September–October 2015
Volume 29, No. 5
AFRP 10-1

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SEADE

Countering the Futility of Network Security

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> *We cannot solve our problems with the same thinking we used when we created them.*
>
> —Albert Einstein

Today's media is flooded with stories of cyber attacks prompting a loss of public confidence, resignations by senior officials, and a significant near- and long-term impact on our nation. Most of these breaches stem from known vulnerabilities in existing network security architecture, presenting a distinct danger to our vital national interests. These vulnerabilities, which vary in sophistication, could be as simple as using weak passwords (e.g., default value, simple number strings, or the word *password* itself). Slightly more sophisticated attacks leverage phishing attempts through e-mail or social engineering, designed to elicit unsafe action or information that would allow adversaries unauthorized access.

The notion of "defense in depth" has been touted by leading security organizations (which rely on the National Institute of Standards) as the basis upon which a security framework can be developed to safeguard our networks. The depth includes both physical security protections (walls, gates, locks, guards, and computer cages) and logical security measures (network firewall and intrusion detection). However, no matter how many layers of network perimeter protection are employed, adversaries continue to overcome defenses through using a variety of countermoves or by exploiting poor cybersecurity practices.

Furthermore, successful cyber attacks highlight the fact that disciplined cyber hygiene is necessary but not sufficient to prevent all potential attacks. Systems are simply too complex to defer application and data security to the supporting network's defense appliances and infrastructure. Therefore, we propose that, from their inception, applications must be designed to protect themselves as stand-alone entities with security built-in and with minimal security dependence on network security appliances (e.g., firewalls).

As Secretary of Defense Ashton Carter proclaimed during a speech at Stanford University, to keep systems secure, we must build "a single security architecture that's more easily defendable and able to adapt and evolve to mitigate current and future cyber threats."[1] We propose that this next evolution be a "designer" security package at the application level: the security-encapsulated application and data enclave (SEADE) architecture composed of a virtual application data center (VADC) and enterprise-level security (ELS). SEADE will redirect the responsibility for an enterprise-level network security perimeter to each application. It will act as a separately secured virtual container that offers users enhanced data access and produces an application package that is exceedingly difficult to penetrate and easy to port; furthermore, SEADE requires little maintenance.

Insufficient Network Perimeter Defense

In the past, strategic endeavors in this area have focused on safeguarding the information that resides within our networks by building higher and thicker walls around our *crown jewels*, posting gate guards that interrogate everyone entering or leaving, and establishing multiple checkpoints. These efforts attempt to mitigate accessibility, the very capability our modern networks have been designed to provide. Clearly, this has been a losing proposition because the cost to safeguard these networks far exceeds that associated with attacking and penetrating them. Critically, it also impedes unobstructed and timely access by our forces to the information they so critically need.

The current network enclave defense model parallels these classic perimeter defenses by restricting accessibility to apparently valid users or transactions. However, it does little to define the purpose behind the effort. Thus, without a clear understanding of what is to be defended, we are left with the daunting task of defending everything in our "house/fort" without having any opportunity to prioritize a specific effort, such as those that will likely have the greatest impact on our ability to accomplish the mission.

It is imperative to note that our traditional approach to protection using only network boundaries is rendered useless when an adversary is already inside the network. Based on recent events and given current levels of network complexity, it is unlikely that adversaries will appear via concentrated denial-of-service attacks as was once the case. Rather, we would be well advised to conclude that such enemies already exist within our networks. More realistically, they are striving to hide their presence in order to harvest information that represents the lifeblood of our companies, plans, and/or intellectual property. Consequently, the three core considerations that must be governed by security measures are (1) accessibility, (2) confidentiality (including the determination that data is correct and has not been altered), and (3) integrity (which relates to the essence of our trust in and reliance on information used in the decision-making process). The complexity of recent cyber attacks has indeed increased. Although they were once focused on pilfering or manipulating data, such attacks now seek not only to steal critical data but also to undermine its use within operational command and control centers. Indeed, threats that have remained dormant until triggered by a specific event (e.g., zero-day attacks) can have devastating consequences at the most inopportune times during military operations. Therefore, we must elevate our awareness of such threats and manage the associated risk by determining what must be defended, how such defenses will be carried out, what objective will be fulfilled, and why it is important. Ultimately, networks that continue to offer unfettered accessibility (albeit a worthwhile quality) will fail to secure the intellectual property that populates today's information environment. Clearly, then, we must take a step back and ask ourselves what we should defend. Should we protect the roads and highways (i.e., the network) leveraged by users and adversaries alike? Or should we protect the data and intellectual property inside?

Current State of Enterprise Defense

Today's perimeter defenses are instrumented for network-traffic-based analysis that assumes nothing bad will happen to applications/data if those defenses prevent malware transactions at the entrance. The solution—based on consistent, quick recognition of these rogue transactions—works well if one knows and understands *all* of the acceptable transactions so that the complement can be characterized as unacceptable (i.e., blacklisting undesirable network traffic).

Another defensive approach entails isolating the application from external access channels, but business requirements mandate access to areas inside the perimeter for collaboration (data sharing), interaction (web services), mobile/remote access (virtual private network), and business-to-business links. Hence, it is extremely difficult to determine which traffic to block because of multiple exceptions that must be accommodated for the business to function. Blacklisting has become slow and unwieldy to maintain and does not scale well, especially with the increasing adoption of IPv6.[2] Whitelisting at the perimeter level has become unmanageable due to the thousands of entries to maintain. The fact that the *walls* have to allow a superset of all of these exceptions creates a porous perimeter. Moreover, adding new or removing existing exceptions may cause unintended effects on other applications, typically discovered only after implementation. Further complicating the situation is the continuing maintenance requirement—for example, obsolete exceptions persist in configurations because of a failure to notify administrators to make the updates.

Compounding the situation is the scaling of network defenses to billions of transactions. The usual response to keeping pace with performance demands has been to increase the sophistication and scale of network defense appliances. Unfortunately, these "improvements" exert more overhead and cause greater latency (despite appearing faster or more robust) and do not always produce more effective systems.

There has to be a better way. To better defend our information, not only do we need to recognize that fact and account for the adversaries among us, but also we must continue to operate within this contested environment. Since our cyber adversaries have made their presence known, we must find novel ways to defend the vital information (today's crown jewels) that enables us to maintain our competitive edge, all the while accepting the idea that we will be operating in a contested environment. As we focus on protecting our property and establishing tighter security perimeters, we will also develop the ability to scale our approaches quickly and overcome continually increasing threats.

In the past, isolated enclave architecture was the initial design of the network—each group had its own enclave with no outside connectivity. The desire to share information led to connecting these enclaves, which generated some concern, but a trust agreement existed between them. As enclaves became increasingly interconnected, the level of trust degraded further, especially when control was lost and anonymity became pervasive within the World Wide Web. Regaining this trust involved employing enterprise perimeter defenses to control access to information and restricting data availability to maintain some degree of confidentiality.

Although this problem has long been recognized and many alternatives have been proposed, only a modicum of success has been achieved in safeguarding intellectual property. The obvious alternative is to construct multiple layers of network perimeter defenses that provide adequate confidentiality of strategic data. However, this approach requires that different settings, configurations, or tool sets be established at each point in the layered defense. Ultimately, such an action increases the maintenance burden and produces delays in transaction flow, the combination of which impedes timely dissemination of vital information.

Incident Identification/Reaction

Considering that network perimeter defenses are generating logs/alerts to billions of transactions in a large organization, how does one analyze these into a coherent picture? Even more desirable, how can one detect in "real time" that malware is present and that an incident can be prevented? This problem is difficult because little information exists to determine which application a specific transaction belongs to unless additional network defenses are placed in multiple locations in the enterprise, usually near data centers, to record and analyze all network traffic. Of course, this scenario generates even more data for analysis, and one winds up looking for the proverbial needle in a stack of needles. An obvious solution involves using special-purpose "big data" analysis tools such as predictive analysis techniques, cross-correlation analysis, and so forth, with plenty of storage for historical transactions. Obviously, this analysis overhead further adds costs and resources to defense efforts. There has to be a better way.

A Better Way

Since attacks continue despite our best network perimeter defenses, what if we begin with the assumption that adversaries are already on our networks? Consequently, we must adjust our threat model and think differently to protect our data and intellectual properties. What if we decrease the attack surface down to the application or data level with the same security capabilities currently used for perimeter defense but specialized for the particular application or data? This vision lies at the heart of the SEADE concept, which defuses the overall attack surface from gateways guarding the enterprise network perimeter to thousands of individual, specialized security enclaves. The multitude of enclaves, consisting of multiple products and specialized configurations, will force the attacker to increase his effort to penetrate a single application. Since each security enclave is specialized to a specific application, the attacker must customize attacks per application rather than focus on penetrating the perimeter to expose the entire network. Thus, it will no longer be possible for adversaries to exist unchallenged inside our networks.

SEADE—Virtual Application Data Center

Virtualization technology, available in the *cloud* or virtual data centers (VDC), has made possible the virtual application data center concept. A VDC is a software-defined data center that supports "infrastructure as a service" for applications. It is a commodity readily available in many commercial and government cloud data centers. We utilize a VDC to define a VADC. Essentially, one VADC is dedicated to only one application, which is supported by a platform as a service (PaaS). It consists of virtualized network monitoring and defense capabilities like firewalls and deep-packet inspection along with its associated web access point, database firewall, and traditional PaaS components of web servers, application servers, and database servers. SEADE-VADC extends this concept for each application.

A significant security benefit of this architecture is that network traffic can remain encrypted until it enters the VADC. Only after packets enter the VADC are they decrypted and inspected. Within each VADC, the application developer has tailored the network inspection defenses, which were "baked in" from the design phase, to the specific ports/protocols, transaction size/format, parameter range, and so forth, for that single application.[3] For instance, some applications may be tuned to support deep-packet inspection with abnormalities reported to the appropriate computer network defense service provider (CNDSP). Individual application risk management will drive the tailoring requirements. The VADC will improve the levels of *accessibility* and *confidentiality* by recognizing specific threats immediately and preventing an incident from occurring.

SEADE—Enterprise-Level Security

ELS is a dynamic attribute-based access-control system developed to reduce overall security risks by automating the access process, based on authoritative, related attribute information.[4] Today, each application has a uniquely configured access-control scheme maintained by system administrators, primarily based on users and groups, which can be quite labor intensive. In the Air Force, the process is further burdened by a form-based, administrative-access approval process. As a new paradigm, ELS automates the authorization maintenance process; validates preconditions for access, such as training, security clearance, rank, and so forth; and allows a person access when an application-owner-defined set of conditions is met.

Accessibility to data is controlled by *claims*, based on a person's (or an entity's) attributes, dynamically generated and propagated when attributes change.[5] Claims can be additions, deprecations, or modifications to existing access rights. They are transmitted via encrypted channels, based on user-access requests in a security assertion markup language (SAML) token. A standard handler evaluates and validates the token (content, timing, and authentication) and passes the claim for access to the application. Logging occurs for every access request, and erroneous access information is sent to the appropriate CNDSP. A standard handler ensures that SAML validation and access logging are performed correctly, further freeing the application developer from producing similar capability.

ELS will improve the levels of *integrity* and *confidentiality* by preventing unauthorized data access. As shown in the figure below, SEADE combines both concepts (VADC and ELS) and is delivered as two VDCs—one for the application (VADC) and the other for the ELS claims engine (which includes the secure token service, enterprise attribute store, and generated SAML claims).

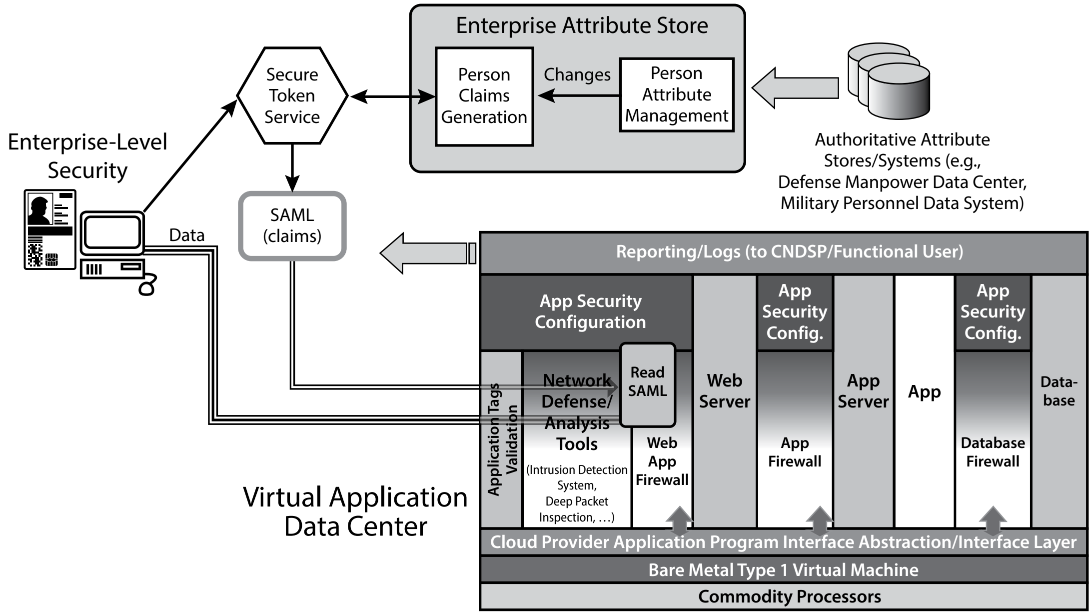


Figure. SEADE diagram

Benefits of SEADE

Employing SEADE throughout a large enterprise-level operation generates the following benefits:

- *Enables application portability*. SEADE promotes such portability by enabling applications to be hosted in any virtualized environment. Thus, owners have the freedom to maneuver applications where they are needed to meet operational and resiliency requirements.
- *Expedites application deployment*. Multiple SEADEs employed throughout the enterprise will significantly decrease the manpower associated with developing and fielding an application. Since network and application defenses are included in the standard PaaS environment, the application itself remains just the logic of the program as it inherits all of the security controls of the PaaS. This architecture has demonstrably decreased the time to production from months to weeks. Since a standard ELS handler may be used for the SAML token, the application developer need only code to the ELS handler's application program interface, further decreasing deployment time.
- *Facilitates accreditation*. Since applications are encapsulated with their own security functions, porting them into new hosting environments will be minimal, including justification of security measures to meet the accreditation process.
- *Eliminates individual access requests*. Dependence on form-based administrative processes will be eliminated, and system administrators' access-management burden will be significantly reduced. There will no longer be user and group permissions to maintain per application, drastically reducing the man-hours required to perform this basic system-administration function.
- *Provides immediate user access*. Users will have immediate access to applications and data, based on their attributes (e.g., position, training, duty location, and so forth). As soon as the authoritative data source is updated with their personnel information—say, to a new assignment—then users will be granted access accordingly.
- *Includes "baked-in" security*. Application development will change fundamentally by baking in security from the start. Developers will integrate network defense configurations (e.g., whitelisting) into their VADC. Further, they will have more options and stronger security-related capabilities by having various network appliances at their disposal. Developers must now think holistically and produce applications to respond to and interact only with defined, valid, and recognized inputs.
- *Focuses incident reports*. Instead of having cyber war fighters *look* at streams of network transactions, trying to determine an abnormality, incident reporting is narrowed to the actual application with detailed information, based on the application's tailored security profile. The CNDSP will be alerted only when thresholds are triggered.

- *Reduces the number of network administrators*. Network security operators will no longer have to make network appliance configuration changes (e.g., firewalls, proxies, and intrusion detection systems) to "allow only" legitimate traffic and block known, bad traffic. Additionally, less time will be spent on configuration-management meetings to approve mundane changes to network appliances.
- *Provides operational resiliency*. Since the VADC is composed solely of virtual components, if an abnormality is detected, the application can be dynamically reloaded from a previously known good image, or snapshot, to continue processing. As an added resiliency measure, SEADE instances can be spawned at multiple locations and numerous environments to attain heightened redundancy and increased mission assurance.
- *Enables continuity of operations (COOP) and agility*. By leveraging virtualization, one can provision applications in multiple environments, as well as COOP to another data center, provided that data has been streamed to the COOP site. This capability of provisioning anywhere further decreases the time for provisioning and provides significant mission agility.
- *Reduces insider threat*. This new paradigm enables creative approaches to data protection. Vulnerability to an insider threat will be reduced since ELS will block unauthorized access and track all access to applications or data. This information can be used to detect or predict abnormal activities. With appropriate data-access tagging, exfiltrated data will be unreadable outside an environment without SEADE.
- *Improves confidentiality, integrity, and availability*. The SEADE combination of ELS and VADC capabilities significantly increases the *confidentiality* and *integrity* of the data by preventing unwarranted access and *availability* of the application (and data) by dynamic analysis and elimination of threats to the application itself.
- *Maintains CNDSP*. The current CNDSP framework does not have to change. Alerts within each SEADE can be sent to the appropriate CNDSP unit, which will continue to triage alerts accordingly.

Trade-Offs

The primary trade-off with employing SEADE is that instead of relying on and deferring to network perimeter security, application developers now will be responsible for considering application security and ELS controls during design, test, and development. The developers must become intimately familiar with their application to address issues for both expected and unknown stimuli. This will undoubtedly increase the initial cost of system development, but it will ultimately save innumerable man-hours and will improve data protection. Developers will be responsible for ensuring that security is incorporated from the onset rather than waiting for operators to address the need retroactively.

Another trade-off is the building of a supporting environment for SEADE services. Application and functional owners must define and govern attributes required to provide the granularity necessary for applications to have the correct level of access-control fidelity. These attributes must come from known, authoritative data sources that have to be identified and integrated into enterprise attribute store for ELS's use.

Air Force Consolidated Enterprise Information Technology Baselines

Today, technology moves so quickly that one will never reach a 100 percent best solution in a reasonable amount of time. Agile solution delivery is the best approach to a problem via focused sprints and spiral development so one can adjust as the available technology changes. This affords the ability to capitalize on and garner strategic advantage from nimble actions and innovative solutions. Unfortunately, this paradigm shift unsettles many people who expect predefined requirements with predestined end points. However, this traditional approach only wastes resources as the environment and requirement change in their midst. As the *cheese* constantly moves in technology and cyberspace, we must be adaptable and decide to venture out to embrace the changes—lest we risk starvation.[6] We must harness and guide this spirit of innovation and provide a framework for inserting new technology—methodically and expediently—into our environment.

Accordingly, it is in this vein that the Air Force chief technology officer established and manages the Consolidated Enterprise Information Technology Baselines (CEIT-B) framework to purposely shape, adopt, and deliver a standard information technology environment. This disciplined effort conforms to the agile paradigm as the future target baseline is developed.[7] SEADE is a substantial component of CEIT-B that addresses security, portability, and efficiency requirements. Additionally, the Air Force, through CEIT-B, is addressing and informing the joint information environment (JIE) requirements for Department of Defense–level enterprise requirements.

Conclusion

The Air Force, as a service, emerged from technology. We must continue to harness the same innovative spirit for cyberspace that has enabled us to dominate air and space. Innovation is the fuel for future success, and we must keep striving to embrace new ways of solving our difficult problems. SEADE, comprised of a VADC and ELS, is a fundamentally different paradigm that will change the way systems are developed, deployed, and defended. By providing a separate security enclave for applications in a VADC, enabled by ELS dynamic access control, we can protect our most important treasure—the data within—as we continue to operate in a contested environment. The SEADE architecture will increase the speed of both user access and application delivery to the mission, decrease day-to-day management of the network and applications, and counter the futility of network perimeter security.✪

Notes

1. Cheryl Pellerin, "Carter Unveils New DoD Cyber Strategy in Silicon Valley," US Department of Defense, 23 April 2015, http://preview.defenselink.mil/news/newsarticle.aspx?id=128659.

2. IPv6 (Internet Protocol version 6) is the latest Internet standard protocol that uses 128 bits versus the current IPv4's 32 bits. The new version has capacity for every person on Earth to have billions of Internet addresses personally allocated. Therefore, blocking by individual address or range of addresses will no longer be effective or efficient.

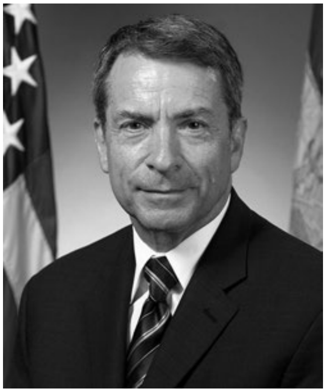
3. "Baked in" refers to integrating desired security features at the initial stage of design and development as opposed to adding them on (i.e., "bolted on") after the product has been released.

4. Vincent Hu, Adam Schnitzer, and Ken Sandlin, "Attribute Based Access Control Definition and Considerations," National Institute of Standards and Technology Special Publication 800-162, n.d., http://csrc.nist.gov/projects/abac/july2013_workshop/july2013_abac_workshop_abac-sp.pdf.

5. Coimbatore S. Chandersekaran and William R. Simpson, "A Uniform Claims-Based Access Control for the Enterprise," *International Journal of Scientific Computing* 6, no. 2 (December 2012): 1–23.

6. Spencer Johnson, *Who Moved My Cheese? An Amazing Way to Deal with Change in Your Work* (New York: G. P. Putnam's Sons, 1998).

7. SAF/CIO A6 CTO, *CIET-B, Target Baseline 2.0*, 2015, https://intelshare.intelink.gov/sites/afceit/TB/default.aspx.



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Col Nevin J. Taylor, USAFR

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Any Time, Every Place

The Networked Societies of War Fighters in a Battlespace of Flows

Maj Dave Blair, USAF

> *In a world of networks, the ability to exercise control over others depends on . . . the ability to constitute network(s), and . . . the ability to connect and ensure the cooperation of different networks . . . while fending off competition from other networks.*
>
> —Prof. Manuel Castells, *Communications Power*

> *It takes a network to defeat a network.*
>
> —Prof. John Arquilla and Gen Stanley McChrystal

In a hypothetical retelling of any of 100 recent battlefield encounters, two networks coalesce around a compound of buildings at the western border of a nation at war with itself. On one side, a disparate assemblage of fighters drawn from the Middle East, North Africa, Europe, and Asia attempts to enter a country at war using an amalgam of ancient trade routes and modern commercial navigational and communications technology. Their stories are as diverse as their backgrounds—for one, an Internet web magazine

linked them to a religious leader they once knew personally; for another, they come to avenge a brother or an uncle; a third comes for the prospect of adventure, as advertised by other fighters on streaming video. In a previous war, fighters might have brought with them their preferred printed propaganda piece, perhaps even a signed copy. In this war, those authors are very much present and part of the conversation, linked to their progeny by way of e-mail and voice over Internet protocol. The financiers are just as present, relationally linked to the real-time consequences of their donations.

This force exists in many spaces at once; it is anchored in relational space but flexible in physical space. The flexibility allows it to coalesce at a time and place of its choosing, achieve fleeting objectives, and disperse before an enemy can respond. This strategy works remarkably well against a conventional adversary, bound by physical areas of operation and beholden to fixed-response timelines.[1]

This force's opposite number is strikingly similar in this regard: a diverse network of special operators, aircrews, and intelligence professionals, bound together by a mix of trust networks and modern communications technology, has been hunting this cell for some time now. One such team—a special operator working from a tactical headquarters, an MQ-1 aircrew in Nevada, a Liberty MC-12 crew, and a team of analysts in at least two places in the continental United States—locates and tracks this cell along a transit route. Upon finding their quarry, helicopters full of operators, fixed-wing gunships, high-speed fighters, and sundry support aircraft press toward the cell before it can flee. Once they are established on scene, the target location provides a focal point for the operation, but the trust networks between operators continue to give the teams the nimbleness necessary to pursue the objective. These trust networks have been built over years through a combination of shared combat experience, in-person exercises, and weekly teleconferences. All of these places and times are invoked at once "on the op."

This is a battle of small margins in brief windows. Victory goes to the side that can fix its opponent in a physical place while retaining the flexibility to bring its own forces to bear across physical space. In this case, it belongs to the special operations team members who can call upon forces from across 10,000 miles and bring them into this place. The terror cell, fixed in place and decoupled from its larger networks, cannot. The special operations team remains in a "space of flows" while the terror cell is trapped in a "space of places."

Castells and the Space of Flows

In his seminal trilogy *The Information Age: Economy, Society, and Culture*, sociologist Manuel Castells describes changes wrought by increasing global connectivity in the way societies perceive the intersection of social space, physical location, and relational networks. He defines space as "the material support of time-sharing social practices."[2] People must be somewhere to be together. In their seminal work on information theory, Claude Shannon and Warren Weaver similarly identify a technologically facilitated layer of communications.[3] Whether through the formal technology of electronic transmission or the social technology of language, societies construct (and are constructed by) shared spaces between people. This article argues that a battlespace is very much a "space" by Castells's definition.

Castells describes two formulations of social space: societies can be organized around physical location, in a space of places, or around relational networks, in a space of flows.[4] The space of places, the traditional mode of social organization, remains the dominant mode. According to Castells, "A place is a locale whose form, function and meaning are self-contained within the boundaries of physical continuity."[5] For instance, decades ago, a physical building might supply a social focal point for organizing the relationships of a company.[6] In this space, flows are contained and summarized by physical geography. Incremental and territorial approaches to combat are captured well by this space of places, a fact demonstrated by both the classic command to "take that hill" and the ubiquitous idea of the combat zone.

In contrast, a space of flows is an abstract space built around social networks; accordingly, it is less bound to physical space and linear time. In Castells's words, "*The space of flows is the material organization of time-sharing social practices that work through* . . . purposeful, repetitive, programmable sequences of exchange and interaction between physically disjointed positions held by social actors in the economic, political, and symbolic structures of society" (emphasis in original).[7] As a practical example, the discussion concerning a Facebook post relaxes the constraints of space and time that a normal conference would demand. A user can interact with a group of people not only without regard to distance but also without regard to time. A post takes virtually no time to update but persists long enough for one to interact with it hours or even days later. In a space of places, distance translates into time via physical transportation media; in a space of flows, distance and time are essentially unlinked due to the near-instant speed of global communications.

This is not to say that physical presence is unimportant in a place of flows. Quoting Gen James Jones and a host of others, "Virtual presence is actual absence."[8] In contemporary "coder" culture, relational network flows organize physical space. Relationships are embedded in semipermanent sociotechnical patterns such as e-mail lists and websites, and these relational networks coalesce into physical spaces.[9] These networks do not diminish the need for interaction in physical places, but the need for a *specific* physical space becomes less important in this world. For instance, coder meet-up groups are structured in virtual space but gather in a variety of physical spaces to reinforce social relationships and accomplish tasks.[10] In a space of flows, physical meetings primarily grow out of relational networks rather than relational networks primarily emerging from physical structure.

We might envision this difference by imagining different modes of interaction between the alumni of a given school. A class reunion that calls members back to the physical college for a homecoming weekend embodies place-based logic. Conversely, monthly happy-hour meet-ups among alumni in a given city grow from flow-based logic, especially if the meetings are arranged through a static online forum.

Flow-based logics increasingly complement, and in some cases supplant, the place-based logics in the business world. Telework has become an option for inclement weather days or as a means of minimizing time wasted during commuting. Increased use of inexpensive and convenient video teleconferencing mitigates some of the concomitant loss of face-to-face interaction. Improved remote desktop capabilities and increasingly accessible security technology allow businesses to maintain enterprise integrity from across diverse locations. Outsourcing and crowdsourcing transfers repetitive tasks to cheaper milieus via communications technology. Some technology startups so fully embrace these concepts that they forgo owning physical space entirely, creating a market for rentable "incubator" space.[11] These same changes map onto emerging trends in warfare.

The Battlespace of Flows

The thesis of this article is straightforward: by means of networking technologies, warfare is increasingly becoming a space of flows. It holds that the flow-based logics that sparked these changes in the business world have initiated similar alterations in the world of armed conflict. Just as telework enhances the modern business space, so do the special operators physically present in the modern battlespace work alongside remote operators. Traditionally, we've seen "reachback" support based in the continental United States for deployed war fighters in the form of intelligence products or technical support, but this is something different. As opposed to traditional off-site support, which assists the decisions and actions of others, these remote operators take action and make determinations themselves that decide outcomes—their choices directly shape the battlespace. In an even more extreme form of flow-based warfare, cyberspace operators do not commit to a physical battlespace at all, except perhaps in their endgame. Even if software could generate physical effects, it would do so ad hoc, without any means or intent to hold that physical space.

Flow-based warfare is a form of fighting that can transcend physicality. The potential for physical effects without being physically proximate enables flow-based warfare to bypass boundaries. For instance, cyber warfare can access locations that would be prohibitively costly or politically difficult to reach through traditional physical force. Just as call centers allow companies to outsource algorithmic tasks, so do data links and satellites allow American commanders to generate persistent surveillance via remote aircraft from the location with the lowest manpower-deployment cost—the United States.

In a place-based world, only a state with fixed-location factories could churn out the tools of modern war. This fact provided the accountability necessary for making the Westphalian system work—a tank came from a factory somewhere, and that factory had a flag attached to it. As spaces of flows democratize information production in the business world (and, potentially, physical production with the advent of additive manufacturing or 3-D printing), they democratize the production of violence in war fighting.[12] For both al-Qaeda and the United States government, flow-based warfare enabled coordinated violent action from network members in sundry locations. Since these flows are more complex than physical place, an organization must be able to think, coordinate, and act on a more abstract level to make use of them. Small organizations tend to be nimbler in dealing with complex problems since they make better use of tacit knowledge and need not reduce a problem to coordinate a solution.[13] Therefore, flow-based warfare likely will be adopted more rapidly and eagerly by small organizations with strong trust networks and less so by industrial, bureaucratic forms.[14]

This article proceeds with a plausibility probe of this thesis, using three cases from the past decade. First, it traces the reciprocal adoption of flow-based logics by al-Qaeda and the US special operations community. Second, it explores the extreme case of the MQ-1 Predator's remote split operations (RSO) concept. Finally, it evaluates the effects of a mature form of flow-based warfare against a place-based adversary through the battlefield use of social media by the Free Libyan Army in 2011.

The article claims that flow-based warfare became a structural feature of the conflicts of the last decade. However, it does not claim that flow-based warfare has become more important than place-based warfare. Scoping the claim in this way diminishes the potential threat of selection bias. By establishing its presence and significance in the defining conflicts of that decade, the article demonstrates this claim. Additionally, since the special operations forces (SOF) case and the related Predator case both involve organizational learning and change toward flow-based warfare, they inherently include both negative and positive valences of our dependent variable. The article seeks to establish the heuristic utility of Castells's concept of flows for describing certain recent changes in warfare. A follow-on research design that pays more attention to these negative cases might trace the contours of flow-based versus place-based conceptions of the battlespace over time.

Special Operations Forces versus al-Qaeda: The Adoption of Flow-Based Warfare

Flow-based warfare offers an excellent tool for an asymmetric adversary to attack a vastly superior place-based opponent. In a space of flows, the production of violence can be democratized in the same way that the production of information shifted from centralized news sources to social aggregation. Command and control can similarly be democratized. In a place-based system, one commander might have a radio channel for a given area—this structure lends itself toward centralized control and vertical command links. A modern war fighter has myriad means of communications that can potentially support communications with vast numbers of peer units—such technologies allow for lateral flat and ad hoc command structures. These flow-based structures can take form in a space, execute their mission so long as they retain relative advantage, and then disperse before a place-based adversary can marshal forces to respond.[15]

Moreover, a flat-networked insurgent group should find these sorts of logics easier to implement than a hierarchical, compartmentalized military.[16] For this reason, illicit actors and terror groups were early adopters of flow-based war fighting.[17] Al-Qaeda's financial and recruiting networks cut across a number of different places. An amalgam of Chechens, Arabs, and Afghans constituted their forces in Afghanistan.[18] Their money was infused through global financial systems from a variety of "donors" and was often conveyed through the technologically facilitated trust networks of *hawala*.[19] Al-Qaeda itself might have been described as a space of flows rather than a space of places.

The Iraqi improvised explosive device (IED) network provided a clear expression of this space of flows. Financiers outside the country would pump resources into that system from sundry locations; engineers inside and outside the "combat zone" would counter coalition countermeasures with new designs; in-country bomb makers would assemble these designs; finally, the network would contract with local nationals to emplace these weapons.[20] This network took ground only in the very last step, when it emplaced the weapon itself; the network held that ground only as long as it took to strike and then fell back to the space of flows. Place-based conventional forces had tremendous difficulty matching this flexibility. Although the flows-based network could not directly control ground, it could make the use of that ground extremely costly to its adversary.[21]

Early moves against this network remained locked in place-based logics. By adding armor and jammers to ground logistics vehicles, coalition forces became better prepared for their physical intersection of the IED network. Similarly, by increasing aerial patrols for IED emplacers, they sought to deny the physical lines of communications to their adversary. Unfortunately, these were both losing bets with terrible exchange ratios—the IED network could export most of its risk upstream to the space of flows, where it could not be targeted through these means. Moreover, the fact that the flow-based network could attack anywhere and at any time forced the place-based conventional forces to commit everywhere at all times. One IED design change could force an order-of-magnitude costlier response in armor, jammers, and patrols.[22] For this reason, an Army brigadier general concluded that "you can't armor your way out of this problem."[23]

The alternative was a move toward flow-based warfare. According to a 2007 *Washington Post* article,

> Ultimately, eliminating IEDs as a weapon of strategic influence—the U.S. government's explicit ambition—is likely to depend on neutralizing the networks that buy, build and disseminate bombs. Military strategists have acknowledged that reality almost since the beginning of the long war, but only in the past year has it become an overarching counter-IED policy. Left of boom—the concept of disrupting the bomb chain long before detonation—is finally more than a slogan. If you don't go after the network, you're never going to stop these guys. Never. They'll just keep killing people, the senior Pentagon official said. And the network is not a single monolithic organization, but rather a loosely knotted web of networks.[24]

Small teams with flat cultures and strong trust networks, empowered with rapid logistics and robust communications, could become the "network to defeat a network."[25] This network emerged gradually from the seedbed of elite SOF teams during the early 2000s. These teams already had strong reputations as well as habitual relationships with members of the interagency process and the intelligence community. Thus, they provided an excellent substrate for the growth of a flow-based network.

The latter took shape, in part, through an expanding group of liaison officers, sent both from and to these teams. These liaisons offered transgeographic and transinstitutional access for these teams. They also created alternative coordination pathways for the interagency process, using the trust networks of the SOF teams as a routing hub, thereby increasing the social power of the teams within that process.[26] Over time, the alumni of the liaison group advanced within their own organizations, further enhancing the access of this network.

The network used this structure to implement a flow-based targeting cycle, which grew both more expansive and quicker throughout the campaign. This find, fix, finish, exploit, analyze, and disseminate cycle allowed coalition SOF teams to pin their adversary network while retaining their own flexibility.[27] The "fix" stage of this cycle invokes the idea of flow most clearly since it attempted to deny flow to the IED network by anchoring and holding its nodes in physical space.[28] Over the course of the campaign, the growth of this cycle shifted the balance of networks in favor of the coalition and helped dislodge al-Qaeda-backed IED networks from Baghdad.

Although the "finish" stage of this cycle was both the most valiant and celebrated, the "fix" stage was often the limiting factor. To carry out an operation, surveillance assets would have to locate and track individuals from an adversary network until a strike force could take action against them. To keep an "unblinking eye" on these targets from identification to action, this network needed heretofore-impossible amounts of low-grade but long-dwell intelligence, surveillance, and reconnaissance time.[29]

Enter the Predator's RSO concept, which uses sociotechnical flow to enable crews in the United States to pilot aircraft "down range." This capability removed the deployment constraint for aircrews. Rather than maintain several crews to keep one deployed at all times, all crews could fly as many aircraft as were available at any given time. However, in doing so, crews from a place-based cockpit culture found themselves struggling to master a new, flow-based conception of what it meant to be a pilot.

Remote Split Operations: "You Are Now Entering the CENTCOM AOR"

Flow-based and place-based logics often fractiously collided in the marketplace. Telework is incongruous with place-based conceptions of work. An employee might be more productive by splitting a would-be two-hour commute between additional work time and additional family time, but this hour of increased productivity would not register with an organization whose incentive structures were oriented toward place. Market forces have adjudicated clashes between flow and place. In the case of place-based information technologies such as video rental stores, these proved fatal. Conversely, a number of ambitious flow-based online stores unpleasantly discovered the continuing relevance of place during the dot-com bubble. Our present business environment presents an incomplete synthesis of these two logics.

These same cultural collisions are happening presently between flow- and place-based logics in the military. From a place-based perspective, a Predator crew's lack of physical presence in the battlespace inherently cheapens its work. This argument takes two major forms. First is the "no skin in the game" trope. A Predator crew does not directly experience risk comparable to that of ground troops in the course of its duties, thus diminishing the crew members' professionalism or seriousness about their duties. Second, the "video game" trope holds that the reality of the experience of remote aviation stops at the ground station, and because of the distance of the connection, crews are held to feel disconnected from the effects of their choices.[30]

In fact, the Predator community members' flow-based perspective concentrates on the equivalence of direct battlefield effects and the ramifications of those effects for their comrades.[31] These institutional struggles over meanings are covered extensively in other works on the history of that technology.[32] Rather than attempt to adjudicate these claims, this article holds that they are incommensurable but demonstrate real tensions between flow and place in the contemporary military context.[33] The Predator community's experience offers a window into cultural clashes that accompany transitions from place-based to flow-based conceptions of warfare.

To situate this case, the move toward flow-based warfare in the Predator platform was not inherent to the airframe's "fly-by-wireless" control system.[34] Pop analysis of the platform typically addresses the onboard automation and computers, presumably as a replacement for human judgment; such an approach is a fundamental misapprehension of the platform's design and capabilities. In the words of Abraham Karem, primary designer of the aircraft, "Almost all of our subsystems from 1985–89 are still flying in some Predators today [in 2012], including its 27-year-old computer and, with minor changes, the ground station."[35] Processors that are outperformed by five-year-old smartphones should prove disappointing to both technofetishists and technophobes who see this aircraft as some sort of advanced war-fighting robot. As with any other aircraft, the heart of the system remains the aircrew, but the sea change is in the relationship of the aircrew to the aircraft.[36]

The craft and crews evolved toward a flow-based understanding of their relationship with each other. Much like previous remotely piloted aircraft (RPA), the GNAT 750, an early model in the Predator's lineage, was essentially a long-dwell radio-controlled plane.[37] This crew controlled the aircraft from a ground station within the combat theater. The production-model Predator incorporated a satellite data link that greatly expanded the range from which the craft could be flown—from line-of-sight range to anywhere in the satellite's footprint. In this intermediate state, crews would still deploy to a forward operating location, and the craft could be flown within the same general theater but outside the immediate combat zone. This general model saw use during operations in the former Yugoslavia.[38]

During the campaigns in Iraq and Afghanistan, the RSO model connected these satellite downlinks to terrestrial communications circuits, allowing the craft to be flown from virtually any location on the global information grid. As previously noted, the act of piloting moved to a place where it was least logistically costly: the continental United States.[39] Moreover, it enables data flows to non-colocated intelligence analysts, resulting in a transgeographic social network built around the focal point of a Predator mission. Managing this network is a primary issue for an RSO crew.

Coming to terms with the demands of a flow-based relationship between aircrew and aircraft proved challenging for previously place-based aircrews:

> During our first year in the Predator, we found learning the domain a much greater obstacle than learning the aircraft. In manned aircraft, space was important—satellite communications and the Global Positioning System (GPS) served as critical mission enablers. In the Predator, though, space became part of our domain. Orbits and footprints turned into practical rather than academic concerns as we realized that losing a satellite link could cut our control cables. Further, cyberspace folded into our world; servers acted as the eyes with which we scanned for other aircraft. Simultaneously, our ability to interpret engine sounds and vibrations through a throttle quadrant atrophied. Our experience of aviation became more abstract as we adapted to our new domain—neither better nor worse but different as we gained a new common sense. For instance, in RPA common sense, it is commonsensical to "demand" effects (rather than "command" actions) from a number of aircraft

> at once through a multiplexer when doing so increases intelligence collection without degrading kinetic capabilities.[40]

Over time, the Predator and Reaper RPA communities reached some synthesis between the old and the new. As a symbol of this synthesis, RPA units began posting large signs over the entryway of their command centers declaring, "You are now entering the CENTCOM AOR [Central Command area of responsibility]." In an explicit formulation of a flow-based conception of a combat theater, the crews inside declared that they were in Afghanistan—in a substantive but nongeographic sense. Their duties, actions, and significant social relationships were more strongly manifest there than in their local physical environs.

In this synthetic identity, what one did in a place constituted his or her presence in that place. For this reason, a number of squadrons began to seek identity in "lineages of action" rather than in similarity of airframe.[41] Narratives of persistent sensor-shooter gunships over the Ho Chi Minh Trail and stories of similarly low-performance but high-impact Cessna observation pilots from Vietnam became reservoirs for identity.[42] This functional, human-centric lineage contrasts the normal hardware-centric interpretation, which traces the Predator to the Firebee "drone" and other remote predecessors.

This synthesis was hardly settled. In his autobiographical account *Predator*, Lt Col Matthew Martin recalled that the aforementioned sign "could just as easily have read *You Are Now Entering C. S. Lewis's Narnia* for all that my two worlds intersected."[43] This idea of living in a space without places proved disorienting to crews over time, especially when life for both their comrades "down range" and their significant home relationships remained oriented around place.[44] We have yet to understand the long-term effects of this conflict between cognitive distance and physical distance, especially when these effects are experienced in isolation.[45]

This situation was further complicated by the firm role of place in the American public discourse about war—to have someone use deadly force from within a place of peace was deeply incongruous with American expectations of a homeland essentially immune to organized armed violence. Perhaps this perspective explains the hyperbolic response to an op-ed by the Brookings Institution's Peter W. Singer during the recent drone performance recognition controversy.[46] Unfortunately, this yields a strange civil-military scenario in which a group of service members who are among those who kill the most in our wars are not included in the constructs that normally legitimate killing in war. Without straying too far into normative territory, the "video gamer" answer to this paradox—the idea that remote killing is less real—induces principal-agent problems into the act of legally legitimated killing. First, it lessens the gravity of lethal policy choices in the popular imagination, and second, it decouples those who carry out those choices from the constructs by which the larger society reconciles itself to those who kill in its name. Suffice it to say, the conflict between the Predator's extreme case of flow-based warfare and traditional place-based conceptions of combat is far from being resolved.

Libyan Rebels: Crowdsourcing Intelligence

Our third case explores how flow can effectively repurpose extant networks against a territorial or bureaucratic adversary. Steve and Sonia Stottlemyre explored the Free Libyan Army's use of online social infrastructure as a means for command, control, communications, and intelligence during the 2011 Libyan civil war.[47] During the period of armed conflict, the same networks that had been built through social media during the uprising hosted ad hoc flow-based forms of command and control. These constructs proved resilient in their battle against Mu'ammar Gadhafi's traditional structures. Three vignettes illustrate this point.

Crowdsourced Human Intelligence

According to John Pollock of MIT's *Technology Review*, one tech-savvy French intelligence officer leveraged social media to build an online human intelligence network with willing Free Libyan Army partners:

> After about a hundred hours of work, Martin [a pseudonym] had 250 or so direct contacts in Libya and elsewhere. He created, in effect, a private intelligence network. Initially, he expected only "ambient" or background information, but the intelligence he gathered soon proved useful for both strategy and tactics. Martin tried alerting his hierarchy to its potential for following the flow of action on the ground. It took a while for them to accept this. "They were very afraid in the beginning, because they had no control," he says, "[so] I ran a kind of laboratory." He set up a desk and was given no military intelligence. His captain asked specific questions and matched Martin's performance against more formal intelligence channels. Precise comparison is difficult, but Martin estimates that eventually 80 percent of the intelligence used by his [unit] came from his sources.[48]

This vignette demonstrates the use of flow that transcends place. The officer was able to build a network rapidly with no physical contact, organized around the simple principle of cooperation between NATO and the Libyan rebels. The network allowed mutual sense-making across geographic boundaries.

Crowdsourced Subject-Matter Expertise

These expertise-seeking flows went both ways. Libyan rebels could ask sundry tactical and engineering questions to networks of supporters and sympathizers around the world. In one particularly memorable episode, according to Pollock,

> After weeks of skirmishes in the Nafusa Mountains southwest of Tripoli, Sifaw Twawa and his brigade of freedom fighters are at a standstill. It's a mid-April night in 2011, and Twawa's men are frightened. Lightly armed and hidden only by trees, they are a stone's throw from one of four Grad 122-millimeter multiple-rocket launchers laying down a barrage on Yefren, their besieged hometown. These weapons can fire up to 40 unguided rockets in 20 seconds. Each round carries a high-explosive fragmentation warhead weighing 40 pounds. They urgently need to know how to deal with this, or they will have to pull back. Twawa's cell phone rings.
>
> Two friends are on the line, via a Skype conference call. Nureddin Ashammakhi is in Finland, where he heads a research team developing biomaterials technology, and Khalid Hatashe, a medical doctor, is in the United Kingdom. The Qaddafi regime trained Hatashe on Grads during his compulsory military service. He explains that Twawa's *katiba*—brigade—is well short of the Grad's minimum range: at this distance, any rockets fired would shoot past them. Hatashe adds that the launcher can be triggered from several hundred feet away using an electric cable, so the enemy

> may not be in or near the launch vehicle. Twawa's men successfully attack the Grad—all because two civilians briefed their leader, over Skype, in a battlefield a continent away.[49]

These approaches, these global collaborations for local effect, became commonplace over the course of the conflict. Again, Pollock writes,

> As with Wikipedia, [weapons] . . . expertise might come from anyone—like Steen Kirby, a high-school student in the state of Georgia. As well as identifying weaponry, Kirby pulled together a group through Twitter to quickly produce English and Arabic guides to using an AK47, building makeshift Grad artillery shelters, and handling mines and unexploded ordnance, as well as detailed medical handbooks for use in the field. These were shared with freedom fighters in Tripoli, Misrata, and the Nafusa Mountains.
>
> The Misratans showed impressive ingenuity. Engineers hacked new weapons—including a remote-controlled machine gun mounted on a children's toy—and adapted technology on the fly. Laptops, Google Earth on CD-ROMs, and iPhone compasses gave the freedom fighters range. After a rocket was fired, a spotter confirmed the hit, reporting that it had landed, for example, "30 yards from the restaurant." They then calculated the precise distance on Google Earth and used the compass, along with angle and distance tables, to make adjustments.[50]

By applying flow-based approaches, the Libyan rebels redefined the boundaries of the battlespace. Rather than solely relying on physically present intelligence forces, a balance that would have overwhelmingly favored their adversary, they leveraged their cultural support through communications technology to pit advanced volunteers who were technically knowledgeable and cyber-savvy groups against their enemies.[51]

Repurposed Civilian Spaces of Flow

Finally, the Libyan rebels made extensive use of extant civilian communications architecture. Pollock notes that "as military budgets shrink, the world urbanizes, and . . . cheap handheld technology is making citizen networks an inevitable feature of the information battle space."[52] This was most apparent with the rebels' use of Twitter, which Stottlemyre and Stottlemyre demonstrate through exchanges among rebels, crisis mappers, and various sympathizers:

> Twitter acted as a platform for collaboration on and compilation of intelligence products. Many separate Twitter users began compiling data and information on their own pages. They Tweeted data they collected, information they processed, links to information provided in crisis maps, and Retweeted information provided via private and professional (i.e., media) Twitter users, thus creating a central repository of links to tactical information they deemed valuable.[53]

The increasingly common use of civilian communications by all parties in conflict supports their finding. Interestingly, since civilian telecommunications is intended to create lateral peer-to-peer communication, the collision of civilian communication with military command and control will likely be fractious. Historical ad hoc uses of such communications—most notably the utilization of a commercial telephone to call down gunship fire support during the invasion of Grenada—have been innovative and unconventional.

Altogether, the case of the Libyan civil war demonstrates how a local rebel group transformed its struggle by globalizing the conflict by employing flow-based tactics. In this campaign, we see a profound blurring of the lines between combatants and civilians because of extensive real-time collaboration. Flow-based conflict patterns may make framing and narrative far more important because people can opt in and opt out more easily through web-based collaboratives than they could with recruiting lines. Therefore, the decision to join a conflict may be increasingly about political will and social popularity since technological ability is ubiquitous. We also see how flow can bring virtual expertise and off-board skills into the battlespace without regard for where those skills are housed. The implications of these cyber-guerilla wars for civil-military interaction and noncombatant immunities bear much thought.

Conclusion: Coming to Terms with Flow-Based Warfare

This article set out to explore the thesis that recent changes in communications technology have increased the prevalence of flow-based warfare in modern conflict. We found either new or geatly expanded flow-based warfare in at least three major contemporary wars, thus demonstrating the utility of Castells's theories as a heuristic for emerging forms of warfare, especially in understanding the adoption of these forms and the cultural clashes that surround them. As a plausibility probe, this effort should be considered theory building rather than theory testing. Follow-on research designs might establish the conditions under which flow-based warfare might be more likely adopted or effective. We also might evaluate the relative balance between flow-based and place-based logic in battlespaces over time.

Moving from academic to policy questions, we see that the rise of flow-based warfare brings with it new questions and new challenges. Such warfare has two imperatives: to protect fluidity and to fix the enemy in place. To the first point, one must protect connectivity and use it both to export risk into sanctuaries and import knowledge and resources from a wide range of sources. Connectivity and its resulting flexibility keep situational awareness strong and allow the network to synchronize actions. This, in turn, enables the network to attack at a time and space of its choosing, attain its goals, and remove itself from the geographical place before the adversary can respond. The second imperative is to deny the enemy the ability to do the same. Fixing his network in place has the effect of isolating flows, interrupting connectivity, and dismembering the network, node by node. Dynamic strategies such as the classic Boydian observe-orient-decide-act loop work well toward these reciprocal offensive and defensive ends.[54]

Following Castells, flow-based warfare has two key types of players.[55] First are the programmers, who build the narratives that bind and grow networks. These narrative-crafting skills are often associated with transformational leaders but are generally difficult to identify directly through status quo bureaucratic personnel systems. Second are the linkers, who identify mutually beneficial partnerships, storehouses of knowledge, and previously untapped resources for the network.[56] The skills that make an excellent linker are often threatening to a centralized bureaucracy since effective linkers maintain wide networks of "off-org-chart" lateral ties.

Finally, flow-based warfare involves two issues. First, as alluded to in the previous paragraph, present industrial-age military personnel systems are poorly suited to managing a flow-capable force. A system that uses the attainment of static, formulaic goals as its primary metric for advancement has little chance of attracting, retaining, and developing these players. If a flow-based force were so easily identified by an algorithm, an enemy would easily pin it down as well.

The second issue is even more difficult. For Americans, the deep constructs that surround the fundamental civil-military problem—how we as a society deal with those who have killed in our name—are based almost entirely around place. The idea of combat as a place of legitimate killing is built explicitly in geographic zones. Someone who kills as part of a flow, as do Predator and Reaper crews, does not fall cleanly into these constructs. This creates a liminal space, which hampers our understanding of the reciprocal civil-military duties and responsibilities in flow-based warfare.

More so, Westphalian understandings of sovereignty and the concomitant accountability for the use of force are built explicitly (at least in their original form) around space. *Cuius regio, eius religio* assumes that *regio* (physical realm) is the core framing logic of the system.[57] Given the increased global impact of transgeographic violence from flow-based networks, ungoverned and poorly governed places take on a new significance. These places can provide sanctuary for a "space of [violent] flows," for which Westphalian accountability cannot provide effective recourse. The adoption of low-based warfare, at least in part, comes as a response to these threats. If sovereignty is a space, then one can envision a difficult debate about whether it is a space of places or a space of flows.

This discussion lies beyond our present scope, but it does highlight one final benefit of Castells's heuristic—it is a critique of the state of the current "drones" debate. Armed RPAs are likely the most controversial expression of flow-based warfare, but the contemporary debate overly concentrates on the hardware and tends to neglect the humans. If a space is a material support to social practices, then it is fundamentally about people.[58] Similarly, warfare is a human enterprise, undertaken by humans against other humans for human objectives. It involves technology, much like any other social practice, but it is never entirely constituted by hardware.[59] Castells's idea of flows refocuses us on the classic military principle that "war is an extension of politics with an admixture of other means" and dissuades us from the temptation to see war increasingly as a technical problem.[60]

Technology matters insofar as it changes relationships between people—in Melvin Kranzberg's classic formulation, "technology is neither good nor bad; nor is it neutral."[61] Here, the communications technologies that enable flow-based operation of the Predator aircraft have no independent agency, but they do deeply shape the agency of all the players in that process. This influence matters in any of a number of ways, not the least of which is how we train and equip future forces and how we hold current forces accountable for their choices. In a closing recommendation, this article proposes that the academic discourse about emerging military technology might shelve the reductionist drones trope for a bit because those arguments tend to fixate on the technical aspects of a largely misunderstood and surprisingly banal technology. The debates that we should have are about the increasingly blurred distinction between combatants and civilians, the meaning of politics and narratives in a world of democratized violence, and the importance of evolving civil-military relations, given the changing meanings of place and flow in the battlespace.

Notes

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4. Castells, *Rise of the Network Society*, 442.

5. Ibid., 453.

6. Robert Sugden, "A Theory of Focal Points," *Economic Journal* 105, no. 430 (1 May 1995): 533–50, doi:10.2307/2235016.

7. Castells, *Rise of the Network Society*, 442.

8. "Keeping America Safe: The New Defense Strategy," Deloitte FedCenter Interview, 7 March 2012, http://federalnewsradio.com/sponsored-content/2012/03/march-7th-2012/.

9. Pekka Himanen, *The Hacker Ethic and the Spirit of the Information Age* (New York: Random House, 2001), xiv–1.

10. See, for instance, "Computer Coding Meetups," accessed 20 July 2015, http://coding.meetup.com/.

11. Idea incubators such as 1776 in Washington, DC, are an outgrowth of this trend. See "1776," accessed 20 July 2015, http://1776dc.com/.

12. A similar trend occurred with the introduction of dynamite, which empowered anarchists around the turn of the twentieth century.

13. To this point, the US Coast Guard adapted more quickly than its larger Bureau of Prohibition counterpart to the challenge of rum-running networks in the 1920s. A major reason concerns the small size and deep connectivity of the Coast Guard's officer corps. There were approximately 300 officers total, the vast majority of whom knew each other from time at the Coast Guard Academy and shared time in service. Effectively, the most junior officer could reach the commandant with an innovation or a novel idea through two or, at most, three steps. National Archives, Records Group 26, Box 178; and Dr. William Thiesen and others, various interviews by the author, US Coast Guard Historian's Office, Spring 2013.

14. James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998), 262–306; and Michael Polanyi, *The Tacit Dimension* (Garden City, NY: Doubleday, 1966), 1–26.

15. McRaven, *Spec Ops*, 1–28.

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17. Arquilla and Ronfeldt, *Networks and Netwars*, 1–28.

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37. Thomas P. Ehrhard, *Air Force UAV's: The Secret History* (Arlington, VA: Mitchell Institute Press, July 2010), http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA525674.

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39. A prima facie case exists for the superiority of RSO in comparing hours of overwatch to resource cost and constraints as compared to traditional deployments. A full-architecture cost comparison between deployed operations and RSO depends greatly on modeling assumptions.

40. Blair and Helms, "Swarm, the Cloud," 21.

41. Anonymous subject, interview by the author, 2013.

42. Anonymous subject, interview by the author, 2012.

43. Matt J. Martin and Charles W. Sasser, *Predator: The Remote-Control Air War over Iraq and Afghanistan: A Pilot's Story* (Minneapolis: Zenith Press, 2010), 45.

44. Hernando Ortega, "Telewarfare," *Air and Space Power Journal*, forthcoming.

45. Ibid.

46. Peter W. Singer, "A Military Medal for Drone Strikes? Makes Sense," *Washington Post*, 15 February 2013, http://www.washingtonpost.com/opinions/a-military-medal-for-drone-strikes-makes-sense/2013/02/15/e90c0638-76e4-11e2-8f84-3e4b513b1a13_story.html.

47. Steve Stottlemyre and Sonia Stottlemyre, "Crisis Mapping Intelligence Information during the Libyan Civil War: An Exploratory Case Study," *Policy & Internet* 4, issue 3–4 (December 2012): 24–39.

48. John Pollock, "People Power 2.0," *MIT Technology Review*, 20 April 2012, http://www.technologyreview.com/featuredstory/427640/people-power-20/.

49. Ibid.

50. Ibid. See also John Reed, "Libyan Rebels' DIY Weapons Factory, Robots and All," Defense Tech, 14 June 2011, http://defensetech.org/2011/06/14/libyan-rebels-diy-weapons-factory-robots-and-all.

51. The Standby Task Force was among these volunteers. Although not directly aligned with the Libyan rebels, they were certainly in opposition to Gadhafi's actions. See "The [Unexpected] Impact of

the Libya Crisis Map and the Standby Volunteer Task Force," Standby Task Force, accessed 20 July 2015, http://blog.standbytaskforce.com/2011/12/19/sbtf-libya-impact/.

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54. See John R. Boyd, "Destruction and Creation," 3 September 1976, http://www.goalsys.com/books/documents/DESTRUCTION_AND_CREATION.pdf.

55. Manuel Castells, *Communication Power* (Oxford, UK: Oxford University Press, 2009), 47.

56. The linkers are like Gladwell's connectors and mavens. See Malcolm Gladwell, *The Tipping Point: How Little Things Can Make a Big Difference* (Boston: Back Bay Books, 2002), 19.

57. The phrase "whose realm, his religion" is a foundation of the Westphalian system, which focused sovereignty at the level of the state rather than a superordinate structure such as Christendom or a flow-based structure such as the Hanse.

58. Castells, *Rise of the Network Society*, 147.

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Dark Horizon

Airpower Revolution on a Razor's Edge—Part Two of the "Nightfall" Series

Capt Michael W. Byrnes, USAF[*]

> *The aviators accepted the robots, as servants, into their house, not because they liked them or even understood them, but because neighbors had eagerly bid for their ownership. The robots, however, kept challenging the boundaries.*
>
> —Carl Builder, *The Icarus Syndrome*

The release of "Nightfall: Machine Autonomy in Air-to-Air Combat" in the May–June 2014 issue of *Air and Space Power Journal* generated substantial conversation about the future of airpower, reaching across the Air Force, the joint team, and the defense industry.[1] Achieving the end states and national advantage proposed by "Nightfall" requires an articulation of airpower theory and a committed

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[*] The author would like to thank the following people for their critical reviews, contributions, and patience in helping to develop this article: Col Case Cunningham, Col Robert Kiebler, Col James Thompson, Lt Col Casey J. Tidgewell, Maj Mike Chmielewski, Maj David Blair, Maj Lewis Christensen, Maj Cody Hern, Maj Joe Rice, Maj Chris Ryan, Capt Andrew Atanasoff, Capt Steven Christopher, Capt D. Jerred Cooper, Capt Brett Cullen, Capt Brandon Magnuson, and Capt Curt Wilson.

institution. Consequently, this second article in a planned series addresses the organization of today's precursors that bear the title "remotely piloted aircraft" (RPA) employed by Air Combat Command, Air Force Special Operations Command, and various other government agencies.[2] As Colin Gray observes, no weapon is strategic in and of itself but is merely a means for the construction of an actual strategy.[3] Nevertheless, RPAs in the hands of coalition forces and other government agencies have done much to reverse the calculus of global counterinsurgency in favor of organized states.[4] Perhaps most telling of all are moments when insurgents beg for a fight but then offer a caveat regarding the invitation by asking for relief from robotic aircraft.[5]

This article introduces a brief sketch of emerging theory to demonstrate how remote and autonomous capabilities are not merely an answer for niche contingency operations but central to the unfolding narrative of humanity's experience with airpower and of key importance to unlocking new insights into its fundamental nature. As multiple media sources have highlighted, however, pressures on Airmen in the RPA enterprise have reached crisis levels. For that reason, this article investigates the community to understand the exodus of talented, highly trained professionals who might have otherwise shaped the next chapter of Air Force history from within.[6] Research methods included surveying 114 pilots and sensor operators from the MQ-1, MQ-9, and RQ-170; conducting several direct interviews; and inspecting records to corroborate assertions.[7] One limitation of the study was a lack of access to RQ-4 users or a non-RPA control group. Because respondent views were sometimes emotionally charged, each section reports firsthand sentiment analysis and then a potential alternative explanation or parallel set of circumstances that occurred elsewhere in the service. The study found three major causes for the exodus: the well-advertised overwork, a service culture with an overt bias toward traditional aviation, and institutional reluctance to plan or provide for these Airmen's attempts to improve their circumstances. The article offers suggestions to posture the Air Force to behave responsively to joint force needs and to better leverage the advent of robotic airborne systems.

Predicament

Since 11 September 2001 (9/11), demand for intelligence, surveillance, and reconnaissance (ISR) has been insatiable. The service's efforts to meet ISR requirements to fight a globally distributed extremist network contend with other problems: aging aircraft fleets in other mission sets, an international financial crisis, and tight federal budgets. Increased reliance on robotic aircraft during this period created a dilemma for accepted Air Force doctrine and culture: satisfying joint force needs predominantly required systems that remove or reinvent many of the familiar elements of aviation and present unknown viability for future conflicts. This tension translated into spectacular fighting between the Air Force and Secretary of Defense Robert Gates as they exchanged alternating accusations of "current-war-itis" and "next-war-itis."[8] The proliferation of RPAs as an answer for ISR made the former iconic of the latter, potentially convoluting means and ways in discussions of either topic. To be clear, decision makers want information superiority and thus drive the increased demand for ISR, much of which the Air Force must supply, while RPAs are one *mechanism* to satisfy that requirement in unprecedented volume.

It is possible to prepare for both present and future styles of warfare for which the Air Force finds itself responsible, but doing so may require thinking as broad as Gen Thomas D. White's willingness to set aside the cockpit—and in more missions than reconnaissance.[9] Yet, the resistance that General White found in his era, the observations of Carl Builder decades later, and the tension that Secretary Gates perceived whenever any of them explored alternatives to the cockpit all suggest that the Air Force has enduring institutional preferences for human-inhabited air vehicles and an unwritten hierarchy among its core competencies. Such predilections are not just a cause of political strife but a mechanism for potentially undervaluing contextually relevant perspectives on the design and use of airpower. In contemporary context, both state and nonstate threats are significant, the aerospace industry is undergoing a revolution in the development of remote and autonomous systems, ISR demand continues to grow unchecked, and yet the Air Force's top acquisition priorities remain human-inhabited systems intended to recapitalize well-understood missions around which the service has organized itself.[10] One need no more complicated a litmus test than to pose this hypothetical question: if recapitalizing RPA systems, infrastructure, and organization to meet urgent needs in the joint community would mean giving up one production lot of F-35s over the next decade and no alternative trade-offs were possible, which would the Air Force voluntarily elect?

In his book *Tomorrow's Air Force*, Jeffrey Smith observed that organizational changes occurred in the service's history when communities brought situationally appropriate capability forward while a dominant community did not.[11] Among all power-projection options, airpower's marriage to technology seems the most extreme and nuanced, and large, upfront investments needed for research and development mean that the Air Force has a particular interest in adapting itself and picking appropriate systems well *before* conflicts arrive. Builder asserted that the service abandoned deliberate development of airpower theory, yet it is clear that when it enacted that discipline, the Air Force enjoyed incredible successes.[12] For example, consider the impact of John Boyd's and John Warden's theories on system design and operational planning, respectively, that undergirded coalition conduct in Operation Desert Storm. Airpower theory is not an abstract luxury: it is today's requisite down payment for winning tomorrow's wars.

Dimensionality

Today's Air Force has no formal, published theories about remote and autonomous airpower, so this section defines two key terms and a construct for predicting success in combat amidst increasingly sophisticated and interdependent autonomous capabilities. Let the term *combat automation* in the context of airpower mean "the transfer of a task normally performed by an operator of a military aircraft to the control of an automated system, typically a digital computer." Further, let the term *emergent combat automation* (ECA) in the same context signify "the advent of a new tactical capability as an *emergent property* of the interaction between integrated automation systems." Devices like autopilots and modern navigation systems are examples of combat automation—computers do some mental or physical task to allow crews to concentrate on other responsibilities and preserve situational awareness, and the notion is well understood. Conceptualizing ECA, however, requires a shift in thinking.

Today's system-design concepts tend to assume a human pilot making decisions about how to engage the enemy. If one removes the human from the equation, instead directing that pilot to provide commander's intent to an onboard machine pilot and monitor its performance, a new set of possibilities emerges. Consequently, the almost comical question "If two robotic airplanes with the same software and processing power fought each other, which would win?" is actually a modern restatement of a need to understand how to predict success in combat when the rules are unclear. Boyd's two chief discoveries—the observe-orient-decide-act (OODA) loop and energy maneuverability (E-M) theory—codified such rules in an era when it was safe to assume that human decision making would be central to the engagement.[13] When comparative OODA and E-M differences become negligible between two highly automated warplanes (or between a warplane and applicable segments of an air defense system), however, a larger framework is necessary to make reliable predictions. The key to such a framework amidst evolving system complexity lies in permitting flexible definitions of dimensionality.

Although four dimensions of space-time are intuitive, physicists conceptualize extradimensionality, computer scientists use "n-dimensional" arrays of variables, and analytic data warehouses often have "star topology" with arbitrary dimensions.[14] A dimension could be any property of an aircraft that presents tactical impact, and some may be derivative values of other dimensions—for example, the frequency range or power available in an electronic warfare module or that module's frequency switching rate (a derivative with respect to time), the vehicle's available g-loading about a particular axis (integrating E-M considerations), the number of targets it can track simultaneously, the spectral or spatial resolution of its sensors, and so forth. To represent OODA using the framework, define an arbitrary dimension for "computational throughput" (the machine's version) or "useful thought" (the human's), and consider it with respect to time.[15] We might refer to this framework as a dimensional theory of airpower and note that Boyd unlocked two of "n" possible dimensions that may be predictors of victory. The two key tasks of dimensional theory are to identify relevant dimensions and then to mathematically express the possible relationships between dimensions. A logical use for the framework involves conducting simulation and analysis whereby artificial intelligence applications may search out ways to exploit the mapped dimensions and discover how emergent properties create novel tactical options.[16] Uncovering such properties for an autonomous aircraft to act upon provides a "third offset" advantage and reveals things a machine can do that a human cannot.[17]

This approach has two important implications. First, under these definitions of automation in airpower, systems like the F-35 are monuments to combat automation but have no concept of ECA—even perfect situational awareness is still limited by human cognition and becomes irrelevant if the machine has considered dozens more dimensions upon which to formulate tactics.[18] ECA goes beyond asking machines to do the "dull, dirty, and dangerous"; instead, it discovers what they can accomplish *past* human abilities. Second, this perspective surfaces only upon the serious consideration of computationally capable robotic aircraft but reveals something about airpower in general and how to structure arbitrarily complex warfare simulations that incorporate both human-inhabited and robotic aircraft. The answer to the question about which robot wins the fight is likely to be remarkably similar to Boyd's: the one that is better prepared and equipped and that encounters opportunity first. The same holds true for which of two modern air forces would defeat the other, but essential to preparation is a realization that remote and autonomous approaches to airpower cannot reach their potential if relegated to supporting traditional pilot-centric models. Instead, they are the next chapter of unfolding discovery; as such, they are unavoidably an affront to the Air Force's demonstrated institutional preferences—a reality with tangible consequences for Airmen today.

Fratricide

The extent of overwork and understaffing at RPA units is well documented, but this study found that chronic overwork accounted for only one-third of the categorical causes for an exodus of RPA pilots. The other two contributors were cultural resistance and the perceived powerlessness to take charge and improve their circumstances. With respect to culture, Smith articulated that the fighter-operations perspective still dominates the service although it is losing momentum.[19] A parallel theme in this article's research concerns the respondents' belief that the dominant culture behaves in a nepotistic manner to preserve power and stereotypically disdains the RPA community. A general RPA impression of fighter culture would ascribe to it a heuristic for self-serving bias in this pattern: *The business of the Air Force is flying airplanes to win wars. Those who fly best are most qualified to lead the Air Force. Fighter pilots are the best pilots; therefore, it makes sense that they lead the Air Force.* Correlating to this perception, Smith's study found that fighter respondents stood alone in their belief that fighter pilots were best suited for senior leadership roles and that RPAs should be the lowest budget priorities—other officers overwhelmingly held opposite views.[20] If it truly is the case that some officers make sense of their place in the service by a biased heuristic, then it is important to note that the failures in this line of thinking are numerous. The most critical misstep is a reversal of ends and ways as Builder examined two decades ago.[21] The business of the Air Force is *actually* to deliver airpower for the nation, which may or may not involve an aircraft—let alone one inhabited or manually operated by a human. Leadership is furthermore both self-evident and self-sacrificing rather than an entitlement.

Smith's work revealed a historical trend for dominant cultural perspectives to suffer logical disconnects in times of transition. Officers flying fighters responded to Smith's survey by affirming their belief that future conflict is more likely to be irregular than conventional, but in subsequent questions they disagreed with any actions to reprioritize Air Force spending for the threat they themselves had identified.[22] Ty Groh's research at Georgetown University affirms that large, well-established states that cannot afford direct confrontation turn to (often irregular) proxy wars, and that insight seems particularly relevant in the present geopolitical order.[23] Corresponding survey data for this article found that a significant number of RPA pilots felt that the Air Force, dominated by fighter-operations perspectives, treated them unfavorably despite extensive combat successes (fig. 1).[24] Among several disturbing comments, one pilot stated that "other pilots scoff at RPAs. I remember the look of [an] F-15C pilot when I told him I flew RPAs, and he looked at me like I was some kind of leper—not remorse but almost disgust. He was a friend, but I don't consider him one now that he did that to me."[25] The prejudice and the reciprocal unwillingness to forgive are both clearly destructive, potentially inhibiting either party from seeking out war-fighting integration opportunities. If there is animosity, alternative reasons may include frustration over the post-9/11 combat environment not matching the expected challenges for which many fighter pilots diligently trained and organized themselves (a reduction in mission satisfaction compared to a better-understood conventional war)—or perhaps that the Transformational Aircrew Initiative for the 21st Century, which involuntarily pulled fighter and bomber pilots to the Predator program, imprinted a negative sentiment regarding the RPA.[26]

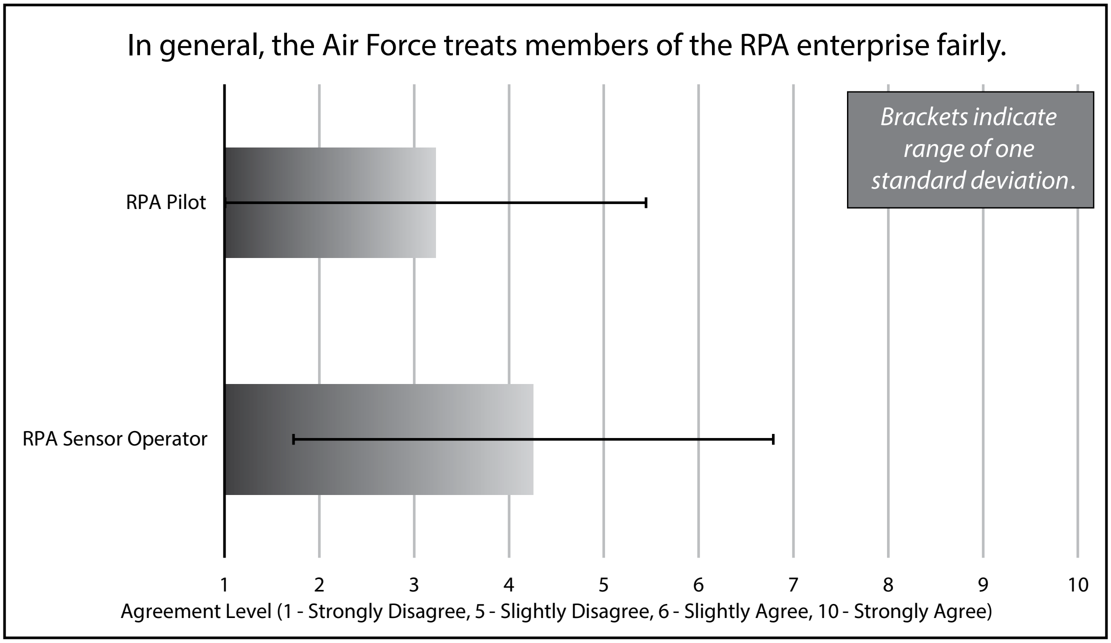


Figure 1. Perceptions of mistreatment

It is equally important to acknowledge that as a consequence of commanders often sending their least-competitive officers, the enterprise did start, as Houston Cantwell reported, like a "land of misfit toys."[27] The community has now formed a nucleus of high-performing teams that continually raise the community's standards, but changing perceptions requires time, consistent performance, and advocacy. Intraservice squabbling, however, conceals the emergence of a *new airpower perspective of globalized operations-intelligence fusion* developed over 15 years of sustained combat. In line with Stephen Rosen's point that those who carry an innovative perspective forward must rise through the ranks for the institution to fully leverage it, the exodus of RPA pilots is of particular concern in terms of the service's ability to transform itself.[28] Members attending a chief of staff of the Air Force (CSAF) roundtable at Creech AFB, Nevada, noted that his desire to fix the low inflow of RPA pilots, accepting inevitable attrition, shows concern for force sustainment but not transformation.[29] Surveys and interviews indicate a corresponding belief among RPA Airmen that they are as desperately needed as they are unwanted.[30] Whereas Gen Mark Welsh said he saw clear potential for an 18X (RPA-only pilot) to lead the service one day, community sentiment is far more pessimistic (fig. 2).[31]

However unintentionally, a number of oversights in basic policy design fuel perceptions of inequity. For example, when RPA crews are in-theater to launch and recover their aircraft, even using them to defend the base amidst incoming enemy fire, the crews' flying time is downgraded from "combat" to "combat support," but all inhabited aircraft overhead (crews not enduring the rocket attack) receive combat hours and earn upgraded medals.[32] If RPA crews switch to the Air National Guard or Reserve, protections of the Uniformed Services Employment and Reemployment Rights Act extended to other aircrews do not address the "deployed-in-place" reality.[33] In 2012 disproportionately low RPA promotions even drove a congressional investigation.[34] An April 2014 Government Accountability Office report confirmed that advancement hovered among the lowest levels in the service from 2006 to 2013. One nuanced detail affecting competitiveness is the number of people assigned to a single wing. For example, in 2013 over 570 company grade officers were on Creech (almost three times the total number of officers on Holloman AFB, New Mexico), severely limiting the number of leadership positions, awards, and stratifications available.[35] The Air Force instructed selection boards to contemplate the fact that the circumstances of RPA organization and workload might mask the leadership potential of officers being considered for promotion and allocated 46 in-residence school spots for the 2012 board.[36] Although promotions improved, by the 2014C majors' board, only nine RPA pilots were selected for in-residence schooling, one of whom was actually an F-15 pilot set to return after an RPA tour (7.5 percent effective selection). By comparison, 47 fighter pilots (24.1 percent) received school selection from the same board.[37] The Government Accountability Office highlighted that the Air Force did not assess the mechanisms actually responsible for selection patterns, but closer inspection of both what is absent and what is present in records yields clues.

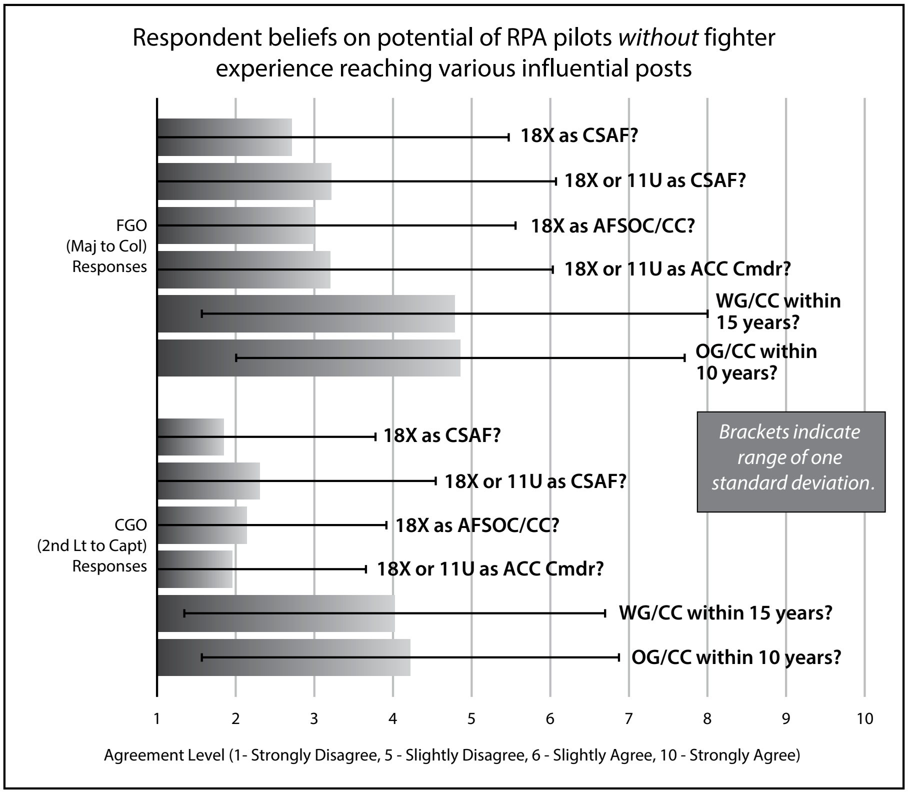


Figure 2. Pessimistic outlooks

18X=RPA-Only Pilot

11U=Pilot Converted to RPAs

ACC=Air Combat Command

AFSOC/CC=Commander, Air Force Special Operations Command

CGO=Company Grade Officer

CSAF=Chief of Staff of the Air Force

FGO=Field Grade Officer

OG/CC=Operations Group Commander

WG/CC=Wing Commander

One pilot reported that an operations group commander at Creech deliberately limited the types of tactical accomplishments that could be included in performance reports.[38] Whatever the intent, the effect was to downplay the contributions of RPA crews and render their reports less competitive than they might have been otherwise. Furthermore, officers encountered irregular behaviors with regard to the stratifications (rankings) on performance reports that frame promotion and school recommendations. While F-22 operators controlled Holloman—also the home of the MQ-1 and MQ-9 formal training units (FTU)—RPA pilots reported that they received ratings like "# 1/28 RPA Majors" when fighter pilots certified the reports. In the strictest interpretation, that kind of rating is called an "illegal strat" and is akin to being paid in counterfeit currency since a promotion board accepts only certain qualifying key words in recommendations.[39] It is plausible that these kinds of reports were partly responsible for overall low promotion and school selection. One interviewed officer asserted that the behavior, coupled with comments during official performance feedback, constituted deliberate messaging that RPA pilots were "second class citizens" compared to fighter pilots. Respondents used that phrase repeatedly during the author's research.[40] Whatever the subjective sentiments, observed outcomes were that several personnel at the FTU, even an MQ-9 flight examiner with otherwise commendable records, were passed over for selection to major while all F-22 pilots were promoted, many with school follow-on assignments. If the staffing crisis inhibiting the growth of the new airpower perspective were solely a product of overwork at Creech and Cannon AFB, New Mexico, the FTU, with opposite characteristics in almost every respect, might have been a relief valve. Instead, reports of alleged sabotage and discrimination gave members incentive to refuse orders and depart active duty.[41] Survey responses reflect this dim view of Holloman: only 46 percent would accept the assignment, 29 percent would leave the service, and the remaining 25 percent were either ineligible to move or would go strictly because their service contracts obligated them (fig. 3).[42]

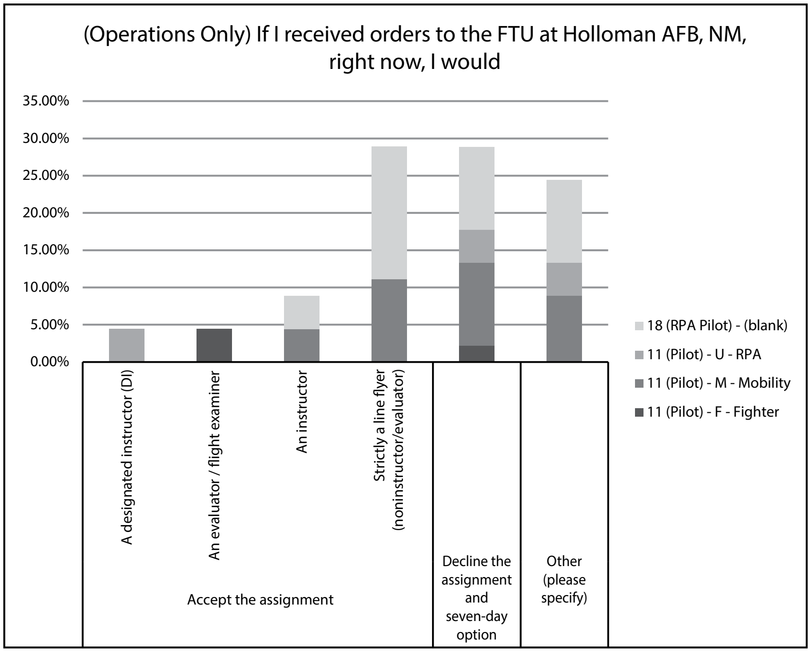


Figure 3. The RPA community's dim view of Holloman AFB

In late 2014, 18X pilots who graduated from training between 2011 and 2013 (about 200 officers) discovered that the Air Force Personnel Center (AFPC) had secretly changed their service commitment dates to extend their required service after it realized they did not have the two years of retention required by policy to force them to accept reassignment to Holloman. These officers petitioned for correction of records and showed the contracts they actually signed but received no response from either AFPC or their chain of command.[43] AFPC destroyed its credibility and harmed that of senior leaders with such unnecessary tactics when it might have simply stated its problem and asked for volunteers. In fact, research revealed that a cohort willing to accept the assignment *does* exist: the subset of predominantly younger officers who are both eager for an opportunity to progress to instructor pilot and who were not exposed to Holloman's internal conflict. The latter fact may indicate some improvement of the FTU's appeal since the F-22s departed. Preserving those gains will likely require that command of Holloman remain with an experienced RPA pilot, potentially complicating proposals to administratively integrate the F-16 training contingent that moved there in 2013.[44]

Given such perceived mistreatment in so many areas, it was unsurprising that surveyed members valued commanders who would be loyal advocates.[45] Between 2012 and 2014, all three flying squadron commanders at the FTU were transplants who kept a "core identifier" in their records of 11F (fighter) or 11B (bomber) rather than redesignating as 11U (RPA). The situation is historically similar at Creech as well. Permanent members of the RPA cadre indicated their belief that they had been "shown the ceiling" and would never be allowed to command their own units because they did not begin their flying careers in an F-16.[46] One exceptional squadron commander with extensive RPA experience and among the first to switch to the 11U identifier made an unfortunate discovery upon assuming command that reinforced this belief. The previous (11F) commander's spreadsheet for stratifying officers had a column that arbitrarily awarded extra credit to those with fighter experience.[47] The behavior was consistent with community perceptions of fighter culture and inspired cynicism: that commander betrayed their trust by quietly propping up fellow members of the "fighter fraternity" and never admitting the action. Such behavior, once exposed, intensified the rift of distrust between the RPA community and outsiders seen as arriving for "drive-through" commander credit.

A fair but contrary hypothesis to explain the lack of RPA pilots taking command of their own units is simply that there are few candidates senior enough to qualify, given the relatively young age of the RPA career field, and that talented officers capable of leading a flying squadron are available in many communities. One F-22 pilot noted a similar pattern as that weapon system began to normalize. He reported that officers from other fighters were selected for command and then sent to F-22 qualification training after the fact. Further, although he noted many challenges associated with mastering a new airframe while learning to command, he did not perceive any resulting cynicism correlating to this article's findings of the RPA.[48] "In-group versus out-group" perspectives might account for the difference in RPAs, an effect Smith observed as a historical marker for impending culture shift.[49] Knowing that fact, individuals entering as commanders must conscientiously assess how their own arrival as outsiders affects organizational dynamics. In the case of the

RPA community, enduring exhaustion and struggling to define its identity within the Air Force, a simple change of identifier can help remove doubts about an incoming commander's prioritization of career ambitions versus leadership responsibilities (fig. 4).

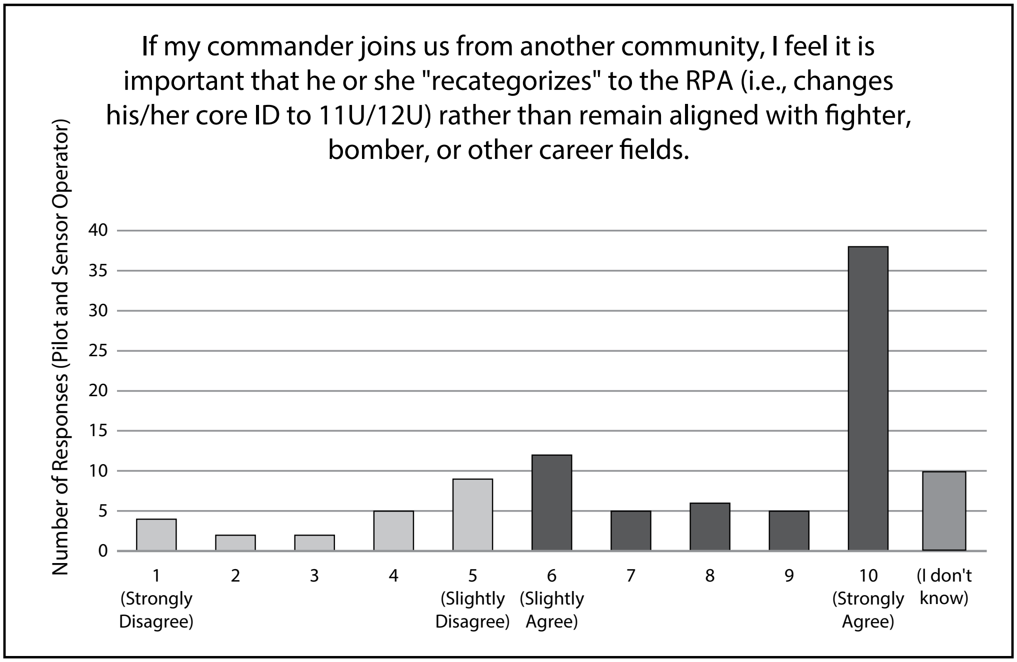


Figure 4. Importance of demonstrated commander allegiance

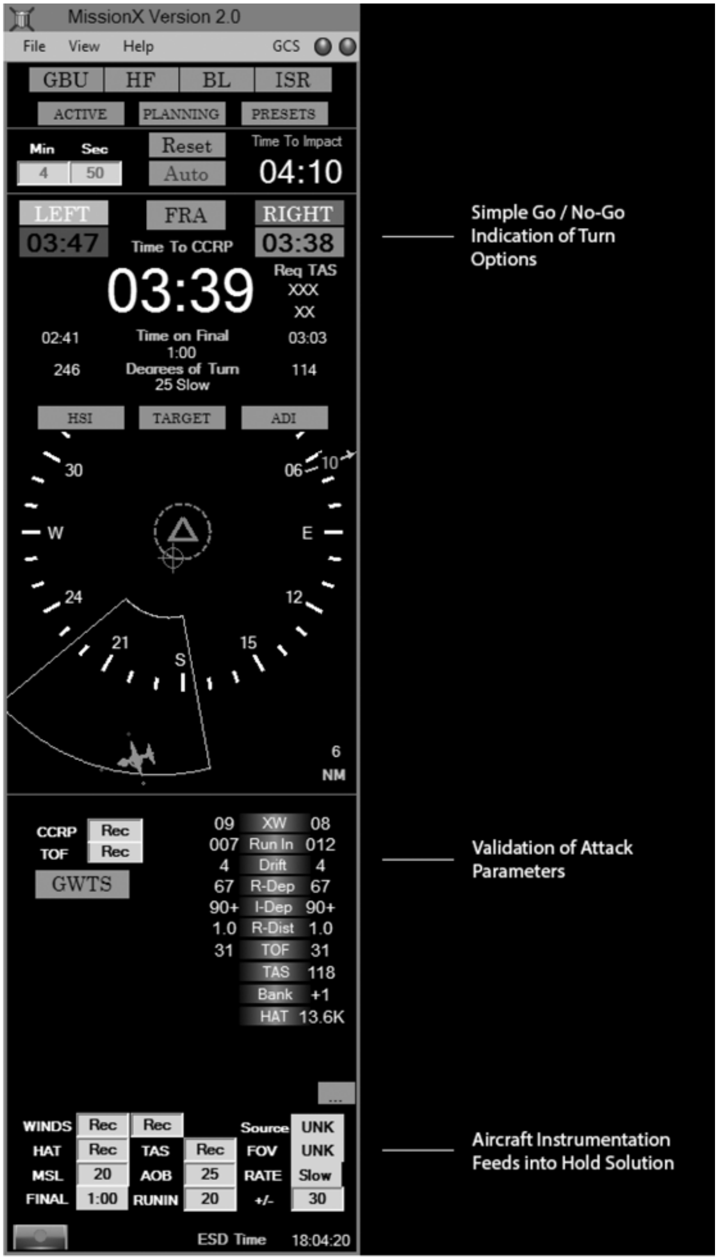
That struggle for identity and credibility even manifests itself in military exercises. Maj Lewis Christensen, an MQ-9 flight examiner, led RPA crews in a Virtual Flag run concurrently with the Red Flag live-fly exercise in Nevada. Largely ignored by the air operations center, he coordinated with other ISR participants to find relevant work. Employing normal RPA tactics that he teaches at the FTU, his team changed the tide of the virtual war in ways the exercise staff did not expect. Instead of seizing the opportunity to study how the RPA had caused that unforeseen impact, the exercise director voiced frustration and threatened to remove them from the scenario if they did not stop. Christensen stood his ground, saying that if they wanted to remove the MQ-9s, they should do so realistically by using their "red air" to engage them. The director agreed but then found it far more difficult to kill the Reaper than he had imagined: diverting fighters to deal with the RPAs created openings that left his forces vulnerable to counterattack, but ignoring them gave the team operational freedom to inflict equally unacceptable losses.

A comment in text chat from an MQ-9 sensor operator, admittedly delivered insensitively, that they appeared to be "single-handedly winning the war" precipitated a vocal outrage from the staff and director that culminated during the exercise debrief. Christensen found himself and his team the objects of indignation for doing their jobs to the best of their ability and succeeding in unexpected ways.[50] This episode yields three important observations. First, the Air Combat Command–led exercise dismissed the RPA and refused to believe its capabilities, but personnel with ISR experience immediately saw an armed reconnaissance system as a natural fit for dynamic air warfare. Second, this kind of doctrinal entrenchment that tries to force outcomes to meet preconceived expectations aligns with Smith's indicators of an airpower perspective losing touch with an evolving reality—one ripe for transition.[51] Third, the devastation inflicted by MQ-9s in a tactically sound, realistic manner questions the validity of bifurcating theaters as "permissive" versus "denied." A more realistic view is that any given environment will be extremely fluid and that the wide variety of characteristics across the fleet will compel enemies to make extremely challenging choices when confronting a fully integrated US Air Force. That level of integration will require forward-looking attitudes toward remote and autonomous airpower across the service.

Lockout

The relatively primitive state of equipment, such as the remote cockpits (ground control stations [GCS]) in which the community has logged millions of flight hours, adds some irritation, but frustration with the community's efforts to innovate is a more central concern.[52] Such frustration by itself might have been trivial, but with heavy workloads, impediments to career progression, and a need to improve the tactical credibility of the community to elevate its standing, innovation represented a productive outlet to take charge of a collective destiny. Outsiders are often surprised to find that the GCS is so limited that squadrons must "bolt on" office computers connected to Air Force networks and build needed functionality with desktop applications. Notable RPA innovators in this realm include Capt Brandon Magnuson and Capt Curt Wilson.

Magnuson is a graduate of the US Air Force Weapons School and the 49th Wing's chief of weapons. Wilson, a former Air Force engineer with ties to science and technology circles in and out of the service, is a dual-qualified MQ-1 and MQ-9 instructor pilot who uses his expertise to develop novel concepts for technological progression of the RPA. Magnuson, an avid computer programmer, found his squadron using spreadsheets to calculate tactical holds, studied the problems, and built "MissionX" (mission execution), which receives networked RPA telemetry, visualizes the tactical situation, and builds maneuvering solutions automatically. With minimal training, a pilot can simply turn the aircraft inbound when the left or right turn time is green and follow that colored indication all the way to an on-parameter release (fig. 5).



Simple Go / No-Go Indication of Turn Options

Validation of Attack Parameters

Aircraft Instrumentation Feeds into Hold Solution

Figure 5. MissionX configured for a heading-restricted, timed GBU-12 attack

Experienced with the processes of defense acquisition, Wilson also sought to remedy the unfortunate state of RPA technical progress that the CSAF acknowledged as late as his March 2015 visit to Creech.[53] Wilson noticed a lack of concepts of operation (CONOPS) with which to map articulated ideas to procurement for the

RPA.[54] In mid-2014, he proposed the Autonomous Mission Planning and Execution (AMPLEX) CONOPS that would negate a 1:1 pilot-to-aircraft ratio requirement by leveraging autonomous capabilities.[55] Aligning Wilson's top-down vision and Magnuson's bottom-up development has important implications. If a person can follow calculated course guidance to hold the aircraft, the next logical step is to let this software directly steer the aircraft's holding patterns. The pilot no longer needs to occupy the GCS and may be collocated with others in an operations center. The pilots would next notice that with many tasks automated, they often have little reason to sit there together; therefore, like emergency service providers, some are "on call" with a predetermined response time, allowing them to do other work and invest time in their Airmen. Although not a singular solution for personnel shortfalls, leveraging autonomy ameliorates the impact and preserves viable manpower levels on a long-term basis. It would also allow one pilot to fly a two-ship formation, effectively doubling sensor and firepower coverage for Army and Marine units in the field if they accepted this packaging construct.

Magnuson faced resistance on the basis of two arguments. First, a sustainment plan had to be in force, other than a coincidental pilot programmer. Second, some leaders feared that if software simplified decision making too much, the construct would cease to be "flying" any longer.[56] Magnuson remedied the first challenge by pitching the idea to a former officer who planned to start a software business, who in turn won a contract to build tools for RPAs. Concurrently, the author, Magnuson, and their colleagues refined software-development methods to rapidly transform code into capabilities. Mining knowledge from Carnegie Mellon's Heinz College, the Human-Computing Interaction Institute, and the US Software Engineering Institute, they created a flow of well-defined activities both to allow military members to participate in design and to simplify statements of work for contractors to do the "heavy lifting" and sustainment of agile software development (fig. 6).

Unfortunately, when these initiatives reached squadron and group leaders, some were intrigued but had no means to take action, and a few saw innovation as a distraction from mission execution. Wilson planned to hand his white paper to a group commander during a luncheon when that commander had responded to someone's unrelated question by saying, "I don't need captains with good ideas—I need captains to be tactically proficient and do their jobs."[57] Leadership views reportedly colored by a traditional "pilots are supposed to fly, not build computer programs to do their flying for them" attitude ultimately derailed these initiatives.[58] Among the tools marginalized was one of Magnuson's designs to pair sensors to mitigate civilian casualties. Individuals enculturated in a legacy fighter-operations perspective had difficulty seeing the extent to which their line of work in the RPA grew to include software management to secure capabilities that affect manpower requirements and tactical flexibility. Pilots might view software development as a "geek" activity, but if it results in two-ship RPA packages arriving armed to the teeth with 22 hours of coverage and improved situational awareness, then the war fighter on the ground will not.

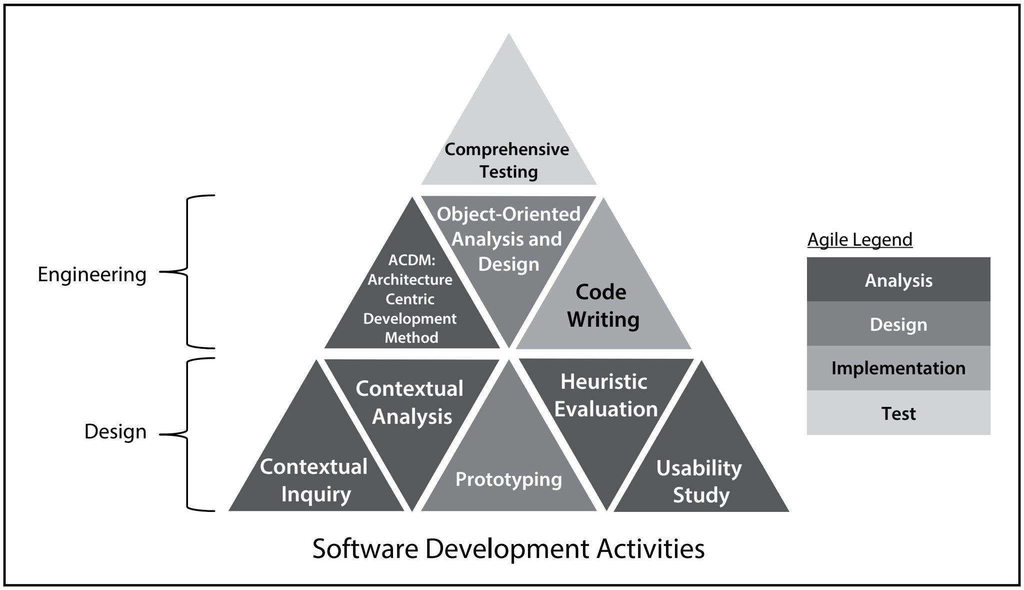


Figure 6. Plug-and-play military/contractor approach to defense software development

Disconnect

In his March 2015 visit to Creech, the CSAF put the onus on the community to generate ideas to establish the way forward for RPAs, unaware that such efforts to take ownership had met with continuous frustration. RPAs demand a global mindset and can be flown from anywhere to anywhere, a fact not lost on their operators pondering why, with a lean logistical footprint that does not even require a local runway or airspace complex, they are still based in remote US locations justified by both. The community has long desired to use the RPA's ability to pass control to another unit to improve flying schedules—a military adaptation of "follow the sun" methods in globalization.[59] In this arrangement—distributed site teaming (DST)—a unit starts operations in the morning, gains control of various aircraft, and passes them to sites in other time zones at the end of its local day. Although such teaming would incur substantial overhead support costs, figures 7 and 8 demonstrate how geographically disbursed units teamed together can provide the same service to combatant commanders without the 24-hour "deployed in garrison" work cycle that has been a negative hallmark of the career field.[60] Arguments against using DST to place permanent RPA wings are in fact problematic for the Air Force: unwillingness to expand ISR provision with RPAs garners resistance from the joint team; additional expansion on current bases further minimizes the number of leadership opportunities available to the community (accelerating departures from active duty); and expansion onto new bases without leveraging time-zone differences is a wasted opportunity.

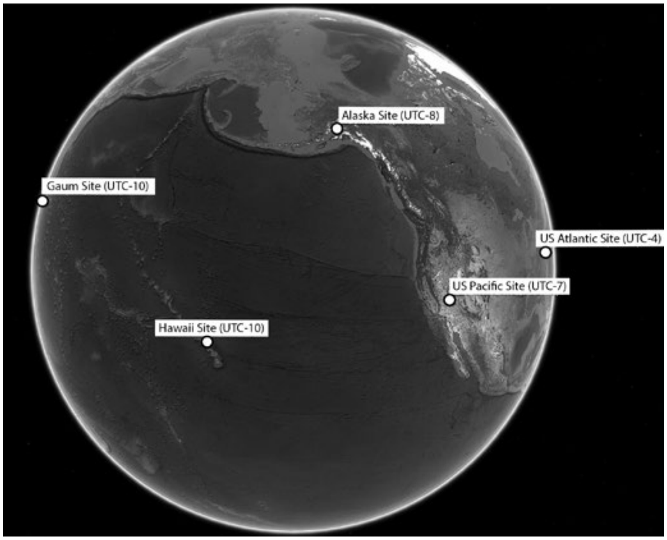
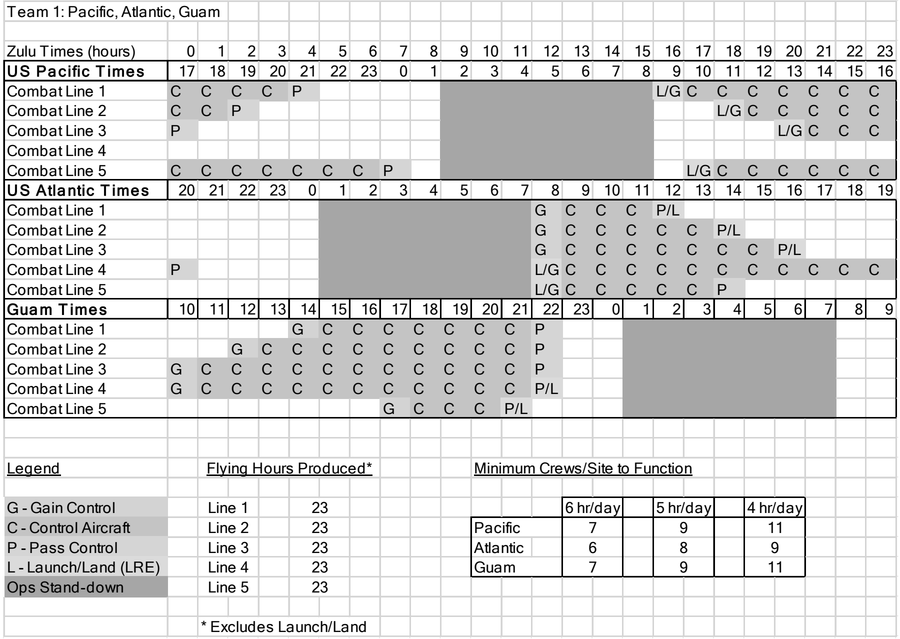


Figure 7. Example of DST—global presence. (From Google Earth image; all copyrighted layers disabled. Derivative image sources [as reported by the software]: Scripps Institute of Oceanography, the National Oceanographic and Atmospheric Administration, US Navy, National Geospatial Intelligence Agency, General Bathymetric Chart of the Oceans, LANDSAT, International Bathymetric Chart of the Oceans, and US Geological Survey.) UTC=Coordinated Universal Time



Team 1: Pacific, Atlantic, Guam

Zulu Times (hours)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
US Pacific Times	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Combat Line 1	C	C	C	C	P					▨	▨	▨	▨	▨	▨	▨	L/G	C	C	C	C	C	C	C
Combat Line 2	C	C	P							▨	▨	▨	▨	▨	▨	▨			L/G	C	C	C	C	C
Combat Line 3	P									▨	▨	▨	▨	▨	▨	▨					L/G	C	C	C
Combat Line 4										▨	▨	▨	▨	▨	▨	▨								
Combat Line 5	C	C	C	C	C	C	C	P		▨	▨	▨	▨	▨	▨	▨		L/G	C	C	C	C	C	C
US Atlantic Times	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Combat Line 1						▨	▨	▨	▨	▨	▨	▨	G	C	C	C	P/L							
Combat Line 2						▨	▨	▨	▨	▨	▨	▨	G	C	C	C	C	C	P/L					
Combat Line 3						▨	▨	▨	▨	▨	▨	▨	G	C	C	C	C	C	C	C	P/L			
Combat Line 4	P					▨	▨	▨	▨	▨	▨	▨	L/G	C	C	C	C	C	C	C	C	C	C	C
Combat Line 5						▨	▨	▨	▨	▨	▨	▨	L/G	C	C	C	C	C	P					
Guam Times	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9
Combat Line 1					G	C	C	C	C	C	C	C	P			▨	▨	▨	▨	▨	▨	▨		
Combat Line 2			G	C	C	C	C	C	C	C	C	C	P			▨	▨	▨	▨	▨	▨	▨		
Combat Line 3	G	C	C	C	C	C	C	C	C	C	C	C	P			▨	▨	▨	▨	▨	▨	▨		
Combat Line 4	G	C	C	C	C	C	C	C	C	C	C	C	P/L			▨	▨	▨	▨	▨	▨	▨		
Combat Line 5								G	C	C	C	P/L				▨	▨	▨	▨	▨	▨	▨		

Legend
G - Gain Control
C - Control Aircraft
P - Pass Control
L - Launch/Land (LRE)
▨ Ops Stand-down

Flying Hours Produced*	
Line 1	23
Line 2	23
Line 3	23
Line 4	23
Line 5	23

* Excludes Launch/Land

Minimum Crews/Site to Function

	6 hr/day	5 hr/day	4 hr/day
Pacific	7	9	11
Atlantic	6	8	9
Guam	7	9	11

Figure 8. Example of a DST schedule concept

With nearly 70 percent of RPA pilots planning to leave, attempts to lead this enterprise like a collection of traditional flying squadrons have failed, even when individual leaders were excellent, because the legacy *airpower perspective* does not account for the complications of a *virtualized cockpit*.[61] Despite improved personnel inflow, failing to adapt will result in the same outcome when ISR demand grows again; thus, organization and policy changes are critical (fig. 9).[62] It appears inconsistent that the most in-demand Air Force specialty—growing while others shrink—finds the majority of its 1,200 pilots crammed into one wing (with contingents in three others) while the fighter enterprise's 2,300 pilots disburse to more than *20 times* as many permanent wings (about 90 pilots per wing).[63] Supporting RPA sustainment without force transformation suggests that the service's leaders still hope that applications for RPAs will subside so they can return to more familiar models of airpower. In 2012 a four-star general with a vested interest in RPAs literally fell asleep in discussions on RPA normalization.[64] The indifference is consistent with institutional preferences; nevertheless, however unappealing to pilots, no evidence suggests that remote and autonomous airpower will fit only ISR contingencies—a spread to other mission areas is overwhelmingly more probable.

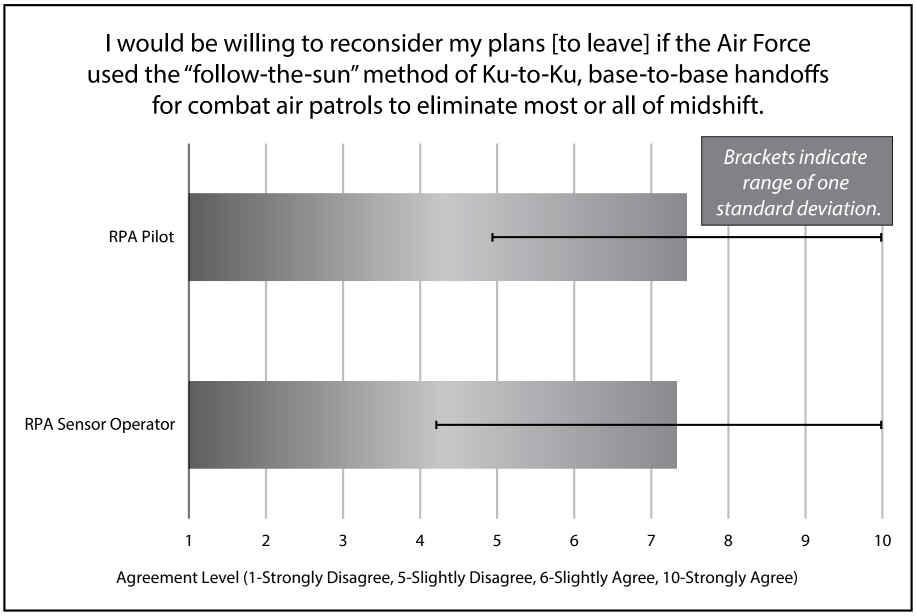


Figure 9. The impact of DST on members committed to leaving

Onward

Institutional resistance makes clear that the technology and concepts demand a safe harbor for development even if their cross-mission proliferation is inevitable. More broadly, ISR requires a home within the Air Force that allows it to perfect the globalized operations-intelligence fusion perspective that underpins the nation's present security. A home, expressed as a major command, would provide an environment less encumbered by cultural opposition and serve as the center for coherently leading, organizing, training, and equipping global ISR forces. Liaisons attached to the headquarters would sync it with science and engineering communities, academe, and industry, keeping the Air Force current in the most aggressive period of technical growth in the history of the aerospace industry. The force presentation to combatant commands would consist of two numbered air forces: the existing Twenty-Fifth Air Force, containing core intelligence capabilities and specialized reconnaissance platforms, and a reactivated Seventeenth Air Force, predominantly providing theater-level armed reconnaissance (fig. 10).

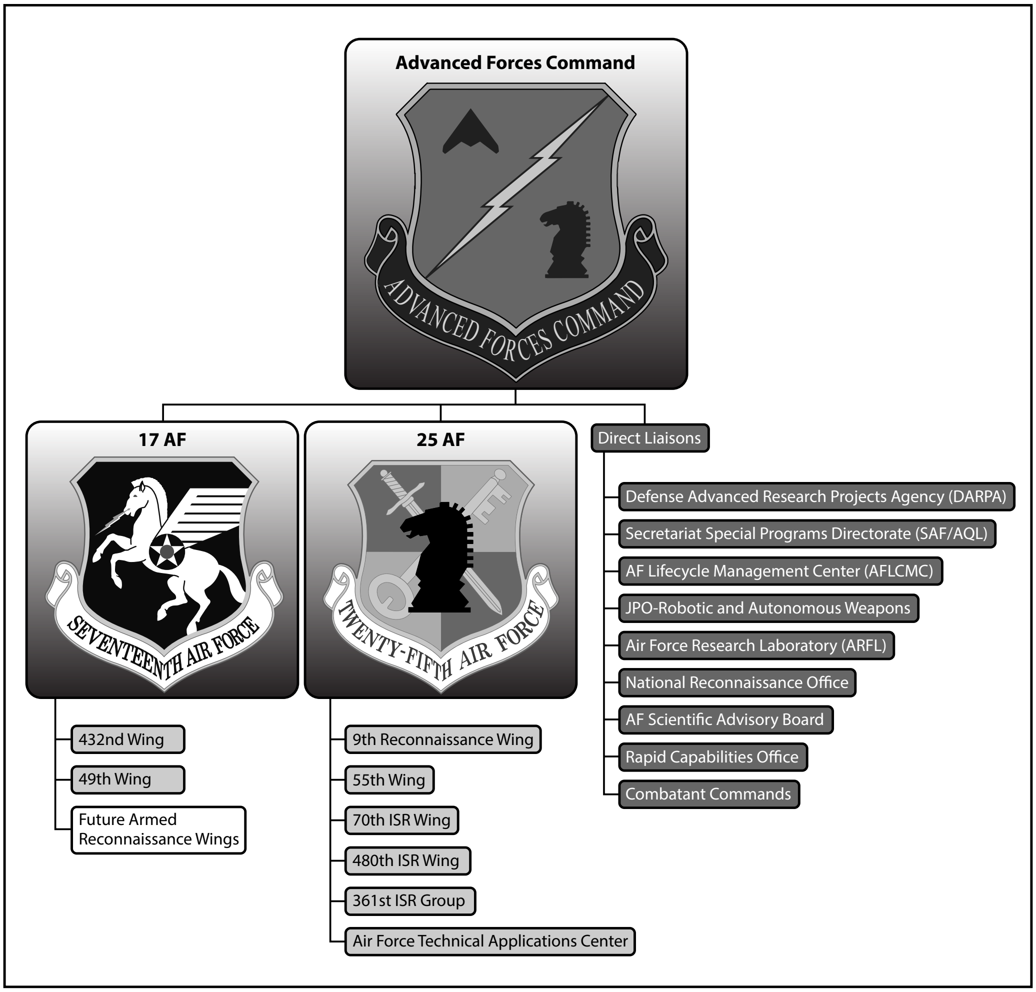


Figure 10. Sketch of a notional "armed ISR" command's initial organizational structure

Even before such reorganization occurs, three categories of recommended policy adjustments would affect the health and viability of the effort to modernize airpower.

Create Equity for the RPA Community

- *Require any rated officer who accepts command of an RPA unit to convert permanently to RPAs.*
- *Establish additional RPA wings: readjust the ratio of squadrons to wings and the number of pilots per squadron* to be commensurate with other flying enterprises (three squadrons per wing and four combat air patrols allocated to each squadron in steady-state operations) in order to level the competitive playing field.[65]
- *Count launch-and-recovery-element flying time* conducted in deployed locations qualified for hostile fire or imminent danger pay *as combat time* rather than combat support.

Improve Retention of Experienced Crews

- *Authorize and fund unit associations and optionally reciprocal personnel exchanges with Guard/Reserve RPA units* to facilitate long-term tactical continuity and expanded basing options. Ensure that these assignments are credited as normal operational flying tours for active duty Airmen without prejudice against their continued career progression.
- *Authorize and fund DST* to stand-up units under the new RPA wings in alternate time zones.
- *Authorize and fund the use of remote split operations to expand RPA FTU operations into geographically separated locations*. This construct is bidirectional: it provides flexibility to place personnel in locations other than bases hosting training ranges, and it facilitates options for the FTU to shift operations from one range to another when weather or airspace availability becomes poor in one location.
- *Count all Guard and Reserve service spent flying or supporting RPA combat lines as "excluded time"* under the Uniformed Services Employment and Reemployment Rights Act.

Provide for the Future of Airpower

- *Petition the Office of the Secretary of Defense to establish a Joint Program Office for Robotic and Autonomous Weaponry* for collaboration on joint requirements, technical standards for interoperability of autonomous vehicles and their control systems, and tactical performance standards. The office should also provide the department's legal and ethical leadership on the use of autonomous weapons and give the secretary of defense a single touch point for all matters relating to the future of robotic and autonomous weapons.

- *Establish an Air Force core function* to account for the pressing need to develop sufficient technological, tactical, and doctrinal sophistication in robotics and computing *to advance the designs of remote and autonomous airpower* for the nation.
- *Authorize competitively selected RPA-rated exchange tours for nonrated officers*. Officers in all career fields will gain more perspective to enlighten decision making in their home communities, and the opportunities to apply airpower will no longer be the sole purview of permanently rated members, leading to a truly universal understanding of what it means to be an Airman.

To do less than right the course of this enterprise leaves the Air Force vulnerable to accusations of stubbornness and strategic myopia and evokes memories of the "incompetence, criminal negligence, and almost treasonable administration" that Gen William "Billy" Mitchell decried almost a century ago.[66] The price of advancement, in this case, is that a previously dominant viewpoint makes room for a new perspective. Thankfully, hope exists that such can happen, evidenced by leaders at many levels setting positive, forward-thinking examples. After having his innovations disregarded, Magnuson taught at the FTU and attended weapons school, influencing thinking at the tactical hub of the Air Force. Christensen stood his ground in a room full of angry officers to prove what his platform could do. Lt Col Scott Frederick, commander of the 311th Fighter Squadron, tells his students about the powerful combination of using RPAs in conjunction with F-16s. After leading the RPA FTU, Col Mark Hoehn was approached about joining the F-35 program, replying, "Thank you, but I'm an RPA guy."[67] Col James Thompson chose Reaper over Raptor to broaden his airpower experience. Col Robert Kiebler stood up during a CSAF-led commander's conference to challenge misperceptions of the RPA. Col Houston Cantwell voluntarily gave up a fighter wing vice-commander assignment to lead an RPA operations group. While earning his MQ-9 qualification, Col Case Cunningham remarked how incredibly lucky he felt to be selected to serve as the next 432nd Wing commander. Though not ready to agree with the secretary of the Navy on the end of human-inhabited fighters, Gen Mark Welsh still stated that he believes in an incredible future for remote and autonomous approaches.[68]

Many of these officers flew fighters, but none of them limited themselves *only* to that experience. They know what Mitchell was trying to tell us when he and his cohort brought airpower into existence: that the *perspective from the air* was the most important lesson of the endeavor. Airpower is about problem solving in multiple dimensions—something that the experience of being an Airman makes intuitive, regardless of the application domain. *That* is what made every maneuver, every intercept, and every attack run satisfying. RPAs require Airmen to think critically in all three of the Air Force's mission domains—not give up airmanship—and they serve as the gateway to a new form of airpower. The RPA community and its shared perspective are threatened by an impending exodus of members who can no longer endure overwork in a force structure seemingly rigged against them, creating a bleak outlook on airpower's next horizon. Several injustices necessitate remediation, yet the correction must be accompanied by forgiveness for injuries, real or perceived. Otherwise, the cycle in which one perspective rises under oppression only to oppress others will continue. The call of airpower and the profession of arms demand more. The substance of airpower, in all its forms, is too consequential to trivialize with any less.✪

Notes

1. Capt Michael W. Byrnes, "Nightfall: Machine Autonomy in Air-to-Air Combat," *Air and Space Power Journal* 28, no. 3 (May–June 2014): 48–75, http://www.airpower.maxwell.af.mil/digital/pdf/articles/2014-May-Jun/F-Byrnes.pdf.

2. US Customs and Border Protection utilizes Predator B and the Guardian maritime variant. See "Why Does OAM Need UAVs/UAS?," US Customs and Border Patrol, accessed 2 July 2015, http://www.cbp.gov/faqs/why-does-oam-need-uavsuas. There is extensive public discussion on the basis of information collected by investigative journalists on alleged clandestine operations by the Central Intelligence Agency. For a well-formulated overview, see Peter L. Bergen and Jennifer Rowland, "Decade of the Drone: Analyzing CIA Drone Attacks, Casualties, and Policy," in *Drone Wars: Transforming Conflict, Law, and Policy*, ed. Peter L. Bergen and Daniel Rothenberg (New York: Cambridge University Press, 2015), 12–41.

3. Colin S. Gray, *Airpower for Strategic Effect* (Maxwell AFB, AL: Air University Press, February 2012), 33, http://aupress.maxwell.af.mil/digital/pdf/book/b_0122_gray_airpower_strategic_effect.pdf.

4. Regardless of who struck which targets where and under what political arrangements, the net effect has been to nearly cripple al-Qaeda and its affiliates before they reach traditional battlefields and to directly combat their terror campaign. For example, attempted "underwear bomber" Umar Farouk Abdulmutallab and Fort Hood shooter Nidal Hasan, among others, were associates (if not disciples) of Anwar al-Awlaki, but he was unable to train or inspire additional followers because he had been killed by US Predator aircraft. See Nicholas Johnston and Martin Z. Braun, "Suspected Terrorist Tried to Blow Up Plane, U.S. Says (Update 1)," Bloomberg, 26 December 2009, http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aMPCgJ4YFUoM; "Expert Discusses Ties between Hasan, Radical Imam," National Public Radio, 10 November 2009, http://www.npr.org/templates/story/story.php?storyId=120287913; and Jennifer Griffin and Justin Fishel, "Two U.S.-Born Terrorists Killed in CIA-Led Drone Strike," *Fox News*, 30 September 2011, http://www.foxnews.com/politics/2011/09/30/us-born-terror-boss-anwar-al-awlaki-killed/. The US District Court, District of Columbia (Washington), dismissed the case involving Al-Awlaki, countering notions that the strike was illegal or that the federal government went beyond its mandate in targeting militants like Awlaki with direct action. See "Nasser Al-Aulaqi, Et Al, Plaintiffs, vs. Leon C. Panetta, Et Al, Defendants," *Transcript of Motion Hearing before the Honorable Rosemary M. Collyer, United States District Judge*, Docket no. CA 12-1192, Washington, DC, 19 July 2013, https://www.ccrjustice.org/files/Transcript%20of%20July%2019,%202013,%20Oral%20Argument%20on%20Defendants%E2%80%99%20Motion%20to%20Dismiss.pdf.

5. Islamic State press secretary Abu Mosa said in a 2014 media interview, "Don't be cowards and attack us with drones. . . . Instead, send your soldiers, the ones we humiliated in Iraq. We will humiliate them everywhere, God willing, and we will raise the flag of Allah in the White House." Instead, Mosa was shot and killed while attempting to attack a Syrian airfield. Noah Rothman, "That ISIS Guy Who Promised to Raise Islamic State Flag over the White House? He's Dead," Hot Air, 21 August 2014, http://hotair.com/archives/2014/08/21/that-isis-guy-who-promised-to-raise-islamic-flag-over-the-white-house-hes-dead/.

6. "Air Force Taking Steps to Fill Drone Pilot Shortage," *Fox News*, 15 January 2015, http://www.foxnews.com/politics/2015/01/15/air-force-taking-steps-to-fill-drone-pilot-shortage/.

7. "RPA Career Satisfaction Survey," designed by the author and conducted between 2 February 2015 and 30 March 2015, eliciting 114 total responses between RPA pilots and RPA sensor operators. Generalizability of the results varies because the significant subdemographics are not uniform in this heterogeneous career field. For example, pilots might be direct-to-RPA (18X), traditional pilots directly from Undergraduate Pilot Training, or converted from fighter, mobility, or other rated utilization fields. Not all subsets of the population have a sufficient number of responses to generalize results. Fighter (11F) conversions, in particular, received relatively few responses. With respect to direct interviews, in some instances, interviewee names are replaced by numbers and broad demographic details for security reasons or as a condition of providing the interview.

8. Secretary of Defense Robert M. Gates, "Remarks to the Heritage Foundation (as delivered)" (address, Heritage Foundation, Colorado Springs, CO, 13 May 2008), http://www.defense.gov/speeches/speech.aspx?speechid=1240. Some people allege that Gates fired the secretary of the Air Force and chief of staff of the Air Force (CSAF) over concerns of aloofness from present joint challenges and that nuclear surety incidents were "final straw" justifications. For an example of that viewpoint, see Caspar Weinberger Jr., "Gates and the Air Force," Human Events, 24 June 2008, http://humanevents.com/2008/06/24/gates-and-the-air-force/.

9. "[US ICBMs:] Early Developments," Federation of American Scientists, 29 May 1997, http://fas.org/nuke/guide/usa/icbm/early.htm.

10. Lt Gen Robert Otto often makes this point publicly: "In 2006 the Air Force supported 11 RPA Combat Air Patrols (CAPs) and they were able to meet 54% of CENTCOM's [US Central Command's] Full Motion Video (FMV) requirements. In 2014, the Air Force supported 65 CAPS and they were only able to meet 21% of FMV requirements; a net decrease of 33% of requirements met despite a 600% increase in fielded capability." Lt Gen Robert Otto, Air Force deputy chief of staff for ISR, "Envisioning the Future of Battlespace Awareness" (address, AFEI Battlespace Awareness Symposium, Booz Allen Hamilton Campus, McLean, VA, 10 April 2015). See also SSgt Christopher Gross, "Priorities of AF Acquisition Outlined at Symposium," Air Force News Service, 18 February 2015, http://www.af.mil/News/ArticleDisplay/tabid/223/Article/566418/priorities-of-af-acquisition-outlined-at-symposium.aspx.

11. Jeffrey J. Smith, *Tomorrow's Air Force: Tracing the Past, Shaping the Future* (Bloomington: Indiana University Press, 2014), 201.

12. Carl H. Builder, *The Icarus Syndrome: The Role of Airpower Theory in the Evolution and Fate of the U.S. Air Force* (New Brunswick, NJ: Transaction Publishers, 1994), 179–88.

13. Grant T. Hammond, *The Mind of War: John Boyd and American Security* (Washington, DC: Smithsonian Institution Press, 2001), 4–5.

14. In mathematics: Duane Q. Nykamp, "Vectors in Arbitrary Dimensions," Math Insight, accessed 7 April 2015, http://mathinsight.org/vectors_arbitrary_dimensions. In computer science: "The N-Dimensional Array (ndarray)," SciPy.org, accessed 7 April 2015, http://docs.scipy.org/doc/numpy/reference/arrays.ndarray.html. In analytic data warehousing: Ralph Kimball and Margy Ross, *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*, 2nd ed. (New York: John Wiley and Sons, 2002), 16–27.

15. There may be several methods for describing the elements of OODA using arbitrary dimensions. For example, it would be helpful to track the percent error between a machine's predictions (or a person's expectations) of a situation and the way that situation actually manifests as a means to assess how well the actor in the system performed the "orient" step of OODA. Some of these measures, such as this "percent error" example, would be lagging indicators although a machine pilot would have a greater chance of processing the learning while flying, whereas a human pilot might have to conduct a debriefing session on the ground to realize where errors occurred and how to formulate methods to prevent them in the future.

16. For an example of machine learning applied to searching high dimensional spaces, see Zhen Li et al., "Learning to Search Efficiently in High Dimensions" (paper presented at the Neural Information Processing Systems 2011 Conference, Granada, Spain, 12–17 December 2011), http://research.google.com/pubs/pub37686.html.

17. Deputy Secretary of Defense Bob Work, "The Third U.S. Offset Strategy and Its Implications for Partners and Allies" (address, Willard Hotel, Washington, DC, 28 January 2015), http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1909.

18. "Northrop Grumman Delivers 1,000th Distributed Aperture System for the F-35," Lockheed Martin, 18 February 2015, https://www.f35.com/news/detail/northrop-grumman-delivers-1000th-distributed-aperture-system-for-the-f-35.

19. Smith, *Tomorrow's Air Force*, 190.

20. Ibid., 167–77. Smith used the term *UAV* (unmanned aerial vehicle) in place of *RPA* but with the same substantive meaning.

21. Builder, *Icarus Syndrome*, 29–37.

22. Smith, *Tomorrow's Air Force*, 169–75.

23. Tyrone L. Groh, "War on the Cheap? Assessing the Costs and Benefits of Proxy War" (PhD diss., Georgetown University, Washington, DC, 2010), 254, https://repository.library.georgetown.edu/bitstream/handle/10822/553084/grohTyrone.pdf?sequence=1.

24. Maj Houston Cantwell, "Beyond Butterflies: Predator and the Evolution of Unmanned Aerial Vehicles in Air Force Culture" (thesis, School of Advanced Air and Space Studies, Maxwell AFB, AL, 2007), 94–95.

25. Survey text-based comment field.

26. Cantwell, "Beyond Butterflies," 104. For an example of discontent with the "Transformational Aircrew Initiative for the 21st Century," which forcibly moved pilots out of fighter and bomber jobs, see Tyler Rogoway, "F-16 Pilots Lament Their Predator Drone Flying Fate in this Rap Video," Foxtrot Alpha, 11 April 2015, http://foxtrotalpha.jalopnik.com/f-16-pilots-lament-their-predator-drone-flying-fate-in-1697200871 (video URL: "One G—Predator Drivers [Once Upon a Time Fighter Pilots]," YouTube, video, 4:34, 1 April 2009, https://youtu.be/K5YD3BZO7Ys). Additionally, the film *Good Kill* (2015) essentially argues that pilots who moved from their previous jobs found killing from a remote platform cowardly and that such a viewpoint was central to their objection to the reassignments. The argument, however, is a red-herring tactic. The cohort members knew that an ethically complex concept in warfare would draw public speculation and imagination, when the most sincere complaint that actually presented was simply that they were frustrated about being taken away from a lifestyle and job they preferred (flying) for sake of an emergent mission need (remote airpower). After viewing the film, one instructor at the RPA FTU described it as "awful, . . . unrealistic, and nothing but the guy whining about not being in his Viper anymore." RPA instructor/field grade officer, informal conversation with the author, 7 April 2015.

27. Cantwell, "Beyond Butterflies," 95.

28. Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1991), 105.

29. CSAF roundtable notes. This sentiment is also reflected in an online publication. Lt Col Tony Carr, retired, "Hold the Line: Welsh Tells Creech No Help on the Way," John Q. Public, 27 March 2015, http://www.jqpublicblog.com/hold-the-line-welsh-tells-creech-no-help-on-the-way/.

30. Survey questions scaled 1–10. Chance of nonfighter-background RPA pilot becoming an operations group commander: 96 responses, mean 4.46, standard deviation 2.86. Chance of becoming a wing commander: 97 responses, mean 4.29, standard deviation 2.90. Chance of becoming commander of Air Combat Command (ACC): 98 responses, mean 2.51, standard deviation 2.35. Chance of 18X becoming commander of Air Force Special Operations Command: 99 responses, mean 2.46, standard deviation 2.10. Chance of nonfighter-background RPA pilot becoming CSAF: 99 responses, mean 2.78, standard deviation 2.58. Chance of 18X becoming CSAF: 98 responses, mean 2.27, standard deviation 2.27.

31. CSAF roundtable notes.

32. "3.3.6.1. Combat. *Aerial activity*, engagements, or attacks *conducted by aircraft* against an enemy of the US or an opposing foreign force *when there is risk of exposure to hostile fire*. Aerial activity in support of forces engaged in combat when there is risk of exposure to hostile fire. Combat includes both elements: activity against an enemy or opposing force (or activity supporting forces engaging an enemy or opposing force) *and* [emphasis in original] risk of exposure to hostile fire" (emphasis added). Air Force Instruction (AFI) 11-401, *Aviation Management*, 10 December 2010, 64–65. In the example provided in the article, RPA crews leaving their hardened shelters to operate an armed Predator or Reaper are certainly exposed to the risk of incoming enemy fires—arguably much more so than a B-1 or F-16 operating far above the battlefield. Yet, the crew of a traditional platform logs "combat" time, and the RPA crew logs only "combat support" despite bearing greater personal risk of injury of death.

33. RPA pilot # 1, Air National Guard, interview by the author, 18 February 2015. This officer described having to leave the Guard to resume his airline job since the protections of the Uniformed Services Employment and Reemployment Rights Act (USERRA) would cover deployed work as "excluded time" but had no concept of the member being deployed-in-place. Additionally, Airmen in that unit described how the 24/7 operations cycle was problematic for traditional reservists. USERRA says the employer must hold the member's job, not that it must pay him or her. Thus, when a commander needs a traditional reservist to come in for a night shift of flying, crew-rest requirements stipulated in AFI 11-202V3, *General Flight Rules*, 7 November 2014 (chap. 2, "Flight Readiness"), mean that the member may lose two days of regular day-shift work from his or her civilian employer. Reservists would most significantly benefit from the Ku-to-Ku "follow the sun" methodology to eliminate shift work for this reason.

34. House, *National Defense Authorization Act for Fiscal Year 2013*, 112th Cong., 2nd sess., 2013, HR 4310, sec. 527, http://www.gpo.gov/fdsys/pkg/BILLS-112hr4310enr/pdf/BILLS-112hr4310enr.pdf.

35. Company grade officer count referenced from the author's own performance report from May 2013; total officer count on Holloman courtesy of the 49th Wing staff.

36. United States Government Accountability Office, *Air Force: Actions Needed to Strengthen Management of Unmanned Aerial Systems Pilots* (Washington, DC: United States Government Accountability Office, April 2014), 28–34, http://www.gao.gov/products/GAO-14-316.

37. Results of the author's direct analysis of calendar year 2014 Line of the Air Force Majors Board on a line-by-line, name-by-name basis of 350 officers selected for school. The author then compared selections to Air Force Personnel Center (AFPC) demographics snapshots for captains in the 2005 year group (the group being considered for promotion) between duty positions of 18XX (RPA assignments) and 11FX (fighter assignments) to render an approximate solution: 9/107 = 8.41 percent, minus the F-15 pilot mentioned, 8/107 = 7.48 percent; meanwhile for fighters, 47/195 = 24.1 percent. AFPC itself will not provide this kind of data directly and even has written guidance with a matrix of options to determine exactly how to obfuscate data from the public and from service members. The author and Maj Lewis Christensen worked with Holloman AFB's military personnel section to seek further data sets to validate the initial correlation. On-base personnel were willing to help, but a Headquarters ACC office labeled "A1RI" actively intervened to stop data collection and prevent investigation, stating that only Headquarters Air Force–sponsored research could be conducted. At the time of submission to *Air and Space Power Journal*, a request on the author's behalf from the office of the 49th Wing commander had not produced the requested data sets. After initial submission, however, the research team did at least identify the percentage breakdown of RPA community demographics as of February 2015: 27.5 percent were 11U; 23.92 percent, 18A; 21.82 percent, 11M; 10.30 percent, 18S; 3.65 percent, 11F; 2.77 percent, 11B; 2.77 percent, 12U; 2.44 percent, 11R; 2.10 percent, 11S; 1.22 percent, 11H; and trace amounts reported of 17D, 18R, 12F, 12R, 13S, 62E, 12H, and 11K.

38. RPA pilot # 6 (field grade officer, instructor pilot), interview by the author, 12 July 2015. This officer reported that the group commander recently forbade reporting "strike observation" duties in performance reports. Much of the RPA's workload is reconnaissance, and its participation with the joint team gives fielded commanders the flexibility to use RPAs and human-inhabited aircraft in concert with surface fires and maneuver tactics. Many strikes, including those that target high-profile members of terrorist networks, are possible only with thousands of hours of reconnaissance work by RPAs. The RPA crews often perform all the steps in the kill chain except the final delivery of weapons—if the ground force commander selects another asset for that task. The arrangement is tactically optimal, but accurately representing the RPA crew's significant contribution to the outcome on individual performance reports requires use of the term *strike observation*. The reasons for this particular group commander prohibiting documentation of these events were not clearly communicated to the pilots whose draft reports were sent back to them for editing with the instruction to remove the affected lines.

39. RPA pilot # 2 (field grade officer, instructor/evaluator pilot), interview by the author, 7 April 2015; and direct inspection of records furnished by the member.

40. Ibid.

41. The results of the 2011 majors board drove substantial discussion throughout the community. The author, for example, even got a phone call while deployed to a forward location from his flight commander at Creech. The call was to "set expectations" and prepare RPA pilots for the reality that they could expect Holloman orders unless they found some other job, such as a special duty or controlled tour, and that upon arrival at Holloman, they should expect discrimination based on career-field alignment with the RPA rather than the F-22. The flight commander's only bit of good news was to say that the F-22s' eventual scheduled departure would open up opportunities for continued service.

42. By these estimates, the CSAF's plans to reduce combat flying temporarily and order pilots to Holloman may result in nearly 50 percent attrition among the personnel selected to move. The consequence would be not getting the increase in production desired and further damaging manpower levels in combat squadrons. The community has repeatedly asked to use its remote split operations (RSO) capability to execute FTU operations from other bases and to execute only launch and recovery of MQ-1 and MQ-9 aircraft from Holloman. The result would be a small footprint in southern New Mexico for launch and recovery, with all other instructors based elsewhere, perhaps starting at Kirtland AFB in Albuquerque (four hours north of Holloman). This idea, no matter how repeatedly voiced, was dis-

regarded when higher headquarters, including the secretary of the Air Force, asked for innovations to improve the RPA enterprise. However, the 49th Wing commander staffed an RSO FTU concept briefing in May 2015 to Twelfth Air Force.

43. RPA pilots # 3 and # 4, phone interviews with the author from Creech AFB and Cannon AFB, 7 and 18 March 2015. A set of redacted records showing the specific manipulation was transmitted to the Air Force Research Institute, Maxwell AFB, AL, and is available upon request. On 29 May 2015, while this article was circulating for peer review and was shared with several flag officers, the officers interviewed reported that their service commitment dates had returned to nominal values but with no more explanation than when they were initially tampered with mysteriously. It is unclear who took action on the matter or how since no one in the chain of command or from AFPC could comment.

44. Capt Erin Dorrance, "Holloman Loses F-22s to Fleet Consolidation, Picks Up F-16 Schoolhouse," Holloman AFB, 27 August 2013, http://www.holloman.af.mil/news/story.asp?id=123361243.

45. Survey question scaled 1–10: 97 responses, mean 7.49, standard deviation 2.75.

46. RPA pilot # 3 (company grade officer, instructor/evaluator pilot), interview by the author, 11 January 2015.

47. RPA squadron commander, interview by the author, 24 November 2014.

48. Maj Keegan McLeese, aide-de-camp to the ACC commander, interview by the author, 28 May 2015.

49. Smith, *Tomorrow's Air Force*, 14.

50. Maj Lewis Christensen, interview by the author, 26 March 2015.

51. Smith, *Tomorrow's Air Force*, 159.

52. Survey questions scaled 1–10. Air vehicle: 103 responses, mean 6.37, standard deviation 2.11. GCS: 103 responses, mean 4.38, standard deviation 2.22. Prefer another contractor: 102 responses, mean 7.54, standard deviation 2.27. Statistics on the MQ-9 responses are slightly inflated as a result of those of one officer, who had elected to separate from the Air Force and accept employment at General Atomics; this individual completed a survey and provided favorable scores and remarks about the product that were well outside the norms for the community. General Atomics has in fact built at least two styles of advanced GCSs, but the Air Force will not purchase them. Informal comments from ACC officials and from then-commander Gen Gilmary M. Hostage III in a June 2014 visit to Holloman fit the theme of concern for being "overinvested in permissive [ISR] assets." See General Hostage, ACC commander, "Q&A Session" (address, Holloman AFB, NM, June 2014); and Lt Gen Robert Otto, deputy chief of staff for intelligence, "AF ISR" (speech, Mitchell Institute for Aerospace Studies, 9 June 2014). Audio available at "Mitchell Institute Presentations," accessed 8 July 2015, http://www.afa.org/mitchellinstitute1/Presentations/.

53. Maj Joe Rice made notes on the CSAF's "roundtable" (small-venue format) discussion, cross-validated with other scribes for accuracy, and sent them to his unit's leadership, team members, and other officers unable to attend the event.

54. That pattern is laid out in Gray, *Airpower for Strategic Effect*, 16–17.

55. Capt Curt Wilson, "Leading Next Generation RPA CONOPs Development" (unpublished white paper, 30 June 2014).

56. Capt Brandon Magnuson, interview by the author, 27 March 2015.

57. Capt Curt Wilson, interview by the author, 24 March 2015.

58. Ibid. The argument against advancing software in the midst of a *completely* computerized flight environment is particularly nonsensical.

59. Erran Carmel and Paul Tjia, *Offshoring Information Technology: Sourcing and Outsourcing to a Global Workforce* (Cambridge, UK: Cambridge University Press, 2005), 11–12. Carmel and Tjia highlight that the principal challenge of "follow-the-sun" or "around-the-clock" models in business is that the coordination and handoff of work must be flawless. The standardized nature of military aviation (following published checklists) means that RPA work distributed around various time zones on Earth has an excellent chance of succeeding.

60. The principal costs are additional GCSs and communications infrastructure as well as maintenance personnel who service both.

61. Senate, Committee on Armed Services, *Current State of Readiness of U.S. Forces in Review of the Defense Authorization Request for Fiscal Year 2016 and the Future Years Defense Program*, 114th Cong., 1st sess., 25 March 2015, 42 (line 22), http://www.armed-services.senate.gov/imo/media/doc/15-34%20-%203-25-15.pdf.

62. Survey question scaled 1–10, filtered for 59 respondents who indicated they planned to leave active duty after their commitments were up. Pilots averaged 7.46 with a standard deviation of 2.52, and sensor operators averaged 7.33 with a standard deviation of 3.16.

63. CSAF roundtable notes, referencing the growth of ISR and corresponding resource impact on other missions. Headquarters Air Force (HAF/A1), "Officer Manning by MAJCOM and Base and Grade," report (Washington, DC: HAF/A1, 31 May 2015), sorted for duty AFSC prefixes of 11F and 18A. Wing counts: Lt Col Lawrence Spinetta, PhD, "The Glass Ceiling for Remotely Piloted Aircraft," *Air and Space Power Journal* 27, no. 4 (July–August 2013): 107, http://www.airpower.au.af.mil/digital/pdf/issues/2013/ASPJ-Jul-Aug-2013.pdf. The 432nd Wing at Creech is the Air Force's only dedicated RPA wing, and the 27th Special Operations Wing has one-third of its squadrons dedicated to RPA operations. The 49th Wing is only momentarily majority RPA since some leaders have an interest in trying to realign the newly arrived F-16 mission under ACC. The wing commander's purpose is to reduce duplicate staff and find greater efficiencies (for example, there are two operations support squadrons since F-16s arrived) as well as to be able to tap into all available talent on the base to build the wing staff. That latter piece of the reasoning seemed to indicate to most officers interviewed that RPAs would not be able to maintain control of the host wing at Holloman since they believe the commander and vice-commander are intent on reinstalling fighter pilots in key positions.

64. RPA pilot # 5 (former ACC staff officer), interview by the author, 30 January 2015.

65. Spinetta, "Glass Ceiling," 107.

66. "Mitchell Flays U.S. Army, Navy: Blames Air Disasters on Sheer Ignorance," *San Antonio Light*, 5 September 1925, Home Edition, 1.

67. Col Mark Hoehn, interview by the author, 6 March 2015.

68. Sam LaGrone, "Mabus: F-35 Will Be 'Last Manned Strike Fighter' the Navy, Marines 'Will Ever Buy or Fly,' " US Naval Institute News, 15 April 2015, http://news.usni.org/2015/04/15/mabus-f-35c-will-be-last-manned-strike-fighter-the-navy-marines-will-ever-buy-or-fly; Brian Everstine, "Manned Aircraft Needed for Future Air Force, As Navy Moves Unmanned," *Air Force Times*, 22 April 2015, http://www.airforcetimes.com/story/military/2015/04/22/welsh-future-aircraft-pilots-needed/26178677/; and CSAF roundtable notes.

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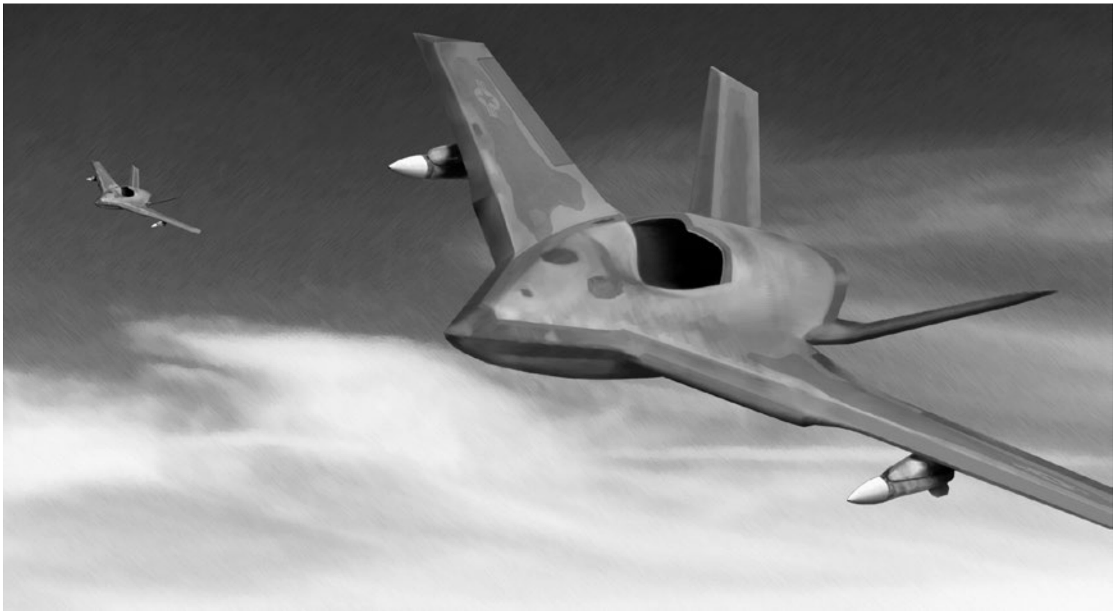
Nightfall and the Cloud

Examining the Future of Unmanned Combat Aerial Vehicles and Remotely Piloted Aircraft

Maj Michael P. Kreuzer, USAF[*]

> *It is very easy for ignorant people to think that success in war may be gained by the use of some wonderful invention rather than by hard fighting and superior leadership.*
>
> —Gen George S. Patton Jr.



In early 2008, the United States began a dramatic increase in the use of remotely piloted aircraft (RPA) as part of the global war on terrorism. Since that time, there has been no shortage of scholarly articles on and public discussion of the legal implications of RPAs, the hazards of their employment in military campaigns, or the prospects for the diffusion of RPA technology. The debate over these aircraft

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[*] The author would like to thank the following individuals for their feedback, insights, and professional critiques: Trevor Albertson, Dave Blair, Wolfgang Danspeckgruber, Doyle Hodges, David "Jake" Timm, and Charles Westenhoff.

and future unmanned combat aerial vehicles (UCAV) is generally one of extremes, much as the one about the value of air warfare more generally for the past century. As early airpower advocates extolled the potential of the air weapon to bring about a decisive end to conflict through the threat of aerial bombardment, critics decried the human suffering that would inevitably result and sought to ban the practice outright.[1] Experiences of the twentieth century would demonstrate how airpower advocates overestimated the likelihood of success of strategic bombing given the technologies available at the time, with doctrines and technology catching up to the theory in the 1990s at the earliest.[2]

The RPA debate has undergone a similar transition from hype, to recognition of shortcomings, to relative acceptance of existing capabilities while looking ahead to the next transformative technology that will almost inevitably be a game changer. The early years of the United States' RPA campaign saw publications touting the potential of these vehicles and other robotics to revolutionize warfare.[3] More current critiques appear to have accepted RPAs in their present form but warn against what they see as the next step of autonomous attack. The prospect of US intervention in Syria in 2012 highlighted the shortcomings of the latest generation of RPAs in a contested air environment.[4] Furthermore, the ongoing debate among the United States and allies at both the diplomatic and domestic politics levels has likely constrained the expansion of RPA programs against al-Qaeda affiliates. One critic of "robotic warfare" put this larger trend most succinctly: "This debate goes well beyond drones, as they are yesterday's news."[5]

Although thoughtful discourse on the realistic future applications of RPAs from an operational or tactical perspective has been in short supply, over the past few years, articles in *Air and Space Power Journal* have elevated this aspect of the debate with several treatments of the subject, notably Maj Dave Blair and Capt Nick Helms's "The Swarm, the Cloud, and the Importance of Getting There First" and Capt Michael Byrnes's "Nightfall: Machine Autonomy in Air-to-Air Combat." Each of their perspectives adds numerous insights into the future capabilities of RPAs and, eventually, toward more autonomous UCAVs.[6] Although Byrnes, to an extent, argues that his vision contrasts that of Blair and Helms regarding the role and degree of automation in future Air Force missions, both share a common vision of autonomous aircraft increasingly taking on the air-to-air role in future conflicts against near-peer competitors. The sharpest contrast between the two perspectives is the level of interaction between human pilots and future UCAVs, Byrnes arguing that the technological attainability of automation in the future, together with reaction and performance considerations, will inevitably lead to a takeover of air-to-air combat.

This article argues that the transformation of airpower to a UCAV-centric force is a more difficult proposition than simply a technical hurdle to overcome. Substantial technological barriers to autonomy remain, but overcoming them would still leave economic, political, legal, and organizational challenges to fielding significant numbers of fully autonomous aircraft in wartime situations. Clearly, the Air Force and US policy makers will consider the possibilities of autonomous aircraft and the tactical advantages that may be gained from removing pilots from cockpits. However, they must remain aware of these limitations and begin to shape Air Force organizations, policies, and doctrines around the realities of a mixed force of manned, remotely piloted, and semiautonomous aircraft and prepare for the issues that such a force entails.

Artificial Intelligence: Always Just around the Corner

The basics of air-to-air combat are largely an algorithmic function. Junior pilots are trained extensively on basic fighter maneuvers to emphasize mastery of the textbook procedures.[7] If future air combat closely mirrors the tactics and proficiency levels we assume today, it is conceivable that programmers could develop an automated system to identify the threat environment and execute preprogrammed maneuvers based on the inputs, much as a junior pilot would. This program would be complex, significantly more so than similar decision-matrix programs for autonomous flight-route programs in other RPAs such as Global Hawk. Enabling the kind of autonomous operations envisioned by Byrnes would demand significant leaps forward in the field of artificial intelligence (AI), allowing future UCAVs to become learning entities that can adapt to circumstances and develop new tactics to overcome an adversary.

This issue is the first major challenge to autonomous UCAVs from a theoretical standpoint because the prospects for the level of AI for such a requirement are consistently overestimated. A brief review of the literature of AI suggests that since the 1940s, both experts and amateurs have perpetually viewed the prospect of AI lying a generation away (roughly 16–20 years).[8] Advancements in memory, computing power, and dynamic programming techniques over the years have increased this sense that we are on the verge of a major breakthrough, but with each breakthrough we have also seen to an extent the complexity of true AI. The examples cited by Byrnes, most prominently the 2010 article by James S. McGrew and his coauthors on the application of approximate dynamic programming to air combat, are indeed examples of advancements in computer technology that give the impression of AI but remain the execution of programs and calculations applied to specific scenarios.[9] We may indeed be on the brink of a major breakthrough that will enable near-human AI in the future, but placing a projection for a time window based on the examples cited is questionable, given the history of AI projections.

Although the ability to run programs that calculate more efficient outcomes creates the impression of AI, the aircraft is ultimately tied to a large data set of preprogrammed options and runs a decision-making process. Theoretically, this process could be built to an extreme degree whereby all possible maneuvers and assumptions about terrain, weather, and adversary logic are programmed, allowing the computer to better access likely outcomes and make decisions; however, that is a fundamentally different dynamic than a true learning process. Preprogrammed assumptions and design limitations ultimately frame the sphere in which the computer makes its decisions while a human operator can access information from a variety of additional sources that may or may not be programmed. Moreover, instincts—although fallible in a number of circumstances—can make the difference in attaining victory in close combat.[10] The assurance we have that the tactical environment will mirror our preconflict notions of air tactics will dictate our confidence in relying on technology alone to secure victory.

In a sense, this issue mirrors in the information age the problems presented by "scientism" throughout the industrial age. *Scientism*, a term of more recent origin, describes the movement from the 1700s forward that views the natural sciences as the source of all human knowledge and seeks to apply those lessons to all human endeavors.[11] In the military sphere, this perspective manifested itself through what might be called the Jominian school of strategy, which values rules of war and prescriptive approaches to conflict. As Christopher Bassford notes, Jomini saw the wars in which he participated as "the technical near-perfection of a fundamentally unchanging phenomenon, to be modified only by superficial matters like the list of *dramatis personae*, technology, and transient political motivations."[12] Conversely, Carl von Clausewitz said of the Jominians, "They aim at fixed values; but in war everything is uncertain, and calculations have to be made with variable quantities."[13] Approximate dynamic programming represents to a large degree a reaction to this critique since pure dynamic programming would be impossible, given the complexity of the operating environment. Even so, many of the approximations made in the program must be programmed in advance of conflict. Without a true leap forward in AI, reliance on extending approximate dynamic programming as the backbone of autonomous air-to-air operations would be a significant gamble in many scenarios for the foreseeable future.

Retaining the human element for remote operations in a supervisory role will thus prove necessary from a technological standpoint for the near future. Indeed, one of the long-standing concerns for the RPA community has been the failure to distinguish between remote control and autonomy. Both are at work in modern RPAs, but automation is generally limited to routine flight operations and issues such as maintaining aircraft control in lost-communications situations. Automating the release of weapons is a greater challenge, not only from a technological standpoint but also from a legal and normative one. Some precedents exist for such operations under human supervision that can be extended to offensive air operations over time, but despite these precedents, the prospect of fully autonomous air-to-air warfare remains low due to obstacles beyond technology. Overcoming them is likely to entail costs well beyond those of existing systems.

Cost Considerations for Remotely Piloted Aircraft and Unmanned Combat Aerial Vehicles

A common strain in the RPA/UCAV debate is that each will revolutionize warfare because of its low cost per unit and the ease of employing off-the-shelf technology. This is true to some extent for the near term, but as RPAs and UCAVs grow as weapons of war and as countermeasures proliferate, the costs associated with specialization will increasingly raise those of UCAVs—just as the costs of aircraft have risen with advancing technology.[14] Further, economic expenses alone do not define the outlay associated with new technologies in war. Political costs are also a consideration insofar as more reliance on technological solutions projects lower commitment to conflicts, potentially escalating the level of violence should an adversary believe he can wait out the threat of attack.

US experience with RPAs to date illustrates the problems with the standard narrative that they are cheap. Analysts often compare the Predator or Reaper to the F-22, noting that "for the price of one F-22 . . . you can buy 85 Predators."[15] By doing so, they omit the clear mission and capabilities distinctions between the Predator and the Raptor, ignoring the prospect of procuring manned aircraft tailored to perform similar missions to the Predator's. (For a better comparison, note the MC-12 Liberty program as an approximation of the RQ-1 [unarmed] Predator.) As the military has invested in newer and more capable RPAs, the cost has steadily risen to levels comparable with manned alternatives (table 1).[16] Not included in this table are the Navy's X-47, with a program cost to January 2012 of $813 million; the often-named manned alternatives such as the U-2 for the Global Hawk; or the aforementioned F-22. The U-2/Global Hawk debate is especially illustrative, given that for much of the past decade, the Global Hawk was more expensive than the U-2 (table 2), and many critics of the transition to Global Hawk see a trade-off of capabilities for cost. The Air Force itself has hedged the cost-savings argument for UCAVs versus manned equivalents, noting in the *Unmanned Aircraft Systems Flight Plan, 2009–2047* that the RPA's/UCAV's virtue lies in "increasing effects while *potentially* reducing cost" (emphasis added).[17] Given the nature of recent spending on research and development and the number of systems that advanced UCAVs would have in common with fifth-generation fighters and beyond, cost savings are likely to be in the range of percentages rather than orders of magnitude.

Table 1. Comparative costs of RPAs

	Raven	*Global Hawk*	*Predator*	*Gray Eagle*	*Predator B Reaper*	*Predator C Avenger*
Operational	2004	2000	1994	2009	2001	Flight Test
Cost	$34,000/aircraft $300,000/system	$46.4M–$80M/aircraft (multiple variants)	No longer in production	$4.33M/aircraft	$11.38M/aircraft	$35M/aircraft
Role	Low-altitude tactical intelligence, surveillance, and reconnaissance (ISR)	Near-real-time high-resolution ISR, persistent maritime ISR	ISR, targeting, forward air control, laser designation, weapons delivery, battle damage assessment	ISR, targeting acquisition, and attack	Multimission attack RPA	Quick-response armed reconnaissance
Max Altitude	500 ft.	65,000 ft.	25,000 ft.	29,000 ft.	50,000 ft.	50,000 ft.
Max Endurance	90 min.	36 hrs. (24 on station)	40 hrs.	25 hrs.	27 hrs.	18 hrs.

Table 1. Comparative costs of RPAs (*continued*)

	Raven	*Global Hawk*	*Predator*	*Gray Eagle*	*Predator B Reaper*	*Predator C Avenger*
Max Speed	44 knots true airspeed (KTAS)	340 KTAS	120 KTAS	167 KTAS	240 KTAS	400 KTAS
Weapons Payload	N/A	N/A	2 Hellfire missiles	4 Hellfire missiles	14 Hellfire or 4 Hellfire and 2x GBU-12 or 2 Joint Direct Attack Munitions	3,500 lb. internal payload, six external hardpoints

Sources: "RQ-11B Raven System," fact sheet, US Air Force, accessed 11 January 2013, http://www.avinc.com/downloads/USAF_Raven_FactSheet.pdf; Joakim Kasper Oestergaard, "About the RQ-4B & MQ-4C," Aeroweb, 4 November 2014, http://www.bga-aeroweb.com/Defense/RQ-4-Global-Hawk.html; "Predator UAS," General Atomics Aeronautical, accessed 11 January 2012, http://www.ga-asi.com/products/aircraft/predator.php; "Gray Eagle UAS," General Atomics Aeronautical, accessed 13 January 2012, http://www.ga-asi.com/products/aircraft/gray_eagle.php; "Predator B UAS," General Atomics Aeronautical, accessed 11 January 2013, http://www.ga-asi.com/products/aircraft/predator_b.php; "Predator C Avenger UAS," General Atomics Aeronautical, accessed 11 January 2013, http://www.ga-asi.com/products/aircraft/predator_c.php; and Joakim Kasper Oestergaard, "About the RQ-11 Raven," Aeroweb, 23 October 2014, http://www.bga-aeroweb.com/Defense/RQ-11-Raven.html. Regarding Predator C, cost is for aircraft estimate. Most reporting suggests it will cost three times the amount of the Predator B. See "Naval Air: Predator C at Sea," StrategyWorld, 17 August 2009, http://www.strategypage.com/htmw/htnavai/20090817.aspx.

Table 2. Comparative costs of the U-2 and RQ-4

	Procurement Cost	*Flight-Hour Cost*
U-2	Classified/no longer in production	$31,000
Global Hawk (2010)	$46.4–80 million	$40,600
Global Hawk (2013)	$46.4–80 million	$18,900

Sources: Michael Hatamoto, "USAF Hopes U-2 to Global Hawk Transition Done in 2015," DailyTech, 13 August 2011, http://www.dailytech.com/USAF+Hopes+U2+to+Global+Hawk+Transition+Done+in++2015/article22425.htm; and Andrea Shalal-Esa, "Cost of Flying Northrop's Global Hawk Down over 50% Sources," sUAS News, 14 September 2013, http://www.suasnews.com/2013/09/25052/cost-of-flying-northrops-global-hawk-down-over-50-sources/.

Beyond these economic expenses, the political costs will weigh heavily on states employing RPAs and UCAVs. Writing about RPAs in 2000, Tom Ehrhard noted that "the unmanned attack communicates shallow commitment, even fecklessness."[18] For a state, such as the United States, reliant on a series of alliance structures, this dynamic poses challenges to the Air Force beyond accessed tactical performance of technology. It raises issues of alliance assurance and the ability of advanced RPAs to convince allies of US commitment in a manner similar to that of a deployment of a fighter squadron or strategic bomber. Beyond deterrence, their actual use in contested airspace has arguably shown the net results of RPAs as a negative for states deploying them too aggressively. Despite numerous predictions that RPAs could exacerbate conflict by undermining sovereignty and allowing states to violate airspace with impunity (a charge often leveled against the United States for its RPA campaigns), experience to date has largely been the opposite. RPAs regularly have been shot down in potential conflict zones like Israel, Azerbaijan, and Georgia, and most negative attention focuses on those employing these platforms. In the run-up to the 2008 Russia-Georgia conflict, four Georgian RPAs were shot down. If they had been manned aircraft, the international condemnation of Russia probably would have been significantly higher. Since they were RPAs, though, both Russia and Georgia were condemned by the UN investigation—Russia for the illegal shoot down and Georgia for aggravating the crisis by flying the aircraft.[19] In this case, the use of RPAs may have weakened Georgia's military posture in the run-up to the August 2008 conflict both by showing weak resolve and by coming at the economic cost of four advanced RPAs, each valued at approximately $2 million.

The need for the tactical advantages provided by future RPAs and UCAVs must be weighed against the probable remaining technical limitations; must be structured within the existing parameters of the laws of war that emphasize the responsibility of actors to control and ultimately be responsible for the application of force within a war zone; and must be evaluated in terms of the strategic costs that come in both political and economic forms. These considerations will ensure a balance of both manned and remotely piloted platforms for the foreseeable future of air warfare, with the relative proportions of semiautonomous UCAVs, RPAs, and manned platforms shifting throughout phases of the conflict.

For the near future, both technological limitations and cost restrictions appear to place autonomous warfare beyond the limitations of military planners. However, even if financial and technological barriers to such operations declined, given new technological innovations on those fronts, significant obstacles to employing such autonomous weapons in a number of wartime environments on a large scale would still remain. The laws and ethics of such warfare and the challenges of leadership and control in such an environment would pose as great a hindrance to state employment of autonomous weapons as these technological barriers.

Laws of War and Autonomous Operations

As Charles Tilly once said, "War made the state, and the state made war."[20] As commonly understood by Western nations, war is an act of states against other states. It is at its most fundamental the imposition of state will by force and coercion to achieve political ends.[21] Politics governs the use of force in war, limits the scale and scope of combat operations, and makes the state responsible for the conduct of those who act on its behalf. This principle of state control of force is essential to the framework of limiting the horrors of war and has remained constant through centuries of warfare.[22] Technological innovations of the information era do not alleviate state responsibility; instead, they present new challenges about keeping the use of technology under the control of the state and holding it responsible for its armed forces should the state choose to employ autonomous actors.

The just war tradition, codified in *jus ad bellum* and *jus in bello*, serves as the baseline for both formal and customary international law regarding the conduct of war and participants. *Jus ad bellum* represents a set of principles designed to limit the horrors of war by providing justification for military action, defining the scope of conflict, and ideally laying the groundwork for reestablishing peace at the end of hostilities. These criteria have been refined over the years through both philosophy and codification in international law, today described generally as having just cause, being a last resort, being declared by a proper authority, possessing right intention, having a reasonable chance of success, and having the end proportional to the means.[23] *Jus in bello* is generally summarized by two criteria: discrimination and proportionality.[24] Underlying the just war criteria is the notion of responsibility, both of states and actors, for the initiation and conduct of war. RPAs and future UCAVs present a series of issues for both aspects of just war tradition, many of which can be normalized within the existing framework of international law but require greater public discussion and knowledge of RPA operations and potential actions by UCAVs.

The main challenge for RPAs in current campaigns is not one of *jus in bello* as often portrayed with a focus on disproportionality and collateral damage but a problem of *jus ad bellum* with ambiguity surrounding the question of whether operations outside campaigns such as Iraq and Afghanistan meet the just war criteria. If so, should they be evaluated by wartime understandings of discrimination and proportionality (codified under international humanitarian law), or if they are extrajudicial actions outside a war zone, should they thus be evaluated under international human rights law? The position of the US government since September 2001 has been that the campaign against al-Qaeda and its affiliates represents a noninternational conflict (a war of a state against a nonstate actor). However, the ambiguity surrounding the proper authority to expand the conflict to new states and the absence of a public declaration of both the zones of conflict and the objectives of the operation leave these conflicts in a legal gray area. Consequently, proponents and opponents of RPA operations talk past each other on the legal rationale for operations, and the United States finds itself at a disadvantage to exploit the tactical gains of operations for strategic effect by not openly discussing the targets of operations and mounting an effective information campaign.[25] The legal problem here, however, rests in the character of the conflict within international law as opposed to the tool employed. Similar criticism of special operations and manned aircraft exists.[26] The RPA receives the most attention because it represents a new technology and because it can make such interventions more common in uncontested airspace.

UCAVs in a traditional international conflict raise a different set of concerns for international law, primarily stemming from the overarching issue of responsibility. International law has codified responsibility both for individual actors and for the states employing such vehicles to varying degrees over time, with an increased emphasis on holding individuals accountable for their actions. Ultimately, however, the state remains responsible for the conduct of its armed forces, and states have historically held the military responsible through the process of commissioned officers. An officer's commission is given in the name of the head of state to act in his or her name overseeing the armed forces, based on demonstrated loyalty to the state and trust in the integrity and leadership of the commissioned officer. This principle was explicitly codified in the Hague Convention of 1899 and 1907, which declares in Article 1 of Annex 1 that "the laws, rights, and duties of war apply not only to armies, but also to militia and volunteer corps fulfilling the following conditions: To be commanded by a person responsible for his subordinates."[27] A fully autonomous

UCAV, at minimum, must retain this requirement for positive control by the operating state. How to do so is to an extent an open question, but existing examples of automatic/autonomous operations suggest that the answer already exists for some environments.

Human Rights Watch, a group that regularly addresses the issue of robotics and warfare, may have inadvertently opened the door for the legal use of robotic weapons through its differentiating existing automated lethal systems from potential future "killer robots" that would be wholly autonomous. In addressing the move toward automation in 2012, Human Rights Watch examined "automatic weapons defense systems" such as the Phalanx or Israel's Iron Dome as a step in the direction of automation but something that remained fundamentally different, being "automatic" versus "autonomous." Human Rights Watch says these weapons systems deserve further scrutiny because of their existing potential for collateral damage and because of concerns about the actual level of human control over the system. On balance, though, the distinction between automatic systems and autonomous systems appears acceptable.[28] If, however, an "automatic" system such as the Phalanx is acceptable, then a similar airborne network of defensive UCAVs to secure permissive airspace would similarly prove acceptable by the same logic. This concept could be taken to the next stage to permit offensive operations in a pure air-to-air environment given human control, either from ground stations or forward airborne control into denied environments—the essence of the "swarm and cloud."[29] The key issue becomes the level and character of human control of the network of UCAVs and the ability to hold both officers and the state accountable for the use of military force.

Outside these environments, as the challenges of discrimination rise, so does the need for higher levels of human supervision. Current international law and the political realities that frame any conflict are likely to dictate this scenario even if it can be shown that new technologies such as visual identification can better identify and target in wartime than a human counterpart. Both the policy makers responsible for the overall conduct of their forces and the populations supporting the war effort are unlikely to delegate decisions that can result either in a criminal action or the unintended escalation of conflict without the prospect of an individual or individuals responsible for and held accountable for the decision. A machine, without self-awareness, cannot fill that role.

Two major factors are thus at work in determining the overall balance of remotely piloted platforms versus manned platforms. The first is the threat posed to aircraft by adversary fighters and other defensive networks (surface-to-air missiles, electronic and cyber attack, etc.), and the second is the ability to discriminate between military and nonmilitary targets. In a hypothetical conflict against a near-peer competitor, the early phases of conflict will likely be dominated by high-intensity conflict in which discrimination is relatively easy—especially in the air-to-air environment—and the threat is very high. Over time, this balance shifts—more so for air assets than ground assets—since attaining air superiority reduces the threat while the progress of bombing campaigns makes target discrimination increasingly difficult. Within the category of RPAs, a shift will also probably occur from semiautonomous UCAVs toward RPAs as the air threat dissipates and the problems of ground-target discrimination increase. The figure below offers a conceptual model for the relationship of manned to remotely piloted airframes across the major phases of conflict, including two mirroring S curves that represent the change in the air threat environment and the matter of target discrimination. Semiautonomous UCAVs face a higher requirement proportional to the level of the air threat, and persistent RPAs are necessary once the air threat is minimized while ground targets are most elusive. Manned airframes are required in all phases, playing the greatest role in phases two and three, when airspace is contested but semipermissive and the primary air-to-ground effort concentrates on both fixed targets and conventional military forces.[30]

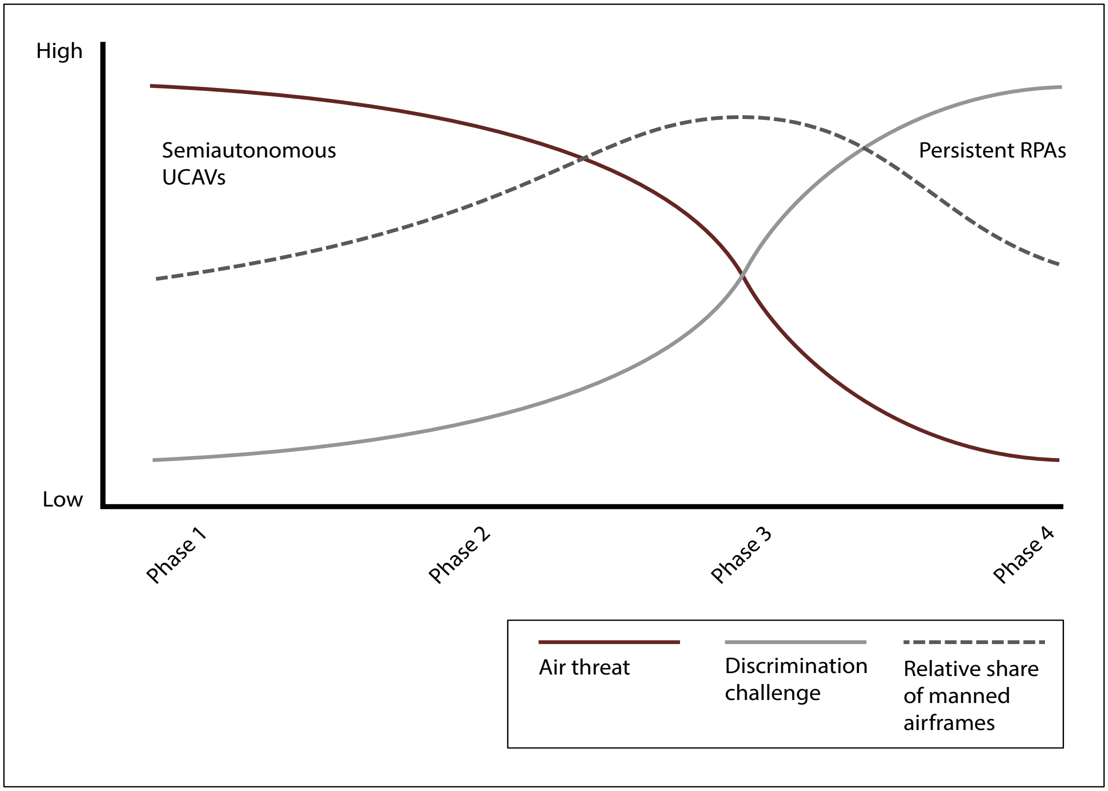

Figure. Estimated share of manned airframes across phases of conflict

Future Challenges for the Air Force

RPAs and UCAVs present significant concerns for the military services that employ them insofar as their use directly confronts the essence of what it means to be a war fighter and the relationship of combat effects to traditional ideals of warfare marked by individual heroism and sacrifice. The US military has had significant issues with this matter recently, both with the questions of promotion rates for RPA pilots and with the debate over the Distinguished Warfare Medal. At issue in this dispute is the role of technology in shifting the relationship of proximity to harm to combat effects and with it the very nature of what it means to be involved in "combat operations." If organizations wish to continue adopting innovations, they must find ways to recognize and promote individuals proficient in these new systems of war, a prospect that represents a greater challenge than quotas or protection of specific career fields. It will demand a fundamental reevaluation of who we are as a service and what it means to be an Airman, compared to the traditional understanding of what it means to be a warrior.

Development of a strong career progression system is vital to the normalization of new technologies and practices within an organization because, as Stephen Rosen notes, innovation occurs "only as fast as the rate at which young officers rise to the top."[31] The issue of promotion ceilings and the integration of new technologies into the armed forces is not a new phenomenon. Billy Mitchell identified promotion ceilings for pilots in 1925 as one of the key justifications of an independent Air Force because such restrictions would be devastating to the development of strategic airpower: "The personnel situation is very serious in all the air services. . . . Their position on the promotion list is hopeless. Some of our lieutenants can never rise above the rank of major or even captain. They see no future before them and consequently are not in the state of mind in which officers in so rapidly developing a service should be."[32] The existing Air Force organizational structure presents a series of challenges to the normalization of RPA culture within the service as increased visibility of a "glass ceiling" for RPA pilots has grown in the past year. Part of this situation proceeds from existing perceptions of RPAs within the Air Force flying community and the process of rapid expansion of the RPA community; another part is rooted in requirements the Air Force places on command position eligibility.[33] The first issue to rise to the attention of both the public and lawmakers (emerging in 2012) was the reported lower promotion rate of RPA pilots compared to that of traditional Air Force pilots.

Closely related to the issue of promotions is recognition. Debate over the Distinguished Warfare Medal is illustrative. The potential recognition of RPA operators with decorations rating above the Bronze Star Medal with "V" resulted in a significant backlash both within and without the Air Force. John Soltz, chairman of VoteVets, a political action committee for veterans, summarized this argument: "I personally don't have an issue with the medal itself. Troops don't set the policy; they just perform their duties. . . . What I do have an issue with is this: The new medal ranks above the Purple Heart. For those who served, that doesn't sit right."[34] Similar arguments were raised by the Veterans of Foreign Wars, the American Legion, and numerous other veterans in editorials.[35] If we accept this framing—that medals represent heroism and that no nonvalor awards should take precedence over valor awards—and if we took the next step that the awards process was independent of the promotion process, this position would be completely valid. However, neither of those conditions is true under the current system.[36] As a result, the failure to recognize those who produce greater operational effects creates a potential disconnect between whom the service promotes and who is a capable, modern war fighter. Heroism and the broader warrior ethos are closely connected to operational effects under a traditional ground operation—and even for tactical airpower—but not necessarily for strategic airpower and war at a distance.

Since 2001 the Air Force has sought to recenter the force around the "warrior ethos" and the tenets of the "Airmen's Creed," both of which emphasize the traditional values of being a "warrior," dating to the Spartan ethos. Steven Pressfield examined the common understanding of the warrior ethos at length in 2011 when he wrote a volume dedicated to members of today's military that discussed the origins of that ethos.[37] To Pressfield, the warrior ethos emerges from a sense of fear on the battlefield, where classic war was fought hand to hand and between roughly equivalent armed forces: "For a Greek or Roman warrior to slay his enemy, he had to get so close that there was an equal chance that the enemy's sword or spear would kill him. This produced an idea of manly virtue. . . . The ancients resisted innovation in warfare because they feared it would rob the struggle of honor. . . . The God who ruled the battlefield was Phobos, fear."[38] Courage and honor represent essential elements of the warrior ethos, which manifests in the Army's ethos as a subset of the drive for victory and the obligation of never leaving a man behind.

The Air Force, from its beginnings, recognized that it was something different. Both Mitchell and Giulio Douhet saw the virtue of the air weapon as its ability to bypass this type of combat and take the fight directly to the adversary with no hope of defense. Douhet, at the most extreme, saw this as completely overturning existing norms of war, eliminating the distinction between militaries and civilians and shattering traditional notions of war and the warrior ethos.[39] Mitchell, while less absolute than Douhet in a number of aspects, echoed a similar theme: "An entirely new method of conducting war at a distance will come into being. . . . As air power can hit at a distance, after it controls the air and vanquishes the opposing air power, it will be able to fly anywhere over the opposing country."[40] This, in turn, Mitchell noted, led to a very different perspective of warfare for airmen versus other combatants: "The air-going people have a spirit, language, and customs of their own. They are just as different from those on the ground as those of seamen are from those of land men."[41] Though bravery and valor remain essential to gaining and maintaining control of the sky, Mitchell and Douhet both saw airpower's main value as the ability to attack at will against an undefended enemy after seizing command of the air. This vision of airpower as unrestricted, combined with the realities at various points in our history of the tactical difficulties of gaining air superiority, has led to some of the greatest organizational problems over time. To varying degrees, bomber and missile forces have embraced Mitchell's vision, which, during the Cold War, often proved detrimental to tactical proficiency and the warrior spirit of tactical engagement. The rise of the fighter-pilot generals beginning in the late 1980s, followed by the challenges of air campaigns in the Balkans and the Middle East, moved the Air Force back in the direction of a more tactical warrior mind-set. Indeed, after 2001 the Air Force was dominated by this perspective that emphasized the traditional values of a warrior over technocratic skills.[42]

The debate over a future of autonomous UCAVs dominating air warfare versus a moral argument against automation represents only the most recent fault line in this ongoing dialogue. Rather than picking winners between rival factions, the organizational goal must be eliminating destructive competition between the factions and refocusing on the larger mission and the tools necessary to carry it out. Doing so will at first involve changing the way we promote and recognize individuals but ultimately must go to the question of what the service really does—deterring and defeating threats to the United States and its interests through the control and exploitation of air, space, and cyberspace. Everything else the service does is a means to this end—not the end itself. Technology will serve as a vital force multiplier, but ultimately war is a contest of people and ideas, with organizations and tactical innovations playing the decisive role in attaining military objectives. Building systems to support innovation and create leaders positioned to capitalize on those innovations must be the greater concern today, rather than the specifics of the tactics employed. The argument must not pit technocrat versus warrior but must leverage the virtues of both to meet the challenges of future conflicts.

Conclusion

From its earliest era, airpower has envisioned a future in which promising new technologies can solve such age-old matters as the fog and friction of war and the swift and decisive domination of a military adversary. To this point, the history of air warfare has shown that, as technologies advanced toward fulfillment of that vision, new obstacles in both technology and the fundamental human nature of conflict remain. The debate over the future of RPAs and UCAVs in warfare represents but the latest in a string of airpower technologies that can significantly increase military capabilities but that will be insufficient by themselves to solving human conflict. Technological barriers to true artificial intelligence, economic and political costs, leadership and organizational obstacles to effectively controlling autonomous operations, and the legal and ethical demands of warfare are likely to ensure a significant role for manned operators and support infrastructure in air warfare for the foreseeable future. The future of the Air Force does not involve a race to or from autonomy but the question of how the organization can integrate manned flight, RPAs, and UCAVs into a single force that maximizes combat power.✪

Notes

1. The Hague Convention of 1907 banned bombardment "of towns, villages, dwellings, or buildings which are undefended." However the ill-defined word *undefended* led to a loophole, allowing bombing in most cases as long as the state was resisting and had some means of defending itself through an armed force. "Laws of War: Laws and Customs of War on Land (Hague IV); October 18, 1907," Art. 25, Yale Law School, accessed 12 May 2014, http://avalon.law.yale.edu/20th_century/hague04.asp.

2. Giulio Douhet in particular underestimated both the cost and number of munitions required to inflict the level of damage postulated by his theories. See Philip Meilinger's summary of Douhet for a more detailed account of his theories and calculations. Col Phillip S. Meilinger, "Giulio Douhet and the Origins of Airpower Theory," in *The Paths of Heaven: The Evolution of Airpower Theory*, ed. Col Phillip S. Melinger (Maxwell AFB, AL: Air University Press, 1997), 1–40.

3. See, for example, P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin Press, 2009); Medea Benjamin, *Drone Warfare: Killing by Remote Control* (London: Verso, 2013); and Nick Turse and Tom Engelhardt, *Terminator Planet: The First History of Drone Warfare* (n.p.: Dispatch Books, 2012).

4. Tabassum Zakaria and David Alexander, "Weapon of Choice against al Qaeda, Drones Marginal in Syria," Reuters, 4 September 2013, http://www.reuters.com/article/2013/09/04/us-syria-crisis-drones-idUSBRE98314C20130904?feedType=RSS&feedName=worldNews.

5. Denise Garcia, "The Case against Killer Robots: Why the United States Should Ban Them," *Foreign Affairs*, 10 May 2014, http://www.foreignaffairs.com/articles/141407/denise-garcia/the-case-against-killer-robots.

6. Maj David J. Blair and Capt Nick Helms, "The Swarm, the Cloud, and the Importance of Getting There First: What's at Stake in the Remote Aviation Culture Debate," *Air and Space Power Journal* 27, no. 4 (July–August 2013): 14–38, http://www.airpower.maxwell.af.mil/digital/pdf/articles/Jul-Aug-2013/F-Blair.pdf; and Capt Michael W. Byrnes, "Nightfall: Machine Autonomy in Air-to-Air Combat," *Air and Space Power Journal* 28, no. 3 (May–June 2014): 48–75, http://www.airpower.maxwell.af.mil/digital/pdf/articles/2014-May-Jun/F-Byrnes.pdf. As the terms appear in this document, *RPAs* and *UCAVs* represent ideal definitions on a spectrum of human control. RPAs remain under the control of a human operator and manned reachback infrastructure with similar human inputs to operations that existing manned airframes require. UCAVs, in contrast, operate with limited supervisory autonomy and can conduct strike missions with minimal direct human intervention. RPAs and UCAVs can be further differentiated by generational differences in aircraft design and survivability similar to differences in generations of fighters. RPAs generally consist of basic airframes designed to operate in permissive environments, and UCAVs incorporate advanced designs and stealth technologies to improve survivability in contested environments.

7. Thanks to Dave Blair for this phrasing.

8. For a good summary of the literature, see Stuart Armstrong's blog *Less Wrong*, which examines 257 total AI predictions and 95 with timeline predictions for "human-level" AI. Of this survey, over one-third of both experts and amateurs consistently predicted AI within 15–25 years, dating to the 1940s. Stuart Armstrong, "AI Timeline Predictions: Are We Getting Better?," *Less Wrong*, 17 August 2012, http://lesswrong.com/lw/e36/ai_timeline_predictions_are_we_getting_better/.

9. James S. McGrew et al., "Air Combat Strategy Using Approximate Dynamic Programming," *Journal of Guidance, Control, and Dynamics* 33, no. 5 (September–October 2010): 1641–54, http://dspace.mit.edu/openaccess-disseminate/1721.1/67298.

10. This is closely related to deductive versus inductive reasoning but imprecise, given the context.

11. Thomas Burnett, "What Is Scientism?," American Association for the Advancement of Science, accessed 13 May 2014, http://www.aaas.org/page/what-scientism.

12. As Bassford and others have noted, Antoine-Henri Jomini himself would likely reject the caricature of his work, which in total is very similar to Clausewitz's though they are often portrayed as writing contrasting positions on the essence of warfare. The distinctions between the two listed here represent a small fraction of the overall work of these theorists but generally describe how they are remembered in the realm of military theory. Christopher Bassford, "Jomini and Clausewitz: Their Interaction," Clausewitz Homepage, 26 February 1993, http://www.clausewitz.com/readings/Bassford/Jomini/JOMINIX.htm.

13. Ibid.

14. I limit this article largely to the use of RPAs by state actors, but factors that will raise the cost of RPAs for states will likely be a greater obstacle for nonstate actors. Small RPAs made from off-the-shelf technology are likely to play an intelligence, surveillance, and reconnaissance role and a limited tactical attack role by nonstate actors. However, as countermeasures are developed and mechanisms to prevent their ability to act in close coordination though "swarm" tactics develop, in the long run this risk will be less than is often predicted. Weaponizing RPAs will add significant weight and increase their size to the point where their utility declines as costs and vulnerabilities increase.

15. Singer, *Wired for War*, 33. See also Michael C. Horowitz, *The Diffusion of Military Power* (Princeton, NJ: Princeton University Press, 2011), 221.

16. Beyond platform costs, a common question that arises is whether life-cycle costs end up lower due to lower training costs and other related issues. This is difficult to quantify at the present time because as some life-cycle costs are lower, the remotely piloted factor of RPAs has led operators to risk the airframes in many situations, resulting in higher loss rates, particularly with tactical RPAs employed by the US Army. Future studies will have to better answer this question as operational use increases

and greater numbers of cases become available. Regardless, the open question suggests that any potential cost gains are likely to be low if at all—and not in orders of magnitude.

17. Quoted in W. J. Hennigan, "New Drone Has No Pilot Anywhere, So Who's Accountable?," *Los Angeles Times*, 26 January 2012, http://articles.latimes.com/2012/jan/26/business/la-fi-auto-drone-20120126.

18. Thomas P. Ehrhard, "Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation" (diss., Johns Hopkins University, 2000), 628.

19. According to the UN Observer Mission in Georgia report, "A reconnaissance mission by a military aircraft, whether manned or unmanned, constituted 'military action' and therefore contravened the Moscow Agreement. . . . However legitimate this purpose may seem to the Georgian side, it stands to reason that this kind of military intelligence-gathering is bound to be interpreted by the Abkhaz side as a precursor to a military operation, particularly in a period of tense relations between the sides." "Report of UNOMIG [UN Observer Mission in Georgia] on the Incident of 20 April Involving the Downing of a Georgian Unmanned Aerial Vehicle over the Zone of Conflict," 26 May 2008, http://globe.blogs.nouvelobs.com/media/01/02/cf530afbef0fb6f305824428f6c83509.pdf.

20. Charles Tilly, ed., *The Formation of National States in Western Europe* (Princeton, NJ: Princeton University Press, 1975), 42.

21. Force and coercion in this context refer to the definitions used by Thomas Schelling, who differentiates between "brute force" (the decimation of the enemy) and "coercion" (violence and threat of further violence, both deterrence and compellence) as parts of a bargaining process. Thomas C. Schelling, *Arms and Influence* (New Haven, CT: Yale University Press, 1966), 5–7, 66–70. Clausewitz is famous for noting that it is the "continuation of politics by other means," but more specifically he defined it as "an act of force to compel our enemy to do our will." Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 75.

22. At the same time state control is vital from a legal perspective to control violence in conflict, one could view the passions of the era of nationalism from Napoleon through at least World War II as exacerbating violence in a number of cases as rational control breaks down.

23. Alexander Moseley, "Just War Theory," *Internet Encyclopedia of Philosophy*, accessed 21 January 2014, http://www.iep.utm.edu/justwar/.

24. Ibid.

25. See Johnston and Sarbahi's work on the military effectiveness of RPAs for an example of how these platforms have had limited but demonstrated tactical success while the strategic impact remains ambiguous. Patrick B. Johnston and Anoop K. Sarbahi, "The Impact of U.S. Drone Strikes on Terrorism in Pakistan," 11 February 2014, http://patrickjohnston.info/materials/drones.pdf.

26. For an example of the criticism extending beyond RPAs, see Jeremy Scahill, *Dirty Wars: The World Is a Battlefield* (New York: Nation Books, 2013).

27. "Laws of War," Annex 1, Article 1.

28. "Losing Humanity: The Case against Killer Robots," Human Rights Watch, 19 November 2012, http://www.hrw.org/reports/2012/11/19/losing-humanity.

29. This could range from a modified F-22 to a larger command post such as an E-3, with the pilot role of the F-22 shifting from direct air-to-air combat toward an air-battle-manager role for a team of UCAVs operating at a distance.

30. The need for continued, elevated high autonomous aircraft in phase two may remain, depending on the progression of automation in the air-to-air environment.

31. Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1991), 105.

32. William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power—Economic and Military* (New York: G. P. Putnam's Sons, 1925), xviii.

33. For further information, see Lt Col Lawrence Spinetta's work examining the "glass ceiling" for RPA pilots. Lt Col Lawrence Spinetta, "The Glass Ceiling for Remotely Piloted Aircraft," *Air and Space Power Journal* 27, no. 4 (July–August 2013): 101–18, http://www.airpower.au.af.mil/digital/pdf/articles/Jul-Aug-2013/V-Spinetta.pdf.

34. Jon Soltz, "The New Drone Medal and Why Troops Need Hagel," *Huffington Post*, 21 February 2013, http://www.huffingtonpost.com/jon-soltz/the-new-drone-medal-and-w_b_2734731.html.

35. See, for example, John Bruhns, "Why the Drone Medal Is Overvalued," *Huffington Post*, 25 February 2013, http://www.huffingtonpost.com/sgt-john-bruhns/why-the-drone-medal-is-overvalued_b_2756375.html.

36. Retired colonel Terry Stevens, an Air Force personnel officer, noted his unofficial formula for the importance of decorations in calculating the prospects of officer promotion: "Company-grade officers will normally have an Air Force Achievement Medal and a Commendation Medal or two. Majors and lieutenant colonels also should have Meritorious Service Medals and/or Joint Meritorious Service Medals, with clusters. If you do, then you've shown initiative, leadership and above-average performance." David Larter, "Officer Drawdown: What Are Your Chances?," *Air Force Times*, 10 July 2011, http://www.airforcetimes.com/article/20110710/NEWS/107100313/Officer-drawdown-What-your-chances.

37. Steven Pressfield, *The Warrior Ethos* (New York: Black Irish Entertainment, 2011).

38. Ibid., 12–13. As examples of Pressfield's central point about the relationship of innovation and the warrior ethos, major innovations of the past were described in terms of being dishonorable to the way the RPA is debated by current advocates of the warrior ethos. In the Second Lateran Council of 1139, the Catholic Church declared, "We prohibit under anathema that murderous art of crossbowmen and archers, which is hateful to God, to be employed against Christians and Catholics from now on." "Second Lateran Council (1139): Canons," accessed 15 June 2015, http://www.ewtn.com/library/COUNCILS/LATERAN2.HTM. Similarly, in the 1600s, Cervantes noted that the "devilish invention [of artillery enables] . . . a base cowardly hand to take the life of the bravest gentleman. . . . A chance bullet, coming nobody knows how or from whence, fired perchance by one that fled affrighted at the very flash of his villainous piece, may in a moment put a period to the vastest designs" J. F. C. Fuller, *Armament and History* (New York: De Capo Press, 1998), 91–92. In World War I, a French general was said to have remarked on how horrible the machine gun was because "three men and a machine gun can stop a battalion of heroes." Kirsten Cale, "Cultural Wars," Clausewitz Homepage, accessed 22 May 2014, http://www.clausewitz.com/readings/CaleReview.htm.

39. For Douhet's discussion of how he sees the aircraft revolutionizing warfare and concepts of what it means to be a combatant, see Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari (New York: Coward-McCann, 1942), 8–11.

40. Mitchell, *Winged Defense*, 11, 16. Between the passages highlighted here, Mitchell details his perspective of the development of warrior cultures and eventually armies in a manner similar to that described by Pressfield but with a distinctly negative view. Airpower, he argues, fundamentally changes the calculus by tying the entire state back to conflict and not just one caste while making the fighters specialists in delivering force rather than overcoming fear.

41. Ibid., 6.

42. A casual sampling of the comments section of articles on the US Air Force's website (http://www.af.mil/), the *Air Force Times*, and controversial pieces in *Air and Space Power Journal* illustrates the fault lines in this debate: those on either extreme view themselves as either the outsider or the one losing influence. Those outside the flying community tend to see the Air Force as dominated by fighter pilots and de-emphasizing other key aspects of the service's mission. Those in the flying and maintenance community point to the current Air Force mission, arguing that they should have more influence but are steadily losing it due to a variety of reasons unrelated to the mission, from political correctness to lack of focus. The comments section for Maj Dave Blair's May–June 2012 *Air and Space Power Journal* article "Ten Thousand Feet and Ten Thousand Miles: Reconciling Our Air Force Culture to Remotely Piloted Aircraft and the New Nature of Aerial Combat" is particularly illustrative (http://www.airpower.maxwell.af.mil/article.asp?id=72).

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Changing the Tooth-to-Tail Ratio Using Robotics and Automation to Beat Sequestration

Capt Rachael L. Nussbaum, USAF

It is a fact that the "tooth-to-tail" ratio in any modern military is heavily weighted towards the "tail." The "tooth"—the personnel and equipment in direct contact with enemy forces—is a small fraction of the remainder (the tail) although identifying exactly where the line between the two falls remains a matter of great debate. The US Air Force is the world's leader in war-fighting automation and robotics. In fact, in accordance with the directive of Gen Larry Spencer, the vice-chief of staff, we are about to push the technological envelope even further by investigating quantum systems, cyber vulnerabilities, and the survivability of remotely piloted systems.[1] Consider our use of drones to multiply the effects of large numbers of attack and reconnaissance pilots—and to remove those personnel from the battlefield. Right now we are developing technology that will enable a single pilot to control a "wolf pack" of drones, further multiplying a single aircrew's mission effectiveness.[2] However, we have not made much progress in using robots to enhance the effectiveness of the larger part of Air Force business. The amount of maintenance required by modern aerial war-fighting capabilities—keeping the planes, people, and air bases in fighting condition—produces a long support tail. If we use our established leadership and knowledge in the field of robotics and automation to address the tail side of the force, we can create a new, better paradigm.

The Current Numbers

To illustrate the need for a new paradigm, we can examine the current fiscal challenges faced by the Air Force as part of the US government—and therefore as a beneficiary of the US tax base. A key point here is that our current fiscal issues are not likely to go away. The taxes that generate the Air Force budget are based on an aging population, currently 15 percent of which is over 65, old enough to receive Social Security (by 2025 it will be 19 percent and rising).[3] Consequently, the portion of the population that pays into not only Social Security but also the general fund, which supports the Air Force, is declining. The cost of Social Security has increased, but federal tax receipts have not. Comparing Social Security Administration data from 1999 to 2012 and Internal Revenue Service data over the same period in 2014 dollars reveals that the cost for a single person receiving Social Security has increased by 44 percent and that total Social Security Administration costs have increased by 88 percent.[4] During that same time period, income tax (the main source of government income) varied wildly (see the table below), not tracking the increasing benefits costs at all. These data points are not comprehensive but simply demonstrative. Budget constraints will not go away.

Table. Federal government individual taxable income in 2014 dollars

1999	$5,873,289,994
2000	$6,225,612,121
2001	$5,719,798,610
2002	$5,406,888,499
2003	$5,418,281,786
2004	$5,837,707,046
2005	$6,215,970,708
2006	$6,527,600,168
2007	$6,912,120,837
2008	$6,218,218,021
2009	$5,597,226,710
2010	$5,997,180,717
2011	$6,033,529,178
2012	$6,547,329,066

Source: "SOI Tax Stats—Individual Income Tax Returns Publication 1304 (Complete Report)," Internal Revenue Service, 22 August 2014, http://www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Returns-Publication-1304-(Complete-Report).

As governmental costs are going up without a corresponding increase in governmental receipts, manning numbers are being forced down to compensate. Today's technology is sufficient to act as a force multiplier and may help with some of the ensuing pain. This article uses broad generalizations to establish a divide between tooth and tail. Such generalizations are not meant to offer surgically accurate definitions but to illustrate the concept and permit a simple level of analysis. The tooth in the Air Force consists of Airmen whose Air Force specialty code (AFSC) is 11X, 12X, 13D, 13S, 18X, 1A7, 1C2, 1C4, and 1T2 (generally, pilots, gunners, pararescue personnel, and combat controllers). Several individuals with such AFSCs will arguably find themselves in a tail position (e.g., headquarters or training), and many without such AFSCs will engage the enemy as the tooth. Determining exactly who falls into these two categories is unnecessary for the purposes of this article.

According to this AFSC-based generalization, the Air Force has on active duty approximately 287,000 military personnel who perform support activities for 20,300 war fighters; 66,000 reservists who support 2,700 Reserve war fighters; and 100,000 guardsmen who support 5,300 Guard war fighters.[5] This ratio of 45:1 (14:1 on active duty) begins to describe the situation. Add the approximately 150,000 civilians to the tail side, and the ratio becomes 60:1 overall although even that number falls short of the full human story.[6]

The tooth is not contracted out; rather, bringing airpower to bear on America's enemies is our core Air Force capability and our reason for being—always performed by "blue suit" Airmen. Contractors are often responsible for the tail and thus multiply our capabilities beyond what our congressionally mandated force can sustain. An additional way to clarify the picture involves following the money. Based on the recently prepared fiscal year 2016 Execution Plan, only 14.25 percent of the overall budget is pure tooth. The remaining 85.75 percent represents the amount necessary to design the weapon, identify the target, and bring the two together for an explosive first impression.[7]

Not all of that 85.75 percent can be reduced by automated systems, but several avenues are worth exploring. Historically, Air Force civil engineer squadrons have multiplied their forces, as well as those of every other unit on base, with the "Big Three" contracts: grounds maintenance, custodial, and refuse collection. Grounds maintenance mows the airfield, reduces the risk of bird aircraft strike hazard, cuts down on pests, and otherwise keeps the base's green areas presentable. Doing so reduces the burden on each unit in terms of policing its own buildings as well as freeing civil engineer personnel to attend to other base operations and support requirements. The custodial contract services quite a few common areas, including every restroom on base. Thus, our junior-most Airmen aren't spending 30 minutes each day cleaning and restocking their building's latrines. Refuse collection multiplies productivity in that it eliminates the need to manage dump sites on base or transport waste to a local landfill. On Seymour Johnson AFB, North Carolina, for example, these three contracts cost $1.45 million each year, $310,000 of which is paid for from proceeds of the base recycling program—for one base.[8] The numbers throughout the Air Force for three recent years average $92.3 million for grounds maintenance, $127.1 million for custodial, and $58.7 million for refuse collection.[9] Each of those numbers can be read as a guide to the price point for development of an automated or robotic system designed to perform this function.

A Different Paradigm

On Seymour Johnson, having such a system carry out the function of all three contracts would not eliminate blue-suit or civilian Airmen or war-fighting capability; furthermore, $1.45 million would become instantly available for other purposes. In addition, the system frees workdays spent managing those contracts in contracting and civil engineer units. Of course, some of the freed resources will be expended in power, maintenance, or oversight requirements for the system, but overall it has the potential to generate useful savings. The mining industry has taken several steps to fully automate its operations in several locations: heavy equipment performs its task without human intervention or control.[10] One company, ASI Robotics, having gone through several such transitions, is confident that it could create a system to safely manage the airfield's green space with no runway incursions or other effect on operations. It would also provide a fleet to collect refuse.[11] This one industry—mining—has already benefited from automation, increasing safety, operating more efficient mines, and lowering costs. It is easy to see how such advantages would prove useful for the Air Force as we keep our airfields mown and the refuse collected.

Cutting personnel, grounding flyers, and eliminating entire fleets of aircraft are negative measures in that they reduce our capabilities and encourage our foes. These steps do not create a new paradigm of Air Force operations; they do not enhance the trust of our allies in the United States' ability to meet treaty requirements or keep faith over the long term; and they encourage errant nations and groups that seek to counter America. Publicizing cuts or the elimination of any part of the force reduces the deterrent effect that the Air Force provides globally, making it more likely that we will have to fight and fight harder when the time comes. However, every crisis presents opportunities. Rather than focus on the abilities we can eliminate, we should multiply effectiveness across the board by using existing expertise in robotics and automation. By doing so, we could redirect dollars to weather sequestration more efficiently, come out stronger, and posture ourselves to shape the long-term future.

Automating jobs done by certain Airmen has been a decentralized process for some time. During the Cold War—before automated alarms, sensors, cameras, and so forth, were reliable enough to entrust with protecting the base perimeter—security forces' resources and personnel had to maintain watch with sentries, a manpower-intensive task. Now guards are on duty around the clock, patrolling every linear foot of the perimeter every instant of the day, keeping an unblinking watch in secured and sensitive areas, and guarding resources. They easily track the entry of every person and vehicle passing through the gate, doing so with a few guards on duty using card readers and a few more on patrol. The remainder of the force consists of a suite of electronic sensors, cameras, and alarms. The latter do not, and cannot, eliminate the need for Airmen; rather, automation is an Airman multiplier that increases the effectiveness of each Airman individually. Now, each modern security forces Airman produces as much security as multiple Airmen from the 1950s. Security forces squadrons routinely replace, repair, and upgrade their tools with even more up-to-date systems, such as remotely piloted vehicles and aerostats.[12] Indeed, of all the members of the support community, security forces squadrons arguably make the savviest use of available technology to conduct their missions.

A Look at Current Technologies

An armed robot guard is not socially feasible, best explained by the *Terminator* movie. Robotics can multiply the effectiveness of security forces but cannot replace them. However, robotics technology today is fast approaching parity in specific tasks with what a human can do. In Japan, Honda's ASIMO robot can manipulate objects as delicate as a paper cup without crushing it or spilling the liquid. It can run, walk, and push a cart with a load.[13] ASIMO will self-charge, engage in basic conversation, and take orders such as "Tea, please."[14] ASIMO may be the pinnacle of humanoid robotics, but it is not the only example. Aldebaran, another Japanese company, has several robots, one of which—the NAO—is fully programmable. At $7,500, it is also relatively cheap. This robot can follow simple commands, differentiate objects, and retrieve a learned item when requested. It can also engage in learning behavior.[15] For example, after being physically moved through a desired task a few times, the robot understands the key points of the task and can adapt to alterations in the environment.[16] Imagine how much time could be saved in any of several career fields if a robot were standing by to hand up parts and tools; put the tools back in storage when the task is complete; and adapt on the fly to changes in the location of the toolbox, the tool, or the person needing it. The NAO, which is marketed as a mechanism for students to practice programming robots, has the shortcoming of being less than two feet tall and does not appear to be terribly durable. Aldebaran has collaborated on a French robot project called ROMEO. At four-and-one-half feet tall, it is intentionally large enough to assist with the aforementioned types of tasks.[17] Designed as a social robot for people, ROMEO is meant to help with tasks that the elderly find difficult, such as preparing meals (perhaps to a degree where hiring, processing, and maintaining watch on other-country nationals in deployed chow halls could become a thing of the past). ROMEO can assure that the stove is not left on and can keep track of appointments and shopping lists.[18] Understandably, the industry is targeting these capabilities because the most advanced robotics companies are in Japan and their most significant emerging need—and, therefore, market—is the burgeoning population of elderly who already cannot perform basic tasks without assistance.

However, consider the underlying raw abilities as indicated by that task list: the robot is capable of tracking inventory, notifying its human handler of a hazardous condition, complying with a schedule, and preparing a load-out of tools and parts. The useful end product of those concepts for the Air Force varies from a grilled cheese sandwich in the chow hall to planned aircraft maintenance, facility repair, and perhaps even preparing a room for surgery. However, we need development and adaptation: "We are at the point where planning and investing make sense," according to University of North Carolina professor Ron Alterovitz.[19]

Leaving aside robots based on mimicking the human shape, we have other options for automation. For example, Amazon's delivery service depends upon warehouse robots—KIVA systems that move the shelves from storage to locations where the packers pull books and other items for the box that arrives at the customer's door.[20] Amazon can afford its low shipping and handling fees in part because of the coordinated ballet performed by these robots. Since the company brings the materials to be packaged or loaded to the point of packing or loading, it needs only a material-handling robot to perform the picking and loading operation—which is a goal towards which Amazon is working. In May 2015, it held a competition called the Amazon Picking Challenge to design such a system, making available to teams various robots such as Rethink Robotics' BAXTER, Clearpath's PR2 ROBOT, and other more basic industrial arms for use in devising a way to automate the picking process.[21] Furthermore, the company seeks to eliminate truck drivers and deliverymen from the equation and has received permission from the Federal Aviation Administration to begin testing a drone system that eventually, after some degree of technological development and after appropriate regulations have been written, will have that effect.[22] Not only academe but also industry considers the anticipated technology sufficient to begin planning and investing in efficient and economical solutions. The Air Force can take advantage of the progress and development that has already occurred and begin researching and developing robotics with the potential to create new paradigms for support operations on bases.

A Near-Term Possibility

As a thought experiment, after imagining a system with the capabilities of KIVA, BAXTER, and a self-driving car (such as Google's), install that system in a single, consolidated shipping and receiving facility on an air base. Tomorrow, tasks are scheduled by multiple agencies—submitted via e-mail, phone call, or online form and prioritized as orders by the automated warehouse system. Since aircraft maintenance is one of the highest priorities on the base, the system begins there: various KIVA robots bring to the side of the Google truck shelves holding the tools and parts needed to change the tires on a jet, and a beefed-up BAXTER mounted on the truck bed takes items from the shelves and arranges them neatly on that bed. That truck then heads out to the designated hangar, where it pulls into an off-loading stall and waits for the maintainers to off-load the items and then release it to return to the warehouse. This single activity multiplies the maintainers' productivity by the time required to select, organize, and load the materials and drive to the work site. While that first movement is en route, another truck can haul material to civil engineer troops at the base gym to complete a work order. A third is en route with food items to the dining facility. Returning in our imaginations to the flight line, as they near completion of their task, the maintainers request a truck for shipping their equipment back to storage, conducting a complete check of their tools, and accounting for everything. As a matter of course, the warehouse system provides a further double check as it returns the tools to their storage location. Nothing is forgotten, nothing is misplaced, and nothing is missing. MSgt Marco Wilson, the 334th Aircraft Maintenance Unit's production supervisor, estimates that eliminating the back-and-forth trips necessary in aircraft maintenance alone could result a 15–20 percent increase in productivity on the flight line.[23]

A near-identical thought experiment must have recently taken place in the US Army because testing has begun on automated systems to see how well they perform certain basic tasks. Specifically, on Fort Bragg, North Carolina, automated shuttles for wounded warriors began to run this summer. Controlled by a kiosk in the wounded warrior barracks and self-charging via solar panels, they may eventually expand their services to include supply runs to field or range training events.[24] The Fort Bragg experiment is part of a larger Army program of automated vehicle testing across multiple bases, including Fort Leonard Wood, Missouri, and West Point, with a long-term view towards aiding the revolution in automating logistics, beginning with the transportation aspect.[25]

Take the basic thought experiment further and imagine adding something similar to the humanoid ROMEO robots to the mix. ROMEO could assist Airmen by carrying items for them, standing at the work site ready to hand up parts, and taking waste to the proper disposal site so maintainers don't need to interrupt their tasks with simple janitorial activities. The ROMEO could automatically note and transmit any request for additional items, thereby eliminating the time an Airman would spend making a phone call or logging into a system to send the request to the warehouse for processing. The robot could then receive a signal when the delivery truck is about to arrive, off-load it, and haul the extra items to the job site—all while the skilled Airman is still turning wrenches, bending metal, or working on the electrical system at the gym. Consider how much of the Airman's time has been redirected from "load and carry" tasks to his or her "real" job. So far, all of these capabilities are Airman multipliers and will require some amount of deliberate research and development. They accomplish necessary tasks, such as taking out the trash, that are too simple and commonplace to train Airmen to do, thereby freeing them to do the job they are trained for.

Some existing options encompass nearly all aspects of our imaginary system. Take, for example, Clearpath Robotics' Grizzly Manipulator robot. Its arm can handle only 22 pounds, but the robot can carry 1,250 pounds on its bed or tow 1,400 pounds; moreover, it has a 4x4 drive and can move at 12 miles per hour for 12 hours, using sensors to avoid collisions. The robot is programmable in multiple languages, comes with Ethernet communication, and is designed for modifications.[26] We could beef up the arm, add a map package for the base, and establish a system it can communicate with to track location and status as well as relay any requests from Airmen on job sites. At this point, it does not take much imagination to envision a very near future in which robotics and automation significantly multiply the abilities of support Airmen. According to Lt Col Debra McAllister, commander of the 4th Logistics Readiness Squadron (LRS), "The types of technology [just] discussed would be very useful to 'warehouse' operations of the LRS."[27]

We find still more examples in industry and academe. MIT has developed CARDEA, a wheeled robot that in 2004 could independently navigate a hallway and move through doors. It is designed to eventually manipulate tools and assist humans although, as with the Japanese companies, the intended use focused on the elderly and basic office tasks—nothing industrial.[28] In 2006 the National Aeronautics and Space Administration (NASA) used Robonaut and a normal power drill to attach lug nuts to a template.[29] Other associated parts of the task were specifically programmed and inflexible. A different array of lug nuts or a different drill would not have worked, but any similarly inflexible task that calls for using a specific tool in a particular manner, with basically identical parts, falls within the abilities of 2006 technology. The rigid task and the customized robot simply needed to be brought together. NASA was working to develop a more generalized ability to use tools—in that instance, a duster to clean a hose. In computing terms, this is all old news. Given Moore's Law—the principle that computation ability doubles every two years—the 2006 robot is now 16 times more capable. To understand how this law works and to illustrate how it is consistently underestimated, we can look to the *Star Trek* movie series. The android known as Data performed at a speed of 60 trillion operations per second (60 teraflops).[30] These days, we regularly measure in terms of petaflops—1,000 times faster than a teraflop. A computer performing exaflops—

1,000,000 times faster than the most advanced computer in *Star Trek*—is not out of reach. An up-to-date phone probably performs at around a gigaflop, a measurement just one step down from Data's teraflops—and people carry that device in their pocket.

However, computation speed and imaginary androids don't tell us where the Air Force might efficiently invest in development. In the near future, Airman-multiplier robots that can load and carry are feasible, and, with some development and testing, the service might create major dividends in Airman productivity, as well as replace certain contracts with an automated system. In the long term, using automated systems to do simple, repetitive physical tasks such as scheduled maintenance is worth developing—for example, replacing all of the tires on an aircraft. The task is simple and rigid, and the parts and tools are uniform for every aircraft of that model. Airmen who would otherwise spend time collecting tools and parts, filing paperwork and reports, replacing the tires, and putting everything back afterwards would perform a quality double check after the robot finishes the task. Those Airmen could now spend their freed duty hours on far more difficult jobs that call for creativity, coordination of different skills, or agility beyond that of a robot. The total output of the unit will increase, perhaps to the point that nobody will have to work overtime. Even better, the bird that would not have been ready to fly might just deploy on schedule since the time spent replacing all of the wheels on every aircraft in the wing (as well as other similarly rigid tasks) is now available for more difficult problems.[31]

The Need to Develop Guidance

Despite the current fiscal climate, all of these advantages must be balanced against the contingencies present in warfare. Should the Air Force proceed with automation and robotic technology wherever useful, careful consideration must be given to retaining the capability to fight wars without automation. The United States has not engaged a peer enemy for decades, and a modern war will include cyber attacks. If we cannot operate without automation, then we create a weakness that no competent enemy will ignore. If we become overly dependent upon robots or automated systems, a cyber attack that neutralizes them could defeat the Air Force by eliminating its ability to get off the ground. Automation and robotics can save significant amounts of money in the near term and help us weather harsh fiscal realities by multiplying Airmen and more efficiently accomplishing a percentage of contracted work. Yet, there will always be a need to have blue-suit manpower trained and able to step in instantly. Therefore, the Air Force needs to consider and develop doctrine that will establish a balance between employing automation for cost savings/general efficiency and providing manpower the necessary time to train for and gain experience in all tasks as well as regular refresher activities. One weekend a month and two weeks a year may be a useful construct for this problem. Determining the proper force requirements to succeed with no automated assistance is the first issue, and determining how much time it takes to perform a task in order to retain basic competence is the second issue. Each career field will have different needs.

The future is uncertain in nearly every way. The international order is growing more inclusive, the global economy is shifting, and governments around the world are jockeying for dominance. Every day, engineers contribute enormously towards a brighter future. The only logical solution is to get on board and take advantage of the work already being done by the private sector. The greatest heritage of the Air Force is changing the paradigm. We have before us an opportunity to live up to the tradition established by Gen Billy Mitchell. ✪

Notes

1. Aaron Mehta, "US Air Force Launches Trio of Tech Studies," DefenseNews, 31 January 2015, http://www.defensenews.com/story/defense/air-space/air-force/2015/01/31/usaf-launches-study-trio-sab/22524543/.

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Capt Rachael L. Nussbaum, USAF

Captain Nussbaum (USAFA; MA, American Military University) is the flight commander, Explosive Ordnance Disposal Flight, Seymour Johnson AFB, North Carolina. She is responsible for training, equipping, and leading her flight to respond to explosive hazards both on and off the installation. She supports 94 F-15E fighter aircraft, manages range clearances, and directs hazardous-device search teams on behalf of the US Secret Service and Department of State. She has a breadth of experience in civil engineering, including standing up the Asset Management Flight at Kunsan AB, South Korea, and serving as programming chief at Lajes AB, Portugal, as well as maintenance engineer at Yokota AB, Japan. She also was the director, US National Support Element, Pápa AB, Hungary, where she led a five-member element consisting of Hungarian contractors, American noncommissioned officers, and a General Schedule civilian. Her element arranged for the provision of nearly all support required by the 121-member US element, including US-specific communications, force support, housing and furnishings assistance, school liaison, and financial and translator services. Captain Nussbaum grew up reading the science fiction of Isaac Asimov, Robert Heinlein, and Arthur C. Clarke, among many others, and firmly believes that we are living in their novel world and that we have a responsibility to create an even better future for our successors.

Twenty-First-Century Air Warfare and the Invisible War

Strategic Agility

Maj Michael W. Benitez, USAF

America's Air Force: A Call to the Future, released in July 2014, asserts that

> *the Air Force's ability to continue to adapt and respond faster than our potential adversaries is the greatest challenge we face over the next 30 years.*
>
> Meeting that challenge will require honest, recurring self-critique, and a willingness to embrace meaningful, perhaps even uncomfortable change. To their great credit, our Airmen—adaptive and resilient—are bridging the widening gap between the dynamic 21st-century environment and our 20th-century bureaucracy. Their initiative and perseverance allow us to succeed in our mission despite sluggish process and cumbersome structure that can engender rigid thinking and stifle the creativity and innovative spirit we seek to champion. *We must commit to changing those things that stand between us and our ability to rapidly adapt*.[1] (emphasis in original)

Who will be our next enemy? Whom will we fight in the next 20–30 years, and how can we be ready? Perhaps even more importantly, how can we prepare the force to deter these fights? To meet its own strategy and the demands of an uncertain global environment, the Air Force must increase its strategic agility. Fundamentally, the service must remain prepared for today's fight yet also ready itself for future conflicts. The Air Force must synchronize these two time horizons and assure that its forces are capable of meeting a myriad of future threats. One step toward realizing greater strategic agility would involve establishing a Warfighter Integration and Innovation Branch (WI2B). However, to understand why this organizational change is necessary, we must first consider the current state of the Air Force.

Recapitalization

We need strategic vision to anticipate global changes in the upcoming decades so the Air Force can maintain a capability and performance advantage in personnel, training, and equipment. Even as we fight today's wars, the necessity of recapitalizing has never been more profound. The average age of our fighter fleet is 30 years, and most of our tankers and bombers are senior citizens.[2] The recapitalization efforts of Gen Mark Welsh, chief of staff of the Air Force, are similar to those of Gen Wilbur Creech in the 1970s, when he corrected what he called a "slippery slope" in combat capability.[3] Within five years, the service was procuring new aircraft, had established Red Flag, and had developed the Air Combat Maneuvering and Instrumentation system to train personnel for more complex missions.[4] Although no one could predict exactly how the world would change (and how Iraq would transition from ally to adversary), General Creech's foresight postured the Air Force for overwhelming success in Operation Desert Storm nearly 15 years later. The Air Force must have large, long-term, high-priority acquisition programs such as the F-35, the Long-Range Strike Bomber, and others to ensure that the United States is prepared for the future "10-year enemy," which may even be a near-peer adversary.

Predicting the Future

Today's enemy may be our future adversary as well, but history has shown that our predictions of the future have proven notoriously wrong. For example, in 2011 Secretary of Defense Robert Gates pointed out that "when it comes to predicting the nature and location of our next military engagements, since Vietnam, our record has been perfect. We have never once gotten it right, from the *Mayaguez* to Grenada, Panama, Somalia, the Balkans, Haiti, Kuwait, Iraq, and more—we had no idea a year before any of these missions that we would be so engaged."[5] Even Gen James Mattis, former commander of US Central Command and a true scholar of the profession of arms, in testimony before the Senate Armed Services Committee, observed, "I think, as we look toward the future, I have been a horrible prophet. I have never fought anywhere I expected to in all my years."[6]

Today's world is radically different than the one 30 years ago when many current senior military leaders first entered service. If we accept that fact, as many of them have, then we must also acknowledge that our organization, planning, and processes should change radically if we wish to adapt. As a well-known cliché warns us, "insanity is doing the same thing over and over again and expecting different results."

As an organization, the Air Force is often unable to react in a timely manner to events that occur in this increasingly unpredictable world. According to Air Force colonel John Boyd, the key to assuring victory lies in maintaining a shorter observe-orient-decide-act (OODA) loop than the adversary's. Our acquisition processes, however, reflect an organizational lethargy that prevents us from keeping pace with global conditions.[7] Although the Air Force is currently addressing these issues with a revised strategy, planning, and programming process, the service's organizational structure remains a concern.

The Effect of Operational Inflexibility on Strategic Agility

Of the three levels of war, the operational level is responsible for the integration of tactical-level missions to attain strategic objectives.[8] Simply put, it determines what will be affected, in what capacity, and with what resources.[9] As the execution mechanism of the joint force air component commander or combined force air component commander, the air and space operations center (AOC) is the air component of the operational level of war.[10] The operational level is the most relevant of the three in terms of reacting to today's enemy.

Issues at that level are most apparent when one observes the amount of deliberate planning versus crisis action planning in Africa Command, European Command, and Central Command over the past four years. The observed crisis action planning processes in recent years confirm a systemic problem: the current Air Force structure lacks flexibility, agility, and integration between the different levels of war. The result, cast in an organizational structure designed decades ago, defines the current Air Force strategic agility problem. The Air Force Posture Statement for fiscal year 2015 expressed the need to review the present structure: "The evolving complexity and potentially quick onset of warfare means that future conflicts will be a 'come as you are' fight."[11] History has shown that the Air Force cannot rely solely on preparing for a presumed future adversary and assume that it is prepared for the actual enemy that its forces will fight or need to deter. To comprehend this issue and support the establishment of the WI2B, the service must conduct additional analysis of current war-fighter integration at the tactical and operational levels.

War-Fighter Integration

The mission of the US Air Force Warfare Center (USAFWC) is to "ensure deployed forces are well trained and well equipped to conduct integrated combat operations . . . across all levels of war."[12] As an umbrella organization, the USAFWC includes approximately 11,000 personnel among several subordinate units, one of which is the US Air Force Weapons School (USAFWS). The Air Force places great emphasis on developing highly qualified tactical-level talent in the form of graduates from the USAFWS. These weapons officers are the subject-matter experts, senior instructors, lead tacticians, and critical thinkers of war-fighting units across the Air Force. The duties of squadron weapons officers include "assess[ing] unit combat capability to accomplish anticipated missions . . .; identify[ing] deficiencies in training, equipment, support or tactics, which preclude optimum mission accomplishment; identify[ing] unit initiatives that may have MAJCOM [major command]-wide or cross MAJCOM applications; recommend[ing] improvements for unit operations; [and] identify[ing] problem areas requiring corrective action above unit level."[13] The current organizational structure dictates that unit weapons officers funnel inputs to the parent MAJCOM; unfortunately, this action alone doesn't fully empower those officers to carry out their duties because the MAJCOM functions as a force-providing organization—not a war-fighting organization.

Another USAFWC unit, the 505th Command and Control Wing, is unique in that it is the sole Air Force wing dedicated to the operational level of war. This wing is responsible for operational-level exercises such as Blue Flag and Virtual Flag; it also retains a unit at Nellis AFB, Nevada. The latter simulates functions of an AOC to support tactical training during Red Flag exercises.[14]

As the epitome of Air Force war-fighter integration across all levels of war, the USAFWC surprisingly lacks an organization to bridge the gap between the tactical and operational levels of war. Under the current Air Force training construct, units refine tactical-level execution by simulating operational-level processes with many flawed assumptions. This disconnect can lead to developing and refining artificial tactics that may have limited operational application at the expense of time and resources. Conversely, when AOCs conduct exercises, they simulate tactical-level units and execution with similarly flawed assumptions. The entire training regime appears to contradict the "train like you fight, fight like you train" mantra because units at these two levels of war have no opportunity to train together. Consequently, when crisis action planning is initiated, organizational inflexibility inhibits optimized application of technological capability and resources. This lack of agility affects theaterwide war-fighter integration and resource optimization to support the joint force commander. This is today. Tomorrow will be worse if we take no action.

Warfighter Integration and Innovation Branch

That said, how does the Air Force evolve and increase its strategic agility? Fundamentally, it needs to create another OODA loop, one capable of responding to today's enemy while the current, larger structure ensures that we are preparing for the future adversary. The keystone of this rapidly responsive process is the proposed WI2B. As a true paradigm shift, the WI2B should not be synchronized, aligned, or otherwise structured with current Air Force organizational constructs. Only then will the synergistic effects of this new structure be realized. This approach is the key to executing both twenty-first-century airpower and exponentially improving strategic agility.

The WI2B should be physically located at the USAFWC for two primary reasons: (1) all weapons officers spend some time at Nellis, where the USAFWC is located, so throughout the USAFWS course, they could easily be exposed to the branch, its people, and processes for integration and innovation; and (2) the WI2B aligns with the current USAFWC mission statement and priorities by allowing the USAFWC to remain abreast of operational-level issues and future plans, yet stay grounded and supportive of the tactical level by focusing on today's conflicts. The WI2B would create a much-needed bridge between the tactical and operational levels of warfare. As a focal point, the branch would have cross-organizational reach to remove the numerous information stovepipes in the current structure.[15] The WI2B should have direct contact with all relevant combatant command and MAJCOM staffs, all AOCs, developmental and operational test units, the USAFWS curriculum, Red Flag, Green Flag, and all wing weapons officers in the combat air forces. Such contact alone would enhance both training realism and tactical application. More importantly, the cross-organizational structure would tear down communication barriers from the 13 regional and functional worldwide AOCs and provide a venue to facilitate timely integration of operational-level processes and developments that are necessary to produce strategic agility.

Innovation from the War Fighter

General Welsh has emphasized that "we must begin designing agility into capability development." He further assets that "those who operate the systems in the field continue to discover uses that designers never imagined. We must strengthen this feedback loop, and rapidly validate operating concepts developed in the field."[16] The WI2B can further aid this vision by providing an avenue for small-scale, tactical-level innovation that has operational effects. It is not enough that the tactical level has a means not only to not *think* innovatively but also to *act* innovatively. Airmen are the Air Force's greatest resource, but they are not being optimized to facilitate this vision. This critical element is also absent from the current Air Force war-fighting construct. Additionally, an overwhelming part of that overlooked war-fighter talent pool is the millennial generation that Col S. Clinton Hinote and Col Timothy J. Sundvall describe in their "Leading Millennials" article published in the January–February 2015 edition of *Air and Space Power Journal*.[17] Currently, multiple Air Force instructions and forms exist for the war fighter to recommend changes to tactics and procedures. All of these processes have in common the fact that they are all reactive and have no innovative component—this is also their greatest limitation.

The astute reader may point to "urgent operational need" and "joint urgent operational need" requests, but these are valid only after the war fighter has already deployed and become involved in the conflict in which the need is identified.[18] Again, these are reactive, not innovative. A "joint emergent operational need" is similar to a joint urgent operational need but doesn't require someone's presence in an actual conflict. However, they are forwarded through the Joint Staff and thus must have a joint requirement to be considered valid.[19] The WI2B could easily solve this deficiency by the nature of its cross-domain construct.

Conclusion

The overwhelming weight of effort toward game-changing technology will continue to be limited by an inflexible organizational structure charged with applying this technology. To utilize its twenty-first-century technological advantage, the Air Force must similarly evolve its twentieth-century organizational structure. The proposed WI2B would increase the service's flexibility and adaptability between tactical- and operational-level units globally by proactively creating a rapidly responsive cross-domain OODA loop and thereby attain strategic agility. Doing so will ensure that the Air Force is prepared for both today's and tomorrow's enemy.✪

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The Limits of Tactical Aviation Technology

Lt Col Thomas R. McCabe, USAFR, Retired[*]

For generations, the American military—and the US Air Force in particular—has relied on the technological superiority of its systems to dominate any battlefield. Against conventional enemies, this paradigm has been so successful for so long that it is often taken for granted. Unfortunately, the question of how much longer we can expect that to be the case is very much open to debate. Many people observe that, in terms of technology, we have fallen into something of a lull, especially regarding tactical aviation platforms. This article suggests two actions we can take to start changing that status.

The Present Situation

Our current aviation superiority is largely based on technologies developed and deployed during the last decades of the Cold War.[1] Since the end of that ideological conflict, however, our aviation technology for combat aircraft has reached a plateau. The only major new capabilities have been (1) a limited deployment of F-22s with more advanced stealth airframes capable of supersonic cruise and (2) the beleaguered F-35.[2] Otherwise, much of our effort has concentrated on limited upgrades of existing capabilities as well as the development and deployment of remotely piloted air systems.[3]

The geopolitical environment of the last two decades has made this situation acceptable. During the 1980s, we largely recapitalized our aircraft force with new equipment and have lacked a peer competitor after the collapse of the Soviet Union. We have focused since then on improved command, control, communications, computers, intelligence, surveillance, and reconnaissance, as well as remotely piloted systems that supplanted the development of manned tactical aircraft technology. Unfortunately, this somewhat permissive geopolitical and operational environment is not likely to continue.

At present, we confront a chaotic and increasingly dangerous threat environment around the globe. China, Russia, Iran, North Korea, and radical Islam/terrorism in all its manifestations, along with a host of others, present challenges to our national security. In particular, China's antiaccess/area-denial strategy, intended to defeat our

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[*] This article includes contributions from Leon McKinney.

ability to project power in the Western Pacific, has made great strides in building the technical base necessary for such a strategy. Furthermore, the Chinese are pursuing what amounts to a staggering list of revolutions in their air and space technology.[4]

When the (potential) opposition is catching up, the obvious counter is—and historically has been—a technological leap forward. Unfortunately, as previously mentioned, manned military aviation technology, especially for manned tactical aircraft, may be reaching a period of little change. Only a small portion of the most recent (2010) Air Force long-range research concept, *Technology Horizons*, dealt with actual aircraft technology. Instead, it concentrated primarily on advanced (and, admittedly, potentially revolutionary) computer applications intended to do what we are already doing—only faster, cheaper, and with less manpower.[5] Most current research on manned tactical aircraft concentrates on what amounts to incremental improvements for and sustainment of existing systems while research on a possible successor generation of such aircraft is only in the preliminary stages. Procurement of manned tactical aircraft for at least the next 20 years effectively will consist of what is presently on the assembly line.[6] The Navy faces a similar situation.[7] Moreover, although we are evidently putting extensive effort into future remotely piloted systems, their ultimate capabilities—especially their survivability on a dynamic, high-threat battlefield—remain to be seen despite the enthusiasm of those systems' proponents.

We must recognize that a central reason for the plateau in manned tactical aviation technology is that we are approaching—if we have not already reached—the limits of what is immediately and affordably available for tactical combat aircraft. Further, it is at least possible that we have reached or nearly reached the limits of what is technically feasible for air-breathing manned combat aircraft. None of the possible upgrades to existing systems are really a breakthrough or a game changer.[8] Beyond these upgrades, there are no readily apparent or available breakthroughs to pursue. At this point, the only evident exceptions are the possibility that active electronically scanned array (AESA) radars can provide us with high-power microwave weapon capability; other exceptions include electromagnetic pulse weapons such as the Counterelectronics High-Powered Microwave Advanced Missile Project (CHAMP) warhead and whatever computer network attack capability we have developed or will develop.[9]

Unfortunately, we are not the only ones with access to such technologies. The rest of the world, especially our rivals, is catching up and is expected to master and deploy these technologies in the near future. In some cases, those rivals are already doing so. Even more ominously, several potential game-changing technologies of the near future, such as very long-range air-to-air missiles (AAM), precision-guided antisurface ballistic missiles, cyber weapons, stealthy cruise missiles, and advanced warheads (such as cluster, electromagnetic pulse, and fuel-air explosive) are as likely, if not more likely, to work against us as for us. This array of technologies obviously has profound implications for the strategic and tactical situations we will encounter around the world. Specifically, we and our allies will not necessarily be able to rely on superior technology and capabilities that served as a force multiplier since the end of the Cold War and compensated for inferior numbers. Meanwhile, our ongoing fiscal and economic situation will make both recapitalizing our aging equipment and pursuing new technology enormously difficult. We should not rely on a cost breakthrough with remotely piloted systems to avoid this situation. Most of those vehicles deployed so far have been relatively inexpensive because their airframes are comparatively simple and cheap. However, costs go up rapidly as airframes and their sensor packages increase in sophistication. So what can we do?

The Way Forward

First, we must water the tree of future research and development and keep it watered—but we can expect results only in the long term. For example, at the moment, the Air Force and the Defense Advanced Research Projects Agency (DARPA) appear to have a reasonably coherent program for hypersonics (flight at or above Mach 5). However, the immediate focus is on tactical missiles, with a larger, reusable remotely piloted hypersonic vehicle expected in the 2030 time frame and a potentially manned hypersonic vehicle for 2040.[10] If we cannot make an immediate or rapid leap ahead in airframes or engines, do other alternatives exist? Might we harvest any low-hanging fruit in the near or intermediate future that could offer new capabilities or at least extend the viability of existing systems, preferably without breaking the bank?

Two areas potentially worth exploring might, if pushed, have an impact as early as the turn of the next decade. Moreover, they would prove especially useful in an environment where we will need to operate at longer ranges against more sophisticated enemies deploying antiaccess/area-denial systems. They include longer-range AAMs and—more ambiguously and much less noticed—improved fuels.

Longer-Range Air-to-Air Missiles

As previously mentioned, we are facing the likely or inevitable proliferation of increasingly long-range AAMs. The Chinese are reportedly deploying these weapons with ranges that at least rival those of currently deployed US AAMs.[11] Consequently, until the widespread deployment of the F-35, the fourth-generation aircraft that the US fighter force and our allies depend on will no longer have a missile-range advantage. The Russians are starting to deploy the R-37/AA-X-13 (reported by some credible sources to have a range in excess of 150 nautical miles [nm]) on their upgraded MiG-31BM.[12] Additionally, the Russians say that variants can also be mounted on other aircraft such as the Su-35 and their T-50 fifth-generation fighter.[13] Even more ominous would be the Russian R-172/K-100, with a reported range of up to 200 or more nm.[14] If produced, it could be mounted on the widely deployed Su-27 family of aircraft.[15] At the very least, such very-long-range systems are likely to pose a major threat to the more vulnerable support aircraft such as tankers and Airborne Warning and Control System aircraft, on which our air operations critically depend.

Aside from the latest version of the advanced medium-range air-to-air missile (AMRAAM), the AIM-120D, which reportedly has a range 50 percent greater than that of earlier AMRAAMs (increasing its range up to a reported 97 nm), the United States has no longer-range AAMs in its inventory or in prospect.[16] The Navy's Phoenix missiles and the F-14s that carried them are long gone. The Next Generation Missile/Joint Dual Role Air Dominance Missile, intended as a replacement for the

AMRAAM (and the AGM-88 high-speed antiradiation missiles), reportedly was cancelled in 2012 for affordability reasons although some sources speculate that classified work has possibly continued.[17] Since one of this missile's major intended characteristics was substantially improved range, its development should be restored as a major priority.[18] At one time, we considered putting a ramjet engine on the AMRAAM to boost its range and capabilities, as is being done on several next-generation missiles such as the British Meteor, reportedly on the Chinese PL-21, and possibly a version of the Russian R-77/AA-12.[19] If doing so will further improve the range and capability of the AIM-120D, we should give serious thought to reviving this development. Finally, Raytheon is developing an extended-range version of the AMRAAM for surface launchers (the AMRAAM-ER) that we should consider modifying for very-long-range air-to-air use.[20] We should also contemplate reviving a version of the Network Centric Airborne Defense Element (NCADE) missile as an alternative very-long-range AAM. The NCADE was intended for boost-phase intercept of ballistic missiles, using an AMRAAM missile frame with an advanced rocket motor and an infrared seeker from an AIM-9X.[21] Early testing was evidently successful, but it does not appear to have been included in the budgets for fiscal year 2013 or later.[22]

An additional feature that we should think about for improving the capability of future missiles involves putting an AESA radar on the AMRAAM, as the Japanese have done with their AAM-4B and as the British may do with the Meteor, if this addition is technically possible. (The AAM-4 is somewhat larger than the AIM-120, allowing it to carry a bigger antenna.)[23] An AESA radar increases the range at which the active radar on the missile can autonomously track a target, reportedly by as much as 40 percent.[24] We may further increase the range of the radar by upgrading it with gallium nitride component technology.[25]

*Improved Fuel*s

An obvious, although little-considered, way of extending the range of aircraft is through fuels with higher energy density per volume, which will yield greater range as long as they do not weigh much more than the fuels they replace. Fragmentary reports indicate that during the Cold War, the Soviets' development and use of a fuel with higher energy density per volume than commonly used Western fuel gave their aircraft considerably longer range than expected, but such reports remain publicly unconfirmed.[26] Recently, the United States has been researching a fuel called JP-900 for two main reasons: as an alternative to fuels produced from petroleum (it comes primarily from coal) and as a fuel having higher heat tolerance than those presently used. (It is called JP-900 for its stability for some specified period at 900 degrees Fahrenheit.) Research has confirmed that JP-900 also has a somewhat higher energy density than present jet fuels but only by several percent.[27] However, higher energy density appears to have been only a secondary consideration in the research. The Department of Defense should make such energy density a primary consideration for such research along with cost considerations (new fuels need to be no more expensive than the current ones) and the ability to immediately substitute for present fuels without modifying aircraft systems.[28]

Conclusions

The days when the United States could take for granted its status as the world's premier air and space technology superpower may not be over, but complacency is clearly not an option. Above all, we need to recognize that we are facing long-term competition and that we must keep our own tree of air and space innovation well watered, especially for tactical systems at a time when, as this analysis has noted, little low-hanging fruit will be harvested in the near future. We should change that prospect for combat aircraft and systems—and soon. It is time to start thinking outside the box.

Aside from applying emerging techniques such as rapid prototyping, we should consider turning to the private sector.[29] Numerous companies are now leading in such fields as cyber and space launch vehicles. For one, SpaceX seems well on the way to revolutionizing the field by providing space-launch-vehicle capability at a cost well under historic norms.[30] Further, the company evidently intends to undertake a further revolution by making such vehicles fully reusable.[31] Of more relevance, civilian companies may be pursuing a similar revolution with high-speed flight. For instance, the Hypermach company is designing the SonicStar, an advanced business jet intended to cruise at over Mach 4.[32] I suggest that DARPA and the Air Force closely monitor its development, and if it actually works, we should explore the feasibility of converting its technology to war-fighting use.[33] ✪

Notes

1. These technologies include the following:
    - Fourth-generation aircraft that were increasingly integrated systems rather than a collection of discrete subsystems: F-15s, F-16s, and F-18s.
    - Stealth aircraft.
    - All-aspect infrared air-to-air missiles (AAM) starting with the AIM-9L Sidewinder.
    - Active radar-guided AAMs: the AIM-120 advanced medium-range air-to-air missile (AMRAAM).
    - Precision-guided air-to-surface munitions.
    - Look-down-shoot-down radars.
    - Precision navigation systems, especially the Global Positioning System.
    - Command, control, communications, computers, intelligence, surveillance, and reconnaissance systems necessary to fight an integrated battle and war.
2. Aside from stealth, many people argue that the F-35A does not provide major improvements over the F-16 and that in some important aspects (maximum speed and maneuverability), it is actually less capable.
3. These upgrades have included improved weapons; more advanced electronics and engines; further integration of sensors both on and between aircraft; improvements of command, control, communications, computers, and intelligence; and maintaining an increasingly aged aircraft fleet while fighting in multiple conflicts simultaneously.
4. The list of revolutions is as follows:
    - In advanced military combat aircraft, including stealth aircraft.
    - In support aircraft.
    - In remotely piloted air systems.
    - In precision-guided long-range missiles, including antiship ballistic missiles.

- In air defense.
- In antisatellite systems.
- In aircraft carriers.
- In manned space systems.

See Lt Col Thomas R. McCabe, *China's Air and Space Revolutions*, Mitchell Paper 10 (Arlington, VA: Mitchell Institute Press, 2013), http://higherlogicdownload.s3.amazonaws.com/AFA/6379b747-7730-4f82-9b45-a1c80d6c8fdb/UploadedImages/Mitchell%20Publications/MP10_China.pdf.

5. Office of the United States Air Force Chief Scientist, *Technology Horizons: A Vision for Air Force Science and Technology, 2010–30*, vol. 1, AF/ST-TR-10-01-PR (Washington, DC: Office of the United States Air Force Chief Scientist, September 2011), http://www.defenseinnovationmarketplace.mil/resources/AF_TechnologyHorizons2010-2030.pdf. More recent studies, such as *Global Horizons*, also show a lack of concentration on aeronautics. See Office of the United States Air Force Chief Scientist, *Global Horizons Final Report: United States Air Force Global Science and Technology Vision*, AF/ST TR 13-01 (Washington, DC: Office of the United States Air Force Chief Scientist, 21 June 2013), http://www.defenseinnovationmarketplace.mil/resources/GlobalHorizonsFINALREPORT6-26-13.pdf. Intriguingly, a briefing on the subject by Dr. Mark Maybury mentioned modularity and speed (not mentioned in the text) as air game changers but gave no specifics regarding efforts to pursue them. Briefing, Dr. Mark Maybury, subject: Air Force Global Horizons, 24 April 2013, http://www.dtic.mil/ndia/2013ST/Maybury.pdf. See also House, *Dr. David E. Walker, Fiscal Year 2014 Air Force Science and Technology, Presentation to the House Armed Services Committee, Subcommittee on Intelligence, Emerging Threats and Capabilities,* 113th Cong., 1st sess., 16 April 2013, http://www.defenseinnovationmarketplace.mil/resources/FY14_AF_ST-Testimony.pdf. In 2014 *America's Air Force: A Call to the Future* did not mention superior aircraft as a priority. See Deborah Lee James [secretary of the Air Force], *America's Air Force: A Call to the Future* (Washington, DC: Headquarters US Air Force, July 2014), http://airman.dodlive.mil/files/2014/07/AF_30_Year_Strategy_2.pdf. Finally, in early 2015, the Air Force's Scientific Advisory Board was concentrating on studies on quantum systems, cyber vulnerabilities, and remotely piloted systems. See Aaron Mehta, "US Air Force Launches Trio of Tech Studies," *DefenseNews*, 31 January 2015, http://www.defensenews.com/story/defense/air-space/air-force/2015/01/31/usaf-launches-study-trio-sab/22524543/. Analysis of future air warfare, both by the Air Force and the Defense Advanced Research Projects Agency (DARPA), also evidently does not expect much in the way of improved aircraft performance and capability. See Marc Schanz, "Rethinking Air Dominance," *Air Force Magazine* 96, no. 7 (July 2013): 36–39; and Graham Warwick, "No Silver Bullet," *Aviation Week* 175, no. 16 (20 May 2013): 52.

6. With the possible (but unlikely) exception of the Long-Range Strike Bomber, none of the Air Force's top modernization priorities (the F-35, KC-46 tanker, Long-Range Strike Bomber, E-8 Joint Surveillance Target Attack Radar System replacement, and the T-X trainer) extend the envelope on aircraft performance. See June L. Kim, "The Top Modernization Priorities Developing Airmen," *Air Force Magazine* 97, no. 11 (November 2014): 39–40.

7. The Navy claims to have three times as many airplane projects in production or on the drawing boards as the Air Force. However, an examination of the actual programs (three variants of the F/A-18, two variants of the F-35, the P-8 patrol aircraft [a redesigned Boeing 737], the V-22 tilt-rotor in production, a new-start advanced fighter, and a stealthy unmanned combat air vehicle in design) shows that the same pattern applies. See John A. Tirpak, "Navy Offers Airplane-Building Advice," *Air Force Magazine* 96, no. 8 (August 2013): 14.

8. These include active electronically scanned array (AESA) radars, which provide improved radar range, greater reliability and survivability, and some degree of detection capability against small targets like stealth platforms and cruise missiles; improved engines that might give aircraft somewhat longer operating ranges and somewhat better speed; improvements to stealth that are likely to concentrate on increasing the range of radar frequencies protected against and improving the ease of production and maintainability; and more capable, better integrated sensors and better computers that may, to a degree, help cope with the fog of battle, data overload, jamming, and hostile stealth.

9. James Drew, "USAF Nominates JASSM Missile to Host New Computer-Killing Weapon," Flightglobal, 14 May 2015, http://www.flightglobal.com/news/articles/usaf-nominates-jassm-missile-to-host-new-computer-killing-412348/. Note the "Suter" airborne network attack system reportedly used by the Israelis in their raid on the Syrian reactor site in the October 2007 CHAMP. See John Antal, "Ray

Guns and War," *Military Technology* 36, no. 8 (2012): 43; and David A. Fulghum and Douglas Barrie, "Israel Used Electronic Attack in Air Strike against Syrian Mystery Target," Aviation Week.com, 8 October 2007, http://abcnews.go.com/Technology/story?id=3702807&page=1.

10. John A. Tirpak, "Getting All Hyper," *Air Force Magazine* 98, no. 3 (March 2015): 18. For details on the tactical missiles, see Kris Osborn, "AF Chief Scientist: Air Force Working on New Hypersonic Air Vehicle," Defensetech, 1 June 2015, http://defensetech.org/2015/06/01/af-chief-scientist-air-force-working-on-new-hypersonic-air-vehicle/.

11. Wendell Minnick, "China Reveals New AMRAAM," *DefenseNews*, 23 May 2011, http://minnickarticles.blogspot.com/2011/05/china-reveals-new-amraam.html; and Richard Fisher Jr., "China's Emerging 5th Generation Air-to-Air Missiles," International Assessment and Strategy Center, 2 February 2008, http://www.strategycenter.net/research/pubID.181/pub_detail.asp.

12. Dr. Carlo Kopp, *The Russian Philosophy of Beyond Visual Range Air Combat*, Technical Report APA-TR-2008-0301, Air Power Australia, updated April 2012, http://www.ausairpower.net/APA-Rus-BVR-AAM.html; and "Russian Air Force Tests New Air-to-Air Missile," *Sputnik International*, 24 January 2012, http://en.rian.ru/russia/20120124/170929008.html.

13. "In the News: Missiles and Radars," *Beyond Defence* (blog), 11 September 2013, https://beyonddefence.wordpress.com/tag/rvv-bd/; and Bill Sweetman, "Cloak and Dagger," *Aviation Week* 175, no. 30 (2 September 2103): 29.

14. Kopp, *Russian Philosophy*.

15. Ibid.

16. Mike Hoffman, "Lockheed Test Pilot Calls for Longer Range AIM-120," Defensetech, 18 February 2014, http://defensetech.org/2014/02/18/test-pilot-calls-for-longer-range-aim-120/. It must be noted that the reported range for the AIM-120 varies widely and may depend on a variety of factors such as altitude of launch and speed of the launch aircraft.

17. Zach Rosenberg, "USAF Cancels AMRAAM Replacement," Flightglobal, 14 February 2012, http://www.flightglobal.com/news/articles/usaf-cancels-amraam-replacement-368249; Dave Majumdar, "AF Looks to Trim Procurement, R&D in 2013," *Air Force Times*, 13 February 2012, http://www.airforcetimes.com/article/20120213/NEWS/202130341/; and Amy Butler, "Next-Generation Fighter, Directed Energy Weapons May Converge," *Aviation Week*, 5 August 2014, http://aviationweek.com/defense/next-generation-fighter-directed-energy-weapons-may-converge.

18. Stephen Trimble, "In Focus: USAF Committed to Replace AMRAAM and HARM with New Missile," Flightglobal, 6 December 2011, http://www.flightglobal.com/news/articles/in-focus-usaf-committed-to-replace-amraam-and-harm-with-new-365333.

19. Douglas Barrie, "British Court Germany and France on FMRAAM Project," Flightglobal, 14 June 1995, http://www.flightglobal.com/news/articles/british-court-germany-and-france-on-fmraam-project-25672/; Dr. Gareth Evans, "Air-to-Air Missiles—Expanding the No-Escape Zone," airforce-technology.com, 11 April 2012, http://www.airforce-technology.com/features/featureair-to-air-missiles-expanding-the-no-escape-zone/; Wendell Minnick, "China Developing Counterstealth Weapons," *DefenseNews*, 31 January 2011, http://www.defensenews.com/article/20110131/DEFFEAT04/101310315/China-Developing-Counterstealth-Weapons; and Douglas Barrie, "Vympel Launches R-77 Ramjet from Su-27," Flightglobal, 5 July 1995, http://www.flightglobal.com/news/articles/vympel-launches-r-77-ramjet-from-su-27-21749/.

20. Richard Tomkins, "Raytheon Developing Extended Range AMRAAM," UPI, 24 February 2015, http://www.upi.com/Business_News/Security-Industry/2015/02/24/Raytheon-developing-extended-range-AMRAAM/5641424782276/.

21. See "NCADE: An ABM AMRAAM—Or Something More?," *Defense Industry Daily*, 20 November 2008, http://www.defenseindustrydaily.com/ncade-an-abm-amraam-03305/. See also "Exhibit R-2, RDT&E Budget Item Justification: PB 2013 Air Force" (U), February 2012, http://www.globalsecurity.org/military/library/budget/fy2013/usaf-peds/0604330f.pdf.

22. Baker Spring, "President Obama's Missile Defense Program Falls behind the Threat," Backgrounder no. 2686, Heritage Foundation, 3 May 2012, http://thf_media.s3.amazonaws.com/2012/pdf/bg2686.pdf; and Spring, "Congress Must Stop Obama's Downward Spiral of Missile Defense," Issue Brief, Heritage Foundation, 20 May 2013, http://www.heritage.org/research/reports/2013/05/congress-must-stop-obamas-downward-spiral-of-missile-defense. Neither have I been able to find any references to testing in the budget for fiscal year 2015.

23. Bradley Perrett, "Japanese Guidance," *Aviation Week* 176, no. 26 (28 July 2014): 27; and Perrett, "Japan Upgrading 60 F-2s with AAM-4, J/APG-2," *Aviation Week*, 27 February 2012, http://www.aviationweek.com/Article.aspx?id=/article-xml/AW_02_27_2012_p27-428848.xml.

24. Perrett, "Japan Upgrading."

25. See Amy Butler and Graham Warwick, "Power Circuit," *Aviation Week* 176, no. 5 (17 February 2014): 45; and Sydney J. Freedberg Jr., "The Biggest Thing since Silicon: Raytheon's Gallium Nitride Breakthrough," Breaking Defense, 20 February 2015, http://breakingdefense.com/2015/02/the-biggest-thing-since-silicon-raytheons-gallium-nitride-breakthrough/.

26. George C. Larson, "Cool Fuel," *Air and Space* 19, no. 3 (August/September 2004): 12. Some sources refer to a Russian T-6 fuel that is heavier than Russia's usual jet fuels, but no specifics are available as to its performance. Lori M. Balster et al, "Development of an Advanced, Thermally Stable, Coal-Based Jet Fuel," *Fuel Processing Technology* 89, no. 4 (April 2008): 366, http://www.sciencedirect.com/science/article/pii/S037838200700238X.

27. The author's estimate, confirmed by a pilot coworker, is that JP-900 has an improved energy density of about 6 percent. However, this improvement comes at the cost of slightly lower fuel performance and somewhat higher weight. Based on Balster, "Development," fig. 1.

28. Some sources report that JP-900 is too dense to be used in unmodified fuel systems. See ibid., 366.

29. Aaron Mehta, "Rapid Prototyping the New Model: Sikorsky's New Norm Saves Money, Time," *DefenseNews*, 31 October 2013, http://www.defensenews.com/article/20131031/DEFREG02/310310025/Rapid-Prototyping-New-Model.

30. See Andrew Chaikin, "Is SpaceX Changing the Rocket Equation?," *Air & Space*, January 2012, http://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation-132285884/.

31. Ibid. Meanwhile, the British are attempting to leapfrog this development with their Skylon single-stage-to-orbit vehicle.

32. Chad Trautvetter, "HyperMach Reconfigures SSBJ Design, Aiming for Mach 4.5," *AIN Online,* 6 December 2012, http://www.ainonline.com/aviation-news/2012-12-06/hypermach-reconfigures-ssbj-design-aiming-mach-45.

33. Admittedly, this is a big "if." Ambitious plans from a decade ago for supersonic business jets have so far come to nothing. See Stuart F. Brown, "Mine's Faster Than Yours," *Fortune*, 28 June 2004, http://archive.fortune.com/magazines/fortune/fortune_archive/2004/06/28/374394/index.htm. Evidently, such supersonic aircraft are not expected to reach the market until at least 2021. See Grant Martin, "The World's First Supersonic Business Jet Will Reach the Market in 2021," *Forbes*, 31 October 2013, http://www.forbes.com/sites/grantmartin/2013/10/31/the-worlds-first-supersonic-business-jet-will-fly-in-2021/.

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Col John Boyd's Innovative DNA

Col Houston R. Cantwell, USAF

Surprisingly, few Airmen have heard of Col John Boyd, and far fewer are aware of his innovative contributions to the advancement of modern-day airpower. As we consider what it means to be "fueled by innovation," I thought it appropriate to recognize an Airman who committed his entire career to innovation.[1] Although Boyd retired nearly 30 years ago, modern Airmen can learn from his success—we can identify the skills that truly fueled his innovation, develop them within ourselves, and spur our own creativity.

Boyd is most recognized for the development of his observe, orient, decide, act (OODA) loop decision-making process, now taught throughout professional military education. Arguably, his most important contribution to the advancement of airpower, however, was his 1970s energy maneuverability (E-M) theory, which revolutionized the study of fighter-jet dogfighting. His in-depth mathematical study of fighter aviation permitted, for the first time, an objective, science-based measure of an aircraft's maneuverability—a tool used almost daily at the US Air Force Weapons School. The theory identified which Soviet-built MiGs had a dogfighting advantage over our jets and vice versa. Given the context of the Cold War and the Air Force's disappointing air-to-air performance in Vietnam, this information was groundbreaking and important. But what character traits enabled Boyd's success? Borrowing from the book *The Innovator's DNA* by Jeff Dyer, Hal Gregersen, and Clayton Christensen, this commentary identifies the five traits of successful innovators and then determines how well John Boyd exemplified those traits.[2]

As Apple Computer's founder Steve Jobs put it, why do some people seem to "think different"? Why are some people more successful innovators than others? Dyer, Gregersen, and Christensen have developed an interesting hypothesis. They believe that five traits fuel innovators: *the ability to observe, associate, experiment, question, and network*.[3] Most importantly, if their theory is correct, then any advancement in developing these qualities should increase our own abilities to innovate. Not surprisingly, John Boyd demonstrated these characteristics in abundance.

He possessed keen observation skills. Boyd studied history, and following the Vietnam conflict, he was all too aware of the slipping kill ratios of American fighter pilots. Furthermore, as a highly respected Fighter Weapons School instructor pilot at Nellis AFB, Nevada, he spent countless hours maneuvering his F-100 jet in relation to numerous other fighter aircraft. He observed adroit pilots aggressively maneuvering their air machines against one another—simulated missiles and cannon fire streaking across the sky and downing the adversary. Other than pilot skill, though, no other attribute contributed to the explanation of why one aircraft outmaneuvered another. Boyd would not be able to explain his observations until he hung up his G suit and grabbed a scientific calculator.

While attending engineering courses at the Georgia Institute of Technology on a scholarship from the Air Force Institute of Technology, Boyd made an innovative association between science and flying jets. During his study of basic thermodynamic principles, he derived a mathematical equation to determine a jet's level of maneuverability based on basic information like thrust rating, aerodynamic drag, lift coefficients, and aircraft weight. His E-M theory codified what no scientist had before—certainly not your typical "knuckle-dragging fighter pilot."

Boyd committed himself to extensive experimentation to prove his new E-M theory. Verification of this complex hypothesis would require hundreds of hours of calculations by the most advanced computers available. Back in the 1960s, however, prior to the advent of the personal computer, access was very limited. Determined to prove his new theory, Boyd used his resourcefulness to gain much-needed computer access. In fact, some individuals almost considered a court-martial for what they characterized as "unauthorized" computer usage while he was stationed at Eglin AFB, Florida.[4] No one ever said that the path to innovation was an easy one!

One of Boyd's strengths was his ability to question everyone and everything around him. His E-M theory armed him to query things that few field grade officers would dare. As the Air Force wrestled with determining the capabilities of its future fighter aircraft, E-M theory gained credibility. Boyd could prove the inferior performance of advanced jets like the F-111 and F-14, compared to their Soviet counterparts. He used the theory to question the service's acquisition priorities and fought for the development of advanced fighters such as the F-15 and F-16—some people even credited him as the father of the F-16.

Throughout Boyd's career, he displayed expert networking skills. He loved to think out loud, often on the telephone to one of six trusted confidants during the wee hours of the morning. Over the years, he gained an affinity for calling his "acolytes" to solicit their perspective on his latest breakthrough. These men shared Boyd's passion for the truth and for doing what was right. Over time they began to share his goals and ideals. Through this trusted communication, Boyd refined his thoughts and prepared himself for the onslaught of disdain for his radical ideas outside his small circle of friends.

John Boyd was far from the ideal officer. He exhibited faults, some more exaggerated than most. Nevertheless, his strength lay in his ability to innovate, and he demonstrated the above-mentioned five traits linked to innovation. Modern Airmen should consider their own abilities in these important areas. Being "fueled by innovation" is more than a slogan. It is a commitment by all Airmen to spark their own creativity and develop these traits within themselves. In that effort, we can all learn from Boyd, celebrate his innovation, and further develop the innovator within each and every one of us.✪

Notes

1. Department of the Air Force, *The World's Greatest Air Force: Powered by Airmen, Fueled by Innovation—A Vision for the United States Air Force* (Washington, DC: Department of the Air Force, n.d.), http://www.osi.af.mil/shared/media/document/AFD-130111-016.pdf.
2. Jeff Dyer, Hal Gregersen, and Clayton M. Christensen, *The Innovator's DNA: Mastering the Five Skills of Disruptive Innovators* (Boston: Harvard Business Press, 2011).
3. Ibid., 41–156.
4. Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (Boston: Little, Brown, 2002).

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The (Honest) Truth about Dishonesty: How We Lie to Everyone—Especially Ourselves by Dan Ariely. HarperCollins Publishers (http://www.harpercollins.com/), 10 East 53rd Street, New York, New York 10022, 2012, 304 pages, $26.99 (hardcover), ISBN 978-0-06218-359-0; 2013, 336 pages, $14.99 (softcover), ISBN 978-0-06218-361-3.

Cheating is a scary word in a profession built on honor. Indeed, "Integrity First" is listed at the top of the Air Force's core values because of the fact that honor turns an Airman's daily work into a profession. Part of putting integrity first, though, involves understanding what drives people to put it somewhere else. Dan Ariely's *The (Honest) Truth about Dishonesty: How We Lie to Everyone—Especially Ourselves* asks questions designed to shed light on why cheating occurs. The result is a collection of surprising anecdotes about how frequently people cheat and what drives them to do so (thankfully, the incriminating evidence of our tendency toward cheating applies only to "other people," not the reader). The lessons of Ariely's book serve as a worthwhile aid to the Air Force's ongoing journey to put "Integrity First."

The author first asks whether the decision to cheat is based on a rational cost-benefit analysis. The Simple Model of Rational Crime (SMORC) assumes that humans evaluate whether to cheat by comparing a payoff with the likelihood of getting caught and the expected punishment. To test SMORC's accuracy, he gave students at the Massachusetts Institute of Technology (MIT) a "matrix quiz" that asked them to solve a series of math problems in five minutes. The problems were not difficult; however, they were time consuming, and the time allotted was not sufficient to solve them. Students were paid for each correct answer. Under the "noncheating" condition, students turned in their answer sheets once time expired. Under the "cheating" condition, students were asked to shred their answer sheets before reporting their number of correct answers. They could report as many correct responses as they desired and not be caught in a lie.

Although the students had an incentive to cheat (a payout for correct answers) and no expected cost (they shredded the evidence themselves), they did not cheat as much as they could have. Under the noncheating condition, the students averaged 4 correct problems out of 20. Under the cheating condition, however, they reported seven correct answers on average. This increase was not the result of a few "bad apples" who claimed 20 out of 20 correct but the fact that almost everyone claimed to have completed a few more than the average under the noncheating condition.

This pattern held even as Dr. Ariely changed the payout for a correct answer. Some variations of the study paid as little as $.25, and others, as much as $10. Contrary to the SMORC model, cheating actually *decreased* slightly at the highest payout amounts.

As an alternative explanation to SMORC, Ariely proposes an identity-based model for cheating, summarized in this question: Can you look yourself in the mirror after cheating and still count yourself honest? He labels the extent to which we can cheat and maintain our honest identity as a "personal fudge factor." Here he asks another simple question: How do we shrink the fudge factor?

Ariely asked a group of students to recall the Ten Commandments prior to taking the matrix quiz while he asked another group to recall 10 books they had read in high school. He found that *regardless of the person's religious beliefs*, the act of recalling the Ten Commandments before the quiz eliminated cheating. Recalling 10 books from high school had no effect. The reminder that morality mattered to the students, in the moment before the quiz, was enough to eliminate cheating.

He found the same to be true of honor statements. With groups of students at MIT and Yale, he included a signing statement with the quiz: "I understand that this experiment falls under the guidelines of the MIT/Yale honor code." Students not asked to sign cheated the standard amount, but those who signed did not cheat at all. Given that MIT and Yale *do not have honor codes*, he found these results surprising. Again, the act of reminding students that an ethical guideline applied to the quiz seemed to be all that was necessary to prevent cheating.

This "moral reminder" effect, however, was limited to the moment before the quiz. Ariely compared the effects of an honor statement with those of an in-depth honor-education course for first-year Princeton students. Waiting until two weeks after the honor code training concluded, Ariely administered his test. He found that the thorough education at Princeton had no effect on how much students cheated. The ethical training was not fresh enough in the students' minds to change their behavior.

This last experiment is cause for examining our own service's education of Airmen in the core values. The intense honor education of Princeton could be equivalent to the weeks-long education of basic military training or commissioning education. The two-week break in Ariely's experiment could be equivalent to the break between a training environment and the operational Air Force. Whereas training environments schedule time for discussing the core values, they may fade from the front of our minds in the operational Air Force because we focus on accomplishing the mission. As we find ourselves further removed from discussions of integrity's importance in the profession of arms, rationalizing dishonesty may well become easier for us. For "Integrity First" to remain an authentic statement for our service, discussing the core values should become part of regular operations.

The (Honest) Truth about Dishonesty is filled with other lessons as well. Ariely's list of questions asks what effect supervision has on cheating and how fatigue affects the decision to cheat, each of which could inform Air Force leaders. "Integrity First" is not a statement of fact but an ideal toward which we strive. Successfully making the journey depends on an understanding of integrity, ourselves, and the relationship between the two. *The Honest Truth about Dishonesty* is mental fuel for the journey.

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Open Skies: Transparency, Confidence-Building, and the End of the Cold War by Peter Jones. Stanford University Press (http://www.sup.org), 425 Broadway Street, Redwood City, California 94063-3126, 2014, 264 pages, $50.00 (hardcover), ISBN 978-0-8047-9098-7.

The Open Skies Treaty was negotiated at a turbulent time when the USSR and Warsaw Pact fell apart and the Western world was declared the de facto winner of the Cold War. With the treaty's ratification and eventual implementation in 2002, the countries of the North Atlantic Treaty Organization (NATO), the former Warsaw Pact, and several nonaligned European nations entered into a regime of cooperative aerial monitoring that would improve the transparency of the region while introducing measures of confidence building which would assure that each state met its numerous treaty obligations. Development and ratification of the Open Skies Treaty, however, was a long and arduous process that had to overcome major hurdles, including radical changes in the structure and personnel of the Soviet and then Russian governments, acrimonious disagreements among NATO members, and the unavoidable struggle between Greece and Turkey over the status of Cyprus. Despite these complications, the nations reached compromises that allowed Open Skies to succeed.

Readers should not be fooled by the book's title. It is much less an account of the Open Skies Treaty and its implementation than it is a behind-the-scenes look at the details of treaty negotiation between major powers and smaller nations. *Open Skies* will be of great value to anyone who deals with negotiations or agreements of an international nature. Author Peter Jones does an excellent job of supplying in-depth details and analyses of the two-year process of developing and ratifying the treaty. At the same time, he fairly explains the contrasting viewpoints of the significant parties and how they were eventually overcome or resolved.

The book progresses chronologically, offering lessons and recommendations at the end of each chapter. Chapter 1 goes back six decades, examining the first proposal of cooperative aerial monitoring made by President Eisenhower at the beginning of the Cold War. The next seven chapters give a thorough account of each round of Open Skies negotiations, from inception to final approval by the convention. They cover the reintroduction of the idea by President George H. W. Bush and the US government, the championing of the concept by Canada and Hungary, the stalling of the talks as the USSR crumbled and was replaced by numerous governments with new interests, and, finally, the compromises made by both sides on key issues, which led to the final agreement and eventual ratification. As Jones explains each major event, be it negotiation or interim period, he highlights key issues that arose as well as the delegates' strengths and weaknesses in dealing with them. More importantly, at the end of each chapter, the author comprehensively analyzes the period and outlines specific lessons for any future treaty negotiations.

In the final chapter, Jones, unlike most political scientists, looks beyond analyses of past treaty negotiations, offering recommendations and considerations for practitioners. Specifically, he argues that the Open Skies concept is ripe for exportation to regions of conflict as a means of promoting stability, verification, and confidence. Cooperative aerial monitoring provides assurance measures that each party involved in the struggle is complying with all treaty and agreement requirements. Further, Jones postulates that such an approach can be used to monitor the proliferation of weapons of mass destruction or even environmental concerns.

Readers learn that Open Skies owed its success to the top-down political direction followed by the various governments involved in the treaty. Otherwise, most government agencies had neither the willingness nor power to successfully negotiate Open Skies. In this context, the possibility of expanding the treaty beyond its current application remains highly unlikely unless some brave senior leaders come forward and champion the cause.

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The War For Korea, 1950–1951: They Came from the North by Allan R. Millett. University Press of Kansas (http://www.kansaspress.ku.edu), 2502 Westbrooke Circle, Lawrence, Kansas 66045-4444, 2010, 816 pages, $59.00 (hardcover), ISBN 978-0-7006-1709-8.

The Korean War transformed the post–World War II contest between the Soviet Union and the United States from one of advancing distrust to an arms-race death pact that appeared to drown out the possibility that the second half of the twentieth century would be less conflicted than the first half. Although a number of histories have situated and addressed the place of the Korean War in the larger context of world and political-diplomatic history, a notable paucity of practiced attention has been paid to the essential military aspects of the conflict. In this area Millett carries out his duty with aplomb, calling into question not only the vicious first year of the war but also how the military consequences of that year goaded decision makers in Washington. With great exactness, Millett proceeds in his effort.

The author begins by predictably grounding his account in the larger milieu of Korean and international politics that set the stage for the multinational war that would consume the peninsula. In so doing, however, he offers an unpredictable assessment that the Korean War was an extension of a Korean civil war that had been in progress since the partitioning of the country in 1945, and by arms since 1948, as much as it was a conflict between compliant proxy states—as the orthodox argument holds. With the proper training and research, most professional historians could understand this conclusion and, given the needed time and perspective, tease it out of the historical record. Millett, however, is not a typical historian in this regard. Having undertaken extensive and evident research in support of his effort, Millett offers a revisionist assessment that is both striking and unexpected; it is also effective.

Much like the oft-applied term *9/11* in the United States, South Koreans typically refer to the invasion from the north as the *6.25 War*. Similar to the September 2001 attacks, the 1950 invasion is remembered as a national tragedy that drew South Koreans together more than it ever did to unify the partitioned totalitarian north and nominally democratic south. Why this attack became known as a catastrophe of epic proportions among the South Korean people becomes immediately evident in Millett's passages. He relates the smashing North Korean surprise attack, enabled by numerous and lethal Soviet arms, and the resulting defeat it initially dealt the Republic of Korea Army—as well as the American advisors assigned to it. Thus Millett brings to life the environment in which a palpable sense of fear developed among American leaders that a larger Communist onslaught was a very real possibility. Standing in the present with the clarity of over 60 years of history to inform contemporary sensibilities, one finds it challenging to discharge the sense of doubt that can readily cloud the once plain emotions and motivations of the past. Millett's work makes it impossible to walk away from this conflict without accepting the once clear sense of fear as quite real and the Western responses to it as justified. In so doing, Millett tacitly reminds readers of the prescience of military history and why it cannot be relegated to the back shelves of popular history or fringes of academic discourse.

As is often the case with many military histories and historians, there is a tendency toward fixation upon the role of military hardware and "order of battle" analysis. Millett fares much the same as his brethren in this way. However, unlike many of his less-grounded colleagues, Millett turns this tactical approach into a strategic lesson that should not be glossed over: there are winners and losers in war, and the winners tend to be better equipped and better prepared. It becomes clear, in the long run, however, that the West was more ideologically, doctrinally, and technologically prepared than its counterparts in the Communist bloc. This advantage, nonetheless, would not be readily apparent in the 1950–51 period covered by Millett.

Ultimately, the author offers several consistent conclusions, most notably within the chronological confines of the present study. The success of the South Korean state would not be dependent upon the ability of the outside world to defend it but would be a responsibility of the Republic of Korea Army. It is difficult to dissent with the author on this account—or with his conclusion regarding General MacArthur's relief by President Truman and the failure of Communist forces to unite the Korean peninsula under a singular and like-minded regime by mid-1951. Given his evidence, the logical approach to marshaling these facts into arguments, and the confluence of these ideas into a singular narrative, Millett's conclusions are likely to stand the test of time.

The specific facts, arguments, and conclusions of this book aside, Millet is known as a sterling scholar for the very same reasons that reside in this work: it is fluidly delivered and introduces the reader to a terrible war with a level of cogency seldom found elsewhere.

Though a father to some flaws, those transgressions are but specks against a larger canvas that readily finds success on a macro scale. Pulling few—if any—punches, Millett's work should have strong appeal to scholars of twentieth-century political-diplomatic and military history alike, as well as among those political, diplomatic, and military professionals who can consider Korea and its history an important aspect of their duties. A dense read for those that do not have a particular scholarly or professional need to engross themselves in such a study, undertaking a read of this scope might, nonetheless, inform the average American as to why the United States continues to post troops in the region—and why that effort remains an important one.

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On Limited Nuclear War in the 21st Century edited by Jeffrey A. Larsen and Kerry M. Kartchner. Stanford University Press (http://www.sup.org/), 425 Broadway St., Redwood City, California 94063-3126, 2014, 312 pages, $90.00 (hardcover), ISBN 978-0-8047-8912-7; $27.95 (softcover), ISBN 978-0-8047-9089-5.

On Limited Nuclear War in the 21st Century reopens scholarly debate on the potential for, the unique challenges related to, and US government preparedness to deter and win limited nuclear war. In a well-crafted argument, Jeffrey Larsen and Kerry Kartchner's team of scholars presents a compelling argument that questions the US government's preparedness either to successfully deter or achieve national security objectives in the event of a limited nuclear war.

Using Cold War history as a backdrop, the volume explains the major theoretical elements in deterrence, assurance, extended deterrence, conflict management, and war termination. It then applies these elements to the changing nuclear landscape. As nuclear weapons proliferate to less powerful states, the same mechanisms that made the Cold War stable between the United States and Soviet Union cease to exist between America and the new nuclear powers. Given the decreasing number of tactical nuclear weapons appropriate for nuclear wars with limited objectives and the dearth of serious discussion in the government on theory and strategies for such a war, the United States finds itself ill prepared to deter or fight a limited nuclear war, despite its tremendous nuclear arsenal. Consequently, America may discover that its strategies to assure allies and offer extended deterrence to encourage some states to forgo nuclear weapons are less effective than it imagined.

The book could not be timelier. The US government and population are coming to grips with the reality of nuclear weapons in the hands of states that they do not trust to act in the same rational way as the Soviet Union and its successor, modern Russia. The prospect of states such as Iran and the Democratic People's Republic of Korea possessing nuclear weapons is leading the United States to spend billions on missile defenses to protect against possible attacks. *On Limited Nuclear War* recognizes that defense may be insufficient to deal with the challenges presented by "rogue" nuclear states, especially in the realm of assurance to allies and extended deterrence.

The second strength of this book is the presentation. The editors have created a clearly written book whose text flows smoothly and logically across the three major parts and chapters, as if composed by a single author rather than 11 experts in the field. Both novice and expert alike can easily follow its theory, history, prediction, and assessment.

If there is a failing in *On Limited Nuclear War*, it is not readily apparent. The book effectively reopens critical debate on the future of nuclear weapons and the more likely scenario of a nuclear war initiated by rogues to realize limited objectives. Military leaders serving in the nuclear ranks should certainly read it, as should individuals aspiring to become general officers, regardless of service or specialty, and those interested in the nuclear enterprise. The book will also prove instructive to politicians, their staffers, think tanks, and others who assist in the development of nuclear policy, including the president. Everyone who delves into the pages of *On Limited Nuclear War* will enjoy this important narrative.

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Billy Mitchell's War with the Navy: The Interwar Rivalry over Air Power by Thomas Wildenberg. Naval Institute Press (http://www.usni.org/navalinstitutepress), 291 Wood Road, Annapolis, Maryland 21402, 2014, 304 pages, $34.95 (hardcover), ISBN 9780870210389.

Billy Mitchell's War with the Navy by Thomas Wildenberg examines the crucial arguments, ideas, and rivalries that shaped US airpower policy during the 1920s–30s and continue to influence modern airpower thought and theory. The author, a historian specializing in naval aviation development, delivers a balanced account of the ideas, people, and events that prompted the airpower debate in the interwar period. The book seeks to give readers of any service or background a richer understanding of Gen William "Billy" Mitchell's role as a leader, theorist, and airpower advocate during a period when airpower theory greatly outpaced technology.

Focusing on Mitchell's actions between World War One and World War Two, Wildenberg appropriately bases his initial analysis on the protagonist's background, rise through the Army, and historic accomplishments during World War One. The author chronicles those achievements as well as Mitchell's historic encounters with the Royal Air Force's Hugh Trenchard following the war, which, according to Wildenberg, molded the American's vision of an independent Air Force. After documenting Mitchell's rise, Wildenberg's analysis shifts to an examination of both his methods and ideas. Mitchell's primary focus on costal defense following World War One placed him in direct conflict with the Navy; however, his advocacy for an independent Air Force infuriated the Army as well.

His desire for an independent service had both a political and public dimension. Mitchell's background gave him unusual access to political leaders in Congress who heard his arguments for Air Service funding and autonomy. Perhaps more important, his connections created a public venue to voice his notions at critical junctures in the interwar airpower debate. Public opinion became Mitchell's greatest weapon in his war with the Navy and, ultimately, the Army.

The best of Wildenberg's analysis is the contrast between public perception and the realities of airpower events—most notably the sinking of the captured battleship *Ostfriesland*—that serve as monuments to the creation of the US Air Force. Other costal defense tests, the US Navy's failure to conduct a nonstop flight to Hawaii, and the crash of the airship USS *Shenandoah* also greatly influenced the public's perception of airpower. Wildenberg superbly documents the details of each event designed to determine the effectiveness of airpower in costal defense, giving equal weight to the facts of the test or exercise, public perception, and Mitchell's interpretation. Simply put, the author is masterful in his simultaneous presentation of airpower's perception and reality in the interwar period. Perception and public opinion culminated in the court-martial of General Mitchell in December 1925 and his resignation in January 1926. Wildenberg briefly documents the trial and chronicles the next series of tests and events in the debate over coastal defense.

Billy Mitchell's War with the Navy offers excellent reading for practitioners of airpower theory because it highlights the gap between that theory and the technological reality that persists today. Ultimately, none of the tests conducted in the interwar period conclusively proved Mitchell's theories regarding costal defense and an independent Air Force. The technology of that time prevented the demonstration of decisive airpower sought by Mitchell. However, his influence in Congress and the battle for public perception successfully established the conditions for an independent Air Force on which advocates such as Mason Patrick and Henry Arnold could capitalize. This book provides a fair chronicle of Mitchell as a skillful airpower theorist and an adroit politician. Wildenberg presents a well-written account of the development of airpower theory in a highly politicized environment framed by constrained defense budgets. Consequently, the concepts presented in *Billy Mitchell's War with the Navy* are as critical to the nation's defense today as they were nearly a century ago.

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US Guided Missiles: The Definitive Reference Guide by Bill Yenne. Crécy Publishing (http://www.crecy.co.uk/), Unit 1a Ringway Trading Estate, Shadowmoss Road, Manchester, M22 5LH, England, 2012, 160 pages, $34.95 (hardcover), ISBN 9780859791625.

In *US Guided Missiles*, author Bill Yenne first takes the reader through a brief yet informative history regarding the development of guided missiles, beginning in World War II and culminating with more recent developments. He expends a good deal of energy explaining the evolution of the designation system and provides a handy chart for deciphering the current naming convention (p. 15). Offering additional context to the study, Yenne educates readers about the interaction and rivalry that pervaded the Army, Navy, and Air Force during the development of these weapons. His description is both informative and useful in understanding the reasons for the various designations used prior to the eventual adoption of the current naming convention.

As an Air Force targeteer at heart, this reviewer was intrigued to read the various histories and factoids for each of the guided missiles. They are easily referenced in numerical order along with a nine-page index that enables a reader to quickly find a specific missile (p. 246). Furthermore, the author's writing style enhances the usefulness of this guide to missiles in the US inventory: "By June 1965, all of the Atlas ICBM fleet had been retired, but the Atlas continued to evolve as a launch vehicle for boosting spacecraft into orbit. . . . The Atlas was also used for all of the orbital flights of NASA's Mercury manned spaceflight program, beginning with John Glenn's February 1962 mission in Friendship 7" (p. 50). Yet another interesting aspect of Yenne's work involves the multiple accounts explaining the activation, and in many cases the deactivation, of military guided-missile units. The author astutely observes the propensity of the Department of Defense to develop and deploy weapons for the defense of the nation, only to mothball them because of the expense of keeping the missiles operational.

Although Yenne provides sufficient cross-references for the historical data, the same cannot be said of the missile specifications. He omits sources for each data point but does include a bibliography. Nevertheless, this lack of adequate sourcing and detailed specifications for every missile variant makes it difficult to cross-reference the information provided. A comparison of Yenne's data with that available in several Jane's reference books (e.g., *IHS Jane's Weapons, Naval 2012–2013)* reveals multiple discrepancies. However, in many cases the numbers were close, allowing for differences in sourcing. In a few instances the ranges were off by upwards of 900 kilometers or more, possibly because the specifications were assigned to the wrong variant.

Additionally, the book is littered with typographical and editing errors. For example, one finds hard returns in locations where there should be none (p. 40), duplicated words (p. 56), and terms misspelled or replaced with the wrong word (pp. 69 and 89). However, such instances of poor editing are not an insurmountable obstacle and can be easily corrected in subsequent editions.

In the final analysis, *US Guided Missiles: The Definitive Reference Guide* is a useful text, filled with pictures, offering numerous interesting facts and figures. In this reviewer's opinion, though, it is neither comprehensive nor definitive. It provides a remarkable historical background and some basic facts for a given guided missile but does not include exact ranges or specifications. Because the book is pleasant and entertaining, it would be a welcome addition to the library of a military history buff or budding airpower professional. However, readers seeking a detailed reference guide for analytical research should look elsewhere.

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An Introduction to Military Ethics: A Reference Handbook by Bill Rhodes. Praeger Security International (http://www.abc-clio.com/Praeger.aspx), ABC-CLIO, P.O. Box 1911, Santa Barbara, California 93116-1911, 2009, 165 pages, $44.95 (hardcover), ISBN 978-0-313-35046-7.

In the last decade, military ethics has inspired a number of opinions and has come under much debate during the global war on terrorism. The subject raises the question of what constitutes a just war and how a state might rightly conduct such a thing. According to Miguel Alzola, "Since the late eighteen century, just war theory has been separated into two parts, *jus ad bellum*—which concerns the justice of resorting to war in the first place—and *jus in bello*—which concerns the justice of conduct within war after it has begun" ("The Ethics of Business in Wartime," *Journal of Business Ethics* 99, no. 2 [2011]: 62).

Author Bill Rhodes confronts adversaries as well as the 2,500-year legacy of just war theory by demonstrating how acts of terrorism by nonstate participants require a new theory and a fresh way of thinking about the justifiable use of armed force. Furthermore, he analyzes how new and emerging theories may alter the fundamental identity of traditional military forces. A scholar and lecturer, Rhodes conducts research and observes developments in professional ethics for the company Aerworthy Consulting. He also serves as director of the International Society of Military Ethics, a nonprofit organization. Rhodes holds several important positions in both the private sector and nonprofit organizations, providing consulting services in the field of military ethics.

The author notes that "military ethics works in a specialized problem space tied tightly to political philosophy, history, and psychology. Influences from all of these characterize the field, helping to define its limits and contributing depth. Its jurisdiction is further characterized and enriched by the nature of military service itself and the functional requirements that nature imposes on military members" (p. 49).

The book "provides an overview of the moral challenges faced by military members. In a practical world of military life, there is no adequate substitute for honest assessments, wise judgments and committed, competent, action" (p. 1). It includes eight well-organized, well-written, enriching, and engaging chapters. Chapter 1 introduces the fundamental concepts of applied ethics, which enhance the philosophical groundwork for framing the practical issues; chapter 2 examines the literature on the Western just war tradition from its inception to the present; chapter 3 explores the importance of military life, military members, and the "use of military force in the name of a political community" (p. vii); chapter 4 addresses ethical aspects of the resort to armed forces in the contemporary arena; chapter 5 conveys the conduct of armed hostilities and the ethical structures of the rules of warfare; chapter 6 notes emerging controversies as well as challenges confronted by modern militaries, setting the stage for humanitarian intervention and dealing with terrorism; chapter 7 addresses cultural issues in the modern military as well as the integration of women and religion into the military; the final chapter evaluates the necessity of addressing professional identity for the modern military. Clearly, chapters 3–6 are the most powerful ones in the book.

The author conveys the concerns and innovative thought required to advance the comprehension and appreciation of military ethics among the populace and the armed forces as well as the business community. He makes excellent use of realistic, applicable examples derived from his research and recognizes the contributions of previous research on virtue theory, consequentialism (utilitarian theory), deontological theory (rights theory), and military training communities. Rhodes clearly communicates the paramount concerns of military ethics within military leadership along with the influence of the global community.

The author highlights the responsibility and obligations of military members and the problems they encounter during both war and peace. Although he does not offer a specific list, the core element of responsibilities and obligations rests on the premise that "an obligation to help cannot justify overriding the rights of others" (p. 17). Moreover, these responsibilities and obligations may be altered by agreements "as some members of a community freely take on obligations that they otherwise would not have" (p. 17). No one has to become a service member; however, if someone does indeed assume the responsibility to perform a certain duty, it becomes an obligation to serve and protect. Rhodes observes that "military people occupy a special place in society. . . . They enjoy privileges and bear burdens that, taken together, form a unique sociological landscape accompanied by equally unique ethical issues" (p. 50). Today, military ethicists are challenged—not with making the right decisions but with doing the right thing at the right time. These issues are associated with concerns of "anticipatory strikes, aid to third parties including political communities that do not enjoy status as full-blown states, and terrorism" (p. 84). The nobility of military service is the moral act of giving oneself to protect and serve for those less able.

A pillar of the commitment of ethics, Rhodes's work reinforces the merits of value for both the armed forces and external communities. In the final chapter, he brings to the reader's attention that military training environments emphasize professionalism and "typically convey the message that 'being professional' is an ethical obligation" (p. 148). He further ascertains that "the question is not whether a military member ought to 'be professional,' but rather just what professionalism means" (p. 148). The caveat of this activity in which obligation is developed and deployed is neither separate from nor ancillary to commitment and responsibility. Nor is it neutral. Rather, it is an integral part of what is actually practiced in wartime as well as peacetime.

An Introduction to Military Ethics is enriching and informative. This reviewer highly recommends it to individuals working in the discipline of ethics, specifically military ethics. Advocates of military policy and compliance, along with lecturers on military leadership and academic researchers, are likely to benefit from Rhodes's exemplary contributions, as are those who embrace the opportunity to enhance the dynamics and practice of global ethical behavior.

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Pursuit of Power: NASA's Propulsion Systems Laboratory No. 1 and 2 by Robert S. Arrighi. NASA History Program Office (http://history.nasa.gov/publications.html), 300 E Street SW, Washington, DC 20546, 2012, 185 pages, $23.23 (softcover). Free download available at http://www.nasa.gov/pdf/696956main_PursuitPower-ebook.pdf.

Research and development (R&D) is risky business. The prospect of creating a laboratory to test technology that does not yet exist and for which we do not know the performance is just one aspect of this risk. However, most people do not realize that money spent on R&D in the early stages of acquisition is the least costly and most valuable investment in the life cycle of any major weapons system. This lesson is just one of many to be reaped from Robert Arrighi's *Pursuit of Power*, the latest addition to NASA's series of historical publications that documents the rise and fall of its namesake—Propulsion Systems Laboratory No. 1 and 2. Written with great attention to detail and the product of exhaustive research, the book, which includes extensive bibliographic and photographic reference material, will certainly become the authoritative source on the subject.

In 1950 "there was pressure to trim the federal deficit and reduce spending on research and development" (p. 13). Additionally, the Korean War diverted much of the defense spending. In this austere environment, the labs were built, and their history begins. Clearly, the labs, the programs they supported, and the fiscal environment in which they survived have much in common. That air and space leaders faced these challenges in the 1950s should immediately highlight the relevance of this story.

The astute reader will find anecdotal evidence of many important issues that existed then, just as they do now, and strategies for coping with the problems we now face. Examples include R&D and its effect on military readiness, high-demand/low-density test assets and resources, integrated test strategies, and the importance of industry cooperation.

R&D and acquisition make up one command in the US Air Force, but the price tag for acquiring a new weapons system almost always makes the headlines. In reality, costs for operation and maintenance far outweigh the initial investment. The *Pursuit of Power* presents a case for making these investments and outlines a strategy for doing it successfully. The Propulsion Systems Lab at NASA Glenn Research Center in Cleveland, Ohio, served the purpose for which it was created and adapted to changing times, technology, and requirements with great flexibility and efficiency. Many notable Air Force aircraft and even some domestic and foreign civil platforms were powered by engines tested there. Government, industry, and military leaders facing the challenges of our future and of our Air Force would do well to study the leaders presented herein, the problems they faced, and the decisions they made.

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