U.S. Air Dominance in a Fiscally-Constrained Environment:
Defining Paths to the Future

Intelligence, Surveillance and Reconnaissance

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Introduction

The United States has enjoyed global air dominance for many decades. No U.S. soldier on the ground has been killed by hostile aircraft since the Korean War, and no U.S. pilot in the air has been killed by hostile aircraft since the Vietnam War.[1] U.S. air dominance has been preserved by pouring vast amounts of money into technology and training, far surpassing the efforts of other nations. The scale of this funding was driven by an awareness of how crucial air dominance was to other facets of warfighting, plus the fear that a few mis-steps might result in America losing its edge in the air.

However, since the Cold War ended, modernization efforts in the Air Force and Navy -- the main providers of U.S. air dominance -- have lagged. Plans to replace Air Force bombers, tankers and reconnaissance aircraft were canceled or delayed, while programs to recapitalize tactical air fleets in both services were repeatedly restructured. In addition, efforts to develop next-generation intelligence, navigation, communication, missile-warning and weather satellites have fallen far behind schedule. As a result, the joint inventory of fixed-wing aircraft and orbital systems enabling air dominance has aged considerably. Unmanned aircraft are an exception to this trend, but their utility in contested airspace is unproven.

While modernization of airborne and orbital assets was lagging, the global threat environment changed. China emerged as the world's second-largest economy, pursuing regional security objectives with increasing vigor. Rogue states of varying stripe developed weapons of mass destruction and the means to deliver them. Non-state actors with extreme agendas were empowered by the proliferation of new military tools and techniques. And the focus of global security shifted from technologies in which only a few countries could play, such as long-range ballistic missiles, to technologies in which many players could develop deep expertise.

If recent trends persist, the United States will gradually lose its claim to global air dominance. That claim is already being challenged in the Western Pacific, where a scattered and aging U.S. air fleet is faced with growing Chinese investment in new aircraft and air defenses. When China's increasing military might is combined with its intrinsic geographical advantages in the region, the possibility arises that America may cease to be the dominant air power in what has become the industrial heartland of the new global economy.[2] Similar outcomes could occur in other regions, because with recent advances in surface-to-air missiles, multi-spectral sensors, tactical networks and other military systems, it is no longer necessary to match every aspect of U.S. air power in order to defeat it.

With all that in mind, the Lexington Institute embarked on a year-long inquiry into the requirements for maintaining U.S. global air dominance. The inquiry focused on the four core components of air dominance: intelligence, surveillance & reconnaissance; air superiority; long-range strike; and mobility. In each area, the inquiry sought to understand the current force structure and modernization programs being funded, and then identify gaps in future capabilities that need to be addressed. It also examined alternative approaches to satisfying operational requirements, and explored how those alternatives might be implemented in varying fiscal circumstances. A series of working groups and studies were conducted in support of the final report, to be issued in Spring of 2013.

The present study is about intelligence, surveillance and reconnaissance -- typically referred to among air-power practitioners as "ISR." Timely, precise insights into enemy actions and intentions have always been valuable in warfare, but with the coming of the information revolution they have assumed overriding importance because there are now so many options for collecting, analyzing and exploiting relevant data. Air power provides a unique perspective on modern warfare, because there are some features of military activity that can only be captured from above. Airborne ISR also generates information essential to the deterrence of aggression, the enforcement of arms-control treaties, and the prevention of nuclear proliferation. In a world of rapidly changing technology and diverse threats, constant vigilance is a necessary cost of preserving the peace, and providing that vigilance is an overarching mission of the nation's air forces.

Current Force Structure

Intelligence, surveillance and reconnaissance (ISR) is a rubric used by the joint force to describe all activities associated with collecting, integrating, analyzing, disseminating and exploiting militarily relevant information about other nations and non-state actors. It includes not only the secret information collected by technical means and human agents, but also open-source intelligence gleaned from places like the Internet. Practitioners often distinguish between strategic ISR that is of interest to national agencies or multiple military services, and more perishable tactical intelligence that is only of use to particular fighting units in specific circumstances, but there is no clear dividing line between the two areas. Whatever the nature of the information, a complete ISR system necessarily includes collection systems for acquiring raw data, hardware and software for fusing the data into a meaningful picture, analytic tools for interpreting that picture, and networks for moving the processed information to potential users in a timely fashion.

Every military service operates ISR systems, but the service with the widest array of systems -- especially for acquiring strategic intelligence -- is the Air Force. It is the lead military service for space programs, including secret photo-reconnaissance and signals-intelligence satellites that provide unique insight into adversary actions and intentions. It also operates over a hundred manned aircraft dedicated to intelligence, surveillance and reconnaissance roles such as the E-3 Sentry radar plane and U-2 spy plane, and about 250 high-end unmanned aircraft equipped to provide various types of reconnaissance.[3] All of the tactical aircraft it operates in combat roles have some potential to collect ISR, and that capability has reached a high level of precision in the most recent, "fifth-generation" fighters it is currently acquiring. Beyond its various airborne and orbital assets for performing ISR missions, the Air Force also operates a global network of ground-based sensors that provides early warning of missile attacks and monitors developments in space.

This report is focused mainly on the manned airborne ISR assets of the Air Force and (to a lesser extent) the Navy, for two reasons. First, manned aircraft are the most versatile components of the ISR force. Although there are some circumstances in which orbital, ground-based or unmanned airborne systems are uniquely suited to ISR needs, those systems are often limited in value by their operational characteristics. For example, a reconnaissance satellite close enough to the Earth's surface to collect fine details will pass over areas of interest relatively quickly, and then be out of range for most of its orbit; in order to dwell above specific locations, it must be parked in a geosynchronous orbit 23,000 miles from the surface. Manned aircraft afford much greater flexibility in acquiring vital intelligence.

A second reason for focusing on manned aircraft is that the Air Force has made major progress in modernizing and diversifying the other collection systems it operates. After long delays in developing next-generation intelligence satellites, every one of the National Reconnaissance Office's major spacecraft programs is now on schedule.[4] The same is true of missile-warning and communications satellites being developed by the Air Force's less secretive Space and Missile Systems Center. Additional progress had been made in upgrading ground-based sensor networks and fielding a robust family of reconnaissance drones. However, there has been much less progress in modernizing the most versatile part of the ISR force structure, the manned aircraft. Although the Navy is moving forward with replacements for its two most important manned ISR aircraft, the Air Force lacks a plan for modernizing its more diverse fleet.

The core of the Air Force's manned ISR fleet consists of 31 E-3 Sentry Airborne Warning and Control System (AWACS) radar planes, 16 E-8 Joint Surveillance and Target Attack Radar System (JSTARS) aircraft, and 17 RC-135 Rivet Joint signals-intelligence planes. The airframes for all of these planes are based on the same 1954 design that Boeing used to develop the 707 jetliner, as are the airframes of nine more specialized ISR planes the Air Force operates for analyzing hostile radar and missile characteristics, monitoring arms-control treaty compliance, and detecting nuclear tests. The Air Force purchased 800 military versions of the 707 designated the C-135 during the 1950s, 1960s and 1970s for use as aerial-refueling tankers, flying command posts and ISR planes. The current inventory of ISR aircraft based on the C-135 airframe is displayed in the following table.[5]

Air Force 707/C-135 Based ISR Aircraft				
Designation	**Number in Fleet**	**Mission**	**Flight Hours Annually**	**Average Age**
E-3 AWACS	31	Wide-area surveillance of airspace	19,000	35 years
E-8 JSTARS	16	Wide-area surveillance of surface areas	12,200	45 years
RC-135 Rivet Joint	17	Signals intelligence collection & analysis	13,800	49 years
RC-135S Cobra Ball	3	Ballistic missile collections & analysis	1,200	50 years
RC-135U Combat Sent	2	Hostile radar collections & analysis	640	48 years
OC-135 Open Skies	2	Treaty compliance verification	1,500	50 years
WC-135 Constant Phoenix	2	Nuclear test detection	650	50 years

Jet aircraft of this vintage are not fuel-efficient by today's standards, and exhibit numerous age-related maladies such as metal fatigue, corrosion and parts obsolescence. The Air Force recognized these problems over a decade ago and developed a plan to replace Cold War ISR planes with a military version of the Boeing 767 transport -- the same airframe selected recently to serve as its next-generation aerial refueler. However, the ISR recapitalization plan was canceled in 2007 due to disagreements about how future missions should be performed. The Air Force currently has no plan for replacing ISR planes based on the 707/C-135 airframe.

The AWACS planes in the current fleet average 35 years of age, the JSTARS planes average 45 years, and the planes based on the Rivet Joint configuration are approaching 50 years. Projections of remaining service life are suspect because the Air Force has little experience with operating jet aircraft that are over half a century old. Air Force sources have told the Lexington Institute that once the 707/C-135 fleet begins to suffer age-related safety issues, it will probably decline quickly and become prohibitively expensive to maintain in a high state of readiness. That process may have already commenced, with up to a third of the fleet unavailable for missions on some days.

One manned ISR aircraft the Air Force operates that is not based on the old 707 airframe is the U-2 spy plane, a high-flying, single-engine reconnaissance aircraft that provides the greatest surface-tracking sensor range of any non-orbital collection system. The 32 U-2s currently in the Air Force fleet are capable of simultaneously collecting various types of imagery, signals intelligence and air samples, and because of their high-altitude flight features can be employed in circumstances that might be too dangerous for other manned ISR aircraft. The U-2's airframe and onboard electronics have been repeatedly upgraded to extend its service life and operational utility -- so much so that the Air Force now proposes to forgo an unmanned successor and keep the planes flying for two more decades.[6]

In addition to its manned ISR aircraft, the Air Force operates a growing fleet of unmanned surveillance and reconnaissance drones categorized in three “tiers” of progressively greater capability. The unmanned air systems that have proven to be of greatest value to the joint force are the medium-altitude, long-endurance vehicles in Tier Two -- the MQ-1 Predator and MQ-9 Reaper -- and the high-altitude, long-endurance vehicles in Tier Three. The best-known Tier Three unmanned systems are very-long-range RQ-4 Global Hawks, although the service also operates more secret systems with similar performance features such as the stealthy RQ-170 Sentinel.

The Air Force currently sustains about 250 Tier Two and Tier Three unmanned systems, mainly to conduct ISR missions. The Reapers are also used to attack surface targets. The ability of high-end unmanned air systems to loiter over areas of interest for long periods has made them invaluable in waging war against terrorists and insurgents, leading some proponents to argue that the Air Force should put more of its investment dollars into unmanned systems in the future. However, non-traditional adversaries such as terrorists typically lack air forces and air defenses, so it is not clear how unmanned aircraft might fare in military campaigns against more traditional, state-based adversaries. The current inventory of Air Force Tier Two and Tier Three unmanned systems is displayed in the following table, except for secret programs such as the RQ-170 where details are not publicly available.[7]

Air Force Unmanned ISR Aircraft			
Designation	**Number in Fleet**	**Ground Control Stations**	**Mission**
RQ-4A Global Hawk Block 10	9	3	ISR
RQ-4B Global Hawk Block 20/30	15	3	ISR
RQ-4B Global Hawk Block 40	1	1	ISR/Battle Management
MQ-1 A/B Predator	161	61*	ISR/Target Acquisition
MQ-9 Reaper	54	61*	ISR/Target Acquisition/ Precision Strike

*Shared by Predator & Reaper

The Air Force is the primary provider of intelligence, surveillance and reconnaissance to the joint force. However, all of the services operate their own ISR systems, and some of the Navy's airborne collection systems are of particular importance to joint war plans. One such system is the P-3C Orion, a land-based turboprop aircraft that conducts anti-submarine and anti-surface warfare. The Navy operates 12 squadrons of P-3Cs equipped in their primary mission configuration, with nine aircraft in each squadron. The planes carry a variety of undersea sensors and weapons, plus a radar for tracking moving surface targets at sea and on land. The service has begun replacing Orions with the P-8A Poseidon maritime patrol aircraft, a militarized version of the Boeing 737 jetliner equipped for conducting the same missions. It plans to eventually acquire 117 of the next-generation aircraft. The surface-tracking radar on the Poseidon matches or surpasses the performance of that on the Air Force's E-8 JSTARS.[8]

The Navy is also purchasing a version of the Air Force's high-altitude, long-endurance Global Hawk unmanned aircraft designated the MQ-4C Triton that will supplement Orion and Poseidon in the maritime-surveillance role; it is expected to enter service in 2015, with a total of 40 airframes likely to be procured. The service has not decided yet what to do about replacement of 11 EP-3 Aries signals-intelligence aircraft derived from the Orion airframe. The Aries aircraft play a vital role in places like the Western Pacific collecting and analyzing potentially hostile communications traffic, however a joint Army-Navy program to develop a successor was canceled in 2006. Lack of a next-generation aircraft has implications beyond the Navy's tactical needs, since the EP-3 also conducts eavesdropping missions for the National Security Agency.

A final airborne ISR asset operated by the Navy is the carrier-based E-2C Hawkeye radar plane, which performs many of the same missions as the Air Force's land-based AWACS planes. Each carrier air wing includes four or five Hawkeye turboprops, which in their latest configuration can track 2,000 airborne targets to distances of over 400 miles while simultaneously coordinating a hundred intercepts. The E-2C is being upgraded with a "D" variant featuring advanced radar, communications and computing technology that greatly enhances its capacity to collect, analyze and share information. Production of the E-2D commenced in 2010, and is an integral part of

Navy plans to strengthen the defenses of seaborne forces as potential adversaries field improved anti-ship capabilities.[9]

Future ISR Requirements

The intelligence, surveillance and reconnaissance activities of the joint force unfold within a complex organizational framework. Sometimes the collections of particular units and systems are only of interest to warfighters engaged in local operations, but the trend since 9-11 has been to integrate all information into databases accessible to diverse users. This reflects the amorphous nature of emerging threats and the unprecedented potential of new information technologies for manipulating and interpreting vast amounts of data. The combination of novel threats and novel technologies has produced a revolution in intelligence gathering and warfighting that some practitioners characterize as a "data-centric environment" -- in other words, an operational setting in which information processes are more important than particular systems or organizational constructs.

This represents a major shift from the Cold War years that spawned the modern intelligence community, when threats were relatively stable and specific communities of collectors and analysts tended to be isolated by security concerns. The compartmented structure of the intelligence community back then was a response to prevailing security conditions, but it proved to be a hindrance once the nation became engaged in fighting non-traditional threats. The familiar metaphor of a stovepipe in which parallel information flows do not converge until they reach the top of the national-security structure illustrates what was wrong with the old approach once unconventional threats emerged: it denied many potential users of timely access to information outside their geographical and functional areas of responsibility. As policymakers have come to understand the varied and unpredictable nature of threats in the new era, they have sought to remove barriers that impeded the sharing of information.

Much of the burden for adapting to new needs has fallen on the Air Force, the service that historically devoted the most resources to collecting intelligence, reconnaissance and surveillance beyond its own narrow tactical needs. The Air Force is the lead service for all aspects of military space, and thus has played a central role at the National Reconnaissance Office (which develops and operates spy satellites) since its inception. Similarly, the Air Force's fleet of manned ISR planes has served the needs of national agencies and policymakers from the earliest days, collecting air samples to confirm Russian nuclear tests, eavesdropping on eastern bloc communications, and collecting imagery on the movement of ground assets from Cuba to Indochina. Other services made vital contributions, for example through the Navy's use of its attack submarines for collection of signals intelligence, but the Air Force has always been the dominant player in joint-force collection and interpretation of ISR.

So it isn't surprising that among the various military services, the Air Force has by far the most sophisticated infrastructure for processing, exploiting and disseminating vital information in a timely fashion. The centerpiece of this system in recent years has been the Distributed Common Ground System (DCGS), a global network for fusing and interpreting ISR collections from the U-2 spy plane and remotely-piloted aircraft like the RQ-4 Global Hawk. DCGS consists of five core centers and dozens of subsidiary operating sites scattered around the world for rapidly exploiting ISR collections, all of them supported by an "information backbone" designed to facilitate the sharing of information. The DCGS network is continually reviewed and upgraded as new requirements and capabilities are identified. Most of the recent upgrades have focused on enhancing integration of multi-source collections and furthering interoperability among diverse users.[10]

Despite ongoing improvements to DCGS and other systems, internal studies conducted by the Air Force during 2011 and 2012 have identified a series of major shortfalls that must be remedied in order to meet the future intelligence, surveillance and reconnaissance needs of the joint force. The most pressing requirements can be grouped under five themes: ability to operate in contested air space, timely integration of diverse data, creation of a more robust network and communications architecture, recapitalization of aging manned aircraft, and reorganization of the ISR community to better utilize emerging capabilities.[11]

Contested air space. The joint force has spent the last dozen years fighting elusive adversaries who lacked aircraft and air defenses. That has enabled it to rely heavily on remotely-piloted aircraft in conducting ISR missions. However, Air Force leaders believe the service is now over-invested in collection systems requiring "permissive" air space to operate -- systems that might not fare well in conflicts with more capable enemies. A key requirement for the future identified in recent studies is the acquisition of ISR aircraft capable of surviving in contested air space, meaning air space defended by integrated surface-based air defenses and/or fighter-interceptors. The service's primary emphasis in defining this emergent requirement seems to be on utilizing stealthy "fifth-generation" fighters as ISR collectors and exploiters, although unmanned aircraft with low-observable features such as the RQ-170 Sentinel might also be suitable. F-22 Raptor and F-35 Lightning II fighters combine the requisite survivability with sophisticated on-board sensors, and therefore will likely play a central role in satisfying the requirement for ISR systems that can operate in contested air space.

Greater integration. At its inception in the early years of the Cold War, the military's ISR network was so compartmented that even collections from satellites in the same constellation sometimes were not integrated. That deficiency was gradually corrected over time as users came to see the value of fusing information from multiple sensors, but it was not until the information revolution began in the 1990s that software tools could be developed for quickly merging diverse collections into a comprehensive picture of all available reconnaissance. The overseas military campaigns that followed 9-11 created an urgent demand for such tools because elusive adversaries were so hard to detect and track, but they also resulted in the fielding of many non-standard systems not fully connected to the joint ISR system. Thus Air Force leaders see an urgent requirement to integrate information originating in diverse domains and locales in order to benefit fully from the all the capabilities that have been acquired. That means fusing radio-frequency, infrared and optical collections from across the electromagnetic spectrum, regardless of whether they were obtained using orbital, airborne or surface-based sensors.

Robust networks. During the Cold-War era, policymakers and analysts typically thought of joint ISR activities as an assortment of signature collection "platforms" associated with particular missions. In today's data-centric environment, though, the networks that move and manipulate information collected by these various sensor platforms are the heart of the ISR system, the vital enablers that facilitate fusion, analysis and timely action. Air Force leaders believe that their current networking and communications architecture is too immature to handle the volume of collections coming from fielded sensor systems, and that developing a more robust network is thus the top technological requirement facing the ISR community. Among the features most needed in an enhanced network architecture would be greatly increased carrying capacity ("bandwidth"), comprehensive integration of multi-source intelligence, easy access for remote users, and reliable protection against enemy interference, interception or penetration. Although the hardware and software tools needed to create such an architecture already exist, developing a global network that can deliver the full value of fielded and prospective ISR systems to a diverse population of users would be a very challenging task.

Fleet recapitalization. As noted in the previous section, the manned aircraft in the Air Force's ISR fleet are aging fast, and some may soon become either too expensive or too dangerous to keep in service. There appears to be division among senior Air Force leaders as to how severe this problem is, but on one score there is no disagreement: aging airframes are expensive to maintain. They are so expensive, in fact, that sustaining a high state of readiness for the heavily-used fleet is impeding the service's ability to buy replacements. At some point, high utilization rates will collide with the inexorable processes of metal fatigue, corrosion and parts obsolescence to create a crisis in the ISR community. Past experience indicates that once aging-aircraft problems reach a "tipping point" fleets decline fast, and the Air Force would be hard-pressed to work around loss of vital assets such as the RC-135 Rivet Joint eavesdropping aircraft. Therefore, timely recapitalization of aging manned aircraft has frequently been cited by Air Force leaders as a key requirement for meeting the future needs of warfighters. The Air Force had a plan for accomplishing that end using modified commercial transports a decade ago, but the plan was canceled and no successor has emerged.

Organizational change. The U.S. intelligence community has been drastically reorganized since the 9-11 attacks in order to foster greater sharing of information across previously isolated domains. However, Air Force leaders believe that the current organization of their own ISR community is still not optimized for making best use of emerging capabilities. That isn't surprising, because many new capabilities such as the Gorgon Stare wide-area surveillance system have only reached the force in the last few years. A recent study by the RAND Corporation noted that, "When the operations in Afghanistan and Iraq began, only a handful of Air Force assets capable of delivering motion imagery were deployed in theater; now they number in the hundreds."[12] Initially, Air Force managers tried to assimilate these new capabilities into the existing organizational structure, but as they proliferated it became clear that prevailing arrangements weren't well-suited to exploiting their full potential. Despite several attempts at reorganization beginning in 2006, some Air Force insiders believe that a more comprehensive overhaul is still needed. One shortfall frequently cited is lack of mechanisms for encouraging collaboration with intelligence organizations outside the Air Force.

Modernization Plans

Despite the importance of airborne ISR collections and analysis to joint warfighting capabilities, efforts to modernize the relevant parts of the Air Force fleet have been repeatedly frustrated since the Cold War ended. The lack of progress can be attributed to four broad factors. First, the focus of security concerns shifted from highly capable, state-based adversaries to stateless insurgents and terrorists, provoking disagreement among policymakers as to the proper military responses. Second, the parallel emergence of numerous new technologies potentially useful to intelligence collection, analysis and exploitation added to the confusion, confounding efforts to fashion a stable framework for ISR activities. Third, other mission areas such as global strike and air superiority often eclipsed ISR needs in the competition for funding. And fourth, the aging fleet of imagery, eavesdropping and radar planes proved both durable and adaptable in the face of new challenges, diminishing any sense of urgency about recapitalizing antique airframes.

These factors help explain why an ambitious plan to recapitalize much of the ISR fleet designated the E-10 Multi-Sensor Command and Control Aircraft was canceled in 2007. The E-10 would have replaced AWACS, Joint Stars and Rivet Joint with a militarized version of the Boeing 767 widebody commercial transport configured in three variants. The 767 was the same airframe that the Air Force was planning to use for its next-generation aerial-refueling tanker, and thus the plane would have enabled sustainment efficiencies across the fleet similar to those afforded by use of the legacy C-135 aircraft for diverse missions. However, the high cost and complexity of the E-10 program made it controversial. Some policymakers felt that in the future more of the ISR mission burden could be carried by space-based assets; others believed that unmanned aircraft offered the most cost-effective solutions; still others argued for downgrading the role of high-cost "platforms" entirely in favor of a networked architecture of distributed collection systems. Whatever the merit of these ideas may have been, they collectively deprived the E-10 of the support it needed to survive.[13]

More recently, the Air Force has sought to cancel the most common version of the high-altitude, long-endurance RQ-4B Global Hawk unmanned aircraft that had been expected to replace the U-2S Dragon Lady beginning in 2015. At its inception, Global Hawk was viewed as emblematic of a revolution in the collection of intelligence, surveillance and reconnaissance, substituting a very long-range, high-capacity drone for more traditional manned ISR aircraft. However, Air Force planners came to view the Global Hawk as too expensive to build and operate in an austere budget environment, and therefore moved to retain the U-2S in service through 2040. Plans to terminate the so-called Block 30 version of Global Hawk met with strong resistance in Congress, though, where legislators were incredulous that the U-2S could perform as well as Global Hawk in the vast distances of the Pacific Basin. Block 30 airframes currently remain in the fleet pursuant to congressional direction and the Air Force still plans to operate other versions of Global Hawk as well, but the status of the program at this point is perhaps best described as unsettled.[14]

The end result of these various machinations is that the Air Force now plans to fly the world's most sophisticated ISR sensors and analytic tools on some of the world's oldest airplanes for the foreseeable future. The planes are not necessarily old in the sense that they are structurally deficient -- they all have many thousands of hours in flight time remaining before they must be retired -- but they were designed in the 1950s at a time when fuel efficiency and maintenance costs were not the issues they have become today. New aerospace technologies such as composite materials and low observables ("stealth") were unheard of at the time, and in most cases cannot be retrofitted onto fielded airframes. Thus, the Air Force's modernization plan for the ISR fleet today consists mainly of equipping old planes with new on-board electronics -- sensors, processors, datalinks, etc. This approach will likely deliver diminishing returns as airframes continue to age.

The Air Force's U-2S Dragon Lady program demonstrates how careful maintenance and continuous upgrades can extend the useful life of ISR aircraft far beyond original expectations. The initial U-2A version of the plane debuted in the 1950s, but it was redesigned in the 1960s to provide a 40 percent increase in airframe dimensions. In subsequent decades the plane's engine was replaced with the same propulsion system used on the B-2 bomber, its cockpit was digitized, and its electrical system was rewired to deliver more power to on-board sensors while minimizing electromagnetic interference. Despite an average service life of 45 years, the U-2S airframes in the current fleet have expended less than a quarter of their certified flight hours, and thus could continue operating to the end of the century at prevailing utilization rates.

From an ISR perspective, the most important features of U-2S performance are the ability to operate at a 70,000-foot altitude (higher than Global Hawk) for ten hours, achieving ranges in excess of 6,000 nm. High altitude enables the plane's 5,000 lbs. of sensors to collect diverse imagery and signals intelligence over distances that no other manned ISR aircraft can match, in effect combining the flexibility of an air-breathing platform with the reach of a reconnaissance satellite. In recent years, the Air Force has gradually upgraded each of the sensors the plane is capable of carrying, which include signals-intelligence systems carried in pods on each wing and various imagery collectors mounted in the fuselage. All of the sensors are tasked remotely by the Distributed Common Ground Station network, and with one exception (a wide-angle wet-film camera) can transmit their collections to troops on the ground or more distant consumers using high-speed datalinks. The latest upgrades are focused on boosting pilot productivity by enhancing aircraft habitability and demonstrating hyper-spectral sensing capabilities.[15]

The E-8C Joint Surveillance and Target Attack Radar System presents a less positive story. The 16 JSTARS planes in the current fleet are unique in the world, using sophisticated radar technology to track moving surface targets and collect imagery -- even in adverse weather conditions, when the effectiveness of other types of sensors would be impaired. This information is especially useful to ground forces that are literally or figuratively trapped in the "fog of battle." For instance, during the 2003 military campaign in Iraq, JSTARS was able to find the location of enemy armored vehicles in a raging sandstorm, enabling friendly forces to precisely target them without harming nearby combatants. However, all of the JSTARS planes are refurbished commercial jetliners that exhibit numerous age-related deficiencies, most notably in the high fuel consumption of their ancient engines. On-board radars lack the resolution of newer surface-tracking radars, and must interrupt tracking of ground targets to collect imagery.

The Air Force had plans a decade ago to replace the JSTARS system, and now seems reluctant to invest heavily in upgrading the aging airframes. A program to install new engines that would be

17 percent more fuel efficient while delivering greater thrust and more electrical power for on-board systems has been repeatedly delayed. The service spent a billion dollars to develop technology that could enhance radar resolution five to ten times in order to track a wider range of targets, and then decided not to install it (the same technology will be used on a version of the Global Hawk unmanned aircraft, but cannot deliver the same precision due to smaller aperture dimensions). And none of the solutions proposed so that target tracks can be maintained while imagery is collected have been implemented.

The Air Force conducted an analysis of alternatives in 2011 which concluded the optimum path forward for the JSTARS mission area would be to integrate a "fourth-generation" radar on a high-end business jet such as the Gulfstream 650, since this would correct both airframe and sensor deficiencies with a platform that is cheaper to maintain. However, Air Force leaders have frankly admitted that they do not have the financial resources needed to implement that option. An alternative approach would be to adapt the aircraft-radar combination being used for the Navy's P-8A Poseidon patrol aircraft as a JSTARS successor, since that program greatly surpasses the current Air Force platform in operating efficiency and radar performance. With so many costly modernization efforts already under way, though, Air Force leaders seem disinclined to invest heavily in a mission area that mainly benefits other services. The ground-moving-target mission area thus looks likely to be neglected for years to come, with potentially fatal consequences.[16]

As with JSTARS planes, the RC-135V/W Rivet Joint signals-intelligence fleet is a "low-density/high-demand" asset originally conceived to perform functions very different from those it has undertaken in Southwest Asia since 9-11. For most of the program's history, Rivet Joint aircraft -- there are 17 in the active inventory today -- flew near Eastern Bloc borders intercepting radio-frequency signals potentially useful in helping the West to win the Cold War. Today, though, they have been adapted to non-traditional "sigint" missions such as combating insurgent use of improvised explosive devices in Afghanistan. This has required a wholesale revision in training and operating practices, with a greater premium placed on providing timely reconnaissance to forward-deployed ground forces. The military does not disclose details about how such missions are executed, but they appear to have necessitated continuous upgrades of on-board receivers, processors, datalinks, displays and other electronic equipment.

In addition to these mission-related upgrades, RC-135s have seen their engines replaced, their cockpit instrumentation digitized, and a variety of other modifications made to keep aging airframes safe and affordable. Air Force planners estimate that the fleet can continue flying through 2040, given the intensive maintenance that the planes receive every four years. Sustaining vintage C-135 airframes is somewhat easier in the case of Rivet Joint than JSTARS, because RC-135s have been Air Force assets throughout their service lives rather than being acquired as second-hand aircraft and refurbished in mid-life. The most important publicly-disclosed modernization move currently being implemented is to provide each Rivet Joint with a high-capacity uplink to the Wideband Global Satcom that would facilitate greater connectivity with deployed forces. Traditionally, Rivet Joint intelligence collections would be interpreted by on-board or remote analysts before reaching forces in the field, but with enhanced connectivity it becomes feasible to share time-sensitive information more quickly with ultimate users. Experts say that the satellite link and other improvements will greatly bolster the productivity of the RC-135 fleet.[17]

Unlike in the case of JSTARS and Rivet Joint, the E-3 Sentry Airborne Warning and Control System fleet has not been under pressure from non-traditional mission requirements since 9-11. The terrorists and insurgents who have preoccupied U.S. warfighters since 9-11 do not have air forces, and thus the 33 planes in the AWACS fleet have largely continued to do what they did in prior years. That consists first and foremost of monitoring vast expanses of air space for threats, and then providing battle management of friendly aircraft if engagements are necessary. The Air Force has gradually introduced new technology such as the Global Positioning System and digital datalinks into the E-3's as it became available in a series of "block" upgrades typically accomplished during scheduled depot maintenance of the airframes.

The biggest upgrade in the history of the program is currently under way, aimed among other things at replacing mission computers originally installed in the 1970s. The "Block 40/45" upgrade will include new mission software and a variety of other enhancements aimed at reducing the workload of on-board personnel. In addition, new datalinks will facilitate the integration of information collected by the plane's radar with collections from various off-board sensors, and the flight deck will be digitized (resulting in a reduction of crew size from four to three personnel). The entire AWACS fleet should be upgraded to the new standards by 2020, barring delays imposed by austere fiscal conditions. The Air Force is also contemplating replacement of the engines on each E-3 with modern turbofans that could provide 19 percent greater fuel efficiency. Although the operational savings from using newer engines are sizable given their lower fuel needs and higher reliability, integrating the engines onto airframes built decades ago is often costly. Thus, a decision to "re-engine" the AWACS fleet would probably signal that the Air Force does not expect to replace the planes for at least two decades. AWACS planes currently average 35 years of age compared to 45 years for JSTARS and nearly 50 years for Rivet Joint.[18]

With the exception of its JSTARS planes, the Air Force has done an adequate to exemplary job of upgrading its manned ISR fleet to extend the life of airframes and incorporate new technology. When the various enhancements of the manned fleet are combined with progress in expanding its inventory of unmanned reconnaissance aircraft and exploiting unprecedented volumes of information, the case can be made that Air Force ISR capabilities are in good shape. Additional investment in networking technology is needed to process and share all the information currently being generated by traditional and non-traditional collection systems, but service leaders recognize that fact and have made network modernization a top investment priority. Against this backdrop, the most troubling aspect of the service's current modernization agenda for ISR is that it may not be adequate if a shift in military strategy requires increased effort in areas where unmanned systems have diminished value. The Obama Administration's Asia-Pacific posture unveiled in early 2012 may be a harbinger of just such a shift, migrating U.S. military operations to a theater of operations where Predators and Reapers are less useful due to the defensive capabilities of potential adversaries.

Of course, the joint force has other capabilities that can be brought to bear in such places, from reconnaissance satellites to naval aircraft and submarines to the intelligence organizations of regional allies. Although it is difficult to gauge the contribution of overhead assets, undersea warships and naval aviation to joint ISR efforts, the evidence suggests that contribution is quite extensive. On the other hand, there are some kinds of ISR collection and analysis that only the Air Force's fleet of U-2s and C-135 derivatives can carry out, so the advanced age of that fleet is rightly a source of concern. As noted earlier in this study, Air Force experts believe that once airframes reach the limits of their endurance due to aging processes, their safety and affordability tends to decline rapidly. It thus is possible that the availability of key Air Force ISR systems may be impaired at precisely the time when the insights they generate are most needed. A prudent course of action would be to begin planning for the recapitalization of the manned ISR fleet now, rather than hoping that no crisis will arise. However, recapitalization would require billions of dollars that service leaders do not anticipate having for the foreseeable future.

Options & Alternatives

The U.S. Air Force received a budget of $163 billion in fiscal 2012, which means it spent more money on sustaining and exercising global air dominance in that year than any other nation except China spent on its entire military establishment. The high level of U.S. military spending that has persisted since the onset of the Cold War -- with five-percent of the world's population currently generating nearly 50 percent of global military expenditures -- is the main reason why the Air Force has been able to accumulate an extensive and diverse portfolio of ISR assets. However, the proposed Air Force budget for fiscal 2013 was eight billion dollars less than the previous year, and not coincidentally the inventory of aircraft was projected to decline by roughly five-percent (from 5,587 to 5,341 planes).[19]

Simply stated, the Air Force and other military services have begun the same sort of fiscal contraction seen when wars ended in the past, aggravated this time by an unprecedented gap between federal tax receipts and outlays. The resulting budget deficit means there is little prospect of stabilizing the funds available for air-power programs until overseas threats give political leaders a reason to rethink their fiscal priorities. In this environment, the Air Force does not have the option of seeking budget increases to address shortfalls in ISR capabilities. It must find a way of meeting joint intelligence, surveillance and reconnaissance needs within budgets that at best will be flat, and quite possibly will be declining in terms of actual buying power.

Against that backdrop, Air Force leaders essentially have four options for addressing ISR requirements. First, they can stay on the path the service already is following, selectively modernizing legacy assets while initiating no major new program starts. Second, they can reprioritize service missions to free up money for ISR by reducing outlays in other areas. Third, they can seek low-cost solutions to ISR shortfalls that enable early recapitalization of key assets within projected budget constraints. Fourth, they can rethink the architecture of current ISR activities, evolving to a different way of doing business that satisfies core collection and analysis requirements in new ways.

The first course, staying on the present path of selective modernization, will tend to deliver diminishing results over time. The existing inventory of manned ISR aircraft was acquired mainly for countering the Soviet Union during the Cold War, and the fleet of unmanned ISR drones was acquired mainly for prosecuting the global war on terror; current Air Force assets thus may not be optimized for dealing with emergent threats, particularly if they come from countries like China that can defend their air space and match the U.S. in relevant technologies. Beyond the changing threat landscape, there is the simple reality that metal fatigue and corrosion are taking an inexorable toll on aging aircraft -- a toll that will eventually make them either too expensive or too unsafe to keep in service. Thus, while the Air Force's current approach to maintaining its ISR fleet fits within prevailing fiscal constraints, the absence of a plan for replacing key systems could make the joint force increasingly vulnerable in the years ahead.

The second course, freeing up money by reprioritizing missions, would be difficult to justify given the lack of investment in new fighters, tankers, bombers and rotorcraft since the Cold War ended. Airlift is virtually the only mission area that has been generously funded in recent years, and even there the service still has much to accomplish. Moving money out of long-range strike, aerial refueling, or combat search and rescue in order to accelerate the pace of ISR enhancements would merely shift the Air Force's operational challenges from one part of the service to another. Proponents of those other mission areas will argue that their contributions are vital in wartime too, and that the service has over-invested in some ISR systems such as unmanned drones. The argument can also be made that new penetrating fighters and bombers have the potential to generate intelligence and reconnaissance in a way that traditional ISR platforms cannot, so slowing their acquisition may actually be detrimental to the force's overall ISR capabilities.

The third course, finding low-cost solutions that enable early recapitalization, is an attractive option but it requires Air Force planners to think differently about how they allocate their budgets. Traditionally, the up-front cost of acquiring new ISR systems has been dealt with separately from the cost of sustaining those systems once they are in service. The illogic of this approach is reflected in the fact that the Air Force is currently precluded from acquiring more fuel-efficient, maintainable aircraft because the cost of sustaining legacy planes is so high. A more integrated approach to life-cycle management would recognize the false economies in putting off recapitalization to keep legacy planes flying. The acquisition cost of new ISR planes could be covered relatively quickly by the savings they generate in operations and maintenance, but because budgeteers compartmentalize acquisition and sustainment, they can't take advantage of such solutions. For instance, recapitalizing the current fleet of four-engine C-135 variants with twin-engine 737 derivatives would save more money over time in operations than it costs to buy the new planes.

The final course of action would be a wholesale reconceptualization of the ISR architecture -- one in which both requirements and the means of meeting them are rethought with an eye to improving efficiency across the mission area. Air Force leaders have already begun that process as they think through how a more robust network for integrating, analyzing and exploiting information from diverse sources might be implemented. Productivity in the Air Force's ISR system is uneven today; in some areas the service is collecting much more intelligence than it can analyze; in others, its collections are inadequate to meet joint needs. The prevailing view among service leaders is that this problem cannot be fixed without a new architecture that includes at its core a network capable of moving and fusing vast volumes of data. Of course, a data-centric architecture can't by itself resolve the challenge of aging airframes and vulnerable drones, but having a network capable of assimilating everything that is collected is the centerpiece of any long-term solution for reconciling operational requirements with available resources.

The Navy faces a simpler task in modernizing its own airborne ISR assets for the future, because it has fewer joint responsibilities in that arena. The P-8A Poseidon patrol aircraft, E-2D Advanced Hawkeye radar plane, and MQ-4C Triton surveillance drone will provide the next generation of warfighters with big gains in situational awareness and operational effectiveness, but they are oriented mainly to Navy needs. For the foreseeable future it is the Air Force that will provide the vast preponderance of airborne intelligence, surveillance and reconnaissance needed by the joint force and national command authorities in wartime, so it is there that policymakers must focus if they are to assure that America preserves global air dominance for future generations.

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[1] The last fatal attack by hostile aircraft on U.S. ground forces occurred on April 15, 1953. See Peter Grier, "April 15, 1953," *Air Force Magazine*, June 2011, page 54. Many U.S. pilots have been downed in combat since the Vietnam War, but none by hostile aircraft.

[2] Numerous studies of Chinese military trends have been published in recent years by the U.S. government and private research organizations. For an up-to-date assessment, see Ashley J. Tellis and Travis Tanner, editors, *Strategic Asia 2012-13: China's Military Challenge*, National Bureau of Asian Research, Washington: October 2012.

[3] Current inventory numbers and performance specifications for all manned and unmanned aircraft operated by the U.S. Air Force can be obtained at www.af.mil/information/factsheets/ unless the airframes are highly classified.

[4] Tony Capaccio, "U.S. Spy Satellite Chief Says Programs Now on Schedule, Cost," Bloomberg News, September 15, 2011. The federal government does not disclose inventory numbers or performance specifications for its reconnaissance satellites, all of which are highly classified.

[5] The chart is adapted from a briefing prepared by the Boeing Company in 2012. All of the data displayed on the chart can be derived from information available at www.af.mil/information/factsheets/ and the relevant Wikipedia entries.

[6] Dave Majumdar, "Plans for reinvigorated U-2 include hyperspectral sensor," *C4ISR Journal*, March 2012.

[7] Data in the unmanned aircraft chart were current as of mid-2012. Inventory numbers for remotely-piloted aircraft fluctuate due to new deliveries and operational attrition, factors that seldom come into play for manned ISR aircraft.

[8] See Loren Thompson, *P-8A Poseidon: A New Model For Military Procurement*, Lexington Institute, Arlington, VA: October 2010.

[9] Current inventory numbers and performance specifications for all manned and unmanned aircraft operated by the U.S. Navy can be obtained at www.navair.navy.mil/index.cfm

[10] George I. Seffers, "Improving Intelligence Interoperability," *Signal Magazine* online, May 21, 2012, www.afcea.org/content/; see also, Michael C. Sirak, "ISR Revolution," *Air Force Magazine*, June 2010.

[11] Much of the information in this section is derived from comments made at a Lexington Institute ISR Working Group held in Arlington, VA on September 28, 2012.

[12] Lance Menthe, Amado Cordova, Carl Rhodes, Rachel Costello, Jeffrey Sullivan, *The Future of Air Force Motion Imagery Exploitation*, RAND Corporation Project Air Force, Washington: 2012.

[13] "E-10A: She's Dead, Jim," *Defense Industry Daily*, October 25, 2010, at www.defenseindustrydaily.com/e10a-shes-dead-jim-3139/

[14] Ben Iannotta, "Will Congress Overrule the White House on Key ISR Programs?," *Defense News*, June 5, 2012.

[15] "U-2 High Altitude Reconnaissance Aircraft," at www.airforce-technology.com/projects/u2/ ; see also, U-2S factsheet at www.af.mil/information/factsheets/

[16] Maggie Ybarra, "JSTARS AOA Concludes That Pricey Biz Jet Approach Is Best Option," *Inside the Air Force*, August 3, 2012; "Re-engining the E-8 JSTARS," *Defense Industry Daily*, December 18, 2011, at www.defenseindustrydaily.com/Re-engining-the-E-8-JSTARS-04891/

[17] Marcus Weisgerber, "21st Century Rivet Joint," *Air Force Magazine*, January 2011.

[18] Courtney Albon, "AWACS Enters Full-Rate Production On Mission Crew Module," *Inside the Air Force*, February 1, 2013, page 4; "E-3 AWACS (Sentry) Airborne Warning and Control System," at www.airforce-technology.com/projects/e3awacs/

[19] Details about the Air Force's budget and spending priorities can be found at the official site of the service's comptroller, www.saffm.hq.af.mil/budget/

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