments

The execution of US-funded MoD requirements are designated as either "on-budget" or "off-budget" (see also Figure 2). The designation as on- or off-budget denotes which acquisition processes will be employed to procure the end item. Off-budget requirements are contracted and managed through US processes. For example, the purchase of an aircraft platform (e.g. A-29) for the AAF is completed as a pseudo-foreign military sale. The contracting and management of that purchase is completed through the A-29 Systems Program Office at Wright–Patterson AFB, Ohio. While the end item (the A-29) is delivered and signed over to the Afghans, the processes that resulted in that delivery are completely outside of Afghan channels. Currently, aircraft platforms, contracted logistics support maintenance, and pilot training are all off-budget AAF requirements.

On-budget funds are executed through the Afghan MoD acquisition processes. Requirements are vetted through a requirements acquisition board and upon approval are executed by the internal Afghan procurement process. Coalition members are available to advise on these processes, but they do not have a direct role in the execution of funds. Typical on-budget requirements are for base and life support: ground fuel, electricity, water, food, firewood, and clothing. Therefore, the important distinction between on- and off-budget is not the source of the funds, but rather the execution of the funds.

The designation of an item as on- or off-budget is becoming increasingly important. US forces in Afghanistan continue to draw down from a peak of more than 100,000 troops in 2010 to a projected force of 5,500 by 2017.[12] As a result, more items transition each year from off- to on-budget. These coalition forces are focused on actively training, advising, and assisting on Afghan financial and procurement processes with the goal to eventually transition all requirements to the Afghan on-budget process.

Current Ministry of Defense Budget Process

To understand the problems the AAF is encountering in the resource allocation process, it is first imperative to possess foundational knowledge of the current MoD budget process. All 24 ministries in the Afghanistan government are designated as primary budgetary units (PBU).[13] A PBU is a legal entity of the state with appropriation provided to it under an act of the National Assembly. Afghan law determines the specific budget amounts appropriated for each PBU. The MoD, as one of the 24 ministries, is a PBU with a specified budget. Thus, fund authority flows from the MoF to the MoD (See Figure 3).

The Ministry of Defense–Finance (MoD–F) is the financial arm of the MoD. It is analogous to the Office of the Secretary of Defense Comptroller in the United States. The MoD–F accounts for and monitors the funds the MoD receives. There are 13 budget builders, including the MoD–F, in the MoD as shown in Figure 3. Budget builders collect requirements, build spend plans, and request funds through the Afghan budget generation process. Once a budget is approved, the budget builder receives the allotment of funds for their areas of responsibility. There are two types of budget builders. The budget builders are either general staff budget builders or MoD organizational budget builders. The primary difference between the two types of budget builders is whether they serve in a numbered staff function (general staff) or a specified organizational function (MoD organization). The general staff budget builders are aligned similarly to the US numbered structure that is rooted in the nineteenth–century French army continental staff system. For example, the General Staff Chief of Communications (GSG6) is the budget builder for communications like J6 is communications in the Department of Defense. The GSG6 budget builder is responsible for all communication unique requirements. Similarly, items that are common to all units (e.g. office supplies) flow through the logistics budget builder—the GSG4. In addition to the general staff budget builders, there are MoD organization budget builders. For example, acquisition, technology, and logistics is a MoD organizational budget builder.

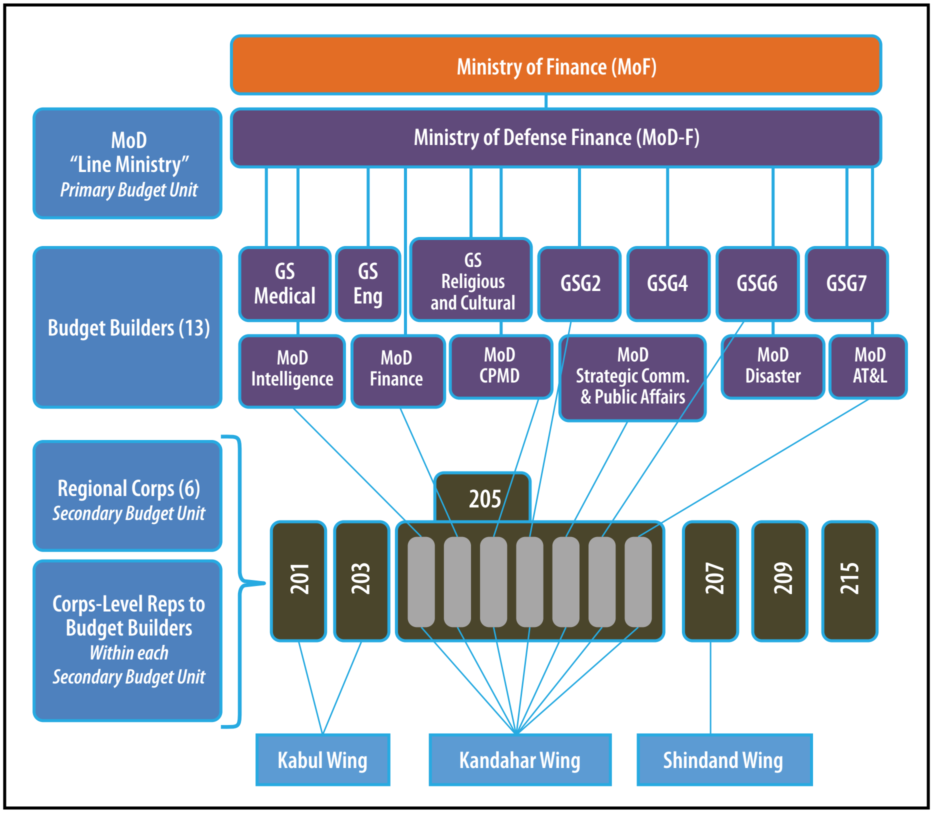

Figure 3. Current Ministry of Defense process

The PBU has the authority to provide suballotments of funds to secondary budget unit (SBUs) for management.[14] Thus, SBUs consist of offices of PBUs that have been delegated responsibility for financial management. When this occurs, the SBU becomes the crucial unit of control. All of the corps from Figure 1 are SBUs.

Significant authorities are conferred by SBU designation. Specifically, the SBU is the entity that has ownership and authorities over all the subordinate units' requirements. For example, the 205th Corps (in the Kandahar area of Afghanistan as shown in Figure 1) has ownership of four brigades and their subordinate units. This includes the AAF Kandahar wing and all other AAF units located in the geographic area of the corps. As an SBU, the 205th Corps receives individual budget suballotments from the 13 budget builders and controls the dissemination of that suballotment to the brigades and wing underneath it. Designation as an SBU results in other authorities that are not strictly financial. For example, an SBU has procurement authority. It can approve contracts under various threshold limits.[15] When these items are procured, they are stored in facilities called depots. Depots in Afghanistan contain anything from paper and pens to spare parts. Gaining access to the items in the depots requires signatory authority.[16] This signatory authority resides at the SBU level. Therefore, a SBU not only has financial and procurement authority but also possesses control of the dissemination of procured items through the depot system. Thus, the authorities that come from SBU designation result in great power.

Current Resource Allocation Problems for AAF

The current construct is causing multiple problems in the resource allocation process for the AAF. First, there is no financial focal point at the MoD-level that can provide a holistic aviation picture. None of the 13 current budget builders (see Figure 3) are designed to support aviation unique requirements. Rather, they are designed for support functions (e.g. GSG2, GSG7, etc.) and other organizational needs (MoD organizations) but not aviation unique requirements. This is not to say the structure as a whole is broken. The current construct is effectively designed to account for those items that are crosscutting across brigades or wings. For example, computers are common to all units in the MoD whether they are part of the army (ANA) or air force (AAF). The current GSG6 budget builder is populated with communication professionals and can effectively build budgets for those requirements. However, when it comes to aviation unique requirements (i.e. aviation fuel, aircraft platform procurement, aircraft contractor logistics support, etc.), there is no current mechanism in place. This has not been a problem in the past because the nascent air force was being built, and the overwhelming majority of aviation unique items were off-budget and therefore budgeted and procured through US processes. As of 2016, the only on-budget aviation unique items are aviation fuel and some unique aviation training. These two items are currently budgeted through the GSG4 for aviation fuel and the GSG7 for aviation training.

Understanding the current issues with the on-budget aviation fuel requirement is illustrative of the greater problem. The GSG4, as the budget builder for aviation fuel, has the responsibility to build the requirement, develop the spending plan, and has a critical role in supporting the payment process upon contract award. The GSG4, however, is responsible for ground fuel in addition to aviation fuel (among many other items). As a result, in the financial system, the GSG4 combines the budget dollars for aviation and ground fuel.[17] Historically, there have been shortages in ground fuel that resulted in a myriad of problems such as electricity loss for weeks on end at various military installations.[18] The reasons for fuel shortages often lead back to corruption.[19] Fuel is diverted and sold on the black market. Unauthorized vehicles are filled with fuel, and even those vehicles that are authorized are used inappropriately for personal reasons.[20] This is not a problem that would be solved through additional budgetary dollars as the current allocation is theoretically sufficient if utilized and accounted for properly. Due to the shortages, it is better for the GSG4 to keep all fuel (ground, aviation, etc.) aggregated in the accounting system to keep the problem opaque and preserve internal priorities. Recall that the GSG4 is comprised of ANA professionals, and the six corps are under ANA command. The GSG4, therefore, receives constant pressure from its ANA brethren in the six corps to meet ground fuel needs. The tendency is to prioritize ground fuel needs over aviation needs. Ground fuel shortages are therefore addressed at the expense of aviation fuel needs. Despite pressure from coalition advisors, the GSG4 has been unwilling to separate the accounting for aviation fuel from the accounting for ground fuel. Why? The simple answer is the transparency this type of accountability would provide is anathema to their objective.

The current accountability and transparency problems experienced by aviation fuel are likely to be exasperated in the future. The extensive expansion of aviation platforms (e.g. A-29, MD-530, C-208, etc.) in the past two years and plans for the induction of more aviation assets constitute a major turning point in fleet size and require a shift in the management of resources. These items and the associated aviation unique requirements that come with them (e.g. aircraft maintenance, spare parts, pilot training, etc.) cannot be moved from off-budget to on-budget with effective accountability under the current system.

The second major resource allocation problem for the AAF revolves around authorities. The AAF does not have ownership over its requirements. As previously discussed, authorities over requirements reside at the SBU level. As shown in Figure 3, the six corps are the only entities designated as SBUs in the MoD. AAF's lack of authority over requirements results in a lack of visibility, transparency, and accountability. It is imperative to understand that the suballotment of funds authority resides at the SBU level and is coded as such in the accounting system. The Afghan accounting system does not break out brigade and wing level units in their chart of accounts.[21] As a result, the AAF often ends up receiving not only less than their full requirement but is often a less-than-proportional quantity than the pure army units within the SBU. Because there is no transparency and visibility below the SBU level—indicating the intention for the suballotted funds—the AAF has no recourse to claim they did not receive their fair share.

The lack of authority negatively affects the AAF in other areas. All items (e.g. printer cartridges, spare parts, etc.) procured for the ANA end up in depots. The AAF lacks the authority to withdraw these items from the depots and track or manage their allotment of resources. It is another area where corruption is problematic. The lack of authority also affects allotment training and travel requirements. The AAF does not have the authority to approve orders but instead must request travel to attend training from its parent organizations. Placing this authority outside the AAF not only results in time delays but also the potential for disapproval by nonaviation professionals who do not fully understand the importance of the travel and training. This affects the human capital in the AAF. Lastly, the lack of authority results in duplicative processes for reporting. AAF units report through their wings to both the AAF HQ and the parent corps in which they reside. This duplicative reporting wastes resources.

In summary, the resource allocation problems the AAF is experiencing today come down to three issues. First, there is not a MoD-level entity that functions to serve aviation equities in the resource allocation process. Second, the AAF does not have ownership or authority over their requirements because this authority resides at the corps (SBU) level. And third, the current resource allocation construct exasperates the widespread corruption problems in the MOD.

Solution: A New Construct for the AAF

This research finds that there are two primary changes that can alleviate the problems the AAF is experiencing in the resource allocation process. First, a change is needed at the MoD level to account for all unique aviation requirements. This can be accomplished through the establishment of an aviation budget builder (ABB) as a new entity. This MoD level ABB would add to the 13 current budget builders as a new, 14th budget builder. The ABB would serve as the financial focal point at the MoD level, providing a holistic aviation picture to leadership. Reporting would be more efficient and streamlined. Additionally, as more and more aviation unique items transition from off- to on-budget, the criticality of an ABB increases. The current MoD financial construct is not designed to handle this transition. The ABB fills the impending gap in the process.

Corruption must also be considered. Visibility, transparency, and accountability would be greatly enhanced with an ABB as allotments of funds would have aviation coded designators. The result is a reduction in corruption as transparency increases. This transparency would flow over to the corps also, as aviation items such as aviation fuel would no longer be bundled with other ground fuels. Thus, increased transparency and accountability of ground fuel transactions would be a positive second order effect of this change.

The second change suggested by this research is to designate the AAF as an SBU. This change necessarily entails breaking the AAF out from under the corps from a financial standpoint. The authorities conferred to the AAF as an SBU would result in air force control over their requirements. Coupled with the ABB, the AAF would have complete visibility, transparency, and accountability in the resource allocation process. Additionally, three other authority issues previously discussed would be solved. First, the AAF as an SBU would have the ability to place and remove items from the depots. This would result in better accountability and less corruption. Second, human capital would be enhanced as training would be controlled by the AAF. The AAF would generate orders and have full control over the timing and placement of individuals into training programs. Lastly, reporting would be streamlined. The duplicative reports that go through both the corps and HQ AAF would cease to exist. Reporting would only be necessary through the AAF channels. Figure 4 shows the new construct with both the ABB and AAF as an SBU construct implemented together.

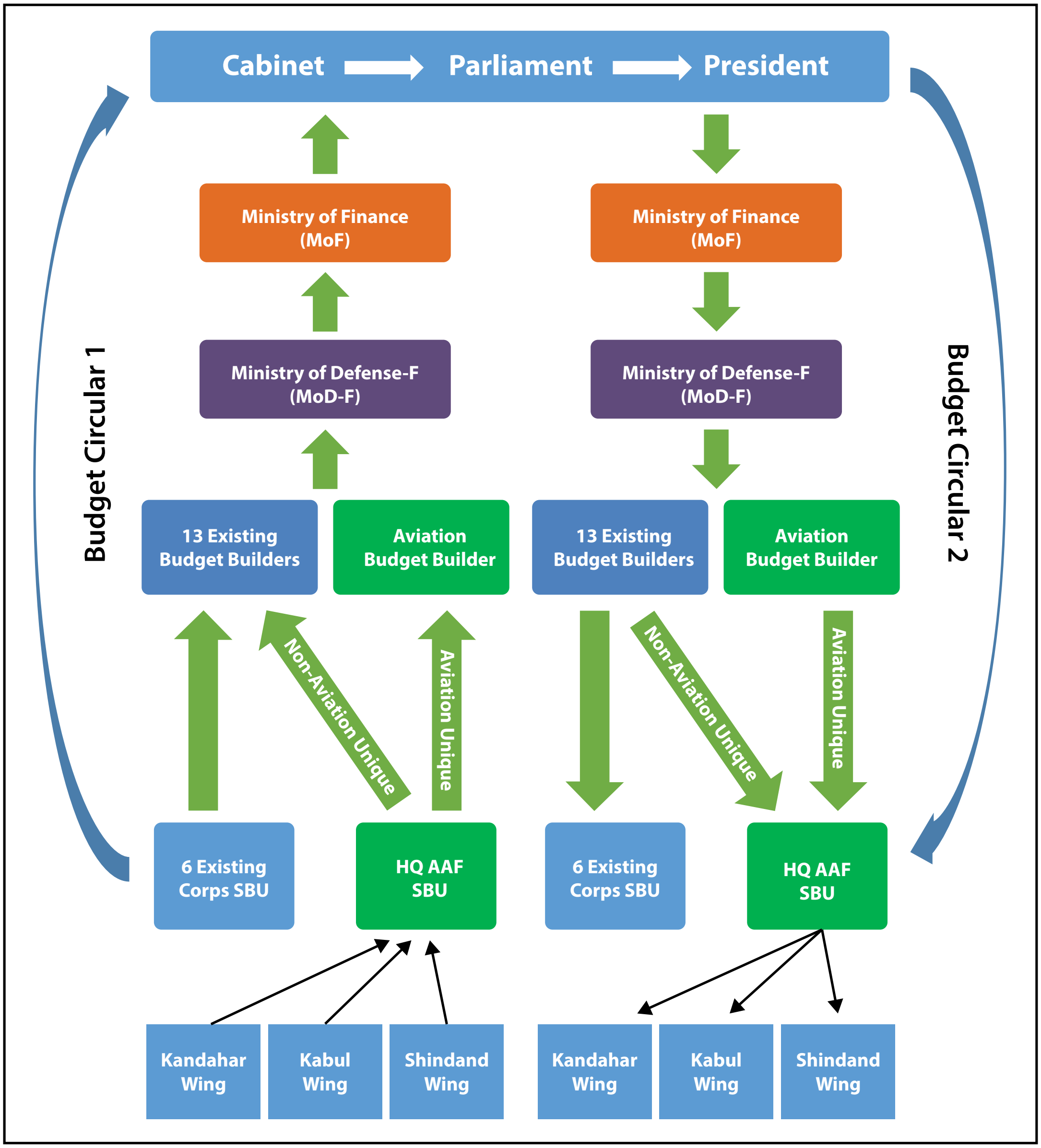

Figure 4. New construct with ABB and AAF with SBU authorities

As shown in Figure 4, the requirements from the wings no longer flow through the corps as previously shown in Figure 3. Instead, all requirements in Budget Circular No. 1[22] flow from the wings directly to the AAF HQ as the SBU. This results in a single line of reporting. Once requirements are consolidated at the AAF SBU, the unique aviation requirements flow up to the newly established aviation budget builder. It is important to recall that only the aviation unique requirements flow through the ABB. All nonaviation unique requirements would flow from the wings to the AAF SBU but then flow to their currently established budget builder. For example, while aviation fuel (an aviation unique requirement) would flow from the AAF SBU to the ABB, computers (a nonaviation unique requirement) would flow from the AAF SBU directly to the GSG6 budget builder. The remainder of the requirements generation process remains unchanged with requirements flowing from the budget builders to the MoD–F and MoF. Budget authority then flows back down through the Budget Circular No. 2 process. However, the allotment of funds now flows down through the ABB to the AAF as an SBU. Accountability and transparency for AAF requirements are achieved. The AAF SBU and ABB are therefore complementary entities in the MoD resource allocation process. Together they provide a holistic, seamless approach to AAF requirement generation and budget execution.

Discussion

Timing is important when implementing change. That window of opportunity is open. AAF personnel and processes are currently postured to successfully transition to a fully functioning SBU. Despite lacking SBU authorities, coalition personnel have been actively training AAF personnel on the processes necessary to succeed. For example, in 2016 the AAF developed their own requirements (more than 22,000 line items) for the first time.[23] As a result, AAF personnel were invited to participate in the MoD-level program working groups that are responsible for developing Budget Circular No. 1. AAF participation in the Budget Circular No. 1 process demonstrated the capacity to function as an SBU, despite lacking the authority to be an SBU. Participation in the process without authority is valuable to develop and demonstrate competency, however, without authority it is an exercise in futility. Accountability and transparency cannot be improved without the necessary authorities in the resource allocation process.

Manning and organizational change are also necessary to implement the change to SBU authority for the AAF. These changes are already in motion. The AAF has postured itself during the past two years with incremental changes to the Tashkil to organizationally align personnel to operate as an SBU. (The Tashkil is the official list of required ANA and AAF personnel by position and rank.) Thus, the AAF has the manpower capacity to operate as an SBU if given the authority.

Similarly, the time is right for the establishment of a MoD-level ABB. The aviation portfolio is rapidly expanding with more aircraft platforms and larger quantities of existing platforms being added to the existing portfolio. These platforms and their associated training and maintenance are all currently resourced off-budget. The transition of these items from off- to on-budget is the ultimate coalition goal. But to effectively transition, a mechanism needs to be in place that allows for visibility, accountability, and transparency. The establishment of an ABB meets that need. Making the change now sets the AAF up for success as the air portfolio expands and enables a phased transition of items from off- to on-budget in future years.

Official approval of an ABB and the AAF as an SBU through MoD channels may be the easier task. Implementation will be difficult. The coalition advisor role complicates this process. Because donor nations provide the overwhelming majority of funds, the coalition advisors have significant influence over the MoD. These coalition advisors, however, have continual turnover with tours in Afghanistan that typically range from six months to one year. The momentum an advisor group builds toward achieving an initiative is often slowed or stopped by the inevitable personnel turnover.

Additionally, Afghan culture is an impediment to implementation. Culturally, Afghans do not typically say "no." Rather, they will concur with a proposal, but they do not necessarily implement it. Previous research demonstrates that culture shapes human behavior and indicates cultural changes are slow to occur. Research by Douglas C. North found that informal constraints (norms of behavior, self-imposed codes of conduct, etc.) comprise the institutions that "are the humanly devised constraints that structure human interaction."[24] While Oliver E. Williamson finds that customs, traditions, and norms take 100–1,000 years to change.[25] Thus, it would not be surprising if the ABB and SBU were agreed upon in principle and codified as policy but simply ignored. To be clear, we are not suggesting it would be ignored by individuals in the AAF. Our interviews indicate that the AAF recognizes the problems and are advocates for the solution presented here. Rather, it is the reality that the AAF resides within the ANA that may be problematic. While ANA members have not explicitly stated they are opposed to these changes, they also have not been actively pursuing change. Thus, coupling cultural inertia with the coalition advisor turnover problem is a potential risk to the successful implementation of the ABB and SBU initiatives. We are, however, cautiously optimistic that these obstacles can be overcome. The benefits of ABB and SBU authorities are too significant to default to the status quo. The structural changes in Afghan financial and procurement processes indicated herein can alleviate the resource problems the AAF is experiencing and at the same time help to reduce corruption in the MOD. ✪

Notes

1. Anthony Capaccio, "Afghan Air Force to Take Delivery of New Light-Attack Plane," Bloomberg, 7 January 2016, http://www.bloomberg.com/news/articles/2016-01-07/afghan-air-force-to-take-delivery-of-new-light-attack-plane.
2. The High Office of Oversight and Anti-Corruption was established by President Karzai in July 2008. This office is responsible for overseeing policy development and implementing anticorruption strategies. For more information on corruption in Afghanistan see High Office of Oversight and Anti-Corruption, Islamic Republic of Afghanistan, accessed 5 February 2016, http://anti-corruption.gov.af.
3. List of Afghanistan ministries, including MoD, retrieved from Afghanistan Culture and Afghanistan Ministries, accessed 16 March 2016, http://www.afghanistan-culture.com/afghanistan-ministries.html.
4. US Government Accountability Office (GAO), *Afghanistan Security: Afghan Army Growing, but Additional Trainers Needed; Long-term Costs Not Determined*, GAO Report GAO–11–66, 2011, 43.
5. Ibid.
6. Personnel numbers from 1395v2 Tashkil. The Tashkil is the MoD's official list of required Afghanistan National Army (ANA) and AAF personnel by position and rank.
7. US Government Accountability Office, *Afghanistan Security*, 43.

8. United Nations Educational, Scientific and Cultural Organization (UNESCO), "Enhancement of Literacy in Afghanistan (ELA) program," UNESCO Office in Kabul, accessed 13 March 2016, http://www.unesco.org/new/en/kabul/education/enhancement-of-literacy-in-afghanistan-ela-program/.

9. International Monetary Fund, "World Economic Outlook Database," *International Monetary Fund*, accessed 13 March 2016, https://www.imf.org/external/pubs/ft/weo/2015/01/weodata/index.aspx.

10. Ministry of Finance, *Afghanistan Income Tax Law*, Income Tax Decree 2005, Official Gazette number 845, 20 March 2005, 1.

11. Ministry of Finance, "Revenue Department," Islamic Republic of Afghanistan, accessed 13 March 2016, http://mof.gov.af/en/page/422.

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13. Anne Evans, Nick Manning, Yasin Osmani, Anne Tully, and Andrew Wilder, *A Guide to Government in Afghanistan*, The World Bank (Washington DC: The World Bank, 2004), 23.

14. Michael Carnahan, Nick Manning, Richard Bontjer, and Stephane Guimbert, *Reforming Fiscal and Economic Management in Afghanistan*, The World Bank (Washington DC: The World Bank, 2004), 18.

15. Afghanistan procurement law sets the threshold for contracting authority. Large dollar procurements are done at the MoD through the Ministry of Defense–Procurement agency and their associated processes. For further information on procurement thresholds see the National Procurement Authority, *Circular 1*, no. 9051, 20 October 2015.

16. The signatory authority consists of a commander's letter and a signature card on file. The SBU has authority to sign the commander's letter.

17. Ground and aviation fuel are combined under object code 22601 in the chart of accounts. All fuel dollars reside in 22601 despite the coalition insertion of an aviation fuel unique object code, 22604.

18. Firsthand experience, as outages due to fuel shortages were common during one of the author's field work in Afghanistan.

19. Special Inspector General for Afghanistan Reconstruction, *Afghan National Army: Controls over Fuel for Vehicles, Generators, and Power Plants Need Strengthening to Prevent Fraud, Waste, and Abuse*, SIGAR Audit 13–4 (Arlington, VA: SIGAR, January 2013), 1–14.

20. Interview with AAF fuels and lubricants officers, January 2016. Additionally, SIGAR reported in 2012 that $201 million in fuel purchases were unaccounted for. See Special Inspector General for Afghanistan Reconstruction, *Afghan National Army: $201 Million in DoD Fuel Purchases Still Unaccounted for Because Records Were Shredded*, SIGAR Investigative Report 13–1 (Arlington, VA: SIGAR, December 2012).

21. Treasury General Directorate, *Accounting Manual, Version 1.26*, Islamic Republic of Afghanistan, 6 March 2012, 3–3.

22. The Ministry of Finance (MoF) sends out budgetary guidance called Budget Circular No. 1 to the MoD. For additional information on Budget Circular No. 1, see Ministry of Finance, "Directorate General Budget," Islamic Republic of Afghanistan, accessed 3 May 2016, http://www.budgetmof.gov.af/index.php/en/85-news/279-1395-budget-circular-1.

23. Firsthand author's experience from field work training, advising and assisting the Afghan Air Force Comptroller and Afghan Air Force programmer.

24. Douglas C. North, "Economic Performance through Time," *The American Economic Review* 84, no. 3 (1994): 359–68.

25. Oliver E. Williamson, "The New Institutional Economics: Taking Stock, Looking Ahead," *Journal of Economic Literature* 38, no. 3 (2000): 595–613.

Lt Col Jonathan D. Ritschel, PhD, USAF

Colonel Ritschel (BBA, University of Notre Dame; MS, Air Force Institute of Technology; and PhD, George Mason University) is an assistant professor and director in the Air Force Institute of Technology's (AFIT) Department of Systems Engineering and Management Graduate Cost Analysis Program. He served as an advisor to the Headquarters Afghan Air Force Comptroller from 2015–2016. He received a bachelor of business administration in accountancy from the University of Notre Dame, a master of science in cost analysis from AFIT, and a doctorate in economics from George Mason University. Dr. Ritschel's research interests include managerial decisions, public choice, and Department of Defense (DOD) cost estimating with publications in the *Journal of Cost Analysis and Parametrics*, *Journal of Public Procurement*, *Econ Papers*, and the *Defense Acquisition Research Journal*.

Tamiko L. Ritschel

Ms. Ritschel (BS, University of Notre Dame; MS, AFIT; and MBA, Wright State University) is an operations research analyst at Headquarters Air Force Material Command. She has extensive expertise in organizational development, including previous research projects for the DOD. She received her bachelor of science in mathematics from the University of Notre Dame, a master of science in operations research from AFIT, and a master in business administration from Wright State University. Ms. Ritschel's research interests include organizational development, decision analysis, and simulation and modeling with multiple publications in the *Air Force Journal of Logistics*.

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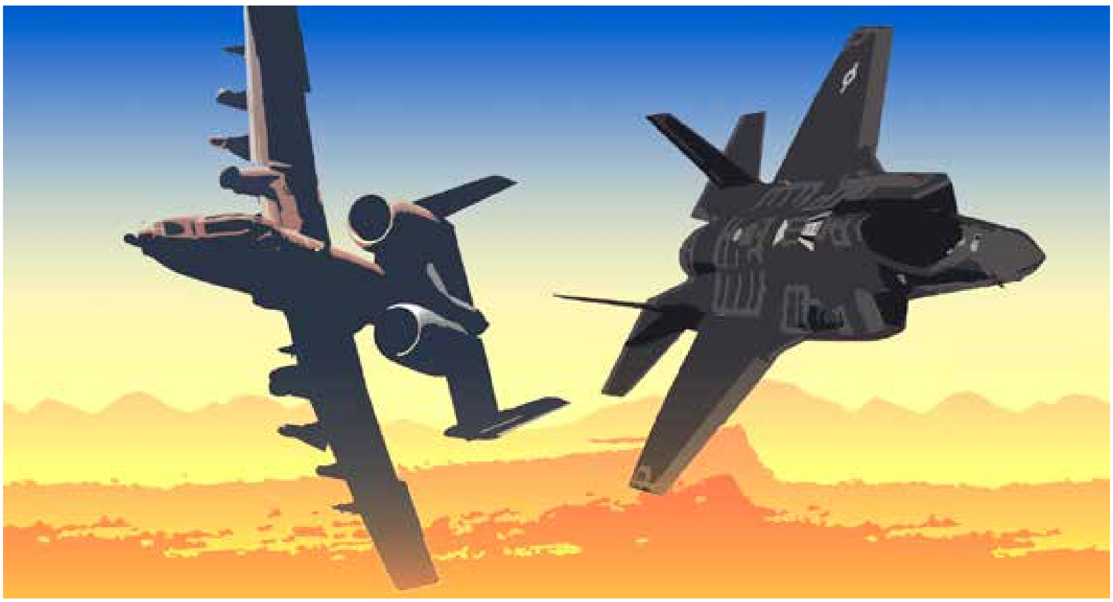
The Coming Close Air Support Fly-Off

Lessons from AIMVAL–ACEVAL

Lt Col Steven Fino, PhD, USAF



At the behest of Congress, the Pentagon is poised to conduct a fly-off to determine the future viability of the Air Force's close air support (CAS) platforms. For the past several years, the Air Force has tried to retire its fleet of A-10s, suggesting that its other platforms, including newly-arriving F-35s, could assume the CAS mission from the venerable but aging Warthog. These more modern platforms armed with an array of high-tech weapons, Air Force officials often explained, could better achieve the desired CAS effects across any battlespace, including regions where enemy defenses might otherwise imperil the low, slow A-10.[1] The service's position met significant opposition, however, extending from the blogosphere to congressional chambers. Advocates for the A-10 countered that the relatively simple, battle-hardened Warthog brings irreplaceable capability and weapons effects to the battlefield, and at a fraction of the procurement and operating costs of the service-favored F-35.[2] To prove their point, several A-10 proponents repeatedly called for a fly-off between the two platforms, but in August 2015 Air Force Chief of Staff Gen Mark Welsh quipped that such a test "would be a silly exercise."[3] Then in the summer of 2016, Rep. Martha McSally (R-AZ), a former A-10 combat pilot, introduced legislation requiring a head-to-head test of the two platforms during a portion of the F-35A initial operational test and evaluation; the fly-off would have to be completed before Congress authorized any additional changes to the A-10 force structure.[4] In an opinion piece published in *The Air Force Times*, McSally outlined the test's objectives, "The testing must demonstrate how the two aircraft can perform missions in realistic combat settings, such as when pilots are required to visually identify enemy and friendly forces in close proximity, both during the day and at night."[5]

While recent reports indicate that the new Air Force Chief of Staff, Gen David L. Goldfein, has elected to push the A-10 retirement out to 2021, the rancorous A-10 versus F-35 debate is likely to persist, and the mandated CAS fly-off is still slated to occur in early 2018.[6] It is, therefore, still worth evaluating the potential merits and pitfalls of the forthcoming F-35/A-10 matchup, which will be conducted under the supervision of the Pentagon's Director of Operational Test and Evaluation (DOT&E). For that, I suggest we first examine the notion of military testing and then turn to a potentially informative historical example of two congressionally-mandated tests conducted 40 years ago—the Air Intercept Missile Evaluation and the Air Combat Evaluation (AIMVAL–ACEVAL).

The Social Construction of Military Testing

From an early age, we are taught that to gain new knowledge we must construct hypotheses, design experiments to test those hypotheses, and then evaluate the results to prove or disprove our hypotheses. The process is known as the *scientific method,* and it brought the world out of the Dark Ages. While the triumph of experimentalism in the mid-seventeenth century and the corresponding scientific revolution has long been assumed to have been a smooth transition—a self-evident and predestined transformation in the development of human knowledge—the historical record suggests otherwise. As Steven Shapin and Simon Schaffer observed, the rise of experimentalism generated existential questions concerning "the nature of knowledge, the nature of the polity, and the nature of the relationship between them." Robert Boyle and the experimentalists prevailed, but "[Thomas] Hobbes was right. . . . Knowledge, as much as the state, is the product of human actions."[7] Shapin and Schaffer's conclusions are not unique. Thomas S. Kuhn, Robert K. Merton, Bruno Latour, and David Bloor have all demonstrated that "discoveries entail more than empirical findings"—they are products of human environments and human interactions.[8] Consequently, despite its aura of objectivity and the search for *truth*, "scientific activity is not 'about nature,' it is," as Latour and Steve Woolgar explain, rather "a fierce fight to *construct* reality" (emphasis in original).[9]

Hence, even if empirical data assume the form of impartial charts, plots, tables, and numbers, it is critical to recognize that the data still reflect the idiosyncrasies of the unique social environment in which they were mustered. The statistician Joel Best reminds us that gathering and interpreting data requires people to make choices; for example, what should and should not be included in the dataset.[10] These dataset choices are defined by individuals' specific understanding of the problem and their hypotheses that identify important contributing factors. While groups can sometimes agree on a common definition of the problem and associated hypotheses, more often they cannot. Conflicting interpretations inevitably yield different datasets, which consequently generate new sets of statistical results. While some may impute malfeasance on those who generate disagreeable data, often the data discrepancy simply results from the different circumstances and contexts in which the data were gathered.[11] Thus, despite the tendency to regard numbers and statistics as unalterable representations of the truth, they are better understood as products of "people's choices and compromises, which inevitably shape, limit, and distort the outcome."[12] Borrowing a term from Trevor J. Pinch and Wiebe E. Bijker's application of social constructivism to technology, data inherently possess "interpretive flexibility."[13]

But if all data are socially constructed, how then can we overcome the associated relativism to discern the *truth*? For Best, the answer is a scientific process that facilitates the cumulative generation of knowledge.[14] Within this model, doubts that may accompany individual test results are gradually removed when multiple researchers exploring similar phenomena, each using a variety of techniques, methods, and data, converge on similar outcomes and understandings. Modern scientific and engineering practice is configured to encourage just such investigation, replication, and corresponding dialogue. Edward Constant's story of turbojet engine development is but one illustration of how "communities of technological practitioners" can help separate spurious data from more promising representations of reality.[15] Walter G. Vincenti offers a complementary example in his history of early aeronautics development.[16]

Unfortunately, structural impediments often limit the military's ability to foster a similar "marketplace of ideas." Unlike the commercial or academic sector, the military cannot rely on Constant's robust yet independent communities of technological practitioners to facilitate the cumulative knowledge generation process. While the Pentagon's DOT&E office represents a non-service-specific organization established to manage military testing, it is only a single organization, and the military's tests still necessarily rely on service-specific personnel, hardware, and training; these resources are not available to other independent agencies outside the military structure that might want to investigate alternative hypotheses. (Of course, the enemy represents an excellent independent authority, but fortunately for humankind's sake, empirical testing opportunities against enemy forces are typically rare.) Additionally, the results of the military's experiments are often cloaked under the veil of national security, restricting independent and nonmilitary researchers' access to the data (military researchers, too, can be restricted by multiple layers of bureaucracy). Finally, military tests can be costly, and they are often tied to specific schedule-driven programmatic decisions, which collectively can conspire to limit the tests' flexibility and their ability to investigate anomalies.[17]

Despite these structural impediments, the military still maintains a robust testing enterprise, which includes its array of recurring exercises, war games, and weapons system test programs. Since Robert McNamara's term as US defense secretary, military leaders have relied on the ever-increasing amounts of numerical data and statistically-informed prognoses produced by these tests to help them navigate the technical and doctrinal requirements of the next conflict.[18] However, as Best inferred, the accumulated data used to guide defense decision making and resourcing remain a product of the unique environment and organization in which they were gathered. Moreover, the interpretive flexibility inherent in the data is exacerbated by divergent, value-laden interpretations of future national defense requirements, themselves buffeted by frequently changing political circumstances and agendas. The famed British strategist Sir Basil Henry Liddell Hart captured the challenge that confronts military leaders sifting through the mounds of data: "Before a war military science seems like a real science, like astronomy, but after a war it seems more like astrology."[19]

Within this context, the military's inability to conduct independent, transparent, and appropriately flexible testing frequently invites outside skepticism, despite defense officials' repeated assurances that their tests are fair and impartial.[20] Indeed, according to the social constructivist perspective, the military's penchant for arguing about the validity of its data is misplaced; there can be no truly fair and impartial environment. However, because of the unique military environment, there is also little opportunity to engage in the robust scientific knowledge generation process that Best and others recommend. This can leave the military in an intractable position.

The history of the joint Air Force and Navy AIMVAL–ACVEVAL tests conducted in 1977 illustrates these limitations of military-generated knowledge, and the two tests foreshadow the conundrum that the Department of Defense (DOD) and the Air Force will likely face when they attempt to address divergent hypotheses about the future of CAS during the coming A-10/F-35 fly-off.

AIMVAL–ACEVAL

AIMVAL–ACEVAL emerged from competing hypotheses about the future of air combat post–Vietnam.[21] By 1975, the Air Force and the Navy had already begun aggressively modernizing their tactical fighter forces to face an increasingly-capable Soviet threat. New technologically sophisticated aircraft such as the Air Force's single-seat F-15 Eagle and the Navy's two-seat F-14 Tomcat were rolling off assembly lines.[22] The services had agreed to outfit their premiere fighters with a common medium-range, radar-guided missile—the updated solid-state AIM-7F Sparrow.[23] However, the services diverged on their requirements for their fighters' shorter-range, infrared (IR)-guided armament. The Air Force preferred a cheap, simple but effective missile for their Eagles, which they appropriately named the CLAW.[24] The Navy, on the other hand, wanted a technologically exquisite, helmet-cued, thrust-vectored, high off-boresight missile they called the Agile.[25] To "bridge the gap" between their Vietnam-era Sidewinders and their futuristic CLAWs and Agiles, the Air Force and Navy were also jointly developing a third short-range IR-guided missile, the all-aspect-capable AIM-9L Sidewinder.[26] When Congress was handed the bill for the three missiles, it balked.[27] Instead of funding the services' requests, in 1975 Congress cancelled the CLAW and Agile programs and ordered the Pentagon's director of Defense Research and Engineering (DDR&E) to conduct a test to identify the best short-range, IR-guided missile, hoping to force the two services into agreement on a common design. The congressionally-mandated test became known as AIMVAL.[28]

DDR&E, in turn, levied its own additional test requirement on the services. With the Air Force and Navy committed to procuring their advanced Eagles and Tomcats, analysts within the DOD realized that they had no data that would allow them to quantify the relative advantage of the services' newest generation of fighters. Most agreed that a single Eagle or Tomcat was more capable than a Soviet MiG-21, but nobody was sure if a single F-15 or F-14 was equivalent to two, three, or even four MiG-21s. The second test—ACEVAL—was ordered to answer this force-planning question.[29] The two tests were to be conducted sequentially by a single joint test force (JTF) operating out of Nellis AFB, Nevada. They were scheduled to commence flying the following year in 1976.

The services recognized immediately that the outcome from the AIMVAL–ACEVAL tests would significantly affect their future acquisition strategies. The first joint test director, RADM Julian Lake, was explicit in his initial communique, declaring, "[AIMVAL–ACEVAL] test analysis will be used in definition of future tactical A/C and weapon systems requirements and as such will significantly influence US TACAIR posture in [the] 80's and 90's."[30] The services also quickly realized that while they were ostensibly working together under a congressional and DDR&E mandate to define future air combat requirements, and while their Tomcats and Eagles would never be in the air at the same time against the opposing aggressor forces, the coincident matchup of Air Force and Navy aircrews with their newest equipment would inevitably invite public comparisons.[31] Consequently, some within the Air Force pressed their colleagues to "explore feasible alternatives to show [the] F-15 in the best light"; the Navy likely did the same for its F-14s.[32]

Despite the threat of service parochialism corrupting the results, test officials repeatedly emphasized during congressional testimony the "complete objectivity" of "the test plan, the test data requirements, and the manner in which the data will be handled and analyzed."[33] One strategy to tamp down service biases was to use a joint test management structure with equal Air Force and Navy representation: a Navy admiral served as the AIMVAL–ACEVAL test director; the deputy test director was an Air Force general.[34] Additionally, JTF analysts spent considerable time artfully crafting the test matrices to ensure statistically significant results within the tests' budget and scheduling constraints.[35] Most significantly, a new data collection technology—Air Combat Maneuvering Instrumentation (ACMI)—was fielded to replace pilots' sometimes hazy, often contested, memories of individual air combat outcomes.[36] One test official boasted that the only way to get a more "exact answer" from the tests would be to "fire real missiles."[37]

However, even the cornerstone of test objectivity—ACMI—still retained a level of subjectivity. Because ACMI recorded aircraft position, attitude, and weapons employment data (for up to eight aircraft), it could determine who was shooting at whom and with what type of weapon. Observers on the ground could then watch the aerial engagements unfold in real time on their computer screens, and they would notify an aircraft that it had been "destroyed" by an opponent whenever the ACMI computers predicted a kill.[38] While ACMI had the ability to account for specific aircraft vulnerabilities when calculating the probability of a successful missile kill, neither service could agree on a suitable model for their fighters: the Air Force argued that its Eagle was more survivable than the Navy's Tomcat; the Navy obviously took the reverse position. Unable to resolve the dispute, test officials reluctantly settled on a common vulnerability model for both aircraft based on an F-4E Phantom II, the now-outdated aircraft that the F-15 and F-14 were designed to replace.[39]

The decision to use ACMI levied other constraints on the test design. ACMI only functioned over an instrumented range, and at the time, Nellis's ACMI range only measured 30 miles in diameter.[40] Conscious of the limited ACMI test space, test officials announced that during both AIMVAL and ACEVAL, all friendly aircraft would be required to close to within visual range to visually identify (VID) their target before firing a missile at it.[41] While the VID requirement was commonplace during Vietnam, the Air Force and Navy investments in the long-range radars installed in their Eagles and Tomcats, as well as their joint development of the AIM-7F, signaled their hope that such restrictions would become a relic of wars past.[42] The unanticipated VID requirement also initiated another round of service one-upmanship, with the Navy suddenly announcing plans to install a television sight system (TVSU) on its AIMVAL–ACEVAL Tomcats that would extend the aircrews' VID capability. The Air Force protested that the Navy's new technological hardware would give the F-14 an unfair advantage and upset the meticulously negotiated and carefully balanced test environment, but the JTF officials ruled in favor of the Navy. The TVSU-equipped Tomcats arrived in time for the testing.[43]

Several USAF organizations registered additional concerns regarding the tests' other artificialities, including the non-combat-representative aircraft configurations and the 5,000-foot minimum test engagement altitude. Some organizations even complained that the pilots would be disadvantaged because real missiles would not be used—the aircrews couldn't look for missile smoke trails in the air to alert them to a potential threat.[44] The tests' identified dependent variables and associated scoring metrics also generated significant consternation within the services.[45] Were the aircrews supposed "to maximize the number of missile firings, . . . maximize the expected kills [while] striving for optimum [offensive] position," or, officials at Tactical Air Command (TAC) wondered, focus on "minimizing their vulnerability"?[46] Succinctly capturing the services' frustration, one Navy official wrote, "The guys who conceived and designed the whole test series clearly didn't know what they were doing."[47] Doubts also spread to Capitol Hill, where at least one Senate staffer questioned whether the test design was even capable of "really proving the thing that [the services] have to prove."[48]

Responding to these and similar criticisms shortly after the AIMVAL trials began, the joint test director, now RADM Ernest Tissot, tried to assuage the services' concerns, explaining, "The majority of the test results and relative effectiveness conclusions [*sic*] . . . should not be treated in terms of specific system absolutes."[49] Lt Gen Alton Slay, the Air Force's deputy chief of staff for research and development, took a similar approach with Congress, reminding it in his March 1977 testimony that, having "theoretically taken a big skyhook and dropped these airplanes into a 30-mile arena," the test was "a canned situation."[50]

All told, it took more than a year to stand up the test team, develop the testing protocols, spin up the aircrews, and field ACMI. AIMVAL commenced testing on 3 January 1977 and continued for more than five months. During the test, five separate short-range IR missile designs ranging from simple boresight-only missiles to extremely sensitive, high off-boresight, helmet-cued weapons, were evaluated on F-14 Tomcat and F-15 Eagle aircraft. In addition to the simulated IR concept missiles, the blue forces were also armed with simulated AIM-7F Sparrow radar-guided missiles and a 20mm gun. Opposing the F-14s and F-15s were Air Force and Navy aggressors flying F-5E aircraft armed with a modified, boresight-only version of the AIM-9L Sidewinder, a representation of a future 1985 Soviet threat. More than 1,000 trials were flown during AIMVAL, accounting for more than 2,600 total sorties.[51]

Even as AIMVAL was still underway, JTF officials declared the test a "positive influence toward the resolution of common Air Force and Navy needs" for the next short-range, IR-guided missile.[52] Of the IR missile concepts tested, however, none were judged satisfactory; all exhibited difficulty distinguishing between the fighter targets and the hot desert background. Shortly thereafter, the two services elected to shelve their advanced IR-guided missile concepts in favor of their bridge all-aspect AIM-9L. They also accelerated their work on a new high-speed, multitargetable, advanced medium-range *radar-guided* air-to-air missile—the AMRAAM.[53]

Although focused on a different question, ACEVAL supported many of AIMVAL's earlier recommendations. Executed from June to November 1977, ACEVAL used the same AIMVAL test management, much of the same Air Force and Navy equipment, and many of the same aircrews. The F-5E-equipped aggressor adversary also remained the same as during AIMVAL. Variation during the 720 ACEVAL trials, which required a total of 3,222 sorties, was primarily a function of setup parameters and force ratios.[54]

The findings from ACEVAL, according to one data analyst, could be captured in a single sentence: "As the number of fighters in an engagement increases, the exchange ratio trends toward One"; or, in other words, the larger the fight, the more likely everybody died.[55] The same analyst also noted that any attempt to view the ACEVAL results strictly in terms of competing technological hardware quickly became "incomprehensible."[56] While DDR&E's desire for a fighter force model to inform defense planning consequently went unfulfilled, some suggested that ACEVAL's "law" supported a requirement for purchasing significant *quantities* of tactical fighters.[57] Others, however, interpreted the ACEVAL results as supporting a requirement to improve the *quality* of the US tactical fighter aircraft and their air-to-air weaponry. These proponents, recalling AIMVAL's similar recommendations, argued for faster, more lethal IR- and radar-guided missiles, as well as improved aircraft radars.[58] Still others saw no need to distinguish between the two requirements. "ACEVAL," one enthusiastic general reported, "strongly inferred that more quality and quantity are required."[59]

There were several, though, who cautioned against drawing anything meaningful from either AIMVAL or ACEVAL. For example, the authors of TAC's final report on ACEVAL warned that the tests were not appropriate representations of future air combat and that the results could not be "directly applied to any actual air-to-air environment."[60] Another senior USAF officer intimated that the JTF performed only perfunctory analysis of the results, complaining that the ACEVAL summary briefing "makes the point several times that numbers are the determining factor in the outcome of air combat. It is obvious that numbers were a dominating factor in determining the outcome of the mock combat in the test. What is not so obvious is what caused numbers to be so important."[61]

Indeed, test officials acknowledged during congressional testimony in April 1978 that one of the tests' key dependent variables, exchange ratio, was ultimately found to be "misleading by itself and insensitive to many factors."[62] After having devoted almost 5,900 sorties to the task, test officials admitted that they now knew a great deal about short-range air combat, but had analyzed "perhaps [only] 2 inches on the yardstick of air superiority" that pilots would face in the future.[63] However, lacking the necessary additional funding and authority to conduct further analysis, and having addressed Congress's immediate test demands, the formal AIMVAL–ACEVAL results were brusquely filed away. They were occasionally dusted off as needed to justify future weapons acquisitions like the AMRAAM.[64]

Almost a half-decade later, interest in AIMVAL–ACEVAL suddenly resurfaced. A group of Pentagon insiders known as the "Reformers" was growing concerned about the DOD's seemingly insatiable appetite for exquisite—and exquisitely priced—technology. The US military, they warned, was on a "curve of unilateral disarmament," and the problem was especially acute in the Air Force and Navy's fighter force. Advanced fighters like the Eagle and Tomcat were so expensive that the services could only afford to purchase limited quantities of them. Exacerbating matters, the complex aircraft also came with burdensome maintenance requirements that further reduced the service's effective force. The net result, according to the Reformers, was that the US military possessed only a "phantom fleet" of fighter aircraft.[65]

As an alternative to the services' favored high-end weapons, the Reformers proposed instead acquiring a fleet of cheap, "brilliantly simple" aircraft. These aircraft, which included the aggressors' F-5 that was used during AIMVAL–ACEVAL, might not match well individually against a state-of-the-art F-14 or F-15, but force-for-force, they were undeniably effective, at least according to the Reformers' interpretation of the tests' results. After all, they pointed out, ACEVAL's law reflected the importance of numbers in combat.[66] For the cost of one F-15, the Air Force could buy four cheaper F-5 fighters. Then, because the F-5 was easier to maintain, the Reformers explained, it could be flown at a higher sortie rate. When armed with relatively inexpensive but lethal short-range IR-guided missiles and a powerful gun, these brilliantly simple aircraft would provide just enough technology to answer America's tactical fighter requirement, but at a much more affordable price that would finally allow the nation to field sufficient numbers of aircraft to defeat the Soviet hordes.[67]

The Reformers' arguments soon caught the attention of James Fallows, an editor at *The Atlantic Monthly*. Leaders on Capitol Hill were already clamoring for defense reform following the Soviet invasion of Afghanistan and the military's debacle Desert One, the failed attempt to rescue the American hostages from Iran in April 1980. In December of that year, Sen. Sam Nunn (D-GA) declared his frustration with the military's recent underwhelming performance as he opened a set of hearings examining the effect of technology on military readiness.[68] A few months later, a Military

Reform Caucus emerged with the stated goal of uncovering waste and corruption within the US military.[69] Fallows's columns and his award-winning *National Defense* drew on the Reformers' arguments and their interpretations of AIMVAL–ACEVAL to fuel the intensifying debate, which quickly spread to the popular media.[70] The *Chicago Tribune*, for example, reported in December 1981 that during AIMVAL–ACEVAL, "the proud 'air superiority fighters,' F-15s and F-14s, . . . had been fought to all but a draw by a comparatively crude $4 million airplane, the F-5."[71] Two years later, the editors at *Time* elected to put Reformer Chuck Spinney on the cover, his charts looming ominously in the background with the question, "US Defense Spending: Are Billions Being Wasted?" bold in the foreground.[72]

The popularity of the AIMVAL–ACEVAL data, and the Reformers' interpretation of it, confounded those within the Pentagon. The services bristled at the accusation that they were being circumspect with their data, especially after having devoted such intense energy to crafting as fair and as objective a test as possible. Moreover, military officials pointed to the looming Soviet threat and argued that US fighter aircraft destined to fight over central Europe had to possess the specialized (and albeit unfortunately expensive) equipment to fly and attack in bad weather and at night, especially given the premium that the North Atlantic Treaty Organization's forward defense strategy placed on American airpower.[73] However, these counterarguments were usually brushed aside by the popular media as uninteresting minutia. According to the *New York Times*, many inside the Pentagon resorted to calling the Reformers "fuzzy heads" and accused them of "doing a disservice to the country" by forcing "plain vanilla airplanes" and "cheap, throwaway fighters" on the military.[74] When asked how the AIMVAL–ACEVAL results could be used to support the Reformers' position, an internal report completed in 1981 at the behest of the principal deputy undersecretary of defense for research and engineering—the same DDR&E organization originally responsible for AIMVAL–ACEVAL—matter-of-factly concluded that the two tests were "badly flawed."[75]

As described earlier, the limitations of the tests were not unforeseen. For example, one Air Force general had warned during the testing in 1977: "The large scale of the test itself, number of trial repetitions, and bounty of data tend to create the impression that the test results can be taken at face value. Characteristic of such a notion is the attitude that what came out of the test must be right, since we did so much of it and the results did not change."[76] Even after the effects of the test constraints became apparent, however, test officials were reluctant to modify the test design for fears of inflaming service parochialism and inviting Congressional accusations that the military was manipulating the test to achieve a more favorable outcome. The JTF officials trudged along, resigned to completing the mandatory tests while gathering as much *useful* data as possible.[77] In the end, the commander of the tests' blue forces offered his appraisal, "The test objective of quantifying the influence of 'numbers' on engagement outcomes had not only not been achieved, but was 'probably an impossible task.'"[78] It was a less-than-enthusiastic assessment of the nearly year-long, $150M set of tests.[79]

Lessons for the Close Air Support Fly-Off

The AIMVAL–ACEVAL tests failed to answer their original motivating questions, and the results that they generated were sufficiently ambiguous to animate both sides of the defense reform debate of the early 1980s. But the two tests were not a total failure. More than three decades after AIMVAL–ACEVAL, former CSAF Gen Larry Welch explained that the Air Force and its fighter pilots learned some "pretty darn good lessons out of a . . . very badly flawed, politically motivated, Congressionally-directed, horribly expensive test program."[80] Data analysts for the tests shared a similar appraisal, "Everything that came out of [AIMVAL–ACEVAL] was a byproduct. . . . [It] was worth it, as an afterthought, but not for the reasons we ran the test."[81] Congress and the DOD have done much to improve the military testing enterprise since AIMVAL–ACEVAL, yet structural impediments remain. While DOT&E and the Air Force may have already taken some steps to address these limitations for the coming CAS fly-off, it's still worthwhile to examine four critical lessons from AIMVAL–ACEVAL that should inform preparation, execution, and expectations of the pending test.

First, the Air Force must recognize that the two-plane fly-off will do little to quell the public debate over the future of the A-10 and the CAS mission. Instead, the test will likely further enflame the debate, regardless of the results. While every effort should be made to ensure that the test is constructed and executed in a fair and impartial manner, because the test must be conducted by Air Force personnel, accusations that service parochialism and biases unduly influenced the results should be expected. These accusations will be particularly acute because the critical insights from the test—those that reveal unique platform capabilities and vulnerabilities—will necessarily be shielded from the public's (and potential adversaries') eyes. As discussed earlier, these two mitigating factors will exacerbate the interpretive flexibility of the data, just as during AIMVAL–ACEVAL before.

Further muddying the test results, the "human factor" will likely loom large in the CAS fly-off test. Indeed, the opportunity to analyze complex human–human and human–machine interactions under semirealistic conditions is an essential benefit of a live-fly test, distinguishing it from typically cheaper modeling and simulation data-collection alternatives. The Air Force recognized the advantage of turning F-5s and F-15s loose on the Nellis ranges during AIMVAL–ACEVAL, with one general testifying that rather than simply putting all the aircraft and missile data in "a computer, kick[ing] that computer and hav[ing] it spit out a roll of tape that tells you what the outcome was," the live-fly tests revealed the "extremely important . . . human factor" that dramatically influenced the real-world performance of the complex weapons.[82] However, human factors are also notoriously difficult to capture, and often proxy metrics must be used for assessment. With the advocates of the F-35 and the A-10 differing in their assessment of the character of future CAS battles and the pilots' critical tasks therein, it's highly unlikely that the two sides will reach a consensus on the test's dependent variables of interest, which will generate even more ambiguity and contention over the public results.[83]

Second, DOT&E and the Air Force must facilitate excursion testing during the CAS fly-off and then encourage supplemental data analysis following the test. One of the principal failings of AIMVAL–ACEVAL was that once interesting anomalies were observed, the test matrix and schedule were too rigid to permit further investigation. On the surface, the two preidentified critical test metrics seemed reasonable—exchange ratio (number of red killed/number of blue killed) and loss rate (number of blue killed in trials/number of blue entering trials)—but as new dependent variables of interest emerged, there was little opportunity to conduct additional experimentation and analysis to determine their relevance. The laborious negotiation and interservice bargaining that produced the test matrix had reduced the massive tests to an unfortunate "one-shot" design that could identify important trends but possessed scant power to then elucidate those trends.[84]

Unofficial analysis conducted after AIMVAL–ACEVAL suggested that other more significant variables were indeed lurking in the background. "Quantifiable variables such as numbers only accounted for about 10–20 percent of the variation in outcomes," one analyst later concluded, "whereas human factors had 'more than five times the effect on results' compared to variables such as 'force ratio or whether somebody does or doesn't have GCI [ground-controlled intercept].'"[85] The same scheduling and budget pressures that unfortunately curtailed additional investigation and analysis during AIMVAL–ACEVAL will likely be present in the CAS fly-off test. But, if the goal is to maximize potential learning, the Air Force and DOT&E must develop a flexible test matrix that facilitates appropriate additional excursion testing. Additionally, the Air Force and DOT&E should commit to sharing the collected data across the DOD, encouraging others to scour the data looking for critical lurking variables that might further our knowledge of how best to execute current and future CAS.

Third, if the lack of resources to conduct additional analysis was one of AIMVAL–ACEVAL's critical failings, then the freedom that the test officials granted to the participants to experiment with novel tactical solutions was one of the tests' principal strengths. DOT&E and the Air Force would be well-served to encourage similar creativity during the CAS fly-off. During AIMVAL–ACEVAL, TAC officials lauded the pilots' impressive "ingenuity" and their ability to develop stylized tactics that maximized their advantages against their adversary.[86] Because this battle of wits took place on both the blue and red sides, the net effect, however, was a tactical stalemate with neither side accruing a significant advantage over the other for any appreciable duration.[87] While some suggested that the overly complicated tactics were yet another artificiality that generated unrepresentative test data, JTF officials deemed that such "tactics change for change's sake was a sound tactical principle," and that the intense competition among the aircrews helped contribute to the "realism" of the test environment.[88] It also produced a persistent, steep tactical learning curve for the pilots. One AIMVAL–ACEVAL F-15 pilot claimed that the lengthy, rigorous tests accelerated air combat tactics development by at least five years.[89] As one example, early in the ACEVAL trials, the targeting process for a four-ship of Eagles required more than 100 separate intraflight radio transmissions.[90] Throughout the test, the F-15 pilots worked tirelessly to streamline the cumbersome radar employment procedures as they experimented with new "sorting" mechanics and radio calls that would facilitate faster, more flexible targeting.[91] These new tactics subsequently became pillars of successful Eagle employment.

In the CAS arena, the last decade-and-a-half of war has provided the Air Force with a crucible for tactics development, but it has been restricted to relatively permissive environments. As more complex, contested environments emerge, there may be future requirements to execute CAS or CAS-like missions under an adversary's anti-access/area-denial umbrella. The Air Force has suggested that its technologically-sophisticated stealth F-35 is an ideal platform for these challenging contested scenarios, but the tactics to use that technology in a future CAS environment, with all the relevant enterprise components, are still embryonic. Additionally, while current CAS tactics may limit the survivability of the A-10 in contested scenarios, the opportunity to experiment with novel tactics in a robust test environment could identify otherwise unexploited capabilities or enterprise synergies that might enhance the Warthog's utility in a future CAS fight. Freeing the CAS fly-off participants to explore creative options to these challenging tactical problems—both with advanced stealth technology and without, and all within the context of the Army's simultaneous effort to update its doctrine for the A2AD environment—will ensure that the Air Force best capitalizes on the fly-off test opportunity.

Finally, the Air Force must be receptive to any jarring insights that might emerge from the CAS fly-off test. AIMVAL–ACEVAL focused on air combat in the close-range arena. The Air Force's F-15 "Superfighter," purposefully built to triumph in a dogfight against any current or planned Soviet fighter, was expected to easily defeat its F-5 aggressor foe.[92] However, those expectations did not match reality. The AIMVAL–ACEVAL tests vividly illustrated that a relatively simple foe armed with an all-aspect, fire-and-forget missile like the AIM-9L could be lethal to advanced US fighter aircraft.[93] The new missile, some officers predicted, would consequently "revolutionize fighter tactics."[94] It also demanded a sudden shift in weapons acquisition priorities. Rather than continuing to maximize fighter capabilities *in* the short-range environment, the Air Force quickly reoriented and instead began focusing on developing capabilities that would keep its fighters *out* of the short-range environment.[95] The decision to accelerate development of the multitargetable, fire-and-soon-forget AMRAAM was one manifestation of the shift. Another was the reinvigorated emphasis on developing long-range electronic identification technologies spearheaded by the new TAC commander, Gen Wilbur Creech.[96]

In retrospect, the Air Force's rapid reprioritization was a remarkable example of bureaucratic agility. Today's Air Force must be ready to respond similarly to any paradigm-shifting signals that might emerge from the CAS fly-off. Tactics and technologies that were designed to enhance performance in the future CAS environment may not, while other technologies that have been deemed inconsequential may instead demonstrate critical utility. A rigorous test can help the Air Force identify these unforeseen challenges and opportunities, but only if the service designs the CAS fly-off test with an eye toward flexibility, encourages the participants to be creative, and most importantly, focuses, not on justifying a favored platform, but on learning how to operate in future CAS environments. Then, it must act boldly.

The coming head-to-head matchup between the A-10 and the F-35 will do little to resolve the public debate over the future of Air Force CAS. All empirical tests bear the imprint of the social organization in which they were developed and executed; their resulting data are inherently socially constructed. The interpretive flexibility of the military's empirical data is particularly acute due to structural limitations that constrain the military's ability to execute independent, transparent, and appropriately flexible tests. It was true during AIMVAL–ACEVAL 40 years ago, and it will likely be true during the CAS fly-off in early 2018. Nevertheless, the CAS fly-off has potential to be more than just "a silly exercise," assuming DOT&E and Air Force leaders are mindful of four critical lessons from AIMVAL–ACEVAL. The coming CAS fly-off must encourage test flexibility, robust analysis, and participant creativity, and its implications, however disruptive, must be embraced and then acted upon. If so, then the Air Force once again will have an opportunity to learn some "pretty darn good lessons" from a congressionally-mandated test. ✪

Notes

1. For a summary of the Air Force argument, see Derek O'Malley and Andrew Hill, "The A-10, The F-35, and the Future of Close Air Support," *War on the Rocks*, 27 May 2015, http://warontherocks.com/2015/05/the-a-10-the-f-35-and-the-future-of-close-air-support-part-i/; and O'Malley and Hill, "Close Air Support in 2030: Moving Beyond the A-10/F-35 Debate," *War on the Rocks*, 28 May 2015, http://warontherocks.com/2015/05/the-a-10-the-f-35-and-the-future-of-close-air-support-part-ii/. The service later attempted to justify its A-10 retirement plans based on limited maintenance manpower, but the argument was deemed specious by many outside the service; see Brian Everstine, "Air Force: Keeping A-10 Means F-35 Delays, F-16 Cuts," *Air Force Times*, 28 April 2015, https://www.airforcetimes.com/articles/air-force-keeping-a-10-means-f-35-delays-f-16-cuts.

2. "Congress Issues Air Force Sharp Rebuke, Bars A-10 Retirement," *John Q. Public*, 30 September 2015, https://www.jqpublicblog.com/congress-issues-air-force-sharp-rebuke-bars-a-10-retirement/; and Martha McSally, "Saving a Plane That Saves Lives," *New York Times,* 20 April 2015, http://www.nytimes.com/2015/04/20/opinion/saving-a-plane-that-saves-lives.html?_r=0.

3. Lara Seligman, "Welsh: F-35 vs. A-10 Testing a 'Silly Exercise,' " *Defense News*, 24 August 2015, http://www.defensenews.com/story/defense/air-space/support/2015/08/24/welsh-f-35-vs--10-testing--silly-exercise/32292147/; and Brendan McGarry, "Welsh Dismisses F-35, A-10 CAS Contest as 'Silly Exercise,' " *DOD Buzz*, 25 August 2015, http://www.dodbuzz.com/2015/08/25/welsh-dismisses-f-35-a-10-cas-contest-as-silly-exercise/. Others have also questioned the wisdom of the proposed test, but for different reasons. For an example see Robert Preston and Don Kang, "A Close Air Support Flyoff is a Distraction," *War on the Rocks*, 29 July 2016, http://warontherocks.com/2016/07/a-close-air-support-flyoff-is-a-distraction/.

4. "National Defense Authorization Act for Fiscal Year 2017," Report of the Committee on Armed Services, House of Representatives, on H. R. 4909, 30–32, https://www.congress.gov/114/crpt/hrpt537/CRPT-114hrpt537.pdf. On the DOT&E plan to conduct comparative testing, see McGarry, "F-35 and A-10 to Square Off in Close Air Support Tests," *DOD Buzz*, 24 August 2015, http://www.dodbuzz.com/2015/08/24/f-35-and-a-10-to-square-off-in-close-air-support-tests/.

5. McSally, "Why We Need an A-10/F-35 Fly-Off," *Air Force Times*, 14 June 2016, https://www.airforcetimes.com/articles/why-we-need-an-a-10-f-35-fly-off.

6. Oriana Pawlyk, "A-10's Earliest Retirement Reset to 2021: General," *Military.com*, 7 February 2017, http://www.military.com/daily-news/2017/02/07/a10s-earliest-retirement-reset-2021-general.html; and Pawlyk, "A-10 vs. F-35 Flyoff May Begin Next Year: General," *DoD Buzz*, 25 January 2017, https://www.dodbuzz.com/2017/01/25/10-vs-f-35-flyoff-may-begin-next-year-general/.

7. Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press, 1985), 344.

8. David Bloor, *Knowledge and Social Imagery*, 2nd ed. (Chicago, IL: University of Chicago Press, 1991), 22; Thomas S. Kuhn, *The Structure of Scientific Revolutions,* 3rd ed. (Chicago: University of Chicago Press, 1996); Robert K. Merton, "Priorities in Scientific Discovery: A Chapter in the Sociology of Science," *American Sociological Review* 22, no. 6 (December 1957): 635–59; Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA: Harvard University Press,

1987). Social constructivism has also been applied to technology studies; see Trevor Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch (Cambridge, MA: The MIT Press, 1989), 17–50.

9. Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts*, 2nd ed. (Princeton, NJ: Princeton University Press, 1986), 243.

10. Joel Best, *Damned Lies and Statistics: Untangling Numbers from the Media, Politicians, and Activists* (Berkeley, CA: University of California Press, 2001); Best, *More Damned Lies and Statistics: How Numbers Confuse Public Issues* (Berkeley, CA: University of California Press, 2004); and Best, "Lies, Calculations and Constructions: Beyond How to Lie with Statistics," *Statistical Science* 20, no. 3: 210–14.

11. Best suggests that the propensity to accuse others of lying with statistics "is often implicitly endorsed in statistics instruction. . . . Students are warned that there are biased people who may deliberately choose to calculate statistics that will lend support to the position they favor." According to Best, this prevalent "statistics-or-lie distinction" is harmful because it "makes an implicit claim that, if statistics are not lies, they must be true—that is, really true in some objective sense." Best, "Lies, Calculations and Constructions," 211.

12. Best, *More Damned Lies and Statistics*, xiii.

13. "There is flexibility in how people think of or interpret artifacts . . . [and] there is flexibility in how artifacts are designed." Pinch and Bijker, "The Social Construction of Facts and Artifacts," 40.

14. Best, *More Damned Lies and Statistics*, 151.

15. Edward Constant, *The Origins of the Turbojet Revolution* (Baltimore, MD: Johns Hopkins University Press, 1980), 8.

16. Walter G. Vincenti, *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History* (Baltimore, MD: Johns Hopkins University Press, 1990).

17. An inflexible, static test design is not conducive to knowledge generation. According to Box and Liu:

> An industrial innovation of major importance . . . comes about as the result of an *investigation* requiring a sequence of experiments. Such research and development is a process of learning: dynamic, not stationary; adaptive, not one-shot. The route by which the objective can be reached is discovered only as the investigation progresses, each subset of experimental runs supplying a basis for deciding the next. Also, the objective itself can change as new knowledge is brought to light (emphasis in original).

George E. P. Box and Patrick Y. T. Liu, "Statistics as a Catalyst to Learning by Scientific Method Part I—An Example," *Journal of Quality Technology* 31, no. 1 (January 1999): 1. See also Donald T. Campbell and Julian C. Stanley, *Experimental and Quasi-Experimental Designs for Research* (Boston, MA: Houghton Mifflin Company, 1963), ch. 5.

18. Howard likened the military leader's challenge to "sail[ing] on in a fog of peace until the last moment. Then probably, when it is too late, the clouds lift and there is land immediately ahead; breakers, probably, and rocks. . . . Such are the problems presented by 'an age of peace.'" Michael Howard, "Military Science in an Age of Peace," *RUSI Journal for Defence Studies* 119, no. 1 (March 1974): 4. Howard's analogy draws on the popular "fog of war" adage in Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 140. Even if wars were more frequent, altering technological and doctrinal development based on their lessons might still result in future failure. For example, the French army's spectacular defeat during the Franco–Prussian War of 1870 led to a new offensive doctrine that emphasized the spirit of élan, which itself contributed to the failure on the Western Front during World War I. Alistair Horne, *The Price of Glory: Verdun 1916* (New York: Penguin Books, 1993); and Jack Snyder, "Civil-Military Relations and the Cult of the Offensive, 1914 and 1984," *International Security* 9, no. 1 (June 1984): 108–46. McNamara is often credited (and maligned) for introducing statistical rigor to Department of Defense research; see Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961–1969* (New York: Harper & Row Publishers, 1971).

19. Cited in John A. English, *On Infantry* (New York: Praeger, 1981), 205.

20. These problems are exacerbated when the public suspects military malfeasance and deliberate misrepresentation of data. For an example, see James Burton, *The Pentagon Wars: Reformers Challenge the Old Guard* (Annapolis, MD: Naval Institute Press, 1993). Burton's story of the Army's Bradley fight-

ing vehicle was later made into an HBO film starring Kelsey Grammer, *The Pentagon Wars*. See also the ill-fated Millennium Challenge 2002 exercise, described in Micah Zenko, *Red Team: How to Succeed by Thinking like the Enemy* (New York: Basic Books, 2015), 52–61.

21. For more on AIMVAL–ACEVAL, see Steven Fino, "Doubling Down: AIMVAL–ACEVAL and US Air Force Investment in TacAir post–Vietnam," *Vulcan: The Social History of Military Technology* 2 (2014): 125–161; as well as brief discussions in Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessments, 2007), 49–50; C. R. Anderegg, *Sierra Hotel: Flying Air Force Fighters in the Decade after Vietnam* (Washington, DC: Air Force History and Museums Program, 2001), 158–64; Brian D. Laslie, *Air Force Way of War: US Tactics and Training after Vietnam* (Lexington, KY: University Press of Kentucky, 2015), 89–92; and Marshall L. Michel, "The Revolt of the Majors: How the Air Force Changed after Vietnam" (PhD diss., Auburn University, 2006), 258–62.

22. Drew Middleton, "Air Force Unveils Fighter Designed to Keep Superiority into the '80's," *New York Times* (27 June 1972); Michel, *Clashes: Air Combat Over North Vietnam, 1965–1972* (Annapolis, MD: Naval Institute Press, 1997), 291–94; Edgar Lewis, "History of the F-15 Eagle: A Corporate Memory," 18 May 1976, 9–11, 35, AF Historical Research Agency (AFHRA) K417.042–18; and "F-15 Rolls Out at St. Louis," *Flight International* (6 July 1972): 11. Development of the Navy's F-14 preceded the F-15 by almost a full year, complicating the Air Force's fighter acquisition efforts; see "Talking Paper on 'Dr. DuBridge Letter to Mr. Packard,' " 12 December 1969, AF Materiel Command/History Office (AFMC/HO) 03936; Jacob Neufeld, *The F-15 Eagle: Origins and Development, 1964–1972* (Washington, DC: Office of Air Force History, 1974): 23–24, AFHRA K417.042-18 (there are two versions of this document; all references are to the original classified [and since declassified] version); Roger K. Rhodarmer, "Oral History Interview," by Neufeld, 29 March 1973, 5, 17–23, AFHRA K239.0512–972; Alexander H. Flax, "Oral History Interview," by James C. Hasdorff and Neufeld, 27 November 1973, 26–28, AFHRA K239.0512-691; and Kenneth P. Werrell, *Chasing the Silver Bullet: US Air Force Weapons Development from Vietnam to Desert Storm* (Washington, DC: Smithsonian Books, 2003), 63–65.

23. Robert C. Mathis, "F-15 Air Superiority Fighter: Presentation for Hon. James R. Schlesinger, secretary of defense," 3 May 1974, AFMC/HO 03887; and D. V. Wells, "Sparrow Missile Program Review," Hearings before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: Government Printing Office [GPO], 1976), 5000–13.

24. Benton K. Partin, "Program Management Directive for Project 670E (Air-to-Air Technology)," 4 September 1973, 2, AFHRA Microfilm 40233; Robert G. Dilger, "CLAW Missile Program Review," Hearings before the US Senate, Committee on Armed Services, 27 March 1974 (Washington, DC: GPO, 1974), 4705–25; Lewis, "History of the F-15 Eagle," 14; and E. J. Griffith, "AIMVAL–ACEVAL: Why/What/How," *Fighter Weapons Review* (Fall 1977): 24. CLAW supposedly stood for "Concept of a Lightweight Aerial Weapon."

25. An off-boresight missile can be cued to a target that is not directly in front of it. J. H. Quinn, "Agile Program Review," Hearings before the US Senate, Committee on Armed Services, 27 March 1974 (Washington, DC: GPO, 1974), 4695–705; Peter Waterman, "Research, Development, Test, and Evaluation: Navy," Hearings before the US House, Subcommittee of the Committee on Appropriations, 25 September 1973 (Washington, DC: GPO, 1973), 794–97; and Malcolm R. Currie, "Statement of the Director of Defense Research and Engineering," Hearings before the US House, Subcommittee of the Committee on Appropriations, 24 September 1973 (Washington, DC: GPO, 1973), 456. Currie, the director of DDR&E, expressed his concerns about the Agile's high price tag, telling Congress, "Estimates indicate that at least a 20-percent reduction (preferably 40 percent) would be necessary to enable procurement of the missile in large quantities." Former CSAF Larry Welch explained that the Navy needed the Agile to be highly maneuverable to compensate for the restricted turning performance of the F-14 Tomcat. Larry D. Welch, interview by author, 10 July 2012; see also James R. Hildreth, "Oral History Interview," by Hasdorff, 27 October 1987, 160–61, AFHRA K239.0512-1772.

26. An all-aspect missile can shoot from any angle relative to the target; prior to the AIM-9L, Sidewinders could only be launched from a limited area behind the target's tail. Ron Westrum, *Sidewinder: Creative Missile Development at China Lake* (Annapolis, MD: Naval Institute Press, 1999), 192–95; William B. Haff, "Sidewinder Program Review," Hearings before the US Senate, Committee on Armed Services, 14 March 1975 (Washington, DC: GPO, 1975), 4619–34; M. O. Beck, "State of the Art," *Fighter Weapons Review* (Winter 1974): 28–33; and W. H. Van Dyke Jr., "Sidewinder Program Review," Hearings

before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: GPO, 1976), 5013–38.

27. "Advanced Short Range Air-to-Air Missile Technology," *Congressional Record* 121, no. 23 (1975): 29370; Julian S. Lake, "ACEVAL–AIMVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: GPO, 1976), 5040; and Griffith, "AIMVAL–ACEVAL," 24–25.

28. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976*, 1: 213, AFHRA K150.01; Lake, "ACEVAL–AIMVAL Program Review," 5038–39; Griffith, "AIMVAL–ACEVAL," 24–25; Anderegg, *Sierra Hotel,* 159; Robert H. Fay, "AIMVAL–ACEVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 9 March 1977 (Washington, DC: GPO, 1977), 4569; and CSAF/XO message to TAC/CV et al., "ACEVAL/AIMVAL Test Directive" (171237Z April 1975), in *History of the Air Force Test and Evaluation Center, 1 January 1974–31 December 1975,* 24, AFHRA K150.01.

29. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 1: 213; Lake, "ACEVAL–AIMVAL Program Review," 5038–39; Fay, "AIMVAL–ACEVAL Program Review," 1977, 4569; Anderegg, *Sierra Hotel*, 159; and Griffith, "AIMVAL–ACEVAL," 24–25.

30. Lake also outlined each test's objectives: "Objective of first test (ACEVAL) is to determine the effect of A/C [aircraft] multiples on air combat engagements using contemporary weapons and aircraft. Second test (AIMVAL) will determine operational utility of advanced conceptual short-range air-to-air missiles." COMNAVELECSYSCOM message to CSAF and CNO, "ACEVAL/AIMVAL Joint Test" (022324Z May 1975), in *History of the Air Force Test and Evaluation Center, 1 January 1974–31 December 1975,* 24. The order of the two tests was subsequently switched, with ACEVAL being flown after AIMVAL. Lake's description of the test objectives differed slightly from those in the initial Air Force test message: "ACEVAL is to determine effect of multiple fighters/initial entry conditions in air-to-air engagements. . . . AIMVAL is to compare operational utility of existing and proposed air-to-air missile concepts. All aspect, acquisition, and large off-boresight capabilities are of particular significance in AIMVAL." CSAF/XO message to TAC/CV et al., "ACEVAL/AIMVAL Test Directive."

31. ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans REF: AFSC/TEV MSG R161900Z Sep 76" (272017Z September 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; "F-15s, F-5Es Catching Up with F-14 OR Rates at Nellis, Ryan Says," *Aerospace Daily* (3 August 1977); James A. Knight, "Oral History Interview," by James C. Posgate, 30 December 1983, 232, AFHRA K239.0512-970; and Hildreth, "Oral History Interview," 161.

32. CSAF/XO message to TAC/CV, "AIMVAL/ACEVAL F-15s" (312111Z December 1975), in "Lessons Learned Symposium, 1974 (AFSC)," AFMC/HO 03951; and Barry Swarts, "Interest Paper on AIMVAL/ACEVAL," 14 July 1976, 2–3, in *History of ADCOM, 1 January–31 December 1976,* 6, AFHRA K410.011.

33. Lake, "ACEVAL-AIMVAL Program Review," 5056; and Fay, "AIMVAL–ACEVAL Program Review," 1977, 4579.

34. COMNAVELECSYSCOM message to CSAF and CNO, "ACEVAL/AIMVAL Joint Test"; and Hildreth, "Oral History Interview," 161–62.

35. Lake, "ACEVAL–AIMVAL Program Review," 5042, 5049; and ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans." The Weapons System Evaluation Group (WSEG) and the Institute for Defense Analysis (IDA) were tasked to provide analytical support for the pending evaluations.

36. Lake, "ACEVAL–AIMVAL Program Review," 5039, 5042; and *History of the Air Force Test and Evaluation Center*, *1 January 1976–31 December 1976*, 1: 218–19. Cubic Corporation's ACMI system was an updated version of a similar system developed a few years earlier for the USN. The Navy's system, called ACMR (Air Combat Maneuvering Range), was developed to help pilots visualize weapons employment zones in accordance with the recommendations of the Ault Report. Frank Ault, *Report of the Air-to-Air Missile System Capability Review, July–November 1968* (Naval Air Systems Command, 1969), http://www.history.navy.mil/branches/org4-25.htm. Describing air combat debriefs prior to ACMI, Anderegg observed, "No one can lie to himself better than a fighter pilot about to pull the trigger." Wallace, one of the eight AIMVAL–ACEVAL Eagle pilots, explained that winning the debrief was all about telling a believable story, "If you could lie better than anybody else, they couldn't refute you." Alluding to a fighter pilot's propensity to use his hands to reconstruct the motion of the fighters during the fight, Welch noted, "If you could get your hand back [farther than the other guy], then you could turn tighter." Anderegg, *Sierra Hotel*, 104, 108–9; Jere Wallace, interview by author, 3 October 2013; and L. Welch, interview by author, 1 October 2013.

37. Fay, "AIMVAL–ACEVAL Program Review," 1977, 4575.

38. Ibid.; Anderegg, *Sierra Hotel,* 108–10; Griffith, "AIMVAL–ACEVAL," 26–27; Taylor, "Air Combat Maneuvering Instrumentation (ACMI)," 1 October 1975, AFHRA 168.7339–79; David Everson, *AIMVAL Final Report,* 7–10, in *History of the Tactical Air Command, January–December 1977,* 2, AFHRA K417.01; James Quick, "Cleared in Hot," *Fighter Weapons Review* (Winter 1974): 9–17; Chuck Turner, "ACMI Update," *Fighter Weapons Review* (Summer 1977): 17–22; Robinson Risner, "Oral History Interview," by Mark C. Cleary, 1 March 1983, 182, AFHRA K239.0512–1370; "Dogfight Pilot Training at Nellis," *Las Vegas Review Journal* (21 December 1976); and "Nellis Pilots Given New Battle Training," *Las Vegas Sun* (29 December 1976).

39. TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan Review" (241945Z March 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; and Robert T. Marsh letter to AFTEC/CC, "AFSC Review of ACEVAL/AIMVAL Preliminary Test Plan (Your 272126Z Jan 76)," 17 March 1976, attachment to Gen William J. Evans letter to HQ USAF/CV, "AIMVAL," 17 March 1976, AFHRA K168.7339-79. The pilots occasionally complained that the red forces' missiles were too effective with ACMI—one pilot said the aggressor force was given "hittles" instead of "missiles." Thomas Sokol, interview by author, 4 August 2013.

40. Having delayed the two tests for almost a year while waiting on ACMI, there was little stomach in the Pentagon for postponing the tests further to gain a larger ACMI test-space—Congress demanded the test results and the services needed to deliver them if they hoped to gain the funding that their acquisition plans required. ACEVAL AIMVAL JTF message to DDRE, "ACEVAL–AIMVAL Monthly Progress Report (as of 6 Jan 76)" (061830Z January 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; and Fay, "AIMVAL-ACEVAL Program Review," 1977, 4571. The Air Force was also in the process of constructing an East coast ACMI range for use by both Navy and Air Force aircraft, but it would not become operational until early 1977; Dave Husted, "1st TFW Inherits Pilot Training System," *The Flyer* (3 March 1977), in *History of the 1st Tactical Fighter Wing, January–March 1977,* 2, AFHRA K-WG-1-HI.

41. Lake, "ACEVAL–AIMVAL Program Review," 5042–43; Fay, "AIMVAL–ACEVAL Program Review," 1977, 4571–72; Robert P. McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 1–5, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 12, AFHRA K150.01; Stephen Dvorchak, interview by author, 3 August 2012; and William Sparks, interview by author, 3 August 2012. To enforce aircrew adherence to the VID restriction during the tests, officials planned to have "random nonexercise aircraft in the exercise area." Shooting down one of the "nonplayers" would, according to one test official, result in "a bad day" for the offending aircrew.

42. During Vietnam, aircrews often had to obtain a visual identification before engaging the enemy and, even though US aircrews "were not too happy" about being unable to employ their longer-range, radar-guided Sparrow missiles as once envisioned, most abided by the combat restriction, saying they "preferred this to shooting down one of their own aircraft by mistake." "Pilots Describe Downing of MiG's: 8 Get Decorations and Tell How Missiles Hit Foe." *New York Times* (12 July 1965): 3; and William W. Momyer memorandum for Gen Ellis, "CORONA HARVEST (Out-Country Air Operations, Southeast Asia, 1 January 1965–31 March 1968," 4, 24, AFHRA K239.031-98.

43. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 1: 216–17; and TAC/DR message to CSAF/XOO, "ACEVAL/AIMVAL Test Constraints" (050200Z May 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21. The Air Force responded with its own VID-enhancing equipment, installed just in time for ACEVAL. Known as the "Eagle Eye," the simple system consisted of an off-the-shelf, six-power rifle scope mounted next to the F-15's Heads Up Display (HUD); see Tim O'Keefe Jr., "Eagle Eye," *Fighter Weapons Review* (Fall 1978): 27–29; Everson, *ACEVAL Final Report*, 4, in *History of the Tactical Air Command, January–December 1977,* 2, AFHRA K417.01; McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 6; Anderegg, *Sierra Hotel*, 161; and Frederick C. Blesse, "Corona Ace Oral History Interview," by Gordon F. Nelson, 14 February 1977, 84–85, AFHRA K239.0512-1077.

44. These and other test constraints were detailed in: SAF/SA message to AFTEC/CC, "Review of ACEVAL-AIMVAL Preliminary Test Plan"; TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan"; Fay, "AIMVAL/ACEVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 5 April 1978 (Washington, DC: GPO, 1978), 5202–3, 5220–21; Lake, "ACEVAL–AIMVAL Program Review," 5049; and ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans." See also

Walter Kross, *Military Reform: The High-Tech Debate in Tactical Air Forces* (Washington, DC: National Defense University Press, 1985), 104–5.

45. SAF/SA explained its concern, "Our fundamental objection to use of the term exchange ratio is based on the fact that actual aircraft killed is not portrayed and therefore indiscriminate use of the term can lead to poorly founded conclusions. The relevant measure of force effectiveness . . . is more related to absolute attrition rates than to exchange ratio." SAF/SA message to AFTEC/CC, "Review of ACEVAL–AIMVAL Preliminary Test Plan." On the test measures, see Fay, "AIMVAL/ACEVAL Program Review," 1978, 5199.

46. TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan."

47. George Haering, "Aim/Ace," *Topgun Journal* 1, no. 3 (Fall 1977): 15.

48. Recorded in Lake, "ACEVAL–AIMVAL Program Review," 5050.

49. Quoted in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 1: 271. SAF/SA officials similarly warned in an internal communique, "The test should not be advertised as something it is not." SAF/SA message to AFTEC/CC, "Review of ACEVAL–AIMVAL Preliminary Test Plan." TAC officials likewise noted that it was "imperative that the impact of the test constraints be highlighted." TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan."

50. Recorded in Fay, "AIMVAL/ACEVAL Program Review," 1977, 4571.

51. Ernest E. Tissot and Hildreth, *AIMVAL Final Report*, 6 September 1977, 1: sec. 3, 1–6, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 14; Everson, *AIMVAL Final Report*, 5–7, 12–14; Lake, "ACEVAL–AIMVAL Program Review," 5050, 5052; and Fay, "AIMVAL/ACEVAL Program Review," 1977, 4573. The Aggressor squadrons consisted of specially trained pilots who mimicked Soviet tactics during training events with other Air Force units; the F-5Es that the aggressors flew simulated the Soviets' MiG-21 fighter. On the Aggressor units, see Jerry H. Nabors, "Aggressor Squadron Briefing," Hearings before the US Senate, Committee on Armed Services, 9 March 1976 (Washington, DC: GPO, 1976), 4907–20; Anderegg, *Sierra Hotel,* 71–88; and Laslie, *Air Force Way of War*, 44–51.

52. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 1: 273.

53. Fay, "AIMVAL/ACEVAL Program Review," 1978, 5206–10, 5225; Newell, "AIMVAL-ACEVAL Results/Lessons Learned," 9 September 1983, 1, AFHRA K168.03-2107; Jasper A. Welch Jr., interview by author, 8 June 2012; Hildreth, "Oral History," 165–66; Hildreth letter to TAC/CV, "AIMVAL Final Report Recommendations," 28 November 1977, AFHRA 168.7339–79; Burt Munger, "Advanced Medium Range Air-to-Air Missile (AMRAAM)," Hearings before the US House, Committee on Armed Services, Hearings on Military Posture and H. R. 10929, 27 February 1978 (Washington, DC: GPO, 1978), 436–54; Robert M. Bond, "Advanced Medium Range Air to Air Missile," Hearings before the US Senate, Subcommittee of the Committee on Appropriations, 17 July 1978 (Washington, DC: GPO, 1978), 348–49, 358; William Perry, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 5, 41; Fay, "AIMVAL–ACEVAL Final Report Briefing," Hearings before the US House, Committee on Armed Services, 27 February 1978 (Washington, DC: GPO, 1978), 430; J. F. O'Hara, "Briefing," Hearings before the US House, Committee on Armed Services, 9 March 1978 (Washington, DC: GPO, 1978), 1018–27; and Tissot and Hildreth, *AIMVAL Final Report,* 1: sec. 5, 1.

54. Fay, "AIMVAL–ACEVAL Program Review," 1977, 4565; Everson, *ACEVAL Final Report,* 4–10, 28; and McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 1–8, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 12.

55. Dvorchak, e-mail to author, 9 February 2012; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5211–12.

56. Dvorchak is quoted in Watts, "Doctrine, Technology, and War" (presented at the Air and Space Doctrinal Symposium, Maxwell AFB, AL, 1996), n65, http://www.airpower.maxwell.af.mil/airchronicles/cc/watts.html.

57. Newell, "AIMVAL–ACEVAL Results," 3.

58. Ibid., 3–4; and Blesse, "The Changing World of Air Combat," *Air Force Magazine* (October 1977): 34.

59. TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings Week of 27 Feb–3 Mar 78" (070200Z March 1978), AFHRA 168.7339–79; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5208.

60. Everson, *ACEVAL Final Report*, 14. The JTF's final report also cast doubt on the test's outcome: "ACEVAL was a *test* and therefore had constraints. . . . The data trends, in a relative comparison, are all that are usable in applying the ACEVAL results to projected conflicts" (emphasis in original). McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 7, 21.

61. J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 5 December 1977, 2–3, in *History of the USAF Tactical Fighter Weapons Center, 1977*, 2, AFHRA K417.0735.

62. Fay, "AIMVAL-ACEVAL Program Review," 1978, 5199, 5201, 5211–12. Describing the analytical difficulties associated with the tests' data, Fay told Congress: "I would like to point out, sir, that we spent 2 years getting prepared for ACEVAL, 6 months running the test, 2 days to reduce this data, and 2 months to figure out how to say it, sir."

63. Fay, "AIMVAL–ACEVAL Final Report Briefing," 435; and Watts, *Six Decades*, 50.

64. The AIMVAL–ACEVAL findings were reportedly "well received by the Congressmen and staffers" during a set of 1978 Congressional hearings, and "substantially justified the AMRAAM program in FY79 [fiscal year 1979]." TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings"; and Fay, "AIMVAL–ACEVAL Final Report Briefing," 430–31.

65. Franklin C. Spinney, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 106–110 (see also "Defense Facts of Life," DTIC ADA111544); James Fallows, *National Defense* (New York: Random House, 1981), 42–43, 100; Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (Boston: Little, Brown and Company, 2002), 345–50; and Michel, "Revolt of the Majors," 326–30, 338.

66. Coram, *Boyd*, 348; and Michel, "Revolt of the Majors," 260–62. Coram noted that using the Pentagon's own experimental data against it was one of the Reformers' favorite tactics.

67. The Reformers' first attempt at pushing the Air Force to acquire a "brilliantly simple" airframe was the Lightweight Fighter, but that effort was foiled when the service began saddling the winning YF-16 prototype with heavy and expensive electronics and ground-attack accoutrements. The F-5E represented an even more austere platform. Coram, *Boyd*, 305–13; Spinney, "Impact of Technology," 92–93; Glenn A. Kent, "Oral History Interview," by Neufeld, 6 August 1974, 15–19, AFHRA K239.0512–970; Michel, "Revolt of the Majors," 81, 178–82, 261–62, 337–39; and Charles E. Myers Jr., "Tactical Air Warfare," Hearings before the US House, Task Force on National Security and International Affairs of the Committee on the Budget, 21 June 1977 (Washington, DC: GPO, 1977), 25.

68. Sam Nunn, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Opening Statement of Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 2.

69. See, for example, Winslow T. Wheeler and Lawrence J. Korb, *Military Reform: A Reference Handbook* (Westport, CT: Praeger Security International, 2007); and Gary Hart and William S. Lind, *America Can Win: The Case for Military Reform* (Chevy Chase, MD: Adler and Adler, 1986).

70. James M. Fallows, "Muscle-Bound Superpower," *Atlantic Monthly* 244 (October 1979): 59; Fallows, "America's High-Tech Weaponry," *Atlantic Monthly* 247 (May 1981): 21–33; Fallows, "I Fly with the Eagles," *Atlantic Monthly* 248 (November 1981): 70–77; Fallows, *National Defense* (New York: Random House, 1981); Coram, *Boyd*, 358; and Michel, "Revolt of the Majors," 339–45.

71. James Coates and Bill Neikirk, "Cheaper Jets Shoot Down Claims for New Models: High-tech Fighters Score Low in 'Combat,' " *Chicago Tribune* (7 December 1981).

72. Characteristic of the statistics feeding the frothing debate, the *Time* article noted that after accounting for inflation, the DOD was spending $4 billion more dollars in 1983 to buy 95 percent fewer aircraft than it had in 1951. Walter Isaacson, Evan Thomas, Bruce W. Nelan, and Christopher Redman, "The Winds of Reform," *Time* 121, no. 10 (7 March 1983): 22–35. If the trend continued, one aerospace industry specialist satirically predicted, "In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and Navy 3 1/2 days each per week except for leap year, when it will be made available to the Marines for the extra day." Norman R. Augustine, *Augustine's Laws,* 6th ed. (Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 1997), 107. Michel concluded that the Reformers had successfully convinced the public that their battle was "a Manichean contest of good vs. evil, of honest men . . . fighting against a cabal of corrupt military officers and contractors." Michel, "Revolt of the Majors," 299.

73. Kross, *Military Reform,* 143–45; Kross, "Military Reform: Past and Present," *Air University Review* (August 1981), http://www.airpower.maxwell.af.mil/airchronicles/aureview/1981/jul-aug/kross.htm; Perry, "Impact of Technology," 9, 40, 48; Anderegg, "Meeting the Threat: Sophistication vs Simplicity," *Fighter Weapons Review* (Fall 1982): 2, 6; and John T. Correll, "The Reformers," *Air Force Magazine* 91, no. 2 (February 2008): 43. Correll noted that the simple, highly-maneuverable aircraft touted by the Reformers might have been "perfectly suited to an imaginary war in which aerobatic fighters dueled in clear skies on sunny days," coincidentally the flight conditions during AIMVAL–ACEVAL, but the "simple" aircraft would have been of little use in midwinter Central Europe in which "airmen could count on no more than three flying hours a day in which lighting and weather conditions would allow visibility of more than 3.5 miles."

74. Charles Mohr, "Drop in US Arms Spurs Debate on Military Policy: Decline in Numbers of US Weapons Spurs Debate on Quality vs. Quantity," *New York Times* (24 October 1982). See also Kross, *Military Reform*, 104. Others labeled the Reformers "Luddites and antitechnology" and "dark and satanic forces." Coram, *Boyd*, 353, 357.

75. The report later noted, "Even with all these flaws, AIMVAL and, particularly, ACEVAL were very useful beginnings." Thomas S. Amlie, "A Non-Statistical Look at AIMVAL/ACEVAL," 3 February 1981, 1, AFHRA K168.03-2107. Michel argued that in contrast to the Reformers, senior USAF leaders "realized the service's arguments were too complex and nuanced for the general public"; consequently, "they worked closely with the administration . . . to develop ways to appeal to a different audience, the Congress." In the end, the USAF's strategy prevailed. Michel, "Revolt of the Majors," 10–11.

76. J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 2.

77. L. Welch, interview by author, 10 July 2012; and Fay, "AIMVAL–ACEVAL Program Review," 1977, 4577–78.

78. Quoted in Watts, *Six Decades,* 50.

79. The final price tag of AIMVAL–ACEVAL is ambiguous, but according to some sources, the bill for the two tests eclipsed $150 million, more than triple the original price tag. See: AFSC/CS message to ADTC, "ACEVAL/AIMVAL Test Plan" (052310Z February 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; DSAF/OIP message to AIG, "ACEVAL/AIMVAL News Release" (111943Z June 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 22; "Point Paper on the ACEVAL Flight Trials," 3 February 1981, AFHRA K168.03-2107; Lake, "ACEVAL–AIMVAL Program Review," 5044; and Fay, "ACEVAL–AIMVAL Final Report Briefing," 420.

80. L. Welch, interview by author, 10 July 2012.

81. Dvorchak, interview; and Sparks, interview.

82. Fay, "AIMVAL-ACEVAL Program Review," 1977, 4578; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5217.

83. The varying assessments of the future CAS battlespace and the pilots' tasks therein are reflected in the language used to describe the F-35 and the A-10. The F-35 Joint Program Office touts the F-35 as being "designed 'with the entire battlespace in mind'—it is equipped with advanced stealth, integrated avionics and an integrated sensor package, which will provide the pilot enhanced situational awareness." According to former CSAF Welsh, these advanced capabilities will be essential since "the F-35's mission in the close air support arena will be to do high-threat close air support in a contested environment that the A-10 will not be able to survive in." In contrast, when describing the F-35/A-10 fly-off, McSally emphasized the requirement to evaluate "continuous weapons delivery, comparisons of extended time over target, survivability from simulated direct hits, and low-altitude employment, including 'shows of force' and strafe. In addition, CSAR missions specifically need to test the critical rescue mission commander role that A-10s fill today, which includes locating and protecting the isolated personnel while coordinating all aspects of a potentially complex CSAR mission." Seligman, "Welsh: F-35 vs. A-10 Testing a 'Silly Exercise' "; McGarry, "Welsh Dismisses F-35, A-10 CAS Contest"; and McSally, "Why We Need an A-10/F-35 Fly-Off."

84. Box and Liu, "Statistics as a Catalyst to Learning."

85. Dvorchak's article, "Getting it on in the All-Aspect Arena," *Tactical Analysis Bulletin* (79:2), is cited in Watts, *Six Decades*, 50. Human factors often refer to the pilots' situational awareness, or their understanding of and ability to process the rapidly changing environment around them. See also Fay, "AIMVAL–ACEVAL Final Report," 435; J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 2–3; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5212–13. On the importance of situational

awareness in air combat, see Mike Spick, *The Ace Factor: Air Combat and the Role of Situational Awareness* (Annapolis, MD: Naval Institute Press, 1988); Watts, "Doctrine, Technology, and War"; and Watts, *Six Decades*, 52–54.

86. Everson, *ACEVAL Final Report*, 10–11.

87. Watts, "Doctrine, Technology, and War."

88. Tissot and Hildreth, *AIMVAL Final Report*, 1: sec. 3, 6; McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 6, 2–3, 30 and sec. 7, 18; and Everson, *ACEVAL Final Report*, 10–11. One pilot compared the test scenarios to "a shootout in an isolated tennis court." J. Welch letter to McMullen, 8 March 1977, AFHRA 168.7339-79; and Thomas H. McMullen letter to Dixon, 15 March 1977, AFHRA 168.7339–79.

89. Sokol, interview; Dvorchak, interview; Sparks, interview; and Jeff Cliver, interview by author, 3 August 2012. Cliver offered another perspective on the tests' impact: "We made eight guys pretty proficient, as proficient as you could get. And God only knows how many lives and systems they touched as they proceeded on through their Air Force careers. So that's kind of cool."

90. Dvorchak, interview.

91. Cliver, interview; Dvorchak, interview; Sparks, interview; and Sokol, interview. The AIMVAL–ACEVAL pilots realized that the "name of the game is sorting. If you sort, you win." The test results agreed. On the occasions when the Eagles failed to sort and instead all locked on to a single target, one data analyst recalled "the *best* they ever did . . . was lose three [F-15s]. . . . When they locked on [to] three out of four [aggressors], they kicked ass." The pilots developed other radar tactics, too. For example, Cliver earned a reputation during ACEVAL for being the first pilot to get a radar contact but the last pilot to ever get a radar lock. He also, on average, had the shortest time from when he took his lock to when he fired his first missile. Although counterintuitive at first, it proved to be a recipe for success; Cliver was one of the most lethal Eagle pilots in the test. In contrast, the worst performing Eagle pilot was on average the last to get a radar contact, first to go into radar track, and spent the longest time in track before firing his missile.

92. Robert J. Hoag, "Superfighter," *Fighter Weapons Review* (Summer 1974): 18–30.

93. One engagement, flown as practice for the upcoming ACEVAL portion of the tests, was particularly illustrative of the increased lethality within the short-range environment. The trial lasted less than two minutes before all eight aircraft, four Eagles and four aggressors, were killed, the last Eagle the "victim of a dead man" because his aggressor target managed to fire a simulated Sidewinder just moments before being "killed" by the Eagle's missile. The pilots and analysts dubbed the trial "The Towering Inferno" (some news reports mistakenly termed the infamous four-against-four engagement the "Towering Infernal") after the popular 1974 disaster film, and it was frequently replayed for distinguished visitors using the playback capability of ACMI. Anderegg, *Sierra Hotel,* 159; Fay, "AIMVAL-ACEVAL Program Review," 1978, 5221–23; "No-Win War at Dogbone Lake," *US News and World Report* (9 January 1978): 56–57; Robert Kaylor, "Mock Dogfights Test Latest Jet Fighters," *Sarasota Herald-Tribune* (7 May 1978); and "Air Force Tried out Controversial Planes," *Beaver County (PA) Times* (7 May 1978).

94. Van Dyke, "Sidewinder Program Review," 5028; Tissot and Hildreth, *AIMVAL Final Report,* 1: sec. 5, 1; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5208. Having served as the commander of the Air Force's first operational F-15 wing, Welch recalled that when the Eagles started flying against the AIM-9L threat, "all these tactics, all of our experiences, everything we've taught each other goes out the window." L. Welch, interview, 10 July 2012. See also "DACT Lessons Learned," Memorandum for Record, in *History of the 27th Tactical Fighter Squadron, April–June 1976, History of the 1st Tactical Fighter Wing, April–June 1976,* 1, AFHRA K-WG-1-HI.

95. Hildreth letter to TAC/CV, "AIMVAL Final Report Recommendations," 28 November 1977, AFHRA 168.7339–79; Munger, "Advanced Medium-Range Air-to-Air Missile," 436–54; Bond, "Advanced Medium Range Air to Air Missile," 348–49, 358; and Perry, "Impact of Technology," 5, 41.

96. "[Gen. Wilbur Creech] seemed to feel that the JTF underestimated [the identification problem] by an order of magnitude. . . . Further he was adamant that present IFF equipment, procedures, reliability and development were inadequate." TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings." On subsequent EID efforts, see Werrell, *Chasing the Silver Bullet,* 70–71.

Lt Col Steven Fino, USAF

Colonel Fino (PhD, Massachusetts Institute of Technology) is currently assigned to the analysis and integration section of the Office of the Secretary of Defense, Cost Assessment and Program Evaluation. His duties include organizing and leading independent analysis of various Department of Defense investments and their ability to meet evolving strategic requirements. Before he arrived at the Pentagon, Colonel Fino was the commander of the 99th Expeditionary Reconnaissance Squadron (U-2 and E/RQ-4) in Southwest Asia. He also served in the Air Force Chief of Staff's Strategic Studies Group, and he was the F-15C operational test division commander at Nellis AFB, Nevada. The colonel is a graduate of the School of Advanced Air and Space Studies, the Air Force Institute of Technology, and the Air Force Weapons School (F-15C). His book, *Tiger Check: Automating the US Air Force Fighter Pilot in Air-to-Air Combat, 1950–1980*, is scheduled to be published by Johns Hopkins University Press in the fall of 2017.

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Break the Paradigm

Prepare Airpower for Enemies' "Most Likely Course of Action"

H. Mark Clawson

After 15 years of fighting in a global conflict with radical Islamic terrorists, the United States finds itself facing the probability of a continuing struggle against asymmetric attacks from an enemy unwilling or unable to face it in open conventional battle. However, more than a decade and a half after the events of 11 September 2001 (9/11), little has changed in the way the USAF envisions the future and positions its force to meet the needs of twenty-first century warfare. Careful examination of the Air Force senior leadership exposes their paradigm for preparing the force for future conflict—but is their paradigm correct or are we developing a force without understanding the way warfare has changed?

Next-generation (next-gen) fighter proponents continue to reign supreme in the halls of senior USAF leadership and strongly influence USAF strategy and major weapons acquisitions. Air Force senior officials place a *singular* focus on low probability, worst-case conflicts with advanced state actors such as China, North Korea, or Russia. This focus drives the USAF to overemphasize procurement of costly next-gen fighters like the F-22 and F-35, at the sacrifice of a balanced force of varied and proven aircraft capable of covering a broad range of possible and more likely scenarios. The overemphasis on next-gen fighters also ignores anecdotal evidence of thousands of engagements in years of fighting on the post-9/11 battlefield against less technologically capable enemies. While there are valid age and maintenance concerns with the current fighter fleet, the most troubling aspect of next-gen fighter proponents revolves around an outdated twentieth-century paradigm of joint warfare. Many advocates of the next-gen fighter and the advanced bomber mistakenly oversimplify twenty-first century conflict and the strategic nature of its complex battlefields, emphasizing accurate bomb delivery against a sophisticated integrated air defense as the sole sufficient contribution for air-to-ground operations. Holding an outdated paradigm, USAF leadership's driving singular focus is on the development of the next-gen fighter which ignores, and may increase, a serious gap in Air Force capability. The essential *missing* "mission effect" *most commonly needed* in our *most likely* wars of the twenty-first century, an effect I'll call the "gunship effect,"[1] is misunderstood and remains marginalized by the USAF and underfunded by Congress. These assertions will be supported as the central argument develops.

Air superiority and the ability for US airpower to operate on the battlefield is still primary in importance for the joint force air component. The USAF must maintain the ability to project and protect air assets to leverage airpower for the war fighter. However, the USAF next-gen fighter paradigm concludes it must develop a force built around faster, stealthier, and more high-tech fighters to thwart enemy competition. The problem with this model is twofold: first, it assumes the enemy we face will fight us in classic conventional force-against-force battle; second, it assumes our adversaries have, or will increase, their capability to a point of making our current generation of fighters inadequate and obsolete. While air superiority is of prime importance to leverage airpower, even optimistic assessments of enemy force capability find few enemies capable of matching our current generation of fighters, especially with the mixture of the already built F-22 (approximately 187 aircraft).[2] Furthermore, continuing a *sole focus* on the F-35 (current USAF requested buys are 1,763 aircraft[3] at $160 million a copy)[4] misses the important problem of winning our nation's most likely foreseeable conflicts. Our reliance on pre-9/11 and perhaps even a pre-1964 view of warfare and establishing an Air Force primarily optimized to fight high-tech air foes with a specialized, "more advanced than any enemy" fighter remains deeply rooted in USAF culture. This paradigm may posture our Air Force to dominate the air while watching helplessly as we lose the war, placing all eggs in the next-gen fighter basket. The plan to purchase large numbers of the F-35 aircraft, and retire most, if not all USAF, US Navy and Marine Corps air-to-ground fighters is needlessly risky and ill-conceived. Never in aviation history has a single aircraft type been a true jack-of-all-trades aircraft, able to conduct air-to-air, denied area interdiction and close air support (CAS) roles with sufficient capability to meet the joint force needs. We must prepare for *both* the enemy's worse case and most likely courses of action. In short, USAF leadership's focus and development of a force built around defeating a "sophisticated state enemy" in a conventional force-on-force fight must be *balanced* with the missing gunship effect or we invite strategic failure in the most likely future conflicts.[5]

In current USAF circles, air interdiction, and specifically CAS, remains a distant second to air superiority focus in terms of design criteria for its high-dollar, next-gen fighters. While the USAF strategic ability to interdict deep targets in a Cold War-style battlefield was greatly enhanced by the B-2 more than two decades ago, CAS continues to lag in development, languishing as part of the outdated USAF paradigm. Conventional USAF thinking has not adequately distinguished our ability to find and fix ground targets from the act of accurate weapons delivery. Instead, USAF design envisions a military only, uncluttered battlefield with easily identifiable targets where collateral damage (CD) plays an insignificant role. In simplest terms, our air-to-ground fighters remain a highly accurate bomb dispensing force. While the advanced cockpit and helmet of the F-35 lends to a better "human factor" assessment of data, in practice, it adds little to our ability to find, fix, and efficiently strike the target with our current complement of F-series USAF and Navy aircraft.[6] The USAF's outdated and singular focus on next-gen fighter development is compounded by a misunderstanding of its air-to-ground role, causing aircraft, sensor, and weapon system procurement errors. This mistaken paradigm makes decisions like the A-10 retirement seem like a suitable course of action despite an ever-increasing need for its unique attributes and mission capabilities.[7] The blinders are strong, and the joint force needs are misunderstood by USAF senior leadership. Gen Gilmary Michael "Mike" Hostage III, the Air Combat Command (ACC) commander, singled out the A-10 for its inability and lack of usefulness on today's battlefields like those found in the Middle East and Syria as examples in 2014, only to have the A-10 redeployed to Iraq for use in Syria less than a year later for just such a purpose.[8] Indeed the animus of senior leadership to suggestions their paradigm is off target from their own very combat-hardened and tested force was again shown when the ACC vice commander, Maj Gen James N. Post III, opened the January 2015 annual weapons and tactics symposium, a collection of the USAF's best tactical experts, by warning officers that praising the A-10 attack plane to lawmakers amounted to "treason."[9] Many USAF planning and procurement cycles have not resolved an appropriate paradigm for the twenty-first century battlefield and US strategic conflict because too many USAF senior leaders still hold an *outdated model* of war in the modern world.

Current conflicts point the way for future enemies of America to fight against our conventional force. Whether tackling a terrorist organization or state actors, the United States will likely face an embedded foe, intermingled with civilian noncombatants. This makes enemy identification difficult with either the existing air-to-ground conventional Air Force (CAF) or the continued acquisition of the F-22 or F-35. Neither significantly advances current status quo in our ability to deal with the twenty-first century battlefield when it comes to finding and fixing the target and engaging with quick, persistent, and appropriate yield weapons. With current capabilities, positive identification (PID) is often difficult for air assets and remains one of the USAF's most troubling weaknesses. Even when the enemy's PID is gained, our available weapons and air platforms lack the ability to attack quickly using the low-yield, low-CD engagements our leaders in Washington expect and public scrutiny demands. The PID and weapons effect weakness cannot be resolved until we break our paradigm and focus our procurement on a glaring gap in our ability to provide gunship effect on a large scale to the joint force on today and tomorrow's battlefield.

Gunship effect is one of the most important, yet misunderstood mission effects the combined joint warfighter needs from its air arm. Despite small overall numbers (currently 28 aircraft in the DOD in just two Air Force Special Operations Command [AFSOC] squadrons), the AC-130 gunship has remained deployed to combat since 9 October 2001, covering both Operation Enduring Freedom (OEF) through today and Operation Iraqi Freedom (OIF) in its entirety. Understanding the high demand for this low-density air asset is important to understanding the way warfare has changed. Gunships fly every night and routinely fire their weapons in battle. While operational needs have changed in both theaters, in the author's experience, gunships have historically shot between 10 percent (low) and more than 30 percent (high) of their sorties in OEF from October 2001 through May 2011, and similarly in OIF from March 2003 through August 2008, making the gunship perhaps the highest weapon-engagement-to-sortie-ratio aircraft in the post-9/11 combat in both theaters.[10]

Why are the gunships, a small percentage of the total force, performing such a large number of CAS engagements? Two significant traits stand out: Gunships provide enhanced situational awareness (SA) and low-yield, quick, persistent, and accurate fires in one combined platform. The gunship effect best meets the ground customer, and indeed, the joint force commander's need for battlefield SA. There are several interrelated qualities the AC-130 uses to amass SA. Unlike most CAS and intelligence, surveillance and reconnaissance assets—the AC-130 has two visual sensors instead of a single sensor, in the form of thermal and television cameras. Unlike remotely piloted aircraft (RPA), these visual sensors work in concert with a pilot's wide field of view and use of night vision goggles (NVG). For the AC-130U, the visual sensors provide video through two sensor operators, while a fire control officer (FCO) directs the sensors and the navigator, trained in tactical navigation and battlefield coordination, communicates with ground parties. This allows for multiple crew positions watching multiple cameras and fields of view. Each visual sensor, operating independently, can zoom in to examine individual personnel movement while the pilot on NVGs, unencumbered by the need to drive the sensor balls himself, provides a wide field of view "slaving" of the sensors to activity on a large scale, instantaneously over an area the size of a small city. This combination of multiple eyes on an objective and multiple humans overlapping their eyes allows the gunship to overcome what other one- or two-person fighters cannot provide: extra brainpower able to track a fluid battlefield environment. While RPAs can add additional personnel to view their single sensor, the lack of an additional sensor and the pilot wide field view greatly restricts RPA SA, especially on a cluttered and dynamic battlefield. Although most fighter aircraft now have one visual sensor, their single all-in-one sensor/operator/pilot is limited in what the pilot can see, hear, and digest. The pilot becomes task-saturated with combined flight and mission duties, restricting the ability to process and act in a cluttered battlefield. While the F-35 is leveraging the latest technology to ease the load, pilots still will be limited by the physical qualities and speeds one human can process information while flying a high-speed or "fast CAS" fighter. A single human focused on a single view is quickly overwhelmed and overly focused on a single target during fluid situations in urban environments or cluttered terrain.

In addition to multiple eyes, the gunship uses multiple ears and data feeds. With more than six radios and multiple personnel able to communicate on different channels *simultaneously*, multiple ground, air, and command and control elements feed the gunship's SA of the battlefield with verbal and data cuing. The pilot and FCO can *listen* to all incoming radio traffic simultaneously from the ground party, other aircraft, and command and control channels, by delegating *outgoing* radio calls to the navigator, copilot, and electronic warfare officer. This enables the pilot and FCO to build their SA in ways no fighter pilot/radio operator can match. While RPAs have taken over for the fighter in many circumstances due to longer loiter time, current RPA views are restricted by its single sensor combined with minimal radio contact (single channel) often restricting their SA to a single contact point literally called "steady stare" by the warfighter. In a real-world environment, this often causes a loss of SA in the fluid dynamic situation of a cluttered or urban environment. Distributed duties and crewmembers working in parallel is a hallmark of gunship operations and the key attribute when combined with multiple visual aids and communication paths allowing its crew to maintain exceptional SA in a fluid, dynamic situation.

As an example of the differences between fighter/RPA coverage and AC-130 coverage, picture an anthill before and after it is kicked to understand how a single sensor from a single/dual manned aircraft or RPA has limited SA. It is like viewing the anthill through a straw. Although you can see very clearly the few ants in your field of view, just outside the "straw-view" are multiple avenues of approach and additional anthills nearby. The gunship maintains better SA by combining its two visual sensors and the pilots' wide field-of-view, having multiple humans with access to the multiple views, using separate scans tracking both close-in action and the avenues of approach and listening to radio chatter from multiple players. This ability of finding and distinguishing the enemy activity from noncombatant activity is strategically important in today's fight, yet the USAF's old paradigm of a conventional battlefield ignores or minimizes the clutter found on a modern battlefield. We fight an unconventional foe who hides their activities among the general populace we endeavor to positively influence. CD concerns cause our troops to move into close contact before the enemy shows its hand and restricts aircraft with less situational awareness from being brought to bear. The United States must combat the enemy's ability to blend with civilians and limit our ability to detect and thwart their activities. In future conflicts like a fight against Iran or even a North Korean invasion of South Korea, the Air Force *must* develop the ability to positively identify enemy forces or activities and strike or suppress those activities while protecting intermixed noncombatants or close-in friendly forces. Finding, fixing, and tracking enemies is overly simplified in the outmoded USAF paradigm. Combat identification, as it is often called, means sifting through a myriad of noncombatant and extraneous activity and is among the most difficult challenges of today's and tomorrow's battlefield. The most conventional opponent will certainly fall back on asymmetric attacks as their force-on-force fails, much the way Sun Tzu predicted, and a force without gunship effect will quickly become paralyzed.[11] One only needs to look at ISIS and Syria to recognize this problem.

Although most gunship missions start with the ability to provide an unsurpassed SA of the battlefield, their unique combination of strike attributes makes them one of the most requested, used, and lethal strike platforms. While many strike assets are available, gunships combine several key characteristics making them more desirable than any strike platform on today's battlefield or any advance the F-35 might make: quick and persistent fires; low-yield weapons for reduced CD; and the ability to fire close to friendly forces.

The AC-130U and AC-130W use guns as "direct, side-firing" aircraft. The gunship's attack orbit and observation orbit for these weapons are the same. The orbit that other ground attack assets now use when viewing the battlefield with their sensor is often not their attack profile. Run-in to the target of some form is often required to dispense ordnance. This difference is highlighted when comparing any forward firing asset attack video versus a gunship video. When forward firing attacks from fast CAS are made, the time between receiving the fire mission from the joint terminal air controllers (JTAC) and munitions on target can usually be measured in minutes, and reattacks often require realigning for another run. (Reattacks often are measured in more than a minute and can be problematic as the sensor often reaches gimbal limits during the attack and must reacquire the target(s), who has often moved, or blended into the local populace). The gunship guns are direct, side-firing, providing quick, highly accurate, and repeatable engagements as the relative position of the target stays fixed in the aircraft orbit or "pylon turn." With roughly 8–10 seconds time of fall, initial attacks on average take less the 30 seconds[12] to impact on target, and reattacks are as simple as pulling the trigger again and again throughout the orbit as the targets are tracked and destroyed. The inherent ability for a side-firing aircraft to quickly, accurately, and repeatedly attack targets and maintain SA as the situation progresses is unmatched in airpower, yet historic air prejudice against side-firing aircraft belies its success and unique ability to provide continuous persistent fires during close contact with enemy forces. While the USAF has developed newer weapons that allow a level of "off-axis" firing, the response time to impact and repeat attacks often remains measured in minutes and the fighter must work to reacquire the target and maintain SA. With the gunship side-fire, the enemy has no chance to regroup and continue attacking, as is often seen during run-in attacks from other aircraft that leave gaps between ordnance impacts.

The gunship also has selectable low-yield weaponry. The AC-130U gunship's largest munition is a 105 mm direct-fired howitzer round. With a projectile weight of approximately 33 pounds,[13] this munition is an order of magnitude smaller than most of the USAF's conventional bombs. The gunship's smaller calibers are often used when the 105 mm is not necessary. In many cases the 40 mm or 25 mm munitions of the AC-130U and 30 mm of the AC-130W provide only small single-digit explosive weights against individual personnel.[14] Consider some of the thousands of gunship engagements during OEF and OIF, replaced with a 2000-lb., or even smaller 500-lb. bombs. Gunship crews practice a simple credo: when prosecuting targets, don't create more future enemies while killing the ones you are targeting. Unfortunately, the current USAF paradigm holds accuracy as the dominant value of air-to-ground operation and the most important factor in the design of its current and next-gen fighters, weapons, training, and employment. Despite their accuracy, even the 500-lb. bombs typically carried by today's fighters dropped with single-digit-miss distances are often not appropriate in a twenty-first century fight, especially in urban operations when the targets are individuals mixed in with the civilian populace.

In today's fight, CD is a major center of gravity, as we attempt to gain public support with the local populace our enemies attempt to control and influence. To this end, RPAs and many rotary wing aircraft employ the AGM-114 Hellfire missile. At approximately 100 lb. of overall weight with an explosive payload of 20 lb.,[15] it is larger, yet comparable to the 105 mm Hellfire missiles are frequently used in a strike role, instead of bombs because of their comparatively low yield. However, Hellfire employment itself can still take a minute or more, depending on the platform carrying it. For example, on a combat employment during OIF surge operations, a ground element requested an air asset target a small building with Hellfire. Despite being on target, the air asset asked for four minutes for setup, and the engagement eventually took almost eight minutes. The AC-130U overhead was then asked to target a nearby small building. The building was destroyed a mere 13 seconds after receiving clearance for fire.[16] All the while troops were within 200 meters of the enemy position taking sporadic fire. It's no wonder ground forces love the quick reaction of a gunship, especially when in direct contact with the enemy!

The final strike attribute necessary for CAS is the ability to fire very close to friendly forces. CAS is defined in joint regulation as "air action. . . against hostile targets that are in close proximity to friendly forces."[17] For decades the distance associated with CAS was 1 km from friendly troops. This basic definition of CAS and the USAF paradigm lumps all CAS together, and many munitions dropped in OEF and OIF could be classified as CAS. However, not all CAS is created equal and is today often conducted at very short distances to both friendly forces and CD concerns. Distances of less than 200 meters to friendlies are common for gunship engagements. In 2007, a gunship crew was awarded Distinguished Flying Crosses for firing less than 15 meters from prone friendly forces in the open, pinned down by enemy personnel.[18] In July 2009, an AC-130U shot multiple targets in mountainous terrain on one particularly harrowing mission, at enemies inside 35 meters and as close as 10 meters to friendly forces.[19] Gunships are routinely used within the "danger close" distances most other air assets rarely cross as ground forces trust the gunship and request the danger close shots when engaged in close-in combat. Even when friendly forces are not within danger close distances, CD concerns restrict most air assets because of the potential damage, as ground forces call for "0 CD estimated" engagements. The exception has been the AC-130 that performs this kind of CAS routinely. Performing such CAS quickly and accurately with low-yield weapons is integral to the twenty-first century fight as it negates the side effects CD can cause to tactical missions and strategic messaging. AC-130s, helicopter gunships and the A-10 often perform this type of CAS, while fast CAS and bombers of our CAF are only used for such CAS when these assets are not available and there is no other option. If the USAF were to poll the JTACs who have more than 50 engagements in combat (which we now have in large numbers), the overwhelming predictable conclusion would indicate gunships and A-10s are performing a variation of CAS the rest of the fixed wing assets cannot provide or do so only in extreme circumstances when gunships (first choice) and A-10s (second) are not available. All other fixed-wing assets would be a distant third—*and the F-35 will do nothing to alter this reality significantly*.

AC-130 gunships have been used in virtually every major (and minor) battle since 9/11. Unlike some SOF aircraft, the gunship has often worked conventional as well as SOF missions. From nightly coverage of Marines in the battles for Fallujah, Iraq in 2004 to working individual SOF high-value targets, gunships are used because ground commanders highly value the gunship effect—SA and quick, persistent, low-yield fires. Between 9/11 and 2011, gunships flew roughly 65 percent of their total annual flight time in direct combat.[20] Total annual time includes all home station training, initial student training, test and evaluation, exercise support, etc. To provide perspective, if the USAF had doubled the number of gunships (and their total flight time) and correspondingly cut the ratio of combat flight hours to all other flight time in half, the gunships would still have one of the highest ratios (roughly 30 percent) of combat flight hours per total hours flown since 9/11.

Although the AC-130J is now being fielded by AFSOC, it will only replace the AC-130U one-for-one. Why not build more gunship effect into the USAF? Part of the answer is who most directly benefits. First, the joint conventional ground force needs more gunship effect. If the gunship were provided with its long-loiter SA and quick, persistent CAS, the ground force commander could directly cover his most dangerous areas of responsibility with a CAS asset *proactively*, instead of waiting for CAS response to a troops-in-contact situation. This would allow ground commanders to take on direct action missions against preplanned and intelligence generated targets with gunships overhead, building the ground forces situational awareness and decreasing risk by making the battlefield more difficult for the enemy to effectively operate undetected.

While the US Army and Marines could greatly use more gunship effect, they lack the authority and funding to build more gunship effect. The USAF is primarily tasked and resourced for airpower development, and the traditional USAF views the gunship effect as a "niche need" or "niche mission," still considering current warfare and today's battlefield an aberration, much as it was viewed in Vietnam. In Vietnam, the inadequacy of high-dollar air superiority fighters like the F-4 (heralded much like the F-35 as a do-it-all fighter) to provide this gunship effect on the battlefield, led to the use of the A-1 Skyraider, similar in mission to the A-10, and the creation of the AC-gunships (AC-47, -119 and finally the AC-130). However, the USAF fought to divest and retire such aircraft, with only special operations managing to save the AC-130 and improve on the original as a special operations asset. On today's battlefields, JTACs and fire direction personnel requesting CAS, use fast CAS as additional ISR, much as they do an RPA, loading the air stack with "eyes." If fighters are used to engage enemy positions by the ground force, it's often as a last resort, when AC-130s, Hellfire-shooting RPAs, or even 30 mm strafing A-10s are unavailable. Even early in the post-9/11 conflict, the changing nature of warfare was highlighted at the 2004 USAF Central Command weapons and tactics conference. Representatives of tactical communities from all USAF specialties in the combat zone got together with US Central Command ground fire support teams.[21] JTACs described fighter weapon employment in OIF as "when I have a big building to break." Otherwise, AC-130 gunships or helicopter gunships were preferred. Ironically, 40 years after Vietnam, the gunship, like the A-10, fights the same USAF paradigm, in a world where its mission effect is needed even more.

There is another factor precluding the development of more gunships. While the USAF pays for the original C-130s, US Special Operations Command (SOCOM) funds all aspects of the C-130 gunship modifications, training, and employment. The cost of gunship operations consumes a large portion of the annual SOCOM flying budget. Bottom line: USAF has the money but wants to spend it on aircraft like the F-35, and SOCOM owns the gunship mission as it currently exists and can't break the SOF budget to support conventional ground force missions, let alone afford to research and develop follow-on systems in anything similar in scope and breadth to the F-22/F-35 programs. Should we build more gunships capacity? An honest, critical analysis of plentiful combat data provides a clear and unambiguous "yes." Moreover, an investment now will also allow for additional gunship capacity in the future.

It is important to understand, while the gunship effect is necessary today and in every conceivable future conflict, the gunship itself and the C-130 platform on which it rests, has many limitations. First, the modern C-130 is still primarily the same platform it was 50 years ago when it was first designed. It is essentially limited to night employment because daytime survival, based on aircraft limitations and the AC-130 employment profile, makes day employment extremely hazardous without serious improvement to defensive systems. Current C-130 platforms in "gunship guise" are '"maxed-out" aircraft, often flying at maximum gross weight for a standard C-130. With almost 200 times the aerodynamic drag of a basic equipped C-130, the AC-130U, in particular, is underpowered and labors tremendously just to reach its relatively low employment altitudes. Such hard use of the maxed airframe and excess operations tempo has caused tremendous wear and tear and shortened the platform's estimated lifespan, expediting the need for the follow-on AC-130J. The plan to build a replacement gunship looked very little at modern options for providing the gunship effect. Even today, it may make near-term sense to convert existing larger lift capacity aircraft like a civilian cargo or passenger jet, or even the USAF's C-17, into gunships. With more thrust and weight carrying capacity, such aircraft could move faster to/from the objective, with the ability to go higher, outside of the threat and provide even longer loiter times, add visual sensors or weapons and provide better gunship effect, but such ideas were seen as unnecessary or too costly to the USAF leadership and were abandoned without careful consideration.

The United States should procure more gunships in the short term and focus on the research, development, and procurement of a 24/7 gunship effect. However, USAF leadership is so entrenched in its paradigm, that despite 15 years of evidence and experience from its war fighters, it is unwilling to give up *any* of the 1,763 F-35 planned aircrafts to save the unique, highly effective and much less costly A-10. The USAF next-gen proponents are mirrored by strong F-35 political support and incentive from a civilian industrial base with thousands of jobs based on F-35 production. The problem is, however, *our world has changed*, and with it, the needs of modern warfare. While the USAF focused on preparing its force for the enemies' most dangerous course of action, it was ill prepared, developed, resourced or trained to fight the war in Vietnam. Today, in much the same way, it still holds to an outdated paradigm. This drives our F-35 procurement, focused largely on a "peer" enemy force fighting a conventional fight on an uncluttered battlefield. Even when examining future conflicts with state actors, we are unlikely to face this style of warfare beyond a few weeks—if at all.

The USAF should channel some of the energy and funds to procure next-gen fighters instead into providing the gunship effect in a modern package. Jobs lost to smaller quantities of fighter production would be replaced and gained back in building gunship effect. This may look very different from today's AC-130. It would be able to survive in both day and night routine use in low to medium threat environments, and probably have some if not all of the gunship crew removed, remotely positioning the gunship team out of harm's way, able to move their airborne office to an actual one! It would improve its sensor suite and weaponry taking the gunship effect to the next-gen level, providing improved SA and quick (less than 30 seconds), persistent (fires gaps less than 15 seconds) and accurate fires with selectable yield (able to target individual personnel within 10 meters of CD concerns). It would meet the *most likely* twenty-first century adversary head on against their method of employment, thwarting their ability to hide in plain sight, hug friendly or noncombatant personnel, and force us to risk public outcry over CD. Sadly however, such dreams remain unrealized "what ifs." The USAF continues to rely on a hodge-podge of multiple aircraft designed to do other things being pressed into service to provide a poor man's gunship effect. USAF leadership equates placing a sensor pod on a B-1 or B-52 creates an acceptable alternative to the A-10 or AC-130.[22] While improving the bomber's usefulness, it does not replace the situational awareness of the A-10 or AC-130, due to its flight parameters, weapons types and delivery modes. One only needs to look at a recent friendly fire incident of a B-1 trying to conduct a less demanding version of this type of modern CAS in 2014 to see the unfortunate result of missing gunship effect on platforms not built to meet the battlefield CAS of today or tomorrow.[23] History has shown that reacting to changes in warfare rather than proactively anticipating those changes can *lose* wars. As Gen Guilio Douhet said in *Command of the Air, 1921*, "Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur."[24] Unfortunately, many are still trying to fight the "last good air war."

In future conflicts, even in a conventional fight against a strong state actor, it is likely US strength and airpower quickly places the enemy at a disadvantage. Soon, however, the limitation of USAF conventional air force shows. The "niche need" for high-tech advanced fighters is gone after the first few weeks or even days, as the enemy cannot defend against current US capability in the form of USAF F-15/F-22 and Navy F-18s. As the fight continues, PID of enemy forces becomes more difficult as the enemy begins to hide, often within the local populace. US political will is strongly adverse to CD. Public support erodes as CD mounts when we must repeatedly drop overly large bombs on *individual* enemy combatants imbedded in civilian populations, (the overwhelming majority of targets in post-9/11 asymmetric battles), regardless of the target's legitimacy or our accuracy. Without 24/7 gunship effect, our ability to observe and discern enemy activity across the critical areas of the battlefield is greatly hampered, and our enemy adopts tactics such as the use of improvised explosive devices (IED). While the IED itself is hard to observe once placed, the enemy activity associated with placing the IED is much more difficult for the enemy to hide with adequate gunship effect. Even today, ground commanders are attempting to find such activity with hundreds of small RPAs. If we caught and destroyed even 10–20 percent of the enemy implanting IEDs, the enemy network and support chain would be greatly damaged and hampered, if not destroyed.

We must carefully weigh the necessity for advanced air superiority fighters like the F-22 and advanced multirole fighters like the F-35 over the current fleet. Their need is the true niche need—when needed, nothing else will do, but once the high threat obstacles are eroded, other purpose built assets are often better suited to the "long war" that inevitably follows. The acquisition of next-gen fighters should be *balanced* with tried and true CAS of the A-10, and a 24/7 gunship effect, mandatory and in constant demand on any conceivable future battlefield. In current and future wars, the gunship effect could protect our ground forces and provide them freedom of movement. It would ensure our own civilian leadership's confidence and garner public support in the strategic concern over CD, denying the enemy the ability to drastically affect public opinion and national resolve. Most importantly, it will provide the joint force unmatched SA of the battlefield and, when the fight gets close-in, it will be the ground force's best friend. The USAF must change its paradigm of airpower and future war. It must reconsider the amount and likelihood of the enemy's most dangerous course of action and rebalance toward the always needed gunship effect, useful in the enemy's most dangerous course and absolutely critical in enemy's most likely course for the twenty-first century. With such focus, we can turn out gunships for today's fight and bring American design and ingenuity to bear, providing next-gen gunship effect and rout the enemy of the future. ✪

Notes

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11. Sun Tzu, "The Art of War," 12, items 24, 25, 26, 28, with special emphasis on 30 and 33 of chapter "Weak points and Strong Points," Kindle edition, trans. Lionel Giles.

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19. From the author's personal copy of denied recommendation for DFC for one of his squadron crews in operation enduring freedom, 16 July 2009.

20. AC-130U flight percentage based on multiple reviews by author during routine inquiries over the 10 years post 9/11.

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H. Mark Clawson

Mr. Clawson is a course director with the United States Special Operations Command (USSOCOM) Joint Special Operations University at MacDill AFB, Florida. From 1995–2011, Mr. Clawson was a 4th Special Operations Squadron (4th SOS) pilot and then retired as a senior evaluator pilot—one of two pilots to surpass 4,000 hours in the AC-130U. He was the 4th SOS tactics chief as one of Air Force Special Operation Command's (AFSOC) earliest USAF Weapons School graduates. As the Joint Special Operations Command J35/Joint Operations Center chief, Operation Allied Force–Kosovo, he integrated seven AFSOC and two Air Combat Command combat search and rescue squadrons from operating locations in four nations. He was one of six original AC-130 aircraft commanders picked to take the fight to the enemy, 9 October 2001, opening Operation Enduring Freedom (OEF). As the 4th SOS expeditionary squadron (4th ESOS) operations officer, Operation Iraqi Freedom (OIF), he oversaw the buildup and initial stage of the Battle of Fallujah in the spring of 2004, and commanded the 4th ESOS during OIF "surge operations" in 2008–2009. He was the US Special Operations Command Europe Special Operations Liaison Element (SOLE), chief of air operations for three years and the founding SOLE member to the NATO Response Force. Mr. Clawson returned from OEF in May 2011, making the final tallies for his career—six contingency (four in Korea) and 13 combat deployments, 1,463 combat hours, and more than 230 combat sorties during nine combat campaigns in three conflicts.

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Critical Thinking Skills in USAF Developmental Education

Col Adam J. Stone, USAF

Introduction

In the September 2015 Air Force Future Operating Concept (FOC), the Secretary of the Air Force (SecAF) and the Chief of Staff of the Air Force (CSAF) identified the need for:

> . . . Airmen who display critical thinking in complex situations, are educated and trained appropriately, and ultimately are empowered and trusted to execute. . . This foundation is built by recruiting Airmen with indicated potential for critical thinking and adaptive behavior; screening for these attributes will require new metrics and forms of evaluation.[1]

However, no published or publicly available data exists to address (1) the current state of critical thinking (CT) skills in the Air Force, (2) a recommended metric by which to measure CT skills, and (3) whether the existing state of CT skills satisfies the AF FOC's intent. Using the Watson-Glaser Critical Thinking Appraisal (WGCTA), I addressed these points by focusing on the active duty (AD) AF students attending Air Command and Staff College (ACSC), School for Advanced Air and Space Studies (SAASS), and Air War College (AWC) in Academic Year (AY) 2016. These three populations within Air University (AU), through the developmental education boarding process, provided a representative sample of the top 20 percent of AD AF officers for AY16.[2] As a point of clarity, I explored the state of CT skills as an indicator for the SecAF and CSAF, not whether, or how much, AU integrated CT into the curriculums.

Since before 1997, the AF has identified CT as a key skill,[3] yet the AF has not established any metrics to provide a baseline assessment of CT. Several AF studies identified the need for CT, but the authors limited the recommendations to ways to improve CT programs without first assessing the state of CT skills.[4] This foundational study, through a quantitative methodology, provided a baseline assessment of CT skills from the sample population.

Thesis

I used the WGCTA to measure the CT skills of a sample of AD AF attending ACSC, SAASS, and AWC to establish the current baseline of CT as represented by the top 20 percent of AD AF officers in AY16. My research answered the following four research questions:

- What was the current state of CT skills as measured by the WGCTA?
- Using t-tests, were there any significant differences between all three schools?
- How did the sample's performance compare with a graduate degree normative group?
- What CT instructional methods could AU apply to in-residence professional military education?

After approaching these research questions, I could assess the following hypotheses:

- H_0—There is no statistically significant difference in the CT skills of intermediate developmental education (IDE) and senior developmental education (SDE) students.
- H_a—There is a statistically significant difference in the CT skills of IDE and SDE students.
- H_b—There is a statistically significant difference in the CT skills of ACSC and SAASS students.
- H_c—There is a statistically significant difference in the CT skills of AWC and SAASS students.

Literature Review

As identified in AF Doctrine Document 1–1, senior leaders expect Airmen to think critically: "Education provides critical thinking skills, encouraging exploration into unknown areas and creative problem solving. Its greatest benefit comes in unknown situations or new challenges; education prepares the individual for unpredictable scenarios."[5] While senior leaders in the AF and DOD frequently emphasized the need for CT, they rarely provided any refined directives defining CT skills or how these skills should be measured and developed. The lack of clear directives leaves implementation to either AU or, for those not selected to attend in-residence IDE or SDE, the individual, and with limited tools for execution. The following section details the challenges of defining the construct of CT, presenting a consensus that CT skills: (1) are the product of a personal and lifelong dedication to improving the accuracy and logic of thought patterns, and (2) can be both taught and measured. Based on a comparison of CT development programs in academic and business settings, the deliberate development of CT skills in both PME and throughout the operational AF would be possible to implement.

Concept of Critical Thinking

Definitions of CT range from abstract constructs to specific, measurable skills.[6] The National Council for Excellence in CT (NCECT) approached the definition with two components: "(1) a set of information and beliefs generating and processing skills, and (2) the habit, based on intellectual commitment, of using those skills to guide behavior."[7] In comparison, Richard Paul and Linda Elder defined CT as: "the art of analyzing and evaluating thinking with a view to improving it."[8] Lewis Vaughn provided a succinct working definition for the construct of CT: "the systematic evaluation or formulation of beliefs or statements, by rational standards."[9] Goodwin Watson and Edward M. Glaser, the creators of the survey instrument used in this study, viewed CT as:

> . . . a composite of attitudes, knowledge, and skills. This composite includes: (1) attitudes of inquiry that involve an ability to recognize the existence of problems and an acceptance of the general need for evidence in support of what is asserted to be true; (2) knowledge of the nature of valid inferences, abstractions, and generalizations in which the weight or accuracy of different kinds of evidence are logically determined; and (3) skills in employing and applying the above attitudes and knowledge.[10]

While even this small sample of available CT definitions provides additional and valuable insight, the focus remains on a systematic evaluation of an individual's thoughts by rational standards. Although simplistic, Vaughn's definition provides the best balance between the scope of the concept and being sufficiently succinct for use in everyday discussions around the AF.

While CT is a vital piece of the spectrum, it is not the only form of thinking. When discussing CT, Airmen frequently blur the lines between CT and creative thinking.[11] Both are important, and they complement one another; however, creative thinking is "resulting from originality of thought; having the ability to create or produce; having or showing imagination and artistic or intellectual inventiveness; stimulating the imagination and inventive powers."[12] One must create the idea before it can be scrutinized with critical thinking. The two forms of thinking work in concert, but CT focuses on systematic evaluation based on rational standards.

With this foundation for the concept of CT, one can identify skills with more specificity for purposes of direct comparison. As tested in the WGCTA, Watson and Glaser delineated the five skills of CT: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments (see Table 1).

Table 1. Definitions of WGCTA skills

Critical thinking skill	*Definition*
Inference	Discriminating among degrees of truth or falsity of inferences drawn from given data
Recognition of assumptions	Recognizing unstated assumptions or presuppositions in given statements or assertions
Deduction	Determining whether certain conclusions necessarily follow from information in given statements or premises
Interpretation	Weighing evidence and deciding if generalizations or conclusions based on the given data are warranted
Evaluation of arguments	Distinguishing between arguments that are strong and relevant and those that are weak or irrelevant to a particular question at issue

Source: Data adapted from Goodwin Watson and Edward M. Glaser, *Watson-Glaser Critical Thinking Appraisal: Manual* (San Antonio, Texas: Psychological Corporation, 1980), 2.

Measuring Critical Thinking

Researchers have dedicated decades of study on various methodologies measuring CT. While there are somewhat intrusive and time-intensive methods where an individual has a one-on-one examination with a trained evaluator, most researchers and organizations use standardized assessment instruments. Although multiple CT tests are available,[13] the WGCTA was the most effective instrument to assess the proposed hypotheses and research questions. The WGCTA is computer-administered and has established validity and reliability, as well as normative groups based on a wide range of populations.[14] The WGCTA assesses the five CT skills through 40 multiple-choice items. Published research relying on the WGCTA is abundant, addressing the importance of CT in career fields to include emergency management, nursing, education, and intelligence.[15]

While the WGCTA itself is broken into the five CT skills, the individual test results yield three categories: (1) recognize assumptions, (2) evaluate arguments, and (3) draw conclusions. Factor analysis revealed a more repeatable and reliable assessment by combining inference, deduction, and interpretation into the category of "draw conclusions." As a new category not defined in Table 1, drawing conclusions is the act of "arriving at conclusions that logically follow from the available evidence."[16]

Professional literature, as well as the research reported in the test manual, established the psychometric qualities of reliability and validity for the WGCTA.[17] For internal consistency reliability coefficients and Standard Errors of Measurement, the

WGCTA scored a 0.83 and 2.63, respectively.[18] The two versions of the WGCTA available for pre- and post-testing options in educational and developmental programs provided split-half reliability as well.

Watson and Glaser examined the WGCTA's validity in several settings with different populations. The graduate degree normative group applied for comparison in this study consisted of 2,321 participants ranging across 38 occupations to include entry-level positions, government service, and executive leadership. Across the dozens of normative groups, with sample sizes reaching 1,699,[19] WGCTA participants at various levels and across several lines of study performed in a manner to lend criterion validity to the multiple attempts to develop CT skills in any environment.[20] Watson and Glaser assessed the construct validity, including content validity, internal factor structure, and convergent and discriminate validity, with supportive results.[21] The established psychometric qualities of the WGCTA make it a useful measuring instrument for research and programs exploring the development of CT.

Given the amount of time and research required to create and validate a survey instrument, the military should use an existing tool to measure CT.[22] AF leaders must remember the WGCTA is a single assessment and is not suitable as the sole metric for identifying critical thinkers. Some critical thinkers may possess different modalities of thinking that does not effectively translate to the WGCTA's measurement. As with any assessment of an Airman, the AF must consider the supervisor's assessment and the individual's performance.

Improving Critical Thinking through Deliberate Development

Upon measuring CT in a population, several participants will likely want to explore different ways to improve those skills. The initiative to develop CT is a legitimate endeavor for all Airmen as these skills are not static.[23] One study comparing the development of CT skills across different age groups found that "adult students do not appear to be dramatically different from their younger counterparts in terms of their reflective thinking, including their epistemic assumptions and the way they justify their beliefs in the face of uncertainty."[24] The development of CT should not be limited to just the brand-new officers and enlisted on the flight line or to the strategic-level thinkers in the Pentagon, and this development must be accomplished with the right instructors.

The importance of selecting the right faculty. When creating a CT program, the organization must know which individuals are critical thinkers before determining the faculty. Lois Magnussen's research in a nursing program suggested the CT skills of graduating students correlated with the CT skills of the instructors, even to the point of fault.[25] Students with low scores improved to approximate the instructors' CT scores and students with scores already similar to the faculty's remained roughly the same. The concerning portion of the research was the fact that the students initially scoring high in CT skills dropped and became average through the course of the multiyear program. Per Laurie Blondy, significantly higher CT skills for a nursing school faculty, when compared to the students, were critical to the success of CT development.[26] In a similar study, there were parallel themes in the difference of CT skills between uniformed police and police cadets.[27] Finally, tutors in a successful WGCTA test preparation program for teachers scored significantly higher than the students did.[28] The significant differences between the instructor and student scores in these studies suggested a successful program require a faculty with strong CT skills, and additional research conducted as part of this project suggested the talent for a successful program was already in existence at AU (see Implications).

The flexibility of the human mind. CT is not a static item such as one's intelligence quotient. Instead, people can improve CT skills at any age.[29] Conversely, CT skills are also perishable and can deteriorate if the individual does not dedicate oneself to their maintenance and improvement over time.[30] Jennifer Reed explored the potential to develop CT skills, concluding, "students in the experimental group performed at a statistically significantly higher level than students in the control group."[31] Reed also determined "age and gender do not appear to play significant roles in developing college students' critical thinking abilities."[32] David T. Moore's research[33] indicated life experience does not necessarily directly correlate with improved CT skills in the intelligence community. However, Stacy L. Peerbolte's study of disaster management professionals' CT skills found "no correlation between a participant's score and the dependent variables of age and gender. . . but positive correlation between a participant's score and the independent variables of years of education and years in occupation."[34] The impact between life experience in general versus the years of education and years in occupation warrant additional exploration, as they would indicate a higher level of CT in AWC participants when compared to ACSC participants.

The AF mission requires personnel capable of recognizing personal thought processes and making structured and reasoned analysis to reach decisions. Research supports that the AF can purposely develop CT, meeting the AF FOC's requirements.[35] Programs supporting CT development already existed around the AF in limited capacity, but these programs were typically limited to a particular set of career fields.[36] A structured holistic approach will be critical to integrate CT improvement programs into several forms of PME, both officer and enlisted. In building CT into PME curriculum, it would be desirable to measure CT objectively through a validated survey instrument and to educate faculty and mentors on educational processes for fostering CT skills.

Considerations when building the critical thinking program. Multiple programs already existed across academia to build CT skills in various disciplines such as organization leadership and nursing, with several organizations publishing outlines of the training programs as well as results. Linda Kiltz assessed "to develop critical thinking skills, students must be active learners in the learning process and they must be required to identify and solve unstructured problems using multiple information sources."[37] Paul and Elder even identified 10 intellectual standards, eight elements of reasoning, and eight intellectual traits, ultimately developing 35 dimensions of critical thought.[38] In essence, the AF needs to apply structured problem solving at PME to develop CT, generating warfighters able to operate more effectively in an ambiguous environment.

The NCECT has provided tailored CT development programs to schools and businesses for more than 30 years. Emphasizing the need for long-term sustained development of CT, business programs tended to consist of five two-day seminars covering the topics of: (1) recognizing the importance of CT, (2) using the tools of CT to make better decisions, (3) understanding the barriers to CT, (4) learning the art of analysis, and (5) learning the art of assessing thought.[39] The program "clarif[ies] what is meant by the concept of critical thinking and develop[s] practical ways to infuse critical thought into our professional work both individually and institutionally."[40] NCECT's website offered additional course structures for consideration in either building an organization's own CT program or hiring a team to visit the site and conduct the training.

Based on various searches through the AU portal, as well as ProQuest and EBSCOhost, very limited publicly available information suggested possible CT programs already in existence across the AF.[41] The Army shared the concern of poor development in CT skills and claimed CT was a vital component of effective mission command.[42] Likewise, a review of Army PME did not reveal programs specifically designed to develop CT skills. Although the AF repeatedly recognized the need for CT development, no single program existed that supported a sustained education as required in the AF FOC or as detailed by NCECT.

Understanding the concept of CT and the composite skills does not effectively transition to a general awareness of an individual's flawed decision-making. Convincing Airmen that they need to improve their methods and models is a difficult task. People will typically "remain convinced that what they are doing is satisfactory. Further, outsiders who attempt to induce change face opposition. . . "[43] Considering potential application through PME, Paul discovered three disturbing trends in an assessment of CT across multiple civilian educational institutions:

1. Most college faculty at all levels lack a substantive concept of critical thinking.
2. Most college faculty [do not] realize that they lack a substantive concept of critical thinking, believe that they sufficiently understand it, and assume they are already teaching students it.
3. Lecture, rote memorization, and (largely ineffective) short-term study habits are still the norm in college instruction and learning today.[44]

In short, a successful CT development program will require senior leadership's understanding and continued support.

In summary, CT is an obvious fit with PME and the operational AF as it is about problem solving in ambiguous situations. PME offers unique opportunities in that Airmen participate in various forms of in-residence and distance learning programs at multiple points across a career.[45] CT cannot just be a matter of an introductory course at the first PME, but be integrated intentionally throughout the PME curriculum in a holistic fashion. Finally, the AF should formally assess CT at each level of PME throughout an Airman's career to determine whether the programs are effective.

Methodology

My purpose was to identify the current state of CT skills among ACSC, SAASS, and AWC students to create a baseline, and, using a series of t-tests, determine any statistically significant differences between the three samples of students. This section covers the details of the populations used for the study, data collection, and data analysis.

Population and Sample

The intended population was AD AF officers, field grade or above, attending ACSC, SAASS, and AWC during AY16.[46] The convenience sample ($n = 133$) is detailed in Table 2.

Table 2. Participation by school

	AD AF population	AD AF participants	Percentage of participation
ACSC	295	82	28
SAASS	36	13	36
AWC	92	38	41
Total	423	133	31

The AF sends officers to schools such as ACSC and AWC if the officers' records are in the top 20 percent of a given year group. SAASS is a highly competitive advanced studies program available to officers as they complete an IDE program, such as ACSC. The three schools do not screen for CT skills specifically as consideration for attendance. The research design sampled the students when they were between three and four months into the academic programs. Conducting data collection this far into a one-year program precluded the option of a pretest and posttest assessment, exploring whether the schools developed CT skills within the course of the year. The schools' curriculums convey fundamental concepts of CT; however, none of the schools has specific programs or courses designed specifically to build CT skills. While the results of this study can only be generalized to the top 20 percent of AD AF officers, the lack of any CT screening as a prerequisite would suggest that the rest of the AD AF officer population would likely have the same or lower average scores, but not higher.[47]

ACSC and SAASS students participated in the study on a strictly voluntary basis. While highly encouraged, AWC student participation was also voluntary. Due to the small size and heavy workload of SAASS, the dean solicited volunteers who then received the link to take the appraisal at their convenience. I selected potential participants from ACSC and AWC through a simple random sampling with replacement[48] and reclaimed expired instruments as individuals chose not to take the assessment. I conducted three rounds of data collection for ACSC and two rounds of data for AWC to collect a sufficient sample.

Results

The results of this research provided a starting point for data-driven decision making regarding the integration of CT into PME as well as the operational AF to meet the AF FOC's requirements. I compared the independent variable of school affiliation (ACSC, SAASS, or AWC) to determine if there were statistically significant differences in the WGCTA scores across the three populations as well as the overall score. My research design applied descriptive statistics and t-tests to analyze the data. Table 3 identifies the mean, standard deviation, and percentile ranking, as well as minimum and maximum scores for each school. The percentile ranking was a comparison between the scores of the population compared to the graduate degree normative group, consisting of "working adults from various industries, occupations, and organizational levels who share a common level of completed education. . . the samples are not limited to students or recent graduates."[49] The graduate degree normative group consisted of 2,321 participants ranging across 38 occupations to include entry-level positions, government service, and executive leadership.[50]

Table 3. WGCTA descriptive statistics

	Mean	Standard deviation	Percentile	Mininum score	Maximum score
ACSC	27.07	6.100	36	13	38
SAASS	30.92	4.958	61	21	36
AWC	27.42	6.664	36	13	38

The t-test is an inferential statistical test "used to determine whether two means are significantly different at a selected probability level."[51] The t-tests explored any differences between (1) ACSC and AWC, (2) ACSC and SAASS, and (3) AWC and SAASS. While there were several small differences between the results of the three schools, only the difference between ACSC and SAASS was statistically significant based on a probability level of 0.05. The abbreviated results for all three t-tests are in table 4.

Table 4. Abbreviated results of t-tests for ACSC, SAASS, and AWC WGCTA scores

		Levene's test for equality of variances		T-test for equality of means			
		F	Sig.	T	Sig. (2-tailed)	Mean difference	Standard error difference
Comparisons	ACSC-AWC	.076	.783	-.282	.778	-.348	1.233
	ACSC-SAASS	1.076	.286	-2.162	**.033**	-3.850	1.781
	AWC-SAASS	1.087	.302	-1.733	.089	-3.502	2.021

Note: difference considered significant (sig.) if it fell below the .05 threshold in the grey column.

Admittedly, an analysis of variance (ANOVA) is the more accurate test for a difference between the scores of three or more populations; however, I went with a series of t-tests as my primary methodology because: (1) the comparison of ACSC and AWC was the primary focus of the research, and (2) the extremely small population of the SAASS students would not be the most reliable indicator. When I ran the ANOVA on the data set, there was still very heavy overlap in the scores of ACSC and AWC; however, the difference between ACSC and SAASS was only approaching significance with a value of .055. Additionally, the post hoc test for the ANOVA was at .725, falling below the preferred value of .8. While there are several ways to calculate the desired sample size, I certainly would have preferred a larger sample to improve the power analysis; however, sampling roughly 30 percent of each population, as reported in table 1, still served as an excellent point of departure for future research opportunities (see Areas for Further Research). While I wanted a greater sample size, and I could test the data in a couple of different ways, every way I analyzed the data showed almost no difference in the CT skills of AWC and ACSC students.

The results as plotted on a histogram (see figure 1) suggested an even distribution without significant kurtosis but with a slightly negative skew.[52] As identified in table 3, ACSC and AWC had very similar mean scores, minimum and maximum scores, and standard deviations. SAASS had a higher mean score, less range between the minimum and maximum scores, and the smallest standard deviation among the three schools.

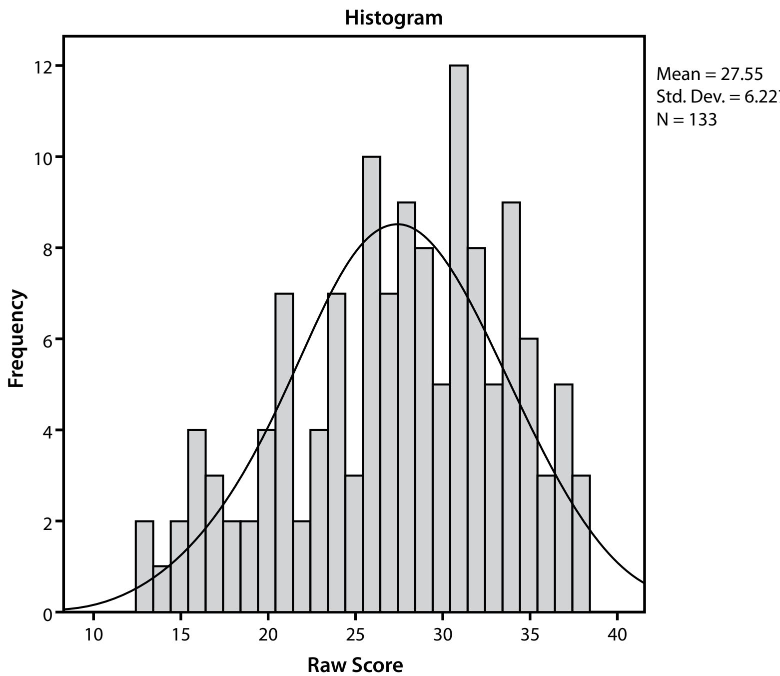

Figure 1. Distribution of raw WGCTA scores for ACSC, SAASS, and AWC (combined)

Discussion

Applying t-tests and basic descriptive statistics, the data supported the null hypothesis that there was no statistically significant difference in the CT skills of AD AF students attending the in-residence ACSC and AWC programs in AY16. More specifically, there was no statistically significant difference between the total scores or across the three individual skills of (1) recognizing assumptions, (2) evaluating arguments, and (3) drawing conclusions. However, SAASS scored significantly higher than ACSC per the t-test and reflected the smallest standard deviation across the schools. The results plotted as a normal distribution without noteworthy kurtosis and a slight negative skew. The average scores of the ACSC and AWC students both ranked at the 36th percentile when compared to the graduate degree normative group.

Implications

In accordance with the AF FOC, CT is vitally important to the success of the AF. ACSC and AWC are a sample of the top 20 percent of officers by their very selection to attend IDE or SDE in-residence. The analysis indicated the top 20 percent of AF officers at the field grade officer-level were below average critical thinkers. The methodology presented provides the AF and DOD with a way to quantitatively measure CT, establish a baseline for military personnel, and implement an educational program where improvements in CT can be clearly measured and sustained. This research does not stop with the small portion of the AF surveyed in the research. Additional research must explore building the CT skills of the junior enlisted and officers executing the tactical mission. The AF cannot afford to consider CT as an expectation or privilege for the senior leadership; it is vital for every Airman to begin or continue the lifelong pursuit of being a critical thinker.

Successful CT programs require strong critical thinkers on the faculty. Although not a sufficient sample size, six CT enthusiasts from AU faculty and leadership volunteered to take the WGCTA as well. The average raw score for all participants was 31.67; however, when considering the possibility of building a CT program, the lower two scores of 25 and 27 would be excluded, resulting in an average raw score for the remaining four of 34.5. The new average placed the four participants in the 86th percentile, higher than that observed with the SAASS students, and suggested the talent was already in place to enhance CT integration for all three schools. These numbers only indicated a potential, and a complete assessment will be required before identifying the right personnel to build a CT development program.

Based on the literature review and the results, the AF needs to implement a CT development program, starting with faculty at ACSC and AWC. This will require first identifying the strongest critical thinkers as assessed by the WGCTA, giving them the time and resources to create a modified series of seminars derived from the NCECT's recommended program, and then begin sessions with all ACSC and AWC faculty to improve CT over a three-month period with quarterly sessions after that. The next phase will entail applying those skills to the in-class discussions through a combination of integrating the faculty program materials into the instruction and weaving measurable CT requirements into the syllabi by modifying existing case studies and exercises in-line with Kiltz's observations.[53] CT should not be a stand-alone block of instruction early in the academic year but a periodic and recurring enhancement throughout the program. The faculty should make their CT development program available to the rest of the AF as a baseline, and the graduates will take their CT skills out to the operational AF, holding their personnel accountable to higher standards and further integrating CT. For AWC and ACSC, the recommended program is not a matter of determining what material to remove from the courses to accommodate a CT program. Rather, it is how to improve the delivery of the existing materials in a manner that fosters CT development.

Areas for Further Research

To explore whether PME improves CT, I recommend either a longitudinal study or a pretest and posttest method. A longitudinal study to track accessions throughout a career would be a valuable and pure comparison but would admittedly be difficult to execute. Higher headquarters endorsement would also help future researchers achieve the higher sample percentages of the target populations to increase the accuracy of the results. Considering the complete lack of significant difference between ACSC and AWC, coupled with previous analysis between junior and mid-level AF intelligence officers,[54] additional research could explore whether the CT skills of SOS students or even accessions and technical school students score any differently. Such a project would be the first study expanding beyond a boarded population and would provide a baseline for the general AF population. The AU command chief reinforced the AF FOC and recommended the AF should ensure *all* Airmen, including the enlisted 80 percent of the force, have the tools to refine their CT skills continuously.[55] For all the recommended studies above, future research should collect additional demographic data to look for additional trends to include AFSC, the level of education, schools attended (e.g., brick and mortar, online, night school), and degrees held. Complementing these quantitative studies, qualitative research should explore opportunities to integrate CT into PME more effectively, both officer and enlisted, and identify specific methods to integrate CT into the operational AF.

Conclusion

AD AF students attending ACSC and AWC during AY2016 collectively scored at the 36th percentile when compared to the graduate degree normative group. This supported the hypothesis that there was no statistically significant difference between the CT skills of ACSC and AWC AD AF students. Through a series of t-tests, the null hypothesis was accepted; however, the analysis also supported the hypothesis H_b with the statistically significant difference in scores between SAASS and ACSC.

This research was the first of its kind, establishing a baseline against which the AF could assess the current state of CT skills among AD AF officers. The methodology was also exportable to the rest of DOD for other services determined to identify and build critical thinkers. Interested organizations in the AF can also apply the methodology to examine the development of CT skills over time, identify best practices, and continue to refine the organization's approach. The AF can measure and improve CT skills across the force by starting with a faculty program at ACSC and AWC, ultimately ensuring a continuous emphasis on CT in both PME and the operational AF. ✪

Notes

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13. For example: (1) the Cornell Critical Thinking Test, (2) the Ennis-Weir Critical Thinking Essay Test, (3) the New Jersey Test of Reasoning Skills, (4) the California Critical Thinking Skills Test, and (5) the WGCTA.
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32. Ibid., 160.

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34. Stacy L. Peerbolte, "Disaster management and the critical thinking skills of local emergency managers: correlations with age, gender, education, and years in occupation" *Disasters* 37(1) (2013), DOI: 10.1111/j.1467-7717.2012.01291.x: 58.

35. Secretary of the Air Force, *Air Force Future Operating Concept: A View of the Air Force in 2035*, (Washington, DC: Air Force News Service, 15 September 2015), http://www.af.mil/Portals/1/images/airpower/AFFOC.pdf.

36. Emilio, "Promoting Critical Thinking," 23–25; and Moore, *Critical Thinking*, 65. Also reference the advanced analysis mobile training team provided for DOD intelligence professionals and run by Dr. Jon Kimminau in AF/A2D.

37. Linda Kiltz, "Developing Critical Thinking Skills in Homeland Security and Emergency Management Courses," *Journal of Homeland Security and Emergency Management*, 5.

38. Linda Elder and Richard Paul, *Intellectual Standards: The Words that Name them and the Criteria that Define them* (Tomales, CA: *Foundation for Critical Thinking*), 10.

39. National Council for Excellence in Critical Thinking, "Professional Development Workshops," accessed 22 January 2016, http://www.criticalthinking.org/pages/professional-development-workshops-for-business-professional-groups/430.

40. Ibid.

41. AU Portal search looked for any paper with "critical thinking" in the title. Only three papers exist, and the most recent was from 2003. For ProQuest, search focused on any dissertation with "critical thinking" in the title, yielding 32 dissertations meeting the criteria, and no dissertation studied the military. In EBSCOhost, the search focused on any scholarly journal with "critical thinking" in the title

from the Academic Search Premier, Military and Government Collection, and Teacher Reference Center databases. The search yielded 480 results addressing challenges across several different career fields; however, when further limiting the search to any document with "critical thinking" in the title and "military" in the abstract, the search yielded two articles, one focusing on Army medicine and the other focusing on Army Decision Support Red Teams. Follow-on searches substituted each of the services for "military" and yielded no results except for the two already identified for the Army.

42. Col Thomas M. Williams, "Education for Critical Thinking," *Military Review* (January–February 2013), http://usacac.army.mil/CAC2/MilitaryReview/Archives/English/MilitaryReview_20130228_art011.pdf.

43. Moore, *Critical Thinking*, 74.

44. Richard Paul, Linda Elder, and T. Bartell, "California Teacher Preparation for Instruction in Critical Thinking: Research Findings and Policy Recommendations," *California Commission on Teacher Credentialing* (1997). For further context, also see Paul's "The State of Critical Thinking Today," *New Directions for Community Colleges* 2005, issue 130 (14 June 2005), http://www.criticalthinking.org/pages/the-state-of-critical-thinking-today/523.

45. For example: accession, Squadron Officer School, Air Command and Staff College, and Air War College for officers and basic military training, First-Term Airman's Course, Airman Leadership School, Non-Commissioned Officer (NCO) Academy, and Senior NCO Academy for enlisted.

46. The research did not collect data on the guard, reserve, joint, interagency, or international fellows at the schools because the potential sample was insufficient for generalizing to a larger population as well as the challenge of scoping the research. Likewise, the research did not collect additional demographic data regarding career field or sources of previous education because the large number of career fields would prevent any accurate correlations and the previous education consideration was beyond the scope of this foundational study.

47. Adam J. Stone, "Critical Thinking Skills of Air Force Intelligence Officers: Are We Developing Better Critical Thinkers?" In this study, a similar methodology using the WGCTA and comparing to same normative group showed both second lieutenants going through intelligence officer pipeline course and senior captains and junior majors going through the Intelligence Master Skills Course had no statistically significant difference in their CT skills as measured by t-test nor were there any reportable results using a Pearson's r to detect any improvement in CT skills based on age. Furthermore, the two samples scored at the 35th percentile when compared to the graduate degree norm group. Although this study was unclassified, the National Intelligence University posts all papers on their TS/SCI JWICS page regardless of classification. If interested in the details of the research, contact the author directly at adam.stone@us.af.mil.

48. The researcher obtained lists of AD AF students, in alphabetical order, attending ACSC and AWC and then provided the e-mail address of every third name to the TalentLens point of contact to send the survey instrument link. When the 12-day period to take the appraisal expired, the researcher coordinated with TalentLens to reclaim expired surveys and start over from the top of the list, again selecting every third name, until a sufficient sample was collected.

49. Goodwin Watson and Edward M. Glaser, *Forms D & E Critical Thinking Appraisal*, 8.

50. Ibid., 8–9.

51. L. R. Gay and Peter Airasian, *Educational Research: Competencies for Analysis and Applications*, 7th ed. (Upper Saddle River, NJ: Prentice Hall, 2003), 457.

52. Figure 1 only displayed the distribution for the entire sample; however, plotting the distribution for the individual schools did not generate any significant visible differences in the normal distribution, kurtosis, or skewness.

53. National Council for Excellence in Critical Thinking, "Professional Development Workshops"; and Kiltz, "Developing Critical Thinking Skills."

54. Stone, "Critical Thinking Skills."

55. CMSgt Timothy B. Horn, interview by the author, 4 December 2015.

Col Adam Stone, USAF

Colonel Stone (USAFA; MAS, Embry-Riddle Aeronautical University; MSSI, National Defense Intelligence College; MSS, Air War College [AWC]; DM, University of Phoenix) is assigned to the LeMay Center for Doctrine Development and Education, Air University, Maxwell AFB, Alabama. He has served a variety of responsibilities as a career intelligence professional. His assignments include those within: special operations, as a fighter squadron intelligence officer, a fighter wing senior intelligence officer, an instructor at the USAF Weapons School, a squadron director of operations, an airpower intelligence, surveillance and reconnaissance strategist for Headquarters Air Force, a squadron commander, a deputy group commander, and an executive officer to the commander of Twenty-Fifth Air Force. Before this assignment, Colonel Stone was a student at the AWC, where he graduated with highest distinction.

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Toward a US Air Force Arctic Strategy

Col John L. Conway III, USAF, Retired

If you don't know where you are going, you'll end up someplace else.

—Lawrence P. Berra (1925–2015)

The US Air Force is no newcomer to the Arctic. It has a long history of aerial operations in the "High North" from fighting the "thousand mile war" in the Aleutians during World War II to expanding its Arctic operations throughout the Cold War and beyond.[1] Today, it maintains a significant Arctic presence with missions, bases, personnel, and aircraft in Alaska and at Thule Air Base, Greenland, 750 miles north of the Arctic Circle. It conducts the Arctic Survival School at Eielson AFB, Alaska, has maintained a radar early-warning system in the High North for more than 60 years, and has flying units (active, guard, and reserve) stationed at Eielson and Elmendorf Air Force bases. The Air Force also operates satellites over the top of the world and launches them into polar orbit.

During World War II the Army Air Corps used the experience of seasoned Arctic flyers to establish several air bases in Greenland as way stations for ferry flights to England and to conduct search and rescue (SAR) missions for downed flyers. To thwart the German U-boat menace, it also performed sea surveillance missions in the North Atlantic from these same locations. Seeing the necessity for a permanent base in the High North, Thule Air Base was constructed in the 1950s in near secrecy; an engineering project that rivaled the construction of the Panama Canal in its size and complexity.[2]

SAC bombers dispersed to remote runways in Greenland during the Cold War, using "floating shelf" ice islands as part of a "live aboard" concept during times of nuclear tension.[3] By 1957 the Distant Early Warning (DEW) Line of more than 30 radar stations was manned from Point Barrow, Alaska to the east coast of Greenland to provide early-warning of Russian bomber and missile attacks.[4] The Air Force even had a specialized research organization, the Arctic, Desert, and Tropic Information Center (ATDIC) at Maxwell AFB, Alabama from 1952 well into the 1960s. ATDIC personnel conducted "mukluks-on-the-tundra" Arctic research, contracted numerous Arctic studies, and published their findings in widely-read newsletters, monographs, and survival manuals.[5]

Despite its long Arctic history and ample time to create one, the Air Force has no formal Arctic strategy. In May 2013 the White House released its rather generic *National Strategy for the Arctic*, concurrent with publication of the Coast Guard's *Arctic Strategy*. The Department of Defense (DOD) published its *Arctic Strategy* later that year and the second iteration of the Navy's *Arctic Roadmap* came out in 2014.[6] However, no Air Force Arctic strategy emerged in their wake.

In February 2017, the DOD released a "Report to Congress on Strategy to Protect US National Security Interests in the Arctic Region."[7] Rather than a periodic update of its previous efforts, this document was mandated by an amendment from a senator from Alaska in the 2016 National Defense Authorization Act.[8] Its 2013 *Arctic Strategy* lacked a sense of urgency, and this latest iteration is mostly a rehash of the former.[9] The DOD viewed its role in the Arctic in 2013 as "support-only:" part of a "whole of government" approach to the region.[10] This reflects its general reluctance to engage in near-term Arctic planning, proposing instead "innovative, low cost, small footprint" solutions to its two objectives—"Ensure security, support safety and promote defense cooperation" and "Prepare for a wide range of challenges and contingencies"—and waiting on solutions until "Combatant Commander's operational requirements" are defined.[11] This is not exactly "if we ignore it, it will go away," but more "we'll wait until we're asked." The 2013 *Strategy* also observed that future projections of Arctic activity may be inaccurate; cautioned that there may be fiscal constraints to new Arctic support initiatives; and felt that being "too aggressive" in addressing future security risks may create "conditions of mistrust."[12] The 2016 version also is littered with caveats: "Arctic operations are inherently difficult and dangerous;" "DOD has few niche capabilities;" "DOD will reevaluate capabilities . . . as conditions change;" and "Some may require an expeditionary approach."[13]

A Sense of Urgency

The cautionary tone in DOD's 2016 *Strategy* continues the thought that there is no great urgency to improve its Arctic posture; a position similar to that in its 2013 iteration. However, recent events in the High North, spurred by receding sea ice, portray just the opposite. Last year Russia resubmitted its territorial claims to the United Nations (UN), claiming that the continental shelf along Russia's northern border extends all the way to the North Pole, well beyond the 200-mile economic exclusion zone outlined in the Law of the Sea Convention.[14] Canada, Norway and Denmark also have seabed claims pending in the UN, increasing the possibility of multiple territorial disputes. What's at stake? The 2008 US Geologic Survey (USGS) estimate of High North energy resources suggested that 13 percent of the world's undiscovered oil and 30 percent of the world's undiscovered natural gas lies in the Arctic.[15]

China has also asserted its rights in the Arctic, although she has no territory there. In March 2010 Rear Adm Yin Zhin was quoted in the *New China Daily* stating, "China must play an indispensable role in Arctic exploration as we have one-fifth of the world's population."[16] Perhaps to make her point, China's first icebreaker (a second is in service, and a third is in construction) transited the Northern Sea Route (NSR) in 2012, and the China Ocean Shipping Group completed its third year of container shipping along the NSR in 2016.[17] It is now eyeing the Northwest Passage for future commercial use, sparking renewed debate about whether the Passage is international water or under Canadian sovereignty. Perhaps to emphasize China's intent to fully participate in Arctic affairs, five Chinese naval vessels passed near the Aleutian Islands in September 2015—a first.[18]

Russia has aggressively improved its own military infrastructure along the NSR since 2014, when a revised *Military Doctrine* declared that Russia's military must protect its national interests in the Arctic.[19] A State Department report in September 2016 noted that the Russian Federation's refurbished Northern Fleet now commands 42 of Russia's 72 submarines and 38 surface combatants, including its largest aircraft carrier.[20] The more troubling issue, from an American Arctic point of view, has been the reopening of several air bases in eastern Siberia opposite Alaska, including the old Soviet bomber base at Mys Shmidta, and an air defense buildup investment (some $4.3 billion by 2020) across the region.[21] In all, Moscow has opened 10 Arctic search and rescue stations, 16 deep water ports, 10 new airfields (for a total of 14), and 10 air defense radar stations to protect its interests along the NSR.[22] While all of these improvements are touted as self-defense, such a huge increase in military capability to the north cannot be ignored. Given the short distances between some of these air bases and the Alaskan coastline, the warning time for any overflight can be measured in minutes. Thus, changes that were thought to occur in "the mid-term" are here now, but the DOD's "near term" planning is inadequate to meet them.

A Lack of "Air-mindedness"

The Air Force's three-plus year silence may be the result of a lack of any service specificity (i.e. air-mindedness) in the DOD's *Strategy* that would prompt the USAF to create a "strategy" of its own. Given the tyranny of time and distance in the Arctic, the current lack of air-mindedness is not only wrong, but dangerous: the only way to quickly get to any crisis above the Arctic Circle is by air. The application of airpower to any situation in the High North provides the quickest response, but there appears to be no DOD-led impetus to do so. Case in point: the term "Air Force" is never used in either the 2013 or the 2016 DOD document; the "Air National Guard" mentioned but once.[23] Instead, the generic word "air" finds its way into the text many times.

The lack of air-mindedness also is reflected in the supporting Arctic strategies of both the Navy and the Coast Guard, as well as that of the Government Accountability Office (GAO). A June 2015 GAO report observed that ". . . since the Arctic is primarily a maritime domain, the Coast Guard plays a significant role in Arctic Policy implementation and enforcement."[24] The GAO also acknowledges the Navy's continuing role in support of other federal agencies and international partners, but it fails to identify one for the Air Force or to even mention the Air Force by name. Thus, an area that is impassable for surface vessels at least part of the year does not have an alternate solution when a maritime one is unworkable due to time, ice, distance, or all three.

The Navy's 2014–2030 *Arctic Roadmap* is rich with objectives, ideas, and goals for the High North, but they aren't objectives, ideas, and goals for the air domain. The

Navy follows the DOD's long lead-time strategy, using near-term (present–2020), mid-term (2020–2030), and far-term (beyond 2030) descriptors. It also echoes the DOD's 2013 assessment that ". . . with the low potential for armed conflict in the region in the foreseeable future, the existing defense infrastructure (e.g. bases, ports, and airfields) is adequate to meet near-to-mid-term US national security needs."[25] Post–2030, the Navy believes it will have the "necessary training, and personnel" to respond to Arctic contingencies and emergencies.[26] After reading the Navy Roadmap, one observer pointed out that even in the out-years, the Navy plans to operate only in open waters and is not planning for any major fleet enhancements (e.g. double hulls, organic ice breakers, major shore infrastructure) based on a perceived lack of any substantive threat.[27]

Even though aviation and space are mentioned several times in the Navy Roadmap, it doesn't acknowledge the need for Air Force support except for intelligence, surveillance, and reconnaissance interoperability. Interestingly, several references to the Air Force and Air Force-related milestones in the Roadmap's previous iteration (October 2009) are absent in the new one. Does this mean that they have been satisfied or just ignored? Perhaps the answer lies in a precursor document to the latest Roadmap, the "Fleet Arctic Operations Game, September 13–16, 2011 Game Report." It refers to Air Force assets at Elmendorf AFB as "sister service Air transport."[28]

In its Arctic *Strategy*, the Coast Guard discusses aviation only in general terms, focusing instead on its maritime needs (read: a glaring lack of icebreakers in sufficient numbers) in the High North. It should be noted that the Coast Guard has taken possession of previously Air Force-owned C-27 aircraft, but it is unclear if any of them will see duty in the Arctic when they enter Coast Guard service later in this decade. Aviation requirements in general—and those in partnership with the Air Force in particular—are missing from the Coast Guard's Arctic planning just as they are from the Navy's. Instead, a report prepared for the Coast Guard in 2010 laments the difficulties in basing aircraft in the High North, even in the summer season. It observed that "No suitable facilities currently exist on the North Slope or near the Bering Strait" that are sufficient for extended aircraft servicing and maintenance. Its "force mix evaluation" only includes surface vessels and helicopters. No fixed wing aircraft appear in the accompanying table, but aircraft are mentioned in its "Concluding Remarks" almost as an afterthought.[29]

The overall effect of this benign neglect *en masse* reduces Air Force motivation to produce an Arctic strategy because there is no clearly stated need to do so by the national command authority, the DOD, or our sister services. There is one other possible reason for the lack of an Air Force Arctic strategy: there is no war in the Arctic. Although the USAF has been at war for the last quarter-century, it hasn't fired a shot in anger in the High North since World War II. The Air Force's warfighting focus is elsewhere because, well, there's no war in the High North.

However, in response to the growing Russian militarization of the Arctic, many observers now maintain that territorial disputes will inevitably spill over into the Arctic, and the region will become another arena of conflict.[30] For example, to enter or exit the NSR or the Northwest Passage from the Pacific side of the globe requires transit of the Bering Strait; a natural maritime chokepoint dividing US and Russian territory that may be a flash point in the future, they argue.

Figure 1. The Northwest Passage(s) and the Northern Sea Route. (Reprinted from "Arctic Ocean," in Central Intelligence Agency, The World Factbook, accessed 3 September 2013, https://www.cia.gov/library/publications/the-world-factbook/geos/xq.html.)

The most pressing issue, however, is a coordinated response to a human or environmental crisis in the High North, not a clash of arms. Although Royal Dutch Shell has withdrawn its oil exploration plans in the Chukchi Sea, plans for drilling efforts in the region by others continue in hopes of tapping possibly the world's last large deposits. Fishing, eco-tourism, and commercial tourism (cruise ships) grow each year on both sides of the Northwest Passage, but this human activity does not come without risks to both persons and the environment. The consequences of one bad decision may require immediate response to mitigate loss of life and damage to a delicate ecosystem.

A major cruise ship successfully transited the Northwest Passage without incident in 2016, and more transits are scheduled for this summer.[31] While there have been a few other successful passages in this decade, the waterways of the Northwest Passage are less than ice-free, navigational aids are sorely lacking, and nautical charts of the region are highly suspect. Experts point to poor navigational aids as a major contributor to Northwest Passage safety concerns. One report cautions that at its current rate, completely charting Canadian Arctic waters will take three centuries.[32]

In 1996 eight nations with territory or clearly defined interests in the region—the United States, Canada, Russia, Finland, Norway, Denmark, Iceland, and Sweden—formed the Arctic Council ". . . to provide a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues."[33]

The Arctic Council is unique in that it only addresses nonsecurity issues faced by the Arctic states and the region's indigenous peoples. Observers have characterized it as ". . . populated more by scientists and scholars than politicians."[34]

The United States is a signatory to the Arctic Council's "Nuuk Agreement on Search and Rescue," which requires each party to establish and maintain an "adequate and effective search and rescue capability" within its designated area (fig. 2). Further, the Nuuk Agreement binds member nations to coordinate its SAR efforts with other members in case of a plane crash, cruise ship sinking, oil spill, or other disaster across the High North.[35] The United States is responsible for SAR operations in Alaska and the western approaches to the Northwest Passage; the eastern approaches to the NSR paralleling Russia's Kamchatka Peninsula; and the Beaufort, Chukchi, and Arctic Seas extending to the North Pole.

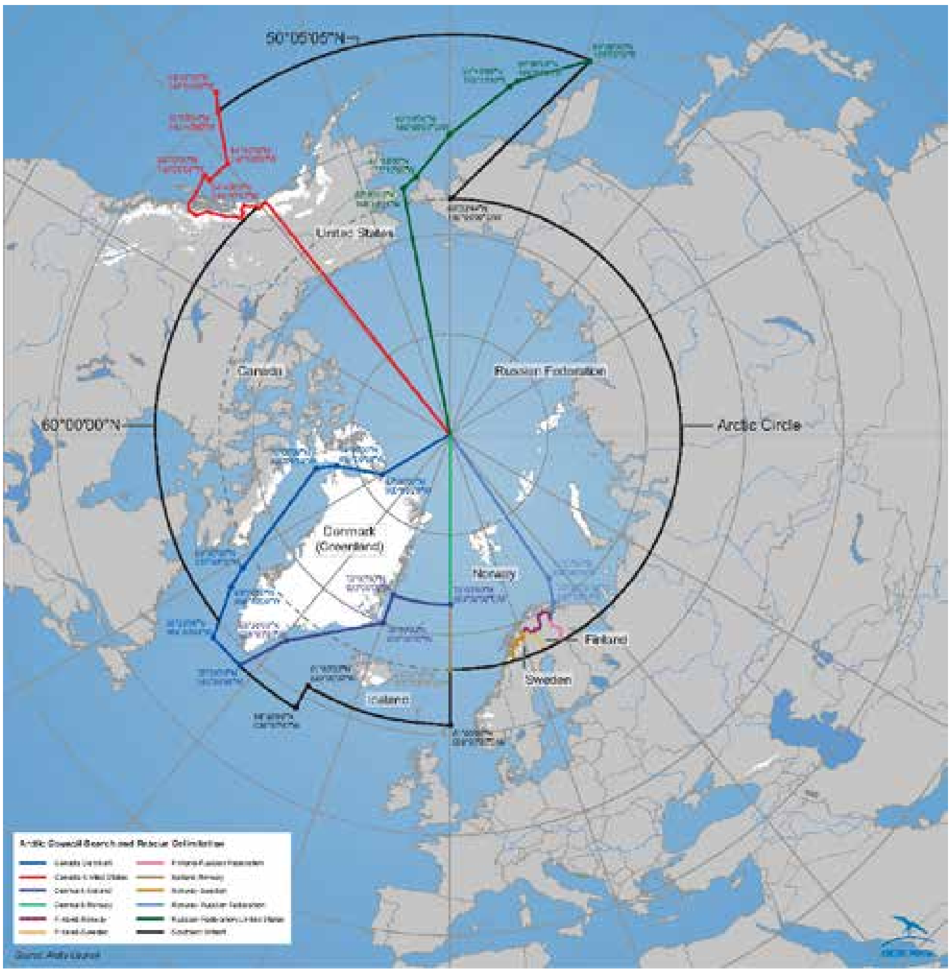

Figure 2. Arctic SAR agreement, areas of application (based on geographic coordinates in the annex to the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, 12 May 2011, http://www.ifrc.org/docs/idrl/N813EN.pdf.

A key point in the Nuuk Agreement is that any party may request the assistance of other party/parties if necessary, ensuring that "assistance be provided to any person in distress."[36] Given the current physical disposition of Canadian SAR forces—some actually closer to the northern coast of South America than to Alert, Nunavut—it is highly likely that the United States will be asked to provide assistance in any emergency. An article highlighting Canadian SAR woes calculates flight time from Winnipeg to Resolute Bay in the heart of the Northwest Passage via a Canadian C-130H at more than five hours; helicopters to the same area from Comox would take more than 11 hours.[37] In contrast, US bases in Alaska and Greenland are much closer and would be a logical alternative to help in times of need.

Increasing maritime traffic in the High North has prompted the shrinking of Arctic ice. The Arctic ice shrinking, combined with the unreliability of High North navigation charts, pose near-term naval problems for anyone who transits the region with only a long-term naval solution. Neither the Navy or the Coast Guard has the current capability to quickly reach any environmental disaster or respond to a SAR event above the Arctic Circle, and neither will have such assets for the foreseeable future, if (in the Navy's case) ever.

Current US strategies see the Coast Guard as the logical service for any rescue in the Arctic. Even though it has several Coast Guard facilities in Alaska, all are located below the Arctic Circle. Coast Guard aircraft are based in Kodiak, about 800 miles south of the most northern point in the United States—Point Barrow. Dutch Harbor, the northernmost major deep water port in Alaska, is 400 nautical miles farther south. The Coast Guard has announced that it had no plans to build any additional shoreside infrastructure in the coming decade, so this force structure is essentially static for the next 10 years.[38] As a frame of reference, sea distances to the heart of the Northwest Passage are portrayed below (fig.3).

What hampers the DOD's Arctic *Strategies* (and those of the Coast Guard and the Navy) and deters the Air Force is not the lack of manpower, equipment, or facilities, but a lack of imagination and inclusion. DOD strategy resides primarily in the maritime domain: the slowest, the most expensive ($1 billion and 10 years construction time per icebreaker), as well as the least flexible method of response to any High North situation.[39] In contrast, the air domain is faster and more agile and primarily, but not exclusively, an Air Force domain. Thus, ignoring the Air Force limits the DOD's Arctic options to only a single choice. It's time to supplement Arctic DOD's proposed "low cost, innovative" programs, with the Air Force's "virtually no additional cost, already in-place" ones.

There is sufficient force structure, manpower, and more than enough Air Force and civilian facilities (e.g. airfields) throughout the state of Alaska (not to mention Thule AB) to respond to any crisis in the High North: be it SAR, environmental disaster, aggression, or support to our Canadian ally to meet any or all three.[40]

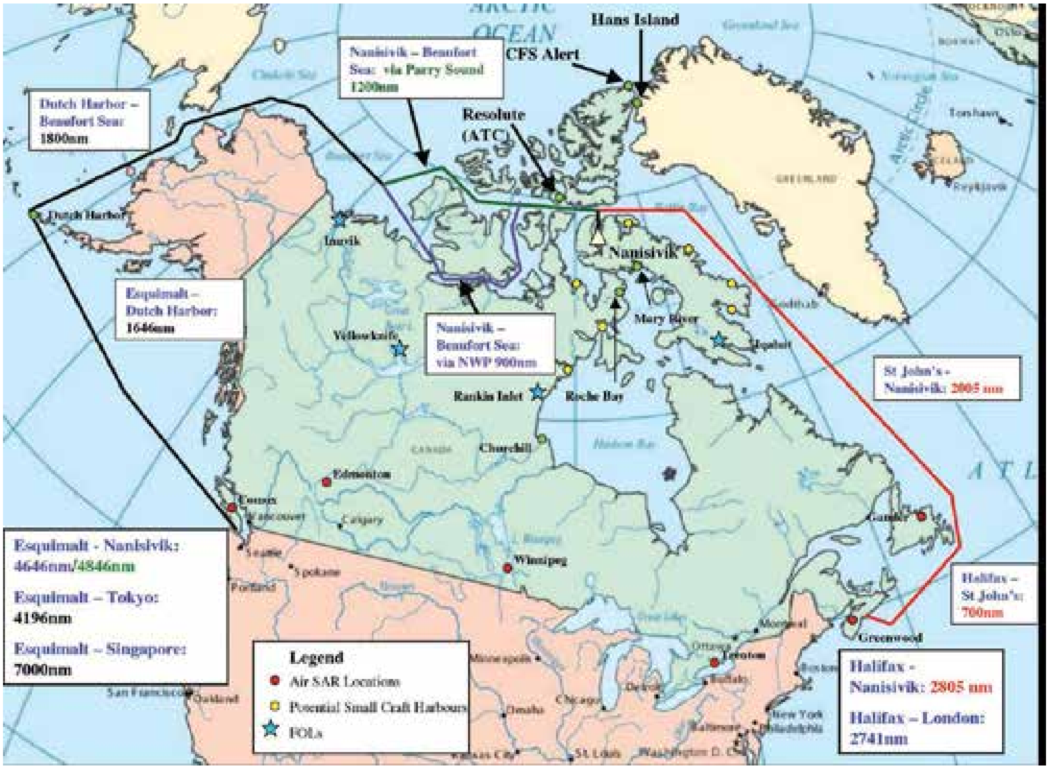

Figure 3. Operational Arctic patrol distances. (Reprinted from Michael Byers and Stewart Webb, "Titanic Blunder: Arctic/Offshore Patrol Ships on Course for Disaster." [Ottawa: Rideau Institute, Canadian Centre for Policy Alternatives, April 2013], http://www.policyalternatives.ca/sites/default/files/uploads/publications/National%20Office/2013/04/Titanic_Blunder.pdf.)

An Air Force Arctic Strategy—What Should It Contain?

An Air Force Arctic strategy should raise awareness—air-mindedness—of the in-place Air Force assets in the Arctic and provide innovative ways to partner them with sister services and other High North nations. It should complement the DOD's Arctic *Strategies*, the *National Strategy for the Arctic Region*, and all presidential directives that set its framework. The overarching goals of an Air Force Arctic strategy should be to highlight USAF Arctic current core competencies, to suggest ways to interface with sister service *Strategies* and *Roadmaps*, and to present future needs to US Northern Command, the DOD advocate for the High North.

Its preface should point out that addressing the effects of climate change is a whole-of-government challenge and that the recommendations of the CNA (Center for Naval Analyses) Military Advisory Board's report, "National Security and the Accelerating Risks of Climate Change," could serve as a benchmark for planning. In particular, its recommendation, "The United States should accelerate and consolidate its efforts to prepare for increased access and military operations in the Arctic," is a clear call for increased action. Further, CNA advises, "The time to act is now."[41]

An Air Force strategy should succinctly comment on emerging events in the region, including climate change, loss of sea ice, increased commerce in the High North, conflicting claims for the Arctic seabed, and the growing militarization of the region by Russia. In doing so, it will convey the message that these important events in the High North will not pause until some future date when sufficient numbers of icebreakers and new deep water ports may be available; they are happening now. The body of an Air Force Arctic strategy should complement and expand the DOD's Arctic guidance, focusing on its supporting objectives and also should support sister service Arctic *Strategies* and *Roadmaps* by finding lanes in these works that align with Air Force capabilities.

The DOD's first objective, "Promote defense cooperation," should be embraced by the Air Force by expanding its military-to-military contacts with other High North nations, especially members of the Arctic Council, to create an interchange of tactics, techniques, and procedures to assure safe and effective flight operations. Joint exercises, mil-to-mil exchanges, and a flow of information and ideas would have a synergistic effect for all parties.

The strategy should call for a survey (actually, a resurvey) of possible forward operating bases above the Arctic Circle using previous World War II, Cold War DEW Line locations, and existing commercial airfields as points of reference. For example, Wiley Post/Will Rogers Memorial Airport services Point Barrow, and its asphalt runway is 7,100 x 150 feet. To the west are three more airfields with runways of 5,000 feet or more: the aptly-named Lonely Air Station, a military airfield supporting the Point Lonely Short Range Radar Site with a 5,000-foot gravel runway; a private airfield, Ugnu Kuparuk, with a 6,551-foot asphalt runway; and Deadhorse Airport, with 6,500 feet of asphalt runway.[42] To the west on the Chukchi Sea is Ralph Wein Memorial Airport, south of Kotzebue, featuring a 6,300-foot asphalt runway, hangers, and commercial service.[43] Additionally, the use of compacted snow and gravel runways—already proven to be viable landing surfaces under the right conditions—could widen the choice of airfields throughout the region.

These—and others in Canada and Greenland—should be considered as contingency airfields for any rescue operation or oil spill event in the Northwest Passage. Projected use would be during the summer season and in the "shoulder" months in late spring and early fall in the Arctic, as these are times when most human activity will occur.[44]

The Air National Guard already has led the way, partnering its ski-equipped LC-130s of the New York Air National Guard's 109th Airlift Wing with Canadian Forces in 2015 in the annual exercise Operation Nunalivut.[45] Active Air Force units should follow suit by joining with nations of the High North in joint/multilateral exercises. Particular emphasis should be on austere airfield operations, interoperability of airframes and communications, logistics, and SAR techniques.

For their part, the National Guard should add state-to-state partnership programs with these same nations to build on its successful Arctic exercises with Canada with military-to-military ties. It must be mentioned that although it maintains 70 state-to-state partnerships around the world, no National Guard partnerships with High North nations currently exist.

The second DOD objective, "Prepare for a wide range of challenges and contingencies," can be met with the same military forces and innovative use of facilities outlined above, much in the way defense support to civil authorities opportunities are used to respond to natural disasters. Other Air Force missions that could be expanded to meet this objective include management and oversight of weather forecasting, surveillance platforms, and an upgrade of communications capabilities. In a region with rapidly changing, often unpredictable weather conditions and notoriously uncertain navigational aids, the Air Force should continue to provide a constellation of overhead capabilities through a strong space launch program. It also can enhance weather forecasting capabilities in the region by engaging its WC-130 assets during the non-hurricane season for additional weather research in the Arctic. Other missions that can be accomplished by in-place assets are those that are already daily mission sets: SAR, airspace sovereignty, airlift, and command and control.

The Air Force's Air Education and Training Command should pursue new initiatives in training and education to further Arctic air-mindedness. It should increase class sizes and throughput at its Arctic Survival School (Detachment 1, 66th Training Squadron) at Eielson AFB, ensuring a cadre of trained and competent Air Force personnel for all Arctic missions. This must include all aircrew members assigned to Arctic bases and all personnel whose duties could place them in cold-weather survival situations. In the long term, it should seek additional funding and instructors from across the DOD to transform it into a joint service school.

AETC also should reinstitute the study of the Air Force in the Arctic at its academic roots—Air University (AU). Utilizing the research capabilities of the entire university, it should explore pertinent Arctic issues and offer courses at Air Command and Staff College and Air War College to encourage Air Force thinking concerning strategic and operational issues in the High North. Course development for Arctic-specific issues could reside in a new Arctic Studies Group at AU, similar to those established at the Naval War College and the US Coast Guard Academy.[46]

Final Thoughts

To operate in the High North without an Air Force Arctic strategy and to remain silent on Arctic issues that are clearly within the Air Force's purview allows other services to dictate its roles and missions there. Although the DOD, Navy and the Coast Guard have ignored in-place Air Force assets in their High North planning, these capabilities—in air, space, and in cyberspace—are the *sine qua non* for success. Bidden or unbidden, the point should be made that the Air Force must be a part of the solution. The Air Force must pursue an Arctic strategy of its own and do it sooner rather than later. The result of further inaction (three-plus years since the first DOD Arctic *Strategy*) will be a loss of visibility for the Air Force and a diminished defense capability for this nation in the last frontier on Earth. ✪

Notes

1. For this article, the "High North" is analogous to the "Arctic" and is used alternatively with that term. The "Arctic is most commonly defined by scientists as the region above the Arctic Circle defined by an imaginary line that circles the globe at approximately 66° 34' North latitude." See the National Snow and Ice Data Center website, https://nsidc.org/cryosphere/arctic-meteorology/arctic.html. However, Scandinavian expert and Polish author Ryszard M. Czanry observes that the High North is solely a Norwegian construct; the English translation of a Norwegian word that became commonly used in the mid-1980s. He believes that the term generally refers to the Europe Arctic; the term "Far North" being used for the US and Canadian regions. See Czanry, *The High North: between Geography and Politics* (Cham, Switzerland: Springer International Publishing, 2015), 7 (footnote 1), 9–10. The US Congress appears to have no quibble with the two terms. See House of Representatives, *The United States as an Arctic Nation: Opportunities in the High North*: *A Hearing before the Subcommittee on Europe, Eurasia, and Emerging Threats of the Committee on Foreign Affairs*, 113th Congress, 2nd sess. See https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwid7oSx3abSAhXCeSYKHeHdDnoQFggmMAI&url=https%3A%2F%2Fwww.scribd.com%2Fdocument%2F321744184%2FHOUSE-HEARING-113TH-CONGRESS-THE-UNITED-STATES-AS-AN-ARCTIC-NATION-OPPORTUNITIES-IN-THE-HIGH-NORTH&usg=AFQjCNGqNp_YgL-xCFPGfOecp3dfraCfkA. Interestingly, the "Bard of the Yukon," Canadian-educated (McGill University) poet Robert W. Service, used the term in his collection, "Songs of the High North," published in 1958. See "Songs of the High North." Robert W. Service, http://www.bloomsbury.com/uk/songs-of-the-high-north-9780713650822/.

2. Most of this effort was overseen by Col Bernt Balchen, USAF. Already an Arctic and Antarctic flying legend (the first to pilot an aircraft over the South Pole with Adm Richard E. Byrd), this native Norwegian was recruited into the Army Air Corps in 1942 by its chief of staff, Gen Henry "Hap" Arnold. For the rest of his military career, he was the driving force for Arctic operations and research in the Air Force. The leader of a successful five-month effort to rescue a downed B-17 crew in Greenland in 1942, he built wartime air bases in Greenland and during the Cold War oversaw Thule AB's construction in near secrecy and surveyed sites for the Ballistic Missile Early Warning radar system. See the Arlington National Cemetery website: "Bernt Balchen, Colonel, US Army Air Corps," http://www.arlingtoncemetery.net/bbalchen.htm, and National Museum of the US Air Force: "Saga of B-17 PN9E," http://www.nationalmuseum.af.mil/Visit/MuseumExhibits/FactSheets/Display/tabid/509/Article/196694/saga-of-b-17-pn9e.aspx. On 23 October 1999 the US House of Representatives (with the Senate concurring) passed a resolution honoring the late retired Colonel Balchen for his extraordinary service to the United States on his 100th birthday.

3. Louis Degoes and James T. Neal, "Selected Military Geology Projects in the Arctic, 1950–1970," in J.R. Underwood, Jr. and Peter L. Guth, eds., *Military Geology in War and Peace* (Boulder, CO: Geological Society of North America, 1998), 205, 208–209.

4. Degoes and Neal, "Selected Military Geology Projects," 205.

5. In the winter of 1953, Artic–Desert–Tropic Information Center (ADTIC) personnel spent 90 days in Greenland leading Project Mint Julip, a study of smooth ice to determine if it were feasible to establish a scientific project on the ice and maintain it solely by air. See "History of the Research Studies Institute, 1 January–30 June 1953. Arctic, Desert, Tropic Information Center (ADTIC)," Maxwell AFB, AL, 14. In 1955, ADTIC specialists investigated possible ice landing strips at proposed Distant Early Warning Line sites. See "History of the Aerospace Studies Institute, Twenty-Fifth (Silver) Anniversary Command Edition, Arctic-Desert-Tropic Information Center," Air University. Maxwell AFB, 25 January 1971, 6.

6. The White House, "National Strategy for the Arctic Region," May 2013, https://obamawhitehouse.archives.gov/sites/default/files/docs/nat_arctic_strategy.pdf.

7. Department of Defense, *Report to Congress on Strategy to Protect United States National Security Interests in the Arctic Region*, OUSD (Policy), December 2016, http://www.sullivan.senate.gov/imo/media/doc/2016_ArcticStrategy-Unclass.pdf.

8. Department of Defense, *Report to Congress on Strategy to Protect United States National Security Interests in the Arctic Region*, Section 1068 of the 2016 National Defense Authorization Act, accessed 7 March 2017, https://www.congress.gov/congressional-report/114/house-report/270.

9. Ibid. 11.

10. Department of Defense, *Department of Defense Arctic Strategy* (Washington, DC: DOD), 2013, https://www.defense.gov/Portals/1/Documents/pubs/2013_Arctic_Strategy.pdf. The strategy acknowledges that it is "nested" under a number of documents relating to the Arctic and "complements" DOD's Strategy for Homeland Defense and Defense Support of Civil Authorities.

11. Ibid. 7, 10.

12. Ibid. 12–13.

13. "Report to Congress," 11.

14. Andrew E. Kramer, "Russia Presents Revised Claim of Arctic Territory to the United Nations," *The New York Times*, 9 February 2016, https://www.nytimes.com/2016/02/10/world/europe/russia-to-present-revised-claim-of-arctic-territory-to-the-united-nations.html. For the exact wording of the Law of the Sea art. 56, see http://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm.

15. USGS appraisal as quoted in "The Geopolitics of Arctic Natural Resources," Policy Department, Directorate-General for External Policies, European Parliament, 2010, 4. See also US Geological Survey, "Circum-Arctic Resource Appraisal (North of the Arctic Circle) Assessment Units GIS Data," 2009, https://energy.usgs.gov/RegionalStudies/Arctic.aspx.

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36. Arctic Council, ibid. art. 7, pars. 3 (d) and (e). The Nuuk Agreement also details each nation's "Competent Authority" (Appendix 1), SAR agencies (Appendix 2), and rescue coordination center locations (Appendix 3).

37. "The Arctic is a Long Way from Canada's Search and Rescue Techs," *Nunatsiaq Online*, 3 November 2010, http://www.nunatsiaqonline.ca/stories/article/556011_the_arctic_is_a_long_way_from_canadas_search_and_rescue_techs/. The original article indicated that Trenton, Ontario, was closer to Quito, Ecuador, than to Nuavut, but that distance was calculated via "flat-earth" Mercator maps. Plots using Google Earth extend the distance to a line just below Panama, bisecting Venezuela and through the northern part of Colombia.

38. US Arctic Research Commission, "Papp: Coast Guard Plans No Arctic Shoreside Infrastructure," Fierce Homeland Security, 23 May 2013, https://www.arctic.gov/arctic_update/2013/2013may23.html.

39. Ronald O'Rourke, Coast Guard Polar Icebreaker Modernization: Background and Issues for Congress, Congressional Research Service (CRS) Report for Congress RL 34391 (Washington, DC: CRS, 24 July 2013), Summary, http://www.fas.org/sgp/crs/weapons/RL34391.pdf.

40. Two Air Force bases sit well above 60 degrees, well-positioned for launch and recovery of any SAR effort: Eielson AFB, Alaska at 64°39'56" N and Thule Air Base, Greenland (with its 10,000-foot runway), 750 miles north of the Arctic Circle at 74°31'52" N. South of Eielson is Joint Base Elmendorf-Richardson (JBER) with another 10,000-foot runway as well as the 11th Rescue Coordination Center. At the outer edge of the Aleutian Island chain sits Eareckson Air Force Station (formerly Shemya AFB), a contractor-maintained alternate/emergency landing field/refueling location and the site of an Air Force Cobra Dane radar installation. Eareckson's 10,000-foot runway and several hangars constitute a far-western basing resource for any SAR operation. The number and variety of Air Force aircraft available at Eielson and JBER would greatly expand SAR response options. Eielson is home to the 354th Fighter Wing (F-16s) and the Alaska Air National Guard's 168th Air Refueling Wing. JBER hosts the Air National Guard's 176th Wing (C-17s and C-130s as well as HC-130 and HH-60G SAR aircraft). It also hosts the Air Force's 3rd Wing, with C-17s, C-12s, the E-3 Airborne Warning and Control System aircraft, fighters, and two air and space operations centers.

41. Center for Naval Analyses (CNA) Military Advisory Board, CNA Analysis and Solutions, "National Security and the Accelerating Risks of Climate Change," (Alexandria, VA: CNA Corporation), 5,

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwitws-lt7HSAhVIbiYKHYjTAJ4QFggdMAA&url=https%3A%2F%2Fwww.cna.org%2Fcna_files%2Fpdf%2FMAB_5-8-14.pdf&usg=AFQjCNHlXdzSJIPnVbEIzaZL5I5cUd7KLQ&bvm=bv.148073327,d.eWE.

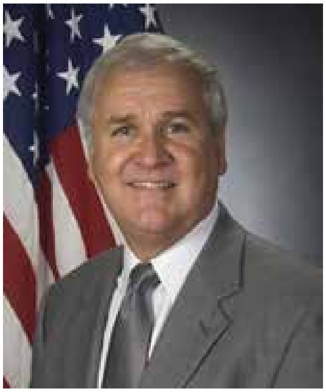
42. Last year, C-17s delivered elements of an Army stryker brigade combat team to Deadhorse as part of Operation Arctic Pegasus.

43. All airfield descriptions noted above can be found at https://www.airnav.com. Last November, C-17s delivered elements of an Army Stryker brigade combat team to Deadhorse as part of Operation Arctic Pegasus.

44. *Navy Arctic Roadmap*, 11. The Bering Strait, according to Navy projections, will be ice-free for 23 weeks by 2020.

45. TSgt Catherine Schmidt, "109 AW Aids Canada with Operation Nunalivut 2015," 109th Airlift Wing Public Affairs, 13 May 2015, http://www.109aw.ang.af.mil/News/Article-Display/Article/867625/109th-aw-aids-canada-with-operation-nunalivut-2015/. The 109th also honors commitments in Antarctica during its summer season.

46. US Naval War College, "Arctic Studies Group," accessed 7 March 2017, https://www.usnwc.edu/Research—Gaming/Arctic-Studies-Group.aspx.



Col John L. Conway III, USAF, Retired

Colonel Conway (BA, MA, University of Alabama) is a military defense analyst at the Air Force Research Institute (AFRI), Maxwell AFB, Alabama. During his more than 30 years in the Air Force, he served as an intelligence officer with major assignments at Headquarters Air Intelligence Agency, North American Aerospace Defense Command, and the National Security Agency. He was the senior intelligence officer at Headquarters Air Force Reserve Command (AFRC), Robins AFB, Georgia, and held several wing and squadron intelligence assignments, including a combat tour with the II Direct Air Support Center in Pleiku Province, Republic of Vietnam. For his last active duty assignment, he was the chief, Counterdrug Support Division, Headquarters AFRC. Following active-duty and before he joined AFRI, Colonel Conway was a systems engineering and technical assistance contractor at the U-2 Directorate at the Warner Robins Air Logistics Center, Robins AFB, Georgia, and a civilian adviser to the commander, Gordon Regional Security Operations Center, Fort Gordon, Georgia. He is a frequent contributor to *Air and Space Power Journal*.

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The Last Prop Fighter

Sandys, Hobos, Fireflies, Zorros, and Spads

Maj Gen Randy Jayne, USAF, Retired

Our Air Force heritage in the pre-Vietnam days, from World War I and II, was the era of the prop-driven fighter. The Korean experience saw our then-relatively new USAF deploy a mix of legacy prop fighters like the P-51 Mustang, and "brand new" jets, the F-80, F-84, and F-86. As the jet era blossomed in the late 1950s and early 1960s, the Air Force deployed F-100, F-101, F-104, F-105, and other second-generation jets. The transition of the Navy's F-4 Phantom into the USAF occurred just as the Vietnam War began, and the first US fighters deployed to bases in South Vietnam and Thailand were all jets, with one notable exception. As F-4 Phantoms, F-100 Super Sabres, and F-105 Thunderchiefs began flying USAF combat missions in Southeast Asia, they were joined by a venerable prop-driven attack fighter, the Douglas A-1 Skyraider. For just more than nine years, Air Force pilots operated that one propeller-driven fighter, transferred from the US Navy (USN) inventory. This is the story of that airplane–its pilots, units, and missions–documenting the last prop fighter to fly combat in our Air Force.

The Douglas A-1 Skyraider was originally a Navy attack plane with an AD label, (referred to as "Able Dog" in those days but later changed to A-1), conceived in the last months of World War II and flown worldwide by Navy units between wars and in combat in Korea in the 1950s. More than 3,000 were delivered, including a combination of single-seat and two-seat attack models and specialized electronic warfare birds.[1] Initial Navy combat deployments to Southeast Asia in response to the Tonkin Gulf incident in 1964 saw each carrier use one or more Skyraider squadrons on attack missions in North and South Vietnam. As the Navy drew down its A-1 force in the 1964–1968 timeframe, the USAF Air Commando force—the precursor to today's Special Operations Command—took the A-1 into our Air Force, given the aircraft's unique combination of close air support accuracy, station time and persistence, and low-altitude survivability.

Compared to other USAF combat fighter/attack planes, the A-1's history with our Air Force was relatively brief. When the United States sent the first surplus Navy Skyraiders to the South Vietnamese Air Force (VNAF) in the early sixties, along with a handful of US advisors, an era began that would span 9 years and more than 90,000 USAF combat sorties, and a peak intensity of more than 1,000 Air Force Skyraider combat sorties a month. Throughout this period, a comparatively small number of USAF pilots flew combat in the A-1. While approximately 1,000 pilots attended the 4407th Combat Crew Training Squadron Skyraider upgrade program at Hurlburt Field, Florida during those years, the best estimates are that only about 700—less than 100 during an average combat year—actually ended up flying the Skyraider in Southeast Asia (SEA)—while others who went through the Hurlburt course went to staff roles at Seventh Air Force (AF), Seventh/Thirteenth AF, Military Assistance Command Vietnam (MACV), Task Force Alpha, and wing and base-level command posts.[2]

For USAF Skyraider pilots, it was not, by any measure, a "milk run" kind of combat tour. We are all familiar with the fortitude and perseverance of our USAF F-105 Thunderchief pilots whose predominantly North Vietnam mission assignments led to the F-105 Thunderchief, nicknamed "Thud," having the highest overall combat loss rate in the war, 2.1 per 1,000 Southeast Asia sorties.[3] What is less well-known, however, is that the A-1 suffered the highest loss rates for missions in North Vietnam compared to F-105, F-100, F-4, and all other USAF and USN aircraft recorded—7.2 for USAF A-1, 4.5 for the Hun, 3.3 for the Thud, and 1.7 for the Phantom. The A-1 loss rates in Laos and South Vietnam were also the highest of any combat aircraft, Air Force or Navy/Marine.

The Skyraider overall SEA loss rate was 1.7, second to the Thud at 2.1. This comparison is driven by the much larger number of Thud sorties flown "up North" as a percent of F-105 total combat sorties in the theater, compared to all other aircraft types. The A-1's 1.7 overall SEA mission loss rate was essentially double that of the next three combat aircraft—USN A-6 at 0.9; USN F-8 at 0.8; and USAF F-4 and RF-4 at 0.8. The Vietnam Memorial Wall bears the names of 104 USAF Skyraider pilots—approximately one out of every seven who flew an A-1 combat tour—and 40 US Navy pilots killed in action (KIA) in Southeast Asia as well.[4]

On the other side of these somber statistics is a benefit that all of us A-1 pilots fully appreciated—when USAF measured the number of aircraft lost as a percentage of aircraft hit by ground fire or SAM's, the A-1 was by far the most survivable when hit, more than double the statistics for the F-105, F-100, and F-4. Skyraider combat losses totaled 157 aircraft, 94 in Laos, 19 in North Vietnam (NVN), and 44 in South Vietnam (SVN). More than 80 A-1 pilots were rescued, including 50 in Laos, nine in NVN, and 22 in SVN.[5] If those numbers don't seem to match, the reason for 104 combat deaths, 157 aircraft lost, and more than 80 aviators recovered is that some A-1 sorties in the E and G two-seat models, particularly in SVN, had two pilots on board.[6]

In his recent book on the A-1, my 1st Special Operations Squadron (SOS) colleague, 1st Lt Bryon "Hook" Hukee, notes that the 602nd SOS, which pioneered the Sandy search and rescue (SAR) mission tactics and execution, on the one hand saved dozens and dozens of downed aviators, many in extremely high-threat environments in NVN and Laos. On the other, the Fireflies paid a huge price. From June 1965 to December 1966, the 602nd lost 35 A-1s, with 20 pilots either KIA or missing in action. By the time the 602nd had moved to Nakhon Phanom (NKP) Royal Thai Air Force Base (RTAFB) and later was inactivated in December 1970, those losses had risen to 77 Skyraiders and 38 pilots—loss rate statistics matched only, per the now declassified DOD statistics, in some of the F-105 Thunderchief squadrons or the F-100 Misty FACs "going North" during these same months.[7]

Overall combat SAR in SEA—the Air Force and Navy versions of "leave no one behind"—was surprisingly effective, even with the technologies and equipment of the time. In the entire conflict, more than 2,700 airmen were shot down. Just more than half of those—50.5 percent—survived. Of those survivors, four out of every five were rescued, sometimes by the USAF SAR force—the Sandies, HH-3 and HH-53 Jollies, C-130 King, and FAC's—and others by *ad hoc* "come as you are" combinations of on-scene aircraft and helicopters. The combat rescue numbers in North Vietnam are perhaps even more significant, and by comparison more impressive. Of all aircrews downed in NVN, 60.8 percent survived. More than half of those survivors were rescued, even given the much higher threat environment in the enemy's "home territory." For the majority of those rescues, A-1 Skyraiders—both USAF, and Navy earlier in the war—were the mission commanders and CAS for the pickup helicopters.[8]

One A-1 Skyraider Sandy Lead, then-Captain Ed Leonard, led the rescue effort for a Navy A-7 pilot, Kenny Wayne Fields, shot down in May 1968 near Tchepone, a notorious choke point on the Ho Chi Minh Trail (HCMT) in Central Laos. When Fields was ultimately rescued by the USAF SAR force after four days on the ground, 189 sorties had been flown, seven aircraft lost or severely damaged, and Captain Leonard was shot down, captured and imprisoned in Hanoi. Fields' telling of this harrowing story gives great insight into Leonard's bravery, and the SAR mission and the respective roles of A-1s, Jolly Green Giant helicopters, forward air control (FAC), C-130 King birds, and supporting strike aircraft, along with the entire USAF command and control structure.[9]

A-1 survivability rates—even in situations where planes were disabled on SAR or close air support sorties below 1,000 feet above the ground—were bolstered by a remarkable insertion of technology into the 1950s-era Skyraiders. The original Navy and USAF A-1 pilots had no ejection seat, and literally had to "step over the side" and activate their parachute, *a la* World War II and Korean War style bailouts. In 1967, after more than three years of combat sorties in SEA by both Navy and USAF Skyraiders, the A-1 was retrofitted with a remarkable Stanley Aviation Yankee Extraction System. The Yankee used a small spin-stabilized rocket to "pull" or "extract" the pilot and parachute upward and out of the cockpit with nylon cables attached to the parachute harness, and then used an explosive charge to rapidly deploy the parachute canopy immediately after the pilot cleared the fuselage. The "zero altitude/zero airspeed," unusual attitude performance of the Yankee system—1.7 seconds from activation to full chute deployment—proved to be a huge factor in improving survival rates for the pilots of stricken Skyraiders.[10] Rube Goldberg has nothing on the Stanley engineers, and those of us who used the Yankee are forever indebted to this amazing inventiveness.

The A-1 was powered by the Pratt and Whitney RD-3350 with its 13-foot, 6-inch, four-blade propeller, and its pilots had a particular swagger and esprit of the bygone prop era. However, that same spirit and bravado, in the face of highly dangerous missions, led to issues back in the continental United States. Because of its "love" of jet aircraft and sometimes blatant dislike of the "prop guys," the leadership of then-Tactical Air Command (now Air Combat Command) looked down upon the Air Commando/Special Operations part of the force. This led to a good number of early Skyraider pilot assignments to people who had been flying other big aircraft—C-47, C-54, KC-97, etc., as opposed to front-line TAC fighter pilots. Early on, the number of lieutenants straight out of undergraduate pilot training (UPT) was also quite small. Later, in the 1970–1972 timeframe, more new UPT grads secured A-1 assignments right after receiving their wings. Another significant source of Skyraider pilots was the old Air Defense Command, where highly experienced F-101, F-102, and F-106 interceptor pilots ended up in the A-1 as well. A fourth source of Skyraider pilots came from experienced ATC FAIPs (first assignment instructor pilots) who had served three to five years as instructors, right out of their UPT classes. USAF Skyraider combat squadron alumni are an interesting cross-section of all four of these backgrounds.[11]

Through the course of the war between 1964 and 1972, USAF A-1 combat operations were flown first by advisors to VNAF units in SVN, and later, by four squadrons, early in the war named air commando squadrons, and later changed to special operations squadrons, the title that remains in our service's special operations force structure today. The 1st SOS Hobos, the 602nd SOS Fireflies, the 6th SOS Spads, and the 22nd SOS Zorros operated throughout the combat theater, flying strike, CAS, special operations, and SAR missions in North Vietnam, Laos, South Vietnam, and Cambodia. The Hobos started out at Bien Hoa, South Vietnam flying T-28s and A-26s, and in 1964, transitioned to the A-1. That same year, the brand new 602nd ACS stood up at Bien Hoa as the second Skyraider unit.[12]

The third air commando squadron flying the Skyraider was the 6th ACS, which formed at Pleiku, SVN in February 1968. The 6th ACS, with 20 aircraft and 25 pilots, operated a detachment at Danang, and in late 1969, was disbanded and the planes and pilots transferred to NKP. In its short 18-month existence, the 6th ACS lost 12 pilots in combat, almost half of its normal manning. In addition to these four A-1 squadrons, other USAF Skyraider pilots flew as advisors to VNAF squadrons and in other short-term alert and forward operating location situations at a variety of air bases in SVN before 1969.[13]

Later in the conflict, as the Central Intelligence Agency (CIA)-directed US war effort in support of General Vang Pao's Hmong tribesmen in Northern Laos heated up, so did the effort to interdict North Vietnamese supply lines in Laos, and provide CAS to the Laotian irregulars. In Laos operating much in secret, the CIA-managed ground war demanded more and more CAS and covert special operations missions. At the behest of the US ambassador to Laos and the CIA, the A-1 force grew, and relocated across the Mekong River to Thailand. In 1968, the 1st SOS moved from Pleiku, SVN to NKP on the Mekong River less than 50 miles from the heart of the Ho Chi Minh Trail in Laos.[14] The 602nd SOS, which had previously shifted from Bien Hoa to Nha Trang, SVN, also moved in late 1966 to Udorn RTAFB, and then in 1968 to NKP. Also in late 1968, USAF stood up its fourth A-1 combat squadron, the 22nd SOS Zorros, also at NKP. The 56th Special Operations Wing, home to a wide variety of special mission aircraft from CH-53s and CH-3s to C-119K gunships to C-123 flareships to QU-22Bs, thus became the Air Force's first, last, and only large-scale, three squadron A-1 Skyraider combat unit, with more than 70 aircraft at its peak.[15] The Raven FACs, living and flying covertly in Laos at a series of airfields, were attached to the 56th SOW as well.[16]

NKP was a hub for USAF support for the air war in Laos, SAR missions across the theater, and a series of highly demanding special operations infiltration/exfiltration sorties for the Army's MACV, Studies and Observations Group (SOG), a special forces program of behind the lines recce, sabotage, road watch, and other covert functions. Flying with the NKP A-1s on these SOG missions, code-named Heavy Hook and Prairie Fire, were USAF forward air controllers—at first O-2s and later OV-10s—from the 23rd Tactical Air Support Squadron Nails, and CH-3s and CH-53s from the 21st SOS Knives, all in support of the MACV SOG mobile launch team (MLT) 3, Heavy Hook, based 100 yards from the NKP "Hobo Hootch" quarters of the 1st SOS.[17] In November 1970, the superbly executed but profoundly frustrating prisoner of war rescue raid on the North Vietnamese camp at Son Tay was launched from NKP, with the CAS provided by a force of five A-1 Skyraiders, call sign Peach 01–05, from the 1st SOS. The almost perfectly flown mission found a recently emptied camp, and the force returned home emptyhanded.[18]

The A-1 pilots at NKP and Udorn had a special relationship with the in-country "air force" of the CIA in Laos, Air America. Air America flew a wide range of supply, medevac, recce, and other support for the Hmong forces in Northern Laos, and for the Royalist forces in central and southern parts of the country. Air America Huey and H-34 helos, and light STOL aircraft like Porters and Heliocouriers, flew dozens of sorties each day in and out of contested territory, and for protection, they frequently asked for a Skyraider flight, either before or after that A-1 flight had conducted a strike or CAS mission, to cover their ingress, ground time, and egress from a wide variety of Lima Sites and other locations throughout Laos.[19]

Since the enemy was generally reluctant to fire on the unarmed Air America aircraft with two A-1s, with 20 mm cannon, 2.75-inch Mk 4 folding-fin aerial rockets, 7.62 mm Gatling gun pods, white phosphorus bombs, and cluster bomb units orbiting right overhead, this "cover" was generally highly effective, and understandably much appreciated by the Air America crews. The extent to which the support was "returned" to the NKP A-1 force is obvious. During my one-year tour from April to April, 1971–1972, all five of my 1st SOS Hobo colleagues who survived a shoot down and extraction in the Skyraider were rescued quickly by Air America, long before our USAF SAR force of Sandies and Jollies could scramble from NKP, Ubon, or Danang and pick them up.[20]

The Raven FACs in Laos were also special "brothers" to the A-1 force operating there. As is now widely known, the then-secret Raven program brought experienced FACs from throughout SEA, willing to extend their one-year combat tours for six more months, to a covert program operating from Laotian bases in support of the CIA's war effort, and directing US and Laotian strike aircraft against a wide range of enemy targets. Interestingly enough, the now-declassified data on SEA combat sorties, loss rates, and other similar data does not seem to include the Ravens and their remarkable covert work in O-1, L-19, and T-28 missions throughout Laos. It is reasonable to assume that, if such data were available, the battle damage and loss rates per 1,000 sorties for these warriors look much like the F-105 and A-1 numbers noted earlier. The Ravens alumni roster includes some notable USAF aviators, as do their combat KIA statistics.[21]

Before my own tour in the 1st SOS, two A-1 pilots from that squadron were awarded the Medal of Honor (MOH) for their bravery under fire on Skyraider sorties. The story of Maj Bernie Fisher is the stuff of legend. On 10 March 1966, while leading a flight of six A-1s in support of US special forces being overrun in their forward base camp in the A Shau Valley in northern South Vietnam, Major Fisher's wingman, Maj D. W. "Jump" Myers, was hit and forced to crash-land on the small airstrip that was itself the object of the attack. Under withering enemy mortar, heavy machine gun, and small arms fire, Major Fisher landed his two seat A-1E on the cratered runway, loaded Major Myers into his empty right seat, and successfully took off through that barrage of enemy fire, returning to Pleiku, their home base. President Lyndon B. Johnson awarded Major Fisher the MOH in January 1967 in the White House. Remarkably, Major Fisher's aircraft on that mission, A-1E SN 52-132649, survived two more years of war, returning home in 1968. Today, it is displayed in the SEA exhibition at the National Museum of the US Air Force Museum at Wright–Patterson AFB, Ohio.[22]

Just 18 months later, after the major standup of A-1s at Nakhon Phanom, Thailand, a Sandy force launched from the 602nd SOS for a SAR effort near Dong Hoi, NVN. During the process of locating and protecting the USAF pilot survivor on the ground, Sandy Lead Lt Col William A. Jones III suffered major battle damage and a raging fire in his A-1H. Realizing the fire was going to consume the cockpit, Colonel Jones pulled the extraction handle. The canopy jettisoned, but the fire had damaged the Yankee rocket, and he remained in the cockpit, now seriously burned. Fortunately, the fire went out with the canopy jettison, and Colonel Jones continued to precisely locate the survivor, leaving Dong Hoi to return to NKP only after he was sure of the survivor's exact location. The downed crewmember rescued later that day, incidentally, was F-4 pilot Capt Jack Wilson, later my colleague in the Missouri Air National Guard's 131st Fighter Wing in St. Louis.[23]

Returning to the United States in 1969, Jones was promoted to colonel, and recommended for the MOH. After that recommendation, but before the award could be made, Colonel Jones tragically died in a private aircraft accident. President Richard M. Nixon presented the medal posthumously to his wife in August 1970.[24] As a final footnote, Colonel Jones' badly damaged Skyraider, A-1H tail number 738, was fully repaired and returned to NKP. During my own tour, I flew that aircraft on eight combat missions, including some challenging SARs. "The Proud American," as it was labeled during 1971–1972, was flown as Sandy 1 on Roger Locher's famous Oyster 01 Bravo SAR in 1972, when my NKP roommate, then-Capt Ron Smith, was awarded the Air Force Cross for snatching Locher after a 23-day evasion and escape near Hanoi in NVN. A-1H tail number 738 was ultimately lost in combat in late 1972. The pilot, 1st Lt and later Gen Lance Smith, successfully extracted and was recovered by Air America in Laos.

When I arrived at NKP in April 1971 to join the 1st SOS Hobos, by then the last prop fighter squadron in combat for USAF, the unit possessed 32 A-1s, 24 single-seat H and J models, and eight two-seat E and G models. When I returned home in April 1972, there were only 13 aircraft left in the Hobos. More than a half-dozen of these losses came in a matter of weeks in April that year, with the North Vietnamese invasion across the demilitarized zone, and the infamous BAT 21 SAR. The NVA use of the shoulder-fired SA-7 Strela-2, a Russian copy of the US Redeye, brought down some of those Hobos. Even after a few more replacement aircraft were delivered from the states, the Air Force literally ran out of flyable airplanes a few months later in late 1972. With the 1st SOS unable to meet basic daily SAR alert and CIA

CAS fragment requirements, the USAF deployed two temporary duty squadrons of A-7s, the recently acquired USAF jet attack aircraft thought most closely suited to perform A-1 missions, to Korat RTAFB, Thailand. Later, some of these aircraft formed the 3rd TFS within Korat's 388th Tactical Fighter Wing, and would fly more than 12,000 combat hours before returning to the United States in early 1976.[25]

Most of the younger A-1 Sandies served "parole" tours as ATC instructor pilots when they returned to the states, because TAC initially refused in 1970–1972 to take any of the returning Skyraider pilots into that command. This reflected the anti-special-operations bias noted earlier, even though these young combat veterans each had 300–500 hours of combat CAS experience. A very special friend of the USAF Skyraider community at the time, particularly given this TAC hostility, was then-ATC commander Lt Gen William McBride. General McBride—via an old-fashioned TWIX message—made a personal commitment to the returning A-1 pilots after their tours, knowing of TAC's refusal to take them into that command. The general's message stated that his staff would make every effort to "give you the ATC base and aircraft of your choice." By my count, every single Spad driver who returned after General McBride's offer—including yours truly who returned to Moody AFB, Georgia in the T-38—got exactly that, the ATC base and aircraft of their choice. This meant that when TAC leadership changed a short time later and Gen Wilbur L. Creech asked "where are all the Skyraider guys with all that CAS combat time?" TAC was able to reclaim a large number of the experienced A-1 pilots, and the proud Sandy tradition was continued, even to this day.[26]

Returning to TAC, many former younger SEA A-1 pilots became leaders in USAF's A-7 and soon-to-follow new A-10 force. Today, in USAF special operations and SAR missions in Southwest Asia, and in Bosnia and Iraq earlier, many of the A-10 mission plans, tactics, and rescue force coordination principles are direct descendants of the A-1 Sandy operations and lessons learned from four decades ago in SEA. Among the more than 600 USAF pilots who actually flew combat in the Skyraider, many of that alumni list went on to serve long and successful Air Force careers. The group includes a former chief of staff, Gen Michael Dugan; four other four-star generals, Butch Viccellio, Jim Jamerson, Al Hansen and Lance Smith; Lt Gen Gordie Fornell, Maj Gens Darryl Tripp, Richard Engle, Larry Fleming, Sam Westbrook, and me; and Brig Gens Richard Head, Robert Winger, Ed White, Garry Willard, and my other NKP roommate, Dick Dunwoody.[27]

One of my 1st SOS colleagues and combat companions, then-Lieutenant Hukee, has created and maintained a remarkable website (http://www.skyraider.org/) that documents the A-1 combat experience in SEA, and has included his own combat journal describing the diverse set of missions that we flew. More recently, Hook has added to his outstanding documentation by publishing *USAF and VNAF A-1 Skyraider Units of the Vietnam War*, a thin but rich documentation of the Spad's combat role in SEA, published by Osprey Press.[28] In 2007, military aviation history author Wayne Mutza, added another outstanding book, The *A-1 Skyraider in Vietnam: The Spad's Last War*, by Schiffer Publishing.

The USAF Skyraider community gathers every other year for a fall reunion and enjoys the occasional visit and participation of some of our amazing crew chiefs, weapons and maintenance colleagues, and other support staff who kept a venerable antique flying decades after it was first deployed. Also, we have been joined by a healthy number of our esteemed VNAF colleagues, many of whom have thousands of combat sorties and thousands of combat hours in the Skyraider, compared to our USAF statistics which measured in the hundreds. Additionally, we are always honored to see the occasional Raven, Jolly Green, Knife, Nail, Covey, King, and other colleagues with whom we flew and fought. Our most recent gathering in the fall of 2015 brought yet another special treat—the presence of a handful of General Pao's brave ground controllers, who forward-air-controlled our Skyraiders in Northern Laos for many years. We were honored to meet them face-to-face and visit with these heroes.

These days as our numbers and memories dwindle based on the march of time, we can still note, on a point of significance for our Air Force colleagues since Army Air Corps days in World War I, that the Skyraider pilots of USAF in Southeast Asia were privileged to fly in the very last propeller driven fighters in combat in our service. A nickel in the grass for all our fallen brothers in that war and others since but especially for those who flew our beloved Sandy SAR missions and Skyraider-style CAS and special operations missions, "up close and personal." ✪

Notes

1. For details on A-1 Skyraider models, development, and numbers of aircraft produced see https://en.wikipedia.org/wiki/Douglas_A-1_Skyraider and Wayne Mutza, *The A-1 Skyraider in Vietnam: The Spad's Last War, Schiffer Military History* (Atglen, PA: Schiffer Publishing, April 2003).

2. The size of this pilot group who did not fly combat in the Skyraider can be estimated by comparing the number of graduates from the Hurlburt AFB, Florida training program, (www.skyraider.org/skassn/classpics/hurphot.htm) versus the numbers listed in the various A-1 squadrons over the years. While this math is anecdotal, it is verified by the actual membership of the A-1 Skyraider Association in four decades.

3. Richard Gabbert, *A Comparative Analysis of USAF Fixed Wing Aircraft Losses in Southeast Asia Combat* (Wright–Patterson Air Force Base, OH: Defense Technical Information Center, 1977), document number AFFDL–TR-77–115.

4. In addition to being etched on the Vietnam Memorial Wall in Washington, DC, these 144 names are memorialized on a plaque at the A-1 Skyraider Memorial at Hurlburt Field, FL. See http://www.skyraider.org/skyassn/menlost.htm.

5. Gabbert, "A Comparative Analysis," Ibid., 39–42, 57–62.

6. Ibid.

7. Byron E. Hukee, *USAF and VNAF A-1 Skyraider Units of the Vietnam War*, Osprey Publishing, 2013, 53. For reference to the MISTY FAC program in the F-100, see https://en.wikipedia.org/wiki/Forward_air_control_during_the_Vietnam_War#Fast_FAC_jet_aircraft, sect. 1.2.2, Fast FAC Jet Aircraft, and http://mistyvietnam.com/.

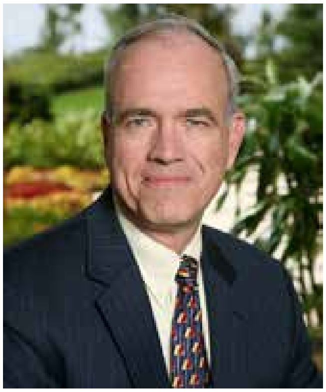
8. Gabbert, "A Comparative Analysis;" Earl H. Tilford Jr., *Search and Rescue in Southeast Asia: USAF in Southeast Asia* (Honolulu, HI: University Press of the Pacific, 2005); and Maj Russell G. Ochs, *The Evolution of USAF Search and Rescue in Southeast Asia, 1961–1968* (Maxwell AFB, AL: Air Command and Staff College), 22.

9. Kenny Wayne Fields, *The Rescue of Streetcar 304* (Annapolis, MD: Naval Institute Press, 2007), 306–308.

10. See http://tailspintopics.blogspot.com/2011_10_01_archive.html for a brief description and photos of the Yankee System installation and operation.

11. This calculation of the prior assignment sources for A-1 pilots is based on personal observation and discussion at many A-1 Skyraider reunions. Throughout the nine years and four squadrons of Skyraider pilots in Southeast Asia, this mix of previous reciprocating engine, Air Defense Command, Air Training Command instructors, and new undergraduate pilot training graduates, was reasonably consistent.

12. Ibid.
13. Ibid.
14. See http://aircommandoman.tripod.com/ and https://en.wikipedia.org/wiki/Nakhon_Phanom_Royal_Thai_Navy_Base for history and background on Nakhon Phanom Royal Thai Air Force Base and its units.
15. See http://en.wikipedia.org/wiki/56th_Fighter_Wing and http://aircommandoman.tripod.com/id3.html for historical detail about the 56th ACW/SOW during the Vietnam conflict.
16. Christopher Robbins, *The Ravens: The Men Who Flew in America's Secret War in Laos* (New York: Crown Publishers, 1987); and Dr. Joe Leeker's history section, 2–3, http://det156sow.com/download/rlaf_t28s.pdf.
17. For insight into these covert operations, see https://en.wikipedia.org/wiki/Military_Assistance_Command,_Vietnam_%E2%80%93_Studies_and_Observations_Group.
18. See Son Tay Raid history and specifics at http://en.wikipedia.org/wiki/Operation_Ivory_Coast.
19. The close relationship between A-1 pilots and Air America is not documented anywhere that I am aware, but can be verified by attendance at any A-1 or Raven reunion, both of which are visited frequently by both former Air America aircrews and our Laotian brothers who fought for General Vang Pao.
20. Ibid.
21. Robbins, *The Ravens*. Also see the website at http://www.ravens.org/.
22. http://en.wikipedia.org/wiki/Bernard_F._Fisher and http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=297.
23. See https://en.wikipedia.org/wiki/William_A._Jones,_III, Biography and Medal of Honor sections.
24. Ibid. http://en.wikipedia.org/wiki/William_A._Jones,_III. See Biography and Medal of Honor sections.
25. See https://en.wikipedia.org/wiki/LTV_A-7_Corsair_II, sect. 2.2, USAF A-7D.
26. The Air Training Command (ATC) honoring of this commitment can only be proven anecdotally, but in my personal accounting of General McBride's commitment and all the new pilots right out of undergraduate pilot training (UPT) and those who had been ATC instructor pilots previously, everyone returned to the ATC base and aircraft (T-37 or T-38) of their choice.
27. While our A-1 Skyraider Association has kept records of alumni for more than forty years, apologies if this list omits any retired flag officer who flew combat with us in the Skyraider.
28. Ibid., USAF and VNAF A-1 Skyraider Units.



Maj Gen Edward R. Jayne II, USAF, Retired

General Jayne (BA, USAFA; PhD, MIT) is a partner with Heidrick and Struggles, Inc., and a veteran of more than 34 years' service in the USAF and Air National Guard. In uniform, he served two combat tours in Southeast Asia—in the A-1 Skyraider and the F-4D Phantom—and flew as a combat-ready fighter pilot in the F-105, F-4E, and F-15 Eagle as well. He also served as the special assistant to assistant to the president for international economic affairs in the Nixon administration, a professional staff member in the National Security Council Defense Policy and Programs Division in the Ford and Carter administrations, and associate director, National Security and International Affairs in the Office of Management and Budget. The general flew as a T-38 jet instructor pilot, and was the first Air National Guard assistant to the commander of Air Force Space Command. The general is a retired executive in the aerospace industry, having served as the vice president and program manager for the F-15 Eagle, and the president of the Missile Systems Company at McDonnell Douglas. General Jayne is currently the chairman of the USAFA Endowment, the fundraising foundation for the Academy.

Data You Can Trust

Blockchain Technology

Col Vincent Alcazar, USAF, Retired

> *They say that coming events cast their shadows before. May they not sometimes cast their lights before?*
>
> —Augusta Ada King–Noel, Countess of Lovelace

The Case for Change

America's military continues its wait for network-centric warfare (NCW) breakthroughs to deliver technological leadership and war-fighting advances that revolutionize the American way of battle. Instead, in the past decade the US military got artifacts: Internet access, laptop computing, the introduction of smartphones, and so forth. The artifacts of technological advancement are often misidentified as the anticipated NCW breakthroughs. At their core, those artifacts are iterative device and machine productivity improvements. If NCW has an insidious weakness, it is its hardware orientation. The focus on artifacts begs a question: what about the data that is transported within the hardware, devices, networks, and associated infrastructure? Despite advancements in technologies and processes, today's software and hardware shells—the things that surround and distribute data—remain chronically vulnerable. Among history's recurring insights is that a military's vulnerabilities—hidden or acknowledged—can become linchpins in an opponent's campaign of surprise. However, surprise need not be strategic to impede the American way of battle. What is to be done?

Against the backdrop of US data vulnerabilities and potential susceptibility to cyberspace surprise, warriors and warrior leaders need a different approach, a big idea—a viable technology that can mitigate the weakness in the DOD's paradigm of centralized data protection. The better (big) idea should not be a continued near-exclusive focus on iterative military computing machine improvements. Instead, this better idea ought to outline a design for the enhanced security of what military information technology (IT) equipment processes, stores, and distributes: data. The better idea exists; it is blockchain technology. Concisely stated, blockchain is a technology that stores data in a way that makes it incorruptible, doing so via its integrated data ledgers. The reasons to adopt blockchain's leap-ahead technology are twofold:

avoiding downside disruption risk and maximizing upside war-fighting opportunity. Regarding downside risk, warriors need to mitigate the operational disruption and degradation resulting from an absence of authentic data, because so many of our weapons systems require data to function effectively, if at all. Blockchain's upside is that the US military could take data corruption and compromise off the table as things an enemy could do to its data. The first reason is important; the second reason is game-changing in warfare.

The development of a blockchain big idea, along with machine improvement, suggest significant growth in DOD IT costs in an era of resource limitations. However, blockchain already exists, and that saves millions of dollars in research and cuts years off a development program. Basically, blockchain is a data management and distribution technology compatible with existing DOD networks. Its game-changing design secures and inscribes data, protecting it from tampering and corruption. Blockchain frees our military from continued competition against state and nonstate actors, who as attackers have vast incentives and agile exploitation development loops that yield an uneven playing field. The unevenness of that playing field is the result of tremendously disadvantageous and deeply inefficient geometry that pits enterprise hardware/software threat mitigation that must be right all the time against a threat security environment where a determined attacker need only succeed briefly. To tilt the playing field in a way that favors America's military, the ideal solution points toward a union of blockchain technology and American computing machine/system ingenuity.

Problem, Thesis, Hypothesis

Data has become the modern military organization's critical dependency. In practice, the lack of timely, accurate data condemns a force and its leaders to operations via a method of guesswork. Generally, the guesswork method of sensing and decision making poses problems. It was a problem when the force was led by a single man sitting on horseback overlooking a battlefield. In this century, a lack of assured data opens any force to traumatic defeat in multiple domains. The paradox is that America's distributed warfare model attains its full potential when its vast, growing data appetite is fed regularly by vetted data known to be secure. The data edge users in the DOD know the problem is not the data appetite of our machines or the scale of that appetite.[1] Rather, any problem statement about the status quo would not be a one-liner but a circle drawn around a cluster of interrelated questions: what is the reliability of the data floating around in our IT systems, the data that warriors need to prosecute the fight? Has that war-fighting data been tampered with, in part or whole? Is that data truly authentic or only authentic in appearance yet actually bogus, planted by a clever attacker? Is the sender a credible entity, or is the alleged source really a system mole seeking to cause havoc? Which of those questions as problems should be solved, and in what order? Actually, warriors do not care, but the answers they hear from IT experts is to attend to all of those matters, simultaneously. And so, each of these matters is worked using separate approaches in separate silos.

Winning the fight to protect and control our IT systems requires a tremendous outlay of resources. But what if we could push all the above questions and the problems they suggest off the table by shifting the focal point of the answer? Instead of asking what could be done anew to IT systems, what if something could be done anew to the data itself? Enter blockchain—it focuses the question and answer on data. Given that, this article's thesis is that if the DOD deploys blockchain—a new and radically different data management technology—then the data attacks of today become much less damaging, with the key benefit being that the data in warriors' hands becomes exponentially more dependable by being virtually incorruptible.

Next, this article's hypothesis is that to best protect war-fighting data in US military networks, the best-known data technology solution is blockchain. Put another way; blockchain can help war fighters escape the hamster wheel of mitigating the cyber attacks we experience while incurring damage from the predation of unanticipated, undocumented, unmapped, and unknown IT hardware/software vulnerabilities.

Blockchain—An Overview

In 2008, an individual using the pen name Satoshi Nakamoto published a now well-circulated whitepaper that outlined the Bitcoin concept and its enabling bedrock system, blockchain technology.[2] Blockchain might be the first technology truly worthy of the label of disruptive data technology. Blockchain is not just a generational improvement over current data logging and documenting technologies. Its importance is its ability to remove a crucial vulnerability in our present network designs: compromise of network trust-management policies. Trust-management functions are a frequent attack target owing to the vital role they play in all cyber networks, including the ones used by the military. The trust manager controls two vital functions: user credentialing and access control. Trust management relies on a hardware device and its software to play the role of the middleman to ensure users and their data transactions remain trustworthy.[3] By targeting user credentials, an attacker can gain network entry to get at the ultimate data target set to attain the objectives of his or her attack.

The founding designers of blockchain understood the limitations inherent in the network design paradigm that require the existence of a trust manager. In creating blockchain's underlying form and logic, they pioneered a technology within a new operating framework that sets aside the numerous weaknesses of the DOD's system-based computing as warriors know it today. The following points are an overview of how and why blockchain qualifies as a disruptive technology.

Blockchain Is a New Source of Strength

Traditional secure network design vests trust-relationship management and gatekeeping roles in a central actor with complete authority within the hierarchy of the network. Blockchain removes the requirements for centralized authority by removing the need for the trust management middleman role. The absence of central control confers a scalability that makes a blockchain network capable of functioning with the same effectiveness and efficiency at any size threshold; that is, a raid-ing party, a large joint task force, and so forth. Another advantage of blockchain is that its decentralized structure (flatter organizations) and less centralized logic (less top-down) decrease latency. More horizontal and less vertical overcomes many of the challenges in military networks fraught with the risks of the loss of the centralized trust manager(s). In other words, making blockchain strong is not something you do to blockchain; it is blockchain.

Blockchain Flips the Data Centralization Paradigm

Advanced persistent threats (APT) and state and nonstate actors all exert substantial influence on American military network design. Those threats compel a broad defensive response that hoards data behind ever more elaborate protective walls sheltered within more layers of security. What results from this mindset of threats, defenses, and responses is a constantly expanding multiplicity of data silos. The security of data becomes its own end, and from that end flows an unintended result: the balkanization of data. To data managers, this construct reads both right and appropriate. However, to the warriors who fight battles in multiple domains and from increasingly distributed battlespace positions, silos put data—a tool of warfare—farther away and not where it ought to be in warfare, close at hand.

Blockchain Reshapes Defense of Data

Blockchain does not make all conceivable actors and threats irrelevant; no affordable military network design can. However, blockchain's structure of network miner proof of work and its distributed ledger of data transactions greatly reduce the possibility of data theft, data corruption, and sender identity compromise.[4] Additionally, blockchain's data encryption standard, SHA–256, makes backward exploitation of sender message content expensive and time-consuming. Even if an opponent could economically break the SHA–256 encryption standard, it is highly unlikely that it could do so at the speed of war; that is, fast enough to matter in a fight.[5]

Blockchain Data as a Woven Fabric

In the current vision of US military data management, data aggregates in data sinks. The very existence of storehouses of data invites attack. If one creates a construct where data is gold, one puts that pile of data at constant risk. Blockchain stands the data-hoarding paradigm on its head. Sure, data is still king, but blockchain entombs data within its arrangement of data blocks, as each is added to the blockchain network's ledgers. Altering the data contained in each block is impossible after a completed block is added to all network ledgers.

Blockchain's Decentralized Structure Complements Distributed Warfare

When temporarily disconnected from their native blockchain network, miners are not disabled, only idling as they await the next data transaction.[6] When a blockchain network reconnects to overarching networks, a block proof of work synchronization occurs. All completed data blocks are exported to every ledger. This routine is designed to ensure that when a network's miners and related machines restart, they do so in unison, on the same new data transaction. This design of blockchain is important to warriors who know that it is not a matter of if but when connectivity falters.

Blockchain, An Option to Manage a Battle Network of Objects

Blockchain's structure lends itself to management of a conceptual battle network of objects (BNO)—a militarized version of the civil Internet of things. Rather than a discreet command path for objects in the BNO, objects would connect to thousands of other BNO devices, all in a blockchain network to send and receive data that, when decrypted, is added to each object's ledger, or perhaps, to machines that host a ledger for clusters of related BNO devices. Blockchain becomes the synchronization mechanism for BNO devices in a network, regardless of its population. Blockchain eases the warrior's burden of maintaining high awareness in a battlefield full of networked objects. With blockchain, each device does not have to be prompted to affiliate with a network to learn; rather, blockchain's ledger structure ensures any device connected to the blockchain network previously learned what it needs to know.

Blockchain, An Option to Control Device Swarms

Blockchain's distributed form, coupled with the algorithms that will be engineered into swarm devices, unlocks authentic swarm behavior, thus realizing a more fully militarized potential. Blockchain could accomplish this in two ways: first, provide for a swarm memory to form a bedrock of swarm actions, and second, provide the means for swarm-to-swarm connectivity and communication. Perhaps most exciting, blockchain technology could enable varying levels of human–robot interaction. Blockchain could accomplish this through swarm memory as described above and the dynamics of emergence (swarm self-organization; both could boost swarm awareness). With elevated awareness, swarms could attain high levels of autonomy, a useful attribute in tactical scenarios where direct operator control is impractical or when operator-swarm connectivity is interrupted.[7]

Blockchain—How Does It Work?

The first Internet-public version of blockchain debuted in different places at different times, starting in late 2008 and early 2009.[8] A blockchain network can be any size, and features interconnected machines termed miners, ledger host machines, and connection points to other networks. Miners are computing machines whose task is to calculate the solution to a sophisticated equation.[9] Elliptic curve digital signature algorithm (ECDSA) is the arithmetic of blockchains, and asymmetric key cryptography is the means by which data transactions are encrypted by a sender and decrypted by a receiver using the paired public/private key method.[10] Once an ECDSA solution is successfully determined by a miner, it is converted by an algorithm into a data string 256 bits in length.[11] The data string is the payload of any given data transaction ordered by blockchain block technology. As the transaction moves from point A to point B in the network, miners in their role as receivers use their individual computing power to solve a transaction's ECDSA equation by repeatedly calculating the equation until its solution output data string matches the data string in the sender's data transaction. Once that match is made, the data block is almost complete and will quickly be eligible to be added to the ledgers—the record of all completed transactions—of every network miner and ledger host machine.[12] Paired public/private key technology protects the solution such that an attacker cannot steal or corrupt solution data within the network. One does not have to be a computer science engineer, a network administrator, or a National Security Agency cryptologist to understand what blockchain is doing: using complex ideas in simple ways to produce something more important than mere data.

Security is a cornerstone of blockchain. The digital cryptography in blockchain is so robust it would take a single desktop workstation an extensive period of time to calculate all the possibilities to hack a sender's data string.[13] The complexity of blockchain encryption can be modulated; that is, dialed up or down.[14] For military blockchain applications, this rheostat feature may prove instrumental in providing flexibility in expeditionary operations; sometimes more encryption complexity is needed, other times less complexity is more appropriate. In routine practice, it takes an average of 10 minutes for current generation blockchain network miners to solve for the standard SHA-256 encryption equation.[15] However, newer blockchain technology can reduce this computation time to three minutes. With next-generation chip speeds and the commercialization of quantum chips, it is conceivable that even today's most rapid computing velocity could be reduced by another order of magnitude (six to eight seconds). At the end of the current 10-minute calculation period, the network performs what amounts to a community synchronization process whereby all networks ledgers are updated in unison. A completed blockchain data block from the miner first to solve the equation and match the data strings—termed a proof of work—is exported to network machines as a copy and to add to each's ledger—the record of all network data transactions since its inception. Imagine the blockchain network in action; a technology that enhances our warfare style, not making that style less flexible and more brittle as we continue our pursuit of digitization.

What occurs when a data block is completed is what makes blockchain unique and superior to data management approaches in today's networks. Recall that corruption of a network's trust management function can bring network users and data into question. However, once a blockchain block is complete, the block's contents are sealed, and its data payload becomes incorruptible. The mechanics of this process are simple: a completed block is published in unison to every network machine's ledger. Concerning attack, the bottom line is that there is no convenient method for an attacker to corrupt transaction data so his recourse would be to attack an entire network. However, short of outright destruction, that network is, at worst, short-term hampered, not long-term defeated.

In military applications, it is likely that blockchain miners would work on different transactions at differing speeds, disconnect, and reconnect to their network at different times and rates. The reasons for this could be machine computational performance differences, communications instabilities, emissions control measures, or attack effects on the network. In any of these conditions, it is possible for multiple blockchains to develop—chains that could compete with the single chain of blocks. In and of themselves, multiple chains cannot be allowed to persist because of the potential for contradictory transactions of data to form in the network's data ledgers. The method to mitigate this problem is simple: miners and participating network machines identify the longest chain of blocks and seek to add future blocks only to that chain. Given the amount of data crunching that occurs on a blockchain network, miners can utilize a logic tool to keep the chain of blocks at a predetermined length. This tool eases machine demand on machine memory as the chain of blocks lengthens. Use of this tool helps to ensure that in military operations, blockchain data transaction flow rates remain at the highest possible speed.[16] The takeaway is that blockchain not only fortifies data but is sensitive to network performance.

Blockchain—What Use Could Look Like?

The following are select examples of how blockchain's organic design can be applied to broad military mission sets:

- **Operations orders and planning documents**. Blockchain's decentralization hints at a network's democratization of sorts when it comes to data. For warriors in a fight, there is nothing more democratic and pressing than the need to know the fight plan and keep up with its changes. Putting relevant aspects of a fight plan like these into the hands of war fighters is a goal of preparation and execution. Blockchain's leap ahead is its technology that ensures that data, in this case operational points, is pushed out horizontally; data is preserved in the stone that is data blocks. If some portion of the network suffers a connectivity break with a headquarters network, that senior network need only pass data blocks to a single miner of a subordinate network. In that scenario, that receiving miner will push that block and others as required to every data ledger in that blockchain network. The so-what is that fight situational awareness is reboosted, and the mission continues.
- **Device swarm control**. Designers are working on carriage systems for swarming devices—a war-fighting method that has attracted the attention of the US military—and engineers are identifying swarm device applications. The biggest challenge to swarm employment is not device design or packaging; it is control.[17] One of the key limitations of the control of hundreds, indeed thousands of devices, within a swarm is what experts call global knowledge. In other words, it is an awareness of not only adjacent devices but also shared awareness among all of the devices within the population.[18] Combined with simple operating routines programmed into each device but managed and orchestrated by the open, distributed design of a blockchain network, all that a swarm sensed would be known and knowable to all devices at the same time. The result is a swarm's ability to act as a single entity. Blockchain technology unlocks the military possibilities of swarms.
- **Logistics**. With so much logistics supply and demand data exchanged between military providers and civilian counterparts, the assurance that data is authentic—not tampered with—is paramount. Blockchain's ledger logic ensures that what is transmitted by credible senders and received by authorized

recipients can be inherently trusted. Blockchain works especially well in the world of logistics given its contracts, agreements, order forms, requisition documents, etc. Whether those logistics documents are computer generated or not, blockchain's organic logic ensures that each document remains reliable, accessible, and incorruptible.

Blockchain—Some Limitations

Vulnerabilities discovered in early laboratory experimentation were recognized and addressed; one such was the selfish miner. The selfish miner problem is based on a situation where a group of miners colludes to prevent or divert transactions for their gain; a challenge in some civilian blockchain environments. In the worst-case example of a selfish miner, a minority of rogue miners seek to recruit other miners to gradually gain the upper hand to eventually control a network. Researchers discovered two aspects of this phenomenon: first, the selfish miner problem has an upper limit whereby the rogues eventually take over the network to become the network reinvented. The second discovery was that a simple coding modification to blockchain logic eliminated selfish miner outbreaks at the outset.[19]

Engineers identified another vulnerability, a Sybil attack. This attack results when an actor adds rogue miners to a network's minor population; not to speed equation solving but to steer honest miners in that network population away from solving certain transactions. The impact of the Sybil attack is twofold: it decreases the network's pooled computational power and slows network ledger updating. Sybil attack vulnerability can be proactively eliminated by altering the single-longest blockchain preferencing behavior of miners; the logic that compels miners to add ledger blocks to only the longest existing chain. In something of a contradiction to normal operating logic, the antidote for a Sybil attack is to divide the miner population such that all miner output blocks are segregated into two discrete chains until one emerges as the longest chain—typically by a single block. When the single chain emerges, the Sybil attack is halted, the shorter chain is discarded, and the miner population resumes normal operation.

Blockchain—Answers to Limitations

To tailor blockchain best to military application, developers will map to insights learned from blockchain's infancy. Advances in artificial intelligence (AI) could be cross-leveraged to deter and suppress selfish mining as an alternative to modifying blockchain logic. Another use for AI algorithms will lie in locating anomalous miner behavior, such as the early formation of selfish mining groups.

Blockchain as a technology continues to evolve, yielding new types and potential uses. An example of such innovation, an alternative blockchain is a variant that creates blockchain networks that only look for and process specific data transaction types. Another blockchain variant is a sidechain, a special cluster of miners to solve specific kinds of transactions in purpose-built networks. In military use, alternative blockchains likely have utility in networks that carry intelligence data transactions.

AI, miners, and machines could team to filter transactions at differing classification levels in alternative blockchain networks. To expand this idea, intelligence blockchain networks would provide data to users using binned access permissions on the same network instead of using separate networks side-by-side for users cleared to different levels and programs. An added security feature would be an anonymizing browser that masks user information and other pertinent data.[20]

In field operations, block sidechains likely have a significant role. Examples include missionized networks that perform data transfer and exchange functions in support of specific missions, such as raids, occupations, high-value-target strikes, and so on. However, an important contrast must be made: current DOD networks reach down (top-down, centralized) to the tactical level. Blockchain is different; it is decentralized (horizontal). Attackers know how to defeat centralized networks and cripple the military mission—that is today's problem. Blockchain takes that problem off the table and ensures that missions are not jeopardized because of data security issues.

A future evolution, blockchain 2.0, arrived several years ago and spawned the rise of more than a dozen new commercial blockchain providers, each customizing blockchain technology to work in specific business applications that ride on various blockchain types. One such entity, ADEPT—a joint development of IBM and the Ethereum foundation—is developing blockchain for civil Internet of Things applications.[21] Ethereum's blockchain variant would overhaul the Internet from its current state to an alternative state where records, titling documents, contracts, and the like are no longer stored and possessed by third-party government or commercial entities. In this perspective, blockchain storage and accessibility applications become the twenty-first century data storage location of choice.[22] To warriors, all of this means blockchain is already taking on new forms and is sufficiently developed for tailored military applications that support our diverse missions.

Blockchain miners require extensive computing power. Adequate facilities to host miners most likely exist at steady state bases, ports, and hubs. To position miners farther forward, near war-fighting forces, militarized miner machine designs must consume less power, take up less space, and become appropriately ruggedized. There is some work to do to make blockchain components deployment ready.

Adoption—What Got Better?

Blockchain is a preexisting cryptography technology expressed in a new concept of application with a chief benefit of ensuring that war fighters maintain high confidence in the authenticity and security of the data they get from DOD networks. The bottom line is that blockchain gives war fighters what they need—trustworthy data. As a benefit, trustworthy data speaks to a concern of the war fighter—data that others cannot corrupt. Putting this notion into practical terms: in the fight, can I trust data to help mitigate cyber vulnerability and preserve operational momentum?

Is the US military aggressively pursuing blockchain development? No. The reasons are loosely rooted in skepticism of new ideas and an unclear development path. Despite the DOD's fascination with innovation, too often a "not invented here" attitude closes minds and doors to thinking and things that challenge status quo norms; think *The Structure of Scientific Revolutions* by Thomas Kuhn. Still, other DOD critics find a reason to eschew new ideas because at first glance they are not mature; neither were radar and jet propulsion technologies when they first burst onto the scene. The insight, of course, is that sometimes you must look beyond present constraints to see what a technology could eventually become. Elsewhere, the idea of better protecting the DOD's data, or at least more of it, is not viewed as credible as pouring billions of more dollars into the hardware side of America's massive military data enterprise.

Finally, there is one thing we can state categorically: acquiring data for military application is important; protecting that data is essential. Develop blockchain, then deploy it to boost data security and enhance the operating performance of every DOD weapons system it touches. ✪

Notes

1. *Edge users* include all users outside of static command and control nodes with an emphasis on tactical users—*warfighters*, in expeditionary settings.

2. Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," accessed 1 September 2016, http://www.bitcoin.org/bitcoin.pdf.

3. Michael Crosby, et al., *Blockchain Technology*, Sutardja Center for Entrepreneurship and Technology, 16 October 2015, 3. Outside of the operators of networking systems, many users do not practically recognize *trust* activities in networks. Crosby, et al., cite familiar activities as the products of network middleman trust activity: verification that one's e-mail is delivered to an inbox, Facebook's verification that one's posts are only shared with friended contacts, etc.

4. In this essay *authenticity* refers to the assurance of a given user's identity.

5. The *Secure Hash Algorithm* (SHA)–256 standard contains a high confidence order of digits up to 256 bits in length. The SHA methodology has its roots in NSA work to improve the integrity of data strings transmitted via message protocols. By using a string of digits 256 bits in length, equivalent to 2,256 possible digital variations, a message receive can run a simple routine that looks at the SHA–256 data string of a specific file before/after transmission. The power behind the SHA–256 standard is the arithmetic power of 2,256. To get transaction processing time down to minutes, network miners compete but ultimately cooperate to pool their computational power to get the correct match—the solution. Future military blockchain applications could leverage even more robust SHA data strings, 512, 1,064, etc.

6. Blockchain miners are special-purpose designed machines with a robust processing power to calculate the unique solution to each SHA–256 transaction data string.

7. Blockchain will not cause devices to operate as a swarm; rather, blockchain is the means by which the swarm can attain the global knowledge within machines innate to swarming creatures in nature.

8. Crosby, 5.

9. Erik Rykwalder, "The Math behind Bitcoin," Next World with Michio Kaku, 19 October 2014, http://www.coindesk.com/math-behind-bitcoin/. 10. Ibid., 1. Note: ECDSA as used in blockchain is related to other elliptical curve cryptographical algorithms. The principle behind ECDSA is simple: sound cryptography turns on the principle of hack-resistant mathematical work. ECDSA is leveraged because blockchain needs public/private keys to complete a data message (transaction). In blockchain, the solution is an identification of the unique solution but the message transaction is completed when that solution is matched against the solution string encrypted by the sender. This complete, the block is time-stamped and is complete. A complete block is eligible for addition to that miner's own ledger; that complete, the miner's proof of work is validated when it is added to all that specific network's ledgers.

11. In blockchain, the principle is: digital object (ECDSA computation) that is processed in the SHA–256 algorithm for which the resulting nearly unique data output is termed a *hash*—the digital fingerprint of the original object.

12. Ibid., 6.

13. Ibid., 8–11. On a 32-bit 20MHz clock speed workstation chip (~ 224 hashes/sec.), it is estimated that the single machine would require 139,461 years to match the 256–bit input/output data strings. Shorter I/O intervals are producible with more chip computing power. The task for militarization will be strike a balance between SHA cryptographic robustness and economy of scale chip performance in light swarm devices. Already "lighter" blockchain technologies are commercially viable with computation intervals reduced from 10 to three minutes.

14. The encryption standard of basic blockchain that supports Bitcoin is the Secure Hash Algorithm (SHA) that is 32 bytes (256 bits) in length.

15. In blockchain systems in the payments industry, the time associated with this synchronization cycle is synthetic. In military applications, it could be increased or reduced. *Litecoin* uses a 2.5-minute synchronization cycle.

16. This logic tool referred to as a *Merkle Tree*. To recover used computer disk space—memory utilized for previous computations—when the chain reaches a given length, the miner's built-in length limiter goes to work trimming the chain from older blocks. There is a deeper relationship at work here that is related to the hash coding inherent in the blocks at the bottom—where the trimming begins. As computing power at each miner node increases, the number of chains that can be retained in its respective *Merkle Tree* differs than other miner memory; however, the quantity of blocks removed from memory never exceed the minimum required to ensure undisrupted network operation.

17. Peter Coy and Olga Karif, "This Is Your Company on Blockchain," Bloomberg Businessweek, 25 April 2016, 8, accessed 2 September 2016, http://www.bloomberg.com/news/articles/2016-08-25/this-is-your-company-on-blockchain.

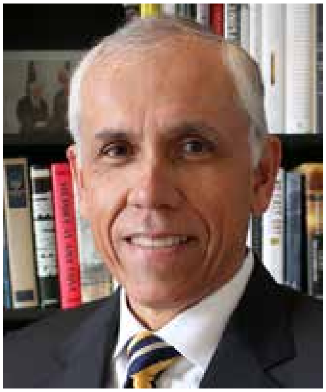
18. Eduardo Castelló Ferrer, "The Blockchain: A New Framework for Robotic Swarm Systems," (Cambridge, MA.: MIT Lab, 3 August 2016), 3, https://www.researchgate.net/publication/305807446_The_blockchain_a_new_framework_for_robotic_swarm_systems.

19. This fix is accomplished by decreasing the number of miners required to attain network consensus. In this scenario, the overall threshold is lowered; this acts as a tool to prevent selfish miners from colluding.

20. The TOR anonymizing browser is one such example.

21. *Ethereum* is a Swiss nonprofit organization, www.ethereum.org.

22. Cellabz, "Blockchain and Beyond," Cellabz, Inc., Paris, France, November 2015, Version 1.0, 16.



Col Vincent Alcazar, USAF, Retired

Colonel Alcazar retired from active duty in December 2014. During his career, he was a fighter pilot with 3,800 hours in various fighter aircraft, a joint specialized undergraduate pilot training instructor, an F-15 formal training unit instructor pilot, and commander of the 479th Flying Training Group and 479th Operations Support Squadron at Moody AFB, Georgia. A veteran of Operation Desert Storm combat missions and of Operation Iraqi Freedom deployments, he is also a former air attaché to Iraq. Colonel Alcazar is the former Air Force lead for Air-Sea Battle and a former planner and strategist with Headquarters Air Force staff experience.

Defeating Small Civilian Unmanned Aerial Systems to Maintain Air Superiority

Lt Col Thomas S. Palmer, USAF
Dr. John P. Geis II, Colonel, USAF, Retired

Introduction

The year is 20XX, and after breakdowns in diplomatic and economic efforts to solve an international crisis, the US Air Force (USAF) has been tasked to lead major combat operations to destroy a hostile country's strategic targets. After weeks of nonstop preparations, planning, and coordination at a hometown USAF base, the first wave of 12 F-22 stealth fighters and two KC-10 aerial refueling tankers are just two hours from starting engines to begin their transoceanic flight.

Without any warning, several small black specks appear on the horizon and quickly head directly for the fighters. As the black specks get closer, they are visually identified by a crew chief as medium-sized civilian quadcopters carrying several small objects. The lead quadcopter drops a Thermite grenade explosive onto the first fighter causing a fuel tank rupture and massive fire. Next, another quadcopter attacks the last fighter in the parking row causing it to burst into flames, blocking any escape for the other 10 aircraft. Five more quadcopters arrive onto the scene, destroy the remaining fighters and then the two KC-10 tankers, killing 20 personnel and injuring 30 more in the resulting catastrophic fires.

As rescue personnel scramble to save lives, 10 more quadcopters swarm the airfield and destroy 20 more aircraft as well as the air base's enormous fuel storage tanks. Almost the entire fighter wing's fleet of fifth-generation fighters, worth billions of dollars, is incinerated. No one knows who controlled the quadcopters, and there was nothing anyone on the airfield could do to stop the onslaught of attacks, or was there? Although this is a fictitious scenario, the technologies to create such a disaster exist today.[1]

Unmanned aerial systems (UAS), also known as "drones," unmanned aerial vehicles (UAV), and remotely piloted aircraft (RPA), have exploded in popularity, availability, and capability in recent years.[2] As batteries, cameras, flight control computers, and other key UAS components have become miniaturized,[3] cheaper, and plentiful, UAS capabilities have greatly increased. Adversaries can now pilot a 70-mile per hour (mph), highly maneuverable four-bladed helicopter known as a “quadcopter,” without any formal training by using a simple smart phone application. This new technology gives potential adversaries an additional and substantial offensive capability against friendly targets, with very little cost or logistics requirements. Gone are the days that a simple barbed-wire fence and a roving security patrol using standard-issue pistols and rifles will sufficiently protect our vital USAF aircraft.

Modern small UASs are versatile and can offset many current USAF capabilities. They are free to offensively maneuver and damage the Air Force’s advanced stealth fighters and bombers, aerial refueling tankers, and cargo aircraft. Small UASs can also hold critical support facilities at risk. This “wicked” UAS problem will only get worse. We seek to build on the challenges presented in the *ASPJ* spring article on “Air Mines,”[4] and argue these new UAS capabilities allow their users to potentially negate advanced nation-state funded aerial and ground-based offensive and defensive systems, and the USAF needs a better capability to defeat these new small UASs.

We explore this topic by first defining and framing the issue of UAS proliferation. We then discuss possible adversary uses of UASs and detail counter-UAS (C-UAS) capabilities, assessing UAS strengths and weaknesses and showing ways adversaries could negate C-UAS defensive systems. We then recommend possible solutions and propose further research to counter ever-improving UAS capabilities.

The Problem of UAS Proliferation

As the information age continued, potential adversaries noticed the US military’s UAS successes and developed their systems using commercially available off-the-shelf components. The USAF and DOD no longer had a monopoly on UAS supremacy. Enormous state-run UAS programs were no longer necessary to accomplish tactical and strategic goals. In August 2014, the terrorist group the Islamic State of Iraq and Syria (ISIS) posted Syrian military target videos that were taken with a simple, widely-sold DJI Phantom quadcopter.[5] More recently, ISIS has used drones as attack vehicles while using additional drones to film the results of these drone attacks.[6]

UASs are proliferating. The Federal Aviation Administration (FAA) estimated that approximately 1.9 million UASs were sold in the United States during 2016 and projects domestic sales of up to 4.3 million UASs annually by 2020.[7] This proliferation is global, with similar sales growth in China.[8] With as little as $130 in hand, virtually anyone can purchase a functioning UAS without any background check to discern hostile intentions.

Potential Adversary Uses of UASs

The low-cost, global proliferation and capabilities of UASs weighing less than 20 pounds make them worthy of specific focus.[9] Future adversaries could use these small systems to play havoc with military operations both in the air and on the ground, necessitating new actions to defend military assets and bases.

As indicated in the table below, several small UASs have payload capacity, extended range, and the ability to be global positioning system- (GPS) or pilot-guided to locations with great precision. For example, the DJI Phantom 3 can fly for 23 minutes at speeds up to 37 mph, carrying a 2-pound payload, on one battery charge to a range of 13 miles if autonomously guided, and only costs $599–799.[10] While there are safeguards to protect airspace from inadvertent penetration by the Phantom 3, these safeguards are easily bypassed. The limitation restricting its maximum altitude to 120 meters (393 feet) higher than the takeoff location can be overridden to fly to its maximum altitude of 6,000 meters (19,685 feet) above sea level. Similarly, while the Phantom 3 has "geo-fencing" that uses its GPS position to determine if it is about to enter sensitive airspace, disabling the GPS antenna allows the pilot to visually navigate the quadcopter to any destination.[11]

Table. Sample of currently available commercial UASs[12]

Drone Name	Parrot "Airborne Night Swat	Parrot "Bebop 2"	SenseFly "Albris" (formerly eXom)	DJI "Phantom3 Advanced"	DJI "S1000"
Type of Aircraft	Palm-sized Quadcopter	Quadcopter	V-shaped Quadcopter	Quadcopter	Octocopter
Possible Hostile Mission	Surveillance, mortar spotting	Surveillance, "Kamikaze" attack	High resolution surveillance, "Kamikaze" attack	Surveillance, sabotage, explosive attack, "Kamikaze attack	Surveillance, sabotage, large-scale explosive attack, "Kamikaze" attack
Wingspan Size	7 x 7 inches	15 x 15 inches	22 x 32 inches	23 inches (diagonal)	41 inches (diagonal)
Empty Weight	63 grams / 2.1 ounces	500 grams / 1.1 pounds	1.8 kilograms / 4 pounds max takeoff weight	1.2 kilograms / 2.3 pounds	4.4 kilograms / 6.2 to 11 kilograms max takeoff weight
Payload: Includes Camera and Other Items	N/A – integrated camera	N/A – integrated camera	N/A – integrated camera	2 pounds	6.6 kilograms / 14.9 pounds
Flight Time	9 minutes	25 minutes	22 minutes	23 minutes	15 minutes
Speed	11 mph	37 mph	27 mph	37 mph	37 mph
Maximum Altitude	N/A	492 feet (150 meters)	N/A	19,685 feet (6000 meters)	Not specified by manufacturer
Pilot to UAS Maximum Range	20 meters / 65 feet	2 KM if used with Parrot Skycontroller	800 meters / 0.5 miles	5 kilometers / 3.1 miles when flying remotely	Not specified by manufacturer
Navigation system	Remote Control	GPS; Remote Control	GPS; Remote Control	GPS or GLONASS and Remote Control	GPS, remote Control
Cost	$129.99	$549.99 MSRP; $483.97 at Walmart	N/A – requires quote from manufacturer	$799.00 MSRP $598.00 at Walmart	$1,499 MSRP
Notes			1.2–mile video streaming range	2.7K streaming video	

This visual navigation is done via first-person video (FPV) capability. FPV allows the pilot to receive a real-time video image from a camera on the UAS, displayed in goggles worn by the pilot or onto an Android, iPhone or iPad type device. This provides a view to the pilot as if they were riding on the quadcopter which can enable the operator to execute evasive maneuvers or navigate clandestine routes while flying to a target.

While the DJI Phantom 3 can carry a single explosive, DJI sells higher-performance, heavy payload, eight-bladed octocopters that may be a bigger threat. The DJI S1000+ eight-bladed octocopter, designed for commercial cinematography, has a 15-minute flight endurance with a payload of 14.9 pounds and costs $1,499.[13] This payload equates to being able to haul six explosives or Thermite grenades while carrying a camera for FPV.

Thermite grenades only weigh 2 pounds and burn at 4,000 degrees Fahrenheit which is sufficient to melt through aircraft skin, rupture a fuel tank, and initiate an aircraft fire.[14] Aircraft-grade aluminum alloys melt at only 1,180-degrees Fahrenheit, and a ruptured fuel tank could sustain a fire by using the aircraft's own fuel.[15] Such an attack would damage or destroy an aircraft, yielding the adversary a psychological victory.

Additional potential uses for these UASs include emplacing spike strips on a runway to deflate aircraft tires, delivering debris to damage jet engines, dropping explosives on other targets, or even being used in a Kamikaze role.[16] Through the FPV, a UAS pilot could fly the UAS into an aircraft's engines during ground operations, on takeoff or landing, or even at extended ranges from the airfield. Attacking during the critical takeoff or landing phases of flight, the UAS could increase the chances of more damages or a catastrophic crash.[17] As the DJI Phantom 3 can climb to above 19,000 feet, attacks at significant distance from airports could complicate postaccident forensics as debris from that altitude scatters widely. The possibility of attacks at distance from an airfield increases the need for high-fidelity C-UAS detection capability at range.[18]

With several hundred dollars and the time to download an eBook and watch a YouTube video, anyone with a little technical expertise can build their own quad/hex/octocopter. These homebuilt UASs might be more capable than and circumvent the built-in restrictions of a commercially available UAS.[19]

Possible Solutions

Traditional base security measures are not designed to detect and defeat hostile UASs. Visual observers shooting small arms are ineffective due to the high speed, maneuverability, and survivability of a small UAS.[20] Traditional base/post security fences are also of limited value, as a pilot using FPV can fly over the barrier and then descend onto the target.[21]

This section will cover a series of systems in development that may help protect AF assets. These potential solutions range from man-portable systems to directed energy weapons, to broader systems of systems.

Drone Defender

The "Drone Defender" is a man-portable 20-pound system that looks a bit like a large fat rifle and is used to disrupt the command link between a UAS and the pilot. Its effective range, from friendly defender to the hostile UAS, is 400 meters. Future development will allow it to jam or spoof the GPS signal to prevent the UAS from using a signal for precise navigation.[22] Overall, the Drone Defender is dependent on a human observer detecting the UAS and then aiming and employing the device. If optimally employed, this system forces a lost-link flight path if it jams the correct command link frequency. Should the UAS escape the 30-degree beam width of the Drone Defender, the UAS may be able to resume normal operations.

An advantage of the Drone Defender is the nonpermanent effect can be stopped immediately if jamming creates an erratic or hazardous UAS flight path. Its disadvantage is the short 400-meter range, which would necessitate at least 25 devices and security personnel to effectively cover an entire airfield and the aircraft parking areas.[23] This makes Drone Defender a simple but resource-intensive, stop-gap measure until more capable C-UAS systems can be fielded.

Enhanced Area Protection and Survivability System

The US Army has tested the Enhanced Area Protection and Survivability System (EAPS) system that can engage a UAS up to 1 kilometer away by firing a 50 mm munition.[24] The system sends the inflight munition flight path corrections as the UAS maneuvers and then commands the munition to explode at the optimum range to shoot down the UAS.[25] This has collateral damage and fratricide concerns requiring careful system placement considerations and very strict rules of engagement.

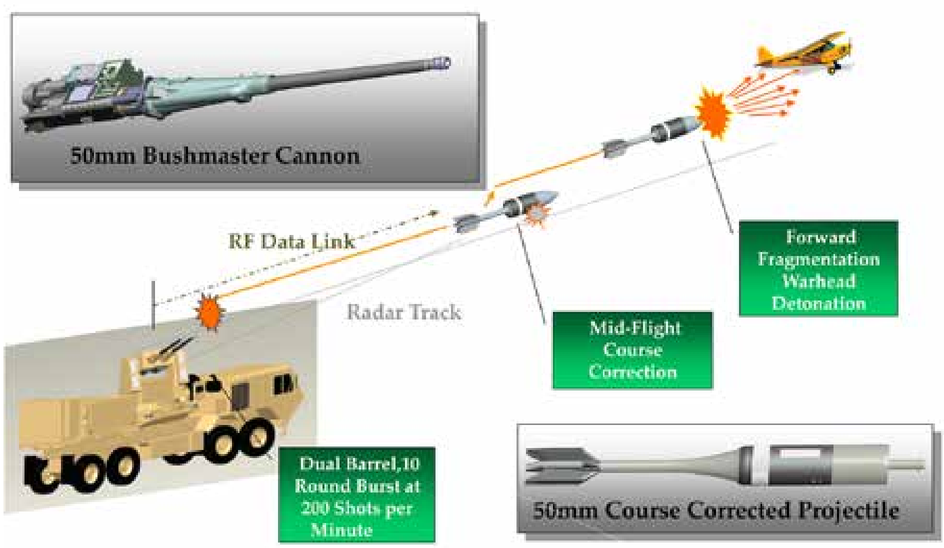


Figure 1. Enhanced Area Protection and Survivability System[26]

Counterrocket and Mortar System

The Northrup Grumman counterrocket and mortar) C-RAM) system is a current air-base defensive system deployed overseas that employs a radar-aimed Gatling gun to fire bullets at a rate of 2,000 rounds per minute to knock down rockets and mortars.[27] This system can also be employed against UAS threats to a range of 1.2 km. The kinetic collateral damage concerns require careful emplacement and employment procedures.

Figure 2. Army C-RAM System[28]

Compact Laser Weapon System "Silent Strike"

Boeing's Compact Laser Weapon System (CLWS) uses a destructive laser, cued by radar, and/or an electro-optical (EO)/infrared (IR) camera to track a hostile UAS.[29] The 10-kilowatt-class laser can heat and destroy UASs at ranges out to 2.5 km.[30] This system does not rely on knowing any UAS command frequencies or navigation techniques and is effective against any UAS modified to use self-contained guidance techniques. The system drawback is the potential for collateral damage short and long of the intended target which limits the engagement window. Laser energy also requires relatively clear air, unobscured by weather, smoke, or dust, etc. Carefully designing the air base defense layout would allow this system to be used to its maximum potential.

Counter-UAS Mobile Integrated Capability

The US Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) has developed the Counter-UAS Mobile Integrated Capability

(CMIC). CMIC is a fully-developed, Soldier-tested, US government-owned, integrated and upgradeable counter-UAS system that can detect, identify, and then defeat a hostile UAS and its pilot.

Figure 3. Army CMIC System[31]

The CMIC system uses many common military parts to integrate multiple sensors into one easy-to-interpret display to provide the war fighter exceptional awareness of hostile UASs and the location of the pilot. The system can cue multiple EO, thermal, and electronic sensors to provide the operator high-fidelity threat information, to then coordinate nonkinetic or kinetic effects to bring the UAS down. CMIC also triangulates the source of the command signal to locate the pilot, which can enable launching a friendly UAS or ground forces to hunt the pilot.

To reduce logistical complexity, the design mounts the counter-UAS equipment onto current military vehicles and uses command and control devices that are widely available in the DOD. The CMIC also has a "flyaway kit" that eliminates the use of vehicles.[32] The CMIC utilizes a civilian SRC Inc. brand LSTAR Doppler radar to detect small UASs and even birds.[33] The bird detection capability gives it added utility for aiding manned aircraft in bird avoidance during the takeoff and landing phases of flight.

Drone Shield

Another spectrum for UAS detection is the unique acoustic signature of the electric motors and the spinning propeller blades. The Drone Shield Company makes acoustic sensors to detect UASs by their distinct noises and then references a library of acoustic signatures to determine the make and model. Drone Shield published the UAS detection range to be 1 km when using the Long-Range Sensor model, versus the shorter 100-meter range of the omnidirectional model.[34] UASs dropping weapons from an altitude higher than the detection limit would potentially negate the acoustic detection system. Using the acoustic system as another sensor to correctly identify the UAS type will enable other defensive systems to properly jam or engage the threat.

High-Power Microwave Weapons

If US forces are deployed to a location with few electronic systems off-base, the use of high-power microwave (HPM) weapon systems might be feasible without collateral damage concerns. HPM weapons disrupt the electrical flow across unshielded wiring and circuit boards in electronic systems. An HPM weapon could be effective against UAS flight control computers to inflict a wide range of effects from barely disrupting a command signal to "frying" the circuit board to cause an immediate inflight failure of the UAS.[35]

Future scientific research should focus on developing high-power *pulsed* microwave weapons to defeat a UAS. The goal would be to create a pulsed-microwave effect to cripple hostile UASs without creating significant collateral energy which could damage friendly military and civilian systems.[36]

Airfield Modifications

Areas with tall buildings, trees, and so forth, that prevent direct line-of-sight to detect a UAS could benefit from tall fencing to channel the threat UASs into more observable areas. Canalizing attacking UAVs would allow security forces to focus the acoustic, radar and camera system capabilities into a more concentrated area. However, regardless of the counter-UAS system employed, fencing should be installed around and above all high-value assets that cannot suffer any UAS interference.

To aid in apprehending hostile or ignorant UAS pilots, a "Hunter Killer" UAS needs to be developed that can quickly fly toward a hostile UAS and use nonkinetic (possibly miniaturized *pulsed* HPM) or kinetic effects to disable the hostile UAS. This friendly UAS could also search for and identify the hostile pilot to allow forces to arrest the pilot (in the United States) or kinetically engage them (combat zone).

Potential Adversary Countermeasures

As many historical examples of military weaponry development have shown, as defensive measures to a new threat were discovered, the hostile actors made slight adjustments to their equipment to degrade the effectiveness of the new defenses. Although the previously detailed C-UAS systems are very capable, many of them rely on jamming the command link between the UAS and the pilot to force the UAS to execute a lost-link flight path. The programmed lost-link flight path might be to return to the home base, hover, or simply land immediately.[37] A hostile actor can bypass this lost-link problem by using the UAS autonomous flight mode which might utilize GPS, Galileo, GPS Aided GEO Augmented Navigation (GAGAN)/Indian Regional Navigation Satellite System (IRNSS), Bei Dou, or the Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) navigation constellations to control the flight path.[38]

If the GPS signal is jammed or spoofed; or if the UAS is purposely not GPS equipped to negate any jamming, spoofing or geo-fencing restrictions; an inertial navigation system (INS) could be used to guide the UAS.[39] An INS works by knowing the takeoff location and then sensing movement and drift to determine the UAS's current location as it flies to the target. An INS would eliminate any requirement for outside signals to navigate the UAS.

Another technique to negate communications link-jamming is for the hostile pilot to input the *target* coordinates as the "home base" so that when the jamming system breaks the command link with the pilot, the UAS actually flies *to* the target. Accurate target coordinates loaded into a UAS using the autonomous flight mode, without using the FPV feature, would only slightly degrade navigational accuracy. With just a little ingenuity and equipment modification, an adversary might be able to negate many of the current defeat mechanisms of C-UAS systems.

Current US laws also prevent utilizing the full capabilities of C-UAS defensive systems. The FAA considers a UAS a civil aircraft that must comply with safety requirements and regulations.[40] Because a UAS is considered a civil aircraft, security forces are prohibited from shooting down a UAS unless it is determined to be in the interest of national defense or for self-defense reasons.[41] Because it is virtually impossible to quickly determine the intent of a UAS, this current guidance could cause delays in responses which might give an adversary vital time to carry out their mission. The USAF must develop procedures and gain FAA and all necessary legal approvals to employ C-UAS defensive systems against any unknown UAS that is in the military airspace, whether it is over military land or not.

During the process of selecting overseas basing locations, the amount of clear areas around the airbase perimeter must be a big consideration to ensure the base is defendable. An extra-large buffer zone would allow for more aggressive C-UAS systems such as the C-RAM Gatling gun system or the use of a destructive laser system, such as the CLWS.

Recommendations

In the near term, the US government must determine who will lead solving the UAS problem. While the DOD can take the lead role in combat zones, within the United States, there are multiple civilian and military agencies working UAS issues, which can lead to confusion.[42] A whole of government approach is needed to make progress. The USAF, DOD, FAA, Department of Commerce, and the Department of Homeland Security (DHS) must quickly form an intergovernmental team to develop a whole of government approach to field effective counter-UAS defensive systems.[43] These agencies also need to solidify airspace defense procedures and make recommendations to Congress regarding more permissive legal authorities to preserve the USAF's ability to maintain air superiority.

The FAA and DOD must immediately initiate a more aggressive countrywide UAS education campaign. "No Drone Zone" signage placed around military airfields and near the approach and departure corridors with phone numbers to call to report illegal UAS activity would improve education and enforcement efforts.[44] Military public affairs engagements with the local media would minimize the number of UAS pilots unaware of the new rules. A well-educated public should reduce the number of innocent airspace incursions thereby allowing security forces to quickly decide hostile intent and immediately take appropriate action.

If laws cannot be adjusted to authorize shooting down a hostile UAS, then another option is to increase the punishment for airspace and procedural violations.[45] Class D (airspace with an operating air traffic control tower such as most military air bases) and restricted airspace (typically military bombing ranges) violations pose the greatest hazard since these are generally congested with very fast military aircraft.[46] The general public will not take the new UAS flight rules seriously unless the punishments for being an ignorant or brazen UAS pilot are widely known and consistently applied.[47]

USAF security forces and other DOD security units, in close coordination with the lead law enforcement agencies, must conduct regular training exercises that include hostile UAS scenarios. The reaction to a hostile UAS flying into military airspace while transiting multiple police jurisdictions must be well-rehearsed, legally reviewed, and trained to the same level as a "front gate-runner" scenario. For example, if someone drives their car from off base through an air base checkpoint without stopping, the guards are trained how to warn the driver, then take prudent and proportional actions up to, and including, deadly force. Security forces must have a similarly well-rehearsed response to a UAS violating military airspace, so they are not paralyzed by indecision, or overreact with pistols and rifles and cause catastrophic damage to an aircraft in the background.

Until adequate C-UAS defensive systems are procured and can be fully employed, a system-of-systems approach is likely required to detect a UAS across the various energy spectrums to cue sensors and weapons to defeat the UAS before it can complete its nefarious mission. Improving airfield and ramp lighting, or adding additional low light EO and thermal camera systems, are relatively low-cost and familiar solutions.[48] Good coordination with a cooperative civilian population will enable emplacement of sensors onto existing infrastructure to provide surveillance of airfield approach and departure corridors. These low-cost surveillance systems at least enable security forces to be slightly more aware of someone flying a hostile UAS near their airfield.

To minimize fratricide to friendly electronic systems, applicable research labs must test the interoperability of C-UAS systems with existing airfield and DOD systems. Additional testing is needed to learn the effects of integrating directed energy weapons, the UAS detection radars, and other sensors to ensure safe interoperability with aircraft navigation and communication systems, flight control computers, instrument landing systems, GPS reception, and air traffic control (ATC) radars. These systems and their human operators all need evaluation to ensure C-UAS systems will not cause hazards for military operations.

Procedures must be perfected between the C-UAS operators and the ATC agencies to quickly communicate the location of hostile UASs to direct evasive maneuvers to airborne aircraft. Close coordination is also required when firing weapons to prevent fratricide. It is beneficial that most C-UAS weapon systems have a short employment time, in the realm of several to tens of seconds, which should minimize disruption to flight operations.[49]

Because of its relative maturity and ability to continuously and automatically fuse multiple sensors into a complete battlefield picture, at the time of this writing, the CMIC is the most promising system available. The approximate cost for the CMIC system, without vehicles, is $1 million for the system and $1.1 million for the LSTARS radar.[50] Because of line-of-sight issues near an airfield caused by topography, buildings, trees, and so forth, multiple radars or installing the sensors on a tall tower may be required to have 360-degree visibility. CMIC's advantages are its multiple sensor fusion combined with multiple engagement methods. As technology improves, other systems are likely to overtake CMIC in capability, but our research strongly suggests the optimum system in the future will involve fusing disparate sensors to detect even the smallest of UASs and provide a variety of defense mechanisms able to engage threats ranging from single UASs to UAS swarms.

As UAS technology continues to improve in the next five to 10 years, civilian UASs will become more popular and useful to civilian industries, thereby increasing the overall number of friendly UASs flying at higher altitudes in congested airspace.[51] Because of this increased congestion, robust detection and flawless inflight identification is necessary to quickly target hostile or suspicious UASs.

Because of airspace saturation with UASs, manned aircraft will soon need onboard detection capabilities or be linked into the ground-based sense and avoid systems to evade single and swarmed UAS airborne threats.[52] The addition of thousands of UASs flying in the low-altitude structure, when combined with the usual bird hazards, could make military low-altitude flying training more hazardous. This risk could restrict low-level training to such confined areas that the training value will be nil, thereby limiting military aircraft combat maneuvering options. The development of onboard UAS avoidance equipment must start immediately.

Conclusion

The threats from hostile UASs will continue to get worse at an exponential rate because of improving capabilities and the sheer quantity being sold in the civilian marketplace. The risk of a major, catastrophic loss of life because of a collision between a hostile UAS and a manned aircraft continues to rise. The USAF must coordinate and accelerate all efforts to acquire a counter-UAS system that will protect aircrew and aircraft.

Although no single system will negate every conceivable UAS threat, the AMRDEC CMIC system, or a more advanced system like it, appears to be the best system today to solving the wicked problem of hostile UAS interference. The blending of multisensor fusion with multiple engagement options against hostile UASs is a powerful combination. While such systems may seem expensive, being proactive can save many lives and millions of dollars while also denying adversaries another attack method to further their goals. One irreplaceable $143 million F-22 "Raptor" or a $98 million F-35 "Lightning II" Joint Strike Fighter lost to a $799 hostile UAS will make a $2.1 million price tag for a C-UAS system, like the AMRDEC CMIC, look very affordable.[53] The AMRDEC system also provides an additional advantage of detecting birds that pose a hazard to aviation operations while continuously standing guard to defeat a hostile UAS.

This article recommends purchasing the AMRDEC CMIC or similar system and maintaining and operating it with a small crew of USAF personnel as the best technical solution to defend an airfield 24 hours a day. At the same time, the legal authorities to employ all its capabilities must be obtained. The DOD, DHS, FAA, USAF, Department of Transportation, and the Department of Commerce are some of the key entities that must form an interdepartmental team. This team must collaborate and recommend legal authority changes to Congress to solve the UAS problem.

Security personnel must have the legal authorities to declare any unauthorized UAS flying in military airspace a hostile threat and take action whether the hostile UAS is over civilian or military property. Security forces must be allowed to immediately nonkinetically engage the threat within friendly territory, or kinetically engage the system if in a combat zone. If the hostile UAS is neutralized off military property, the USAF must have procedures for off-base civilian law enforcement assets to secure the downed UAS and apprehend the offending pilot.

If the fictitious airfield described in the introduction were properly equipped with C-UAS systems, the attack would have been an air superiority success story instead of a nightmare scenario. It is only a matter of time before our nation's adversaries will utilize these incredibly capable UAS threats to attempt to defeat the most advanced air force in the world. ✪

Notes

1. Richard Whittle, "Military Exercise Black Dart to Tackle Nightmare Drone Scenario," *New York Post*, 25 July 2015, http://nypost.com/2015/07/25/military-operation-black-dart-to-tackle-nightmare-drone-scenario/. The 2015 Black Dart exercise was designed to test counter drone systems against 55 drone systems encompassing a wide range of drone sizes and capabilities. The focus of the exercise was on smaller drones due to the recent events of small drones flying near prominent politicians. German chancellor Angela Merkel's incident in Dresden two years ago involved an unmanned aircraft system (UAS) flying near her, and the Japanese prime minister Shinzō Abe had a drone land on top of his residence. This article stated that British officials are concerned the Islamic State Iraq and Syria (ISIS) will try to bomb festival crowds using small drones.

2. Since a significant amount of unmanned aerial system literature comes from the Federal Aviation Administration (FAA), the term *unmanned aerial system* (UAS) will be used in this article and is synonymous with drone, remotely piloted aircraft (RPA) or unmanned aerial vehicle (UAV).

3. Leslie Hauck and John Geis, "Air Mines: Countering the Drone Threat to Aircraft," *Air and Space Power Journal* 31, no. 1, Spring 2017, 26–40.

4. Ibid. These two articles emanate from Air University's newly-created Airpower Research Task Force and associated Airpower Vistas elective program.

5. Jamie Conliffe, "ISIS Militants Use Same Drones as Ordinary Folks," *Gizmodo*, 29 August 2014, http://gizmodo.com/isis-militants-use-the-same-drones-as-ordinary-folks-1628376186. ISIS showed how a widely available UAS could easily be used for tactical purposes.

6. Jody Warrick, "Use of 'Weaponized' Drones by Islamic State Spurs Terrorism Fears," *Chicago Tribune*, 27 February 2017, http://www.chicagotribune.com/news/nationworld/ct-islamic-state-drones-20170225-story.html.

7. "FAA Releases 2016 to 2036 Aerospace Forecast," https://www.faa.gov/news/updates/?newsId=85227, 24 March 2016.

8. Paul Bedard, "Drone Sales Surge 167% to 4.3 million, U.S. leads but China Catching Up," *Washington Examiner*, 29 May 2015, http://www.washingtonexaminer.com/drone-sales-surge-167-to-4.3-million-u.s.-leads-but-china-catching-up/article/2565240. This article states that 4.3 million consumer drones, worth 1.7 billion dollars, were sold worldwide in the first five months of 2015, which was a 167 percent jump in only two years.

9. Another very capable quadcopter is made by Mobile Recon Systems. Their Kitty Hawk HDX4 Supreme Heavy Lift Quadcopter has a payload of 22 pounds (total weight of up to 41 pounds) and a 30-minute flight time. See http://www.mobilereconsystems.com/?page_id=32 for more details.

10. DJI website accessed 2 February 2016, http://store.dji.com/compare-phantom-3. Prices have dropped by $200 in two months, making UASs even more affordable. Autonomous flight-range limit would be approximately 13 statute miles (35 mph x 23 minutes = 13.41 statute miles), assuming no wind conditions; and DJI website accessed 6 December 2015. Payload weight also includes the camera which is necessary for the first-person video capability, but would not be needed for autonomous flight, http://wiki.dji.com/en/index.php/Phantom_3_Advanced#GENERAL_FEATURES.

11. Geo-fencing is only accurate if the UAS has been updated with the most recent information. If an airport's airspace changes, but the UAS is operating with old data, the geo-fencing feature will be ineffective at preventing an airspace violation.

12. Data in the table comes from: https://www.parrot.com/us/minidrones/parrot-airborne-night-swat#parrot-airborne-night-swat-details for the Parrot Airborne Night Swat; https://www.parrot.com/us/Drones/Parrot-bebop-2 for the Bebop-2; http://drones.specout.com/l/1103/senseFly-albris for the10-V-Palmer-Geis.indd 113 4/27/2017 10:10:56 AM114 | Air & Space Power JournalAlbris; http://www.dji.com/phantom-3-adv/info#specs for the DJI Phantom III; https://www.dji.com/spreading-wings-s1000 for the DJI S1000.

13. DJI company website, accessed 27 February 2017, http://www.dji.com/product/spreading-wings-s1000-plus. This price includes the global positioning system (GPC) receiver and guidance unit as well as some special flight controller logic to handle an engine failure, thereby making it even harder to shoot it down since it can handle an engine failure. See also *Spreading Wings S1000+ User Manual V 1.4*, available at http://www.dji.com/spreading-wings-s1000-plus/info#downloads.

14. Federation of American Scientists (FAS) Military Analysis Network, accessed 6 December 2015, AN-M14 TH3 incendiary hand grenade, http://fas.org/man/dod-101/sys/land/m14-th3.htm. This site references US Army Field Manual (FM) FM23-30 *Grenades and Pyrotechnic Signals*, 27 December 1988.

15. Aviation Metals Inc., company website, accessed 8 December 2015, http://aviationmetals.net/aluminum_sheet.php. Standard aircraft-grade aluminum alloys melt at 1,180-degrees Fahrenheit/580-degrees centigrade. These aluminum alloys are commonly used for aircraft structures and aircraft skins to form wings, external fuel tanks, or the fuselage.

16. Aardvark company website accessed 9 December 2015, https://www.aardvarktactical.com/products/caltrops. Tire deflation Caltrops spikes would be very effective. These spikes have three points and always land with a point up. Multiple spikes can be strung together to any length to meet UAS payload weight limits. Once the aircraft tire is punctured, the spike will stay in the tire to allow rapid deflation. Although aircraft tires are rugged, the high pounds per square inch makes them vulnerable to violent deflation if pierced.

17. Aviation Safety Boeing Commercial Airplanes, *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2014,* August 2015, 20, *http:*//www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf. These data show from 2005–2014 that 13 percent of fatal accidents occurred during takeoff and initial climb phases, and 48 percent of fatal accidents occurred during final approach and landing phases. See also Hauck and Geis, "Air Mines," 26–40.

18. Rollin Bishop, "Record-Breaking Drone Swarm Sees 50 UAVs Controlled by a Single Person," *Popular Mechanics*, 16 September 2015, http://www.popularmechanics.com/flight/drones/news/a17371/record-breaking-drone-swarm/. This demonstration was conducted by the Naval Postgraduate School and proved the ability to control 50 UAVs with just one pilot. The UAVs could maintain safe separation and adhere to the commands of the one pilot; and Steve Crowe, "Tests Show Drone Strikes Could Cause Jet Engine Failure," *Robotics Trends*, 28 October 2015, http://www.roboticstrends.com/article/tests_show_drone_strikes_could_cause_jet_engine_failure. "Researchers at Virginia Tech's College of Engineering

say drones as small as 8 pounds will have devastating effects if sucked into the turbofan engines of commercial aircrafts." Currently the FAA rules don't require aircraft engine manufacturers to test against the damaging effects of ingesting a UAS (just birds). Hard plastic/metal parts and the lithium-ion batteries can cause massive damage to jet engines.

19. Small Drone Reviews *Best eBook Drone Tutorial—Build Your Own Quadcopter,* http://smalldronesreview.com/2015/10/10/how-to-build-your-own-quadcopter-drone-best-bookebook-tutorial/. This website has many eBooks to cover a range of homebuilt quadcopter designs.

20. Kelsey D. Atherton, "How Hard Is It to Shoot Down a Small Drone?," *Popular Science*, 14 April 2014, http://www.popsci.com/article/technology/how-hard-it-shoot-down-small-drone-video-0. Big Sandy Shoot is a group of machine gun enthusiasts in Arizona who flew small UASs in front of their firing line. The machine gunners required hundreds of rounds and many passes of the UAS flying directly in front of the firing line to have even a minute for the chance of hitting the cooperatively flown UAS. Their assessment was that it was very difficult to hit the small UAS. The small UASs sustained bullet strikes to noncritical sections of the airframe and were still able to fly.

21. Michael S. Schmidt, "Airmail via Drones is Vexing for Prisons," *New York Times*, 22 April 2015, A13, http://www.nytimes.com/2015/04/23/us/drones-smuggle-contraband-over-prison-walls.html?_r=0. Prisons are starting to experience an increase in UAS use to deliver contraband (drugs, weapons, cellphones, etc.) to prisoners. The UASs are flown over the high barbed-wire fences and are either landing, or simply dropping the objects onto prison property. If a UAS can successfully bypass armed guards, cameras, and fencing at a relatively small exercise yard at a medium or maximum security prison, it should be incredibly easy to fly over a USAF airfield perimeter fence that spans for many miles. Even if fencing was installed over a prison exercise yard to prevent a UAS from landing, the mesh would have to be small enough to prevent smugglers from dropping small items through the mesh.

22. Kelsey D. Atherton, "This Device Turns Any Gun into an Anti-Drone Ray," *Popular Science,* 15 October 2015, http://www.popsci.com/dronedefender-is-an-anti-drone-rifle-attachment.

23. Using a calculation that assumes security personnel with Drone Defenders would be no more than 800-meters apart (400-meter range for each Drone Defender), a standard 11,000-foot long runway would require at least 10 spotters/Drone Defenders to cover the length/sides of the runway, plus five more to cover a small parking ramp, plus at least 10 more spotter/Drone Defenders to cover two miles of the approach and departure corridors. In total, at least 25 security personnel would be assigned to spotter/Drone Defender duty 24/7. More personnel might be required to utilize night vision devices during hours of darkness. Also, these personnel would be outside (not in an enclosed vehicle or watchtower) to have any reasonable chance of hearing the incoming UASs.

24. David Szondy, "US Army Tests Drone-killing 50 mm Cannon," *Gizmag*, 11 October 2015, http://www.gizmag.com/us-army-eads-anti-drone-system/39781/.

25. Edward Lopez, "Army Engineers Demonstrate Anti-drone Technology" *Army.mil*, 5 October 2015, http://www.army.mil/article/156634/Army_engineers_demonstrate_anti_drone_technology/.

26. Ibid.

27. Andrew Tarantola, "The C-RAM Centurion Tears up Warheads with a Stream of Hot Lead," *Gizmodo*, 4 April 2012, http://gizmodo.com/5907237/the-c-ram-centurion-tears-up-warheads-with-a-stream-of-hot-lead.

28. Photo courtesy of Senior Airman Brittany Bateman, through Wikipedia Commons, https://commons.wikimedia.org/wiki/File:C-RAM_test_fire_JBB_Iraq.jpg.

29. Electro-optical (EO) cameras are similar to standard television cameras, relying on light to capture an image, whereas the infrared (IR) camera uses a thermal difference between the UAS and the background to generate an image. Small UASs typically have a very small thermal signature due to the electric motors (versus gas-powered) that power the propellers.

30. Boeing company website accessed 10 December 2015, http://www.boeing.com/features/2015/08/bds-compact-laser-08-15.page. This destructive laser shows great promise for use in more congested areas since it isn't as powerful as some other destructive lasers which were designed for use on the open seas.

31. E-mail between Mr. Steve Bramlett, Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) program manager and the author.

32. Briefing slide from Bramlett on 26 January 2016 (Annex C). The AMRDEC "flyaway" kit is all the electronics but isn't mounted onto a vehicle. For austere overseas air bases, this fly-away kit would

drastically reduce the logistics footprint. Eliminating a vehicle would save thousands of dollars by not maintaining a vehicle that is simply a mount for the Counter-UAS Mobile Integrated Capability (CMIC) equipment.

33. Syracuse Research Corporation (SRC) Inc., company website accessed 10 December 2015, http://www.srcinc.com/what-we-do/radar-and-sensors/lstar-air-surveillance-radar.html. This radar system has several versions for different applications.

34. Drone Shield company website, accessed 2 February 2016. The acoustic sensors are a lower cost solution or an addition to a complete system. These acoustic sensors can differentiate from aircraft and UAS noise signatures. The exact range of detection for the omnidirectional sensor is not published on the company website. However, the long-range sensor is published to detect UASs up to 1 kilometer and states it is 10 times farther than the standard omnidirectional sensor which would imply only a 100-meter range for the omnidirectional sensor. The Drone Shield system can provide alerts to security personnel when a UAS is detected. Information about the omnidirectional sensor can be found at https://www.droneshield.com/omnidirectional-sensor. Information about the long-range sensor can be found at https://www.droneshield.com/long-range-sensor.

35. If high-power microwave (HPM) weapons can't be miniaturized or tailored to reduce collateral damage, the use of stronger weapons could be used at austere locations since there wouldn't be the collateral damage concerns compared to modern urban areas. There would still be concerns about affecting coalition aircraft and electronic systems, but that risk could be mitigated through smart HPM weapon layout on the airfield as well as good coordination when employing HPMs to ensure no manned aircraft are harmed. If electronic systems are hardened/shielded against HPM, the HPM weapon will be ineffective.

36. Boeing Company website, "CHAMP—Lights Out," 22 October 2012, http://www.boeing.com/features/2012/10/bds-champ-10-22-12.page. The Boeing Counter-electronics HPM advanced missile project (CHAMP) weapon is a great example of a small size HPM weapon and the selective effects that are possible. It can fire the selective high-frequency radio wave energy at specific buildings and targets.

37. Da-Jiang Innovation (DJI) website accessed 6 December 2015, http://www.dji.com/product/phantom-3-standard/feature?www=v1. There are several other lost-link options with different UAS brands. Also, some minor flight control malfunctions and GPS and controller signal interruptions will cause "fly-aways" where the UAS is unresponsive to controller inputs and fails to follow the preprogrammed lost-link profile. Fly-aways could be an innocent source of airspace incursions.

38. US GPS is the commonly used global positioning system. Galileo is a European GPS constellation with a 1-meter accuracy. Bei Dou is the Chinese GPS navigation system. GPS-aided, GEO-augmented Navigation (GAGAN) is a partially land-based component of the Indian navigation system which augments the US GPS constellation. In addition to GAGAN, India is creating its GPS-like navigation system with seven satellites currently part of its Indian Regional Navigation Satellite System (IRNSS). Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) is the Russian navigation system.

39. SBG company website accessed 20 January 2016, http://www.sbg-systems.com/products/ellipse-n-miniature-ins-gps. The Ellipse-N miniature Inertial Navigation System (INS) also incorporates GPS+GLONASS/Bei Dou information to keep the INS very accurate and ready to provide navigation info if the GPS signal is jammed. This system is very lightweight and small enough to be installed onto a quadcopter/UAS. This system eliminates the need for any outside signals to navigate a UAS to the target.

40. Federal Aviation Administration (FAA) guidance, "Law Enforcement Guidance for Suspected Unauthorized UAS Operations," accessed FAA website 27 January 2016, http://www.faa.gov/uas/law_enforcement/. An applicable section from this guidance: "A UAS is an 'aircraft' as defined in the FAA's authorizing statutes and is therefore subject to regulation by the FAA. 49 U.S.C. § 40102(a)(6) defines an aircraft as "any contrivance invented, used, or designed to navigate or fly in the air." The FAA's regulations (14 C.F.R. § 1.1) similarly define an aircraft as "a device that is used or intended to be used for flight in the air." Because an unmanned aircraft is a contrivance/device that is invented, used, and designed to fly in the air, it meets the definition of aircraft. The FAA has promulgated regulations that apply to the operation of all aircraft, whether manned or unmanned, and irrespective of the altitude at which the aircraft is operating. For example, 14 C.F.R. § 91.13 prohibits any person from operating an aircraft in a careless or reckless manner so as to endanger the life or property of another."

41. The right to self-defense comes from common law. Refer to the 3121.01B, "Standing Rules of Engagement/Standing Rules for the Use of Force for US Forces (U)," See also: The Judge Advocate

General's Legal Center and School, "Domestic Law, 2013 Handbook for Judge Advocates" US Army Center for Law and Military Operations, 2013. This handbook is also available electronically at https://www.jagcnet.army.mil/.

42. Ben Wolfgang, "FAA's Failure to Regulate U.S. Drone Boom Creates Climate of Confusion," *Washington Times*, 6 January 2015, http://www.washingtontimes.com/news/2015/jan/6/faa-failure-to-regulate-us-drone-boom-creates-clim/?page=all.

43. According to the Department of Homeland Security (DHS) website, their No. 1 core mission is to: "Prevent terrorism and enhancing security." DHS states that "Protecting the American people from terrorist threats is our founding principle and our highest priority." The Department of Homeland Security's counterterrorism responsibilities focus on three goals: (1) prevent terrorist attacks; (2) prevent the unauthorized acquisition, importation, movement, or use of chemical, biological, radiological, and nuclear materials and capabilities within the United States; and (3) reduce the vulnerability of critical infrastructure and key resources, essential leadership, and major events to terrorist attacks and other hazards. DHS website accessed 2 February 2016, http://www.dhs.gov/prevent-terrorism-and-enhance-security.

44. The "No Drone Zone" info can be found at the FAA website, https://www.faa.gov/uas/no_drone_zone/.

45. Law Enforcement Guidance for Suspected Unauthorized UAS Operations, Version 3, Issued 11 August 2016, pp. 5, 8 www.faa.gov/uas/resources/law_enforcement/media/faa_uas-po_lea_gu... Accessed 29 March 2017, regarding enforcing UAS violations:

> It is extremely difficult to provide a "one size fits all" guide to cooperative investigation of suspected unauthorized UAS operations...The FAA may assess civil penalties up to $27,500. Criminal penalties include fines of up to $250,000 and/or imprisonment for up to three years."

46. Federal Aviation Administration educational briefing, "Airspace, Special Use Airspace, and Temporary Flight Restrictions," 7, accessed 27 January 2016, https://www.faasafety.gov/files/gslac/courses/content/42/565/Airspace,%20Special%20Use%20Airspace%20and%20TFRs%20-%20Text%20Only.pdf.

47. UAS pilots are required to become registered UAS pilots by logging on to the FAA website https://www.faa.gov/uas/registration/ and paying five dollars. The UAS pilots then print off a registration number to affix to their UAS to allow authorities to know who owns the UAS if it is found.

48. The forward looking infrared (FLIR) systems website accessed 6 December 2015, http://www.flir.com/surveillance/display/?id=63907. FLIR technologies have developed incredible thermal camera capabilities such as their Ranger high-resolution camera (HRC).

49. Liz Klimas, "'Silent Strike' Laser Weapon Burns Down a Drone in 15 Seconds," *The Blaze*, 28 August 2015, http://www.theblaze.com/stories/2015/08/28/silent-strike-laser-weapon-burns-down-a-drone-in-15-seconds/. This article highlights the Boeing "Silent Strike" Compact Laser Weapon System and how it can damage a test UAS in only 15 seconds of firing its laser weapon.

50. Cost estimate is a rough order of magnitude from Steve Bramlett, the counter-UAS mobile integrated capability (CMIC) program lead at AMRDEC, via e-mail to the author on 9 December 2015.

51. Samuel Gibbs, "Nearly 300,000 Civilian Drones Were Registered in US in 30 days," *The Guardian*, 26 January 2016, http://www.theguardian.com/technology/2016/jan/26/300000-civilian-drones-registered-in-us-compulsory. UAS registration with the FAA was occurring approximately 10,000 times a day after the FAA formalized the requirement for UAS pilots to register. Although this implies registered pilots will attempt to comply with regulations, this number doesn't account for illegally made and illegally flown UASs.

52. Kelsey D. Atherton, "FAA Tests System to Let Drones Sense and Avoid Obstacles," *Popular Science*, 13 November 2015, http://www.popsci.com/faa-tests-drone-obstacle-avoidance-system. Sense and avoid systems can use cellular phone networks to relay the locations of UASs to aid the UASs in deconflicting their flightpaths. A noncooperative (hostile) UAS might be able to stay off of this system to allow more freedom to operate undetected.

53. Joint Base Eustis–Langley website accessed 29 March 2017. The 1st Fighter Wing flies the Air Dominance multirole F-22 fighter valued at $143 million each. See http://www.jble.af.mil/About-Us/Fact-Sheets/Display/Article/257723/f-22-raptor. According to the Lockheed Martin website on 6 December 2015, it states a USAF F-35 variant (F-35A) will cost $98 million, https://www.f35.com/about

/fast-facts/cost. The AMRDEC CMIC flyaway kit is estimated to be $2.1 million according to Steve Bramlett at AMRDEC via e-mail to the author on 9 December 2015.

Lt Col Thomas Palmer, USAF

Colonel Palmer is assigned to the Air War College, Air University, Maxwell AFB, Alabama. He is a US Air Force pilot, highly experienced in the F-15E Strike Eagle and its tactical employment and aircrew training processes. He also has extensive experience serving in South Korea, first as an air liaison officer with the US Army, and years later on a joint staff at the US Forces Korea headquarters in Seoul, South Korea. Colonel Palmer also recently commanded an F-15E formal training squadron at Seymour Johnson AFB, North Carolina.

Dr. John P. Geis II, Colonel, USAF, Retired

Dr. Geis (MA, Air University; MS, Auburn University; BA, MS, and PhD, University of Wisconsin) is the director, Airpower Research Task Force at Maxwell AFB, Alabama. He was the chief meteorologist of WISC-TV before entering active duty in 1983. His Air Force career spanned training and combat operations in which he flew the T-37, AT-38B, T-43, two variants of the F-111, and the AC-130H special operations gunship. A distinguished graduate and the Commandant's Award winner at Air Command and Staff College, Colonel Geis coauthored the Alternate Futures monograph for the Air Force 2025 Study. In 1998–2000, he served as the director for strategic planning, doctrine, and force integration for all US Air Force special forces. Beginning in 2001, Colonel Geis served as the director, US Air Force Center for Strategy and Technology, a position he held for eight years. During this time, he and his team created what is now known as the Blue Horizons Program, which examines the strategic implications of emerging technology.

Let us know what you think! Leave a comment!

Social Media and the DOD

Benefits, Risks, and Mitigation

Lt Col Dieter A. Waldvogel, USAF, PhD

Description of the Issue

Social media and social networking sites (SNS) are used commonly and synonymously in information technology (IT) literature. SNS, including Web 2.0 Internet-based capabilities, are umbrella terms used to define the various activities integrating web technology, social interaction, and user-generated content. Social media refers to the various activities integrating web technology, social interaction, and user-generated content. Social media includes blogs, wikis, social networks, photo libraries, virtual worlds, location-based services, and video sharing sites.[1] Today's most commonly used SNSs include Facebook, Twitter, Google Apps, YouTube, LinkedIn, and Snapchat. On 25 February 2010, US Deputy Secretary of Defense William J. Lynn III issued the first directive-type memorandum (DTM) on the "Responsible and Effective Use of Internet Capabilities,"[2] and within months, service members had access to SNSs on their computers at work.[3]

The benefits and opportunities offered by these Internet-based capabilities are many. Among others, the opportunity for troops stationed abroad to have instant access to their loved ones at home, a public marketing and recruiting tool for military services and DOD organizations, and a tool for personnel to gain real-time situational awareness and the ability within DOD networks to share lessons learned in real time across pertinent communities. According to Air Force instruction (AFI) 35-101, *Public Affairs Policies and Procedures,* [4] Airmen are encouraged to use social media, interpersonal communication, community engagements, and other methods to share experiences with the public and tell the Air Force story while maintaining operational security (OPSEC). *The United States Army's Social Media Handbook*[5] "allows every Soldier to be a part of the US Army's story, and it allows America to connect with its Army."

This medium, however, also comes with big risks and vulnerabilities—both technical and behavioral. SNSs pose serious threats to the Department of Defense Information Networks (DODIN) and military operations as cyber criminals and adversaries are finding SNSs to be a major attack vector and entry point to infiltrate our networks and exfiltrate its data.[6]

Technical threats. SNSs are vulnerable to web application attacks such as buffer overflows, cross-site scripting (XSS), code injections, and so forth. XSS attacks are a type of code injection in the form of a browser-side script. Many SNSs allow users to publish content in plain text, HTML, or active content such as JavaScript and Flash. If these posts contain malicious content, the web browser can be forced to perform a variety of unintended actions such as downloading malware, surfing to a malicious website, and even denial of service.[7] Code-injection attacks allow cyber criminals and adversaries to inject malicious codes (i.e., instructions) into a system that are then executed by an application. If performed successfully, code injections can result in sensitive data exfiltration and even destruction of the affected system. Also, SNS phishing attacks can escape e-mail content filters since these messages do not flow through network e-mail servers. Finally, SNSs are not subject to federal or DOD information assurance standards, controls, or enforcement, and therefore may not consistently provide confidentiality.[8]

Behavioral/OPSEC threats. Information security (INFOSEC):

> . . . refers to the processes and methodologies which are designed and implemented to protect print, electronic, or any other form of confidential, private and sensitive information or data from unauthorized access, use, misuse, disclosure, destruction, modification, or disruption.[9]

OPSEC, is one of the main components of INFOSEC, which, in turn, is "the pinnacle of social media security concerns."[10] OPSEC includes processes and actions taken to protect unclassified information that can be used against us by adversaries.

SNSs are valuable resources for cyber criminals and adversaries and can create serious OPSEC vulnerabilities for the Air Force and the DOD as a whole. SNSs provide adversaries with a nonregulated mass dissemination channel which allows them to conduct real information operations and gather intelligence.[11] According to a 2010 survey by *Computerworld* magazine,[12] more than half of SNS users in the United States post sensitive information that makes them vulnerable to cybercrime. It is estimated that SNS users receive 71 percent of spam and 46 percent of phishing attacks through social media.[13] Of particular interest to the DOD is the fact that adversaries are using SNSs to choose targets and to detect imminent attacks.

There have been some incidents involving service members and civilians tweeting about their location and ongoing operations. On 2 May 2011, a resident of Abbottabad, Pakistan was tweeting about helicopters hovering over his apartment in the middle of the night. He later discovered that this incident was a Navy sea-air-land (SEAL) team member's raid on his neighbor, Osama Bin Laden. Although inadvertently, this top-secret mission by US Special Forces was almost jeopardized by tweets from someone witnessing the operation.[14]

In January 2010, in what became known as the Robin Sage experiment,[15] an American security consultant ran a social-engineering experiment targeting the US intelligence and defense communities with a fictitious cyber character. The fictitious persona posted photos of an attractive young woman with profiles created to appeal to government and cleared defense contractors. During the 28-day operation, more than 550 people, including very senior government officials, interacted with the fictitious female through several SNSs. The profile also attracted several senior defense contractors within Lockheed Martin, Northrop Grumman, and Booz Allen Hamilton. In one instance, the fictitious female managed to get sensitive information and photos with geo-locational information from a US Army Ranger in Afghanistan.

Current DOD social media policies. Current DOD policy, as well as the *Uniform Code of Military Justice*, require personnel to follow certain rules when publishing information on public websites.[16] These rules, however, are not intended to limit free speech. Instead, rules are there to ensure DOD members do not compromise sensitive information or OPSEC. For example, disparaging senior government officials, revealing operational details, or divulging classified information are offenses punishable under the *UCMJ*. Thus, the issue the DOD is grappling with is how to allow full access to SNSs while at the same time minimize the risks. In 2010, the DOD released a policy memorandum on the use and access to Internet-based capabilities including SNSs—DTM 09–026. This policy was later superseded by DOD Instruction 8550.01, DOD Internet Services and Internet-based Capabilities in 2012. According to this latest DOD chief information officer guidance:

> DoD Internet services and IbC [Internet-based Capabilities] used to collect, disseminate, store, or otherwise process DoD information shall be configured and operated in a manner that maximizes the protection (e.g., confidentiality, integrity, and availability) of the information, commensurate with the risk and magnitude of harm that could result from the loss, compromise, or corruption of the information.[17]

Even though the DOD social media policy does not require organizations to have a presence in SNSs, it has an entire hub dedicated to social media.[18] The Army alone has hundreds of registered FaceBook pages. Thousands more comprise the collection of Army, Navy, Air Force, and Marine pages, mostly Facebook, Twitter and Flickr pages that are listed on the online registry.

AFI 1-1, Air Force Culture, updated on November 2014, is the only recent policy that briefly addresses behavioral best practices on SNSs within the Air Force. According to AFI 1-1, every Airman is personally responsible for what they say and post on SNSs. So where does that leave commanders? AFI 1-1 addresses both OPSEC concerns and the responsibility of each Airman to protect sensitive information from public disclosure, but it does not set policy for protecting networks against the technical threats posed by SNSs.

Problem Statement

Today, the only official Air Force regulation that briefly addresses the OPSEC concerns posed by SNSs is buried on page 21 of AFI 1-1. The "Air Force Social Media Guide" offers Airmen and their families some guidance on the appropriate use of SNSs, but neither of these publications addresses the technical risks and possible mitigations associated with this medium.[19] The Air Force does not have a coherent policy, regulation, or instruction specifically governing the use of SNSs. Current Air Force web policies and instructions are currently under revision to address operational and procedural changes involving public and private web content and may soon offer better guidance and policy addressing the use of SNSs. Without concrete and up-to-date official guidance, however, and considering all the risks discussed herein, how can Air Force commanders balance appropriate security measures to protect information and sensitive operations while taking advantage of the Internet-based capabilities SNSs can to offer our personnel?

Recommendations

1. The Air Force must ensure that the Nonclassified Internet Protocol Router Network (NIPRNET) is configured to maximize technical security. To better protect DOD networks from Internet technical threats, the National Security Agency's Systems and Analysis Center[20] offers recommendations and best practices for the use of social media. Their recommendations for technical best practices include:

   a. Ensure operating systems and web browsers are up-to-date with the latest patches. Maintain a blacklist of blocked sites for the network.

   b. Update virus scanners with the latest definitions and patches, and scan often.

   c. Do not browse the Internet from privileged accounts such as root or administrator.

   d. Enable data execution prevention in the operating system to prevent buffer overflow attacks.

   e. Install an application firewall or host intrusion prevention system and enable whitelisting.

   f. Apply software restrictions policies (SRP) on machines running Microsoft Windows platforms (most Air Force workstations run Windows platforms). SRP keeps a white-list of allowed executables, preventing the installation of malicious downloads.

2. SNSs offer vast amounts of information that adversaries can use to gather intelligence or to exploit DOD operations and personnel. The latest DOD Internet Services and Internet-based Capabilities Instruction, DOD Instruction 8550.01, states that "DoD employees shall be educated and trained to conduct both organizational and individual communication effectively to deny adversaries the opportunity to take advantage of information that may be inappropriately disseminated."[21] Although most technical threats posed by SNSs can be mitigated through the proper use of security measures already in place in most Air Force networks that is perimeter defenses, firewalls, and so forth, information and operations security hinges mainly on the OPSEC and INFOSEC mindset of each and every Airman, and their willingness to divulge—whether intentionally or unintentionally—sensitive information in public forums. Based on the evolving global nature of SNSs and the increasing vulnerabilities brought about by a lack of OPSEC and INFOSEC awareness, it is increasingly evident that the Air Force must step up its OPSEC and INFOSEC training as it

relates to SNSs. This training must be continuously emphasized throughout an Airman's career. Social media INFOSEC/OPSEC awareness training must become a mandatory annual or biannual training. This training must include OPSEC lessons learned, as well as SNS behavioral best practices and possible repercussions for posting inappropriate content online. The Air Force must train its Airmen to refrain from posting personally identifiable information or any information that could reveal sensitive military operations or compromise security. A good training resource for commanders is the Joint OPSEC Support Element at Joint Base San Antonio–Lackland, Texas, which offers OPSEC training materials and resources, some of which now focus on social media.

3. The Air Force must draft policy that specifically addresses the risks and vulnerabilities that come with the use of SNSs. This policy should spell out general guidance for SNS technical and behavioral best practices, social media INFOSEC/OPSEC training standards, and possible consequences or disciplinary actions for violating OPSEC principles on social media. Also, this policy should be broad and flexible enough to be able to adapt to the evolving nature of SNSs. In *The Human Side of Cyber Conflict: Organizing, Training, and Equipping the Air Force Cyber Workforce*,[22] the authors offer some excellent recommendations that address SNS threats and mitigations.
4. Finally, every commander must ensure that any official website or SNS presence be vetted through the proper Air Force public affairs (PA) office and that it meets Air Force web policies. However, this may prove to be a challenge at units that do not have a PA representative.

If used in concert, technical best practices, along with an increased emphasis on OPSEC and INFOSEC awareness training, can help minimize the risks of exposing privileged, sensitive, or even classified information, to adversaries and cybercriminals.

Conclusion

Despite all the vulnerabilities and technical risks associated with SNS, it is unrealistic to attempt to block access to the ever-growing number of SNSs and expect our networks to be safe from attacks and exploits. Instead, the DOD and the Air Force should focus on regulating, not restricting, social media use. DOD and Air Force SNS policies should be broad and flexible enough to be able to adapt to the evolving nature of SNSs. There are proven technical mitigations and best practices that, when properly followed, can offer a strong defense against adversaries. A proper social media OPSEC/INFOSEC awareness training campaign, coupled with robust security features within the DODIN, can go a long way in protecting USAF personnel, networks, and missions while allowing service members access to sites that promote real-time information and collaboration opportunities. The DOD's challenge is to come up with a permanent social media policy that is broad and flexible enough to fill all the security gaps that have emerged, and will continue to emerge as SNS evolve. This task won't be easy but, as Corrin stated,[23] SMSs have become too powerful as an information and strategic messaging platform to be dismissed or ignored. ✪

Notes

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7. National Security Agency Information Assurance Directorate, Pamphlet MIT–005FS–2013, "Best Practices for Keeping your Home Network Secure," May 2014, http://dodcio.defense.gov/Portals/0/Documents/Cyber/Slicksheet_BestPracticesForKeepingYourHomeNetworkSecure_Web_update.pdf.

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13. Shullich, *Risk Assessment.*

14. Ibid.

15. Krombholz, Katharina, Heidelinde Hobel, Markus Huber, and Edgar Weippl, "Advanced Social Engineering Attacks," *Journal of Information Security and Applications* 22 (2015): 113–22.

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18. DOD chief information officer, "DOD Social Media Hub," 7 March 2017, http://dodcio.defense.gov/Social-Media.

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23. Corrin, "DOD's New Policy," 2.

Lt Col Dieter A. Waldvogel

Colonel Waldvogel (BA, Texas Tech University; MA, Embry Riddle Aeronautical University; and PhD, University of Texas–Austin) is a cyberspace operations officer, a senior Latin America regional affairs strategist, and currently a professor of foreign languages at the US Air Force Academy (USAFA), Colorado. Colonel Waldvogel is the director of assessments in the Department of Foreign Languages and International Programs at the Academy. As a cyberspace operations officer, the colonel served in leadership positions with the 789th Communications Squadron, Air Force Space Command Headquarters Directorate of Logistics and Communication, 379th Air Expeditionary Wing Mission Support Group, and the National Security Agency/Information Assurance Directorate.

The *ASPJ* staff would like to correct the following errors in the Spring 2017 edition:

1. On page 30 of the article "Air Mines: Countering the Drone Threat to Aircraft" an editing error resulted in a sentence reading ". . . stealth aircraft, such as the very large B-52. . .". The sentence should be corrected to read ". . . stealth aircraft like the B-2 bomber that has a very large dimension of. . .".
2. Due to an error at the contract printers, some hard-copy journal editions had pages 17–32 inverted.