ASPJ

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AIM HIGH . . . FLY-FIGHT-WIN

AIR & SPACE POWER JOURNAL

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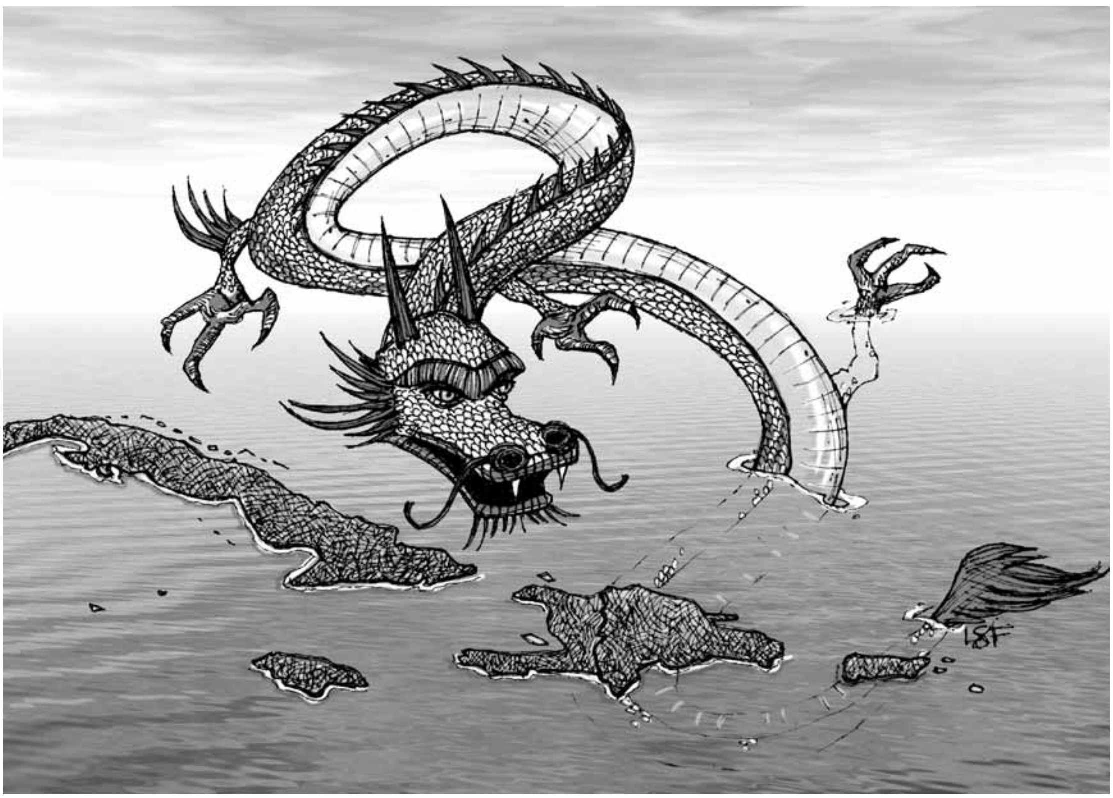
Hic Sunt Dracones (Here Be Dragons)

Lt Col Michael S. Tate, USAF, Chief, Professional Journals

Dating back to medieval times, the expression *Hic Sunt Dracones*, or one like it, adorned ancient maps and charts that marked unexplored territory. Fantastic, dreadful creatures such as serpents with wings symbolized the mysterious vastness lying beyond familiar, commonly traveled areas. Inadequate transportation, superstition, fear, or complacency prevented ventures into those regions so creatively adorned on maps of the day. As better vessels and circumstances expanded their capabilities, however, explorers gained the confidence necessary to step boldly and courageously beyond the known, comfortable world and take on the dragons of nameless lands. The United States Air Force has followed a similar path, as has its professional journal.

Sixty-four years ago, Maj Gen Muir S. Fairchild, then the commanding general of Air University, issued a memorandum es-



tablishing a professional publication devoted to the advancement of airpower. This grand endeavor, appropriately titled the *Air University Quarterly Review*, created a vehicle that allowed professional Airmen to make significant contributions to scholarly thought concerning the exploitation of airpower and the development of forces dedicated to this pursuit. Since that time, the Air Force's professional journal has appeared under various other titles: *Air University Review*, *Airpower Journal*, *Aerospace Power Journal*, and, currently, *Air and Space Power Journal* (*ASPJ*). Today's *Journal*—published in six languages—boasts a worldwide reach, each edition tailored for regional audiences in over 150 countries and 40 territories. Simply stated, *ASPJ* has consistently pushed into the unknown, vanquishing dragons and then redrawing the map that represents the landscape of professional debate among Airmen.

As our leadership has taught us and history has confirmed, change is inevitable. It is time for the Air Force's professional journal to embrace the innovative spirit of those early leaders and commit itself to advancing further into the technological realm. Just as explorers contemplated sailing beyond the edge of the chart or as test pilots and engineers prepared to push the limits of flight, so has *ASPJ* arrived at such a moment in its history. After 64 years of traveling and exploring the known world of traditional publishing, the *Journal* now faces the dragon of the cyber frontier. Though not altogether strange, that realm represents a substantial departure from the familiar domain that *ASPJ* has inhabited.

Although the *Journal* has maintained an online presence for several years, in many ways the print version defined the limits of its electronic counterpart. Thus, transitioning to an online-only publication fundamentally alters our presentation. No longer shackled by the limitations of hard copy, *ASPJ* will soon be available on readers' PCs, tablets, Kindles, or smartphones. Financial constraints that bound our award-winning artists to black-and-white illustrations and our printing specialists to finite page counts no longer apply. In 2012, following this—our last—printed issue, we will introduce an innovative electronic format featuring several timely, novel subject-matter categories along with changes to our publication schedule. We believe that our entry into this brave new world is all to the good.

This final hard-copy edition includes senior leaders' views on measuring success and inspiring innovation. Additionally, articles that offer an intriguing look at the autonomy of remotely piloted aircraft; varying approaches to intelligence, surveillance, and reconnaissance; targeting in cyberspace; and advanced academic degrees are sure to spark discussion. This issue also reprints the first feature article to appear in the inaugural number of *Air University Quarterly Review* (Spring 1947), a piece which presciently set the course that airpower has followed ever since. We believe that it is fitting to include Colonel Glantzberg's article as we reach the end of this chapter in the *Journal*'s history.

Accompanying that ending, however, is a beginning. General Fairchild's vision for this publication's mission, as articulated in the editorial of that first issue of *Air University Quarterly Review*, has not changed:

> This journal of Air Power will not be just another news-magazine. . . . Rather, it will be a professional publication in the highest sense of the word and will reflect not only the high scholastic standards and educational accomplishments of the Air University, but also—and more important, perhaps—the best professional thought concerning global concepts and doctrines of air strategy and tactics.

We will continue to discharge this mandate by publishing scholarly, thought-provoking articles relevant to airpower. Only the method of delivery will change. Advances in technology and the operational environment now enable us, the *ASPJ* staff, to cross the boundary into the uncharted landscape of the future.

Hic Sunt Dracones. ✪

We Measure Success through the Eyes of the War Fighter

Gen Duncan J. McNabb, USAF, Retired

United States Transportation Command (USTRANSCOM) provides strategic mobility to our nation. No other government, commercial, or private agency can move as much to as many places as quickly. The spirit and flexibility of the people who make up the Total Force USTRANSCOM team put the command on the world's stage. The past two years have been among the most challenging in USTRANSCOM's history. The simultaneous drawdown of 80,000 troops in Iraq, the surge of forces into Afghanistan, Haitian earthquake-relief operations, and the Pakistani flood-relief effort confronted us in 2010.[1] The year 2011 has proved no less dramatic. The "Arab Spring" began in Tunisia and quickly spread to Egypt, Libya, Bahrain, Syria, and Yemen. USTRANSCOM supported each situation, evacuating innocents, moving security forces, and delivering humanitarian-relief supplies. In Libya the command moved forces and offered around-the-clock air-refueling tanker capability for North Atlantic Treaty Organization forces while also supporting the president's travels in Brazil, Chile, and El Salvador. Then, the fourth most powerful earthquake since 1900 struck off the east coast of Japan, lasting over six minutes, literally knocking the earth off its axis, and shortening the length of a day.[2] Worse, the tsunami that followed devastated Japanese coastal areas, caused a nuclear meltdown, and even damaged property in California. USTRANSCOM's emergency airlift and air-refueling support not only evacuated over 7,500 people and 400 pets but also made available crucial transport of nuclear expertise and material to help control the reactors at Fukushima. We did all of this in addition to supporting combat operations in Afghanistan, Iraq, and the Horn of Africa. In March 2011, for the first time in USTRANSCOM history, the command supported simultaneous priority-one movements in all six geographic combatant commands—truly March madness! In the face of two unbelievably difficult years, I'm proud to say that USTRANSCOM, together with our components and commercial partners, never failed to fulfill our promises to the war fighter, the president, and our nation. Yet, even as the wars in Afghanistan and Iraq wind down, future challenges demand continued advances.

Strategic Context Demands More with Less

Against a backdrop of rising national debt and an uncertain future security environment, USTRANSCOM can do its part to secure our nation's interests by improving the access and efficiency of our strategic mobility system—a national asymmetric advantage. The ongoing threats of global extremism, the rise of China, a nuclear North Korea, the possibility of a nuclear-armed Iran, and the war in cyberspace are but a few of the difficulties we can see on the horizon. Even as we prepare for these kinds of problems, we know we will face disaster-related humanitarian crises like those that have occurred in Indonesia, Haiti, Japan, Pakistan, New Zealand, the United States, and elsewhere. Covering this crisis spectrum demands a wide range of capability, one in which our logistical forces must be equally capable of meeting warfighter needs in uncontested, semicontested, and contested domains; favorable and unfavorable terrain; all types of weather; and places with limited or no infrastructure. In short our mobility enterprise must have assured access to the entire globe, able to reach even the remotest areas and project power where our national interests dictate we must—a tall, expensive order.

Our nation's debt of $14.5 trillion (and growing) will shape future military capability more than any other factor. The enormity of this indebtedness led Adm Mike Mullen, former chairman of the Joint Chiefs of Staff, to declare it "the most significant threat to our national security"[3]—one that we simply cannot address without considering defense. Our spending on national security—$881 billion in fiscal year 2012—consumes more than any other category of the federal budget.[4] As the debate rages in Washington over how to handle our debt issues, it seems only prudent that the Department of Defense (DOD) find ways of operating in a shrinking budget environment. To do so, we must become more efficient at all levels—strategic, operational, and tactical.

Balancing the opposing challenges of increasing access while using fewer resources will likely produce an ever-growing demand for mobility. The DOD probably will not be able to recapitalize its aging inventory of ships, planes, and vehicles on a one-for-one basis. A RAND study of 2008 concluded that the annual cost growth of all types of military aircraft has far outpaced inflation because of many factors, the lion's share coming from technological complexity of design—a trend not unique to aircraft.[5] Analyses of the US Navy's ship fleet and the US Army's / Marine Corps's tactical vehicle fleets show similar trends in cost growth. Across the board, Services are forecasting declining platform numbers because of such growth and budgetary constraints.[6] All the while, the world security environment is becoming more complex and multipolar. Quite simply, the American military will have to do more with fewer things and in more places than it ever has before. As the more-with-less trend accelerates, strategic mobility will increasingly assert itself as a multiplying force for good—a prospect that will necessitate a global network of interconnected ports in suitable positions to enable global reach.

Doing More by Expanding Mobility Access

As I told the House Armed Services Committee,

> On August 9, 2010 USTRANSCOM submitted its inaugural En Route Infrastructure Master Plan (ERIMP) 2010 to the Chairman of the Joint Chiefs of Staff. The purpose of the ERIMP is to guide the en route infrastructure investment decisions necessary to ensure we can support the regional Combatant Commander Theater Campaign and Theater Posture Plans. The ERIMP frames the en route strategy by identifying our most important enterprise-wide infrastructure requirements for improving our global access.

The plan recommended enhancements at Rota, Spain; Camp Lemonier, Djibouti; Souda Bay, Crete; and Guam. A C-17 operating from Camp Lemonier can reach two-thirds of the African continent, and its proximity to a seaport makes the camp an ideal multimodal site. "Located on the island of Crete in the central Mediterranean Sea, Souda Bay is [a key access hub] due to its proximity to the Black Sea, the Middle East, and Africa." However, its roads, aircraft parking, air operations support, and the Marathi logistics facility need attention. As our key multimodal location in the Pacific, Guam requires an air-freight terminal complex and an air-passenger terminal / joint personnel deployment center. USTRANSCOM's new role in the Unified Command Plan as the global distribution synchronizer (GDS) will help realize these improvements.[7]

This GDS authority will allow USTRANSCOM to coordinate with all combatant commands to synchronize their distribution plans, creating a more effective and efficient global distribution system for all. Improving en route ports as identified in the ERIMP offers a perfect example of what USTRANSCOM intends to accomplish in its new role as the GDS. As stated in our air component's recent "Global Mobility En Route Strategy" white paper, "For [the] strategy to succeed, it must be implemented at the operational level, which implies occasional subordination of operational efficiencies to the greater strategic need and desired long-term effect."[8] This means that the future strategic success of one combatant command will rest on decisions and investments made by another as coordinated by USTRANSCOM. These improvements will enable the command's airlift fleet to reach new areas. Ninety percent of the time, reaching a port is sufficient, but sometimes we must go the last tactical mile—a necessity that has made possible a new strategy.

Historically, we used airdrop resupply when conventional forces were cut off in an emergency. The precision and reliability of today's airdrop systems have permitted conventional ground forces to operate purposely in very remote, cutoff areas. For instance, many of the forward operating bases in Afghanistan rely almost exclusively on vertical resupply for sustainment. In Paktika Province near the Pakistan border, 12 of 18 Army forward operating locations receive their supplies through parachute drops and helicopter lift alone. "Without aerial resupply, we would have no supply," said Capt Cole DeRosa, US Army, whose company operated at one of the locations.[9] Over the last five years, demand for airdrop has increased from two million pounds in 2005 to over 100 million pounds in 2011. To put these figures in perspective, the Air Force dropped over 16 million pounds of supplies in 78 days during the 1968 siege of Khe Sahn for an average of 208,000 pounds per day. The pace in Afghanistan has averaged 275,000 pounds per day—for more than 365 days and counting. US ground forces have never before *deliberately* relied on airdrop resupply on such a wide scale as they do in today's Afghanistan conflict.[10] Airdrop is indeed effective, and recent advances have made it more efficient.

The newly fielded Low Cost Aerial Delivery System, which has taken the airdrop world by storm, includes the low-cost container as well as the low-cost, high-velocity and the low-cost, low-velocity parachutes. The high-velocity chute falls about three times as fast as the low-velocity version, sacrificing load-impact survivability to gain drop accuracy. As their names imply, these polypropylene chutes are cheaper to manufacture and purchase than conventional types.[11] Moreover, since they are one-time-use-only, we don't have to retrograde them after a resupply drop. Better still, they also come prepacked from the factory, saving countless man-hours compared to rigging legacy reusable chutes such as the G-12. In fact, if not for prepacking, we could not sustain our current airdrop volume with legacy methods. Given the cost, time, and retrograde benefits, these parachutes have rapidly replaced their legacy counterparts and are now used on 96 percent of all airdrop bundles in Afghanistan. In spite of its huge success, airdrop is one-way-only, so we are now exploring ways to conduct two-way mobility operations just about anywhere in the world.

In the near future, hybrid airships may allow us to deliver and retrieve personnel and material directly to and from the point of need in volumes never before possible. These vehicles are a cross between traditional blimps, which rely purely on buoyancy to fly, and airplanes, which use aerodynamic lift to overcome the force of gravity. Aerodynamically shaped blimps, hybrid airships generate both buoyant and aerodynamic lift. The US military will soon take delivery of operational airships for use in a surveillance role. Several viable airlifter designs could lift 20–70 tons; others may even handle 500 tons and move at speeds in excess of 100 knots over intercontinental distances.[12] Our analysis of a 70-ton payload craft indicates that airships are less than half as expensive as C-17s on a cost-per-pound-delivered basis. Faster than ships and cheaper than planes, these aircraft can land almost anywhere—a fact that may finally enable strategic mobility to *and from* the point of need.

If operationalized, hybrid airships will revolutionize the global distribution system. Like the 40-knot, 600-ton-capacity Joint High Speed Vessel, the airship can operate without fixed infrastructure, eliminating the need to build, protect, operate, and maintain as many fixed logistical sites and thus reducing cost. For the first time ever, we could move large end items, such as tanks, by air to and from nearly anywhere on the planet. This ability could put into play the US Army / Marine Corps mounted vertical maneuver concept, but its greatest effect would involve making almost any location a multimodal port. Smartly redesigning the global en route infrastructure, exploiting airdrop, and developing new ways to deliver to the point of need will significantly expand our strategic mobility access. However, our *ability* to access the globe is only part of the solution; much of the rest depends on countries *allowing* us access.

Diplomatic entrée to air and ground space can make or break grand strategy. Afghanistan presents a valuable case study in and of itself. Had we not secured diplomatic access through Pakistan, Operation Enduring Freedom would have assumed a very different form. The addition of access troubles in the central Asian states would have left the United States only with clandestine military options, dramatically reducing our ability to provide logistics superiority and diminishing the possibility of toppling the Taliban in Afghanistan.

The Pakistan ground line of communication (PAKGLOC) links the southern seaport of Karachi with Afghanistan through border gates called Chaman and Torkham (see figure on the next page). As recently as 2008, 80 percent of all US military cargo flowing into Afghanistan moved through these two gates. This reliance on one route made us vulnerable. For instance, in October 2010 the Pakistan military shut the Torkham gate in response to a Pakistani fratricide incident with US helicopters.[13] Besides being cut off, the supplies already on the PAKGLOC began to pile up and overflow storage yards in Pakistan, spawning opportunistic pilferage. Furthermore, in 2010 historic floods that covered a fifth of the country disrupted the PAKGLOC supply lines. Even though the Defense Logistics Agency maintains a number of warehouses in-country to mitigate such incidents, success in Afghanistan demanded an alternative supply route.

Foreseeing the strategic vulnerability of the PAKGLOC, USTRANSCOM, together with the Defense Logistics Agency and our commercial partners—US Central Command (CENTCOM), US European Command, US Pacific Command, the DOD, and the Department of State—undertook what has become a major success: the Northern Distribution Network (NDN). Built in 2008, the network opened multiple air and ground lines of communication from Eastern Europe through the Central Asian states of Georgia, Azerbaijan, Uzbekistan, Tajikistan, Kyrgyzstan, Kazakhstan, and Russia into Afghanistan. Much more difficult than telling carriers to take a different

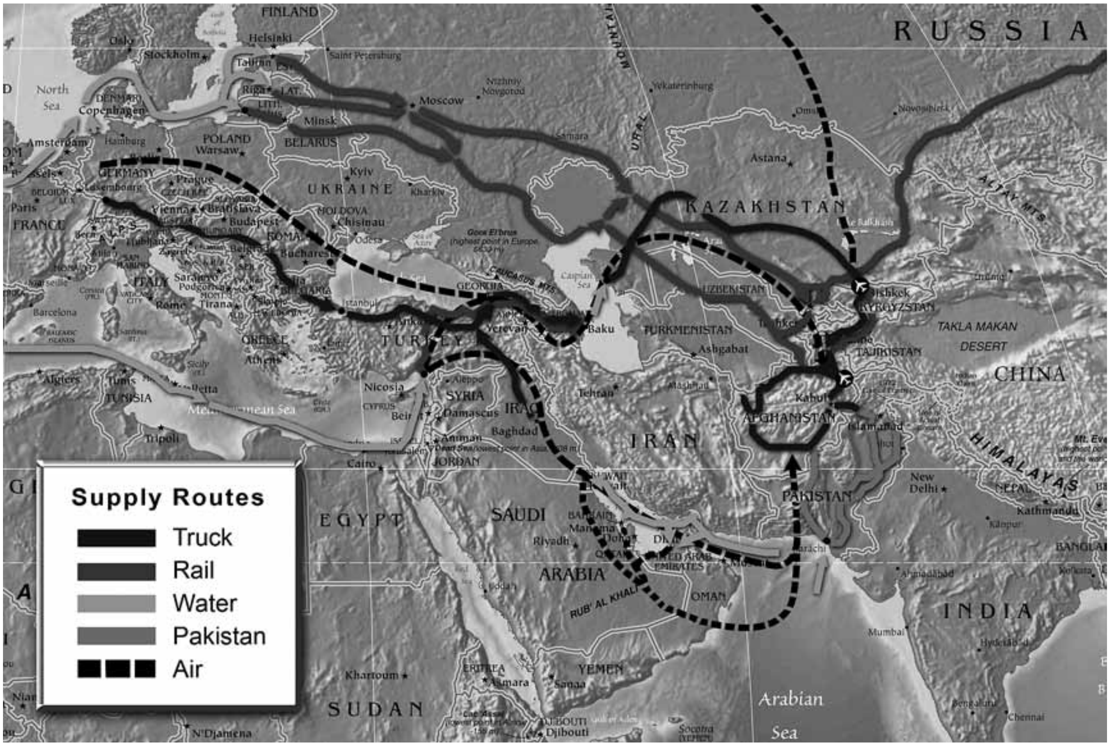


Figure. Strategic lines of communication into Afghanistan

route, this approach involves negotiating not only higher capacities and overflight counts with each country in the NDN but also such details as determining which classes of supply; originating from what countries; going to what locations, for what purposes, by which carriers; and deciding whether these items can flow one way (to Afghanistan) or both ways (to and from). These arrangements entailed extensive negotiations at all levels, down to individual air, truck, and rail operators. Success hinged on "what was in it for them," namely a stable Afghanistan and economic benefits produced by local sourcing and transit contracts. Providing a necessary strategic alternative, the NDN stands as an example of what diplomatic access "buys" and what the (potential) loss of it (Pakistan) "costs." Strategic access to airspace is similar.

Since the terrorist attacks of 11 September 2001, USTRANSCOM has moved approximately 12 million passengers supporting the CENTCOM theater of operations, about 90 percent of whom moved on contracted commercial aircraft.[14] Until June 2011, the best option for these movements called for traveling either from the eastern continental United States (CONUS) through European airspace to the theater or west across the Pacific and then through the Arabian Peninsula or the Central Asian states. In partnership with the Department of State and with the help of the National Security Council, USTRANSCOM succeeded in negotiating military-contracted commercial and military airlift routes from the CONUS; over the Arctic, Russia, Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan; and into Afghanistan. These near-polar routes are significantly more efficient, saving time, energy, and wear and tear on airframes. They also improve diplomatic relations as part of a larger US effort in the region to promote democracy, peace, and security. Access is essential, as is being allowed access—yet, what if we must operate in denied airspace?

Our airlift fleet can already operate safely in lower-threat environments. Designed with redundant systems (multiple engines and control systems) and protected with self-sealing fuel tanks, armor, and defensive systems, our airlift aircraft have taken fire hundreds of times, and scores have been hit in both Iraq and Afghanistan. Fortunately, we have yet to lose a US airlifter to enemy surface-to-air fire, a fact that attests to the robustness of our aircraft and tactics, the training of our crews, and our ability to stand off when necessary.

The addition of high-altitude, improved-container delivery systems and joint precision airdrop system (JPADS) platforms guided by the Global Positioning System has equipped our airlift fleet with both vertical and horizontal standoff capabilities. Traditionally, we air-drop supplies from a few hundred feet above the ground using unguided parachutes. The JPADS allows our aircraft to do so from more than 20,000 feet yet maintain accuracy because the dropped platform glides itself to a programmed landing location. The JPADS 2K airdrop system can carry a payload of between 700 and 2,200 pounds and can fly to steer points along its glide route. Larger systems boasting heavier payloads up to 30,000 pounds are undergoing tests.[15] A JPADS 2K dropped from 30,000 feet above ground level with a 3.25:1 glide ratio allows the dropping aircraft to stand off from the resupply location a distance of 16 nautical miles, enough to outrange antiaircraft artillery, man-portable air defense systems, and many tactical radar-guided surface-to-air threats. Mitigating longer-range threats will require a different approach.

The High Speed Containerized Delivery System (HSCDS) will facilitate airdrop at higher speed and low altitude. The system seeks to provide a tow-initiated, parachute-extracted container delivery system for use on C-130J and C-17 aircraft at up to 250 knots (maximum ramp open airspeed) from altitudes as low as 250 feet. The HSCDS will let war fighters conduct very low altitude, fast, and accurate resupply of up to 16,000 pounds of supplies via eight containerized delivery system bundles.[16] This system will greatly diminish aircraft exposure in higher threat areas, compared to our current chute-driven limits of 140 knots and 400–600 feet above ground level. Moreover, airdrop done this way will not compromise the ground party's position since the plane's speed and altitude do not give away the location of the drop zone. And since the aircraft maintains a higher airspeed, it has a greater stall margin, which improves flight safety. The HSCDS will further expand our access to denied areas, enhance the safety of ground parties, increase accuracy, and improve flight safety. Better access will allow USTRANSCOM to move a budget-constrained fighting force to more places—a multiplying force for good.

Using Less through Smart Efficiencies

Just as success in Afghanistan and in future crises relies upon strategic mobility access, so does our worsening national financial situation demand that we find more efficient ways to project and sustain military power. This task will not be easy, but several USTRANSCOM initiatives already under way have returned billions of dollars to the DOD—and we have more on the way. These initiatives fall into two broad classes: operational efficiencies and organizational ones. The former deliver financial and energy savings directly while the latter save indirectly by eliminating expensive overlap as well as redundancies and/or by making more efficient use of existing resources.

With regard to operational efficiencies, making the global mobility network more efficient demands a comprehensive perspective. Every year the strategic transportation system takes in about $14 billion via the transportation working capital fund, primarily to offset operational costs. Yet, capturing the true cost of mobility effects requires a much broader viewpoint. Global movement depends upon a network of people, infrastructure, information systems, and platforms. The national cost of acquiring, modifying, maintaining, and operating this network then helps define the perspective we need as we consider how to improve the performance of strategic mobility. We seek to lower the fully burdened cost of moving people and material after all of these costs are factored in. USTRANSCOM's global nature and viewpoint have enabled it to attain high effectiveness and high operational efficiency simultaneously.

The increasing adoption of multimodal operations and recent arctic overflights demonstrate the possibility of improving efficiency and effectiveness simultaneously. Such operations are the coordinated use of multiple modes of transportation to move forces or sustainment from its source to its destination. With visibility and tasking authority over its air, sea, and land transportation components, USTRANSCOM is uniquely positioned to drive multimodal solutions—with impressive results.

To better understand the impact of multimodal operations, let's begin with the single-mode movement of mine-resistant, ambush-protected (MRAP) vehicles to Iraq. The MRAP came from an urgent need to protect coalition soldiers from improvised explosive devices (IED), which by 2007 had claimed over 3,000 lives, accounting for 60 percent of all casualties in Iraq.[17] In response, former secretary of defense Robert Gates fast-tracked the fielding of the MRAP, which has a V-shaped hull to deflect explosions from below. USTRANSCOM flew 80 percent of the first 1,000 MRAPs directly to Iraq, primarily aboard C-5s, C-17s, and contracted An-124s before transitioning the bulk of the work to sealift. Whether flown or shipped, MRAPs then drove to their final destinations. The fact that these vehicles have saved thousands of lives, proving 10 times safer than their Humvee counterparts, demonstrates the wisdom of fielding them.[18] Shortly thereafter we needed MRAPs in Afghanistan because the insurgents there began copying their Iraqi counterparts' IED tactics with similarly deadly results. However, the MRAPs that had worked so well in Iraq were too large and ungainly for use in the mountains and primitive roads of Afghanistan.

The MRAP all-terrain vehicle (MATV) offered a solution to this problem, and USTRANSCOM transitioned it much sooner to multimodal operations. This vehicle is a smaller, much more maneuverable MRAP designed for our Soldiers in Afghanistan. Since the original award in June 2009, the DOD has contracted for 8,731 MATVs. USTRANSCOM began movement of 7,341 of them to the theater in October 2009 via CONUS air-direct. As demand for the new vehicles in Afghanistan exploded, CENTCOM raised its delivery requirement from 500 to 1,000 MATVs per month. In contrast to driving MRAPs from Kuwait into Iraq, driving MATVs up the PAKGLOC from the seaport of Karachi involves a hazardous 60-day trip, so we changed MATV deliveries from air-direct to multimodal operations in May 2010. We shipped these vehicles to seaports in-theater and then transloaded them to C-17s for the final leg into landlocked Afghanistan. Shorter-cycle distances allowed each C-17 to carry five MATVs instead of three and to make several deliveries per day. Leveraging the cost-effectiveness and bulk capacity of ships with the ability of C-17s to access Afghanistan safely, multimodal operations produced $485 million in savings during the movement of 4,210 MATVs from May 2010 through August 2011.[19]

In another real-world multimodal example, CENTCOM tasked USTRANSCOM to move a Stryker brigade, including 328 Strykers, 46 trailers, 509 containers, and 52 pieces of rolling stock from Fort Lewis, Washington, to Kandahar, Afghanistan, in May–June 2009. USTRANSCOM executed this move by shipping the equipment from the port of Tacoma, Washington, to Diego

Garcia aboard two commercial ships where it was transloaded onto C-17s and An-124s for the flight to Kandahar. Fifty C-17 and 90 An-124 sorties later, USTRANSCOM had completed the move five days ahead of schedule. Had we flown this brigade directly from the United States using available airlift (four C-17s and four An-124s), it would have cost $170 million and taken 118 days to close. As it happened, multimodal operations closed the move in 80 days at a cost of $68 million—*38 days faster* and *$102 million cheaper*. Contrary to intuition, multimodal operations have proven that in terms of effectiveness versus efficiency, you can have your cake and eat it too.

Mentioned earlier, in June 2011 USTRANSCOM began contracted commercial and military cargo flights directly from the CONUS, over the arctic, through Russia and Kazakhstan, into Afghanistan and Kyrgyzstan. These flights save money and time. For example, during a recent tanker unit rotation, swapping aircraft and personnel between Manas AB, Kyrgyzstan, and Fairchild AFB, Washington, each KC-135 saved 8.5 airframe hours and $77,000, thus completing the round-trip move 50 hours sooner than the previous routing. Commercial rotators can now fly nonstop to Manas AB from the CONUS, saving three airframe hours and $146,221 each way. Given the number of deployment and redeployment sorties flown, these savings add up in a hurry. Analysis shows that these routes will return $9.8 million, save 425 airframe hours, and spend 2,500 fewer hours in transit time per year. Again, smart global thinking enables effective, efficient operations.

Using these types of operational initiatives and smartly combining surface and air modes, USTRANSCOM is doing its part to steward our nation's resources wisely. From 2003 until June 2011, efforts such as leveraging multimodal operations and rerouting traffic over previously inaccessible airspace have allowed the command to return $4.9 billion in overseas contingency operations funds and have saved millions of gallons of fuel. These operational efforts continue today with proven success. USTRANSCOM is also hard at work improving organizational efficiencies.

Maximizing the performance of the entire distribution network calls for an organization with a holistic viewpoint and commensurate authorities. This global enterprise consists of numerous organizations like USTRANSCOM and its components, the Defense Logistics Agency together with its three regional commands and six field-level activities, 34 commercial air and 48 commercial sea partners, six geographic combatant commands and their components, as well as scores of foreign nations. Each of these parts shares a common goal of providing world-class service. However, as with any large enterprise involving so many parts, individual interests do not always align, and subsystems do not necessarily work well together. All too often we see organizational boasts of saved costs that are actually just shifted to others and stovepiped information systems that are incompatible across organizational boundaries. We also see organizational interests impeding strategic objectives. After 10 years of war, we have learned a great deal about how to best support the war fighter, and we seek to institutionalize these lessons.

Responding to former secretary of defense Gates's department-wide challenge to find $100 billion in efficiencies, USTRANSCOM proposed 15 new initiatives (12 of which were accepted). Some of them include aligning C-130 and KC-135 aircraft outside the CONUS under USTRANSCOM and making the command the DOD's lead proponent for in-transit visibility. We also proposed expanding USTRANSCOM's authorities over distribution systems in the cyber domain, transitioning theater patient movement requirements centers to detachments under the Global Patient Movement Requirements Center. In addition, we proposed strengthening the command's role in decision making regarding Service deployment and distribution.

These 12 proposals would create a more effective enterprise by unifying command and control, focusing disparate interests, eliminating redundancies, and synchronizing information systems to enable USTRANSCOM to more rapidly pivot the enterprise and optimize end-to-end support to the geographic combatant commanders. As of this writing, 10 of the 12 proposals have been accepted in some form, and implementation will soon follow. Although these proposals cross several external organizational boundaries, USTRANSCOM has also been relentlessly improving itself from within.

Specifically, in 2006 the command launched Agile Transportation for the Twenty-First Century (AT21), a multiyear program designed to give decision makers automated tools to optimize the end-to-end distribution of forces and sustainment. For years the Joint Deployment and Distribution Enterprise (JDDE) has relied on scores of incompatible information systems that "grew up" in separated stovepipes requiring tireless manual oversight and brute force to coordinate strategic distribution. This lack of integration produced an inefficient, labor-intensive patchwork that caused degraded delivery through poor utilization of aircraft, trucks, trains, and ships. AT21 will largely eliminate the manual, unsynchronized nature of legacy systems and replace them with new business processes, technology, and enhanced data integration that will allow JDDE operators to optimize the end-to-end distribution enterprise.[20]

Leveraging cutting-edge gaming technology and optimization engines, a planner in USTRANSCOM's operations center—the fusion center—will soon be able to see everything in the JDDE and conduct what-if analysis in real time with the push of a button. We will dramatically improve performance through data integration across numerous information systems, both military and commercial, as well as new business processes that functionally link the entire enterprise across organizations—and it's almost here. By the time you read this, the first increment of AT21 should have reached initial operating capability, on its way to full capability in 2016. USTRANSCOM is committed to delivering vastly improved time-definite and cost-specific mobility performance.[21]

Conclusion

In the face of unfavorable strategic headwinds caused by our national debt and uncertain security environment, the team at USTRANSCOM has set in place a strategy to balance these challenges in an effective, efficient manner. No one can be certain where the next crisis in the world may occur, but assured global access will guarantee our readiness. We will expand our strategic access by leveraging our role as the GDS to improve key infrastructure and use diplomacy to open new lines of communication, as demonstrated by the NDN and arctic overflight. We will also improve our ability to deliver to the point of need by exploiting new systems such as low-cost, high-speed airdrop and transformational systems such as hybrid airships. The historic and deliberate placement of forward operating posts beyond ground lines of communication in Afghanistan, completely reliant on aerial delivery, speaks volumes about the trust we have earned from our Soldiers, who know that USTRANSCOM and its air component will always—ALWAYS—deliver.

Even as we enhance our access, our national financial situation demands that we find ways to carry out our mission using fewer dollars. As those fewer dollars shrink our military force structure, USTRANSCOM will create strategic efficiency by enabling a smaller force to do more in more places than ever before. As we do so, the professionals in our command will relentlessly strive to provide the lowest fully burdened cost possible through multimodal, infrastructure-independent operations and future innovative ideas that one can only imagine. Our efforts through June 2011 not only have delivered over $5.6 billion in savings but also have increased effectiveness. Nevertheless, our efficiency proposals to the secretary of defense and our AT21 program will improve our organization even more by properly aligning command relationships while eliminating redundancies and optimizing our use of technology. These initiatives will allow USTRANSCOM to pivot the enterprise rapidly in support of national objectives and ensure that strategic mobility remains one of our country's most asymmetric advantages—guaranteeing that we measure success through the eyes of the war fighter. ✪

Notes

1. *USTRANSCOM 2010 Annual Report* (Scott AFB, IL: USTRANSCOM, 2010), 3.

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4. "Summary Tables," in *Budget of the United States Government, Fiscal Year 2012* (Washington, DC: US Government Printing Office, 2011), 174, http://www.whitehouse.gov/sites/default/files/omb/budget/fy2012/assets/tables.pdf.

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6. House, *The Long-Term Outlook for the U.S. Navy's Fleet: Statement of Eric J. Labs, Senior Analyst for Naval Forces and Weapons, before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, U.S. House of Representatives*, 111th Cong., 2nd sess., 20 January 2010, 3, http://www.cbo.gov/ftpdocs/108xx/doc10877/01-20-NavyShipbuilding.pdf. See also Terrence K. Kelly et al., *The U.S. Combat and Tactical Wheeled Vehicle Fleets: Issues and Suggestions for Congress* (Santa Monica, CA: RAND Corporation, 2011), xxv, http://www.rand.org/content/dam/rand/pubs/monographs/2011/RAND_MG1093.pdf.

7. Paragraph largely quoted and paraphrased from House, *Statement of General Duncan J. McNabb, USAF, Commander, United States Transportation Command, before the House Armed Services Committee on the State of the Command*, 112th Cong., 1st sess., 5 April 2011, 16–17, http://www.dod.gov/dodgc/olc/docs/testMcNabb04052011.pdf.

8. Air Mobility Command, "Global Mobility En Route Strategy," white paper (Scott AFB, IL: Air Mobility Command, 2008), 32.

9. Michael M. Phillips, "U.S. Ramps Up Airdrops to Forces in Afghanistan," *Wall Street Journal*, 22 April 2011, http://online.wsj.com/article/SB10001424052748703461504576230602684196740.html.

10. Maj Gen Burl W. McLaughlin [commander, 834th Air Division, Tan Son Nhut AB, Vietnam], "Khe Sanh: Keeping an Outpost Alive," *Air University Review*, November–December 1968, http://www.airpower.au.af.mil/airchronicles/aureview/1968/nov-dec/mclaughlin.html. During Operation Junction City (22 February–14 May 1967), another large airdrop operation during Vietnam, tactical airlifters dropped 3.4 million pounds (1,700 tons) over 82 days, averaging about 41,000 pounds (20 tons) a day. Another notable effort in Vietnam came at A Luoi in April 1968 when C-130s averaged 255.6 air-dropped tons per day; on 30 April, they set a single-day airdrop record of 380 tons, smashing the previous 225-ton record set during Khe Sahn on 18 March 1968. However, the fact that the operation lasted only nine days doesn't come close to the sustained pace in Operation Enduring Freedom. Finally, the siege of An Loc in 1972 led to a sustained effort from 15 April until 31 December 1972, when US Air Force C-130s air-dropped a total of 10,707 tons over the course of 263 days, averaging 40.7 tons per day. Ray L. Bowers, *Tactical Airlift*, United States Air Force in Southeast Asia Series (Washington, DC: Office of Air Force History, US Air Force, 1983), 339, 555. The Korean War also featured notable airdrop resupply efforts. The Chosin Reservoir emergency resupply occurred on 27 November–9 December 1950: "The first aid to reach the Marines was 25 tons of ammunition airdropped on 28 November by 16 C-47s. The next day, 16 C-47s dropped 35 tons and 15 C-119s another 80 tons of ammunition. By 1 December, the Combat Cargo Command had dedicated all of its C-119s to the Chosin resupply effort." Military Airlift Command Historical Office, *Anything, Anywhere, Anytime: An Illustrated History of the Military Airlift Command, 1941–1991* (Scott AFB, IL: Military Airlift Command, May 1991), 77. "During the two days which the FEAF [Far East Air Forces] Combat Cargo Command required to gear its dropping capability up to 250 tons per day, the limited-scale drops were continued at Yudam-ni and Sinhung-ni. On 1 December, however, the airdrop machine was in full

sway." Robert F. Futrell, *The United States Air Force in Korea, 1950–1953*, rev. ed. (Washington, DC: Office of Air Force History, United States Air Force, 1983), 258. "Between December 1 and 6, 238 C-119 sorties dropped 970.6 tons of cargo to the marines and soldiers of X Corps, mainly at Hagaru-ri and Koto-ri. The high point of this massive airdrop effort came on December 5 when 63 C-119 sorties delivered 297.6 tons of ammunition, medical supplies, and gasoline to the frozen troops. 'There can be no doubt,' Smith acknowledged, 'that the supplies received by [airdrop] proved to be the margin necessary to sustain adequately the operations of the division during this period.' " William M. Leary, *Anything, Anywhere, Any Time: Combat Cargo in the Korean War* (Washington, DC: Air Force History and Museums Program, 2000), 20. Finally, humanitarian airdrops such as those in Bosnia have been impressive and sustained but do not count as resupply of US ground forces. Still, from February 1993 to April 1994, coalition aircraft dropped 18,000 tons of humanitarian aid in Bosnia for a daily average of about 40 tons. A. Martin Lidy et al., *Bosnia Air Drop Study* (Alexandria, VA: Institute for Defense Analyses, 1999), ES-8. Over the years, numerous air assaults—Operation Overlord and Operation Market-Garden in World War II, Operation Chromite, or the assault on Munsan in Korea, to name a few—have exceeded Enduring Freedom's airdrop tonnage averages, but they were limited in duration. Nothing like today's sustained pace of airdrop resupply—day in and day out, year after year—has ever occurred before.

11. A low-cost, low-velocity bundle rigged with its associated low-cost container costs $2,850, and the low-cost, high-velocity / low-cost container $1,035. By contrast, a legacy containerized delivery system bundle using a G-12 parachute costs $4,570—or $1,420 when paired to a 26-foot high-velocity ring slot chute.

12. "Northrop Grumman Gets $517M Army Airship Contract," *Bloomberg Businessweek*, 14 June 2010, http://www.businessweek.com/ap/financialnews/D9GBB90O2.htm.

13. Jim Garamone, "Work Continues to Re-open Torkham Gate," 5 October 2010, Department of Defense, http://www.defense.gov/news/newsarticle.aspx?id=61153.

14. Command briefing, Headquarters Air Mobility Command, 2011, slide 35.

15. See brochures for 2K Firefly, 10K Dragonfly, and 30K MegaFly available at Airborne Systems, http://www.airborne-sys.com.

16. Air Mobility Command (A3D), "High Speed Containerized Delivery System Joint Capability Technology Demonstration Concept of Operations," draft Air Mobility Command staff document (Scott AFB, IL: Air Mobility Command [A3D], June 2011), sec. 2, p. 4.

17. Clay Wilson, *Improvised Explosive Devices (IEDs) in Iraq and Afghanistan: Effects and Countermeasures*, CRS Report for Congress, RS22330 (Washington, DC: Congressional Research Service, 28 August 2007), http://assets.opencrs.com/rpts/RS22330_20070828.pdf.

18. Tom Vanden Brook, "Gates: MRAPs Save 'Thousands' of Troop Lives," *USA Today*, 27 June 2011, http://www.usatoday.com/news/military/2011-06-27-gates-mraps-troops_n.htm.

19. USTRANSCOM J3-G Sustainment Division. As of August 2011, 7,147 MATVs had been delivered: 2,672 via direct airlift, 265 via driving, and 4,210 via multimodal operations.

20. *USTRANSCOM 2010 Annual Report*, 6.

21. Ibid., 6–8.

Gen Duncan J. McNabb, USAF, Retired

General McNabb (USAFA; MS, University of Southern California) served as the commander of US Transportation Command, Scott AFB, Illinois, the single manager for global air, land, and sea transportation for the Department of Defense. Previously, the general commanded the 41st Military Airlift Squadron, earning Military Airlift Command's Airlift Squadron of the Year in 1990; the 89th Operations Group, overseeing the air transportation of our nation's leaders; the 62nd Airlift Wing, earning the Riverside Trophy as Fifteenth Air Force's outstanding wing in 1996; and the Tanker Airlift Control Center and Air Mobility Command. General McNabb's staff assignments included a variety of planning, programming, and logistical duties, such as serving as the deputy chief of staff for plans and programs on the Air Staff, chairman of the Air Force Board, and director for logistics on the Joint Staff. Prior to his last assignment, he was vice-chief of staff of the Air Force. General McNabb began his aviation service as a C-141 navigator. He later went to pilot training and finished his career as a command pilot, amassing more than 5,400 flying hours in transport and rotary-wing aircraft. The general is a graduate of Squadron Officer School, Air Command and Staff College, Air War College, and the Industrial College of the Armed Forces.

Cursor on Target

Inspiring Innovation to Revolutionize Air Force Command and Control

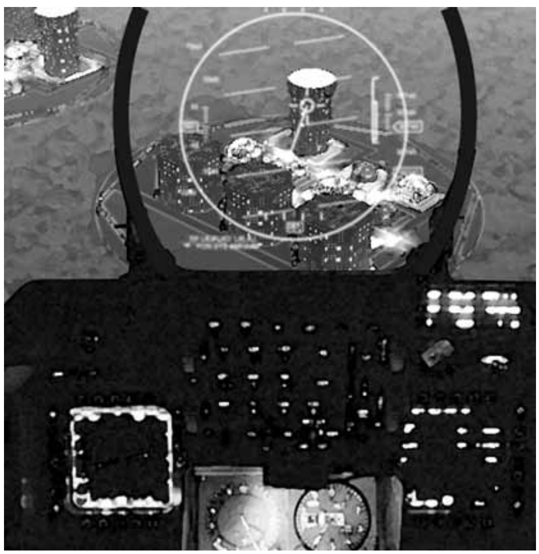
Dr. Raymond A. Shulstad, Brigadier General, USAF, Retired

In this article, Ray Shulstad tells a compelling story of the power of technology inspired by a concept of operations that puts technology to work directly for commanders—no endless list of requirements, no overreach for impossible technology. Using a simple organizing principle of "cursor on target" allowed everyone to visualize the same goal and focus on a comprehensive solution. There is no better example of engineers, industry, operators, and commanders being on the same page and delivering technology that has saved many lives on the battlefield. We need more of the same!

—Gen John P. Jumper, USAF, Retired

Because innovation is the key to increasing organizational effectiveness, improving efficiency to reduce cost, and applying technology that leads to new products, increased revenue, and profit, all leaders have a responsibility to inspire innovation within their organization. Leaders like Microsoft's Bill Gates and Apple's the late Steve Jobs have spoken extensively about inspiring innovation as the key to the success their companies have enjoyed. Gates clearly recognizes the tremendous potential of information technology, noting that "never before in history has innovation offered the promise of so much to so many in so short a time." And Jobs indicated how strongly he felt about a leader's responsibility in this area: "Innovation distinguishes between a leader and a follower." Some leaders, such as these two individuals, can inspire simply by coupling their vision with comprehensive knowledge of the technology and driving the organization toward that vision. Others, like General Jumper, inspire by coupling their vision with passionate demands that the organization respond by bringing that vision alive.

This responsibility to inspire innovation becomes especially important if the organi-



zation's mission focuses on research and development. I understood that fact firsthand from my experience in the Air Force, where I led engineering organizations and commanded a major research laboratory. From May 2001 to April 2006, I applied that experience numerous times to the benefit of the service as the senior vice president and general manager of the MITRE Corporation's Air Force Command and Control Center.[1] At that time, my center was one of three in MITRE's Department of Defense (DOD) Command, Control, Communications, and Intelligence (C3I) Federally Funded Research and Development Center, charged with providing systems engineering to the government's programs to modernize its C3I capabilities.

This article offers one specific example of how inspiring innovation revolutionized the Air Force's command and control (C2) capabilities. It reveals how General Jumper, as chief of staff of the Air Force, inspired a revolution with his vision of an automated and integrated C2 system capable of significantly reducing targeting-cycle timelines and friendly-fire casualties. Furthermore, the article shows how I responded to General Jumper's challenge by driving MITRE's Air Force Center, in collaboration with the service's acquisition and operational communities, to bring such a system alive by using rapid prototyping and information technology to deliver machine-to-machine targeting.

Background

When I took over the Air Force Center in May 2001, I found that I had about 1,000 engineers deployed across hundreds of programs. My predecessor, Dr. Hal Sorenson, a former chief scientist of the Air Force, recognized that the legacy C3I systems had major interoperability problems and that the information technology revolution offered the promise of automating and integrating the DOD's C3I systems in ways that could solve these problems. To do so, Hal had launched an architecture-based technical strategy that would use standards like Internet protocol (IP) communications and extensible markup language (XML) to tag and share data. With the support and encouragement of Lt Gen Leslie Kenne, then the commander of the Electronic Systems Center (ESC) and our largest Air Force customer, I drove the Air Force Center to bring the strategy to maturity and begin implementing it across ESC's C3I programs. Although we made progress, the initial pace was slow and evolutionary.

Inspiration

That situation changed, and the evolution became a revolution when General Jumper became chief of staff of the Air Force in September 2001. He was already well known for inspiring innovation in the service. As commander of Air Combat Command in 2000, he had challenged Air Force acquisition "to demonstrate a weaponized [remotely piloted vehicle (RPV)] with the ability to find a target [and] then eliminate it," which led to the fielding of a Predator RPV armed with two air-to-ground Hellfire missiles in less than a year.[2] In a well-publicized story, the acquisition community responded to General Jumper's challenge with a "business as usual" approach requiring five years and $15 million. He gave them $3 million and three months. Sixty-one days and $2.9 million later, a Predator fired Hellfire missiles in a flight test on 21 February 2001, and in September of that year, the Predator/Hellfire weapon system deployed to support Operation Enduring Freedom in Afghanistan.

General Jumper understood the force-multiplying advantages of information superiority and the fact that integrating and automating the C2 system to take advantage of that superiority was the key to shrinking the timeline for attacking time-critical targets. Therefore, he spoke widely and passionately of that vision, demanding that industry as well as government acquisition organizations like ESC and MITRE change the paradigm and start applying information technologies to attain the necessary automation and integration.

At the Command, Control, Intelligence, Surveillance, and Reconnaissance (C2ISR) Summit hosted by General Kenne and ESC in April 2002, General Jumper and his 12 four-star commanders made an impassioned plea to horizontally integrate C2ISR machines (i.e., sensors, air and space operations center [AOC] targeting systems, and shooters) to allow them to talk to each other and thus eliminate the time-consuming, error-prone manual translations by humans. To make sure everyone understood the degree of integration he sought, the general gave a specific example based on his experience as an F-15 fighter pilot. He told the audience of using his combat flying skills to position his aircraft behind the enemy fighter and then put his targeting cursor on it. That done, the machines took over. The aircraft avionics locked on the target, shared target information with the air-to-air missile's avionics, and readied the missile for launch automatically. When ready, the system gave him visual and audio commands to fire, after which he was completely certain the missile would fly to and destroy the target without any further help from him. He closed that presentation and many others with a reminder that for warriors, "the sum of all wisdom is a cursor over the target."[3]

Listen and Respond

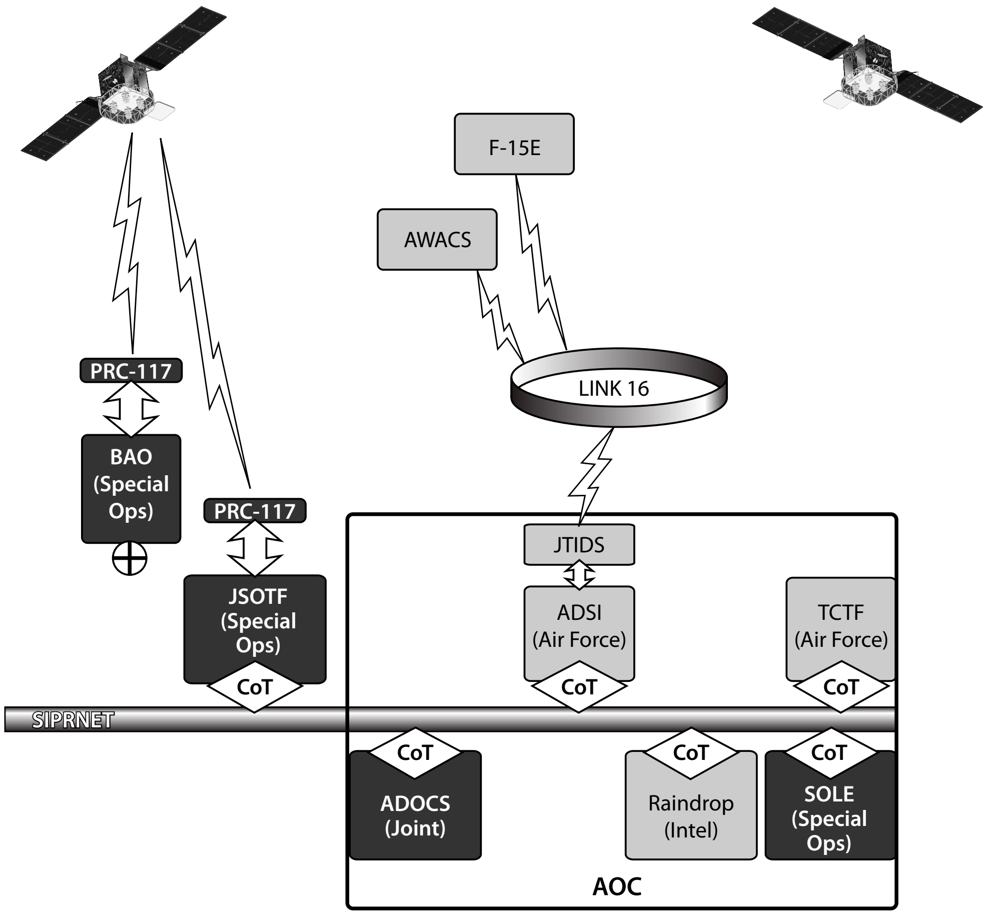
Shortly after the summit, I held a management off-site with the leadership of the Air Force Center. I told my executive directors that after listening to General Jumper and the other Air Force four-stars, we had an important responsibility to respond to their challenges and demands. I made sure they understood that business as usual was not a sufficient response. Over a two-day period, we embraced the integrated C2 system as our vision and put several teams together to spearhead progress. One team would finalize the technical strategy and obtain support from the ESC program offices to fully deploy it across all new C2ISR programs as well as to upgrades of legacy systems. A second team would define a system-of-systems or enterprise engineering process. A third team would reinvigorate MITRE's rapid-prototyping capabilities and define specific opportunities to use that capability and information technology to demonstrate and quickly transition automated, integrated C2 capabilities to war fighters.

Moreover in May 2002, shortly after the summit, Lt Gen Bill Looney assumed command of ESC, and Lieutenant General Kenne went to the Pentagon to stand up the Deputy Chief of Staff for Warfighter Integration, a new staff organization charged with attaining the integrated C2 system. After my off-site, I briefed both General Kenne and General Looney on MITRE's strategy for realizing General Jumper's vision via an architecture-based technical strategy, enterprise engineering, and rapid prototyping. Both gave me their enthusiastic pledges of support.

I put Jason Providakes and Rich Byrne, two of my brightest and most creative executive directors, in charge of the rapid-prototyping team.[4] Though small, Rich's team included several of the best engineers in the center, including Mike Butler and Doug Robbins. After two days of brainstorming, they told me at the off-site outbrief that they would initially concentrate on automating the targeting cycle via machine-to-machine interaction, an effort that Mike would lead. Since that proposal clearly addressed one of General Jumper's top priorities, I gave Mike a budget (less than $100,000) to get started. The team gave me a progress report about every two weeks and briefed me in early June on a specific concept and the prototype demonstration plan.

Innovation

Their idea involved automating a very real-world-like concept of operations for engaging time-critical targets. As depicted in figure 1, a Battlefield Airman would use a laser range finder, the Global Positioning System (GPS), and a compass to obtain the target coordinates and send them over the PRC-117 radio to the Joint Special Operations Task Force (JSOTF), which would manually send the target and its coordinates over the Secret Internet Protocol Router Network (SIPRNET) into the AOC. There, the intel cell would prosecute it, using tools such as Raindrop, as would the planning cells, using tools like the Automated Deep Operations Coordination Sys-



ADOCS = Automated Deep Operations Coordination System
ADSI = Air Defense Systems Integrator
AOC = Air and Space Operations Center
AWACS = Airborne Warning and Control System
BAO = Battlefield Air Operations
JSOTF = Joint Special Operations Task Force
JTIDS = Joint Tactical Information Distribution System
SIPRNET = Secret Internet Protocol Router Network
SOLE = Special Operations Liaison Element
TCTF = Time-Critical Targeting Functionality

Figure 1. Machine-to-machine targeting using the cursor-on-target XML schema (special tactics to F-15E). (From Rich Byrne, briefing to the MITRE Board of Trustees, subject: Making a Difference to the War Fighters, 1 October 2003, chart no. 20.)

tem (ADOCS) and the Special Operations Liaison Element (SOLE). After approval, the AOC would manually transmit the target coordinates using Link 16 to the Airborne Warning and Control System (AWACS) and F-15, which would then attack the target. The process at that time involved many lengthy voice or typing transactions that, despite verification and reverification, still remained prone to errors. For example, in one tragic friendly-fire accident, the coordinates of the Battlefield Airman rather than those of the target were sent to the F-15.

Mike's team proposed automating this entire process by putting the target's "what (type), where (coordinates), and when (time)" into an XML data schema and transmitting the data directly, machine to machine, without human involvement other than decision making. This concept offers a good example of an enterprise data strategy whereby various users (e.g., the intelligence cell, planning cell, and attack fighter) subscribe to data published in XML. Each small diamond in figure 1 labeled CoT (cursor on target) represents a few hundred lines of software at machine input and output ports that can publish or subscribe to the targeting data. The final step called for automating transmission of the target data with a CoT publisher over the air defense system integrator (ADSI)—the AOC's interface with Link 16 to the F-15.

After hearing the concept and plan, I gave the team members approval to proceed. In early July, they asked me to come to a MITRE laboratory for a prototype demonstration that included using a laser range finder, the GPS, a compass, and a laptop computer to obtain the target coordinates. Using CoT, the laptop published the coordinates directly onto a Raindrop display map where, after the Raindrop operator clicked on the target on the map, the coordinates were sent directly over a laboratory Link 16, showing up automatically on an F-15's head-up display in the laboratory. It truly was one of the most amazing things I had ever seen in the more than 35 years of my professional career.

Operationalizing and Deploying

> *Innovation by definition will not be accepted at first. It takes repeated attempts, endless demonstrations, and monotonous rehearsals before innovation can be accepted and internalized by an organization. This requires "courageous patience."*
>
> —Warren Bennis

During July 2002, we showed the laboratory demonstration to most of the senior leadership at ESC, including its new commander—General Looney—and John Gilligan, the Air Force's chief information officer, both of whom were very impressed and excited about what the capability could do to automate and integrate Air Force C2. General Looney again pledged his enthusiastic support for rapid prototyping in general and to CoT specifically. When he returned to the Pentagon, John sent a note about the accomplishment and its potential to General Jumper. In late August, we performed the laboratory demonstration for Secretary of the Air Force James Roche, who urged quick fielding of the capability.

In November 1982, a variant of the prototype underwent testing with F-15Es at Nellis AFB, Nevada, in a live-fly exercise. In March 2003, with strong support from the secretary and Air Force Special Operations Command, ESC stood up a program office and formalized a machine-to-machine targeting program. During that same month, an enhanced variant of the prototype went through accelerated operational test and evaluation at Hurlburt Field, Florida. The results were spectacular—a threefold reduction in targeting timelines with a significant increase in accuracy! In July 2003, ESC and MITRE mobilized the prototype and, with General Kenne's sponsorship, took it to the Pentagon to present to General Jumper. Needless to say, he was impressed and ecstatic. A freeze on AOC software at the beginning of Operation Iraqi Freedom delayed deployment until September 2003. Nevertheless, moving from a laboratory prototype to fielding an operational capability in only 14 months equates to speed of light for the acquisition process!

This accomplishment involved overcoming a number of barriers, none of them technical in nature. Organizations that had not responded aggressively to General Jumper's challenge were somewhat embarrassed and exhibited the "not invented here" syndrome by trying to slow down the initiative with "better" ideas of their own, including some that were proprietary and not net-centric. Others expressed concern over their false perception that machine-to-machine targeting would eliminate humans from the targeting cycle. As mentioned earlier, although CoT eliminated manual transactions, humans remained involved in each step of the decision process to attack the target. Others cited the lack of a validated requirement and the fact that the Air Force program objective memorandum had no budget for CoT. In fact, formally documented requirements to automate the AOC targeting cycle did exist, and CoT simply represented a solution to those requirements. Moreover, war fighters were more than willing to pay for the extremely small funding associated with the capability. Others objected to fielding prototypes directly instead of following the formal acquisition process, which would have taken years. Still others wanted the XML schema to cover all militarily useful information rather than just "what, when, and where," which would have added significant complexity and demanded prohibitive bandwidth. Finally, some objected to combining developmental test and evaluation and operational test and evaluation, which also became a nonissue because of the simplicity and low risk of the concept and because war fighters supported this approach to accelerate fielding of the concept.

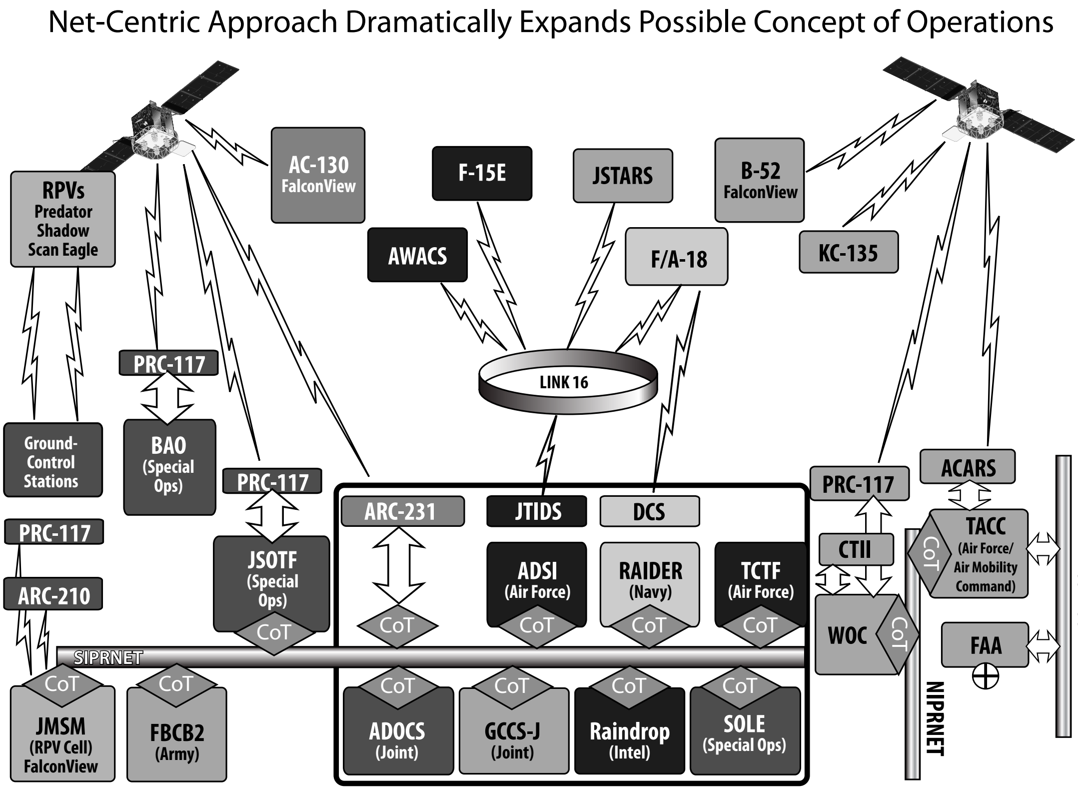
We overcame all of these obstacles due to the support we had from the top leadership of the Air Force, including not only General Jumper, our champion, but also the senior leadership of the acquisition and operational commands. At the working level, we worked collaboratively as a team with personnel from the ESC acquisition office, Air Force Special Operations Command, the operational test and evaluation agency, and industry. That teamwork was also a critical factor in keeping the initiative on track in spite of the barriers.

Expansion to the C2ISR Enterprise

Word quickly spread around the Air Force and DOD about the powerful CoT data exchanges of "what, when, and where" information. The DOD adopted the CoT XML schema as a data standard for sharing militarily significant "what, when, and where" information.[5] Additionally, Mike's team continued to expand and help others extend the applications to such capabilities as conducting blue force tracking; overlaying blue force, RPVs, and enemy positions on common operational picture displays such as FalconView; synchronizing global combat and refueling missions; and bringing Link 16 displays on board C-130 gunships that lacked Link 16 capability. Today, over 100 C2ISR systems (i.e., sensors, AOC targeting system tools, and shooters) have incorporated CoT at an average cost of about $100,000 per system. Figure 2 shows a small subset of these systems that, by means of CoT, are providing revolutionary, net-centric capabilities to our war fighters. The fielding of CoT dramatically illustrates the power of a common, net-centric, information-sharing strategy.

Benefits

Unlike Microsoft and Apple, MITRE and our government sponsor—ESC—were not driven by the promise of increased revenue and profit. Nevertheless, we reaped many benefits from the CoT rapid-prototyping effort. The MITRE team and its ESC partners have won numerous awards, including a highly coveted Armed Forces Communications and Electronics



ACARS = Aircraft Communications Addressing and Reporting System
ADOCS = Automated Deep Operations Coordination System
ADSI = Air Defense Systems Integrator
AWACS = Airborne Warning and Control System
BAO = Battlefield Air Operations
CTII = Combat Track II
DCS = Defense Communications System
FAA = Federal Aviation Administration
FBCB2 = Force XXI Battle Command Brigade and Below
GCCS-J = Global Command and Control System-Joint
JMSM = Joint Mission Support Module
JSOTF = Joint Special Operations Task Force
JSTARS = Joint Surveillance Target Attack Radar System
JTIDS = Joint Tactical Information Distribution System
NIPRNET = Nonsecure Internet Protocol Router Network
RAIDER = Rapid Attack Information Dissemination Execution Relay
RPV = Remotely Piloted Vehicle
SIPRNET = Secret Internet Protocol Router Network
SOLE = Special Operations Liaison Element
TACC = Tactical Air Control Center
TCTF = Time-Critical Targeting Functionality
WOC = Wing Operations Center

Figure 2. Expansion of the CoT application. (From Rich Byrne, briefing to the MITRE Board of Trustees, subject: Making a Difference to the War Fighters, 1 October 2003, chart no. 22.)

Association Golden Link Award in 2004 recognizing innovative applications of technology in government operations. Many articles on the achievement have appeared in technical journals.[6] From a business standpoint, MITRE and ESC's image with war fighters and customer-satisfaction ratings soared to new heights. Furthermore, MITRE's stature within the technical community grew significantly. Finally and most importantly, our initiative gave our war fighters improved operational capabilities that reduced the targeting-cycle timeline enabling attacks on time-critical targets and diminished the potential of casualties from friendly fire.

Additional Spin-Off Benefits

At least as significant as these direct benefits is the fact that the CoT initiative led to reinvigorating MITRE's rapid-prototyping capability and to ESC's embracing rapid prototyping as a key part of its acquisition strategies.[7] With Rich's leadership and support, more than 50 other rapid prototypes were developed and demonstrated in ESC programs. For example, we showed how easily we could use legacy radios to bring IP communications and the Internet onto platforms like the Joint Surveillance Target Attack Radar System (Joint STARS). In another case, we automated production of the air tasking order briefing and reduced the time required from more than 12 hours to just a few hours. An additional rapid-prototyping effort with industry demonstrated a way of synchronizing force-level and unit-level planning.

By means of rapid prototyping, we showed the possibilities to war fighters and a means of lessening the fielding risk. The urgent needs of war fighters directly drove the swift fielding of prototypes like CoT; others transitioned into upgrade plans for the systems of record and were fielded as part of the upgrades. Some did not receive war-fighter support and were not fielded, but in these cases, we refocused our efforts after a few months without expending much money or time—something quite different on both accounts from the normal acquisition process.

Keys to Success

As I look back on the CoT rapid-prototyping initiative, I see that a number of keys proved important to its success—keys that have wide-ranging applicability to other innovation initiatives. First, inspiring innovation allows us to derive tremendous benefits at relatively little cost. Having a champion like General Jumper who has an important, urgent need and who demands innovation probably represents the most critical element for this inspiration. My role as leader of an engineering organization was also significant, starting with my insistence that the organization not simply listen to the passionate demands of champions like the general but respond to those demands with innovative solutions.

I also take credit for putting a small but world-class team on the project and giving it very talented and creative leaders like Jason Providakes, Rich Byrne, and Mike Butler. Additionally, empowering the team and providing it with resources to be successful proved important. Initial laboratory demonstrations of the prototype, from working levels to senior levels of the government acquisition and operational user communities, played an essential role in obtaining their support and shaping the prototype prior to operational testing. Because engineers tend to want to tinker with prototypes in the laboratory and not show them to anyone until they are perfect, such early demonstrations are something of an unnatural act for them; however, user exposure and feedback at the beginning is invaluable to prototyping initiatives. As I mentioned earlier, collaborative teamwork with the acquisition, operational and test communities, and industry proved instrumental in overcoming a number of barriers.

Golden Nuggets

The keys to the success of the CoT initiative in generic form have broad applicability to inspiring innovation in general. Other leaders can use the following "golden nuggets" or takeaways to inspire innovation in their organizations:

1. Find a champion with a pressing, important need.
2. Demand that the organization respond to the champion with innovation.

3. Establish, empower, and support a talented, creative team to develop the innovation.
4. Demonstrate the innovation to capture advocacy.
5. Anticipate and eliminate obstacles.
6. Operationalize the innovation in a collaborative team effort with acquirers, users, testers, and industry.
7. Transition the innovation into products, services, or capabilities
8. Seek opportunities to expand and apply the innovation to other needs.

Summary

This article has examined how a senior leader's vision and demand for innovation can inspire his organization and others to respond to that vision with innovative solutions. It used a specific example involving the use of rapid prototyping and information technology to automate and integrate the Air Force's C2 system. However, the approach and strategy as embodied in the "golden nugget" takeaways have broad applicability to inspire innovation of other types and in other organizations. Therefore, I hope that future leaders will find this article useful in meeting one of their basic responsibilities—inspiring innovation! ✪

Notes

1. MITRE is a nonprofit company that manages federally funded research and development centers for the government.

2. "Predator Hellfire Missile Tests 'Totally Successful,'" *CheckPoint*, 12 May 2001, http://www.checkpoint-online.ch/CheckPoint/J4/J4-0003-PredatorHellfireMissileTests.html.

3. "Cursor on Target: The 'Sum of All Wisdom' Comes of Age," *MITRE Digest*, December 2010, [1], http://www.mitre.org/news/digest/pdf/MITRE_Digest_10_4266.pdf.

4. At that time, Jason was my executive director for Air Force communication programs, and Rich was my executive director for human resources and for our research program. Today Jason is the senior vice president and general manager of MITRE's Center for Connected Government, and Rich is the senior vice president and general manager for MITRE's Command and Control Center.

5. For the DOD CoT data standard reference, see the Defense Information Technology Standards Registry at https://disronline.csd@disa.mil. (Access to this site requires a government common access card [CAC].)

6. See Rich Byrne, "The What Where and When of Making Net-Centric Warfare Real Today," MITRE Corporation, n.d., http://www.mitre.org/work/tech_papers/tech_papers_05/03_0948/03_0948.pdf; Byrne, "Cursor on Target: A Case Study on Deploying What, When and Where in the Battlefield," MITRE Corporation, December 2004; Byrne, "A Few Choice Words Can Make Network Centric Warfare a Reality Today," *Signal Connections: AFCEA's Official E-Newsletter* 1, no. 4 (15 January 2004), http://www.imakenews.com/signal/e_article000214973.cfm; Byrne, "'Cursor on Target' Improves Efficiency," *Edge: MITRE's Advanced Technology Newsletter* 8, no. 2 (Fall 2004), http://www.mitre.org/news/the_edge/fall_04/byrne.html; Byrne, "Managing Complexity: An Approach to Net-Centric Ops," Association of Old Crows Symposium, Burlington, MA, 26 September 2005, https://www.myaoc.org/EWEB/images/aoc_library/patriotsroost/AOC_Briefs/Managing_Complexity_An_Approach_to_Netcentric_Ops_Rich_Byrne.pdf; Elizabeth Harding, Leo Obrst, and Arnon Rosenthal, "Creating Standards for Multiway Data Sharing," *Edge: MITRE's Advanced Technology Newsletter* 8, no. 1 (Summer 2004): 16–17, 20, http://www.mitre.org/news/the_edge/summer_04/edge_summer_04.pdf; and Dino Konstantopoulos and Jeffery Johnston, "Data Schemas for Net-Centric Situational Awareness" (presentation at the 2006 Command and Control Research and Technology Symposium, San Diego, CA, June 2006), http://www.dodccrp.org/events/2006_CCRTS/html/papers/073.pdf?q=cot.

7. Although this point is not related to our rapid-prototyping initiative, it is interesting to note that DOD Instruction 5000.02, *Operation of the Defense Acquisition System*, 8 December 2008, http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf, now mandates competitive prototyping to demonstrate technology readiness before entering engineering development.

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In air combat, "the merge" occurs when opposing aircraft meet and pass each other. Then they usually "mix it up." In a similar spirit, Air and Space Power Journal*'s "Merge" articles present contending ideas. Readers are free to join the intellectual battlespace. Please send comments to aspj@maxwell.af.mil.*

Air Force Policy for Advanced Education

Production of Human Capital or Cheap Signals?

Maj Tobias Switzer, USAF*

In the first decade of the twenty-first century, the US Air Force experienced a significant policy debate regarding officer education. The question at hand concerned why officers attain graduate-level education or advanced academic degrees (AAD) and how those achievements should affect promotions. On the one hand, some officers, such as those serving as researchers, political affairs officers, or academic instructors, need education above and beyond their undergraduate training because the level at which they work is more specific than general. On the other hand, it is not completely clear why the vast majority of Air Force officers, such as those serving on aircrews, in personnel and finance units, and so forth, need more education than necessary to conduct their work.

This second group of officers, the generalists, represents the source of contention and debate. Moreover, this controversy led to conflicting policies from the most senior leadership, leaving the issue muddled and confused for today's junior and field-grade officers. This article discusses the main points of each policy and interprets them through the lens of modern economic theory. Using the well-developed ideas of human capital and signaling, along with empirical evidence, it argues that advanced education has become not a means of increasing knowledge and ability so much as a proxy for officers' commitment to their careers. The article extends this line of inquiry to nonresident professional military education (PME) programs, in which it finds much similarity. Finally, it offers a different vision, modeled on a sister service's program, that would make the education experience more valuable for both our officer corps and the Air Force by expanding opportunities at civilian universities in exchange for long posteducational commitments.

Conflicting Visions

In 2005 Gen John P. Jumper, chief of staff of the Air Force, wrote a letter to all members of the service describing a significant change in promotion procedures and the Air Force's treatment of education in

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general.[1] Specifically, he directed the Air Force Personnel Center (AFPC) to mask officer education data on promotion boards through the rank of colonel, making it available only for brigadier general and above. By doing so, General Jumper intended to stop officers from pursuing AADs for the sole purpose of increasing their chances for promotion, also known as "square-filling" or "checking the box." Although he acknowledged the value and importance of education to the Air Force and its officer corps, the general believed that the pursuit of AADs should be deliberate and focused.

An earlier letter of General Jumper's, written in 2002 regarding force development, foreshadowed his education policy.[2] In that letter, he echoed the criticism of the status quo regarding education opportunities: "I know that a lot of you feel there are many reasons to be discouraged or dissatisfied with our current system—limited PME in-residence slots, limited advanced degree opportunities, or worse, square-filling master's degree programs that do little to make you better at your job or get you closer to your goals. I have experienced some of these issues myself and I hear the same feedback from you. So let's fix it."[3]

In 2006 the next chief of staff, Gen T. Michael Moseley, and the secretary of the Air Force, Michael W. Wynne, issued a letter to Airmen that reversed General Jumper's decision. General Moseley also lauded the importance of education in his letter, stating that the value for the Air Force lay in having "intellectual throw weight." He announced that AFPC would unmask officer education data, starting with the promotion boards in 2008.[4] Thus, because of a sweeping policy change followed by a rapid reversal, the Air Force held promotion boards between 2005 and 2007 that excluded any and all information about an officer's education.

In determining the correct position, we should consider what Air Force instructions (AFI) say regarding official policies on advanced education for officers. Unfortunately, at least two AFIs directly address this topic, each of which takes a slightly different tack concerning the purpose and aim of graduate education for officers. Though not entirely inconsistent, each instruction's objectives are vague enough to encompass almost any viewpoint: General Jumper's, General Moseley's, or something in between.

AFI 36-2611, *Officer Professional Development*, notes that "AADs are important to officer professional development to the extent they enhance the officer's professional qualifications. A degree which is directly related to the primary utilization area is appropriate at any level since this degree adds to depth of experience. An advanced degree in management or more general studies tends to enhance job performance for officers reaching the field grade ranks where breadth development begins to take place."[5] AFI 36-2302, *Professional Development*, observes that "Graduate Education programs are designed to manage limited resources and support National, Military, and Air Force strategic objectives in an increasingly complex international environment with rapidly changing science and technology. Graduate education requirements are identified as specific positions for which an Advanced Academic Degree (AAD) is necessary to accomplish the job and meet the overall Air Force mission."[6]

AFI 36-2611 presents a wide and liberal view towards graduate education for officers, informing us that it improves job performance and is important to the development of all officers. Accordingly, education that enhances the depth or breadth of knowledge remains vital to winning the current wars. This slant on graduate education aligns with General Moseley's position: "As we continue to fight this Global War on Terror, we will be conducting operations in both familiar and unfamiliar places, with both old and new friends. To succeed, our expeditionary Air Force will need all the cultural, political and technical skills available."[7] Although General Moseley does not explicitly cite AFI 36-2611, his argument for unmasking education data on promotion boards and his encouragement of AADs are in complete agreement with this instruction.

Yet, a close reading of AFI 36-2302 reveals that only some positions need advanced education in order to carry out our mission. Graduate education, according to this instruction, should provide a very specific skill set required for designated billets. However, it does not address what the vast majority of officers should seek educationally. By emphasizing the scarcity of resources for graduate education, the AFI implies that possession of an AAD by all Air Force officers is not "mission essential." This educational philosophy seems to support General Jumper's position of offering graduate education as a deliberate development step: "We must make sure Airmen get the training and education required for their specialty or area of expertise. If you need additional education or training—you will get it. . . . Education must be tailored to benefit Airmen in doing their jobs."[8]

Given the differences in these instructions, we can see how the two chiefs of staff could have claimed to grasp the importance of postgraduate education as essential to mission accomplishment yet employed policies that mostly opposed each other. Each of their positions is perfectly justifiable in light of the AFIs on officer development.

The central question then becomes whether or not most officers engaged in voluntary off-duty education programs do so to augment their promotion opportunities or to improve their ability to serve the Air Force—or both. To help dissect and answer this question about the role of AADs in our promotion systems, the article draws upon current economic theory of labor and education—particularly the theories of human capital and of signaling, two distinct ideas postulated by economists Gary Becker and Michael Spence.

The Theory of Human Capital

The modern economic theory of human capital looks at workers in the labor force as a sum of acquired skills and knowledge.[9] Some of our personal human capital is useful in any setting, such as the ability to read, write, and do simple math. These abilities are designated *general human capital* because they can transfer to any work environment. Other dimensions of human capital are useful only in very narrow settings, such as the ability to operate a fighter aircraft in combat. We refer to these skills as *specific human capital*. We acquire specific and general human capital through both formal education and experience.

Applied to the Air Force, we could say, roughly speaking, that one acquires specific human capital through formal training courses and general human capital through education programs. For example, a Senior Airman crew chief who attends a technical training course on working on C-130s does not learn finance or even how to work on and launch F-16s. The human capital he has is very narrow and specific—fixing C-130s. However, many of the skills acquired in Airman Leadership School increase his general human capital. Advanced abilities in team leadership, written communication, and critical thinking would serve this Senior Airman in any Air Force specialty or in the civilian sector.

Higher levels of human capital typically show themselves in wage differentials. In a normal labor market, the more skilled and productive individuals receive more compensation than their peers. If human capital increases with training and education, then we expect income to do likewise. However, in the military our base pay depends upon rank and years of service, regardless of career field or skill level. Thus, we would expect to see differences in human capital among Airmen not in wages but in promotions. Those with the human capital deemed most valuable to the Air Force should be promoted above those with less.

The remainder of this article simplifies matters, discussing human capital as the composite of these two distinctions—general and specific. In reality most producers of human capital (training courses, education programs, on-the-job-training, etc.) reflect a mix of general and specific and do not divide neatly into one or the other. However it is helpful to keep both concepts in mind when evaluating education programs available to military members. We want to ask ourselves if a particular education program boosts a student's general or specific human capital—or both.

Signaling

Let's assume that master's degrees as we currently obtain them do not increase human capital relevant to the Air Force's needs. Under certain conditions, using AADs as a mechanism for sorting and stratifying officers for promotion purposes could have considerable merit. An AAD may convey information about the level of human capital possessed by the officer who completed it. Even if no production of human capital took place, the process or act of completing an advanced degree may provide useful information and justify our practices—a concept known as *signaling*.[10]

In short, a signal offers an indirect means of communication when people wish to convey information about themselves but cannot do so directly. The Air Force promotion board wants to know candidates' intelligence, their amount of human capital, and their capability to perform the duties of the next rank. However, members of the board do not have information such as IQ, Air Force Officer Qualifying Test, Graduate Record Exam, or Scholastic Aptitude Test scores to help them understand the cognitive abilities and human capital of the officers in the pool.[11] In theory, completion of an expensive and selective master's program would send information about a candidate's level of human capital compared to that of his or her peers without a master's degree.

For example, a Harvard graduate's diploma serves as a very powerful labor market signal when he or she applies for a job. The hiring company knows well that Harvard screens prospective students heavily, requires astronomical College Board scores, rejects a high percentage of applicants, and charges steep tuition.[12] With regard to signal efficacy, an undergraduate degree from Harvard is extremely effective because it conveys much information, costs a great deal of money, and is quite difficult to earn.

In the case of Air Force AADs, a *separating equilibrium* occurs only if high-ability officers obtain the signal (e.g., a master's degree), despite the cost or difficulty of the program, to give the promotion board a means of distinguishing them from their lower-ability peers. The latter officers will choose not to obtain the signal because they find the time-money investment prohibitive or the difficulty of the education program insurmountable.[13]

Conversely, a *pooling equilibrium* occurs when the signal is inordinately expensive and nobody obtains it—or if it is very cheap and everyone obtains it. In the former case, one could imagine earning a doctorate degree in five years as a signal of higher human capital, a costly signal that would deter nearly all officers. In the latter case, a master's degree acquired simply by paying a small fee offers a cheap signal of higher levels of human capital easily obtained by all officers.[14] In either case, a promotion board could not discriminate between high- and low-ability officers, based on education, because everyone would do the same thing. The signal becomes useless because it conveys no information.

Again, even if no production of human capital occurred as Air Force officers toiled away to earn graduate-level diplomas in their off-duty time, demanding AADs would still have some usefulness. If one had to be highly intelligent, insightful, and more capable than one's peers to complete a master's degree at an on-base program or through distance learning, then the diploma would send a powerful signal of an officer's level of human capital and abilities. Such a situation creates a separating equilibrium that would help promotion boards identify officers with higher levels of human capital.

Critique of the Status Quo: Cheap Signals of Human Capital

Given the paradigms previously laid out, we should ask ourselves whether our AADs from off-base and distance-learning programs increase human capital relevant to the Air Force and whether they serve as effective signals of high levels of human capital for promotion boards. A careful examination of the writings of Generals Jumper and Moseley, a review of a recent government report on tuition assistance (TA) programs, and a close analysis of recent promotion statistics indicate that, for the most part, they do neither.

When General Moseley emphasized the importance of education and justified his decision to reverse the directive of his predecessor, he was highlighting the value of human capital acquired through the pursuit of advanced education. According to the general's letter, the Air Force should have access to an officer's education records during promotion boards because an individual who has completed advanced education has the knowledge needed for present and future wars. As officers move up in rank, their responsibilities demand even greater abilities in communication, leadership, critical thinking, and knowledge of Air Force organization and doctrine. From General Moseley's perspective, masking education data (both undergraduate and graduate) removed the promotion board's ability to identify officers with high levels of human capital and decreased their incentive to attain those levels.[15]

What did General Jumper see in an officer's education that led him to order the masking of data on promotion boards? In his letter of 2005 he wrote, "For years, Master's degrees had a significant impact on promotion potential. This must change—our focus should be on deliberate development and not 'square filling.' "[16] In effect, General Jumper implied that too many Air Force officers were pursuing advanced education to enhance their chances for promotion, regardless of the value of the education program. He readily admits to doing so himself:

> Just like many of you, I spent many hours in night school to earn a master's degree. Why? So I could get promoted. It's not that the time was wasted, but the course of study was not designed to maximize my own development, or to deliver the best return on that investment to the Air Force. And, it took me two years of time shared with my Air Force duties and away from my family. To top it all off, the Air Force viewed my MBA in the same light for promotion as if I had attained a Master's in Quantum Physics from MIT.[17]

General Moseley essentially conceded this point in his letter: "Over time, earning a post-graduate degree deteriorated into a method to increase the likelihood of promotion. People used their education benefits and precious free time to pursue degrees that may or may not have been relevant to their Air Force duties."[18] To be clear, although Generals Jumper and Moseley differed in their response to AADs obtained through off-duty and TA programs, neither one questioned the value and importance of degrees obtained at the Air Force Institute of Technology or by means of full-time studies at traditional universities.[19]

A recent investigation into TA programs by the Government Accountability Office (GAO) criticized the Department of Defense's (DOD) lack of oversight of the quality of education received by service members through on-base education programs.[20] The study, which extensively examined base education centers, incorporated data from all four services.

> DOD verifies whether a school is accredited; however, it does not gather some key information from accreditors when conducting its oversight activities, such as whether schools are in jeopardy of losing their accreditation. Accreditors can place schools on warning or probation status for issues such as providing inaccurate information to the public and poor institutional governance. Schools can experience various problems within the 3- to 10-year accreditation renewal period, and these prob-

> lems can negatively affect students, including service members. Additionally, DOD does not require schools to have new programs and other changes approved by accrediting agencies in order to receive TA funds. Currently, students enrolled in unapproved programs or locations are ineligible to receive federal student aid from [the Department of Education], but can receive TA funds.[21]

In short, the DOD allows military members to use TA funds at institutions that have met the bare minimum of education standards and that may be experiencing other problems. The GAO report states that it did not even begin to address distance-learning programs that made up 71 percent of courses taken in 2009.[22] The information contained in the report is not prima facie evidence that all on-base and distance-learning graduate programs offered to military members are devoid of any production of human capital, but it should at least give us pause regarding the quality of AAD programs available to officers. The value of an off-duty graduate program should not be ambiguous.

Turning to actual promotion statistics, we would expect certain results if AADs significantly enhanced an officer's human capital. We anticipate that, as a group, officers with AADs would be more productive than their non-AAD peers and therefore promoted at higher rates. This expectation should be a robust finding, regardless of the promotion board's ability to see education data, because the fruits of increased human capital should show up in performance reports and promotion recommendation forms. As a cohort, officers with graduate degrees should work more efficiently, solve tougher problems, and better organize the people and resources under their spans of control. Therefore, if AADs do in fact significantly increase human capital relevant to the Air Force, promotion results should be essentially the same, despite the availability of education data to a promotion board.

We can test this hypothesis by looking at promotion results from years when AFPC masked education data, 2005–7, and comparing them to results from previous and subsequent years. The most compelling evidence that this hypothesis is false comes from statistics published for O-5 (lieutenant colonel) promotion boards (table 1). One can see that in 2005–7, in-the-promotion-zone (IPZ) promotion rates for officers without an AAD shot up dramatically. For example, promotion rates to O-5 without a master's degree went from an average of 15.7 percent in the 10 O-5 promotion boards prior to 2005 to an average of 48.6 percent in the years 2005–7. Although more majors approached their promotion boards without having completed an AAD (from a 7.6 percent average in 1996–2004 to an average of 16.2 percent in 2005–7), this fact cannot explain the more than tripling of promotion percentages for non-AAD officers.

One could challenge this assertion by claiming that the Air Force must have been promoting more officers to lieutenant colonel, but such was not the case. From 2002 through 2009, promotion rates to lieutenant colonel remained steady at 73–74 percent. If an AAD bolstered human capital, then promotion rates should not have changed because personnel with graduate degrees, armed with more skills and more productive capability, should have outperformed individuals without AADs at a similar rate as before—but they did not. Many officers holding AADs became indistinguishable from those without such degrees.

Looking at promotions to O-6 (colonel) (table 2), we see more evidence, albeit less powerful statistically. In the years 2000–2004, no officers without an AAD were selected for promotion to the rank of colonel. To be fair, very few officers who reached the promotion board for colonel had not obtained their AADs. However from 2005 through 2007, a few without AADs slipped past, selected by the board for promotion. After the enactment of General Moseley's policy, officer promotions regressed to the trend, and since 2007 no officer without an AAD has become a colonel. But those officers promoted to colonel without an AAD must have had excellent performance records

Table 1. Results of USAF lieutenant colonel promotion board, calendar years 1989–2009

	Overall			*By Advanced Degree*					
					Yes			*No*	
Board	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*
1989	2,495	1,586	63.57	2,130	1,453	68.22	365	133	36.44
1990	2,495	1,601	64.17	2,125	1,476	69.46	370	125	33.78
1991A	1,765	1,161	65.78	1,513	1,056	69.80	252	105	41.67
1991B	1,988	1,332	67.00	1,725	1,220	70.73	263	112	42.59
1992	1,887	1,196	63.38	1,634	1,098	67.20	253	98	38.74
1993	2,246	1,413	62.91	1,930	1,308	67.77	316	105	33.23
1994	2,930	1,843	62.90	2,599	1,738	66.87	331	105	31.72
1996	2,200	1,386	63.00	2,066	1,353	65.49	134	33	24.63
1997	1,845	1,163	63.04	1,717	1,139	66.34	128	24	18.75
1998	1,774	1,110	62.57	1,650	1,086	65.82	124	24	19.36
1999A	1,817	1,179	64.89	1,711	1,167	68.21	106	12	11.32
1999B	1,690	1,112	65.80	1,594	1,095	68.70	96	17	17.71
2000	1,718	1,118	65.08	1,616	1,102	68.19	102	16	15.69
2001	1,989	1,304	65.56	1,859	1,292	69.50	130	12	9.23
2002	1,765	1,265	71.67	1,622	1,253	77.25	143	12	8.39
2003	1,502	1,085	72.24	1,333	1,057	79.30	169	28	16.57
2004	1,676	1,223	72.97	1,456	1,189	81.66	220	34	15.46
2005	1,454	1,073	73.80	1,180	947	80.25	274	126	45.99
2006A	1,426	1,063	74.54	1,196	950	79.43	230	113	49.13
2006B	1,470	1,099	74.76	1,230	984	80.00	240	115	47.92
2007	1,198	895	74.71	1,032	810	78.49	166	85	51.21
2008	1,388	1,026	73.92	1,260	1,004	79.68	128	22	17.19
2009	1,412	1,045	74.01	1,267	1,014	80.03	145	31	21.38

Source: "Active Duty Officer Promotions Line of the Air Force (LAF) Historical," Air Force Personnel Statistics, Air Force Personnel Center, http://w11.afpc.randolph.af.mil/demographics/ReportSearch.asp.

Table 2. Results of USAF colonel promotion board, calendar years 1989–2009

	Overall			*By Advanced Degree*					
					Yes			*No*	
Board	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*
1989	1,204	531	44.10	1,081	496	45.88	123	35	28.46
1990	1,228	540	43.97	1,139	518	45.48	89	22	24.72
1991	1,134	510	44.97	1,053	483	45.87	81	27	33.33
1992	1,279	535	41.83	1,203	513	42.64	76	22	28.95
1993	1,102	458	41.56	1,050	444	42.29	52	14	26.92
1994	1,308	548	41.90	1,227	530	43.20	81	18	22.22
1995	1,198	502	41.90	1,139	491	43.11	59	11	18.64
1996	834	349	41.85	787	345	43.84	47	4	8.51
1997	921	384	41.69	885	380	42.94	36	4	11.11
1998	798	330	41.35	761	327	42.97	37	3	8.11
1999	927	384	41.42	890	382	42.92	37	2	5.41
2000	1,188	530	44.61	1,145	530	46.29	43	0	0.00
2001	927	432	46.60	908	432	47.58	19	0	0.00
2002	791	363	45.89	780	363	46.54	11	0	0.00
2003	795	355	44.65	783	355	45.34	12	0	0.00
2004	808	372	46.04	798	372	46.62	10	0	0.00
2005	736	331	44.97	730	330	45.21	6	1	16.67
2006	806	365	45.29	788	363	46.07	18	2	11.11
2007	1,010	459	45.45	981	457	46.59	29	2	6.90
2008	958	434	45.30	946	434	45.88	12	0	0.00
2009A	846	372	43.97	833	372	44.66	13	0	0.00
2009B	982	447	45.52	970	447	46.08	12	0	0.00

Source: "Active Duty Officer Promotions Line of the Air Force (LAF) Historical," Air Force Personnel Statistics, Air Force Personnel Center, http://w11.afpc.randolph.af.mil/demographics/ReportSearch.asp.

since historically only about 43.85 percent of IPZ lieutenant colonels advance in rank.

Because of the change in promotion results from the years when AFPC masked education data until its unmasking, we know that boards used AADs as a discriminator for selection. In contrast we expect that information such as eye color would have no effect on outcomes, whether available to the board or not. Assuming that each of the officer cohorts considered for promotion resembled those preceding and following, we can infer that during the masking of education data, the selection boards promoted some people that would not have been selected in previous years because they lacked an AAD. In 2005–7, those promoted to major, lieutenant colonel, and colonel must have had better performance records than those not selected because the boards had no other information available. Before and after this period, we cannot say that every officer selected for promotion had a better record of performance than those not selected. If that statement were false, then promotion rates between AAD and non-AAD officers should have remained unchanged, regardless of the availability of education data.

Even before one read the GAO report or analyzed promotion data, a perusal of the list of off-duty education programs marketed to military personnel, such as those offered by American Military University, Embry-Riddle Aeronautical University, University of Phoenix, or Troy University, would have revealed that the opportunities available to most Air Force officers are not of high quality. If one were to cross-reference on-base or distance-learning programs with *US News and World Report*'s rankings of graduate schools or any other reputable ranking system, one would find no mention of the above-mentioned institutions. The fact that these systems of rankings do not even attempt to evaluate most of the graduate programs in which military members enroll speaks volumes about their reputation and quality. This article maintains that the path to a master's degree from institutions such as these is not a trial of intellect but of time management.

In sum, the statements of both General Jumper and General Moseley, the GAO report, an analysis of promotion data, and the author's personal experience indicate that we should be highly skeptical of the proposition that AADs from off-duty and distance-learning programs significantly advance the levels of human capital in the Air Force. In the aggregate, no evidence suggests that this is true. Still, if AADs served as a strong signal of already existing human capital and created a separating equilibrium, then the Air Force would have an excellent system for identifying officers with higher levels of human capital. However, no such evidence presents itself.

Between 2002 and 2009, the Air Force conducted 10 separate O-4 promotion boards (table 3), producing a mean promotion rate for IPZ captains of 92.7 percent with little variation. During the seven promotion boards that had access to education data, almost exactly 50 percent of IPZ captains had an AAD, with a difference of roughly 5.9 percent between the average promotion rates of AAD and non-AAD captains (95.4 percent and 89.5 percent, respectively). On the one hand, it seems plausible that a separating equilibrium existed since only half of the captains obtained an AAD. On the other hand, it is difficult to confirm this when nearly everyone advanced to major and very little difference in promotion rates existed between the two groups. An AAD may have acted as an excellent signal for higher levels of human capital, but because the Air Force promotes nearly every captain to major, it is not a useful signal at this stage of career progression.

Returning to the O-5 promotion boards, we observe a large change in IPZ promotion rates between AAD and non-AAD officers (see table 1). During the five promotion boards held between 2002 and 2009 when education data was available, 79.6 percent of AAD officers were promoted compared to only 15.8 percent of non-AAD officers. The disparity between promotion rates suggests

Table 3. Results of USAF major promotion board, calendar years 1989–2009

	Overall			*By Advanced Degree*					
				Yes			*No*		
Board	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*	*Considered*	*Selected*	*Percent*
1989	4,584	3,846	83.90	2,945	2,644	89.78	1,639	1,202	73.34
1991	4,137	3,083	74.52	2,892	2,382	82.37	1,245	701	56.31
1992	2,915	2,191	75.16	1,964	1,562	79.53	951	629	66.14
1993	2,741	2,003	73.08	1,838	1,458	79.33	903	545	60.35
1994	2,891	2,098	72.57	1,973	1,535	77.80	918	563	61.33
1995	2,564	1,874	73.09	1,824	1,434	78.62	740	440	59.46
1996	2,859	2,088	73.03	1,950	1,502	77.03	909	586	64.47
1997	2,862	2,323	81.17	1,947	1,667	85.62	915	656	71.69
1998	2,497	2,062	82.58	1,518	1,327	87.42	979	735	75.08
1999	1,953	1,689	86.48	1,214	1,106	91.10	739	583	78.89
2000A	2,195	1,943	88.52	1,316	1,223	92.93	879	720	81.91
2000B	1,841	1,620	88.00	1,027	949	92.41	814	671	82.43
2001	1,909	1,685	88.27	1,150	1,053	91.57	759	632	83.27
2002A	2,048	1,814	88.57	1,247	1,132	90.78	801	682	85.14
2002B	1,681	1,557	92.62	894	858	95.97	787	699	88.82
2003A	1,973	1,824	92.45	981	940	95.82	992	884	89.11
2003B	2,287	2,132	93.22	1,027	983	95.72	1,260	1,149	91.19
2004	2,360	2,197	93.09	929	883	95.05	1,431	1,314	91.82
2005	2,057	1,901	92.42	828	783	94.57	1,229	1,118	90.97
2006	2,363	2,204	93.27	821	777	94.64	1,542	1,427	92.54
2007	2,348	2,211	94.17	887	852	96.05	1,461	1,359	93.02
2008	2,520	2,366	93.93	1,235	1,191	96.44	1,285	1,175	91.51
2009	3,147	2,950	93.74	1,674	1,640	97.97	1,473	1,310	88.93

Source: "Active Duty Officer Promotions Line of the Air Force (LAF) Historical," Air Force Personnel Statistics, Air Force Personnel Center, http://w11.afpc.randolph.af.mil/demographics/ReportSearch.asp.

that an AAD did indeed serve as a useful signal of relatively higher human capital levels. However, one wonders why AAD officers constituted 89.6 percent of the IPZ majors under consideration for promotion during these five promotion boards. Given the supposed difficulty of obtaining a good signal, how could nearly nine out of 10 majors have done so? Unfortunately, an examination of the O-6 data will not help because nearly 99 percent of IPZ lieutenant colonels competing for promotion hold an AAD (see table 2).

At least two explanations account for these findings. First, perhaps the Air Force has many officers with high levels of human capital and few with low levels, thus heavily skewing the distribution of talent and human capital. Additionally, promotion boards would evidently have little ability to distinguish between high- and low-ability officers during their review of performance reports and other information. If this were all true, then an officer would do well to earn a difficult, time-consuming AAD if he or she had high levels of human capital. The graduate degree may represent the only way such officers can separate themselves from the few low-ability officers unable to obtain an AAD.

Tuition Assistance AADs and Nonresident PME: Signals of Commitment

A second explanation, more believable and consistent with the evidence, maintains that the AAD does not signal high human capital but something else—commitment. Completion of an on-base or distance-learning AAD program conveys nothing other than an officer's willingness to sacrifice a considerable amount of personal time towards that end. Typically, monetary cost is not a factor because the officer shifts that expense to the Air Force, which heavily subsidizes AADs through the TA program. However, one cannot shift the substantial time expended and labor invested to anyone else. Thus, commitment to the institution rather than human capital creates a separating equilibrium.

For example, we know that scalpers can charge multiple times the face value of a ticket to important concerts. One might ask why bands and venues do not simply set their prices higher or hold an auction to increase profits. If one believes that bands are interested not only in their profits but also in the experience of performing in front of highly dedicated fans, then not selling tickets to the highest bidders makes sense. By forcing fans to wait in long queues or make repeated calls to an authorized vendor, they can ensure that the highly committed, not simply the wealthiest, ones attend. In this case, an overnight campout at the local venue to buy a ticket for a concert is a signal of commitment.[23]

With that thought in mind, this article argues that a promotion board does not need education data to determine promotions because nearly all of the information regarding a person's performance, intellectual strength, and prospects for success at higher levels of responsibility resides in training reports, evaluations, decorations, and personnel records. However, that data does not help the board determine levels of commitment to the Air Force. But a master's degree from Trident University does exactly that, and it becomes an effective signal in that regard. Instead of the AAD's signaling higher levels of human capital, it signals loyalty to the Air Force.

In trying to decide who should receive a valuable "definitely promote" (DP) on a Promotion Recommendation Form, a special assignment, or selection to a school, the senior officer or selection board would like to know something about candidates' dedication to the service, whether they plan to serve at least 20 years, and whether they wish to become senior leaders. Given the limited supply of DPs, developmental education slots, or positions for promotion, selection boards and leadership may reasonably want to adopt commitment into their decision calculus.

Simply asking subordinates about their commitment to their careers and to the Air Force would be useless. Replying truthfully about one's career plan is not always the best strategy since any answer other than a desire to be the chief of staff might hurt the subordinate's stratification or leadership support for special programs and jobs—hence the efficiency of nontraditional AADs as signals. A unit commander does not need to ask subordinates about their career intentions because he or she knows that officers who want to be promoted will complete their off-duty AADs and that those less committed to promotion will not.

A unit commander does not need to ask subordinates about their career intentions because he or she knows that officers who want to be promoted will complete their off-duty AADs and that those less committed to promotion will not.

Similarly, our Air Force leadership now uses nonresident PME courses as signal mechanisms for commitment. Like most off-duty AADs, our nonresident PME courses are not difficult to complete, but they do require a commitment of time. Thus, they are cheap signals for knowledge and human capital; that is, they convey no information about an officer's intellect relative to that of his or her peers. However, they are excellent signals for commitment because they demand many hours of reading, writing, and taking exams. An ambivalent or uncommitted officer would have little reason to finish a nonresident PME course.

Originally, such programs targeted officers unable to attend in residence to obtain knowledge necessary for the next level of leadership and remain competitive with their peers for promotion.[24] Never intended as a prerequisite for attendance in a full-time PME program, nonresident PME has become exactly that. How many times a day do our captains think to themselves, "Why do I have to do Squadron Officer School by correspondence just so I can go and do it again in-residence?" Similarly, our majors ask themselves or their commanders, "Why do I have to do Air Command and Staff College by correspondence just so I can do a resident intermediate developmental education program?" The author has never heard a justification for this practice other than the idea that it helps with promotion boards and selection for resident PME programs.

To check this hypothesis, one need only determine how many officers reach their promotion boards having first completed a nonresident and then a resident developmental education program. If the former were not a prerequisite of the latter, then we would expect that nearly all officers who complete their appropriate level of PME would do so by one method or the other—but not both. We can look at the records of officers and see how many complete nonresident Squadron Officer School before going to Maxwell AFB for the resident course, just as we could check the same information with Air Command and Staff College and Air War College. If this hypothesis is correct, then we will find that most officers who complete resident PME programs did so after finishing the nonresident version.

In the broadest possible terms, our off-duty AAD programs neither increase human capital in a way relevant to the Air Force nor offer efficient signals of high human capital. Instead they represent extremely efficient signals of officer commitment and institutional loyalty. On the face of things, this system is not necessarily so terrible. Highly committed officers have a way to signal their desires to senior officers and promotion boards by completing an off-duty AAD and nonresident PME courses. Through the TA program, the Air Force finances a generous amount of the cost of AADs, so the monetary burden does not fall on the officer. However the question is not "Is our system good or bad?" but "What is the opportunity cost?" If another education policy allows us to increase human capital as well as signal both high levels of human capital and commitment, then we should explore it.

A Better Way to Educate Our Officers

There exists an alternative vision to a world where Air Force officers spend too much of their time earning advanced degrees of dubious value or halfheartedly studying nonresident PME material for courses that many of them will repeat as full-time students. This vision restores education to its rightful position—a human-capital-producing venture that creates a good signal of ability and commitment. To pursue this concept, we should study its implementation by one of our sister services—the Army.

Because of historically low retention rates among junior officers, the Army not only failed to fill positions that require senior captains and junior majors but also lost the ability to keep its most talented officers.[25] In 2005 Army ROTC and West Point began the Officer Career Satisfaction Program (OCSP), designed to retain officers.[26] It offered cadets a fully funded graduate school option that vested after completion of their initial active duty service commitment (ADSC)—as well as an extra three years of service as the price for the option—demonstration of good service, and attainment of the rank of captain. When the graduate school option vests at seven or eight years of service, the officer can leave the Army, remain but decline the opportunity to go to graduate school, or attend a civilian graduate school program of his or her choice for two years to obtain a master's degree at the Army's expense (including salary, benefits, and tuition). In return for the last option, the officer would "pay back" with an ADSC of six years, typically taking him or her to 15 or 16 years of active duty service. At that point, with so little time left to vest a valuable retirement annuity, the Army expects that officers who exercise their graduate school option will most likely put in at least 20 years of service.

This system offers a number of advantages. First it very clearly identifies the commitment levels of young and midlevel officers. Those willing to contract for the graduate school option are obviously serious about their career in the Army and are worth the investment of additional resources because they have no intention of leaving anytime soon. Second, junior and midlevel officers do not have to allocate an inordinate amount of time away from their work and personal lives. They can focus on the mission, their Soldiers, and their families. Contracted officers know that at a certain time, the Army will free them from their day-to-day duties, guaranteeing them the funding and time to study for a degree. Finally, the knowledge and abilities acquired during the two years of study will allow the Army to reap the increased human capital for its own benefit as well as the officer's. Because that individual must serve six years after finishing graduate school, the Army guarantees itself more human capital in positions of higher authority. Furthermore, officers exercising the graduate school option are not limited to on-base or distance-learning programs; instead, they can apply for and complete degrees at world-class universities like Stanford, Johns Hopkins, or the University of Michigan.

Full-time graduate students also enjoy the benefit of peer effect. That is, officers enrolled in civilian programs are exposed to ideas and people far removed from their normal sphere. Officers in an off-duty education program study either by correspondence, without any peer interaction at all, or at a facility on or near the base with other military members and DOD civilians. This situation does not, ipso facto, mean that the class will lack diverse thought and opinion; however, if nearly all of the students bring a relatively similar background and set of experiences to the classroom, the probability of cross-pollinating ideas is low.

In contrast, at a civilian institution, student-officers most likely will find themselves in the minority, affording them an opportunity not only to learn from civilian peers who have experience in industry, business, government, and academia, but also to share their military experiences with people who may not know anyone who has worn the uniform. One cannot understate the importance of exposing future civilian leaders to the culture of our defense institutions for which they will develop and implement policy. Officers participating in full-time graduate study are not simply students but ambassadors for a culture that has become increasingly alien to the rest of America, particularly the well-educated elite.[27]

Upon implementation of OCSP, the Army discovered among its cadets and officers a nearly insatiable demand for incentives such as the graduate school option. Cadets willingly committed to a tour above and beyond their initial ADSC in exchange for the service's commitment to them. Obviously the Air Force is not the Army, and our unique circumstances would make imprudent the notion of simply mimicking what the Army has done. Our leadership might look skeptically at OCSP, declaring the impossibility of allowing Air Force officers a two-year sabbatical for graduate studies. Although this type of program would require much personnel flexibility and career juggling, the Air Force should not dismiss the idea outright unless it is only paying lip service to the importance of education. When we consider that US Army Soldiers have assumed the lion's share of sacrifice and pain during our wars in Iraq and Afghanistan as well as the global war on terrorism, this argument does not hold water.[28] In the midst of massive shortages of junior officers and multiple wars, if the Army can commit to its officers' education and extract a similar commitment from them, then so can the Air Force.

Conclusion

For unknown reasons, the Air Force lost its way regarding the value and importance of graduate-level education for its officers. Instead of AADs representing something of value that increased skills and knowledge and signaled higher levels of human capital, they and the process of earning them devolved into a test of loyalty or a sign of commitment to an Air Force career; the same is true of nonresident PME courses. The Air Force, of course, has every right to know the commitment levels of its officers before determining promotions, assigning in-residence PME slots, and filling important developmental positions. However, in allowing our advanced education and nonresident PME process to become a race to the bottom, the ability to discern commitment levels has come with a huge opportunity cost to the Air Force and a time cost to its officers. General Jumper may have enacted an extreme policy by masking all education data on promotion boards, but his instincts were correct. Thankfully, we do not need to return to measures like these to break the cycle. Adopting programs like the Army's OCSP would allow the Air Force to invest seriously in human capital and enjoy a much larger return on its education dollars. Concurrently, Air Force officers could send a strong signal of commitment and ability to promotion boards, thereby ending the practice of cheap signaling and "box checking." We could then truly call our officer corps well educated and have at our disposal real intellectual throw weight to fight the wars to come. ✪

Hurlburt Field, Florida

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The New Air Force and Science*

Colonel Frederic E. Glantzberg

DESTRUCTION from the air is the most efficient method of defeating an enemy. It is possible to make this statement without the necessity of outlining the accomplishments of the strategic Air Forces in Europe, where they broke the back of German production, or in the Pacific, where they forced the capitulation of Japan without the necessity of ground invasion.

We have had it drilled into us that future air warfare will be a push-button affair. Most of us probably imagine that at some indefinite time in the future, aerial warfare will be fought from a master control center hundreds of feet under the ground, protected by many layers of concrete and steel. In such a control center, we might imagine a super radar-scope on which we study the world tactical situation and then, by push-buttons, send guided missiles off to remote corners of the world to implement our world-wide strategic plan.

As fantastic as such a war appears, there nevertheless seems to be general agreement that there probably will be a push-button war at some time in the future. However, when it comes to predicting the year in which we will be equipped to fight such a war, there is wide divergence of opinion. There is not even general agreement on the specific items of equipment that will be used, let alone their details of design. If we cannot agree as to what kind of equipment we will have in the future, how can we be so sure as to what kind of war we will have?

Are we not really trying to say that we are certain only that future wars will be fundamentally different from anything we have known in the past? Why do we think this? Has some new factor appeared which completely alters the picture of aerial warfare? When we entered the last war, we entered it with conventional weapons. Now, however, we talk in terms of unconventional weapons, for which the principles of operation have yet to be devised. We speak confidently of future 1,500-mile radar ranges. Yet, to date, radar is limited to line-of-sight projection. We speak of offensive missiles with ranges of 5,000 to 10,000 miles as if they were a reality, when in fact there are many complex problems of propulsion, control, and guidance that are far from being solved.

We speak confidently of setting up elaborate nationwide air-defense systems for the purpose of intercepting long-range, high-altitude guided missiles of the V-2 type, but we have yet to devise an effective means of intercepting such missiles. We even talk

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glibly of satellite observation platforms, although, except for brief periods, we have not yet overcome the earth's gravitational pull at the higher altitudes.

A few years ago such thinking would have been passed off as crack-pot or visionary, and certainly would never have been considered seriously. What has happened? The answer is that a new element has been added to air warfare which has revolutionized our thinking. This new element is the *decisive contribution of organized science to effective modern warfare*. Never before have so many scientific workers been united in the application of science to military purposes.

DURING THE war both sides developed weapons with astonishing effects, weapons which before the war would have been considered impossible. These appeared in such profusion that we became conditioned to accepting the most fantastic ideas. Outstanding examples of the many results of wartime scientific research were radar and the atomic bomb on our side. On the German side, a wide variety of jet-propelled missiles appeared.

These new developments were the direct results of scientific or applied research. For this reason there is a tendency, until they appear in final form ready for operational use, to leave such projects entirely to the scientists. New developments, however, place serious added responsibilities upon military planners. These are the writing of suitable military characteristics, the development of new tactics, and the establishment of adequate training programs.

Sound military characteristics must be written to guide development toward end products that will be of maximum military utility. New tactics must be devised to employ these weapons to best advantage. In order for new weapons to be utilized as soon as they become available, adequate training programs must be established well in advance of the completion of these weapons. For example, we received blind-bombing equipment in the 15th Air Force without either trained operators or maintenance personnel. Precious time was wasted training these people in the field. Then, when we did have them trained, a new model came out and we had to repeat the process. Planners can no longer wait for science to present them with new weapons. Rather, by acquiring a knowledge of the capabilities of science today, they must anticipate tomorrow's weapons.

NOW LET us consider the new aspects of aerial warfare which will confront us as new scientific developments are realized.

With the advent of jet propulsion, reference to supersonic aircraft has become rather common. Yet, since the speed of sound is about 764 miles per hour at sea level and about 664 miles per hour at 40,000 feet, it may be seen that we have not developed a supersonic aircraft. Within a year, however, we should have experimental service-type aircraft approaching the speed of sound, and special research aircraft beginning to go beyond the speed of sound. Some of the optimistic hopes are for speeds as high as 1,500 miles per hour.

In the conception and design of new weapons we must keep in mind that there is overwhelming advantage in the development of air weapons which travel at supersonic speeds so that they do not require "air superiority" before they can be used. For example, the German V-2 was highly effective even though we had almost complete mastery of the air as far as conventional aircraft were concerned. Although considerable effort is being expended on counter-measures, no effective means have been developed to date for stopping V-2 type attacks other than by destruction of launching facilities. This is the kind of weapon we should strive to develop, a type with tremendous destructive power which does not require air superiority to be effective. Only by the possession of such weapons can we immediately accomplish the destruction of vital enemy objectives in the first round of a new and sudden war.

In addition to the V-2, the Germans also investigated the effectiveness of guided missiles as defense against bombers. Although they were well ahead of us in this field of development, we were fortunate that they were unsuccessful in completing them in time to get them into service before the end of the war. The necessity for weapons of this type, however, is now thoroughly appreciated in this country, and we have a variety of projects under way for developing all types of guided missiles.

AFTER a discussion of supersonic velocities and guided missiles, the mere mention of atomic bombs and other deadly agents should suggest the possibility of weapons for offensive warfare that stagger the imagination.

Four years of vicious air war made it evident that the development of electronic equipment is closely associated with the problem of control of Air Force operations. Within five years we should see the development of communication equipment linking all Air Force units on a world-wide basis; navigation equipment for piloted aircraft which will provide safe and accurate navigation on missions up to 6,000 miles under all conditions of weather and visibility; control equipment for accurate guidance of missiles at ranges up to 5,000 miles at transonic and supersonic velocities; automatic radar-bombing and fire-control equipment to permit precision bombing and firing under all operating conditions; and high-powered fixed and mobile early-warning systems to alert this country for any offensive thrust.

Science will also contribute to the perfection of airborne armies. In spite of their great complexity, airborne operations in the recent war were not very impressive. But the probable capabilities of future airborne operations cannot be compared with, or judged by, present standards. Many new developments are in sight which will increase the range, versatility, and effectiveness of future airborne operations. Furthermore, with the development of an all-weather Air Force, we can expect that the present limitations imposed on airborne operations by weather and darkness will gradually be minimized.

ALL THESE developments may have a profound effect on future aerial warfare. Some of them have already progressed well beyond the standard equipment of World War II. However, the path of research and development is long, arduous, uncertain, and often bitterly disappointing. For this reason it is especially undesirable at this time to adopt definite assumptions regarding the exact nature of future aerial warfare. It is rapidly becoming apparent, however, that for future planning certain new possibilities of aerial warfare must be considered as being within our grasp. These are: (1) that aircraft—manned and pilotless—will move with speeds far beyond the velocity of sound; (2) that, as the result of improvements in aerodynamics, propulsion, and electronic control, unmanned devices will transport means of destruction to targets at distances up to several thousand miles; (3) that defense against present-day aircraft will be perfected by target-seeking missiles; (4) that only aircraft or missiles moving at extreme speeds will be able to penetrate enemy territory protected by such defenses; (5) that small amounts of materials will cause death or destruction, or both, over areas of several square miles; (6) that perfected communications systems will permit direction and control of national air defense from a single master control center; (7) that location and observation of targets, of take-off, navigation and landing of aircraft, and of communications will be independent of visibility and weather; and (8) that fully equipped airborne task forces will be enabled to strike at far distant points, will be supplied by air, and will be recovered by air as soon as their mission is completed.

The nature and composition of the Air Force needed to perform the mission of Air Power in the future will depend upon the ability of the Air Force and science to get together. We must realize that the task ahead involves much more than merely inventing gadgets and trying to make them work. Rather, there must be a systematic analysis of the various tasks which conventional airplanes equipped with bombs, guns, and rockets have performed in the past, tasks which now may be performed by pilotless aircraft. In other words, two developments must occur for successful solution of the problems: the *tactical viewpoint* must lead to the choice of types of weapons, and *physical science* must make possible more and more extended ranges and improved accuracy.

THE MOST familiar method in which science assists the Air Force is by contributing to the development of new and improved weapons, i.e., specific items of military equipment. Such weapons have long and complicated ancestries. Many persons take part in their development, which springs from many apparently unconnected scientific discoveries in the past. To ask who fathered any single invention has as much meaning and no more as to ask who your ancestors were. Each generation multiplies the number. Although inventive ingenuity is still of great importance, the individual inventor today plays an insignificant part in most developments. The mobilization of a large number of people, with a variety of skills directing their efforts toward a common task, accounted for the striking advances of the last war. Such groups as the Germans had at Peenemunde developed the V-2; our own Radiation Laboratory designed most of our important radar equipment.

Many steps are involved in the development of a specific weapon, although some of them may be omitted in special cases. The steps may be designated as follows: pure science, applied science, development, laboratory tests, service tests, production, training, tactical evaluation, and service use. As the steps are interrelated, they cannot easily be separated. The well organized attack has the virtue of maintaining continuous contact between groups responsible for the various steps.

Strong interactions between pure and applied science occur as the latter develops better implements to probe the unknown. Furthermore, applied science uses all the methods of pure science to make advances in the major fields of knowledge.

THE UNITED STATES has taken the leadership in applied science, but it has contributed less than its due proportion to pure science, largely because our national characteristics are such as to emphasize immediate and practical goals, and to be less interested in projects which promise material benefits only at some future date. Today's applied science rests on the pure science of the preceding generation. Just as replacing our forests or replenishing the fertility of the soil has less attraction to the American mind than the rapid exploitation of presently available resources, so the support of pure science is less popular than the application and exploitation of scientific knowledge.

The present military system of establishing requirements based on service needs is effective, provided the requirements are consistent with the state of development of pure science. To make significant progress, pure science must be supported in its efforts to advance fundamental knowledge. Many authorities have called attention to the fact that applied science has virtually caught up with knowledge of pure science. This is why the armed services are sponsoring basic research.

The recent war not only demonstrated the great power of science, particularly when specialists were organized into groups for developing new and effective weapons, but it also saw the birth of a much broader application of science to military problems. This resulted from a consideration of military problems and objectives in the most general manner, expressed in terms of over-all tasks to be accomplished rather than in terms of the component steps calling for specific weapons. In this application, science was not restricted to physics and chemistry applied to produce gadgets, but the scientific method of procedure was applied to tactical and strategic problems. This work was pioneered by the operational analysis groups attached to the staff of most of the field commanders.

Scientific procedures involve such features as objective and quantitative analysis, objective observation of data, use of experimental method where possible, control and study of effects of variables one at a time where possible, and willingness to use all available techniques and sources of expert knowledge. These procedures can be applied to practically any type of problem with profitable results, and this fact was recognized by military leaders towards the end of the war.

In terms of such broad problems, the mission of the Air Force has been analyzed from the technical point of view by Dr. Theodore von Karman, Chairman of the Air Force Scientific Advisory Board, as follows: (1) to move swiftly and transport loads through the air; (2) to locate and recognize targets; (3) to hit targets accurately; (4) to cause destruction; (5) to function independently of weather and darkness; (6) to defeat enemy interference; (7) to perfect communications; and (8) to defend home territory.

AIR POWER is directly proportional to the effectiveness with which these tasks can be accomplished by the equipment and personnel at hand or available in a short time. It is the broader role of science to inquire as to the most effective accomplishment of these tasks, to suggest lines of development of the most suitable types of equipment, to aid in such development, to devise testing methods, and to evaluate performance in terms of the over-all mission.

Every citizen and group of citizens, including those from science and industry, has an inescapable responsibility for national defense and the security of the nation. The Air Force, however, is entrusted with final responsibility for insuring that the nation is prepared to wage victorious air warfare offensively and defensively, if attacked. We are thus led to consider the responsibility of the Air Force in promoting science, a responsibility which cannot be delegated to any other agency. Yet the Air Force would be unwise to rely solely upon its own resources in fulfilling its responsibility.

The Air Force must take the initiative in securing the cooperation of science and industry. All three groups must arrive at an understanding in order to fulfill separate responsibilities for national security. The problem of securing this cooperation during peace-time is difficult, and positive steps must be taken to insure such cooperation.

Although it is readily apparent that science must be made a member of the Air Force team, the challenge of the day is the job of building an effective partnership between the Air Force and the nation's scientific and technological potential to maintain for the United States the technical superiority in the air which will insure victory in any future war.

There are two outstanding reasons why the Air Force must view this job as one of its gravest and most urgent responsibilities. In the first place, the outlook for a possible war is not promising for America's side insofar as superiority in natural resources and manpower, the principal hope of victory, rests in superior quality of weapons. The second reason springs from the catastrophic destructiveness of atomic warfare. The best informed men say that national survival will be at stake during the initial phases of an atomic war.

MANY FACTORS have had an adverse effect on research and development in the Air Force. One of the most important was the apathy of the American people to their Air Force in the face of our nation's struggle for existence; others were the lack of funds for the Air Force, the natural lack of interest on the part of civilian scientists in military scientific problems, the fight for Air Power, the tremendous expansion which the Air Force underwent on the heels of a battle for existence—all these factors and many others have a profound influence on research and development. Certain aspects of the military and civil service systems have also had their effect; for example, the over-abundance of security regulations and lack of incentive inherent in seniority promotion methods, the limited career opportunities for Regular Army personnel who tried to emphasize their technical education at the expense of tactical experience, the tendency to use technically trained Regular Army personnel as administrators rather than as technicians during the early portion of their careers when they should be still learning, and the limited career opportunities open to civilians and non-rated Reserve Officers.

The need for changing regulations which limit the responsibilities and career opportunities of non-rated technical officers was first stated by General Arnold in January 1945 and reiterated by General Spaatz in 1946. Thus the problem has been recognized, and initial steps have been taken on the road toward a stronger union between science and the Air Force. However, much work remains to be done.

The welding of a solid and permanent bond between science and the Air Force requires action in many fields and on many levels. One of the salient problems is the education of the American people and the education of Congress by means of more effective public relations action, so that both the people and Congress appreciate the needs and understand the problems of the Air Force. This will insure that science in this country is not hampered by unrealistic security policies, and that cooperation with other branches of the service in scientific and related matters will be established.

LET US examine briefly what the Air Force is doing to foster cooperation with science and industry in order to utilize both most effectively in the interest of national security. As already indicated, the background of basic scientific knowledge accumulated over a number of years prior to the war has been virtually exhausted by maximum exploitation during the war in the development of new weapons. While the war was being fought, little basic research was done because almost all of our scientists were engaged in developing projects essential for victory.

The result is that we now find ourselves practically bankrupt in fundamental scientific knowledge necessary to carry on applied research. This basic knowledge must be augmented and the frontiers of science pushed back if we are to make appreciable progress in the development of new weapons. For example, it is wasteful to make a contract for developing a radar set with a range of 1,500 miles until the basic research has been done to find a way of bending radar signals over the optical horizon. Similarly, there is not much point in constructing a guided missile with a 5,000-mile range when there is no known means of controlling it. We must first accomplish the basic research necessary to find means of control effective at such ranges.

Consequently, the Air Force, like the other services, is granting direct research contracts to industry and universities in an effort to further basic scientific knowledge. This year the Navy is spending $70 million on basic research; the Ground Forces, $100 million; and the Air Force, $127 million—considerably more than the other two. None of this includes the $375 million for the Manhattan Project. It is appropriate that the armed services should foster basic research, but they certainly should not have to bear the full cost. It must be remembered that basic research may have commercial as well as military value. Therefore it is hardly reasonable to charge the whole cost to the military establishment.

Much of this necessary research requires large and expensive facilities which neither industry nor universities are able to afford. Consequently, some means must be found to aid them even if at government expense.

MODERN scientific developments have shown the necessity for much closer integration of the contributions of the specialist laboratories. Even in aircraft design it is now recognized that armament and electronic equipment cannot be regarded as accessories to be installed on almost any aircraft after completion. Just as the engine and airframe have always had to be designed together as a unit, so now the complete military weapon must be designed and developed as a whole. It is no longer possible to develop separately engine, airframe, electronic equipment, and armament, and to assemble them into a satisfactory weapon. The whole purpose of the weapon must be studied and the conflicts in design requirements of the components resolved in such a way as to accomplish the purpose most efficiently.

German experience indicates the effectiveness of development centers like the one at Peenemunde, which are needed to carry on such integrated development programs in three fields, i.e., supersonic and pilotless aircraft, nuclear aircraft, and aircraft operations. The first is self-explanatory; the second deals with the application of nuclear energy to aircraft propulsion (see [Gabriel M. Giannini, "Nuclear Energy for Aircraft Propulsion," *Air University Quarterly Review* 1, no. 1 (Spring 1947): 43–51]); the third provides for the study of traffic control at military air fields, fighter control, and radar and television applications to navigation and other operations.

Development centers of this type are likely to require test installations of large size and cost, consuming vast amounts of power. Such large facilities present many special problems. Because of their size, cost, and power requirements, more than one such facility cannot be supported by any nation. Many groups require the use of these facilities, including military and civilian governmental agencies, manufacturers holding government contracts, and other civilian groups. For this reason, the Air Force is proposing the Air Engineering Development Center.

THE TOOLS for the development and evaluation of new weapons and new tactics are laboratories, test stations, and proving grounds. The Air Force has extensive facilities of this type at Wright Field, Eglin Field, and Watson Laboratories, but these are inadequate in the light of the more recent scientific developments.

The effectiveness of these facilities depends entirely upon the caliber of the men using them. It is a common mistake to judge the scientific competence of a laboratory by the number, variety, and appearance of special pieces of apparatus. The most impressive laboratories can conceivably turn out inferior scientific work, and many major contributions to science have come from inadequately equipped and poorly supported laboratories. The point is that the effective use of scientific and technical facilities requires the best available personnel, and that good facilities are not a substitute for able scientists. We are thus led to consider the scientific and technical training of Air Force personnel.

Recruiting and training scientific personnel to staff the service laboratories, test stations, and proving grounds is but one aspect of the broad problem of the scientific and technical training of Air Force personnel. Well qualified scientists are needed not only in research and development activities but also as members of staffs and of operating units. Moreover, all personnel in positions of responsibility should be able to evaluate scientific facts with sound judgment and with some vision of future developments.

WE CANNOT expect that every member of the Air Force will be trained as a specialist in all fields of science and engineering, but specialists in all fields are needed. Each member must attain a broad knowledge of scientific and technical matters, and some must be leaders in highly specialized fields. Without such leaders the Air Force is doomed to mediocrity in scientific and technical matters, with personnel who are jacks-of-all-trades and masters of none. Our program of scientific education must provide both types of training. The needs for highly specific and specialized training of technical leaders are as great as those for similar specialized training of tactical leaders.

The problem of recruiting and training technical leaders is now under study by the Air Staff. The major source of such personnel at present is the large number of people with scientific backgrounds who are already in the Air Force but whose scientific skills are not being utilized. Another source will undoubtedly be the ROTC groups of the graduating classes at various colleges.

The Air Force has an educational program to supplement these sources. The Air Force Institute of Technology at Wright Field is graduating 190 officer-engineers this year. This number will probably be increased to 250 next year. In addition, increasing numbers of officers are being sent to schools such as the Massachusetts Institute of Technology for graduate courses in aerodynamics, propulsion, electronics, and nuclear physics. In time this program should furnish the Air Force with an adequate number of technical personnel. Means must be found, however, to make the service attractive to these officers so that they will not be lured into civilian occupations after acquiring this education. This problem, too, is under study, and undoubtedly changes will be made in personnel policies. These will make it possible for personnel to follow an engineering specialty without requiring an undue amount of time away from it because of requirements for foreign service or duty with troops.

The problem of creating conditions within the Air Force that are attractive to technical personnel is extremely complex and difficult, but it is one which we must solve if America is to remain a first-class power.

The War Department believes that the Air Force has proved it occupies a dominant position in war. We believe the Air Force represents the only immediate weapon available for retaliatory action if we are attacked.

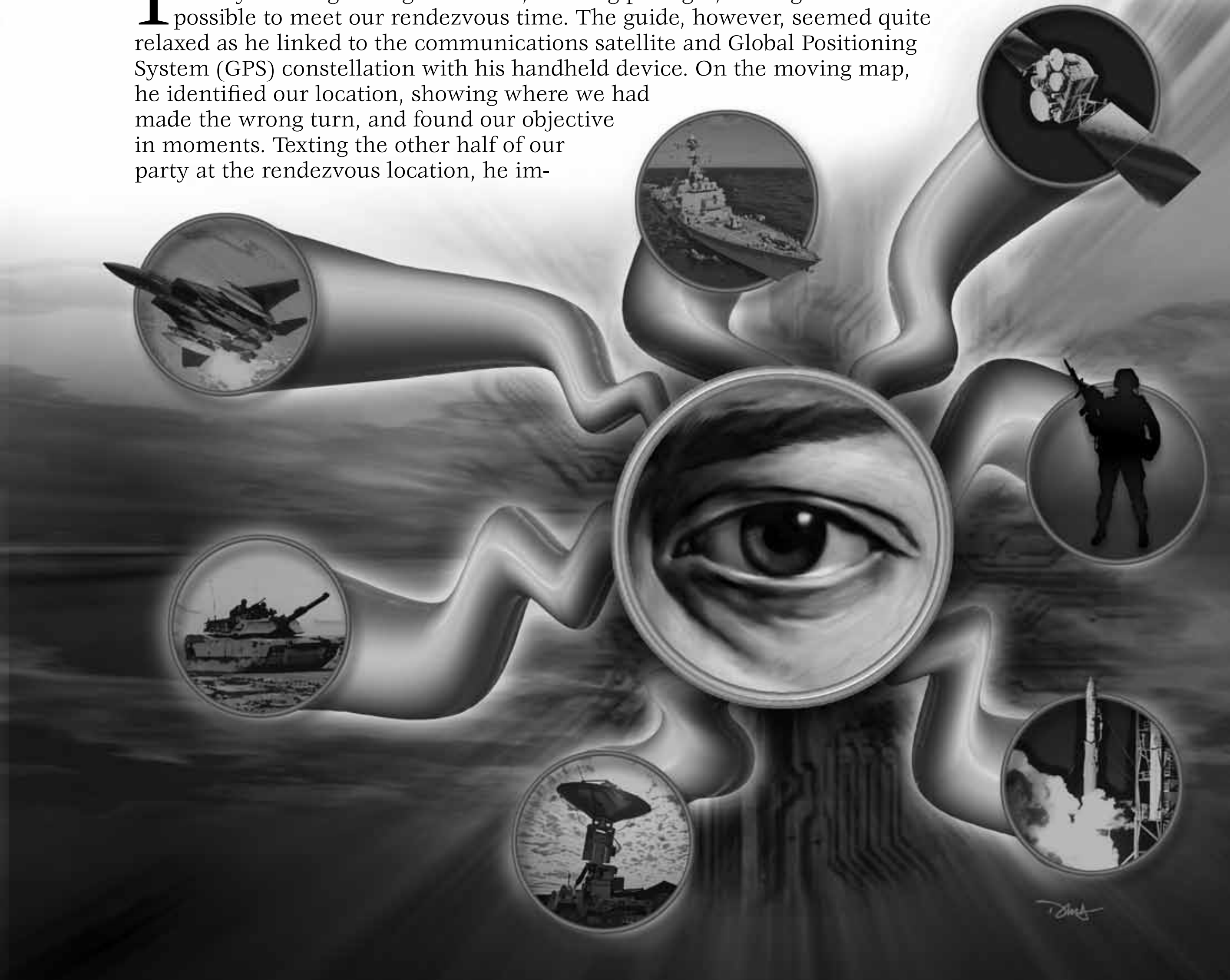
—General Dwight D. Eisenhower,
in a speech to the National
Press Club (March 1947)

Col. Frederic E. Glantzberg, chief of the New Developments Division of the Air Command & Staff School, Air University, is a Massachusetts Institute of Technology graduate who flew 50 missions in Italy and was subsequently deputy director of the Scientific Advisory Group at Hq, AAF; his article in the current issue is based partly upon the work of Hugh L. Dryden of the U.S. Bureau of Standards.

A Holistic Approach to Intelligence, Surveillance, and Reconnaissance

Col Dagvin R. M. Anderson, USAF

I was in a strange city, much of it foreign to me and my guide, who was leading our convoy. Moving through crowded, winding passages, I thought it would not be possible to meet our rendezvous time. The guide, however, seemed quite relaxed as he linked to the communications satellite and Global Positioning System (GPS) constellation with his handheld device. On the moving map, he identified our location, showing where we had made the wrong turn, and found our objective in moments. Texting the other half of our party at the rendezvous location, he im-



mediately established a new meeting time. Then, pulling in the latest video feeds on the same device, my guide confirmed that the planned route was clear. Another vehicle joined our convoy en route, and we rendezvoused silently as the GPS device updated both of our locations in real time on the moving map. As we neared our destination, he used the same handheld device to check the latest intelligence postings for the area, noting that his buddy had been here a couple of days ago. His friend had left a posting, warning him to avoid the place on the corner across from our destination, and had marked several other postings showing not only shops with helpful owners but also places to avoid. I was amazed at the amount of data available at his fingertips, easily accessible in near real time.

Of course, all of this transpired on his smartphone, and we were merely trying to maneuver three cars across Boston to meet some friends at a local restaurant. Nevertheless, I was struck by the seamless integration of multiple forms of what I termed intelligence (but what my civilian friends called common information). Starting with several independent applications, they easily integrated full-motion video (FMV), human intelligence (HUMINT), signals intelligence (SIGINT), and communications into a single, intuitive device with a common display—a feat that many people in the military would envy.[1] That amount of information, shared so easily and constructively, made me wonder what it would take to provide the same kind of integration for our forward-deployed forces. What prevents us from developing an intuitive program that would allow the user, a Soldier on the battlefield, to acquire needed information?

To do so, we must treat intelligence, surveillance, and reconnaissance (ISR) holistically. The Department of Defense (DOD) should empower a single agency to address the development and deployment of new technology, consider the overall architecture and standards, examine service culture as it relates to ISR, and work with partner nations to advance their ISR capabilities in a manner that augments the overall intelligence picture. These actions can improve our ISR posture and position us to better incorporate developing technology as new sensors, processing equipment, storage devices, and means of dissemination become available.

Background

One of the most common questions heard at senior levels in the military is, Why is ISR still a high-demand, low-density capability after several years of needing it? We have done much to boost the number and quality of assets in combat, such as flying more sorties on the battlefield and standing up the ISR Task Force within the DOD to expedite the fielding of ISR platforms and sensors. Since 2009 the number of ISR sorties in Afghanistan alone has quadrupled, and in just the last year the Air Force has fielded wide-area surveillance systems such as Gorgon Stare that represent a leap forward in technology, taking ISR from the proverbial "looking through the soda straw" to maintaining surveillance across an entire city.[2] The Air Force has even developed an independent training pipeline for operators of remotely piloted aircraft to help address the demand for their surveillance platforms. Despite this effort, the Air Force still cannot meet the demand.[3]

The service is addressing the imminently correctable shortage of physical assets even if the results are not as forthcoming as many would like. Issues include the development of better sensors, fusion of multiple forms of intelligence into an integrated picture, automation of analysis, expansion of bandwidth, and storage of data. Granted, these efforts entail technological difficulty, but much of the work is already under way and reflects significant progress.[4] The ISR Task Force has cut through much of the bureaucratic red tape, rapidly fielding programs such as the MC-12 Liberty aircraft for manned ISR and helping to expedite the introduction of Gorgon Stare wide-area video surveillance to the battlefield.[5]

Remotely piloted ISR assets will continue as one of the primary tools employed by the international community, as seen in the recent unrest in Libya during which Predator aircraft have conducted both ISR and air strikes.[6] The North Atlantic Treaty Organization considers remotely piloted ISR a critical component of its efforts in the ungoverned regions of Pakistan, having conducted 117 attacks in 2010—more than in any other year.[7]

Even beyond the current usage of ISR, we will experience greater demand to help track fleeting targets. Already in the counterterrorism manhunt, we've had difficulty tracking targets as they hide within the noise of society. Identifying terrorists or collaborators and then tracking them to fix their location will continue to represent the most difficult challenge to any nation that attempts to counter terrorism—and ISR is crucial to this effort.[8] Finding and tracking other types of fleeting targets such as mobile missile launchers or submarines will also amplify the demand for information generated by ISR assets.[9] The real effort here will not involve gathering the data so much as coordinating across multiple sources and domains to display information on a usable, real-time interface that allows us to observe a target continuously from one asset to another without blinking. In short, not creating but bringing many eyes together to form a coherent picture is our challenge.

Current demand has already flooded the skies with aircraft and, more critically, the communications links and intelligence analysts with data.[10] Indeed, we now have a secondary problem—too much data. Inundated with information, our forces either cannot sift through it all to discern key elements or find themselves overwhelmed with irrelevant data that does not directly support the needs of war fighters on the ground.[11] Having more information than we can distribute and use effectively is quickly becoming more problematic than creating more and better ISR platforms and sensors since we cannot productively utilize the data they collect from signals, FMV, and bandwidth-consuming radar images. Several projects in development, however, seek to process data on board the ISR platform itself, which would limit the amount of bandwidth required for transmission and reduce the quantity of raw information delivered to analysts for conversion into intelligence. In short, significant improvements now in progress or on the horizon are addressing the problem of technology as a limiting factor in the exploitation of ISR data.[12]

The fact is, the creation of DOD policy and enforcement of standards do not match the pace at which technology is advancing. This lag in policy prevents us from fully exploiting current and developing technology, creating a situation in which technology drives policy instead of vice versa. Although the DOD is in a hurry to move new technology to the fight, it has not fully addressed the formation of better policy and reorganization to accommodate the growth of ISR.[13] By taking certain steps, the department can keep policy ahead of technology and shape the development of ISR assets instead of simply reacting to the emergence of new technology.

Common Architecture

Among other critical elements, the common architecture that underlies the system allowed my young guide in Boston to bring several pieces of information together on his smartphone. He was able to choose from several specific applications to create a system of information management that gathered the information he needed and presented it in an easily digestible form. In the smartphone market, Apple and Android represent the only two major systems. The fact that anyone who wants to devise an application does not have to create a separate set of standards or communication protocols allows for rapid, cheap development and focuses competition. Smaller applications that solve discrete problems can then be aggregated as needed to enable greater information sharing and exploitation. We need something similar for the ISR community. Currently the ability to communicate and pass information between assets exists, but a common architecture that allows plug-and-play integration does not. An overarching architecture outlining common standards, metadata tagging (simply defined as "data describing data," simplified information that documents what the stored data contains, enabling easier search and retrieval), connectivity, and processing elements would allow the introduction of new sensors without requiring new operating systems, user interfaces, or protocols to permit communication with other assets currently in use. The lack of common standards and protocols produces inefficiencies within the ISR community; consequently, the inadequate sharing of data results in a lack of information to the war fighter, which in turn creates a false demand signal for more ISR assets.[14] The Government Accountability Office has often cited the need to develop common sensors and platforms that accommodate a plug-and-play concept which facilitates the interchanging of sensors, regardless of manufacturer or platform; this would also provide a framework for the development of new sensors that would not demand proprietary equipment.[15] Additionally, the Air Force has a goal of creating modular plug-and-play payloads with standard interfaces across platforms.[16] Arguably the most important element of our current ISR shortcomings is developing the architecture.[17]

Furthermore, we must ensure that the information from multiple types of sensors—including FMV, radar returns, and signals intelligence—is integrated as well as tagged with the minimum metadata, such as time and location.[18] Today not all data is tagged even with basic metadata, thus leaving it useless for anything other than immediate tactical applications.[19] Simply tagging the information would form the basis of a recallable library. Despite considerable work toward integrating FMV data and ensuring compatibility, we have done little to incorporate either SIGINT or radar data—critical pieces to developing a complete ISR picture.[20] As other forms of information are integrated into a common picture, adding a baseline of certainty to the metadata will improve its utility to both analysts and users in the field. For example, SIGINT or radar information may only reveal the presence of the target in a building, on the roof, or merely at a location nearby. However, by incorporating the level of certainty of target location into the metadata, the end users will have a better understanding of the ambiguity of the information and can use it appropriately when correlating multiple sources of target information.[21] This baseline tagging of information would provide the foundation for pulling these currently disparate data streams together and overlaying them onto a common picture. Bringing video, radar, and SIGINT together into an easily digestible display would allow greater situational awareness to command and control elements as well as enable us to rapidly track and fix fleeting targets. Moreover, it would permit virtual time travel; that is, video surveillance of a meeting between two vehicles might not trigger any action or even be noticed, but the video would be coded with time and location. Later, after other sources, possibly HUMINT or SIGINT, correlate one vehicle as a known target, the video could be rewound to the original meeting. With wide-area surveillance, both targets would be recorded, and the analysts could then track both vehicles as they fast-forward the data to real time, thereby locating them. From there, we could continue tracking or strike, as required. Fully compatible forms of intelligence that come in with common metadata dramatically reduce the time spent correlating and displaying the data to build a common picture. Such correlation is possible now, but it demands a significant effort in manpower and assets and is therefore reserved only for high-level targets such as Abu Musab al-Zarqawi in Iraq.

Beyond the common architecture, we must solve several technical issues, such as the overwhelming requirement for data storage and the increasing demand for bandwidth. However, we have no reason to believe that technology will not continue to progress and eventually solve these problems. In the meantime, we should establish an overarching architecture to guide this development and assure the integration and easy presentation of data; otherwise, it will have only limited usefulness, even if the other issues are resolved. In addition to interoperability and ease of sharing, a common architecture will reduce costs by combining redundant programs, decrease the amount of money and effort put toward the production of proprietary systems, and facilitate the development of software to share data more efficiently and effectively. By creating a common architecture to enable a smartphone-type interface, the military will revolutionize mobile communications, moving from voice to data and transforming World War II–era radio/telephone operators into battlefield information managers.

Establishment of the Architecture

ISR has become not only a critical element to the conduct of operations but also a minimum force requirement.[22] Given the intelligence-intensive nature of both counterinsurgency and counterterrorism, the proliferation of FMV has greatly enabled the effectiveness of US forces. This has led to enormous demand for ISR assets, eventually resulting in former secretary of defense Robert Gates's establishment of the ISR Task Force to speed the development and deployment of ISR platforms for contingency operations. The main priorities of the task force include rapidly fielding and sustaining ISR initiatives; ensuring that adequate processing, exploitation, and dissemination exist; and ensuring that joint and coalition forces can share ISR data.[23] The task force, which has proved quite successful in operating outside the standard Pentagon procurement channels, will become a permanent part of the DOD's Office of the Undersecretary of Defense for Intelligence. In order to proceed in an orderly manner, reduce redundancy, and establish an overall framework for data sharing, the DOD needs to expand the task force's charter and empower it to bring together current guidance and standards, define a single vision for ISR that will articulate its operational use, and form the strategic architecture to provide for future growth.

Establishing the ISR Task Force as a permanent organization is a step in the right direction toward empowering it to act beyond its initial charter and set the vision for ISR development across services, creating guidelines that will become an overall architecture for ISR data sharing. Rather than merely rushing more assets to the theater, having the task force define what ISR should do and how it should fit into the overall future of operations from the DOD level could produce synergistic effects. This will help industry and research institutes focus their efforts and improve productivity. The task force can also help enforce a common set of existing standards and require the compatibility of information for sharing. This function of the task force would prove especially valuable in terms of taking advantage of numerous platforms already in existence by efficiently fusing various types of data collected from radar returns, SIGINT, and FMV to offer a common picture.[24] By having a common database and architecture, we can write the software and applications that meet the ultimate goal of allowing Soldiers in the field to pull or request information in usable form and tailor it to their requirements.[25] Giving the ISR Task Force the authority and budget to generate the overall architecture that will push information to the operational level constitutes a crucial next step.

Because ISR is incorporated into joint concepts such as AirSea Battle that will further drive demand for integrated ISR, the task force would be the natural choice for supplying the overarching guidance. AirSea Battle will rely on integrating Air Force and Navy assets, of which ISR is a key component.[26] This particular joint concept also highlights the need to look beyond the traditional domains of air and space for ISR. Remotely operated ISR platforms for underwater surveillance, now in development, will track submarines, give us time-critical offshore strike capability, and place stay-behind devices that can monitor traffic through strategic choke points.[27] These assets allow access to denied areas or those that pose unacceptable risks to manned ships (such as shallow or mined waters). Again, to build a common picture with a truly unblinking eye, we must bring such platforms—as well as land-based stay-behind devices for monitoring roads, compounds, or other high-interest areas—into the same architecture and planning system. At present there is little integration of remotely piloted aircraft, underwater vehicles, and other stay-behind devices because of the lack of overlap and the overwhelming amount of data.[28] However, as the ISR field develops and more information from various domains becomes available, we will rely on the integration of information driven by common standards and an overarching architecture to compile a usable database that brings together and displays both real-time and historical information.

Cultural Change

Culture is one of the obstacles to fully exploiting the data gathered by ISR assets. Many individuals and organizations have not fully kept up with the rapid shift in data sharing, distribution, and ways of thinking about and treating information. As we saw in the scenario that opened this article, a 20-year-old has a vastly different relationship with, and expectation of, technology than people just a generation older. Rapid changes in information technology have altered the paradigm of experience. No longer does experience necessarily equate to knowledge when it comes to employing information technology. The military needs to embrace emerging technology culturally, engage with the younger generation, and change how it looks at intelligence and ISR by fully incorporating intelligence into operations.[29]

The most urgently needed cultural shift is the fusion of operations and intelligence, two functions that we can no longer consider separate entities that work independently. The special operations community has fused these two functions to great effect in the counterterrorism effort, with ISR a critical component of operationalizing intelligence.[30] The cultural shift is beginning to take place within the services as well, as evident in the Navy's merging of the intelligence and command and control career fields.[31] The Air Force has also addressed the rising importance of ISR by creating the Office of the Deputy Chief of Staff for Intelligence, Surveillance, and Reconnaissance in 2006 to manage the service's ISR effort. This position has helped expedite the fielding of new technology and has pushed a cultural shift within the Air Force to integrate operations and intelligence as well as operationalize the employment of ISR.[32] A significant cultural shift is already occurring, especially within the intelligence community, but it needs to be institutionalized and expanded within the Air Force.[33] Intelligence is no longer solely a support function. Often, the purpose of a mission is to gather information, develop patterns of life, and locate targets. We can take additional steps to further the integration of operations and intelligence and thereby fully exploit the data collected by ISR platforms by giving intelligence the operational assets to develop real-time intelligence. For instance, the Air Force can put ISR on par with its strike and mobility assets by forming a major command responsible for ISR and making intelligence and data sharing an operational function. Such an agency already exists and has much of the structure needed for success. The Air Force ISR Agency is a two-star command within Air Combat Command (ACC), but as a subordinate unit, it is often overlooked when ACC faces more pressing issues such as bringing on two new platforms—the F-22 and F-35. The fact that much of the infrastructure for a major command exists within the agency would limit the costs and personnel necessary to establish a smaller two-star headquarters similar to Air Force Special Operations Command.

A separate ISR command would highlight the Air Force's commitment to ISR and lead its development, integration, and operations within the DOD. We could then present ISR as a cross-domain capability including both operational assets and multi-intelligence capabilities. Intelligence would take on an operational focus so that the command would have the purpose of managing operational intelligence gathering. This command would be able to prioritize ISR and the development of the technology as well as the organization, dissemination, and fusion of intelligence with operations. Intelligence would support other ongoing operations and targeting efforts, and the gathering of intelligence would be an operational goal in and of itself. Having its own command would allow the development of an ISR culture outside ACC—one that would fully exploit ISR capabilities and operationalize intelligence for use across the services.[34] Also, an ISR command would serve as the single voice for ISR issues and present a unified vision for the future of Air Force ISR—something currently missing.[35] Furthermore, this command could become the basis for future development of a larger command that encompasses intelligence and both airborne and space-based ISR platforms, thus creating a cross-domain organization that leverages the synergy among operations, intelligence, and eventually communications; it would also speak to the combatant commands as a single voice for Air Force ISR.

Additionally, we should view ISR as a sharable asset that is prioritized and allocated. Because we often cannot task assets outside the owning agency, they are not fully utilized.[36] Empowering the ISR Task Force enables it to oversee the full employment of ISR assets, maximizing the number of sensors and platforms in use. By centralizing the allocation of limited ISR assets, we can utilize the optimal number of them, resulting in increased utilization rates and intelligence value of collected data. Doing so would mean that some units and organizations that can currently access ISR assets would have to change their culture and thus help blend operations and intelligence.[37]

Building a Partner Nation Network

The United States should use its position of information preeminence to help build relationships with our partner nations and develop their ISR capabilities. The *Quadrennial Defense Review Report* notes that both ISR and capable partner nations are critical to the new security environment.[38] Although the report mentions that investments in airborne ISR will contribute to US capacity for security force assistance missions, it does not emphasize the key role that ISR can play in building partner nation capacity and improving relations with those countries.[39]

As a relatively reliable and affordable means of enhancing existing ground and air forces, ISR presents partnership opportunities to nations that wish to improve their capabilities in this area. The 6th Special Operations Squadron, whose primary mission is to train foreign air forces, is rapidly building an ISR training capability; furthermore, Air Force Special Operations Command is looking at ways to build a modular ISR training program around relatively cheap, light fixed-wing aircraft that we can easily export to partner nations. These aircraft are fairly reliable, readily available, and easily maintained and flown. A relatively small investment in equipment and training can produce a robust, sustainable means of augmenting a partner's capability, not only that of its air force but also that of its ground forces and intelligence apparatus. (Improving intelligence is especially attractive to nations involved in countering terrorists or conducting counterinsurgencies.)

In order to meet the demand for ISR, the Air Force should look at both exporting older equipment and developing a program that will meet partner nations' needs, based on an analysis of their intelligence requirements and capabilities.[40] Such a tailored ISR program for addressing these countries' shortfalls can include manned and remotely piloted systems as well as old and new equipment, including SIGINT and other technical intelligence.[41] A key component would involve the ability to tie their intelligence into the US system to take advantage of the data gathered and the partner nation's analysis of that data, which, of course, would have the advantage of familiarity with the local culture and current security situation. Despite the many issues that accompany the sharing of intelligence and technology, we still have an opportunity to take advantage of partner nations' expertise and gain intelligence from areas that would otherwise go unexplored while at the same time reduce the US footprint involved in collecting this information.

Building our partners' ISR capabilities gives us a chance to establish continuous engagement with their forces in an operational environment by employing ISR platforms and interacting with intelligence officers. By developing an intelligence-sharing relationship, we can cultivate a more enduring engagement than the current episodic one.[42] Doing so requires development of force structure to engage in US Security Force Assistance to train, advise, and equip partner nations to conduct airborne ISR and SIGINT as well as integrate the data to create usable intelligence.[43] These interactions will create exchange opportunities for both operations and intelligence officers to immerse themselves in a foreign culture and move from merely gathering data to acquiring knowledge, building trust, and, eventually, understanding the culture, ideas, and sociology that affect decision making in relevant populations. Ultimately the relationships and understanding that come from working with such countries are the key to producing usable intelligence and increasing the effectiveness of our counterterrorism and counterinsurgency operations, with the goal of developing an intelligence strategy that intertwines with and supports the operational strategy.[44]

Conclusion

We can make changes now that will maximize the available ISR infrastructure within current technological and budgetary constraints.[45] Indeed, we can still make significant progress as we wait for additional technology to develop and create a better environment for the addition of new platforms and sensors. The largely unaddressed issues that will allow further exploitation of ISR both now and in the future include the following:

- Empowering the ISR Task Force to set the vision for ISR and defining the capabilities that the DOD wants from ISR
- Establishing an overarching architecture that addresses ISR across all domains
- Enforcing established standards to attach basic metadata to all ISR products, including FMV, SIGINT, and radar images
- Addressing the cultural change required to integrate operations and intelligence and keep ahead of the rapid pace of technology and information
- Establishing an ISR major command within the Air Force to address ISR as a separate function
- Developing an ISR network with partner nations

Empowering an organization to set the vision for ISR across all domains will reduce redundancy, improve interoperability, keep the services moving forward in concert, and ease the shift in culture to fully exploit information technology.

We still need more sensors and platforms to meet the demand for information, but without a means to incorporate the data that they produce into a common database easily shared with user-friendly, customizable displays, we will reach a point of diminishing returns and values. It is critical that we develop a flexible architecture with standards, structure, and commonality to exploit the data currently available and that we have the ability to incorporate new technology seamlessly. Even if they are not perfect, a vision and an organization to keep the DOD moving toward that goal will go a long way to improving the access to and processing of ISR data. Instead of reacting to new technology and letting it drive policy, the DOD needs to have a coordinated effort for guiding the development of technology and exploiting ISR's capabilities to better meet future requirements. ISR has become too critical to the way we fight for us to do otherwise.

By treating ISR holistically, we can address the development of new technology as well as the overall architecture and standards, look at service culture as it relates to ISR, and work with partner nations to advance their ISR capabilities in a manner that augments the overall intelligence picture. Empowering a single agency to set a common vision and take charge of ISR will substantially improve both the effectiveness and efficiency of that capability. Furthermore, by taking such actions as making the Air Force ISR Agency a major command, we can create organizations within the services to fully address ISR issues and integrate operations and intelligence. As technology continues to advance rapidly, ISR will fuse operations and intelligence in a way few other mediums can, thereby paving the way for the development, processing, and execution of actionable intelligence by the same asset. Again, rather than simply react to future developments, it is imperative that the DOD be ready to guide the many aspects of ISR in concert. ✪

Notes

1. These applications include Google Maps, Traffic Boston, foursquare, and Yelp. Though not tailored to intelligence, they do provide a great deal of information that can be combined to generate a clear picture of what is in the area. Foursquare uses the signal from a cell phone to send its location to a central database that then makes it available to others. Many traffic sites allow the transmission of real-time video from cameras in several major cities as well as other camera applications that show surf conditions, the weather, or scenic views. Applications such as Yelp let users leave ratings and commentary on local businesses that others can access in real time via GPS signal, based on their position. So simple a thing as a person's location opens up a wealth of instantly available information that can easily be overlaid onto a single map.

2. Ellen Nakashima and Craig Whitlock, "With Air Force's Gorgon Drone 'We Can See Everything,'" *Washington Post*, 2 January 2011.

3. Ibid.

4. Brig Gen Dale Waters, USAF, retired (Defense Advanced Research Projects Agency), interview by the author, 19 January 2011.

5. Nakashima and Whitlock, "Air Force's Gorgon Drone."

6. Martha Raddatz and Kirit Radia, "Pentagon Confirms First Predator Drone Strike in Libya," *ABC World News*, 23 April 2011, http://abcnews.go.com/International/pentagon-confirms-predator-drone-strike-libya/story?id=13442570; and "U.S. Authorizes Drone Strikes in Libya, McCain Visits Opposition in Benghazi," *PBS Newshour*, 22 April 2011, http://www.pbs.org/newshour/rundown/2011/04/syria-beefs-up-security-for-protests-mccain-visits-libya-rebels.html.

7. Eric Schmitt, "New C.I.A. Drone Attack Draws Rebuke from Pakistan," *New York Times*, 13 April 2011, http://www.nytimes.com/2011/04/14/world/asia/14pakistan.html. Note that some sources put the total number of strikes at 118. See, for example, "The Year of the Drone: An Analysis of U.S. Drone Strikes in Pakistan, 2004–2011," New America Foundation, accessed 12 October 2011, http://counterterrorism.newamerica.net/drones.

8. Michael T. Flynn, Rich Juergens, and Thomas L. Cantrell, "Employing ISR: SOF Best Practices," *Joint Force Quarterly* 50 (3d Quarter 2008): 56–61, http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA516799. The integration of operations and intelligence has transformed the ability of our forces to hunt terrorists and find fleeting targets. Moreover, the integration of FMV has become an integral part of operations and critical to both the development and prosecution of targets. Accounts such as the killing of Abu Musab al-Zarqawi, which reflect the successful fusion of operations and intelligence with the integration of ISR assets, are well known. The hundreds of hours of ISR development that led to the killing of Iraq's most notorious terrorist leader and the subsequent dismantling of his network were only one part of the process. The integration of ISR into an all-source intelligence system and into operations allowed us to prosecute these targets.

9. Rebecca Grant, "U.S. Needs to Deter China's Mobile Missile Launchers," UPI.com, 25 March 2009, http://www.upi.com/Top_News/Analysis/Outside-View/2009/03/25/US-needs-to-deter-Chinas-mobile-missile-launchers/UPI-75531237999938.

10. Stew Magnuson, "Military 'Swimming in Sensors and Drowning in Data,'" *National Defense*, January 2010, http://www.nationaldefensemagazine.org/archive/2010/January/Pages/Military%E2%80%98SwimmingInSensorsandDrowninginData%E2%80%99.aspx.

11. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, *Report of the Joint Defense Science Board / Intelligence Science Board Task Force on Integrating Sensor-Collected Intelligence* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, November 2008).

12. Mark Luettgen, PhD (president, Systems and Technology Research), interview by the author, 12 February 2011.

13. Maj Gen Blair Hansen (deputy commander, Joint Functional Component Command for Intelligence, Surveillance, and Reconnaissance), interview by the author, 2 March 2011.

14. US Government Accountability Office, *Intelligence, Surveillance, and Reconnaissance: Overarching Guidance Is Needed to Advance Information Sharing*, GAO-10-500T (Washington, DC: GAO, 17 March 2010), http://www.gao.gov/new.items/d10500t.pdf. This document indicates that standards are not being evenly applied across ISR programs, resulting in inefficiencies: "It is not clear how much of the collected data are not being shared. Until DOD identifies what types of ISR information should be shared and assigns priorities for sharing data, it is unclear whether mission-critical information will be available to the warfighter. In addition, the inability of users to fully access existing information in a timely manner is a contributing factor to the increasing demand for additional ISR collection assets" (9).

15. US Government Accountability Office, *Defense Acquisitions: Opportunities Exist to Achieve Greater Commonality and Efficiencies among Unmanned Aircraft Systems*, GAO-09-520 (Washington, DC: GAO, July 2009), http://www.gao.gov/new.items/d09520.pdf. See also US Government Accountability Office, *Intelligence, Surveillance, and Reconnaissance*.

16. US Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan, 2009–2047* (Washington, DC: Headquarters US Air Force, 18 May 2009), http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA505168&Location=U2&doc=GetTRDoc.pdf.

17. "The architecture and compatibility piece is huge. The more I get involved in the details of the ISR business the more I find things that don't talk to other things. All the solutions appear to be just 2–3 years off, but like a mirage the 2–3 years keep sliding to the right." Konrad Trautman, director of intelligence, US Special Operations Command, to the author, e-mail, 12 May 2011.

18. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, *Integrating Sensor-Collected Intelligence*, 63.

19. US Government Accountability Office, *Intelligence, Surveillance, and Reconnaissance*.

20. Luettgen, interview; and Hansen, interview.

21. "A measure of certainty is important to enabling humans and automated processing to combine information across different sources. Uncertainty could be as simple as a CEP [circular error probable] 50 number for the location data, or it could be a list of possible identifiers for an object with probabilities for each (e.g., human 60 percent, vehicle 10 percent, animal 30 percent), or it could be something more complex if the underlying data is more complex. Many modern systems (e.g., next-generation GMTI [ground moving target indicator] radars and the next increment of Gorgon Stare) can detect multiple types of objects simultaneously (humans, vehicles, animals), and there is often ambiguity in what has been detected. Also, with increasingly accurate terrain models, the location ambiguity becomes more complex (e.g., in radar or signals intelligence, it may not be apparent if the target is on a building roof, or inside, or on the ground), but it would be valuable to understand the nature of the ambiguity to facilitate correlation with video. We need ISR data sources to adhere to standard uncertainty representations in the same way that they do for other data and metadata to enable consistency of interpretation and simplified integration of new capabilities, which again points to the need for DOD-wide coordination." Luettgen, interview.

22. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin Press, 2009), 216–17.

23. Harrison Donnelly, "ISR LEADER: Ensuring Warfighters Have the Intelligence Support They Require," *Geospatial Intelligence Forum*, September 2010, http://integrator.hanscom.af.mil/2010/September/09232010/09232010-15.htm.

24. Hansen, interview; Luettgen, interview; and John T. Bennett, "Gates' ISR Task Force to Join Top DoD Intel Office," *DefenseNews*, 7 October 2010, http://www.defensenews.com/story.php?i=4863676.

25. "One of the benefits of the common architecture will be the ability for users to not only pull existing information but to request new information, subject to resource availability and priority. Right now, the ability to request resources is very limited, but the common architecture will make this easier and will allow us to use the assets we have more wisely and responsively to get information to the Soldier on the ground." Luettgen, interview.

26. Jose Carreno et al., "What's New about the AirSea Battle Concept?," US Naval Institute *Proceedings* 136, no. 8 (August 2010), http://www.usni.org/magazines/proceedings/2010-08/whats-new-about-airsea-battle-concept; Greg Grant, "CSBA [Center for Strategic and Budgetary Assessments] AirSea Battle Concept: More Stealth, Long-Range Strike to Counter Chinese Battle Networks," Defense Tech, 18 May 2010, http://defensetech.org/2010/05/18/csba-releases-its-airsea-battle-concept/; Andrew F. Krepinevich, *Why AirSea Battle?* (Washington, DC: Center for Strategic and Budgetary Assessments, 2010), http://www.csbaonline.org/wp-content/uploads/2010/02/2010.02.19-Why-AirSea-Battle.pdf; and Department of Defense, *Quadrennial Defense Review Report* (Washington, DC: Department of Defense, February 2010), 33, http://

www.defense.gov/qdr/QDR%20as%20of%2026JAN10%200700.pdf.

27. Singer, *Wired for War*, 114–16; and Hunter Keeter, "Navy Unveils UUV [Unmanned Undersea Vehicle] Master Plan—New Capabilities, New Vehicle Classes," *Undersea Warfare* 7, no. 3 (Spring 2005), http://www.navy.mil/navydata/cno/n87/usw/issue_26/uuv.html.

28. Paul Geier (chief of RPA/UAS [remotely piloted aircraft / unmanned aircraft system] Interoperability and Future Capabilities, AF/A2CU), interview by the author, 10 March 2011.

29. Hansen, interview.

30. Flynn, Juergens, and Cantrell, "Employing ISR," 56–61.

31. Robert K. Ackerman, "Navy Builds around Intelligence, Information Consolidation," *SIGNAL Magazine*, May 2010, http://www.afcea.org/signal/articles/templates/Signal_Article_Template.asp?articleid = 2282&zoneid = 254; and Jim Garamone, "Intel, Ops Fusion Aids Warfighters, Roughead Says," American Forces Press Service, 23 March 2011, http://www.defense.gov/news/newsarticle.aspx?id = 63278.

32. Lt Gen David Deptula, USAF, retired, interview by the author, 19 January 2011; Rebecca Grant, "Actionable Intelligence: It's the Holy Grail, and the Air Force Is Taking Big Steps toward Getting It," *Air Force Magazine* 90, no. 6 (June 2007): 40–43, http://www.airforce-magazine.com/MagazineArchive/Documents/2007/June%202007/0607intelligence.pdf; and 17th Training Wing Public Affairs, "ISR Leader Passes Torch to New Generation," Air Force Print News Today, 8 October 2010, http://www.af.mil/news/story_print.asp?id = 123225750.

33. "ISR Surgeon: Finding and Fixing Enemies and Friends in Theater [interview with Maj Gen Blair E. Hansen, director of ISR capabilities, Air Force]," *Geospatial Intelligence Forum*, July/August 2009, 24, http://www.kmimediagroup.com/files/GIF_7-4.pdf.

34. Dave Majumdar, "F-35 as ISR Collector: Air Combat Command Isn't So Sure," *C4ISR Journal*, 1 November 2010, http://www.c4isrjournal.com/story.php?F = 4756598; Deptula, interview; and Hansen, interview.

35. Majumdar, "F-35 as ISR Collector."

36. Deptula, interview; and Hansen, interview.

37. Luettgen, interview.

38. Department of Defense, *Quadrennial Defense Review Report*, 13, 22–23, 28–30.

39. Ibid., 29.

40. Geier, interview.

41. Briefing, Konrad Trautman, director of intelligence, US Special Operations Command, subject: Intelligence Strategies for Persistent Conflict, National Defense Industrial Association, Special Operations, and Low Intensity Conflict, 11 February 2009, http://www.dtic.mil/ndia/2009SOLIC/5Trautman.pdf.

42. Trautman, e-mail.

43. Trautman, briefing.

44. Ibid.

45. These include the cancellation of supporting programs, such as the Transformational Satellite Communications System, that are proving too expensive yet would help increase the bandwidth to transmit greater amounts of data. See Robert M. Gates, "Defense Budget Recommendation Statement" (speech, Arlington, VA, 6 April 2009), http://www.globalsecurity.org/military/library/news/2009/04/dod-speech-090406.htm.

Col Dagvin R. M. Anderson, USAF

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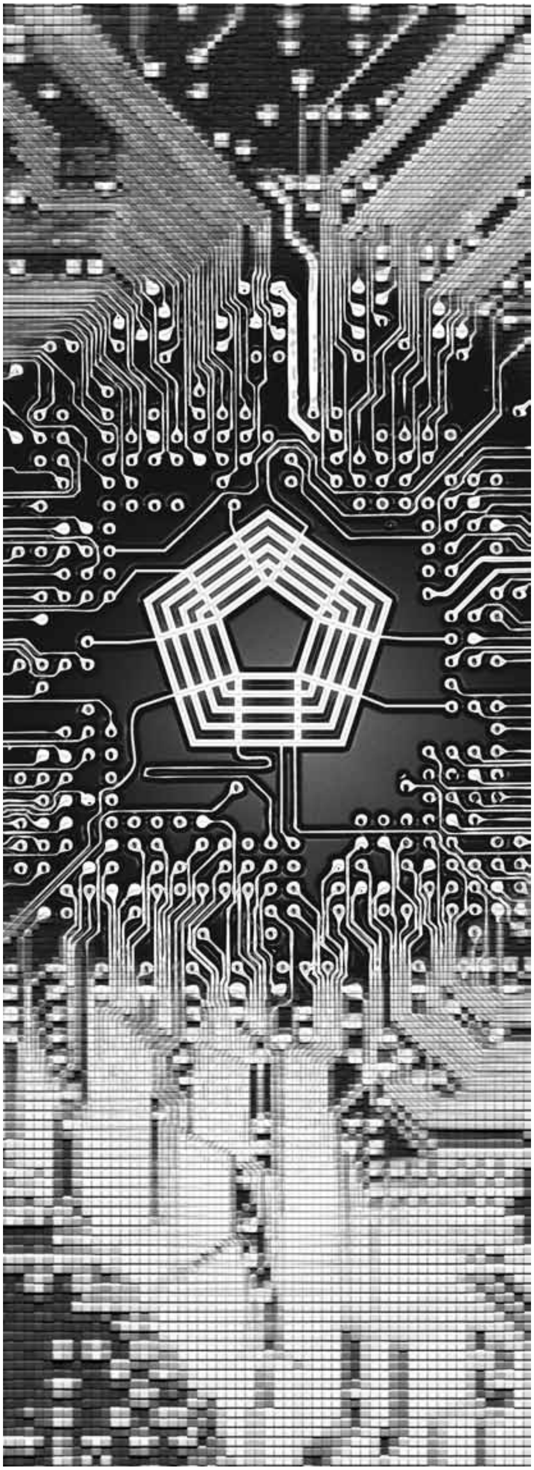

Joint Targeting in Cyberspace

Maj Steven J. Smart, USAF

America relies on our digital infrastructure daily, and protecting this strategic asset is a national security priority.

—President Barack Obama, 2010

Security in cyberspace is a clear national priority, but the role of the US military in this new domain is not so clear. With the activation of US Cyber Command in 2010, debate concerning the militarization of cyberspace and the conduct of cyber "warfare" has taken center stage among US government policy makers.[1] Complicating matters is the uncertain practice of governing behavior in cyberspace by applying domestic legal and policy guidelines as well as international treaties based on kinetic warfare.[2] Despite this uncertainty, Department of Defense (DOD) policy requires that DOD components "comply with the law of war during all armed conflicts, however such conflicts are characterized, and in all other military operations."[3] Although it remains to be seen what roles and responsibilities policy makers in Washington, DC, will carve out for the military, the DOD should prepare to conduct military operations in the cyber domain. To do so effectively, the department should apply, with slight modification, time-tested joint targeting principles to military operations in cyberspace.[4] This article explores the efficacy of Joint Publication (JP) 3-60, *Joint Targeting*, as applied to military operations in cyberspace and proposes recommendations for joint targeting doctrine for cyberspace.[5]

Foundational Principles of Joint Targeting

Before we can address the adequacy of applying JP 3-60 to cyber targeting, we must understand the foundations of its principles, the reason for its application, and the relationship between doctrine and law. "Joint doctrine presents fundamental principles that guide the employment of US military forces," and "[commanders] at all levels [must] ensure their forces operate in accordance with the 'law of war,'" which is "binding on the United States."[6] Joint doctrine incorporates what the United States has agreed to follow in international law as well as operational best practices. The "law of war" consists of conventional international law (treaties and agreements between nation-states) and customary international law (based on state practice).[7] The latter develops from state practice—namely, official governmental conduct reflected in a variety of acts, including published doctrine. Thus, joint doctrine not only reinforces binding legal obligations but also advances the development of customary international law.

For simplicity, the primary canons that set the foundation for the modern law of war are divided between rules for the *conduct* of war and the *treatment* of parties to the conflict and its bystanders: the Hague and the Geneva conventions, respectively.[8] Additionally, the Charter of the United Nations outlines obligations of the organization's member states with regard to the "use of force" against other states.[9] Domestic law (federal statutes and judicial decisions), US government policy, joint and service doctrine, as well as rules of engagement (ROE) specify how US military forces will comply with these international obligations. We must understand that neither military doctrine nor ROEs, whether standing or mission specific, replace or supersede the laws of war. Rather, they represent US implementation of agreed-upon international principles to a specific situation.

We can distill this vast body of rules, regulations, and doctrine to five simple principles that apply to any specific operation. First, the use of force presupposes the existence of *military necessity* (a valid military reason to use force necessary to carry out the mission).[10] Second, the proposed employment of force must not cause the civilian population or the targeted enemy force *unnecessary suffering*.[11] Commanders must apply this principle—the basis for later conventions that outlaw certain types of weapons and munitions (e.g., chemical weapons)—not only to potential "collateral damage" (incidental loss of civilian life or damage to civilian property) but also to the intended object of attack. Third, the employment of force must *discriminate* or distinguish between combatants and noncombatants as well as forgo intentional attacks against civilian populations not directly participating in hostilities.[12] In short, the operator must use a weapon capable of being aimed and must distinguish between civilians and adversaries—the underlying principle that guides joint targeting analysis, explored in greater detail below. Fourth, the proposed military operation must be *proportional*—that is, it must avoid excessive collateral damage in light of the expected military advantage.[13] Finally, the parties in the armed conflict must maintain *chivalry* or a "certain amount of fairness . . . and a degree of mutual respect and trust."[14] Applying these principles guides the employment of force in general and individual targeting decisions in particular.

In military circles, the term *targeting* often describes an action of a military force engaging, or preparing to engage, an adversary. Officially, joint doctrine defines targeting as "the process of selecting and prioritizing targets and matching the appropriate response to them, considering operational requirements and capabilities."[15] This definition—specifically, the process of selecting the target and matching the appropriate response to it—most directly entails obligations under the law of war. Target selection is the primary premise upon which the principle of discrimination rests. *Military* objects are lawful targets, but forces should not attack civilians intentionally and should spare them from collateral effects as much as possible.[16] Therefore, the law of war holds the military commander and operator responsible for identifying, functionally characterizing, and attributing to a combatant—as accurately as practicable—the intended object of a proposed military operation.

Military doctrine sets forth principles to guide forces in carrying out their obligation of discrimination. JP 3-60 includes the overarching targeting principles for conducting combined or joint operations. Military service doctrine, such as Air Force Doctrine Document (AFDD) 2-1.9, *Targeting*, complements joint doctrine with principles specifically designed for the individual service's primary responsibility.[17] These principles derive from best practices, drawing on the collective experience of the US military and its allies during previous military campaigns and operations. Because no military service has primary responsibility for the cyberspace domain and because little, if any, collective best practice for military operations in cyberspace exists, current doctrine for other war-fighting domains shapes cyber operation planning and informs cyber targeting decisions.[18] Therefore, JP 3-60 is *by default* the current foundational publication on joint targeting in cyberspace.

Application to Cyberspace

Applying existing military doctrine (specifically, targeting and law-of-war principles) to operations in cyberspace is easy in theory but may prove extremely difficult in practice. Cyber warfare differs fundamentally from traditional armed conflict. Unlike the conduct of past warfare, opponents (including state actors, criminals, terrorists, and hackers) can wage cyber warfare from far reaches of the globe rapidly, cheaply, anonymously, and devastatingly. Current military doctrine looks to the experiences and theories of *kinetic* warfare between nation-states in battlespaces that exist almost exclusively in a physically recognizable and understandable area (air, land, sea, and space). Cyber warfare, by contrast, occurs in "a realm located simultaneously at logical and physical layers that intersects activities in, through, and concerning the electromagnetic spectrum which seamlessly crosses other domains as well as geographic and recognized political boundaries."[19]

The extent to which cyber warfare differs from kinetic warfare and represents a paradigm shift in modern military affairs is a contentious subject best suited to academic historians. However, differences exist between the actors and the means/methods of armed conflict in the physical world and their counterparts associated with conflicts in cyberspace. These variations illustrate the complex challenges of applying current law, policy, and military doctrine to keystrokes and mouse clicks.

First, participation in cyber warfare is not limited to agents of the nation-state. Unlike conventional military attack, conducting a strike in cyberspace does not require government sponsorship.[20] Second, the attacker does not need expensive, traditional weapon systems—only a computer, an Internet connection, and basic cyber expertise.[21] Third, unlike attributing an attack in the kinetic world, identifying the source of a cyber strike is extremely difficult. For example, finding the aggressor nation responsible for a missile attack is relatively easy because key "fingerprints" such as the missile's size, speed, range, and type of warhead point to a relatively small list of countries that have the technology, will, and expertise to conduct such an attack. A cyber attack, however, can originate from anywhere and with anyone, including state-sponsored "hacktivists," nonstate actors, or "free lancers packing a politically motivated laptop punch."[22]

The key differences between cyber warfare and its kinetic cousin raise pertinent questions. First, is it realistic to expect even state-sponsored cyber operators to comply with legal principles and military doctrine based on traditional notions of kinetic war in this new domain? Second, do we need a new joint publication specifically dedicated to cyberspace targeting to account for these differences?

Despite disparities in the operational domains, cyber warriors are fundamentally the same as their counterparts on land, at sea, and in the air. Both rely upon their knowledge of the domain, operational environment, and weapon system capabilities. The complexity of war fighting resists any attempt to reduce it to a formulaic checklist for commanders. Astute leaders may discern and apply enduring truths of war, including the framework for its legal use, within the context of a particular operational or strategic environment. With a few modifications, cyber operators can apply legal principles and military doctrine based on traditional kinetic warfare to cyber operations and still produce the intended effects. Similarly, with only slight adjustments for cyber nuances, JP 3-60 can continue to serve as the US military's foundational publication for both kinetic and nonkinetic targeting.

Military Doctrine in Cyberspace

In the recent past, only one joint publication concerned itself exclusively with conducting military operations in the cyber domain.[23] JP 3-13, *Information Operations*, identified information operations (IO) as "the integrated employment of electronic warfare (EW), computer network operations (CNO), psychological operations (PSYOP), military deception (MILDEC), and operations security (OPSEC), in concert with specified supporting and related capabilities, to influence, disrupt, corrupt or usurp adversarial human and automated decision making while protecting our own."[24] Doctrinally, CNO, including computer network attack (CNA) and defense (CND), represented just a subset of a larger category of arguably dissimilar activities. Doctrine asserted the centrality of these capabilities to IO as a whole, noting that they would help the joint force commander influence an adversary. But grouping them together suggested that IO itself is a war-fighting specialty capable of rapid integration into a joint task force. Unfortunately, this is not the way the services train their personnel. Rather, they currently train an individual in one or two competencies, such as EW or PSYOP. Within CNO, only rarely does a person have both CNA and CND proficiency. Therefore, an IO cell at the joint task force level may be composed of "cylinders of excellence" (i.e., individuals well versed in their narrow field of training but possessing little understanding of the other capabilities). This is particularly true with regard to the concept of targeting: JP 3-13 does not contain guidance on the topic.

Assuming the "core" nature of these capabilities, why does JP 3-13 include no instruction on targeting? Three reasons come to mind. First, targeting is so essential to war fighting that nearly every military member has a general understanding of the concept. However, targeting that successfully attains both military and political objectives is an extremely complex process that relatively few individuals have mastered. Simply put, most military professionals know what targeting means, but few of them know how to do it. Second, JP 3-13 does not address the specifics of core capabilities. Rather, it refers the IO planner to other publications for guidance, suggesting that these capabilities are not as closely linked as JP 3-13 asserts. Instead, in the minds of conventional military planners, they are merely several unique, unconventional military activities difficult to integrate into an operations plan. Finally, many planners believe that "targeting is targeting," no matter the platform or domain.

Most cyber operational planners would declare that they understand the general concept of targeting as contemplated in the official doctrinal definition and as outlined in JP 3-60. However, their application of the concept and definition to their core IO capability may mean something very different. For example, a proposed PSYOP activity might "target" a foreign audience whose behavior and actions targeteers want to influence, but an EW operation might target signals from a radio tower. JP 3-13 suggests that the five types of IO functions listed above are operationally interrelated yet offers no guidance on how to target the adversary using these functions specifically.[25] The IO planner or operator must then refer to another subject-matter-specific publication for guidance.[26] The fact that JP 3-13 represents the only joint guidance on network operations complicates matters for the CNO planner.[27] Thus, CNO planners at the joint level must often look backward to service doctrine for such guidance.

The Air Force recently released AFDD 3-12, *Cyberspace Operations*, which differentiates between cyber and information operations.[28] This document represents the service's best effort to understand, organize, train, and guide Airmen in cyberspace operations. Basic enough for the cyber novice yet comprehensive enough for the expert, AFDD 3-12 provides technically sound and operationally relevant guidance to Airmen in the absence of guidance at the joint level—a particularly remarkable feat. Even more impressive, the document relates principles of joint operations to cyberspace operations, offering input across the range of military operations and outlining fundamental principles for the Air Force cyber warrior.[29] Arguably, AFDD 3-12 is the most comprehensive document on cyber operations in the DOD; indeed, the joint force would be well served by a joint publication having its breadth and depth. Admittedly, even though AFDD 3-12 discusses many issues useful in cyber targeting, such as technical relationships in cyberspace infrastructure, information assurance, compressed decision cycles, and the anonymity and attribution challenge, it does not specifically address cyber targeting per se.[30] In fact, the document refers readers to JP 3-60, suggesting that the joint publication's principles, guidance, and theory properly apply to Air Force operations in cyberspace.

On the one hand, the subject of targeting seldom appears in current DOD, joint, or service doctrine on cyberspace, perhaps because the military has only now begun formally organizing its cyber forces or because the services do not have a large, collective cyber-targeting experience from which to draw.[31] On the other hand, DOD leaders may simply believe that JP 3-60's principles of targeting are so sound that they translate easily to military operations in the cyber domain. Whatever the rationale, JP 3-60 remains the seminal joint publication on targeting in cyberspace despite the fact that it makes no reference to the domain itself.

Review of Joint Publication 3-60

Organized in three main sections—fundamentals of targeting, the joint targeting process, and duties and responsibilities—JP 3-60 proceeds logically from defining the term *target*; through target development, target engagement, and damage assessment; to command responsibilities and oversight. A targeting novice can quickly grasp the fundamentals of this concise, well-written document. For example, one simple chart (fig. II-1, the Joint Targeting Cycle) conveys the essence of combat targeting.[32] To understand the cycle is to understand targeting.

The joint targeting cycle quickly outlines the who, what, where, when, why, and how of adversary engagement.[33] After the joint force commander announces an *end state and objective*, planners *develop and prioritize targets* toward that end. Target selection drives *weapon/capability pairing*, which ensures successful engagement while minimizing collateral damage. The particular weapon selected determines *force assignment*, which informs *mission planning* and drives *execution*, after which an *assessment* tells the commander whether the mission has fulfilled the objectives or whether additional targeting is necessary, as determined through evaluation of predetermined measures of effectiveness and measures of performance. Skipping steps in the cycle jeopardizes mission effectiveness; adding steps outside the cycle is superfluous. From a legal perspective, adherence to the joint targeting cycle process and to other fundamental principles in the publication, coupled with sound command judgment, virtually assures compliance with the laws of war.

Thus, JP 3-60 appears to be a "plug and play" guidebook for targeting in any domain. Unfortunately, analysis which assumes that the cyber domain shares essentially the same characteristics with air, land, sea, and space fails to account for its uniqueness.

Like the other domains, cyberspace occupies an area, is subject to exploitation by governments and entrepreneurs, and serves as a medium for the exchange of commerce among corporations, nations, and individuals. Yet this unique medium "has to be appreciated on its own merits; it is a man-made construct."[34] Computers enable actions in near real time and may provide near anonymity for the user. The fact that criminals, terrorists, and state actors use the same cyber infrastructure employed by commercial enterprises and individuals to conduct their operations adds a "social context" to military operations in this domain.[35] In the air, space, and sea domains, relatively few adversaries are competent enough to effectively threaten or challenge the United States and its military. By contrast, the cyber domain is crowded with actors capable of pressuring, confronting, or intimidating the United States, its allies, and each other. This congested battlespace complicates using JP 3-60 as a guide to cyber targeting in five key areas: (1) positive identification of targets, (2) location of targets, (3) attribution of attack, (4) capability/target pairing, and (5) assessment of potential collateral damage.

First, positive identification of a potential cyber target is complicated by the intricacy of the dual-use global cyberspace infrastructure. The two sections of JP 3-60 that address target identification—chapter 2, "The Joint Targeting Process," and appendix E, "Legal Considerations in Targeting"—make clear that a valid and lawful military target requires a degree of distinctive identification and characterization conducted during either a normal or time-sensitive targeting cycle. Neither section addresses the fleeting nature or uniqueness of cyber targets or notes that the latter exist almost exclusively in a dual-use medium.

To illustrate, suppose that planners nominate three targets to a joint targeting coordination board, a group that "facilitates and coordinates joint force targeting activities . . . to ensure that the [joint force commander's] priorities are met."[36] The first nominated target is a tank, the second a website, and the third an online "persona." Initially, the board might validate the tank as a military target but hold that neither the website nor the persona qualifies as a valid military target as contemplated by JP 3-60 or the laws of war because it is not a physical object but a formulaic composition of ones and zeros—an incorrect assessment. In fact, JP 3-60 does not limit a target to the physical world, instead defining it as "an *entity* or object considered for possible engagement or action. It may be an area, complex, installation, force, equipment, capability, function, individual, group, system, *entity*, or *behavior* identified for possible action" (emphasis added).[37] This broad definition encompasses both the website and persona.

The lawfulness of engaging an adversary's tank is clear because of that weapon's exclusive purpose of destroying and killing within the confines of armed conflict, but a law-of-war analysis of the website and persona must go one step further. Both the website and persona would have to meet a "use" rather than a "purpose" test—that is, at the time of the proposed attack, is the adversary using them to further his war-fighting or war-sustaining capabilities? If so, then they may be the lawful objects of military attack. The exact timing of when these dual-use objects, entities, or behaviors in and through cyberspace actually contribute to the adversary's cause makes engagement difficult. Unlike the validation of targets during kinetic warfare, the process with cyber targets demands both consistent updating of the validating intelligence and positive identification in near real time.

Second, the location of a cyber target presents unique challenges. JP 3-60 and the laws of war address target location in the context of physical encroachment on a sovereign nation. Neither the doctrine nor the law contemplates one target existing in several different places around the globe at the same time or causing effects in multiple theaters of conflict, as can happen in cyberspace. For instance, an adversary can conduct command and control through websites hosted simultaneously on servers in different countries and can thwart attack by moving those websites frequently. Problematically, the particular ROEs applicable to the military planner and operator may preclude actions in certain places outside the joint operations area even though the adversary uses an ever-changing global network to deliver effects there. This dilemma leads to a significant and an important debate. What is the target? Is it the adversary physically located in the joint operations area, or is it his globally distributed command and control network? If location precludes engagement, then the military planner naturally reassesses the exact target. Is it the fielded forces or their networks?

Third, attribution of cyber capabilities, equipment, and usage to a particular, declared hostile entity is demanding in cyberspace. Even though attribution may fall under positive identification, this article treats it as a separate issue to illuminate differences between offensive and defensive cyber targeting.[38] The anonymity afforded by cyberspace allows an enemy to mask his actions and falsely attribute them to a noncombatant or any other entity. An adversary could hijack the computers of innocent civilians, groups, or governments and use them as a "bot net" to launch a cyber attack. Once the victim of the attack conducts rudimentary forensics, attribution of the attack would point to the innocent noncombatants rather than the true perpetrator. Strictly speaking (depending upon the amount of damage), the law of war could view such an attack as the war crime of perfidy. Practically speaking, if the attack were continual (e.g., a distributed denial of service), must the victim obtain positive identification of each target, in essence attributing it to a declared hostile entity, prior to launching defensive measures at the "attacking" computers? Fortunately, as mentioned above, the law of war recognizes the inherent right of self-defense (focusing on location of the threat) and does not require positive identification of the attacker. But in cyberspace, even a purely defensive response to an attacking computer could have severe cascading, unintended consequences for the global cyber infrastructure—not to mention the political nightmare of counterattacking against the wrong party.

Fourth, the pairing of capability and target in cyberspace entails unique issues. Offensive action may call for precision capabilities to avoid significant collateral damage. A defensive posture (or crisis response) may necessitate the use of powerful counterattack and deterrent capabilities against a broad range of attackers—creating more of a broad firewall rather than a pinpoint strike.

Fifth, the arduous process of assessing potential collateral damage in cyberspace demands significant intelligence, and the interconnectivity of networks and the redundancies in systems require meticulous planning. At present we have no formal methodology of collateral damage estimation for cyber targeting.[39] Applying kinetic formulas would be problematic because cyberspace exits at both physical and logical levels.

Despite these unique challenges to targeting in cyberspace, JP 3-60 provides a sufficient doctrinal framework for the military cyber operations planner.[40] There is, however, room for improvement and clarification with regard to cyber operations, particularly in the areas of collateral damage estimation and battle damage assessment.[41]

Recommendations

Improvements to existing cyber-targeting doctrine should start with a declaration in the next edition of JP 3-60 that the fundamentals described in the publication apply to targeting in the newly recognized cyber domain. Such a statement would have the twofold purpose of recognizing the importance and uniqueness of military operations in cyberspace and affirming the universality of the publication's combat-targeting principles.

As mentioned above, JP 3-60 should provide an overview of how to conduct collateral damage estimation and battle damage assessment in cyberspace, perhaps including tactics, techniques, and procedures for identifying other hostile and civilian websites located on a server or tracing potential second- and third-order effects and their likely geographic location. In reality, because most offensive cyber operations would not cause physical damage, JP 3-60 should describe methodology for determining collateral *effects* in cyberspace by distinguishing between effects and damage in cyberspace. This distinction should use "kinetic damage" (physical destruction or degradation caused by a cyber operation) as the determining criterion. Any cyber operation that does not cause physical destruction would yield only "effects." Planners would collect battle damage assessment only for actions that cause physical damage to intended targets and nontargeted systems and would measure collateral effects much as they do for other cyber operations.

An updated JP 3-60 should contain a brief section about the complexity of the cyber domain, utilizing the "Understanding Cyberspace" and "Operational Environment" sections of AFDD 3-12 as an excellent template.[42] Such a discussion would allow the joint planner to recognize the unique, additional considerations of deliberate and time-sensitive targeting in and through cyberspace.

Furthermore, the next version of JP 3-60 should pay careful attention to the differences between offensive and defensive cyber targeting—specifically, the level of attribution necessary for positive identification of a cyber target. For offensive cyber operations (e.g., CNA), attribution of a computer network, website, persona, or infrastructure should approach complete certainty (a true representation of positive identification) so as to comply with the law of war's principle of discrimination. Application of the principle of self-defense to cyberspace allows greater flexibility for the joint planner, having the goal of repelling an attack or imminent strike against friendly computer systems. The recommended course of action for cyber defense would involve implementing a sliding scale of adversary attribution whereby the confidence level is commensurate with the level of anticipated damage or effects produced by the response. At one end of the scale, a response whose scope, duration, and intensity will likely cause significant kinetic damage would demand almost complete certainty of attribution. At the other end, a purely technical—perhaps even automated—administrative self-defense action not really amounting to a use of force would require no attribution. Such cyber "countermeasures" include detecting, quarantining, and removing a virus or simply blocking malicious traffic and disrupting network connections between the attacking and targeted computers.

Finally, an updated JP 3-60 should introduce the concepts of an *adversary's cyber center of gravity* and a *cyberspace joint operations area*. An adversary's cyber presence consists of computers, information systems, hardware, online personas, and so forth, which may be geographically separated from his physical center of gravity. Once planners identify the cyber center of gravity (a critical point—a source of power for the adversary's cyber operations), they can target it. The joint task force commander would establish both the physical and logical boundaries of a cyber joint operations area and specify targeting ROEs for that area. Partitioning cyberspace in this manner minimizes the potential for cascading collateral damage and effects.

In conclusion, JP 3-60 offers the joint cyber war fighter adequate targeting guidance applicable to the cyber domain. With slight modification and incorporation of domain-specific guidance, however, that publication will become even more useful to cyber warriors. ✪

Notes

1. Wesley R. Andrues, "What U.S. Cyber Command Must Do," *Joint Force Quarterly* 59 (4th Quarter 2010): 117, http://www.ndu.edu/press/lib/images/jfq-59/JFQ59_115-120_Andrues.pdf.

2. Tom Gjelten, "Extending the Law of War to Cyberspace," National Public Radio Online, 22 September 2010, accessed 4 October 2010, http://www.npr.org/templates/story/story.php?storyId=130023318. For the purposes of this article, *kinetic* means physical actions traditionally associated with military combat.

3. DOD Directive (DODD) 2311.01E, *DOD Law of War Program*, 9 May 2006 (incorporating change 1, 15 November 2010), 2, http://www.dtic.mil/whs/directives/corres/pdf/231101e.pdf.

4. This article uses the term *principles* (1) within the context of targeting to describe the primary beliefs, accepted best practices, and military philosophy for producing desired operational effects, and (2) within the legal context to describe core tenets of law. Synthesized in joint publications, these meanings are broken out here to highlight certain differences between traditional kinetic military action and potential cyber operations.

5. Joint Publication (JP) 3-60, *Joint Targeting*, 13 April 2007, https://jdeis.js.mil/jdeis/new_pubs/jp3_60.pdf.

6. JP 1, *Doctrine for the Armed Forces of the United States*, 2 May 2007 (incorporating change 1, 20 March 2009), I-1, I-21, http://www.dtic.mil/doctrine/new_pubs/jp1.pdf.

7. The law of war is "a branch of public international law, and comprised of a body of rules and principles observed by civilized nations for the regulation of matters inherent to, or incidental to, the conduct of a public war." *Black's Law Dictionary*, 6th ed. (St. Paul, MN: West Publishing, 1990), 1583.

8. International Conferences (The Hague), *Hague Convention (IV) Respecting the Laws and Customs of War on Land and Its Annex: Regulations Concerning the Laws and Customs of War on Land*, 18 October 1907, http://www.icrc.org/ihl.nsf/full/195. Hereafter Hague IV. See also *Hague Convention (III) Relative to the Opening of Hostilities*, 18 October 1907, http://www.icrc.org/ihl.nsf/FULL/190?OpenDocument; *Hague Convention (V) Respecting the Rights and Duties of Neutral Powers and Persons in Case of War on Land*, 18 October 1907, http://www.icrc.org/ihl.nsf/FULL/200; and Geneva Conventions I–IV, 12 August 1949, International Committee of the Red Cross, http://www.icrc.org/eng/war-and-law/treaties-customary-law/geneva-conventions/index.jsp.

9. Charter of the United Nations, Article 2(4), 26 June 1945, http://www.un.org/en/documents/charter/chapter1.shtml.

10. Hague IV, Article 23(g).

11. Hague IV, Article 23(e).

12. United Nations General Assembly Resolution 2444 (XXIII), 19 December 1968, as cited in International Committee of the Red Cross, *Weapons That May Cause Unnecessary Suffering or Have Indiscriminate Effects: Report on the Work of Experts* (Geneva, Switzerland: International Committee of the Red Cross, 1973), 13, http://www.loc.gov/rr/frd/Military_Law/pdf/RC-Weapons.pdf.

13. See Geneva IV, Articles 4 and 27.

14. Judge Advocate General's School, *Air Force Operations and the Law: A Guide for Air, Space, and Cyber Forces*, 2nd ed. (Maxwell AFB, AL: Judge Advocate General's School, 2009), 21, http://www.afjag.af.mil/shared/media/document/AFD-100510-059.pdf. See the introduction to Hague IV: "The inhabitants and the belligerents remain under the protection and the rule of the principles of the law of nations, as they result from the usages established among civilized peoples, from the laws of humanity, and the dictates of the public conscience."

15. JP 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 8 November 2010 (as amended through 15 May 2011), 362, http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

16. See MAJ Keith E. Puls, ed., *Law of War Handbook* (Charlottesville, VA: International and Operational Law Department, Judge Advocate General's Legal Center and School, US Army, 2005), 139–42, http://www.loc.gov/rr/frd/Military_Law/pdf/law-war-handbook-2005.pdf.

17. Air Force Doctrine Document (AFDD) 2-1.9, *Targeting*, 8 June 2006, http://www.e-publishing.af.mil/shared/media/epubs/AFDD3-60.pdf.

18. Cyberspace is a global domain. See JP 1, *Doctrine for the Armed Forces of the United States*, GL-7; and Cheryl Pellerin, "Cyberspace Is the New Domain of Warfare," *U.S. Air Force AIM Points*, 18 October 2010, accessed 20 October 2010, http://aimpoints.hq.af.mil/display.cfm?id=41748&printer=no.

19. Maj Steve Smart, "Warfare in the Cyberspace Domain" (thesis, Air Command and Staff College, Maxwell AFB, AL, 2010), 3. This is the author's proposed new definition of "cyberspace domain." The characterization of cyberspace as an operational domain is sensitive and controversial. See the unclassified "White House Guidance Regarding the Use of 'Domain' in Unclassified Documents and Public Statements," 14 March 2011. (FOUO)

20. Christina Mackenzie, "Do No Harm," *Aviation Week: Defense Technology International—Cyber War Issue*, September 2010, 37.

21. Ibid.

22. Michael Dumiak, "Casus Belli," *Aviation Week: Defense Technology International—Cyber War Issue*, September 2010, 31.

23. The undersecretary of defense for policy and the chairman of the Joint Chiefs of Staff will revise IO policy and doctrine documents to reflect directed integration of IO into military operations and away from a focus on its core capabilities. This shift marks a significant step toward "mainstreaming" cyber operations. See Robert Gates, secretary of defense, memorandum, subject: Strategic Communication and Information Operations in the DOD, 25 January 2011, http://www.carlisle.army.mil/dime/documents/Strategic%20Communication%20&%20IO%20Memo%2025%20Jan2011.pdf.

24. JP 3-13, *Information Operations*, 13 February 2006, I-1, http://www.dtic.mil/doctrine/new_pubs/jp3_13.pdf. The new definition of IO is "the integrated employment, during military operations, of information-related capabilities in concert with other lines of operation to influence, disrupt, corrupt, or usurp the decision-making of adversaries and potential adversaries while protecting our own." See Gates, memorandum, 2.

25. JP 3-13, *Information Operations*, II-1.

26. See JP 3-13.1, *Electronic Warfare*, 25 January 2007, https://jdeis.js.mil/jdeis/new_pubs/jp3_13_1.pdf; and JP 3-13.2, *Psychological Operations*, 7 January 2010, https://jdeis.js.mil/jdeis/new_pubs/jp3_13_2.pdf.

27. This is not to suggest that the DOD offers no cyber guidance but to make the point that little warfighter guidance exists. See DODD 3600.01, *Information Operations (IO)*, 14 August 2006, http://www.dtic.mil/whs/directives/corres/pdf/360001p.pdf; and DODD O-8530.1, *Computer Network Defense (CND)*, 8 January 2001.

28. AFDD 3-12, *Cyberspace Operations*, 15 July 2010, 2, http://www.e-publishing.af.mil/shared/media/epubs/AFDD3-12.pdf.

29. Ibid., 16–20, 22–28.

30. See AFDD 3-12, *Cyberspace Operations*.

31. US Cyber Command is working various roles and missions in the cyber domain and is building a "unified vision." Mark V. Schanz, "Cyber Command Working Out Roles and Relationships," Daily Report, *airforce-magazine.com*, 21 October 2010, http://www.airforce-magazine.com/DRArchive/Pages/default.aspx. The 460th Space Wing at Buckley AFB, CO, completed its first exercise focused exclusively on cyber issues. MSgt J. LaVoie, "A First-of-Its-Kind Cyber Exercise," Daily Report, *airforce-magazine.com*, 29 October 2010, http://www.airforce-magazine.com/DRArchive/Pages/default.aspx.

32. JP 3-60, *Joint Targeting*, II-3.

33. Ibid.

34. Martin C. Libicki, *Cyberdeterrence and Cyberwar* (Santa Monica, CA: RAND Corporation, 2009), 11, http://www.rand.org/pubs/monographs/2009/RAND_MG877.pdf.

35. See Timothy L. Thomas, *Cyber Silhouettes* (Fort Leavenworth, KS: Foreign Military Studies Office, 2005), 19.

36. JP 3-60, *Joint Targeting*, III-2.

37. Ibid., I-2.

38. A policy debate is in progress among cyber professionals and government leaders about the necessity of positive identification for all cyber operations and its feasibility during crisis responses.

39. See United States Joint Forces Command, *Joint Fires and Targeting Handbook* (Suffolk, VA: Joint Warfighting Center, Joint Doctrine; Norfolk, VA: Joint Capability Development, Joint Integrated Fires, 19 October 2007), http://www.dtic.mil/doctrine/doctrine/jwfc/jntfiretar_hdbk.pdf.

40. Maj Kevin Beeker (acting J2T, US Cyber Command) and MSgt Dustin Dargis (US Cyber Command), interviews with the author, 2–4 November 2010.

41. Ibid.

42. AFDD 3-12, *Cyberspace Operations*, 2–5.

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Embracing Autonomy

The Key to Developing a New Generation of Remotely Piloted Aircraft for Operations in Contested Air Environments

Caitlin H. Lee

On 22 March 2011, two US Air Force pilots ejected from an F-15E Strike Eagle that crashed in Libya, beginning a complex rescue mission with life-or-death consequences. The US Marine Corps launched a search-and-rescue package of two V-22 Ospreys, two CH-53E Super Stallion helicopters, and two AV/8B Harrier jets. An Osprey rescued one of the pilots after the Harriers dropped two bombs to keep locals away. Rebel forces took in the other pilot, eventually turning him over to US forces.[1]

A few months later, on 21 June 2011, a heavy antiaircraft weapon shot down a US Navy remotely piloted helicopter over Libya, its remains scattered around a stronghold loyal to Mu'ammar Gadhafi—the object of its surveillance.[2] This time, rather than launching a complex search-and-rescue mission, Navy officials simply expressed disappointment in losing the Fire Scout's full motion video feeds. "The loss of aircrews would have been much worse if that had happened, but operationally it did impact us," said Capt Patrick Smith, Navy and US Marine Corps program manager for Multi-mission Tactical Unmanned Air Systems. "We always want our air vehicles to come back to us. The downside of it is the loss of capability. . . . It does impact what the war fighters have available in their magazine to continue operations."[3]

The contrast between these two incidents highlights the political and military advantage of remotely piloted aircraft (RPA) and the critical need for their evolution if they are to continue to provide an operational edge in an increasingly complex air environment. The Pentagon must fully embrace the concept of autonomy, thus allowing RPAs to perform the more complicated tasks expected of aircraft in the coming decades. Failing to do so would represent a missed opportunity to pursue a new generation of RPAs that could save American lives; potentially outperform their manned counterparts in contested airspace; and multiply political options, giving US leaders the flexibility to choose between a manned or remotely piloted system for surveillance and strike missions, depending on the political and security circumstances.

Today we risk losing the advantages offered by autonomous RPAs. The *United States Air Force Unmanned Aircraft Systems Flight Plan, 2009–2047* predicts that autonomy will compress decision cycles in combat to "micro or nano seconds" by perceiving a situation and acting independently with limited or little human input.[4] Quick decision making could allow autonomous RPAs a decisive operational advantage in fast-moving, information-saturated (i.e., complex) air environments. For these RPAs to advance to this point, however, the flight plan suggests that they must attain "a level of trust approaching that of humans charged with executing missions"—trust built incrementally over time.[5]

Today, RPAs are far from inspiring such confidence. Gen Norton Schwartz, Air Force chief of staff, has plainly stated that autonomous systems are not ready to support development of a next-generation remotely piloted bomber.[6] Lt Gen David Deptula, USAF, retired, who released the flight plan in 2009, questioned whether RPAs would ever garner sufficient confidence from US leadership to perform the most high-threat, politically sensitive missions: "Technologically, we can take [RPA autonomy] pretty far, but it won't be technology that is the limiting factor; it will be policy. . . . For example, will US leadership accede to sending off an aircraft with 12 to 20 2,000-pound bombs and have it independently target and deliver them? How about with nuclear weapons? I don't think so."[7] The international community and the American public have also indicated a distrust of RPA autonomy. The National Air and Space Museum in Washington, DC, was closed on 8 October of this year when protesters tried to enter the building to object to an RPA exhibit.[8] A United Nations report of May 2010 concluded that RPAs promote a "Playstation" mentality toward killing.[9] Questions about trusting remotely piloted technology also raise a broader issue about the direction in which RPAs may take the Air Force. Embracing a new generation of highly autonomous, remotely piloted systems may eventually require a sweeping reinterpretation of what it means to be a pilot or even an Air Force officer—a topic worthy of further exploration.

Though difficult, building stakeholders' confidence in autonomy is essential since, if RPAs are to remain a highly effective option, they will need to act more independently. This article calls on the Pentagon to take the lead in building trust in autonomy through sustained and systematic investment in the development and testing of new, autonomous systems for RPAs. It begins by describing why these aircraft will need more autonomy to operate in the emerging security context. The article then devotes considerable attention to more fully defining the concept of autonomy, arguing that a fuller understanding of the latter as a matter of degree—rather than an all-or-nothing proposition—can mitigate some doubts about independent RPA operations. It also contends that because today's RPAs have not been sufficiently tested in dynamic air environments to determine their true limits, the Pentagon should aggressively fund the development of new verification and validation procedures to build the trust and confidence required to ensure continuation of the momentum for development of autonomous technology. In particular, the article notes that the Air Force's plan to build a new long-range bomber offers a unique opportunity to develop and test autonomous decision aids that can "dial in" various levels of autonomy, depending on the mission.

Threat Assessment: A More Complex Air Environment

The General Atomics Aeronautical Systems, Incorporated (GA-ASI) MQ-1 Predator became the world's first weaponized RPA after live-fire tests in 2001. Since then, both the Predator and the larger, more heavily armed GA-ASI MQ-9 Reaper drones have conducted strike missions. The Central Intelligence Agency (CIA) also uses the Predator to carry out covert or "black" operations against suspected al-Qaeda targets. RPAs conducted 117 strikes on targets in Pakistan in 2010, up from just 53 in 2009.[10] Though capable of carrying arms, these drones spend most of their time conducting intelligence, surveillance, and reconnaissance missions; detecting targets and alerting other strike aircraft to their presence; or identifying threats such as improvised explosive devices to ground forces. These so-called hunter-killer RPAs, with their long-loiter capability, have proven well suited to conducting low-level policing actions in Afghanistan and Iraq.[11]

However, today's RPAs would struggle in enemy-controlled airspace due to a lack of survivability and insufficient capacity to respond to contingencies such as incoming threats and changes in the weather. Operational experience suggests as much: US and North Atlantic Treaty Organization (NATO) allies lost at least 15 RPAs in Kosovo to heat-seeking missiles and fire from door gunners in helicopters flying alongside them.[12] Some of the aircraft lost in the conflict were early models of the Predator.[13] Kosovo represents the last time that allied RPAs faced a highly contested air environment, and the nature of armed RPA missions in Iraq and Afghanistan has not presented a pressing need to adapt to new threats.

To remain integral to US air operations in the future, RPAs must evolve to operate in more dangerous air environments. Indeed, the battlespace will not get any easier for the current generation of RPAs. Without venturing into the perilous business of predicting the nature of future conflicts, one may still make some inferences about the changing character of the global air environment (inferences essential to force planning). The United Kingdom's (UK) Ministry of Defence paints a daunting picture of "congested, cluttered, contested, connected and constrained" airspace.[14] A brief assessment of this environment highlights why the current generation of RPAs needs to evolve.

Most significantly, RPAs will have to operate in more contested airspace. As the current conflicts wind down, the US military is shifting its planning focus from operations in benign airspace to those in contested air environments on a global scale—a change embodied in the Air Force's agreement with the Navy to develop an operational plan known as AirSea Battle. This plan stems from growing US concern that rising powers with access to emerging weapon systems—such as China, Iran, and North Korea—may seek to deny US access to air, sea, and space.[15] Already widely available and posing a serious threat to American aircraft, "double digit" surface-to-air missiles (SAM) such as Russia's SA-10 and SA-20 boast greater engagement range and speeds as well as higher probability of kill than older SAM systems.[16] NATO was so concerned about these systems that it decided against sending Airborne Warning and Control System aircraft into Georgia during the conflict with Russia in 2008 due to the latter's deployment of the SA-20.[17] China possesses both SA-10 and SA-20 missiles.[18] Other SA-20 customers may include Iran, Syria, Libya, and Algeria, among others.[19] It also seems plausible that the recent Fire Scout shoot-down involved a SAM, based on the Navy's description of events. Although still in the developmental stages, next-generation air-to-air threats also represent an emerging challenge. China recently unveiled its new J-20 stealth fighter, and India and Russia have partnered to build a "fifth generation" fighter known as PAK-FA. These fighter development programs aim to incorporate stealth technology and sophisticated radars that allow a pilot to target an adversary beyond visual range (BVR), killing the enemy before the enemy sees him or her. Today America has the corner on the BVR market, but research and development under way in China and Russia could change that status. Lastly, short- and medium-range missiles pose a threat to US overseas bases that station short-range aircraft and provide them with landing and refueling facilities.

All of these perils challenge American air dominance. During a speech at the US Air Force Academy in March of this year, former secretary of defense Robert Gates confirmed that the US military no longer can take for granted ownership of the skies in future conflicts: "It would be irresponsible to assume that a future adversary—given enough time, money, and technological acumen—will not one day be able to directly threaten U.S. command of the skies."[20] General Schwartz confirmed the requirement to field new aircraft that can operate in contested airspace in 2010 when he said that the Air Force must balance its budget between assets to fight today's wars "while recognizing that proliferation of anti-access and area-denial capabilities will increasingly challenge America's ability to penetrate contested airspace."[21]

Additionally, as mentioned above, the UK Ministry of Defence warned that the battlespace will become more congested, cluttered, connected, and constrained. Congested airspace is already a major issue in terms of deconflicting the flight paths of manned and remotely piloted platforms, not only in the continental United States but also in combat zones—witness the destruction of an Army RQ-7 Shadow in a collision with an Air Force C-130 over Afghanistan on 15 August 2011.[22] The fact that adversaries hide among civilian populations also clutters the battlespace, presenting a daunting challenge for both manned and remotely piloted aircraft surveillance systems, which will need to sift through large amounts of data to identify targets of interest. Furthermore, the importance of aircraft in establishing communications links and situational awareness in the battlespace reflects the air environment's emerging feature of connectedness. RPAs need large amounts of bandwidth for two-way satellite communications, and they cannot operate without links to their operators. Overall, it is clear that today's RPAs are poorly positioned to accommodate these realities of the battlespace. Even if they did already possess the autonomy necessary to overcome these challenges, they would be severely constrained by major legal and ethical concerns regarding their operations in more demanding combat operations, as noted in the report of the UK Ministry of Defence.[23]

Overcoming this fundamental distrust of autonomy is easier said than done. Yet if the Pentagon takes deliberate steps to develop and test new autonomous decision aids, confidence in autonomous RPAs will likely build over time. After carefully testing and allowing autonomous systems to mature, we would find that their use on board RPAs would almost certainly give the United States and its allies a considerable operational advantage. Indeed, a new generation of these aircraft could actually outperform their manned counterparts in the perilous environment described above.

Autonomy: Key to the Evolution of Remotely Piloted Aircraft

Autonomy will be the driving force behind the development of a new generation of RPAs optimized for more complex air environments, and human *distrust* in autonomy will lie at the heart of limitations on the design and deployment of these aircraft. Given the huge role that autonomy will play in determining the extent to which the US military effectively incorporates new RPAs into its inventory, it is essential to define this concept. Doing so will allow for a practical discussion of how autonomous systems could enhance the design of RPAs in a way that addresses serious and legitimate concerns about their operations in the battlespace.

Currently no universally agreed-upon definition of autonomy exists, but a consensus is emerging in the engineering and scientific community that a good starting point involves viewing it as degrees of RPA independence from human control. In 1978 Thomas Sheridan and William Verplank laid the groundwork for describing autonomy in terms of a continuum of human and machine interaction rather than an all-or-nothing concept (see table on the next page).[24] One end of the spectrum represents full manual control with

Table. Levels of automation in man-computer decision making

Automation Level	*Automation Description*
1	The computer offers no assistance: human does the whole job up to the point of turning it over to the computer to implement.
2	The computer helps by determining the options.
3	The computer helps determine options and suggests one, which the human need not follow.
4	The computer selects action, and the human may or may not do it.
5	The computer selects action and implements it if the human approves.
6	The computer selects action, informs the human in plenty of time to stop it.
7	The computer does the whole job and necessarily tells the human what it did.
8	The computer does the whole job and tells the human what it did only if the human explicitly asks.
9	The computer does the whole job and tells the human what it did if it decides he should be told.
10	The computer decides whether or not to do the whole job. If it decides to do the job, it can determine whether or not to tell the human about it.

Source: Adapted from Thomas B. Sheridan and William L. Verplank, *Human and Computer Control of Undersea Teleoperators* (Cambridge, MA: Man-Machine Systems Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, 1978), table 8.2, pages 8-17 through 8-19.

no computer assistance, and the other represents full machine control with machines doing everything and ignoring human input.

Mark Maybury, the Air Force's chief scientist, put these degrees of autonomy in the context of RPA design, describing four levels of human control: (1) "no autonomy" (i.e., complete manual control of the RPA); (2) "partial automation," with a human "in the loop" manually performing some tasks; (3) "supervisory control," with a human in the loop overseeing or guiding tasks, or selecting among possible alternative actions; and (4) "full autonomy," with no human intervention other than starting or canceling an action.[25]

The scientific community widely acknowledges Sheridan and Verplank's levels of automation as a starting point for describing autonomy in terms of degrees of human control. Viewing autonomy as a continuum frees RPA designers and operators to develop and employ decision aids for these aircraft at varying levels of autonomy on a case-by-case basis, depending upon the RPA's mission.[26] In the context of a next generation of RPAs, the existence of such distinctions invalidates the notion of having to choose only between a manned "manual control" aircraft and a "fully autonomous" RPA.

Although Sheridan and Verplank's definition is useful for understanding that autonomy entails something more than all or nothing, it does not fully flesh out two other very significant dimensions of autonomy: mission complexity and environmental complexity (see figure on the next page). Mission complexity measures an autonomous system's ability to perform various missions and tasks, ranging from those at the lower level (e.g., simple sensors and actuators supporting basic flight control and guidance, such as maintaining altitude) to those at the higher campaign level (e.g., planning or operating multiship RPA actions such as distributed search, tracking, and weapons engagement).[27] Environmental complexity measures an autonomous system's ability to adapt and respond to changes in the environment, such as terrain and climate variations as well as the availability of communications.

The multidimensional definition is important because it conveys the reality that RPAs must do more than operate independently from human control; after all, so can a washing machine.[28] Effective RPA autonomy involves developing decision aids that can work independently, understand the air

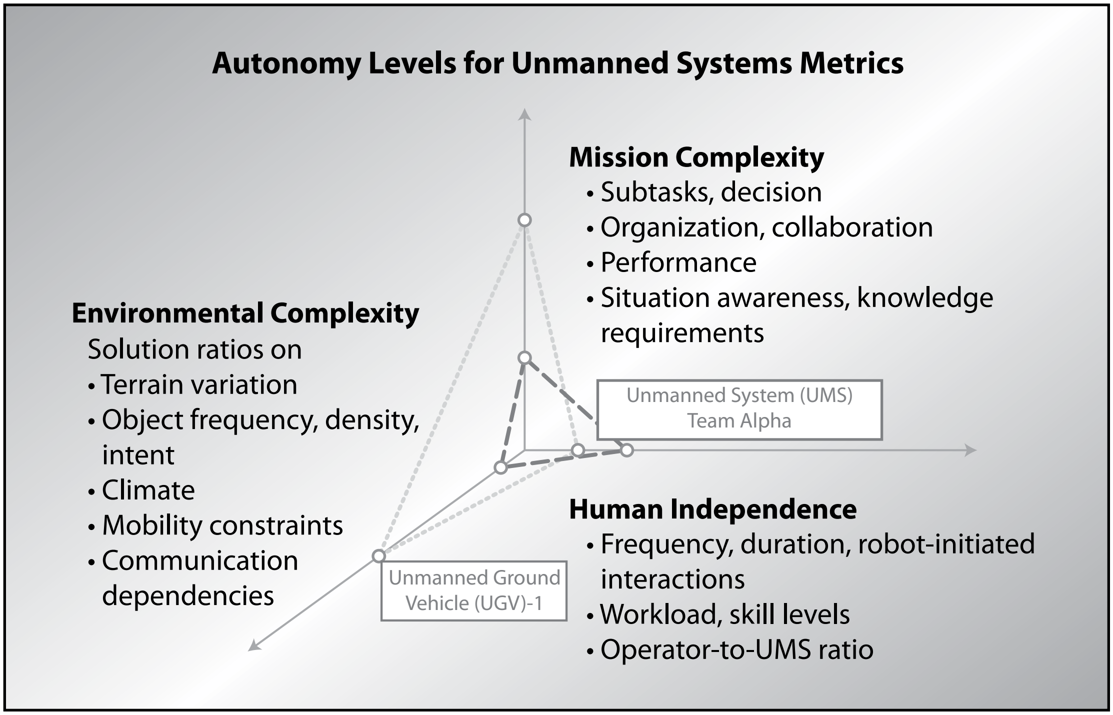

Figure. The three dimensions of autonomy. (Adapted from Hui Min-Hang, "Autonomy Levels for Unmanned Systems [ALFUS]," National Institute of Standards of Technology, ALFUS Working Group, slide 8, accessed 23 July 2011, http://www.nist.gov/el/isd/ks/upload/ALFUS-BG.pdf.)

environment, and operate effectively in that environment with other systems.

This multifaceted view of autonomy lends itself well to describing RPA operations in complex air environments. These platforms may need a high degree of independence from a human to operate quickly in response to changes in such environments, from weather patterns to pop-up threats like a mobile SAM. Mission complexity would also become important if, for example, a swarm of RPAs were operating together to conduct distributed identification, tracking, and prosecution of that SAM.

Further fleshing out the multidimensional definition of autonomy, one can identify specific ways in which decision aids would enable RPA operations. Activity in congested airspace, for example, would benefit from the development of new air- and ground-based collision-avoidance systems. After the recent collision of an RQ-7 with a C-130, mentioned previously, the Army noted that a sense-and-avoid technology now under development could have prevented the mishap.[29]

The Small Sense and Avoid System (SSAAS), under development by the Army in partnership with AAI, a Textron Systems operating unit that makes the Army's RQ-7 Shadow, includes three electro-optical cameras mounted on the nose of the Shadow, designed to collect live video feeds of the airspace. High-speed processors identify moving objects in the video and then send that information to the flight-control system and ground operators. The initial concept of operations for the technology involves the ground operator's receiving data about an object in the Shadow's flight path and then redirecting the

RPA. Over the long term, however, autonomous decision aids will come into play. Ultimately, SSAAS seeks to maneuver the aircraft first and then inform the operator.[30]

RPA activity in cluttered operational scenarios, in which friendly and enemy forces are intermingled, also could benefit from new autonomous decision aids that can improve situational awareness. The Navy, for example, is installing the Telephonics RDR-1700B maritime radar on the Fire Scout, which will allow the RPA to track vessels at a greater standoff range. Able to cue an electro-optical/infrared camera, the radar can track more than one vessel at a time, so Fire Scout operators will need new autonomous decision aids to help determine which target they should single out for further electro-optical/infrared tracking.[31]

Moreover, enhanced RPA autonomy will enable more connectedness—another essential ingredient for operating in complex air environments. The Navy's Unmanned Combat Air System Demonstration program will build on the success of the automated takeoff and landing system installed on the manned F/A-18 Hornet fighter jet to develop an RPA—the X-47B—that can take off and land on a carrier deck.[32] With no pilot in the cockpit, the RPA needs more robust communications links to remain in contact with the carrier throughout the flight envelope, rather than just on approach, so that the aircraft can try to land again if it skips the arresting hook on the carrier deck. Additionally, a new automated messaging system will allow the carrier's air traffic control to send messages to the X-47B about its operations in congested airspace around the carrier.[33] Even though automated messaging will increase connectedness, it is also important to note that other autonomous decision aids will reduce RPAs' requirements for connectedness, removing their tether to vulnerable satellite and Global Positioning System (GPS) data links. (Alternatives to the GPS currently under investigation at the Air Force Institute of Technology include radio beacons as well as man-made and naturally occurring signals of opportunity, such as magnetic fields and vision aiding.)[34]

Lastly—and perhaps most significantly, given the emergence of new air-based threats—autonomy will be essential to the operation of RPAs in contested airspace. In this dynamic environment, autonomy will allow RPA weapons to respond to threats—such as SAMs—quickly and efficiently without waiting for a human operator to make every incremental decision. In one extreme example, autonomous decision aids could enable an electronic jamming system to detect an enemy signal, determine an electronic response, and jam the signal before a human RPA operator has time to react. In the near term, autonomous decision aids could simply identify incoming frequencies and defer a decision on how to respond to the human operator.

All of these innovations in autonomy have the potential to increase decision speed dramatically. According to the Air Force's 2010 science and technology road map, in a fast-changing and contested air environment, autonomous decision making could enable "operational advantages over adversaries who are limited to human planning and decision speeds."[35] RPA autonomy may also provide a key advantage as war becomes "too complex for a human to direct," requiring autonomous decision aids to handle information overload.[36] Retired general James Cartwright, former vice-chairman of the Joint Chiefs of Staff, notes that the "competitive" edge provided by RPAs "is in the cognitive power we can put into those platforms to operate and inter-operate with each other without intervention of a human being."[37] In other words, autonomous RPAs could allow the United States to sort through the complexities of decision making in combat—a process described by military strategist John Boyd as the observe, orient, decide, act loop—more quickly than an opponent, striking before the adversary can respond.

Roadblocks to the Deployment of Autonomous Systems

Given the significant advantages offered by autonomous systems, it seems that, from a purely technological perspective, we should develop and add a new generation of RPAs to the US aircraft inventory. Deployment of a highly capable robotic aircraft fleet holds the promise of meeting or exceeding the Pentagon's requirements for operating in complex air environments, reducing risk to American lives, and creating new options for decision authorities. However, doing so depends upon Pentagon decision makers agreeing on the degree of autonomy needed by new types of RPAs and then deciding on whether they are willing to make the investment necessary to adequately fund research, development, and testing of the appropriate autonomous systems.

As discussed earlier, autonomy is an "adjustable" concept that one can employ to varying degrees, depending upon the role of an aircraft and its mission—a critical point because of the tendency to view autonomy as an all-or-nothing proposition. For example, an influential report on long-range strike from the Center for Strategic and Budgetary Assessments claimed that without either full autonomy or a human making all decisions on the ground, a remotely piloted bomber would be little better than a (reusable) cruise missile.[38] The argument maintains that such a bomber will not exert an operational advantage in contested airspace until it has the "true autonomy" necessary to respond at least as quickly and efficiently as a human. Thus the bomber would need autonomous decision aids at least as capable of the same 360-degree situational awareness and rapid-response time that a pilot brings to the cockpit. By this standard, the bomber must have sensors to understand a dynamic threat situation and highly autonomous systems to make decisions about target cueing and weapons release as quickly as a human could.

However, one cannot say without question whether only "true" autonomy would allow a bomber to operate effectively in such an environment. Although true autonomy may lie beyond the limits of today's technology, remotely piloted bombers capable of highly autonomous operations in some level of contested airspace are certainly within reach.[39] Industry is already prototyping new autonomous decision aids to enable the use of these platforms in such situations. According to Michael Leahy, Common Mission Management Systems program manager at Northrop Grumman, "The ability [of an RPA] to go in, route around threats like ground radars, integrated air defense systems, and other threats, to then recognize those threats and retask itself, has already at some levels been demonstrated and is today in the prototyping stages."[40]

As these decision aids continue to mature, the question of how much trust one should place in remotely piloted systems becomes increasingly urgent. The CIA hesitated to deploy the first armed Predator due to concerns about unproven technology as well as ethical and legal issues.[41] More autonomous RPAs optimized for high-risk environments will fuel similar apprehensions. The possibility that RPAs might have to operate with a mix of manned and remotely piloted platforms raises the issue of fratricide, just as the prospect of a remotely piloted bomber carrying nuclear weapons (in which case nuclear surety and safety requirements would come into play) brings up questions about mission reliability.

To move forward with the development of a new generation of RPAs, decision makers must recognize that one can adjust the degree of their autonomy in accordance with the role and mission and that robust testing can build trust in autonomous decision aids. If they wish to advance beyond prototyping, Pentagon officials have to determine whether they are ready to foster a research and development environment that promotes breakthroughs in remotely piloted systems. In particular, we must bring into play comprehensive computer simulations and live-testing programs to establish trust in the safety and reliability of autonomous RPA operations.

Institutionalized testing procedures will become even more important as innovation allows for more rapid and independent RPA decision making. A report by the UK Ministry of Defence on the future of RPAs predicts that fielding artificially intelligent RPAs—totally independent from human control—

could be anywhere from five to 15 years away and that this capability will likely raise not only ethical but also legal problems with their operational deployment. The report questions whether such an RPA could make targeting decisions based on guiding principles of the Laws of Armed Conflict, such as proportionality and distinction.[42]

Clearly, the deployment of a new generation of more autonomous RPAs depends upon their ability to give the United States a military advantage without risking lives. Without robust testing procedures, such platforms optimized for use in complex battlespaces will likely lose political and financial support to more technologically mature manned aircraft options or "optionally manned" designs. Granted, such options might complete the mission, but they do not offer some of the major advantages of autonomous RPAs.

Requirements of the Long-Range Bomber: The Importance of Innovation in Autonomous Systems

Concerns about the development of autonomous systems are playing out in the Pentagon's decision to build an optionally manned long-range bomber. This design appears to represent a compromise between those who believe that autonomous RPAs are ready to operate in complex air environments and those who do not. Dr. Mark Lewis, former chief scientist of the US Air Force, compared this configuration to "the age of the sail," referring to the nineteenth century practice of putting both steam engines and sails on ships, the sail serving as a backup in case the engine failed.[43]

One the one hand, as mentioned earlier, General Schwartz does not believe that RPA technology has evolved sufficiently to permit effective operations in contested airspace: "Current technology does not allow for the type of fully autonomous and dynamic systems that are required in an opposed and degraded network environment."[44] On the other hand, as recently as the summer of 2011, General Cartwright asserted the readiness of a remotely piloted bomber for operational deployment: " 'Nobody has shown me anything that requires a person in that airplane,' he said. That applies, too, if the future bomber carries out the nuclear mission, he said. 'I don't remember the last time I manned an ICBM or SLBM or a cruise missile, so I'm not sure I understand that logic.' "[45]

An optionally manned design allows the Pentagon to begin to explore the possibilities of more autonomous RPAs without fully committing to their use in contested air environments. In its report, the Center for Strategic and Budgetary Assessments says that an optionally manned bomber will provide "mission flexibility," flying without a crew for long durations in high-threat areas and flying with a crew when pop-up threats, fleeting targets, and nuclear targets demand the presence of humans.[46] Given the need to further develop and test autonomous systems for threatening environments, perhaps this cautious approach makes sense (although one can certainly debate the financial benefits of adopting a hybrid design). That said, an optionally manned design could easily become little more than a political label while in practice the bomber ends up optimized for a pilot in the cockpit and flies most of its missions in a manned configuration. This scenario would represent a major missed opportunity to develop and test autonomous decision aids that will increase the safety and effectiveness of remotely piloted systems.

A closer examination of the benefits of a remotely piloted bomber—equipped with sufficient autonomous decision aids—demonstrates the importance of sustaining momentum for the development and testing of highly autonomous RPAs. Pentagon officials have described requirements only in general terms: a "long-range, nuclear-capable penetrating bomber" that will "have the option of being piloted remotely."[47] That said, one can still identify some broad requirements for the bomber, based on the Pentagon's AirSea Battle operational scenario and the UK Ministry of Defence's analysis of increasingly complex air environments.

Given these assumptions, the bomber likely will need significant capability in at least four areas: range and persistence, survivability, independence of action, and affordability. An analysis of these attributes indicates that, when the technology is ready, a highly autonomous, remotely piloted bomber could deliver at least the same level of capability as—if not more than—a manned version.

In range and persistence—perhaps the most critical of all the requirements—one finds the biggest advantage that RPAs have over manned platforms.[48] Because US military bases overseas face threats from ballistic missiles, the new bomber will have to fly great distances from locations in the continental United States. The absence of human limitations on flight time (such as the need to eat, sleep, and go to the bathroom) increases the range of a remotely piloted system. Innovations in autonomous aerial refueling also create the possibility of further extending those ranges.[49]

Once the bomber reaches the area of operations, persistence becomes paramount. In 2010 General Schwartz said that long-range strike assets must be able to "gain access to, and then loiter in, potentially denied or contested airspace, in order to find, fix and track high value targets."[50] A remotely piloted bomber could loiter for extended periods of time to identify targets, possibly retask dynamically to hit emerging targets, and conduct battle damage assessment after an attack. Like a manned bomber, it could also return in the event of a mission cancellation.

The proliferation of new air threats such as double-digit SAMs demands that the new bomber be highly survivable. Obviously the remotely piloted option eliminates any risk to aircrews. Of course, to complete its mission effectively, the aircraft would still need stealth characteristics, the ability to reroute its flight path to avoid SAMs, and self-protection systems. In terms of stealth, a remotely piloted design eliminates the cockpit, thereby making for a smaller aircraft that could have a less-detectable radar cross section.[51] Although some question exists about the degree of reduction in that cross section, an autonomous RPA clearly has the potential to adopt the decision aids necessary to let it reroute around SAMs as well as employ jamming and air-to-air-missiles—and do so more quickly than a human could.

Independence of action would allow the bomber to quickly and responsively employ self-protection and route around threats in hostile airspace. Such independence calls for major—but attainable—advances in autonomy already being demonstrated piecemeal across the aviation industry, as described above. If effectively tested and integrated into a remotely piloted design, autonomous decision aids could enable development of a bomber with "cognitive" capability and decision speed surpassing that of a human. Eventually, autonomous systems could allow independence to the extent that perhaps only one human in the loop could operate several RPAs flying together in a "swarm." Researchers at the Massachusetts Institute of Technology are investigating such swarming concepts today, as are personnel at General Atomics, maker of the MQ-1 Predator and MQ-9 Reaper.[52]

Finally, in these times of fiscal austerity (the Pentagon budget is expected to flatten over the coming decade), keeping costs down becomes an important consideration.[53] A remotely piloted bomber, made smaller by eliminating the cockpit and cabin, could offer an advantage here as well. Most savings, however, would come in the form of reductions in life-cycle costs associated with flight hours since pilots would not need to maintain currency in the bomber, and in expenses associated with sorties and attrition rates, the number of which would decline because of the remotely piloted bomber's greater endurance.

Conclusion

Despite the clear operational advantages of more autonomous RPAs, this article does not insist that the Pentagon develop a totally independent bomber. Rather it urges that we embrace autonomy in RPAs by recognizing the adjustable nature of autonomous decision aids and realizing the importance of investing more time and attention in testing procedures that can build trust in these systems. Development of a remotely piloted bomber offers an excellent opportunity to mitigate any lingering distrust—assuming a sincere commitment to such a viable option—since the process will necessarily involve the evolution and testing of new autonomous decision aids. Furthermore, building an optionally manned bomber could dispel the all-or-nothing view of autonomy and validate its adjustability to the mission set.

We must maintain the momentum for developing and testing autonomous decision aids. By failing to fully embrace advances in autonomy, we miss an opportunity to pursue a new generation of RPAs that could save American lives by taking a pilot out of the cockpit, potentially outperforming manned aircraft, and creating new military options for US leaders. The Pentagon should ensure that the optionally manned bomber has a robust "remotely piloted" development and testing plan. Moreover, the Air Force and other services should take seriously the call to develop new verification and validation procedures for highly autonomous RPAs even though they represent "a major challenge . . . that may require a decade or more to solve."[54] However, bringing attention, time, and funding to this important research area will contribute to the development of an RPA fully capable of performing some of airpower's riskiest, most sensitive missions more effectively than a manned aircraft—backed by the full confidence of military and civilian leaders and the American people. ✪

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Allied Air Power over Libya

A Preliminary Assessment

Dr. Christian F. Anrig*

In a private meeting during the Libya crisis summit at the Elysée Palace, French president Nicolas Sarkozy informed US secretary of state Hillary Clinton and British prime minister David Cameron that French combat aircraft were en route to the Libyan coast to enforce United Nations Security Council Resolution (UNSCR) 1973. With none of them objecting, the Armée de l'Air (French air force) opened the allied campaign in the afternoon of 19 March 2011.[1] In these opening strikes, Rafale and Mirage fighter-bombers destroyed several armoured vehicles at the outskirts of Benghazi, the rebel stronghold in eastern Libya.

The initial strikes highlighted specific characteristics of the air operations over Libya. In contrast to the practice found in conventional Western air power doctrine, the campaign did not begin with offensive counter-air strikes to take down the Libyan integrated air defence system (IADS) but sought to produce an immediate impact on the ground. It is also the first allied air campaign of the post–Cold War era in which selected European air forces shouldered a significant portion.

One can argue that French and British decision makers diplomatically and militarily confronted their counterparts with a fait accompli before reaching consensus. From a French and British perspective, the situation on the ground dictated the pace, requiring immediate action that only air power could deliver. Finally, on 31 March 2011, 12 days after the initial air strikes, the North Atlantic Treaty Organization (NATO) took over the allied air operations.

The Opening Diplomatic Moves

In the run-up to the air strikes against Col Mu'ammar Gadhafi's military machine, which was violently oppressing the domestic anti-government movement, France and the United Kingdom forced the diplomatic pace. In late February 2011, Cameron unambiguously stated, "We do not in any way rule out the use of military assets, we must not tolerate this regime using military force against its own people." He went on to add, "In that context I have asked the Ministry of Defence and the Chief of the Defence Staff to work with our allies on plans for a military no-fly zone."[2] For his part, Sarkozy was the first Western leader to acknowledge the Libyan National Transitional Council on 10 March 2011, 21 days after the popular uprising began in Benghazi on 17 February 2011.

Although the United Kingdom and France displayed unusual unanimity, the European Union's view on tackling the crisis in Libya was far from homogeneous. A union summit in early March ended without support for military intervention. On the diplomatic front, a crucial turning point was the Arab League's endorsement of a no-fly zone over Libya on Saturday, 12 March 2011. Amr Moussa, secretary-general of the Arab League, indicated after a six-

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hour-long meeting that "the Arab League has officially requested the United Nations Security Council to impose a no-fly zone against any military action against the Libyan people."[3] Reportedly, Algeria, Sudan, Syria, and Yemen opposed the Arab League's vote for a no-fly zone.

While diplomatic support for a no-fly zone gradually grew, the unorganised Libyan rebel forces continued to lose ground to the superior firepower of Gadhafi's forces, which, after the initial shock of the revolution, started to reorganise and seize the initiative. Besides heavy tanks and artillery, Gadhafi's forces had a decisive advantage in airborne and shipborne firepower. On 12 March, when the Arab League declared its support for a no-fly zone, forces loyal to Gadhafi reconquered the oil port of Ras Lanuf in eastern Libya, at the gates to the rebel stronghold Benghazi. As a consequence, the situation for the Libyan opposition movement became drastically serious. Gadhafi's son Saif al-Islam confidently predicted that loyalist forces would soon thwart the revolution, announcing no negotiations with the rebels but a war to the end.[4]

Support for a no-fly zone by Arab nations and the deteriorating situation of the anti-Gadhafi forces on the ground encouraged the United Kingdom and France to step up their diplomatic efforts. Along with Lebanon, the two permanent members of the UN Security Council came up with a draft resolution, increasing the pressure for military intervention.[5] Finally, in the evening of 17 March 2011, the council adopted resolution 1973 by a vote of 10 in favour, with five abstentions (Brazil, China, Germany, India, and Russia). UNSCR 1973 authorised member states, "acting nationally or through regional organizations or arrangements, to take all necessary measures to protect civilians under threat of attack in the country, including Benghazi, while excluding a foreign occupation force of any form on any part of Libyan territory."[6] Hence, UNSCR 1973 relegated any potential military intervention to the predominant use of air power, avoiding the presence of Western militaries on the ground of yet another Arab nation.

Two days after the Security Council adopted UNSCR 1973, Sarkozy ordered fighter-bombers to take off towards hard-pressed Benghazi. Critics of the French president argue that he primarily acted on domestic reasons. Whatever Sarkozy's motivations, the threat of a massacre in Benghazi was imminent in the second half of March 2011 and required immediate military action.

In contrast to the British and French, former US secretary of defense Robert M. Gates used cautious rhetoric at a press conference on 1 March 2011: "All of the options beyond humanitarian assistance and evacuations are complex. . . . We also have to think about, frankly, the use of the U.S. military in another country in the Middle East."[7] Gates's words unambiguously signalled scepticism within the Obama administration about militarily intervening in Libya. Adm Mike Mullen, former chairman of the Joint Chiefs of Staff, and Gen James N. Mattis, head of US Central Command, publicly shared his concerns. Accordingly, the secretary of defense might primarily have had humanitarian assistance and evacuation operations in mind when he ordered the two amphibious assault ships USS *Kearsarge* and USS *Ponce* from the Red Sea into the Mediterranean. The focus on evacuation operations and humanitarian relief is underlined by the absence of a carrier strike group and by the fact that 400 additional Marines deployed from the United States to the *Kearsarge* while the 1,400 Marines assigned to the ship were fighting in Afghanistan.[8] In short, Gates questioned the wisdom of militarily intervening in yet another Muslim country.

According to Washington-based commentators, the Obama administration's passive stance in the opening diplomatic moves partly stemmed from a concern that Arab leaders would have difficulty sanctioning an American-led operation, not to mention the spectre of another protracted military involvement.[9]

Where Is the Raptor?

On Saturday, 19 March 2011, French combat aircraft entered Libyan airspace at 1:30 p.m. Seeking to obtain an immediate impact, the aircraft aimed at armoured vehicles just outside Benghazi.[10] At night, US Navy ships and Royal Navy submarine HMS *Triumph* launched 112 Tomahawk land-attack missiles (TLAM) against critical nodes of Libya's IADS and fixed-site surface-to-air-missile systems. These cruise missile strikes were followed by three B-2 offensive counter-air sorties against key airfields in Libya. With the Libyan air defences having absorbed serious losses, US Air Force F-15Es from Royal Air Force (RAF) Lakenheath, United Kingdom, and F-16CJs from Spangdahlem Air Base, Germany, as well as US Marine Corps AV-8B Harrier IIs, supported by US Navy EA-18 Growler stand-off jamming aircraft, flew follow-on attacks against Gadhafi's forces outside Benghazi.[11] Given their proximity to the Libyan coast, the *Kearsarge*'s six AV-8Bs could fly two sorties per night, demonstrating the advantages of seaborne air power in the opening of the campaign.[12]

During the initial strikes, significant confusion arose about command and control arrangements. According to French official sources, national general staffs commanded their respective assets, and the sorties were coordinated amongst the allies.[13] According to American sources, however, US Africa Command directed coalition operations.[14] The fact that the Norwegians held back their six F-16s on Crete pending clarification of the command and control structure reflected the lack of clarity in command arrangements.[15] Only after NATO had taken over air operations on 31 March did command and control become more integrated. Operations thus shifted from Operation Odyssey Dawn, essentially a coalition of the willing, to Operation Unified Protector, led by NATO.

On Thursday, 17 March, two days before the initial air strikes, Gen Norton Schwartz, chief of staff of the US Air Force, testified before Congress. Reportedly, he anticipated up to a week's preparation to impose the no-fly zone. Moreover, it was understood that the F-22 Raptor would play an essential role in kicking in the door. Yet the absence of the most advanced fighter aircraft prompted widespread speculation, also by retired US Air Force generals, that the F-22 would have made any allied contributions obsolete and that, for this particular reason, it had to stay away.[16] Given Schwartz's timeline for preparing offensive operations and Gates's focus on evacuation operations, the French might simply have surprised their allies in the afternoon of 19 March 2011. As a consequence, the United States did not have enough time to bring the Raptor into place or to deliberate about the corollaries of an F-22 deployment for US allies.[17] Undoubtedly, the Raptor is the world's premier air superiority fighter, but allied air operations went beyond establishing a no-fly zone, the real challenge having to do with influencing events on the ground. In such an environment, aircraft such as the AV-8B might actually have proven more suitable.

Although one should not take for granted Western, particularly American, capabilities to take down an IADS, the coalition swiftly dealt with air threats. On 24 March, Libyan forces launched a Galeb jet aircraft over Misrata. After it landed, French Rafales destroyed the aircraft on the ground.[18] On a later occasion, Gadhafi's forces reportedly employed agricultural aircraft to bomb fuel tanks in Misrata, but these remained singular incidents.

A Common European Defence Identity?

The intervention in March put into concrete action what American, British, and French leaders had deliberated in the preceding months. In particular, a new entente cordiale was emerging in 2010. In November, for instance, the United Kingdom and France signed treaties foreseeing military cooperation in various areas such as common support of A400M airlifters, cross-deck operations of aircraft carriers, or maintenance of nuclear warheads. This rapprochement was underlined by increased cooperation between the RAF's Eurofighter Typhoons and the French air force's Rafales.[19] According to Liam Fox, the United Kingdom's secretary of state for defence, cooperation with France was desirable because it met two key criteria: the willingness to deploy and the willingness to spend on defence.[20]

Unlike his predecessor Jacques Chirac, Sarkozy wishes to reinforce French ties with his Anglo-Saxon counterparts. Under his presidency, France returned to NATO's integrated military command structure in 2009. One also sees France's new attitude on an air force level. The US Air Force, RAF, and French air force established strategic studies groups staffed by officers from each organization. According to General Schwartz, this exchange of ideas concerns "how the best air forces in the world mix and match their capabilities for the best defense."[21] These ties were borne out during the campaign itself. In particular, the French and British exchanged and mixed aircrews on the dual-seat Tornado GR4 and Mirage 2000D fighter-bombers. Accordingly, Gen Jean-Paul Palomeros, chief of staff of the French air force, argued in June, "I can tell you the level of confidence with the Royal Air Force is very, very high."[22]

One month after the start of operations, the troika became especially apparent again in a letter signed by US president Barack Obama, British prime minister Cameron, and French president Sarkozy. Leading newspapers of the three countries published the letter with the intent of demonstrating continued resolve and a united front against Colonel Gadhafi. It even went beyond UNSCR 1973, stating unambiguously that "it is impossible to imagine a future for Libya with Gaddafi in power."[23] The letter appeared after the US military officially ceded its leading role and pulled all combat aircraft from operations in early April. Consequently, doubts emerged, particularly in the United States, about whether NATO air strikes could succeed with US aircraft such as the A-10 Warthog or the AC-130 gunships grounded.[24]

> With regards to Libya, one finds basically three categories of NATO countries: those that conduct offensive air operations; those that relegate their actions to air policing, effectively a non-combat role; and those which fail to appear at all.

Although the United Kingdom and France are willing to make substantial contributions, the situation in Europe as a whole remains very heterogeneous. With regards to Libya, one finds basically three categories of NATO countries: those that conduct offensive air operations; those that relegate their actions to air policing, effectively a non-combat role; and those which fail to appear at all. As of mid-April, only six alliance countries, including France, the United Kingdom, Canada, Belgium, Denmark, and Norway, were conducting strike missions, influencing events on the ground.[25] Canadian forces undertook a particularly swift overseas deployment when six CF-18 and two tanker aircraft departed from Canada on 18 March, and Canadian combat aircraft reportedly engaged a target near Misrata on 22 March.[26]

Interestingly, the Koninklijke Luchtmacht (Netherlands air force), formerly at the vanguard during the Balkan air campaigns and a significant participant in operations over Afghanistan, was restricted to imposing the no-fly zone. Since early 2010, a marked shift seems to have occurred in Dutch policy, which also led to the Netherlands armed forces pulling out of Afghanistan. In contrast, Belgian aircraft operated across the spectrum of military force. Usually, the role of the two countries had been reversed, the Netherlands military taking a more proactive stance. Belgium's proactive involvement and the active lobbying for an air campaign by Guy Verhofstadt, the liberals' leader in the European Union parliament, put into question remarks made by a prominent British defence scholar in 2004—that Belgium is the most conspicuous example of a European tendency to use military force only reluctantly.[27]

Italy offered lukewarm support of the campaign. Though it provided seven of its air bases, its active military contribution to the air campaign was limited. Having maintained extensive economic ties with Libya, Italy felt uneasy about resorting to military force. In the early stages, eight Italian combat aircraft—four Tornados and four F-16s—reportedly took part in enforcing the no-fly zone.[28] According to an interview with the chief of staff of the Aeronautica Militare Italiana (Italian air force) in mid-June, the Tornados were interdiction strike variants, conducting intelligence, surveillance, and reconnaissance (ISR) missions with Reccelite pods, thus refraining from carrying out air strikes.[29] Yet the Italian air force could have made a much more substantial contribution in the early stages of the campaign. It has a dedicated suppression of enemy air defences (SEAD) variant of the Tornado in its inventory, equipped with AGM-88 high-speed anti-radiation missiles (HARM). The Tornado electronic combat/reconnaissance (ECR) aircraft is in fact one of the world's most sophisticated SEAD platforms. Interestingly, development of the latest HARM version, the AGM-88E advanced anti-radiation guided missile, originated with a joint venture between the Italian Ministry of Defence and the US Department of Defense. To the author's knowledge, there are no disclosed reports on Italian Tornado ECRs firing anti-radiation missiles against Libya's IADS in the opening of the campaign. By not unleashing the full potential of these dedicated SEAD aircraft, the Italian air force missed an opportunity to punch above its weight. Only from late April onwards did that air force become involved in offensive strike missions, using almost the complete inventory of precision-guided munitions (PGM). After the Italian air force's MQ-9 Predator B/Reaper remotely piloted aircraft achieved initial operational capability, Italy again found itself in a position to provide a special capability to the campaign.[30]

Yet the global financial downturn had a severe effect upon Italy's budget. As a cost-saving measure, Italy removed its aircraft carrier *Giuseppe Garibaldi* from the operational theatre in July. Earlier, in late June, Italian decision makers called for a cease-fire, manifesting Italy's ambiguous position towards the allied campaign.[31] Since the Italians could not afford not to shape Libya's future, they were literally forced to participate in the operations. Doing so rather reluctantly, they attempted to mitigate military operations.

It is also interesting to look at the European non-contributors, Germany foremost amongst them. A dilemma between its strong emphasis upon NATO as the bedrock for German security and the country's reluctance to employ its armed forces across the spectrum of military force—a prerequisite for making credible contributions to alliance operations—will likely persist. Germany's historical legacy still exerts tremendous inertia upon a proactive defence policy. For the foreseeable future, the use of military force will remain a sensitive issue for the German constituency. Nevertheless, the German military has developed into balanced forces in the post–Cold War era, particularly in the last decade. As such, Germany has evolved as a key player in several air and space dimensions, including synthetic aperture radar satellite reconnaissance/surveillance, theatre ballistic missile defence, or deep strike by acquiring an impressive number of indigenous air-launched cruise missiles. Moreover, it has retained niche capabilities such as a very sophisticated and proven SEAD capability. In 1999 a lean Luftwaffe (Bundeswehr) (German air force) SEAD component, including 10 Tornado ECR aircraft, released approximately one-third of all HARM missiles expended during Operation Allied Force.[32] By opting out of military operations against Gadhafi, Germany missed a further opportunity to translate the German air force's new potential into effective operational output.

Equally interesting is the absence of the new NATO countries—the former Warsaw Pact nations, in particular Poland, which operates an advanced F-16 attack force. One might speculate three reasons for their absence: lack of operational preparedness, lack of funding for deployed fighter operations, or lack of political willingness to contribute—the latter due perhaps to Gates's lukewarm support for operations against Gadhafi. Eastern European nations, particularly Poland, put a premium upon staying in line with American goals—hence their support in 2003 for Operation Iraqi Freedom. With the United States ceding its leading role in Unified Protector, Poland might have felt less inclined to get involved.

Besides the NATO allies, Sweden, Qatar, the United Arab Emirates, and Jordan have taken part in the operations. For Sweden this meant the first deployment of combat aircraft to a real operation since the early 1960s, when Swedish fighter-bombers supported UN operations in the former Belgian Congo. Initially, this Nordic country with a legacy of neutrality deployed eight JAS 39 Gripen aircraft, their employment relegated to air policing and reconnaissance. On 1 May, Mirage 2000-9s of the United Arab Emirates, up to that time restricted to air policing, reportedly were carrying PGMs and targeting pods. Actual strikes, however, could not be confirmed at the time.[33] For its part, Qatar deployed six Mirage 2000-5s to Crete and flew that country's first air-policing sorties on 25 March alongside French Mirage 2000-5s, marking the first combat mission of an Arab League nation against the backdrop of operations over Libya.[34]

To conclude, Europe's defence political fragmentation will persist, and Libya has offered the latest examples of this political reality. Historical national experiences are too different when it comes to the use of military force. Yet as the Libya campaign aptly highlights, no carved-in-stone patterns about particular national behaviours exist. Who could have foreseen the reversed roles between Belgium and the Netherlands or, even more tellingly, the "renewal" of the entente cordiale between Britain and France, particularly after the fierce debates against the backdrop of the invasion of Iraq? In early 2003, Donald Rumsfeld, former US secretary of defense, divided Europe into the new and old. Establishing such fixed patterns, however, does not adequately address the problem. National historical experiences as well as the context of a particular campaign, regarding both domestic and foreign policies, will likely determine European contributions and the resulting European force mix. As such, it is also highly unlikely that Europe as a whole will ever bring to bear its full military potential for a specific political purpose.

Accordingly, the author argued in an article published in 2009 that, although one cannot expect all European alliance partners to contribute to a particular operation, it is realistic to assume that any two of the larger European air forces, combined with a number of smaller air forces, will commit themselves. Hence it is vital that the RAF, the French air force, or the German air force retain a balanced core of air power capabilities that the smaller European air forces can augment.[35] Provision of this European core of air power capabilities by the RAF and the French air force could successfully sustain the air operations over Libya. Yet as this article further analyzes below, a significant imbalance exists between combat air assets and force enablers such as air-to-air refuelling. This disequilibrium between the spear and the shaft will likely hamper European operations in the future. In the case of Libya, significant US support in the domain of force enablers and the geographical proximity of Libya could mitigate the problem.

Depleted Munitions Stocks?

On 15 April, less than a month into the Libyan air campaign, the *Washington Post* published an article entitled "NATO Runs Short on Some Munitions in Libya." Observers quickly concluded that the Libyan campaign lay far beyond French and British capabilities. Probably the most prominent of those critics, John Pike, director of GlobalSecurity.org, argued that Libya "has not been a very big war. If [the Europeans] would run out of these munitions this early in such a small operation, you have to wonder what kind of war they were planning on fighting. . . . Maybe they were just planning on using their air force for air shows." The *Washington Post* article founded its assertion on vaguely citing senior NATO and US officials, and it prominently highlighted long-standing controversies over transatlantic burden sharing.[36]

In response to this article, the chairman of NATO's military committee as well as British and French officials denied any reports on depleted munitions stocks. Current consumptions of British and French PGM stocks reportedly did not inhibit the conduct of the air campaign.[37] Unlike the United States, which maintains a relatively constant production flow, the United Kingdom and France buy munitions in batches and stockpile them. Depletion of the stocks means that production lines must restart, and the retooling of factories consumes additional money and time.[38] In the case of the British Brimstone PGM, the European missile manufacturer MBDA started to equip the United Kingdom's existing stockpiles with upgraded dual-mode seekers. The company also noted that if the tempo of the campaign slowed down, the "high tempo" of conversion would decrease significantly.[39] In a statement as of 23 June 2011, Dr. Liam Fox, secretary of state for defence, estimated the United Kingdom's costs of replenishing munitions for a six months' campaign at £140 million (approximately $220 million).[40]

In the air-to-ground role, the RAF has so far used a complementary mix of PGMs, consisting of Paveway II, Paveway IV, and dual-mode-seeker Brimstone munitions. In the second half of May, the RAF also deployed Paveway III, a 2,000-pound bunker-buster weapon, to Gioia del Colle Air Base in southern Italy.[41] While the service readied the Typhoon to release Paveway II in the early days of the campaign, its Tornado GR4s normally carried a mix of the lighter Paveway IV together with up to six dual-mode-seeker Brimstone munitions. The latter provided the RAF with extra leeway to engage mobile targets. The weapon was originally designed as a "fire and forget" anti-tank missile for use against massed enemy armour using a millimetre wave seeker. Since avoiding collateral damage is pivotal in operations in Afghanistan, an objective that requires a "man in the loop," some Brimstone munitions came fitted with a semiactive laser. According to *Jane's Defence Weekly*, French defence officials were impressed with the performance of the dual-mode-seeker Brimstone. US officials reportedly showed similar interest.[42] Given its limited size, Brimstone allows conducting surgical strikes in areas having significant potential for collateral damage.[43] As such, RAF Tornado GR4 fighter-bombers employed the weapon effectively not only against main battle tanks and armoured personnel carriers but also against targets such as surface-to-air-missile launchers or military radar stations.[44]

In the opening strikes of the Libyan campaign, a Rafale reportedly destroyed a Libyan tank at a stand-off range of 55 kilometres (km) by means of an *armement air-sol modulaire* (AASM), or modular air-to-surface armament, essentially an all-weather PGM propelled by a rocket booster. Depending on its release altitude, it can engage targets at close or medium ranges exceeding 50 km with various options of terminal impact angles. Currently, two guidance systems are available; the more sophisticated one integrates an infrared imager seeker with a combined inertial measuring unit / Global Positioning System receiver navigation kit. Delivery of a third guidance system specifically adapted for engaging mobile targets is expected for 2012. In April 2008, Rafale fighter-bombers engaged Taliban positions with AASMs for the first time.[45] Like Brimstone, the weapon has thus proved effective in both the Afghanistan and Libya theatres. Yet with the third guidance system not yet operational, current AASMs are not suited for engaging mobile targets—hence France's interest in the United Kingdom's dual-mode-seeker Brimstone. French forces have also extensively relied on Paveway II and enhanced Paveway II kits of US provenance.[46]

In the light of operational needs, the French arms supplier Sagem had sped up AASM production since the start of the air campaign.[47] Not only has the French industry's ability to respond to urgent and unforeseen requirements improved but also larger stocks of PGMs have accrued since Allied Force in 1999. "Since the Kosovo campaign," General Palomeros mentioned in a June 2011 interview, "we knew we could not afford a shortfall in munitions, so we gradually built up stocks. That's why we started this campaign, with Afghanistan going on, with reasonable stocks. We thought it could be a long-term campaign, so we started to optimize stocks with an eye to the future. There was no crash program to execute this campaign. In the past, we had to go for crash programs because we ran dramatically short." Also with regards to aircraft serviceability, General Palomeros was very confident in his air force's ability to run a protracted campaign.[48] Despite these improvements, French industrialists perceive the need to further optimise their ability to deal with sudden surge requirements, combined with their customers keeping even larger stocks.[49]

In line with the French armed forces' overall good performance in keeping up with the operational pace of Libyan operations, on 12 July the French parliament authorised, with an overwhelming majority, an extension of France's military involvement.[50] A month earlier, Gen Sir David Richards, the United Kingdom's chief of the Defence Staff, declared that British operations in Libya could continue for as long as necessary.[51] Unlike their British and French counterparts, however, smaller nations involved in the campaign have found it more difficult to keep pace with the air campaign. Both Norway and Sweden confirmed on 15 June that they meant to scale back their contributions.[52] The Flyvevåbnet (Danish air force), which had dropped in excess of 500 PGMs by mid-June and faced severe shortages, expected to have its stocks topped up by purchases from the United States and the Netherlands.[53] Given the limited size of Denmark, the number of PGMs expended is impressive. Yet smaller nations which lack an industrial base for indigenously producing munitions find that engaging in protracted offensive air campaigns represents a major challenge for their air forces. One cannot establish whether the RAF's dispatching four additional Tornado GR4 fighter-bombers in July represents a direct response to the Norwegian and Swedish announcements. Nevertheless it effectively made up for their decreased involvement.[54]

Libya also saw the employment of cruise missiles by European air forces. During the first night of operations, British Tornado GR4 fighter-bombers flew long-distance sorties from RAF Marham, their home base in the United Kingdom, to deliver Storm Shadow cruise missiles, dubbed "Scalp" in France, against unspecified targets.[55] Within a couple of days, fighter-bombers from both the French air force and navy attacked an isolated air base 250 km south of the Libyan coast by means of Scalp cruise missiles.[56] Like its French counterpart, the Italian air force also used Storm Shadow cruise missiles operationally for the first time.[57] Libya thus provided the first occasion in which Continental European air forces employed these air-launched weapons. Yet, unlike the Royal Navy, which contributed to the initial cruise missile strikes against Libya's IADS, the French navy was not in a position to do so. In contrast to their British counterparts, French decision makers put a premium upon French defence industrial autonomy in strategic key areas. Instead of purchasing TLAMs of US provenance, France embarked upon its own naval cruise missile programme. On 8 June 2011, an underwater platform fired a prototype of the Scalp naval (maritime Scalp), simulating a submarine launch. This policy allows the French to develop and retain key competencies, but it does not immediately address operational requirements—the weapon was not ready in time for operations in Libya. A future campaign, however, will see a European maritime cruise missile capability.

The Air Campaign Unfolds

Prior to NATO's taking over air operations in support of UNSCR 1973, America essentially led the campaign, with the US Air Force bringing to bear a vast array of capabilities. As such, units participating in Odyssey Dawn included B-2 stealth bombers from the 509th Bomb Wing at Whiteman AFB, Missouri; F-15Es from RAF Lakenheath, United Kingdom; F-16CJs—dedicated SEAD aircraft—from Spangdahlem Air Base, Germany; or EC-130 Commando Solo psychological operations aircraft from the 193rd Special Operations Wing, Pennsylvania Air National Guard.[58] Although each of these aircraft offered unique capabilities, KC-135 tanker aircraft were about to make the US Air Force's key contribution for the remainder of the campaign. According to the chief of staff of the French air force, they shouldered approximately 70 per cent of NATO's air-to-air refuelling, highlighting the European gap in this important domain of air power.[59] In light of the United Kingdom's expecting its new Airbus tankers, the RAF managed to muster just three of its 1960s-vintage VC10 air refuelling aircraft to support air operations over Libya.[60]

Just prior to the United States' pulling out all combat aircraft from operations over Libya in early April, the Department of Defense announced that the A-10 and AC-130 had begun operations over Libya on 26 March.[61] Both aircraft, especially suited for this particular campaign, thus made only brief appearances.

NATO's assumption of operations over Libya on 31 March 2011 coincided with the adaptation of Gadhafi regime forces to the air strikes by shifting to non-conventional tactics. Libyan government forces started to blend in with civilian road traffic and to use civilians as a shield for their advance. On many occasions, they used pick-up trucks and technicals instead of main battle tanks and armoured personnel carriers. Moreover, weather conditions deteriorated for a few days. Against this backdrop, Gadhafi's regime forces partly seized the initiative again and recaptured territory in eastern Libya, once more posing a threat to the rebels in Benghazi.[62] At the time, many Western commentators blamed NATO for not dealing with the situation. Yet the regime forces' gradual shift to non-conventional tactics was a natural consequence of the air strikes insofar as they aimed to mitigate the effectiveness of Western air power.

As a result, allied air power had to adapt to the regime forces' non-conventional tactics—witness the efforts of the French armed forces. From 7 to 14 April, French air force and naval aviation flew 20 per cent of the overall NATO sorties and 25 per cent of the offensive sorties, neutralising slightly more than 20 targets, of which 15 were military vehicles and five artillery pieces, including one multiple rocket launcher.[63] One and a half months later, from 26 May to 2 June, the French conducted 30 per cent of the overall offensive sorties, enabling them to take out twice as many targets.[64] From 23 June to 1 July, French efforts neutralised approximately 100 targets, of which 60 were military vehicles, including tanks and armoured personnel carriers, and 10 were artillery positions.[65] Just prior to the pulling out of the French aircraft carrier *Charles de Gaulle*, from 3 to 11 August, targets destroyed by French aviation peaked at 150, among them 100 military vehicles and 20 artillery pieces, including multiple rocket launchers.[66]

In the initial strikes, French combat aircraft operated from the French mainland and from Corsica. To save transit time, those aircraft gradually forward-deployed to Souda Bay, Crete, and later to Sigonella, Sicily.[67] The composition of the French contingent changed over time. In mid-August, after pulling out the *Charles de Gaulle*, France had eight Mirage 2000D, four Mirage 2000N, and four Mirage F1 strike aircraft at Souda Bay. Five Rafale multirole aircraft were stationed at Sigonella.[68] According to official French sources, with these aircraft in place at forward-deployed bases, French armed forces continued to conduct one-third of the offensive sorties.[69]

The *Charles de Gaulle* supported combat operations from 22 March until 12 August, when it returned to its home port Toulon in southern France. Counting its previous deployment to support operations in Afghanistan, it operated more than eight months at sea with a brief break at the beginning of March. The carrier's air component included Rafale and Super Etendard Modernisé strike aircraft, E-2C Hawkeyes, and a combat search and rescue component.[70]

Naval gunfire complemented the air strikes, with British and French navy vessels contributing to lifting the siege of Misrata. In the night from 7 to 8 May, for instance, the French navy frigate *Courbet* detected rocket launchers firing into the city and, after receiving authorisation, effectively engaged the targets.[71] Royal Navy vessels supported air strikes by firing illumination rounds, allowing fixed-wing aircraft to engage regime targets accurately, and like their French counterparts, they engaged artillery positions along the shoreline.[72]

In mid-April, after the United States had ceased its lead in offensive operations against Gadhafi's regime, the *Washington Post* claimed that the US armed forces were doing virtually all of the ISR and "thus are chiefly responsible for targeting."[73] True, the United States continued to make significant contributions to ISR, but the newspaper's claim completely ignores European ISR assets involved in the campaign.

Accordingly, the chief of staff of the French air force put into perspective American contributions in an interview of June 2011. Although he acknowledged the vital US support in air-to-air refuelling, European reliance upon American ISR was less severe. In particular, he highlighted the French air force's and navy's role in supplying the coalition with imagery intelligence by means of the Rafale's advanced digital reconnaissance pod.[74] The French navy also deployed maritime patrol aircraft to Souda Bay, those platforms performing surveillance and guiding coalition strike aircraft.[75] Moreover, the Harfang—the French medium-altitude, long-endurance remotely piloted aircraft (MALE RPA)—conducted its first sortie over Libya on 24 August.[76] Finally, one should note that France is the European key player in military satellite ISR.

Within the first 24 hours of Odyssey Dawn, the RAF's Sentinel R1 Airborne Stand-Off Radar aircraft, essentially an equivalent of the E-8 Joint Surveillance Target Attack Radar System, began to conduct wide-area surveillance.[77] Given the size of Libya, it provided NATO with a unique capability. In particular, it proved instrumental in cueing the US Air Force's MALE RPAs, which then identified targets and cleared them for air strikes.[78] During the siege of Misrata, US Air Force MQ-9 Predator RPAs were crucial in identifying regime forces in built-up areas.[79] In the ensuing sensor-to-shooter loop, NATO, US Air Force, RAF, or

French E-3 Airborne Warning and Control System aircraft relayed attack authorisations from the combined air operations centre at Poggio Renatico in northern Italy to NATO's strike aircraft.[80]

According to a statement by Brig Gen Mark van Uhm, chief of allied operations at NATO's Supreme Headquarters Allied Powers, Europe in late April, only 10 per cent of the daily sorties represented designated targets; dynamic strikes dealt with the remainder. In these cases, strike pilots regularly loitered for a couple of hours in search of targets.[81] Hence, a vast proportion of air strikes must have taken place within the framework of armed reconnaissance missions along the main lines of communications and, as such, must not have required an extensive ISR network.

About a month after NATO had taken charge of the air operations, it claimed to have degraded Gadhafi's military machinery by one-third.[82] Against the backdrop of an apparent stalemate, these claims seemed to lack credibility. The target sets consisted of military headquarters; communications nodes; ammunition bunkers; defence radar sites; artillery pieces, including multiple rocket launchers; tanks; armoured personnel carriers; armed vehicles; and other military assets. The French effort, as examined above, concentrated on fielded forces that immediately threatened the civil population. This focus, however, did not preclude taking out operational- and strategic-level headquarters. Unlike Allied Force, this operation included no dispute about the most effective centres of gravity. In 1999 some military leaders were not inclined to emphasize the destruction of Serb forces in the field.[83] Despite NATO's continued focus on fielded forces, better-armed regime troops have forestalled rebel advances. As of late June, the Western Mountains south of Tripoli represented the only front where the rebels had steadily advanced.[84]

The extremely fluid situation on the ground in the early stages of the campaign complicated the synchronization of ground manoeuvres and air strikes. Unlike the early phases of Operation Enduring Freedom, during which American special operations forces tightly synchronised air strikes with Northern Alliance movements, the political situation dictated that NATO air power not serve as the immediate air arm of the rebels.[85] Thus NATO air power occasionally hit rebel forces, particularly when they used tanks.[86] Synchronisation also proved difficult because the rebel forces lacked effective organization.

By early June, coordination of air and ground manoeuvres had reportedly improved.[87] Yet one might attribute this to the fact that the front lines had become less fluid and more rigid. Due to the UN mandate, NATO confirmed that the coalition forces and rebels still had no direct-line communications between them.[88] Coalition aircraft also minimised collateral damage by using only PGMs, a landmark for Western air power.[89]

Like its French counterpart, the RAF shouldered a heavy burden of the air attacks and proved its effectiveness once more. Over the weekend of 9 to 10 April, for instance, NATO reportedly destroyed 61 armoured vehicles and air defence assets, the RAF engaging one-third of the targets.[90] In the second half of May, RAF attack aircraft also engaged Gadhafi's navy. On 19 May, they destroyed two corvettes at the naval base at Al Khums, the nearest military harbour to the port of Misrata, as well as a facility in the dockyard that constructed fast, inflatable boats. By means of the latter, regime forces intended to mine the harbour of Misrata and attack nearby vessels.[91] The RAF particularly excelled through demanding targeting. On 17 August, RAF attack aircraft engaged a small tugboat under way at sea with a laser-guided Paveway bomb. This action required the aircrew to track the moving target with the laser designator.[92] According to sources in the United Kingdom, the RAF had flown approximately 90 per cent of its combat missions against dynamic targets, which are more demanding than pre-planned static objectives.[93] As of 24 August 2011, UK forces had destroyed over 890 former regime targets, including several hundred tanks, artillery pieces, and armed vehicles.[94] When the street fighting started in Tripoli, RAF aircraft maintained a presence over the city, destroying military intelligence facilities in a pre-dawn strike on 21 August or engaging heavy weapons such as main battle tanks on the outskirts of Tripoli.[95] Interestingly, British attack aircraft staged a mini Scud hunt on 24 August, destroying three Scud-support vehicles near Sirte, a site from which former regime forces launched Scud ballistic missiles against the city of Misrata.[96]

As in the case of the French air force, the RAF contingent changed over time. Originally, the UK fighter force consisted of 10 Typhoons in the air defence role and eight Tornado GR4s in the attack role. Libya was a first for the Eurofighter Typhoon. Two days after the start of the air campaign, on 21 March 2011, RAF Typhoons patrolled the Libyan no-fly zone, their first-ever combat mission. However, the air-to-air component gradually decreased in favour of the attack component. In early April, two Typhoons returned to the United Kingdom, while the addition of four aircraft boosted the Tornado GR4 component to a total of 12. Simultaneously, four of the remaining eight Typhoons had shifted from air defence to ground attack. The resulting 16 ground-attack aircraft allowed the RAF to provide a quarter of NATO's ground-attack assets.[97] In the second half of July, the RAF once more boosted its attack and reconnaissance capabilities by deploying another four Tornado GR4s, one of them equipped with a reconnaissance pod. Henceforth, the RAF operated 16 Tornado GR4s and six Eurofighter Typhoons from Gioia del Colle Air Base in southern Italy.[98] Notably, the combat-proven Tornado GR4 remained the RAF's preferred aircraft.

Task Force Hawk Coming of Age

During the course of Allied Force, Gen Wesley Clark—supreme allied commander, Europe—assembled Task Force Hawk in Albania, intending to bring more pressure to bear against Slobodan Milošević, then president of the former Federal Republic of Yugoslavia. Task Force Hawk's main manoeuvre element was its Apache combat helicopter component. After Clark's several attempts to request permission to employ the Apaches, Washington finally turned him down. The Joint Chiefs of Staff had severe concerns about risking sophisticated combat helicopters to attack tactical forces. According to Clark, though, the Apaches could identify targets from across the border that fixed-wing aircraft had not struck.[99]

Twelve years later, in May 2011, the resolve to deploy combat helicopters gradually grew both in the United Kingdom and France in order to further restrain the ground manoeuvres of Gadhafi's forces. In the night from 3 to 4 June, French and British combat helicopters for the first time engaged ground targets. British Army Apache helicopters, launched from helicopter carrier HMS *Ocean*, operated in the area of Brega, helping to soften the front deadlock in eastern Libya. They reportedly faced incoming fire.[100] Despite the threat, *Ocean* again launched its combat helicopters the next night to engage multiple-launch rocket systems.[101] French and British combat helicopters operated in close cooperation with fixed-wing aircraft, the latter gathering intelligence both to select targets and to provide assessments of potential surface-to-air-missile threats. They also remained on stand-by to launch complementary strikes.[102]

British Army Apache helicopters engaged both ground and maritime targets in the area of Misrata. On a raid in early June, they first destroyed high-speed inflatable boats attacking the harbour of Misrata and then opened fire on a ZSU-23-4 self-propelled anti-aircraft gun near Zlitan as well as a number of armed vehicles, displaying the flexibility of helicopter operations in this particular theatre.[103]

Launched from the amphibious assault ship *Tonnerre* in the night from 3 to 4 June, Tigre and Gazelle combat helicopters engaged approximately 20 ground targets.[104] Like their British counterparts, the French army combat helicopters reportedly faced incoming fire by man-portable air defence systems. In the first week of French helicopter operations, the number of destroyed military vehicles increased. Amongst the 70 targets destroyed by French forces from 2 to 9 June, approximately 40 were military vehicles, two-thirds of them destroyed by helicopters.[105] In mid-August, French attack helicopters, launching from the amphibious assault ship *Mistral*, conducted a major interdiction strike. Ten of them struck at two choke points along the lines of communications west of the front deadlock at Brega, destroying several vehicles, surveillance radars, and defensive positions.[106]

Unlike the Americans in 1999, the British and French might have perceived their combat helicopters as an important means of making up for their limited fixed-wing assets in order to run a sustained and protracted air campaign. General Clark also noted a profound difference in the ways of war. Specifically, the United States musters overwhelming force to produce decisive results at the least cost of lives. In contrast, former European colonial powers have a history of fighting outgunned and outnumbered. Thus in 1999, "European officers saw a leaner campaign, focused on Kosovo, characterized by more flexible and daring tactics. They were prepared to take greater risks with their troops and to ask for less from the supporting arms such as artillery and airpower."[107] This attitude is also reflected in the French air force's initial strikes on 19 March 2011. Some commentators were quick to play down the risks involved, arguing that the French had identified a gap in the fixed-site air defence system, but the threat of mobile surface-to-air missiles undoubtedly remained.

Drawing upon Comparative Advantages

In his book *The Causes of Wars*, renowned British scholar Sir Michael Howard outlined four dimensions of strategy: the social, operational, logistical, and technological. In his view, "no successful strategy could be formulated that did not take account of them all, but under different circumstances, one or another of these dimensions might dominate."[108] The German Wehrmacht of World War II, for instance, is a prime example of an armed force that attempted to exploit the operational dimension. On most occasions outgunned and outnumbered, it nevertheless remained confident of achieving victory by virtue of superior skills in the operational dimension. Yet as the logistical dimension started to dominate, superior allied resources both in equipment and manpower undermined this German strategy. The technological dimension very much shaped the battle of the Atlantic. The British achievement in breaking the Enigma code, combined with US and British advances in anti-submarine warfare, gave the Western allies the decisive advantage to secure a safe passage across the Atlantic and to mitigate the German U-boat threat to a "tolerable" level. Counterinsurgency campaigns, such as France's or the United States' involvement in Vietnam are by their very nature dominated by the social dimension while one strives for success in the operational dimension. As recent campaigns have borne witness, winning hearts and minds is extremely difficult. Can Western armed forces effectively bring across their benign intentions in a culturally alien environment?

Hinging upon air and naval power, the Western alliance could confine its intervention to the operational and technological dimensions as the predominant ones, both with regards to Libya, the wider Arab community, and their domestic constituencies. Support for the campaign in France and the United Kingdom did not wane. The zero own-casualty toll, enabled by air power's superior technology, might have significantly contributed to this public backing. In the absence of ground troops in Libya, France disclosed on 29 June its having air-dropped weapons to rebel fighters in the Western Mountains south of Tripoli—the first time that a Western country acknowledged arming the rebels.[109] Qatar, for its part, reportedly supported the rebels by funnelling arms into Benghazi from where they were further distributed to the various fronts, also by air. Moreover, various allied countries sent military-liaison advisory teams to support the National Transitional Council, and Western alliance special forces evidently offered immediate advice to rebel front-line forces. All of these measures fall short of deploying regular ground forces with a large footprint into the theatre.

By staging successive offensives, Western forces have repeatedly attempted to turn the Afghan conflict into a situation dominated by the operational dimension. Though most of these offensives have been militarily successful, the conflict remains dominated by the social dimension, making it nearly impossible for the West to effect decisive results at the strategic level, even after 10 years of continuous deployments.

In the 1970s and the 1980s, the United States confined its military involvement in the Persian Gulf to carrier strike groups and naval air power without a single boot on the Arabian Peninsula. "Offshore balancing" allowed the United States to secure its oil interests effectively at the least price. Against the backdrop of Michael Howard's theory on the dimensions of strategy, the reason for this becomes obvious. By concentrating on the maritime and air environments, the United States could draw upon comparative advantages while at the same time managing to avoid becoming an occupying force and arousing grievances in the local populations. This was no longer the case in the 1990s. Osama bin Laden's speeches and sermons drew attention to the massive Western, particularly American, military presence on the Arabian Peninsula. In this regard, the American scholar Robert Pape, author of *Bombing to Win: Air Power and Coercion in War* and the more recent book *Dying to Win: The Strategic Logic of Suicide Terrorism*, argues that the presence of American ground troops in Muslim countries is the main factor driving suicide terrorism. According to this logic, Islamic fundamentalism is not the principal driving factor of suicide terrorism against the United States' interests, thus explaining the absence of al-Qaeda terrorists from Iran or Sudan, which harboured bin Laden in the 1990s. Suicide attacks aimed against the West, however, surged in Iraq after Western forces with a different religious background occupied that country. This difference in religion between the occupier and the occupied community is—according to Pape—the key reason for suicide attacks. Prior to Iraqi Freedom, Iraq reportedly had never experienced a suicide terrorist attack.[110]

From this vantage point, arguments made by various commentators like retired general Henning von Ondarza, former commanding officer of Allied Forces Central Europe, that called for ground troops to control the situation in Libya do not take account of all dimensions of strategy.[111] Although such an approach might have delivered swift military results in the operational dimension, "infidels" on the ground scoring decisive victories and "occupying yet another Muslim country" might have led to strategic backlashes, with the great potential of the social dimension becoming the predominant one. Western boots on the ground, also not backed by the Arab League, would likely have caused massive grievances, including suicide terrorism. The very fact that the Western alliance refrained from deploying ground units helped retain the intervention in a situation that placed the operational and technological dimensions at the forefront, despite concerns about collateral damage and international objections to issues such as air-drops of weapons supposedly violating UNSCR 1973.

Most interestingly, making sure that the operational and technological dimensions remain predominant helps to prevent significant strains in the logistical dimension of strategy. According to the UK Defence Committee's fifth report as of 19 July 2011, estimates of additional costs of operations in Afghanistan during the current year amount to just over £4 billion (approximately $6.3 billion). Yet the report admitted that the total costs of operations in Afghanistan remain unknown.[112] In contrast, Secretary of State for Defence Fox estimated the costs of six months of military operations in the framework of Operation Ellamy, the United Kingdom's contribution to the allied effort in support of UNSCR 1973, at £260 million (approximately $410 million). This figure includes the cost of replenishing munitions.[113] Accordingly, one can estimate an entire year at approximately £520 million (approximately $820 million). Even though very rough estimates, these figures by no means fail to reveal the large discrepancy between the costs of UK operations in Afghanistan and Operation Ellamy in Libya.

To put the UK costs involved into perspective, the RAF was providing about a quarter of the ground-attack assets as of mid-April.[114] Given the estimated yearly UK costs of $820 million and its estimated 25 per cent share of the offensive air campaign, about $3.3 billion would theoretically cover the costs of an entire operation at the current pace for a year's duration. Particularly expensive were TLAMs launched from US Navy ships to shut down Libya's IADS and other strategic key targets at the onset of the campaign. The approximate cost of missiles and other American munitions expended from 19 to 28 March comes to $340 million.[115] The above figures combined would be significantly less than the United Kingdom's estimated additional costs of operations in Afghanistan during 2011.

Towards the end of Operations Northern and Southern Watch over Iraq, Gen John P. Jumper, then the Air Force chief of staff, argued that the air blockades caused his service to fly some aircraft longer than the average amount of time. However, he was not certain whether doing so would actually result in more wear and tear on the fleet since the majority of missions did not involve violent manoeuvring.[116] The degree to which European air forces in Libya will feel the effects of increased wear and tear and additional costs involved remains to be seen. Based upon Jumper's comments on the US Air Force's experience in Iraq, though, these additional costs are unlikely to be excessive.

Not only are costs in treasure significantly lower in comparison to those associated with operations in Afghanistan but also—and even more importantly—the human cost is dramatically reduced. For instance, in the first half of 2011, the British armed forces suffered 27 fatalities in Afghanistan, not to mention the number of wounded and maimed. The 108 fatalities in 2009 and 103 fatalities in 2010 made the two previous years the bloodiest for British troops in Afghanistan.[117] As of August 2011, however, the allies had suffered no fatalities in Libya. Unlike the situation in Afghanistan, the allies could fully draw upon their asymmetric advantages in the technological dimension of strategy, significantly improving force protection.

This article does not contend that the use of ground forces is too costly in modern warfare. In fact, joint manoeuvre warfare, as conducted by the West's most advanced forces, has proven extremely effective and powerful in conventional campaigns, sweeping away conventional resistance. Yet in stabilisation operations, Western allies should shape their involvement in ways that allow them to effectively draw upon the comparative advantages in the operational and technological dimensions. In contrast, winning hearts and minds is excessively difficult, highlighting the extreme challenges for Western intervention forces in the social dimension.

As a rule, warfare does not lend itself to a recipe, and the weight and characteristics of each dimension of strategy depend upon its context. In Bosnia in 1995, deployment of a heavy multinational brigade did not undermine the West's standing in the social dimension. Together with air power, it produced synergistic joint effects against the Bosnian Serbs' ground manoeuvres, thereby providing significant combined-arms leverage that Allied Force lacked in 1999. Hence, ground forces strengthened the operational dimension of strategy during Operation Deliberate Force, which led to the Dayton Peace Accords in late 1995.

Due to the specific circumstances, however, the West made air power its weapon of choice against Mu'ammar Gadhafi. However protracted the campaign seemed, it proved significantly cheaper in both resources and lives than current or recent stabilisation operations in Iraq and Afghanistan that demanded a great influx of ground forces.

Conclusion

The Libyan campaign stands as a successful example of how Western air power shifted the balance of power in favour of a resistance movement against superior armed regime forces. Essentially, it levelled the playing field. Nevertheless, the Libyans themselves must make the final decision. Without intervention from the West's air power, forces loyal to Gadhafi could have inflicted tremendous carnage on both Benghazi and Misrata. The siege of Misrata was terrible, but without air power, it most certainly would have become another dark chapter in Europe's history.

During the course of the campaign, renowned commentators made various claims. Against the backdrop of the air campaign's becoming protracted, one of them argued that the West should have better armed and trained the rebels before intervening militarily. Aside from political concerns, this proposed course of action completely ignores the time-sensitivity of this operation. The overrunning of the rebel strongholds in late March would have left no time for such arming and training. Other commentators downplayed the intervention as a rather small campaign. Yet assessing a campaign by assets involved is not the most sophisticated approach. At the end of the day, the effect is important. Probably the most frequently raised claim involved the need for ground forces to effectively turn the table in Libya. Granted, this strategy might have produced swift military effect, but at the strategic level of warfare, it might have caused backlashes—allowing the social dimension of strategy to dominate the conflict.

Moreover, commentators raised concerns about a protracted air campaign, implicitly referring to the excessive costs involved. Both the Iraqi no-fly zones of the 1990s and the Libya campaign, however, bear witness that relegating an intervention to air power—if circumstances permit—is far less costly than, for instance, ongoing operations in Afghanistan. For some unjustified reason, interventions by air power attract criticism that they consume vast amounts of treasure. Yet air power, combined with its ability to reduce collateral damage significantly, helps keep an intervention in the operational and technological dimension of strategy, where the West can draw upon its comparative advantages. In particular, the technological dimension yields an asymmetric advantage in force protection that can reduce allied fatalities to a minimum. Short of deploying ground troops, the British and French deployed combat helicopters. After their first missions in the night of 3 to 4 June, commentators expected casualties. These daring attacks undoubtedly and visibly demonstrated NATO's resolve and thereby generated additional coercive leverage.

Other critics charged that, instead of conducting a shock-and-awe campaign, the West used air power only gradually, thus dissipating its true value. Even if the coalition had staged massive air strikes, who could have actually exploited their effects in the early phase of the conflict? As much about protecting civilians, this campaign was about a contest of will between Gadhafi's regime and NATO, whose willingness and ability to conduct a protracted air campaign slowly ground down the dictator's forces and denied him the use of superior conventional weapons on the ground. As it proved, NATO occupied a position to do so. The French air force's contingent on Crete, for instance, contained about a tenth of the entire French Mirage 2000D and 2000N fleets, a ratio perfectly suited for a prolonged air campaign.

However, the campaign once more revealed the European imbalance between shaft and spear, the effects of which could be mitigated only through significant American support and Libya's geographical position. This imbalance will likely persist—witness the RAF's and French air force's acquisition of or plans to acquire 14 modern multirole transport tanker aircraft each and the remainder of Europe placing even less emphasis on air-to-air refuelling, a situation that will hamper Europe's reach and mobility in the future. Luckily, Europe's only true aircraft carrier, the *Charles de Gaulle*, was immediately ready for action, but France had to pull it out of operations on 12 August after more than eight months of almost continuous service. Clearly, the West could have waged the Libyan campaign without naval air power, but the geographical position of the next contingency might require the availability of more seaborne flight decks.

The campaign has also shown the limits of force specialisation within Europe. With countries such as Germany opting out or others, such as Italy, offering only hesitant support, the campaign kicked off without vital European capabilities (both Germany and Italy operate the most advanced European SEAD forces). To secure political discretion, the larger European countries need to retain balanced air forces. Smaller European air forces that are willing to deploy could punch above their weight by reinforcing Europe's force enablers. A willingness to take risks could also make up for the absence of certain capabilities. Thus French fighter-bombers opened the campaign on 19 March with no dedicated SEAD aircraft, and the employment of combat helicopters effectively compensated for limited numbers of fixed-wing aircraft.

The campaign will likely reshape European force transformation. For example, the authors of the United Kingdom's *Strategic Defence and Security Review* of late 2010 undoubtedly wrote that document against the backdrop of ongoing operations in Afghanistan. The RAF earmarked such assets as the Sentinel wide-area surveillance aircraft, which saw only limited use in Afghanistan but proved extremely valuable in Libya, for phasing out in the coming years. Consequently, decision makers might need to reconsider certain plans. At the least, the RAF deferred retiring its last Nimrod R1 signals intelligence aircraft by three months, extending its service to support Operation Ellamy—the United Kingdom's contribution to NATO's air campaign.

Overall, even though the military gap across the Atlantic undoubtedly remains, the Libyan campaign demonstrates that the gap has narrowed, not only in terms of equipment but also in terms of willingness to intervene. ✪

Triesen, Principality of Liechtenstein

Notes

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To a Distant Day: The Rocket Pioneers by Chris Gainor. University of Nebraska Press (http://www.nebraskapress.unl.edu/catalog/CategoryInfo.aspx?cid=152), 1111 Lincoln Mall, Lincoln, Nebraska 68588-0630, 2008, 264 pages, $29.95 (hardcover), ISBN 978-0-8032-2209-0.

The history of rockets did not begin with Sputnik. Rather, it had a much longer story, and the science involved had an international flavor including much more than just the efforts of the USSR and United States. In modern times, the work began with individuals but eventually required the establishment of large organizations for research and development in order to reach the threshold of space. *To a Distant Day* focuses on the story up to *Sputnik I* in 1957 and then adds the tale of carrying the competition to the moon landing in a summary way.

Author Chris Gainor emphasizes biographical matters, notwithstanding the fact that from World War II onward, most of the space research, development, and testing emerged from large organizations in the USSR and United States. Furthermore, he recognizes that competition between those two for international prestige represented the major motivation for the advance to the moon landing. Unfortunately, that rationale obscures the very real scientific gains that came out of the moon landing, as well as the continuing need for more such advances. The author regrets the subsequent emphasis on a trip to Mars, feeling that additional moon exploration would prove much more productive.

A nice international quality about *To a Distant Day* gives credit where credit is due. It explores early foundations of the science in the USSR and United States and covers the role of rocket enthusiasts in Germany both before and during Hitler's regime in a deliberate way. Particularly interesting is the way the United States captured German scientists and their technologies, successfully harnessing their talents to its own rocket and space effort—no easy task. Gainor also makes the valid argument that, generally, his neighbors to the south have no familiarity with the substantial contribution that Canadians made to the US effort in rocketry and space.

To a Distant Day is a worthy read for aspiring warrior-scholars. However, for more comprehensive treatment, they would do well to examine David Spires's *Beyond Horizons: A Half Century of Air Force Space Leadership* and Walter A. McDougall's *The Heavens and the Earth: A Political History of the Space Age*—both of which Gainor cites in his bibliography.

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On the Cutting Edge: Tales of a Cold War Engineer at the Dawn of the Nuclear, Guided Missile, Computer and Space Ages by Robert F. Brodsky. Richard Altschuler and Associates (http://www.richardaltschuler.com), 100 West 57th Street, New York, New York 10019, 2006, 220 pages, $18.00 (softcover), ISBN 1-884092-62-4.

In *On the Cutting Edge*, Dr. Robert Brodsky compiles stories from his long career as an aeronautical engineer, covering a half century that spans the Cold War and includes the "glory days" of engineering in the 1960s. Readers learn that Brodsky had a hand in improving the aerodynamic stability of atomic bombs, solving guidance and control problems on Navy missiles, and designing satellites and a moon rover, among other accomplishments. His account of the time he devoted to writing proposals, managing departments, and leading research and development efforts also offers insight into the culture of large defense contractors. Furthermore, Brodsky touches on giving testimony as an expert witness in aircraft accident cases and describes his academic roles, teaching courses as well as developing the first degree program in astronautical engineering. Students of Cold War history will recognize many projects, weapon systems, and facilities—perhaps, as I did, dog-earing certain pages for additional research.

Brodsky's doctorate in engineering (he performed calculations for his dissertation on ENIAC, the first general-purpose electronic computer!) prepared him well for the interesting—and, by his account, very satisfying—career that lay ahead. He writes from firsthand experience in hands-on engineering as well as business development and management roles. But readers shouldn't anticipate anything dry and stuffy; Dr. Brodsky has a sense of humor, and it shows in his writing. He also simplifies technical matters, so a non-rocket-scientist can follow his points easily.

He includes his failures as well as successes, laying out events and results, good or bad. In this regard, the book contains subtle lessons in leadership, management, and problem solving—a nice departure from polished biographies that read like award nominations. Brodsky occasionally drifts from science to the mundane (a rant on an airline's lack of service, for example), but not often.

History-minded readers with an interest in air and space topics will enjoy *On the Cutting Edge*. Rather than including complete details of any given program or product, it features an insider's perspective on many events and developments—some famous, some not. Those who read about military and space technology for fun—not just because it's good for them—will enjoy this book!

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American Secret Pusher Fighters of World War II by Gerald H. Balzer. Specialty Press (http://www.specialtypress.com), 39966 Grand Avenue, North Branch, Minnesota 55056, 2008, 182 pages, $42.95 (hardcover), ISBN 1580071252.

In 1940 the US Army held a fighter-design competition to produce an aircraft capable of reducing the time necessary to intercept enemy bombers. The three winners—the Vultee XP-54 Swoose Goose, Curtiss-Wright XP-55 Ascender, and Northrop XP-56 Black Bullet—featured the unconventional pusher design, which placed the engine in the back. These aircraft had a significant impact on US aviation and aviation design.

The author, retired aeronautical engineer Gerald Balzer, is to be commended for this heavily illustrated (385 black-and-white and color photos), excellent work. During his career with Northrop, McDonnell, and TRW, he worked on various aircraft projects, including the T-38, F-4, F-5, and F-15 as well as the F-89 Snark missile and the Defense Support Program satellite constellation. With this book, Specialty Press adds another distinguished work to its aviation history series.

Following the foreword by retired Air Force colonel Walter J. Boyne—prolific aviation author and former director of the National Air and Space Museum—chapter 1 chronicles the origins of the pusher fighters; the state of military aviation prior to World War II; aircraft procurement; advances in the field in Europe; and government specification R-40C, which called for radical aircraft designs. Chapter 2 details Vultee's two XP-54 prototypes, distinguished by their ducted and inverted gull wing, pilot seat, and entry to the aircraft. In chapter 3, Balzer describes Curtiss-Wright's production of three prototypes of the XP-55, notable for being the company's first fighter with a tricycle landing gear configuration. Finally, chapter 4 addresses not only the tailless design of Northrop's XP-56 but also the company's construction components and techniques. Although these three aircraft—all of them developed secretly—never reached full production, they influenced postwar airplanes and today's remotely piloted aircraft.

Well written and researched, *American Secret Pusher Fighters of World War II* reflects the author's mastery of the developmental history of these aircraft. All readers, but especially scale-model enthusiasts, aviation designers, and aviation historians, will appreciate the vast amount of detail on aerodynamics and construction features offered by this indispensable account, augmented by rare photos, cutaway drawings, sketches, and layouts. Without a doubt, Gerald Balzer has written the definitive work on the XP-54, XP-55, and XP-56.

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Storming the Bombers: A Chronicle of JG 4, the Luftwaffe's 4th Fighter Wing, vol. 1, **1942–1944** by Erik Mombeeck, translated by Neil Page. ASBL la Porte d'Hoves (http://www.luftwaffe.be/), Esselaar 22, B-1630 Linkebeek, Belgium, 2009, 242 pages, $69.00 (hardcover), ISBN 978-2930546018.

At the start of World War II, the German Luftwaffe undoubtedly was the world's preeminent air force. Its pilots and leaders effectively refined the skills and tactics they had used in the Spanish civil war, developing and applying them a few years later against the armed forces of Western and Central Europe.

Erik Mombeeck, a Belgian author of several internationally acclaimed books on the history and operations of German fighter wings, took up the challenge to document the history of the Luftwaffe's 4th *Jagdgeschwader* (Fighter Wing) (JG 4). This first volume examines the wing's activities from its formation in 1942 through its involvement in the US Army Air Forces' week-long operation against German oil refineries in mid-September 1944, after which JG 4 faced reconstitution after losing a significant number of pilots and aircraft.

By all accounts, JG 4 was a relatively young unit, its first *Gruppe* standing up in Romania in 1942 to defend the Ploesti oil complexes. By the end of the next year, the *Gruppe* had the dubious honor of having flown only one combat mission—probably the only Luftwaffe unit to have done so. To the *Gruppe*'s credit, the mission had an honorable outcome (pp. 5–6).

Mombeeck also documents the creation of the *Sturmstaffel*, a concept that Maj Hans-Günter von Kornatzki championed to the German General of Fighters. The pilots of this elite group flew specially modified Fw 190s that attacked bomber formations from the rear en masse, using cannon fire at close range to tear into a bomber and, if all else failed, ramming the aircraft to bring it down. A viable concept, the *Sturmstaffel* soon found a place at squadron strength in some German fighter wings such as II. (Sturm), JG 4 (Second Squadron, 4th Fighter Wing).

I consider *Storming the Bombers* a very good account of JG 4 during this time. The personal reminiscences of the few surviving pilots, as well as extracts from letters and diaries of other pilots in the wing, bring faces and depth of feeling to this history. Moreover, the book is awash with black-and-white pictures of crews and aircraft that thoroughly illustrate the two-year segment.

However, a few missteps intrude themselves upon the narrative. For example, despite Mombeeck's effective introduction of the *Sturmstaffel*, he does not immediately clarify its place in JG 4's history, waiting until the following chapter to do so. Furthermore, a few charts and diagrams explaining tactics would have been helpful. Finally, British spelling aside, some minor errors in translation occur but are not so serious that they impair the reader's understanding.

In sum, *Storming the Bombers* is an enlightening history of JG 4 during its first two years of existence. Luftwaffe aficionados will find it a valuable addition to their collections. Mombeeck's extensive research and comparisons of both German and Allied mission records add validity to the many battles he recounts. I can't wait to read the second volume.

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Military Airpower: A Revised Digest of Airpower Opinions and Thoughts by Col Charles M. Westenhoff, USAF, Retired. Air University Press (http://aupress.au.af.mil), 155 N. Twining Street, Maxwell AFB, Alabama 36112, 2007, 277 pages (softcover), ISBN 1-58566-163-5. Available free at http://aupress.au.af.mil/digital/pdf/book/Westenhoff_Military_Airpower.pdf.

Military Airpower, a compilation of quotations on war fighting and, in particular, air and space power, is an essential addition to the library of any student of war in the air, space, and cyberspace age. This book came about as a result of a request by Gen T. Michael Moseley, former Air Force chief of staff, that the author, retired Air Force colonel Charles Westenhoff, update *Military Air Power* (1990)—the original version. Colonel Westenhoff, a former forward air controller and fighter pilot, became an esteemed member of the Air Force's cadre of military strategists and theorists. He served at Maxwell AFB, Alabama, contributing to the development of Air Force Manual 1-1, *Basic Aerospace Doctrine of the United States Air Force*, and at the Pentagon, where he worked on quadrennial defense review issues in the 1990s and, after retiring from service, as a Checkmate senior mentor. The author's contributions across the spectrum of airpower application inform his choice of thoughts and remarks for inclusion in this book, giving them direct applicability to today's war fighter—whether as essential background reading for the development of briefings and white papers or as primary reference material for the formulation of strategic plans.

In the foreword, General Moseley remarks that "this book is about what Airmen have in common—our heritage, capacity, and future potential. It also illustrates that while we're on the leading edge, we're also part of the sweep of military history" (p. vi). Both of these points speak to the utility of *Military Airpower*.

First, with regard to what Airmen have in common, Colonel Westenhoff designed this book to help them fill their *clue bags*, a term familiar to pilots and others, whether those bags are empty or full. I do not necessarily suggest that readers memorize all of the quotations and regurgitate them cadet-style in the Fort Myers Officers' Club. The selected quotations are not random thoughts but useful examples of synthesis realized by past and present leaders on topics important to Airmen at large. For example, according to Gen Carl "Tooey" Spaatz, "The argument has been advanced that the Air Force should be concerned with land objectives, and the Navy with objectives on and over the water. That distinction is to deny the peculiar quality of the air medium, the third dimension. The air is indivisible; it covers land and sea" (p. 53). Such an observation is not just good fodder for a professional military education research paper; it is a position taken by a founding member of the Air Force that still applies in joint discussions at combined task forces today.

Second, by offering historical quotations, Colonel Westenhoff helps tie classic military thought and principles of war to modern air, space, and cyber technology, doctrine, outcomes, and arguments. The book weaves together the thoughts of contemporary air and space power leaders and thinkers as well as those of classic military strategists. For example, most Airmen have at least a passing familiarity with Carl von Clausewitz and his seminal book *On War*, excerpts from which pepper the pages of *Military Airpower*, such as the familiar statement "The ultimate object of our wars, the political one, is not always quite a simple one" (p. 63). To be compelling in a joint arena, however, that observation could benefit from insight offered by a modern airpower leader like Gen Charles G. Boyd: "Above all, PGMs [precision-guided munitions] connect political objectives to military execution with much greater reliability than ever before. The political leader can have far greater confidence that discrete objectives can be met and can thus gain broader latitude in formulating the overall objective. This is not just a change in air power or even in military power; it is a fundamental change in warfare" (p. 146).

Military Airpower is not simply another book of quotations. Rather, it covers old and new, touching on concepts dear to the hearts of air and space power theorists and armchair strategists alike. Colonel Westenhoff ranges across the principles of warfare, outcomes, and arguments from Operations Desert Storm, Deliberate Force, Allied Force, Enduring Freedom, and Iraqi Freedom—as well as from classic battles and strategists during the world wars—exploring airpower, technology, command and control, and doctrine.

I suggest that all serious students of war and military history obtain a copy of *Military Airpower* and peruse it every now and then to reboot their notion of airmanship. The thoughts and ideas found therein will enhance discussions about joint and combined arms, doctrine debates, and especially conversations that take place in the halls of the Joint Staff—where Soldiers, Sailors, Airmen, and Marines know their own service's dogma. The quotations themselves tell a story, and the organization of the book helps compare apples to apples. As Sir Winston Churchill reportedly said, "It is a good thing for an uneducated man to read books of quotations" (p. 4). That goes double for the educated ones.

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A History of Air Warfare edited by John Andreas Olsen. Potomac Books (http://www.potomacbooksinc.com/books/features.aspx), 22841 Quicksilver Drive, Dulles, Virginia 20166, 2010, 506 pages, $44.00 (hardcover), ISBN 978-1-59797-440-0; $28.00 (softcover), ISBN 978-1-59797-433-2.

In *A History of Air Warfare*, John Andreas Olsen, dean of the Norwegian Defence University College and a visiting professor at the Swedish National Defence College's Department of Military Studies, has compiled a series of essays discussing airpower contributions from World War I to the Israel-Hezbollah war of 2006—analogous to Phillip Meilinger's efforts to assemble a tome of airpower's genesis and evolution in his edited work *The Paths of Heaven: The Evolution of Airpower Theory*. The difference between the two works is that Meilinger, then commandant of the School of Advanced Air and Space Studies, sourced his contributors from within, using the school's faculty members and some graduates as his primary authors. Olsen sourced from outside, assembling a pantheon of air warfare giants: Lawrence Freedman, Williamson Murray, and Benjamin Lambeth, to name a few. He selected his contributors based on their analytical skills, combined with their ability to write prose in a concise and readable fashion (p. vii); the product validates his selections. As to be expected, each contributor is well published and an expert in his subject matter—most of the contributors have larger compendiums from which their essays derive.

Despite the powerhouse of contributors, Olsen has a practicable objective for this anthology: to provide an introductory text for air warfare students by examining what he assesses are the most important conflicts in which airpower played a significant role (p. xvi). He executes via requested evaluations of airpower contributions in World War I, World War II, Korea, Vietnam, the Israel-Arab wars, the Falklands, Desert Storm, Deliberate Force, Allied Force, Enduring Freedom, Iraqi Freedom, and the second Lebanon war. Olsen then finishes with three summary essays: James Corum's incisive summary of airpower in small wars from 1913 to the present (p. 327); Martin van Creveld's hypothesis that airpower is in real trouble (p. 369); and Richard Hallion's counter that it is premature to bury the manned military airplane, air forces, and airpower (p. 389).

In addition to offering the expected basics of background, actions, and significant events, Olsen tasks each contributor to include the outcomes and their associated impact on airpower's development, making for a tidy conclusion to each section. Discussion within the historical essays is limited to the actual hostilities under examination. Readers seeking literature on interwar dynamics and developments will need to go elsewhere. Additionally, the essays acknowledge airpower technological evolutions and developments but never treat them as the primary subject matter.

Olsen's effort does not disappoint. Not everyone will agree with the various conclusions, but all will agree that the points are made in a cogent, easily readable fashion.

To be expected, some essays are more likeable than others. Most are easy to follow although Robert Owen's review of airpower during Deliberate Force will force readers unfamiliar with the operation to review separately exactly who was fighting whom. As well, all except Wayne Thompson's Vietnam piece offer the requested conclusion summarizing the author's view on the key airpower learning point(s). The final anomaly is Shmuel Gordon's work. Instead of selecting a specific Israel-Arab conflict, he elected to undertake an air superiority study for the Israel-Arab wars from 1967 to 1982, which is planted in the middle of the book. The effort is solid but out of step as it neither analyzes airpower contributions for a specific conflict nor provides a holistic summary of an airpower core function over an available larger period of time.

Errant facts are few and far between, but they are present. Van Creveld states that Billy Mitchell was imprisoned following the court-martial of 1925. That was not the case although Mitchell likely felt as if he had received a prison sentence and resigned soon after the proceedings. Hallion applauds airpower's effective contributions to the fight against improvised explosive devices (IED) (p. 392) but offers little rigor to justify this claim other than his own recollection of the C-12's capabilities: no studies and no references to statistics (p. 439). The counter-IED mission area is too ripe for study to assume it away via casual observation. Admittedly, however, these minor miscues are rare. Even identifying these two could be viewed as caviling since they in no way detract from the contributions or the book's stated objective.

In the end, the contributors provide enough history and perspective for the airpower novice to appreciate airpower's advantages and disadvantages. For the well-versed airpower scholar, *A History of Air Warfare* is a fine review of publications likely already consumed, along with some additional food for thought provided by van Creveld's and Hallion's final essays. For the intermediate air warfare student, it offers fine excerpts for both examination and rumination. And Olsen met his true end-state goal: to provide an airpower anthology to help air warfare students be not just clever for next time but wise forever (p. xiv).

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Leaderless Jihad: Terror Networks in the Twenty-First Century by Marc Sageman. University of Pennsylvania Press (http://www.upenn.edu/pennpress), 3905 Spruce Street, Philadelphia, Pennsylvania 19104, 2008, 208 pages, $24.95 (hardcover), ISBN 978-0-8122-4065-8.

In *Leaderless Jihad*, forensic psychiatrist and counterterrorism consultant Marc Sageman contributes to the field of international security by providing a detailed look into the current global

Islamist terrorist threat, examining its evolution since the 1980s and the demographics of who is behind the latest wave of terrorism. Initially, the book lures the reader with its discussion of the waves of Islamist-based terrorism: the first wave, beginning in the 1980s with individuals who fought alongside the mujahideen in Afghanistan and formed the core of what is now al-Qaeda; the second, occurring in the 1990s and motivated by Muslim suffering around the world; and the third (the main subject of *Leaderless Jihad*), involving jihadists motivated by the US invasion of Iraq. In his description of these waves of Islamist terrorism, Sageman addresses the evolution of al-Qaeda from its incarnation as "al Qaeda Central," led by Osama bin Laden, to "the al Qaeda social movement . . . composed of informal networks" that, with the help of the Internet, has become a leaderless jihad under the stewardship of the third wave of terrorists (p. 31).

Sageman offers a better understanding of the threat we currently face by examining methods of studying terrorism and by discussing microlevel analysis of the individual and macrolevel analysis of the sociological root causes of terrorism, as well as problems and limitations associated with both methods. He then recommends "Middle-Range Analysis" (p. 23), a scientific method that considers terrorism in the context in which it occurs.

In conducting this new study, the author developed a database of over 500 terrorists, beginning with "the nineteen September 11, 2001, perpetrators" (p. 27) as the index sample, focusing on their "relationships with other terrorists, nonterrorists, ideas, and the social, political, economic, cultural, and technological context" (p. 25). The database allows Sageman to dismiss many misguided beliefs about jihadists—for example, that poverty, lack of traditional education, and deeply religious backgrounds lead them to terrorism. On the contrary, most come from middle-class families, have a college education, and reflect moderately religious to secular upbringings (pp. 48–51).

"The Atlantic Divide," one of the more intriguing chapters, discusses differences between Muslims' experience in America, where they have assimilated relatively easily, even in the aftermath of 9/11, and in Europe, where they are seen as outsiders. Sageman believes that the latter perception has led to increased rates of radicalization in Europe, resulting in post-9/11 attacks there by homegrown terrorists.

Sageman ties all of these elements together by connecting the growth of the Internet to the loss of physical habitat that has all but neutralized al-Qaeda Central and has prompted that organization's social movement to seek the safety of chat rooms, where it flourishes today (p. 121). This phenomenon has added a new layer of complexity to combating terrorism. Whereas in the other waves, groups may eventually moderate and look beyond terrorism to attain their goals, virtual leaderless movements may not: "Unlike traditional terrorist organizations that have physical sites and more territorial ambitions, there is no incentive for a leaderless virtual social movement to moderate or evolve beyond terrorism" (p. 123).

Sageman makes a number of recommendations for combating this new wave of terrorism. Several are sharply perceptive (removing the glory from terrorism, countering the enemy's appeal, and funding scientific research on terrorism); others seem oversimplified and idealistic (diminishing moral outrage, ending discrimination against Muslims, and eliminating terrorist networks). Nevertheless, given the newness of this approach, the author's recommendations merit investigation.

Disappointingly, Sageman's expanded database does not include the detailed data that appeared in his previous work *Understanding Terror Networks* (2004). Matching the names of the perpetrators to terrorist acts would make the information all the more compelling. Regardless, *Leaderless Jihad* provides new insight and a fresh perspective on the study of Islamist-based terrorism in the twenty-first century, clarifying the motivations, demographic background, and contextual circumstances behind that threat.

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Harnessing the Heavens: National Defense through Space edited by Paul G. Gillespie and Grant T. Weller. Imprint Publications (http://www.imprint-chicago.com/), 207 E. Ohio Street, no. 377, Chicago, Illinois 60611, 2008, 235 pages, $29.95 (softcover), ISBN 1-879176-45-9.

Harnessing the Heavens, an edited compilation of presentations delivered at the US Air Force Academy's 21st Military History Symposium, addresses the early history of and roles played by various organizations—both military and civilian—in the exploration and exploitation of the newest medium of military competition—space. (Some individuals might argue that cyber is an emerging one as well, but it is too early to tell.) Written by several acknowledged experts in the field, the articles chronicle events familiar to readers with a developed knowledge of the history of military space, but even they will benefit from the numerous anecdotes that lend richness to the general story lines. The volume covers numerous efforts—American, Soviet, and Chinese—designed to capitalize on the emerging potentialities of space as envisioned by members of the Eisenhower administration and elsewhere in the early part of the Cold War and beyond. The heady years preceding Sputnik and the frantic activity that followed dominate the pages of this informative addition to scholarship on the history of military space. What comes across loud and clear in *Harnessing the Heavens* is the fact that space exploration was driven largely by national security concerns, not the often trumpeted rationale of extending the horizons of human knowledge. In short, realpolitik trumped idealism—a fact as true today as it was then. The political, technological, and societal challenges of the day (or some combination thereof) serve as the canvas upon which some fascinating aspects of the space race are painted. A sampling of the contributions follows.

In "National Security, Space, and the Course of Recent U.S. History," Roger Launius tracks the evolution of American thinking about space from the Eisenhower era to that of George W. Bush, highlighting the fact that in the near term, difficult, thorny issues surrounding the establishment of a workable space regime will percolate to the top of the national security debate and have serious implications for terrestrial geopolitics if no consensus emerges. In staking out the current debate regarding whether or not to weaponize space, Launius invokes RAND analyst Karl Mueller's useful identification of six distinct perspectives spanning the gamut from genuine space sanctuary to outright hegemony, as espoused by thinkers like Everett Dolman.

Howard McCurdy ("The Race to the Moon: Imagination and Politics as Shaping Forces in Space Policy") and P. Myles Smith ("Starting the Space Race: The Early Development of the Soviet Space Program") deliver thoroughly interesting pieces filled with little-known insights regarding the enthusiastic, naïve, and sometimes hegemonic aspirations of pioneering military and civilian visionaries. Piled atop these aspirations were fears, tragedies, and accidents that culminated in awe-inspiring technological progress and epic failures. McCurdy points out what made the moon effort possible: "impossible-to-replicate series of planned and unanticipated public events rooted in a war [the Cold War] that no longer exists. That is the great lesson of the race to the moon" (p. 46). This observation contrasts sharply with the often depicted programmatic and measured evolution from Mercury to Gemini to Apollo.

Regrettably, three articles seem strangely out of place in the volume. Amy Foster's "Coping with Celebrity: Women as Astronauts and Heroes" examines the complexities attached to women who enter the astronaut program seeking acceptance as equals with their male counterparts while simultaneously seeing their groundbreaking roles leveraged by leaders of the gender equality movement in society at large. Foster details how each woman coped with the dual demands in different ways. Though historical, the essay represents a sort of thematic speed bump in the otherwise smooth transition between the other pieces. "Giving Voice to Global Reach, Global Power: Satellite Communications in U.S. Military Affairs, 1966–2007" by Rick Sturdevant is rather technical and brimming with acronyms. To someone unaccustomed to considerable technical jargon, the article is a tough read. Finally, Dolman's contribution, "Astropolitics and *Astropolitik*: Strategy and Space Deployment," though well presented, is a theoretical argument in favor of space weaponization and American leadership regarding future control of space. As such, it is at variance with the historical bent of the other articles in this collection. Undeniably, his arguments have gained significant traction with a notable minority in the weaponization debate who advocate a more muscular and assertive US space policy; however, his theoretical posturing remains somewhat out of step with the theme of this monograph. These three ill-fitting—albeit interesting—contributions could well be standalone pieces or complementary additions to alternatively themed volumes; nevertheless, in this reviewer's opinion, they are incongruous with the overarching theme of *Harnessing the Heavens*.

"The Long March Upward: A Review of China's Space Program" by Dean Cheng is quite good but underdeveloped (likely due to the publisher's requirements). The evolution of the Chinese space program is a study in innovation, not so much in terms of technology per se (much of it given to China or obtained via espionage) but in terms of China's doing as much as it did with what little it had. Granted, the Chinese space program did in fact enjoy patronage from the People's Liberation Army and protection from many of the most egregious aspects of the Great Leap Forward and the Cultural Revolution (as well as the chaos and suffering wrought by those tumultuous and incredibly destructive events) due the centrality of nuclear, ballistic missile, and space efforts within Mao's grand geopolitical scheme. However, budgetary and resource constraints proved severe compared to those confronting scientists and strategists of the superpowers—a fact often overlooked by casual observers.

On balance, *Harnessing the Heavens* is relevant and worthwhile to the Air Force community. Of course, for readers already well versed in the challenges faced by decision makers during the time frame examined, the book is not all that earth shattering. It does, however, offer some new threads that add to the context of these times and further explain why certain events played out the way they did. For service members relatively unfamiliar with the history of military space, this addition to the scholarship represents a handy reference and stepping-stone to more in-depth coverage of the specific facets that it examines.

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Leathernecks: An Illustrated History of the United States Marine Corps by Merrill L. Bartlett and Jack Sweetman. Naval Institute Press (http://www.usni.org), 291 Wood Road, Annapolis, Maryland 21402, 2008, 479 pages, $60.00 (hardcover), ISBN 978-1-59114-020-7.

Leathernecks is a comprehensive and marvelously illustrated account of the history of the United States Marine Corps. Its authors, award-winning military historians Merrill L. Bartlett and Jack Sweetman, examine the personalities and events that have shaped the Corps over its 235-year history, from the service's inception in 1775 through its most recent operations in Iraq and Afghanistan.

Bartlett and Sweetman begin their story not in the legendary Tun Tavern in Philadelphia but, interestingly, in the village of Passamaquoddy, Nova Scotia. In November 1775, the citizens of that remote Canadian town sent a petition to the Continental Congress in Philadelphia requesting "to be admitted into the association of North Americans, for the preservation of their rights and liberties" (p. 13). Despite its appeal, the idea of liberating Passamaquoddy was quickly overshadowed by the prospect of capturing the nearby British naval base in Halifax. Thus, Congress recommended that Gen George Washington conduct an amphibious operation on the coast of Nova Scotia, "that two battalions of Marines be raised" from among his forces, and "that they be distinguished by the names of the first & second battalions of American Marines" (p. 14). Washington wisely rejected the scheme. At the time, his nascent army was fully occupied with the investment of Boston, and he could ill afford the loss of two battalions. Nevertheless, Congress decided to raise the Continental Marines separately from the army and began appointing officers in Philadelphia.

This little-known account of the Marines' founding is but one of the many nuggets in this veritable gold mine of interesting information. Through a concise and lively narrative, the authors relate numerous anecdotes from the Corps's past while providing a comprehensive organizational and operational history of the service. They examine the development of the Corps through the Revolution, detailing the Marines' first amphibious landing at Hog Island in the Bahamas as well as their role as ships' troops serving in every major naval engagement of the war. They go on to examine the service's activities during the Quasi-War with France and the First Barbary War. During the latter conflict, Lt Presley O'Bannon and seven other Marines carried the American flag to the shores of Tripoli—an event later memorialized in the Marine Corps Hymn.

The leathernecks—so named because of the broad leather stocks that Marines wore for protection against sword slashes—would go on to serve heroically at sea and on land during the War of 1812, the Seminole War, and the Mexican War. The Corps was not immune to the sectional tensions that would eventually lead to the Civil War in 1861. Of the 63 officers on active service, 20 would resign their commissions at the outbreak of that war, many to accept commissions in the new "grayback" Marine Corps of the Confederacy. Both corps saw considerable action during the conflict, for the most part aboard ship but also at the First Battle of Bull Run and the Battle of Drewy's Bluff. Bartlett and Sweetman do an admirable job of detailing these events, particularly in shedding light on the organization and operations of the Confederate Marines as well as the many amphibious operations conducted by the US Marine Corps across the globe during the nineteenth century.

Looming large over the second half of the book is the Corps's service in the world wars. During World War I, the Marine "Devil Dogs" in France served with the Army's Second Infantry Division, most conspicuously at the Battle of Belleau Wood near the Marne River. The authors do justice to World War II, perhaps the "Golden Age" of amphibious warfare and an important era in Marine history. They develop a clear analysis of how amphibious techniques evolved in this period with masterful retellings of the epic Pacific battles—Guadalcanal, Peleliu, and Iwo Jima, to name just a few—now firmly entrenched in Marine Corps lore.

The last four chapters of the book cover the time between the beginning of the Korean War and 2008. Bartlett and Sweetman consider such well-known battles as the Chosin Reservoir and Khe Sanh in addition to lesser-known events such as Capt John Ripley's heroism at the Dong Ha bridge in central Vietnam and the disastrous *Mayaguez* incident. The final chapter thoughtfully analyzes the Corps's many recent contributions to the war on terror, from the first F/A-18 air strikes in Afghanistan to pitched infantry battles in Iraq.

The authors make use of numerous primary and secondary sources to document their work, and they provide a sample of these sources in a comprehensive "Suggestions for Further Reading" section. This leads to what is perhaps the work's only weak spot: the absence of citations and a complete bibliography, both of which would be useful to other researchers. Nevertheless, the strengths of the book are many, including its high-quality scholarship and excellent writing, as well as the numerous full-color illustrations—112 in all. Additionally, *Leathernecks* is populated with over 140 photographs and 30 detailed maps. In short, the book is a masterpiece of visual and written history. Bartlett and Sweetman have produced a genuinely important book that will be a valuable addition to the bookshelf of anyone interested in the history of the United States Marine Corps.

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Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First Century Defense Industry by James Hasik. University of Chicago Press (http://www.press.uchicago.edu), 1427 East 60th Street, Chicago, Illinois 60637-2954, 2008, 224 pages, $35.00 (hardcover), ISBN 978-0-226-31886-8.

For the audience of *Air and Space Power Journal*, the "Arms and Innovation" portion of the title of James Hasik's book *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First Century Defense Industry* will probably prove more intriguing than "Entrepreneurship." But that shouldn't put readers off. The work at hand has appeal for both the operational and logistical parts of the Air Force. The author probably intended his book for businessmen and industry engineers, but it has real value for military aviators, engineers, and acquisition officers as well.

Hasik has solid qualifications for the work, and his writing style is good, though some of the business jargon may seem a bit cumbersome. A senior consultant with Charles River Associates International and an adviser for businesses in the armaments industry, he has an economics degree from the University of Chicago and a bachelor's degree in both physics and history from Duke. Hasik has also coauthored *The Precision Revolution: GPS and the Future of Aerial Warfare*, another well-received work relevant to Airmen.

The theme of *Arms and Innovation* is that small firms can turn a profit in an industry dominated by a few giants like Boeing, Northrop Grumman, and Lockheed-Martin. They can do so by taking advantage of their strengths in innovative technologies that do not require deep scientific research, long production runs, or large-scale integration capabilities. Such small companies can survive by conducting independent work, partnering with the major corporations, or acquiring what they need in the way of unfamiliar technologies through market mechanisms. They should proceed with care, though, because the giants can overwhelm smaller businesses in some circumstances.

To make his point, Hasik uses several case studies, apparently drawn from his previous writings. Obviously his chapter on the Joint Direct Attack Munition system looks to his book on precision weapons and the Global Positioning System. He includes similar chapters on space programs, remotely piloted aerial systems, small naval vessels, and—especially—new vehicles to cope with mines and roadside bombs in the

Middle East. Hasik discusses opportunities to take advantage of innovation in overseas communities (Australia for small vessels and South Africa for armored vehicles) to the profit of both—new ideas for America and profits for the overseas businesses.

Notions about innovation are useful for officers in every field. People in both the technical and business fields of Air Force Materiel Command will find the case studies instructive. Operators will benefit from the book by adding to their understanding of the innovation and acquisition processes against the day when they become involved in the generation of requirements. Everyone needs to understand that innovation can come from a host of different directions—in new technologies and in better ways of combining and using older ones. I recommend that air warrior-scholars give *Arms and Innovation* a high place on their reading lists.

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The Black Swan: The Impact of the Highly Improbable by Nassim Nicholas Taleb. Random House (http://www.randomhouse.com), 1745 Broadway, New York, New York 10019, 2007, 400 pages, $28.00 (hardcover), ISBN 978-1-4000-6351-2; 2010, 480 pages, $17.00 (trade paperback), ISBN 978-0-8129-7381-5.

Even the most casual observers of history concede that attempts to predict the next threat to national defense are often erroneous and, consequently, not only futile but also misleading. In elegant yet candid fashion, Nassim Taleb addresses the inclination to fallaciously predict by conceptualizing the "black swan" phenomenon, which involves highly improbable events, thus almost impossible to anticipate, that inflict disproportionate influence. Subsequently, we examine these events in hindsight and rationalize them with prescriptive remedies. Though doing so is a human tendency, such a retrospective analysis ignores the fact that these events transcend normal expectations and, therefore, are innately unpredictable. Taleb's *The Black Swan* is an inviting narrative of this phenomenon, driving deeply into the author's philosophical approach to life and, in the process, providing an invaluable education in history, philosophy, economics, and foreboding—all of which make the book a welcomed companion for those who seek to understand the future.

The Black Swan is the second piece of Taleb's work on probability, randomness, and the repercussions of our inability to predict. As in his other books, Taleb's upbringing in war-torn Lebanon offers a foundation not only for his theories but also for the development of the author's intellectual understanding. This artful approach gives the book depth and richness, and in doing so inundates the reader with humor, satire, and sarcastic explanations for humanity—which, if not for the engaging prose, would alienate the book's audience. Far from alienating readers, however, Taleb draws them to the book, thereby stimulating philosophical contemplation.

His frustration with academia stems from the latter's inability to supply useful prescriptive recommendations that account for randomness. Taleb summarizes this resonating theme with a pragmatic look at economists, whose predictive "insight" into markets frequently leads to errors and miscalculations. Most economists remained oblivious to conditions that drove the Great Depression; furthermore, they failed to anticipate the recent crash in the housing market and subsequent "Great Recession." Yet, in hindsight, economists downplay their ineffectiveness in foreseeing economic events as failures not in prescriptive methodology but in technical analysis. Thus, they fail to acknowledge the underlying problem in prediction: randomness and the role of improbable events (which, oddly, can and do occur).

Taleb makes the compelling argument that economists, like other professionals, suffer susceptibility to black swan phenomena. The term itself derives from a cautionary tale rooted in scientific deduction. The very notion of a black swan was inconceivable to Europeans before their discovery of Australia. The idea that all swans were white enjoyed such prominence that people dismissed the sighting of the first black swan as an error. Despite the relative insignificance of this story (except to a few ornithologists of the time), it illustrates that "what we see is not necessarily all that is there" (p. 50), revealing the "limitation to our learning from observations or experience and the fragility of our knowledge" (p. xvii). This single event disproved the axiom—brought about through countless observations of white swans—that all swans are white, bringing to light a problem with the philosophical logic that drives learning and knowledge. One does not have to search far for black swan events, which characteristically demonstrate "rarity, extreme impact, and retrospective (though not prospective) predictability" (p. xviii).

The history of national defense is dense with black swan events, from the rise of Hitler to the demise of the Soviet bloc. Recently, the terrorist attacks of 11 September 2001, the insurgency in Iraq, and the Sunni Awakening show that history is rich with unpredictable yet highly consequential events. It is human nature that, after the fact, we assume we could have foreseen these events had we just been looking at the right things or drawn the appropriate conclusions. According to Taleb, this is the crux of human knowledge: we misinterpret history, and we dismiss the impact of randomness as improbable.

As for recommending the best way to cope with the black swan phenomenon, Taleb falls short. Although he devotes significant effort to explaining how to deal with improbable events, the conclusion is fiscally oriented. The beauty of Taleb's argument, therefore, is not its prescriptive element but the far-reaching applicability of black swan events. Human history (and even our personal lives) is shaped to a large degree by events we could not have predicted. The very fact that these events lay beyond our comprehension of what we expected made them significant. Unfortunately, Taleb fails to capitalize on the elegance of the far-reaching applicability in his theory, instead focusing on academia and finance. The reader may walk away with a sense of irresolute applicability of the black swan phenomenon, but the book's philosophical examination of the unknown has considerable value.

Why then, would *The Black Swan* interest those of us who study air and space defense? The answer lies in understanding the limitations of human knowledge and the validity of empirical evidence to derive what is "fact." Taleb's resounding explanation serves as an ominous warning: do not attempt to foretell the next threat or war—instead, prepare for the unexpected and the highly improbable. Chances are, luck and improbability will play a dominant role in tomorrow's conflict.

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Radical Wings & Wind Tunnels: Advanced Concepts Tested at NASA Langley by Joseph R. Chambers and Mark A. Chambers. Specialty Press (http://www.specialtypress.com), 39966 Grand Avenue, North Branch, Minnesota 55056, 2008, 160 pages, $36.95 (hardcover), ISBN 978-1-58007-116-1.

Commonly called the "Mother Center," the National Aeronautics and Space Administration's (NASA) Langley Research Center in Hampton, Virginia, was the United States' first civil aeronautical research laboratory. The National Advisory Committee for Aeronautics (NACA), NASA's predecessor, created its first laboratory at Langley in 1917. In their book *Radical Wings & Wind Tunnels*, Joseph and Mark Chambers explore the history of the Langley test facilities and some of the aircraft tested there, focusing on two main areas: the wind tunnels and the aircraft that have gone through them.

Built in 1922, the first wind tunnel—the variable-density version—accurately tested subscale models. By the 1930s, Langley boasted five tunnels: the variable density, propeller (for component testing), spin, full scale, and free flight, all of them described in detail, including their dimensions and operating capabilities. The authors also provide diagrams of the wind tunnels and period photographs of aircraft such as the P-26 Peashooter and P-51 Mustang during their testing.

Numerous aircraft went through evaluation at the Langley facilities (both wind-tunnel and flight testing), a process that yielded various aerodynamic discoveries. This portion of the book examines early aeronautical developments (testing prior to 1958), support to spaceflight, extremely radical wing designs (reflected in the book's title), and more recent military and civil testing. The testing of 27 early aircraft led to the development of aeronautical advances such as low-aspect wing-ratio airfoils, all-movable horizontal stabilizers, advanced flaps, aircraft cooling, more aerodynamic cowlings, and laminar-flow airfoils. With the transition of the NACA to NASA, manned space exploration became the organization's primary interest, as was the case with the Langley facilities. Researchers explored such concepts as the parawing, for landing after a visit into space; lifting bodies; and the lunar-lander training vehicle. The truly radical wings and aircraft included tilt and tilt-duct wings as well as vertical-take-off-and-landing and tail-sitter aircraft. The book concludes by addressing more recent research on the civil and military fronts, including thrust vectoring and sonic booming.

The authors fill *Radical Wings & Wind Tunnels* with photographs of wind tunnels, aircraft, and spacecraft. Despite its technical orientation, the text is accessible to aviators and nonaviators alike. Pilots, for example, will immediately recognize the numerous aeronautical advances produced by Langley's research efforts, but readers with no flight experience will also find the book fascinating. One should note, however, that even though the book seeks to document the "more interesting radical aircraft concepts" tested at the Langley facilities, the authors' discussion of sources is lacking, reflected by the absence of a bibliography. Nevertheless, *Radical Wings & Wind Tunnels* demonstrates that NASA is more than just spaceflight and space exploration. Clearly, we have the Langley test facilities to thank for many of the aviation concepts and innovations that we enjoy today.

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Empire of the Clouds: When Britain's Aircraft Ruled the World by James Hamilton-Paterson. Faber and Faber (http://www.faber.co.uk), 74-77 Great Russell Street, London WC1B 3DA, 2010, 304 pages, £20.00 (hardcover), ISBN 9780571247943; 2011, 396 pages, £9.99 (softcover), ISBN 9780571247950.

Empire of the Clouds is a cautionary tale in the loss of national capability. A world leader in jet aircraft technology in 1945, Britain needed only a little more than a decade to lose its lead decisively in the development and production of both military and commercial jet aircraft. This was the result not merely of inept political decisions—such as the 1957 Defence White Paper that cancelled many aircraft programs on the grounds that guided missiles made manned aircraft obsolete—but also of poor management at many levels within industry itself.

The book is neither a scholarly work nor a comprehensive examination of British postwar aircraft, aircraft-industry management practices, or industrial policy. Author James Hamilton-Paterson tells his story primarily from the perspective of the pilots who tested prototype aircraft. In particular he focuses on Bill Waterton, a Canadian who joined the Royal Air Force in 1939 and who was the chief test pilot for Gloster Aircraft from 1946 to 1954, when clashes with Gloster's management led to his dismissal. As a journalist for the *Daily Express*, Waterton wrote scathing critiques of Britain's aircraft industry until pressure from advertisers forced the paper to fire him in 1956.

The tales of test-pilot derring-do are exciting but, unfortunately, get in the way of understanding the decline and fall of the British aviation industry in this period. For example, why was the DH.110 so poorly designed as to break apart in midair, killing two aircrew members and 29 spectators at Farnborough in 1952? Why did the Hawker Hunter take so long to enter operational service, allowing the North American F-86 to dominate world export sales? Why did the de Havilland Comet airliner take so long to develop and deliver, even before the disastrous accidents that forced its withdrawal from commercial service, leaving the field to the Boeing 707? Why were the British still flying straight-wing Gloster Meteors and de Havilland Venoms in the late 1950s while the French, whose aircraft industry lay in ruins in 1945, began operating the swept-wing Dassault Ouragan in 1952 and the Mystère in 1954? Hamilton-Paterson's answers to these and similar questions are unsatisfactory. He repeatedly notes the excessively long lunches and stuffy, conservative attitudes of the senior managers of British aircraft companies in the 1950s, perhaps because his sources (test pilots) personally witnessed these shortcomings. However, the problems went much deeper than this, and only at the end of the book does the author note the real problem—a lack of systems engineering expertise below top management. As a result, Britain could develop cutting-edge prototypes but could not manufacture large quantities of high-quality aircraft in a timely and economical manner. This problem prevailed not only in the aircraft industry but also in British manufacturing as a whole, contributing to the decline in national competitiveness from the 1950s onward.

Hamilton-Paterson highlights the role of government decisions in the decline of British postwar aviation. For example, in 1946 the government parsimoniously cancelled the Miles M.52, which might have been the first aircraft to break the sound barrier, and stupidly gave samples of the Rolls-Royce Nene engine to the Soviets, who promptly copied and used it in the MiG-15. Worst of all, the Defence White Paper of 1957 cancelled the Fairey FD.2 (potentially a competitor to the Mirage III), the Avro 730 (a Mach 3 bomber), and the Saunders-Roe SR.177 supersonic interceptor (potentially a competitor to the Lockheed F-104), and many other aircraft. One program that survived the axe in 1957, the British Aircraft Corporation TSR-2, was cancelled in

1965 in favor of buying the General Dynamics F-111, but then in 1968 the government rescinded the decision to purchase F-111s! The author correctly notes that Britain lacked a national industrial strategy to sustain its air and space leadership after World War II and thus made many decisions based on short-term political and economic needs. Britain emerged from the war with a massive aircraft industry, and 1945 might have been a propitious time to rationalize the industry. However, in the absence of a long-term strategy, the political pain of doing so and putting many famous names out of business proved too great. When such rationalization became inevitable in 1957, Britain had already lost its leadership in aviation technology, and the program cancellations and corporate mergers served only to demoralize the workforce. Less convincingly, Hamilton-Paterson hints at a long-term political conspiracy

> to eradicate [aviation] industry [with] contradictory policies, the withholding of support and funds, and the progressive poisoning of morale. . . . [This was] merely part of a historic policy change to do away with all Britain's capacity as a serious industrial nation. . . . There is surely no other interpretation to be made of the steady, decades-long demolition of the country's manufacturing capacity, including its most charismatic industry, other than at some level it was absolutely intentional (p. 329).

Parenthetically, the author sneers at remotely piloted aviation as insufficiently glamorous—"merely a radio-controlled model for grown-ups in uniform" (p. 332). Undoubtedly, controlling a remotely piloted aircraft is less glamorous than flying an aircraft and much less dangerous than being a 1950s test pilot. Still, from the standpoint of the British air and space industry, remotely piloted aircraft represent a realm in which Britain could in principle compete effectively. Thus far, however, its home-grown remotely piloted aircraft programs have been unimpressive, suggesting that the chronic problems of the British air and space industry outlined in this book persist to this day.

I recommend reading *Empire of the Clouds* with a view to understanding the lessons for the United States today. Happily, America still has the national will to remain a world leader in air and space. However, we must maintain a highly trained air and space workforce proficient in systems engineering disciplines, and we must manufacture enough aircraft in this country in order to have the capability not merely of developing ingenious prototypes but of producing operationally suitable aircraft in the numbers and of the quality required. Resting on its laurels after 1945, Britain lost the capability to develop *and produce* the most advanced aircraft in significant numbers and never regained it.

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My Life as a Spy: One of America's Most Notorious Spies Finally Tells His Story by John A. Walker Jr. Prometheus Books (http://www.prometheusbooks.com), 59 John Glenn Drive, Amherst, New York 14228-2197, 2008, 349 pages, $25.98 (hardcover), ISBN 978-1-59102-659-4.

An intense, captivating, and challenging book, John Walker's *My Life as a Spy* reflects an important, growing political discussion about information security. Furthermore, it is interesting for a variety of reasons—first, as a true-life spy story. Curious readers will wonder how Walker got away with selling secrets to the Soviet Union and will compare his experience to the depiction of spies, fictional or otherwise, in the media of popular culture. Second, the suspenseful narrative not only offers insight into a successful spy program but also addresses the mistakes that led to Walker's undoing. Third, the book appeals on a personal level, revealing what this master spy was like and why he would risk his own life as well as the lives of friends and family members (notably, Walker's plans to expand his spy ring over time even extended to his own son). Fourth, *My Life as a Spy* raises powerful, thought-provoking political questions by addressing the disingenuousness of politicians, America's historical tendency to inflate the severity of Soviet threats, the Navy's weak security measures, the Department of Defense's long-standing practice of overclassifying records, and the matter of whether or not compromises of secret documents actually cause harm to national security.

Many of the political issues that Walker writes about are recurring ones—witness the current debate over the Wikileaks release of military and diplomatic records. This leads to questions that face world governments, which must decide the proper level of access in this modern information age. Indeed, given the proliferation of computers and Internet connections, one wonders whether secrets can even exist. Walker obtained information by photocopying documents and taking pictures with a microcamera; currently, devices such as pinhole cameras, spy cameras, and other high-tech equipment are generally available to the public. Computer users have access to a wide range of information, including documents, audio and video files, and live video from broadcast agencies and webcams, not to mention satellite photos—all of which is easily posted on the Internet in seconds.

Thus, governments must consider the possibility that information released to the public might help their people move towards democratic governments and/or overthrow dictators. Instant information access could also lead to a state of perpetual unrest instigated by individuals demanding immediate gratification and results. Consequently, governments must decide if it is more important to control information by making it secret or to mine available open-source data.

Walker claims that he divulged secret information to assure the Soviet Union that the United States was not planning a first strike, arguing that if the two countries knew more about each other, they would be less likely to go to war. Readers must decide whether he is rationalizing or genuinely promoting the optimal use of information.

I recommend *My Life as a Spy* because it holds the reader's interest on many different levels and because it intriguingly explores a variety of political issues. This worthwhile book should appeal to a broad audience.

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Al-Qa'ida's Doctrine for Insurgency: 'Abd al-'Aziz al-Muqrin's *A Practical Course for Guerrilla War* by 'Abd al-'Aziz al-Muqrin, translated and analyzed by Norman Cigar. Potomac Books (http://www.potomacbooksinc.com/books/features.aspx), 22841 Quicksilver Drive, Dulles, Virginia 20166, 2008, 210 pages, $44.00 (hardcover), ISBN 978-1-59797-252-9; 2008, 224 pages, $21.56 (softcover), ISBN 978-1-59797-253-6.

In *Al-Qa'ida's Doctrine for Insurgency*, Norman Cigar delivers a tour de force in terms of terrorist/insurgent training and doctrine by translating a major piece of terrorist thought from 'Abd al-'Aziz al-Muqrin, one of the founding members of Saudi Arabia's al-Qaeda network. This book offers a fascinating look inside the mind of an insurgent intellectual who had 15 years of practical experience throughout the Middle East, Africa, and Bosnia-Herzegovina. Much of this work could easily apply to any terrorist group in the world, regardless of ideological makeup.

After al-Muqrin's death at the hands of Saudi security forces in June 2004, al-Qaeda of the Arabian Peninsula (QAP) declared him a martyr, posted many of his teachings online, and published *A Practical Course for Guerrilla War*, a collection of al-Muqrin's writings. The collection appeared after QAP members voted on the specific presentation of his works (p. 88).

Before addressing *A Practical Course for Guerrilla War* itself, Cigar highlights al-Muqrin's analytical insights as well as his life and works. A research fellow at Marine Corps University with extensive experience as a political-military analyst, Cigar offers a good but rather lengthy overview of his subject. (Many of his comments, though helpful, are more appropriate for footnotes, which would have left additional room for Cigar to expound upon al-Muqrin.) In *A Practical Course for Guerrilla War*, a comprehensive approach to asymmetrical warfare within the radical Islamic framework, al-Muqrin presents his real-life experiences, from Afghanistan to Saudi Arabia, in a classically structured guerrilla warfare doctrine. He defines concepts such as conventional and unconventional war prior to laying out the basic structures and operations of a "good" terrorist/insurgent organization. Dealing with leadership, logistics, and training, this "practical course" stresses the importance of propaganda and psychological warfare, making a number of recommendations. Al-Muqrin offers a relatively objective, straightforward, and intellectual description of guerrilla warfare in the Middle East, despite the occasional outburst at Jews and Christians (see, for example, his ranking of occupations and countries for destruction, pp. 127–31).

The course concentrates on the issues and locations most relevant to al-Qaeda operations, taking a step-by-step approach to the latter, from carrying out assassinations and taking hostages to conducting attacks on motorcades and making dead drops. The discussion includes gathering intelligence; preparing for attack; selecting personnel; executing with quick, deadly precision; and withdrawing afterward. Throughout, the treatise stresses the long-term, unconventional nature of jihad and the need to survive to fight another day (the course makes no mention of suicide attacks), covering such details as types of operational cell structure and size along with the characteristics of personnel and job functions for a typical organization.

Interestingly, al-Muqrin appears to have had an inordinate fear of opposition security forces, reflected in his suggestion that each operational cell have an assault team of two to four people, quite a small number. Although he does mention combining teams, this solution seems ad hoc and fails to address the matter of training and preparing teams for large-scale attack. Al-Muqrin seems to relegate his operation to minor attacks that have little impact, all out of fear that the enemy's security forces could decimate his personnel. Indeed, terrorist/insurgent organizations frequently debate over the amount of separation among cells that is necessary to avoid complete annihilation of the organization brought about by information extracted from a captured member. To confirm the minimal impact of these small operations, one need only look to Saudi Arabia, where Saudi security forces took out al-Muqrin and many top QAP operatives between 2003 and 2004, soon after establishment of their Arabian network.

Cigar acknowledges the existence of many articles, videos, and manuals based upon al-Muqrin's ideas—items either not included or given short shrift in this text. For example, readers find little if anything about terrorist activities in rural and nonmountainous areas, weapons of mass destruction, plans affecting the United States and other Western countries, financing, recruiting, specific training and development beyond a few types of attacks, and operations against critical Arab infrastructure such as oil fields and refineries. Granted, the QAP simply may have withheld some items or heavily edited the ones that appear in the text. Nevertheless, the inclusion of more of al-Muqrin's works or those inspired by him would have provided a fuller picture of terrorist doctrine.

In sum, *Al-Qa'ida's Doctrine for Insurgency* is a must-read for policy makers, military personnel, academics, and the general public—for anyone interested in terrorism, especially the version practiced by al-Qaeda. Because many of al-Muqrin's precepts and standard operating procedures apply to any terrorist/insurgent organization, understanding the intellectual underpinnings of al-Qaeda and its operational doctrine can lead to much better countermeasures against terrorism in general. Although al-Muqrin's death in 2004 obviously put an end to the development of his thinking on terrorism, resulting in the relatively unsophisticated treatise presented in this book, enough remains to give terrorists/insurgents something to build upon if they obtain the necessary experience, intelligence, and proficiency. However, the incomplete nature of texts such as this one perhaps played a role in leaving terrorists vulnerable to their enemies—witness the ignominious end of al-Muqrin and other prominent QAP leaders such as Osama bin Laden. Taking full advantage of this vulnerability represents yet another reason to read *Al-Qa'ida's Doctrine for Insurgency*.

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Cyberdeterrence and Cyberwar by Martin C. Libicki. Rand Corporation (http://www.rand.org/pubs.html), 1776 Main Street, Santa Monica, California 90401-3208, 2009, 238 pages, $26.40 (softcover), ISBN 978-0-8330-4734-2.

You're a system administrator running some routine checks on your data-management functions when you come across something that at first looks like nothing more than a system hiccup. Upon closer examination, which includes checking the servers and hardware, you find that some codes and information have been changed, revealing a more serious problem. Is this the work of thrill-seeking hackers, attempted sabotage by internal personnel, or a cyber attack? If the latter, do you retaliate or simply pretend it never happened?

Martin Libicki's *Cyberdeterrence and Cyberwar*, which addresses the subjects of the book's title in the Internet age, examines cyber war's radical differences from conventional war and the difficulty of implementing and enforcing a policy of cyber deterrence. With regard to a nation that has a policy of cyber deterrence, the author also raises such issues as determining the identity of the attacker, his motive, and the nature of the response (e.g., retaliating, ignoring the incident, or pretending it caused little damage); assessing the importance of such a determination; following a "no tolerance" policy versus attempting to distinguish between a true cyber attack and hacking; and conducting a cyber war or implementing a deterrence strategy, which includes formulating reasons for doing so and ending a war that has no outward signs of damage, casualties, or immediate (theoretically) effects. Libicki concludes by discussing cyber defense, its construction, and its procedures (e.g., "deception methods" and "red teaming," pp. 171 and 173).

The fact that Lt Gen Robert Elder Jr., USAF, retired, former commander of Eighth Air Force and joint functional component commander for space and global strike, US Strategic Command, sponsored *Cyberdeterrence and Cyberwar* gives it considerable credibility. Readers knowledgeable about the now-global cyber wars (conducted by such groups as Anonymous and LulzSec), as well as readers working as systems administrators and computer designers, should find some of the book's theories and cases familiar. The book's primary strength is that it presents the rapidly developing and ever-changing fields of cyber war and cyber deterrence in a fairly easy-to-comprehend format, free of overly detailed technical terms or information processes.

However, one does find flaws in formatting, organization, and the use of abbreviations that may detract from the study's value and impact. For example, the presence of pages only partially filled with text (e.g., pp. 75, 147, and 149) and of unnecessary hyphenation (e.g., "locked-down" [p. 151], "more-violent" [p. 72], and "flow-rate" [p. 155]) gives the book the feel of a rough draft rather than a finished manuscript. Furthermore, readers find no information about the author, his credentials, his motivation for writing the book, or his methodology. Lastly, the author's inclusion of a list of abbreviations (p. xxiii) with which most people are already familiar seems unnecessary, and his tendency not to reidentify infrequently occurring abbreviations creates difficulty for the reader (e.g., "RF" [p. xxiv], which doesn't appear again until p. 164). Together with the absence of an index and the confusing, poorly explained charts in Appendix B, such flaws are certainly distracting and give readers an unfavorable impression of the book.

Is *Cyberdeterrence and Cyberwar* relevant to the Air Force community? Despite the abovementioned problems, it does raise interesting questions and theories about cyber warfare and cyber deterrence as well as what they mean to today's military operations and civilians. I recommend it to all military personnel, even those not directly involved in system security or computers in general.

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U.S. Air Force Tactical Missiles, 1949–1969: The Pioneers by George Mindling and Robert Bolton. Lulu (http://www.lulu.com), 2008, 318 pages, $19.95 (softcover), ISBN 978-0-557-00029-6.

Prior to the publication of *U.S. Air Force Tactical Missiles, 1949–1969*, information on these early missile systems—the predecessors of today's cruise missiles—was superficial at best. Neither these tactical missiles nor their programs, hardware, and worldwide alert/launch sites have received the documentary attention of combat aircraft and strategic missiles, despite their importance to conventional and nuclear deterrence. Authors George Mindling, who served eight years in the Mace missile program, and Robert Bolton, who served on Mace "A" launch crews for four years, strive to close this informational "missile gap." They do so by writing from a combination of firsthand experience and in-depth research to help the reader fully appreciate the pervasive deployment of these systems and their importance with regard to both their air defense and regional nuclear-deterrence roles. The authors carefully blend cited material with anecdotal support to bring these systems to life, just as they were nearly five decades ago. Their story unfolds with some big-picture information on policy and development, and lots of nuts-and-bolts detail to please the hardware enthusiast.

Early chapters provide background on the German V-1, from its development at the Peenemünde test site, through the mass attacks on England in 1944, to its reverse-engineering into the JB-2 Loon back in the United States. The book also discusses the Kettering "Bug" Aerial Torpedo, a less-than-successful pilotless weapon that shared features with the V-1 and, later, the Matador. Other early, remotely piloted bomber projects are briefly mentioned, such as the MX-771 project, later known as the B-61 Matador, phased out (only briefly) in favor of the Navy's Regulus project. The authors devote most of their attention to operational units in West Germany that deployed in 1954, developed the Matador system, and then replaced it with Mace "A" and eventually Mace "B" missiles, which remained operational until 1969.

Mindling and Bolton describe both the Matador Airborne Radio Control and the Short-Range Navigation Vehicle guidance systems as well as the scheduling construct of nuclear alert status, known as Victor Alert. Furthermore, they examine the little-known communications and guidance detachments, with their guidance and control vans at remote locations between the launch sites and the Czechoslovakian border. The authors also explain the map-matching Automatic Terrain Recognition and Navigation guidance system used in the Mace A missile and the Mace B's inertial guidance system.

Readers will find less coverage (due to the secrecy of the Pacific deployments at the time) of the Matador missiles deployed at Tainan Air Station (Taiwan) as well as Osan Air Base (South Korea) and of the Mace missiles later deployed at Kadena Air Base (Okinawa). Although this discussion helps paint the broader picture, the authors concentrate on the European deployment.

In terms of omissions, the book lacks maps. I recommend the inclusion of (1) overview maps showing the general location of the Matador and Mace launch sites and the target areas they could reach, (2) vicinity maps of the missile bases showing their off-base missile sites and support areas, and (3) layouts of typical Matador and Mace sites showing the various structures and pads. Readers would also appreciate a one-page chart explaining the Matador and Mace missile designations over time (one finds the details in the text, but a quick-reference timeline would make the story much easier to follow). Editing is generally good within chapters but not between them, insofar as readers will encounter information covered in a previous chapter.

Students of Cold War history will find that *U.S. Air Force Tactical Missiles, 1949–1969* offers a good overall look at one important aspect of our military presence overseas. These missiles were a key part of our forward-based nuclear presence for many years. Despite numerous references to the larger geopolitical picture, the authors have not written a general history of the Cold War. Primarily, they offer a thorough reference work on the Mace and Matador missile systems. Indeed, the carefully researched, detailed information found here will aid any researcher of missile systems and deployment. After having read this book, veterans of Germany or Okinawa will better understand what they saw or worked with. For me, I have more appreciation of the significance of those strange, abandoned bunkers I photographed at the Rittersdorf missile site in West Germany three decades ago. I recommend *U.S. Air Force Tactical Missiles, 1949–1969* to readers with an interest in this subject.

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Aces High: The Heroic Saga of the Two Top-Scoring American Aces of World War II by Bill Yenne. Berkley Caliber (http://www.penguin.com), 375 Hudson Street, New York, New York 10014-3657, 2009, 368 pages, $25.95 (hardcover), ISBN 978-0-425-21954-6.

Bill Yenne, a prolific writer, was born in 1949 and graduated from the University of Montana. The title of his book *Aces High: The Heroic Saga of the Two Top-Scoring American Aces of World War II* might suggest that he writes for the popular market, and the widely diverse books he has produced support that idea. This is not to suggest that Yenne's writing is weak and his grasp of air history imperfect. On the contrary, he writes quite well, only rarely making a historical error in the book under consideration. He has published works on Alexander the Great, the history of beer, and Sitting Bull, not to mention airpower subjects. The catalog of the academic library at Air University lists 17 of his books. Clearly, he must read at blazing speed and write briskly with good style. Nevertheless, I do not recommend that *Aces High* occupy a high place on the reading lists of *Air and Space Power Journal*'s (*ASPJ*) audience.

Yenne tells an adventure story about P-38 pilots Richard Bong and Thomas McGuire—two leading American aces, both of them recipients of the Medal of Honor—who flew in the Southwest Pacific and died at age 25. The author injects some human interest into the story by discussing their personal lives in training as well as their wartime loves. Gen George Kenney, Douglas MacArthur's air commander, took a personal interest in both heroes; in fact, he wrote a biography of Bong after the war.

ASPJ readers will find that the book concentrates almost wholly on operational history at the tactical level, tending toward a sortie-by-sortie description of the work of both pilots, set in a story of competition between the two for the title of America's leading ace. Doubtless, some rivalry did exist, but here it dominates the tale. Modern expeditionary warriors will find little to enhance their understanding of tactical principles, logistics, campaign strategy, surface operations at sea and on the ground, and air support of the latter. The problems of higher command and the difficulties of imposing unity of command in the Pacific are worthy of study but receive no attention in this work—as is the case with the air campaign in the Southwest Pacific, one of the primary sources of modern tactical air doctrine.

Aces High is an adventure story, pure and simple. McGuire died in combat near the end of the war, and Bong in a jet crash in California not long after he returned home—tragic endings that enhance the book's value in the popular market.

Readers who wish to further their professional education should bypass *Aces High*. For those reading for recreation, then it is worthy up to a point, but the long recitation of individual sorties does become wearing. Readers might be better served by General Kenney's own books, on which Yenne heavily depends (*General Kenney Reports: A Personal History of the Pacific War* [1949, 1997] and *Dick Bong: Ace of Aces* [1960, 1980]), or by Thomas Griffith's wartime biography of Kenney, *MacArthur's Airman: General George C. Kenney and the War in the Southwest Pacific* (1998).

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The Supermarine Spitfire by Chaz Bowyer. Prentice Hall (http://prenticehall.com/), One Lake Street, Upper Saddle River, New Jersey 07458, 1983, 64 pages, $18.00 (softcover), ISBN 978-0138758073.

The Supermarine Spitfire—a famous British fighter of the Second World War, noted for its actions during the Battle of Britain—was the only Allied fighter in continuous production throughout the war. In this fascinating account, British aviation historian Chaz Bowyer narrates the Spitfire's story from the aircraft's beginnings to its retirement from the Royal Air Force (RAF) in 1950.

The opening chapter relates the progress of the Spitfire, a replacement for the RAF's Bristol Bulldog, from the drawing board to its first flight in 1936 and entry into service two years later. The Spitfire joined the fight when a flight scrambled to intercept Luftwaffe Ju 88 bombers headed for the dockyard at the Firth of Forth, Scotland.

Subsequent chapters cover the fighter's actions at the Battle of Britain (the highlight of its career along with that of the Hawker Hurricane) and during the Allied offensive from late 1941 to 1944. Bowyer also chronicles the Spitfire's desert service during campaigns from the Island of Malta to North Africa, through the invasion of Sicily, to the independence of Israel in 1947. Notably, the air forces of both Israel and its adversaries flew Spitfires.

The naval version of the Spitfire, the Seafire, saw action in North Africa, the Mediterranean, and the Baltic against German battleships and with the British Pacific Fleet. They were also in the Pacific, arriving in-theater in mid-1942 during operations against Japanese forces from Malaya and Australia up to India. Bowyer also mentions the RAF's using the Spitfire for photoreconnaissance as early as 1939.

The penultimate chapter of the book focuses on the aircraft's last years in the RAF through retirement in early 1950. Retirement did not mark the end of its career, however, since a number of Spitfires and Seafires continued to fly with the air forces and naval air arms of European, Middle Eastern, African, and Southeast Asian nations until 1960.

Each chapter is fully illustrated with photographs, cutaway drawings, and full-color artwork that would appeal to scale modelers. Supplementing the book are an appendix including performance data on all Spitfire models, a comparison of the Spitfire and Seafire, and a listing of all RAF, Royal Navy (Fleet Air Arm), and Commonwealth Air Forces squadrons that flew these magnificent aircraft. Furthermore, a four-page pictorial account introduces readers to famous Spitfire pilots and aces of the RAF, such as Wing Cdr Johnnie Johnson, credited with 38 victories, and Col Chesley Peterson, US Army Air Forces, who served in the "Eagle Unit."

Aviation author Chaz Bowyer, who served in the RAF for 26 years, is to be commended for this impressive book. I highly recommend it to all aviation enthusiasts, scale modelers, military and civilian historians, students, and readers interested in the history of the RAF.

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