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Near Space

Should Air Force Space Command Take Control of Its Shore?

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Foreword

In a time of transformation, the Department of Defense is pursuing a future force that will continue to adapt and build to meet new challenges. As the department shifts its capabilities across the four categories of challenges—traditional, irregular, catastrophic, and disruptive—joint concepts and capabilities develop. After learning of significant shortfalls during operations in Afghanistan and Iraq, the Joint Chiefs of Staff developed a capstone concept for joint operations that attempts to integrate the full spectrum of military efforts to meet any possible threat to security. These shortfalls include beyond-line-of-sight (BLOS) communication and persistent intelligence, surveillance, and reconnaissance (ISR)—enabling mission areas that support joint operations.

To solve such shortfalls, Gen John P. Jumper, former Air Force chief of staff, tasked Air Force Space Command with the responsibility of developing, fielding, and executing tactical and operationally responsive space capabilities near and through space. The newly created initiative known as Joint Warfighting Space focused on near space due to the advantage of achieving spacelike capabilities at a lower cost. Such capabilities could offer continuous, organic, survivable, and "stay and stare" persistence to theater commanders, thus potentially relieving the need for national and strategic systems. Effects-based operations, network-centric warfare, and rapid maneuver demand this persistence.

However, when one attempts to solve shortfalls, looking toward new technologies becomes just one of many possibilities. Optimizing existing capabilities, changing organizational structures, and refining tactics, techniques, and procedures (TTP) emerge as other options. Fully defining the capability within the context of the platforms, processes, organizations, and TTPs ensures the proper application of effort. This remains true when one defines persistent ISR, a more detailed definition of which would clarify the changes and investments that have the greatest impact on mission effectiveness.

This paper recommends caution before developing the near-space capabilities required for stay and stare, persis-

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tent ISR, and BLOS communications. The technical challenges can prove more daunting than those associated with development of the high-altitude unmanned aerial vehicle, a similar program lasting a decade and costing close to $2 billion. Several lessons from recent operations provide greater improvements to persistence and do not require additional collection systems. Finally, the paper offers several recommendations concerning the way ahead for near-space development.

As with all Maxwell Papers, this study is provided in the spirit of academic freedom, open debate, and the serious consideration of issues. We encourage your responses.

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Abstract

Last century, the United States successfully translated lessons learned from past conflicts into needed capabilities to prepare for future threats. These capabilities took the form of new weapon systems, facilities, doctrine and training, and organizations. The Department of Defense (DOD) balanced limited resources to meet challenges across the entire range of military operations, accepting risk in some areas with the lowest probability of occurrence. The DOD examines this century's conflicts, develops solutions, and balances resources in the same way. US armed forces demonstrated new technologies and approaches to conducting military operations in Afghanistan and Iraq. They also supported disaster relief and humanitarian efforts, both in the continental United States and abroad. However, because the military still experienced inadequacies in some mission areas designed to combat the global war on terror, defend the homeland, and support federal and international agencies, the cycle of translating lessons learned into needed capabilities and balancing resources continues. From the myriad of lessons learned, the Joint Chiefs of Staff developed a capstone document for joint operations that attempts to integrate the full spectrum of military efforts to meet any possible security challenge, thereby allowing effective development of joint capabilities with an efficient use of limited resources. Services develop and lead joint capabilities in their respective core competencies to ensure that all can access, share, and use these capabilities.

One lesson the DOD realized from recent conflicts as well as humanitarian and relief operations involves significant shortfalls in command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), the enabling mission area that supports joint operations across the range of military operations. These shortfalls include tactical beyond-line-of-sight (BLOS) communications on the move, persistent ISR, red-force tracking, change detection, detection of mines and improvised explosive devices, and all-weather imaging. To correct these shortfalls, Gen John P. Jumper, the former Air Force chief of staff, tasked Air Force Space Command (AFSPC) with the respon-

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sibility of developing, fielding, and executing tactical and operationally responsive space (ORS) capabilities near and through space. Although it has expertise in providing capabilities through and in space, AFSPC possesses no such skills in near space—the portion of Earth's atmosphere above internationally controlled airspace (65,000 feet) and below the recognized limit of orbital space (60 miles).

Thus, AFSPC created the Joint Warfighting Space (JWS) initiative, which focuses on near space due to the claim of achieving spacelike capabilities at a lower cost and providing them directly to tactical commanders. AFSPC claims that future near-space systems will have BLOS communications and ISR persistence measured in days, weeks, and months, greatly exceeding the capabilities of long-endurance vehicles such as unmanned aerial vehicles (UAV). These systems will look like neither satellites nor launch vehicles but more like balloons and blimps. The United States has had experience with the latter two since the 1930s—but at aircraft altitudes. Accordingly, the JWS team galvanized universities and commercial companies to improve current near-space capabilities, and recent experiments with balloons and tactical radios for BLOS communications show promise.

Certainly, effects-based operations, network-centric warfare, and rapid maneuver demand persistent C4ISR, but this paper urges AFSPC to exercise caution before investing in the development of near-space capabilities required for "stay and stare," persistent ISR, and BLOS communications. It points out that daunting technical challenges exceed those encountered in the development of high-altitude UAVs, a similar program that began with significantly more technical maturity but took a decade and close to $2 billion to develop. The vehicle's planform as it transits the atmosphere to its mission altitude, payload mass fraction at these altitudes, and gas management represent just a few of near space's technical challenges. Investing in the development of near space would require the Air Force to drastically delay or terminate existing air and space systems, which offer dramatically more support and more return on investment. The need for and support of UAVs has grown exponentially since they first appeared in conflict six years ago. ORS initiatives such as transformational satellites have support at the highest levels of defense.

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The paper also notes that several lessons from recent operations point to better solutions with more return on investment and do not require additional collection systems. Not investments in materiel, they are what the DOD refers to as doctrine, organization, training and education, leadership, personnel, and facilities (DOTLPF). Finally, the paper offers several recommendations regarding AFSPC's monitoring of improvements in near-space technology as well as advances in C4ISR, all the while enhancing C4ISR support to the war fighter with existing space capabilities.

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Near Space

Should Air Force Space Command Take Control of Its Shore?

Globalization and the Cold War's end fundamentally changed the US security environment. In addition to traditional enemies such as hostile nation-states with large military formations, new foes now include asymmetric actors—terrorists, weapons proliferators, organized criminals, cyber criminals, and drug traffickers—that represent small, fleeting targets. Higher demand for natural resources will lead to tension, migration, exploitation, and desperation. Causes of future disputes will reflect those of the last 15 years—borders, religion, ethnicity, culture, and resources—but will become more complex. Furthermore, as recent events have shown, strife will extend far beyond the affected region.

The Department of Defense (DOD), which demonstrated new approaches to conducting military operations in Afghanistan and Iraq, continues to digest lessons from recent conflicts as well as humanitarian-assistance efforts. The Joint Chiefs of Staff developed a capstone document for joint operations that attempts to integrate the full spectrum of military efforts with other instruments of national power to meet any possible security challenge. The document seeks to lead fiscally constrained force development and employment by providing a broad description of future joint operations.[1]

Key characteristics of this new concept include knowledge, networking, interoperability, expeditionary capability, adaptability/tailorability, endurance, precision, agility, and lethality.[2] The enabling mission area known as command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) makes these characteristics possible.[3] The need for intelligence gathering and target acquisition is as old as warfare itself. In the last century, fixed- and rotary-wing aircraft as well as satellites performed this function. Having launched new ISR systems such as high-altitude-endurance unmanned aerial vehicles (HAE UAV) during Operations Enduring Freedom and Iraqi Freedom, the DOD began to realize these key characteristics.

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However, it also continued to experience C4ISR shortfalls, including those involving tactical beyond-line-of-sight (BLOS) communications on the move, persistent ISR, red-force tracking, change detection, detection of mines and improvised explosive devices, and all-weather imaging.[4]

To solve these shortfalls, Gen John P. Jumper, former chief of staff of the Air Force (CSAF), tasked Air Force Space Command (AFSPC) with the responsibility of developing, fielding, and executing tactical and operationally responsive space (ORS) capabilities near and through space. AFSPC created the Joint Warfighting Space (JWS) initiative, based on combatant commanders' feedback that requested improvement in the tailoring and responsiveness of space.[5] The JWS team focused on the near-space realm since it offered the prospect of achieving spacelike capabilities at lower cost. Moreover, AFSPC claims that future near-space systems will have BLOS communications and ISR persistence measured in days, weeks, and months.[6] The command anticipates solving this need by operating communications and ISR payloads from near-space balloons and airships.[7]

Will near space be the final solution to persistence? Should AFSPC lead the near-space effort? This author urges caution before proceeding. Near space is not a panacea for difficulties with BLOS communications and persistent ISR; in fact, it may actually exacerbate current problems. An examination of Iraqi Freedom provides an overview of the current transformation of military operations and the capabilities required by the joint force commander (JFC). Like past transformations, this one demands C4ISR. Lessons learned from Iraqi Freedom also show the need for near-space capabilities. Effects-based operations, network-centric warfare, and rapid maneuver demand BLOS communications and persistent ISR. Admittedly, near space may offer a lower-cost solution than other capabilities.

Analysis of the technical and cost challenges of utilizing near space as compared to HAE UAVs provides an estimate of future investment by AFSPC. Despite the numerous potential benefits of near space, the associated technical hurdles are more substantial than those faced by UAVs (thus generating greater development and unit costs). In addition, overselling near-space capabilities before solving these problems could lead to cancellation of other AFSPC pro-

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grams. This paper compares near-space vehicles with HAE UAVs only for the purpose of evaluating cost and technical concerns. Its focus remains on assessing near space's contribution to BLOS communications and persistent ISR against all parts that comprise those systems. Shortfalls lie more within processing, exploitation, and dissemination. Smaller investments such as training make a greater contribution to solving the "intent" of persistence. Finally, this paper offers recommendations on how AFSPC should pursue near space.

Historically the Air Force has tried to solve problems with technology before fully optimizing organizational structure and operational concepts from newly fielded systems. Services also separately developed many systems that support inherently joint mission areas. As one of these areas, C4ISR has experienced these problems. Full realization of the characteristics of the joint concept of operations, within fiscal constraints, proposed by the chairman of the Joint Chief of Staff will require greater integration, system trade-offs, and better-trained personnel.

Operation Iraqi Freedom: New Concepts Support Old Demands

According to Adm Edmund P. Giambastiani Jr., JFC, the US military has gone through another transformation. Over the last 15 years, it transformed from "overwhelming force" to "overmatching power." The former calls for the fielding of well-trained and well-equipped forces to ensure victory, and the latter involves the harnessing of all DOD capabilities in a coherently joint way, providing the attributes of knowledge, speed, precision, and lethality.[8] The DOD shifted from service-centric forces needing deconfliction to a well-trained, integrated joint force. One mission area underpins these attributes: C4ISR.

National and theater C4ISR allowed rapid maneuver of Army and Marine forces toward Baghdad in a coordinated land campaign that covered ground in one quarter of the time it took to do so during the first Gulf War. According to the Air Force, assigned UAVs—part of the JFC's theater ISR assets—augmented the U-2 Dragon Lady aircraft and provided continuous intelligence collection to support the com-

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bined force commander's operational and strategic objectives.[9] Of the 1,801 coalition aircraft used during the campaign, 80 supported the ISR mission—more than in any previous conflict.[10] From airborne ISR alone, aircraft flew 1,000 sorties and collected 3,200 hours of streaming video; 2,400 hours of signals intelligence; and 42,000 images.[11] It is impossible to analyze these figures in relation to the separate parts of the operation. The combined force air component commander did not count apportionment percentages by mission for ISR assets, referring to ISR as "the cost of doing business."[12] However, all services agreed that UAVs played a critical role in the coalition's success.

The introduction of UAVs as a new C4ISR system, integrated with other ISR platforms, helped transform the first Gulf War's creed of "one plane, one target" to today's "one bomb, one target," demonstrated during Iraqi Freedom.[13] The Air Force achieved regional ISR persistence by using distributed operations and reachback for smaller footprint, flexibility, and analytical capability.[14] UAVs proved integral to operational planning and execution for the first time in a large-scale surface war. The MQ-1 Predator, for example, provided battlefield commanders real-time intelligence and demonstrated the feasibility of "hunter-killer" operations. Ground commanders relied heavily on Predators' performing 24-hour operations and sorties averaging 20 hours.[15] US Central Command (CENTCOM) planners based their daily war plans on the RQ-4 Global Hawk, which conducted strategic reconnaissance by flying 40-hour sorties.[16]

The Marines employed two UAV squadrons using RQ-2 Pioneers to scout the road ahead, allowing sought-after battlefield flexibility necessary for rapid maneuver.[17] The Army used the RQ-5 Hunter and the RQ-7 Shadow in a similar fashion.[18] Gen T. Michael Moseley, combined force air component commander for Iraqi Freedom, stated that "we're at a threshold of something very, very exciting and very, very new with unmanned aerial vehicles, whether they are unmanned combat aerial vehicles or reconnaissance vehicles."[19] UAVs proved so successful for employment of ISR that Congress provided more funds than the DOD requested. Thus the department plans to have 14 different UAVs in the force structure to perform a variety of missions, such as offensive combat using Hellfire missiles, sea-based opera-

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tions, and improved situational awareness for force protection.[20] Apparently UAVs are here to stay.

Marine and Army units operated new C4ISR communication systems during Iraqi Freedom. The Army's 3d Infantry Division (Mechanized) successfully communicated over greater distances using mobile command posts equipped with multiple single-channel radios, Iridium, and International Maritime Satellite communication systems. The division acquired and outfitted three M4 command-and-control vehicles, each possessing a tailored communications package including frequency modulation, high frequency, Enhanced Position Location Reporting System, tactical satellite (TACSAT) radios, Iridium phones, Force XXI Battle Command Brigade and Below information system, blue-force tracking, International Maritime Satellite data connection, and external connections for more robust data and phone connectivity.[21] "The single channel TACSAT, [Force XXI Battle Command Brigade and Below], and Iridium served to provide a minimal [command-and-control], on-the-move capability." The 1st Marine Division used similar satellite communication equipment, including devices for data transfer.[22] Even with these capabilities, the 3d Infantry Division (Mechanized) and 1st Marine Division experienced significant C4ISR shortfalls.

The numerous lessons learned from operations in Afghanistan and Iraq offered conflicting information as to what went well and what needed improvement. Admiral Giambastiani undertook a pathfinding approach to lessons learned during Iraqi Freedom, deploying over 30 members of US Joint Forces Command (JFCOM) to the CENTCOM area of responsibility to observe the major combat operations phase.[23] Lessons from special operations, the Army's 3d Infantry Division (Mechanized), and the 1st Marine Division (the major ground force during Iraqi Freedom) confirm the JFCOM lessons that require enhancement or new initiatives.

JFCOM identified ISR as a capability that needs enhancement. Repeated shortfalls from conflicts since the first Gulf War include knowledge of enemy-force composition and disposition in support of targeting.[24] Neither the Army nor Marines had enough ISR assets to achieve conditions for effects-based operations, and only some of their battalions had organic UAV support for ISR.[25] The Marines faced three

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Iraqi divisions without theater priority for ISR, and the Army had similar problems.[26] Marines relied on nontraditional reconnaissance augmentation such as Cobra helicopters so that effects-based targeting assessment could keep up with rapid maneuver.[27]

Battle damage assessment and fratricide prevention continue to recur as lessons learned. According to JFCOM, these capabilities require new initiatives.[28] Gen Tommy R. Franks, former CENTCOM commander and JFC for Iraqi Freedom, described fratricide prevention as an area requiring "additional work."[29] Army and Marine units voiced a need for better BLOS communications as well.

Admiral Giambastiani summarized lessons from Iraqi Freedom by detailing our force's inability to perform effects or battle damage assessments during a high-speed, fast-moving campaign. Whether special operations need to look over the next ridge in search of insurgents, or whether Army brigades require rapid maneuver for conventional forces using unconventional tactics, or whether Marine platoons need to look around the next corner in urban operations, all of them require C4ISR. To conduct those operations in an effects-based and network-centric manner requires persistence. The Air Force claims that near space is the solution.

Near Space

Near-space platforms carrying critical systems into the far reaches of the atmosphere could include balloons, airships, or anything else that is persistent, cost-effective, survivable, and responsive.

—Gen Lance Lord, USAF, Retired

The Air Force's charter calls for commanding the "vertical dimension," which begins at Earth's surface and extends to over 22,000 miles, capturing the furthest orbiting military satellites. Near space, which encompasses altitudes from 65,000 to 325,000 feet, remains the least exploited part of this dimension.[30] The lower limit of near space begins above the internationally accepted ceiling of controlled airspace, where the air becomes too thin for most air-breathing aircraft. Its upper limit ends where air fric-

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tion becomes too strong for low Earth satellites to maintain an orbit.

As mentioned above, General Jumper asked AFSPC to explore ways "to provide tailored, tactical-level space effects to combat forces."[31] The former CSAF highlighted the need for persistent ISR capabilities resulting from Iraqi Freedom.[32] AFSPC's Joint Warfighting Space initiative asserts that current technology shows promise in exploiting near space. Toward that end, the Air Force Space Battlelab conducted technology demonstrations using commercial technologies requiring minimal modifications.[33]

Current near-space vehicles take the form of helium-filled balloons. Interestingly, the Air Force has 50 years' experience working with high-altitude balloons.[34] Tests of numerous space probes use them.[35] Moreover, the DOD has used these aerostats in border protection and coastal radars.[36] Business people, academicians, and hobbyists with an interest and experience in near space have developed prototypes for military applications. For example, students at Johns Hopkins University's Applied Physics Laboratory built a 17-foot steerable helium blimp to help professional engineers who will build a full-scale military airship.[37]

Services within the DOD recently developed mission-needs statements for near space. A comparison of the need for UAVs with the Marines' need for near-space vehicles highlights two solutions to the same shortfall—both of them unmanned systems (table 1). The key feature or selling point of each such statement entails how a new technology or capability can solve apparent weaknesses of fielded systems or gaps in capabilities. Systems providing extended, high-altitude surveillance and communications include HAE UAVs and high-altitude, long-loiter airships. The Marine Corps' near-space mission-needs statement of 2004 suggests recognizing the weaknesses of space as well as manned and unmanned air systems in delivering kinetic and nonkinetic combat functions from a stationary platform above the battlefield.[38] The need for UAVs arose from gaps in space and manned ISR air capability in providing the same combat functions. How does near space solve weaknesses in the current system?

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Table 1. Comparison of mission-needs statements

ISR Platform	*Statement of Need*
Endurance UAVs Joint Requirements Oversight Council Mission-Needs Statement 003-90 (1990)	War-fighting commanders in chief have a need to provide lower-level tactical units real-time, responsive reconnaissance, surveillance, and target acquisition; electronic warfare; battle damage assessment; and nuclear, biological, and chemical detection capability against defended areas in close proximity to friendly forces. This capability is urgently needed to provide Army brigade commanders with improved situational awareness, to permit maneuver forces to move to points of positional advantage with greater speed and precision, avoiding enemy strengths, and then combine the effects of direct and indirect fires to seize and retain terrain or destroy enemy forces. Additionally, the close-range/tactical UAV will give maneuver-brigade commanders superior situational awareness for improved wide-area target acquisition and tracking of high-value targets to conduct both shaping and decisive operations with greatly increased lethality. The need is for a day/night, adverse-weather, multisensor collection system with improved connectivity to joint forces that provides needed, real-time battle information that cannot be observed from standoff airborne-sensor systems, ground-collection systems, and scouts.
Multimission Expeditionary Overhead Platform (2004)	Overhead-platform capabilities are critical, and the need for multimission expeditionary overhead platforms recognizes the weaknesses of current space, UAV, and manned-aircraft solutions to the tactical needs and challenges. Specifically, there is a capability gap—an unfulfilled need for the maintenance of continuous, unobstructed line of sight between operators in compartmented, urban, and otherwise denied terrain and overhead systems that are fielded to support those operations. Space, UAV, and manned-aircraft limitations highlight this capability gap.

Adapted from Dr. Gerardo Melendez et al., "Real Time Simulation Experiment of an Integrated Concept for UAV / Direct Fire Weapons Systems," http://cpof.ida.org/Uavpap~1.doc; a concept of operations for various classes of endurance UAVs, http://www.fas.org/irp/doddir/usaf/conops_uav/part01.htm; and deputy commandant for plans, policies, and operations, to deputy commandant, Marine Corps Combat Development Center, memorandum, 22 November 2004, 2.

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Benefits of Near Space

Near space appears to offer compelling advantages. Lt Col Edward Tomme, with AFSPC's Tactical Exploitation of National Capabilities program, characterizes near space as a combat-effects enabler that offers survivable, organic, and continuous persistence to theater commanders for "stay and stare" space capabilities. One achieves such persistence in space only by means of either constellations or very distant and expensive geostationary orbits. Near-space vehicles could stay and stare for weeks or months as opposed to UAVs, whose missions last 24–40 hours.[39]

Communications have immediate utility. The services experienced a shortage of single-channel TACSAT ultrahigh frequencies to support all of CENTCOM's needs during Iraqi Freedom.[40] Recent demonstrations of the Space Battlelab's Combat SkySat offer potential satellite augmentation by extending ground-force communications from line of sight to 400 miles.[41]

With this capability, near-space systems could function as surrogate satellites, offering the advantages of shorter transmission distances and shorter ranges for sensor surveillance. Near-space advocates also suggest economic benefits. Estimates for low-end near-space vehicles run approximately $1,000 per platform, excluding payload, whereas those for high-altitude airships—the high end of near space—come to $50 million per platform.[42] Advocates claim that, compared to manned and unmanned ISR satellites, near space "easily win[s] the cost competition."[43]

Near space also offers more responsiveness than space systems. After attaining their orbits, satellites can take months for system calibration and checkout, whereas a near-space vehicle requires only two hours to arrive at an altitude of 120,000 feet and can then reach Korea or Afghanistan from the continental United States within a week.[44] Proponents of near space also point to coverage as an advantage. Near-space vehicles could possess imagery footprints similar to those of satellites in low Earth orbit but house smaller payloads because they do not need to work through the ionosphere.[45] Thus near space offers unique opportunities for communications, reconnaissance, and surveillance.[46]

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Employment in Near Space

At the low end, employment benefits of near space include disposable free-floating balloons, launched by Air Force tactical-air-control-party Stryker units, with organic BLOS communications capability for better close air support. Typical weather-style balloons could place tens of pounds to altitudes up to 20 miles.[47] Because of their very low unit cost, balloons maintain persistence through replenishment.

At the high end, airships launched and maintained from the continental United States by US Strategic Command (STRATCOM) forces as global ISR assets would offer zero footprint in-theater. The command's forces would assign geostationary locations prior to launch, based on requests from theater commanders. Once an airship arrived in-theater, its adaptive C4ISR node would provide the JFC with a programmable radio-frequency system as well as signals-intelligence, electronic-warfare, and imagery-intelligence architectures.[48] The combined force air component commander would own the asset as well as the payload operated and managed by the air and space operations center's ISR division. As the theater commander's "eye in the sky," an airship hovering at 90,000 feet produces a line of sight to the horizon of approximately 325 nautical miles.[49] Thus one airship could monitor almost all of Afghanistan, sending data to the Distributed Common Ground/Surface System—a new joint-service, Internet-like, intelligence-sharing network. Since airships are operationally similar to UAVs, the potential exists for sharing facilities and communications for flight control.[50]

Clearly, one sees great opportunities for near space. Vehicles operating there could also apply kinetic effects, as did UAVs in Pakistan against suspected al-Qaeda leaders. Although these craft could perform a variety of missions, this paper limits itself to BLOS communications and persistent ISR—the focus of current JWS and Missile Defense Agency demonstrations.

Investments

Near space could provide the theater commander with organic stay-and-stare ISR and BLOS communication ca-

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pabilities at both a lower cost and a smaller deployed footprint. However, can the Air Force invest in near-space development, given its present space systems and ISR commitments? In actuality, making smaller investments in ISR can produce greater returns in a shorter time.

Limitations

As mentioned earlier, near-space technologies offer tremendous benefits. At the low end of technology/cost, minor modifications would make some systems available today, but as technology moves toward the high end, limitations and vulnerabilities become daunting. The maneuver airships required to house U-2, Global Hawk, or TACSAT communication packages remain on the drawing board because engineers must solve a number of technical issues.

Structure may pose the greatest challenge. According to a RAND study, helium leakage will likely represent the "binding constraint to high-altitude, long-loiter airship endurance," and ultraviolet radiation degrades hull fabric.[51] Designers and engineers must allow for the hazardous and turbulent lower atmosphere, where vehicles ascend and descend. Although metallized and reflective coating in the fabric might increase hull strength, the increased radar cross section could make the craft vulnerable to air defenses.[52] Operating at near-space altitudes also presents a mass-fraction challenge for airships.[53] Lowering altitude to below 65,000 feet would help, but overcoming atmospheric gusts requires an increase in hull strength (and empty weight) and decreases available payload mass.[54] Because gust criteria significantly influence an airship's hull strength and shear feasibility, high-altitude, long-loiter vehicles would then fall under the same air-defense vulnerabilities as do HAE UAVs.

Controllability represents another significant concern. An airship, which must take off and land through the normal atmosphere, requires greater downwind segments because engineers match its propulsion system to the vehicle's operating altitude. Since air is less dense at operating altitudes, designing a maximum speed of 90 knots at 65,000 feet results in a top speed of only 38 knots at sea level.[55] Furthermore, if the vehicle launches in the United States,

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air-traffic control becomes an issue. Additionally, the effects of airspace, weather, and the airship's large inertia create a need for power and lift controls. Trade-offs among safety factors, weight, and operating altitudes will occur, possibly driving the reduction of operating ceiling and endurance and thereby negating the benefits.

Power, gas, and heat management present smaller challenges but require innovative solutions. Fossil fuel adds more weight; thus solar cells become the power source of choice, especially for the endurance benefit. However, propellers, gas pumps, compressors, and, of course, payloads increase the demand for power. Engineers must also design helium cells to expand and contract at the same rate for load distribution, hull stress, and control.[56] Again, trade-offs may drive lower operating altitudes and endurance.

Despite its smaller radar cross section, an airship possesses a distinctive infrared signature due to the high temperature of the skin and internal gases. Moreover, normal communications broadcasting or surveillance-radar emissions produce radio-frequency signatures. If the design drives the operating ceiling to 65,000 feet, Russian SA-5, SA-10, SA-12, SA-20, and Chinese MIM-104 2000 missiles could reach these vehicles. Although tests show that a small, nonrigid airship could withstand numerous bullet holes and perform a controlled landing, the design requires sufficient strength to prevent "unzipping" or a tear propagating across the fabric.

Cost

Development and employment of airship systems will resemble those procedures for UAV systems. Indeed, the *Unmanned Aircraft Systems Roadmap, 2005–2030* uses UAV development and unit costs to obtain an idea of the investment required for airship systems. Comparing airships to HAE UAV systems (Global Hawk and DarkStar, see below) provides an understanding of the complexity of airship development in relation to other such efforts. Before proceeding, however, one should realize that (1) airship design appears to have more development challenges than the HAE UAVs of the 1990s and (2) UAVs saw three decades of poor performance. Technical difficulties led to cost increases and schedule ex-

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tensions, resulting in the cancellation of programs in almost every case. Although near-space initiatives can benefit from these lessons, advocates should not become overly optimistic about easily overcoming technical challenges.

The Global Hawk system consists of several mission segments: an air vehicle, payload, engine (power and propulsion), communications, and ground element. Airships will have similar segments. Additionally, airships could use many of the Global Hawk's key components, available as commercial off-the-shelf equipment. The Global Hawk's basic air-vehicle planform was not revolutionary and did not pose any difficulty to speak of.[57] In the case of the DarkStar UAV's planform, engineers relied on F-117 and B-2 technologies to demonstrate a multiaspect, low-observable capability.[58] As described above, this will not hold true for an airship's planform. The most significant challenge for Global Hawk and DarkStar entailed integrating payload with the aircraft and developing connectivity required to move data (imagery, signals, etc.) from the aircraft to multiple users.[59] Development of airship connectivity can benefit greatly from the work already accomplished for UAVs, but airships will also face sophisticated software and systems-engineering hurdles.

Airship designers must also develop and integrate reliable sensors for on-site or onboard meteorological data by which controllers or onboard computers can predict turbulence, icing, and violent gusts, any of which can jeopardize the vehicle.[60] No current database predicts aerostructural interactions of large airships with turbulence and gust criteria.[61] The Navy's airship program came to this realization during the 1930s, when 73 crew members lost their lives when the USS *Akron* crashed in a storm off the New Jersey coast in 1933.[62]

Airship-acquisition strategy will likely be the same as that for HAE UAVs, which used a multiphase Advanced Concept Technology Demonstration approach. These programs originally called for completion of the first three phases in five years, but Global Hawk needed seven. After five years, several cost increases, and schedule extensions, the Air Force cancelled the DarkStar program. After one rules out 30 years of development woes, it appears that at the low end, the DOD needs to invest $1.4 billion to develop an airship system. Considering the daunting technical chal-

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lenges, $2 billion plus and almost a decade may come closer to the actual expenditure and time required (table 2).

Table 2. Cost comparison of HAE UAVs versus near-space vehicles

Vehicle	*Estimated Development Costs ($)*	*Estimated Unit Costs ($)*
Global Hawk	1.4–1.9 billion	70 million
DarkStar	324 million	program cancelled
Near-Space Airship	2 billion+	50 million

Derived from Lewis Jamison, Geoffrey S. Sommer, and Isaac R. Porche III, *High-Altitude Airships for the Future Force Army* (Santa Monica, CA: RAND, 2005), http://www.rand.org/pubs/technical_reports/2005/RAND_TR234.pdf; and Robert S. Leonard and Jeffrey A. Drezner, *Innovative Development: Global Hawk and DarkStar—HAE UAV ACTD* [Advanced Concept Technology Demonstration] *Program Description and Comparative Analysis* (Santa Monica, CA: RAND, 2002), http://www.rand.org/pubs/monograph_reports/MR1474.

Best Bang for the Buck

As we have seen, Iraqi Freedom forces had at their disposal 80 ISR aircraft that provided thousands of hours of information and tens of thousands of images. When one adds these aircraft to satellite and nontraditional collectors, the amount of information and imagery rises by well over an order of magnitude. Having access to an unprecedented amount of data, the JFC allowed ground forces to maneuver more rapidly than in past operations. This information also permitted the military to realize the beginnings of effects-based operations and network-centric warfare, the foundations for overmatching power. Fully supporting these concepts, senior military leaders continue to press for persistent ISR. But what exactly is persistent ISR, and which direction should the DOD take to obtain it?

Although no joint definition for this concept exists, James Roche, former secretary of the Air Force, observes that persistent ISR is "a matter of integrating various and sundry sensors into a portfolio of sensors, making them all work together."[63] Michael Keebaugh offers another, perhaps more

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accurate, definition: "an uninterrupted flow of information over extended periods to provide knowledge of an adversary's capabilities and intentions."[64] Although accurate, neither is complete.

All combatant commanders agree that persistent ISR is mandatory across the spectrum of military operations, so successful operations require a better definition. Responding to the enemies of today demands adaptability through rapidly mobilized, specialized local knowledge; the capability for networked, multilateral threat analysis; and the quick delivery of rapidly packaged information to the operator. Thus, one can describe persistent ISR as the uninterrupted flow of *actionable intelligence* over extended periods that remains *accessible to the operator* and that provides knowledge of an adversary's capabilities and intentions. Having further defined persistent ISR, we can now inquire about the existence of better investments with quicker returns than high-altitude, long-loiter systems.

Maj Gen James "Spider" Marks, USA, the senior intelligence officer during combat operations in Iraqi Freedom, recalls that trained analysts had trouble deciphering data in the battle zone because enemy forces were changing their organization and grouping.[65] As a result, analysts lost track of what was happening. Lt Gen William S. Wallace, USA, V Corps commander during Iraqi Freedom, stated that "the intelligence analysts were trying to fit a pattern we were seeing into an order of battle that was increasingly irrelevant. You had this squirrelly combination of foreign fighters in different forms and Iraqi paramilitary. The paramilitary forces . . . had no discernable pattern."[66] Gen T. Michael Moseley, the current CSAF, also subscribes to intelligence analysts who possess more in-depth culture and red-team training. Adding more collection systems cannot solve this problem.

A related issue concerns the training of junior intelligence officers in basic analysis and targeting. A team from the Center for Army Lessons Learned observed intelligence functions during Enduring Freedom and Iraqi Freedom, finding that intelligence officers did not understand the targeting process, could not build products that supported the process, lacked briefing skills, had few to no analytical skills, and did not understand ISR planning.[67] Again, collection systems will not solve this problem.

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One must also raise the issue of poor collection management due to the lack of formal training of managers. During Iraqi Freedom, collection managers did not have a full understanding of the capabilities and limitations of the ISR assets tasked.[68] For example, they tasked UAVs to find buried aircraft and either ignored or forgot collection-control measures.[69] Adding more collection systems would compound this problem.

Human intelligence (HUMINT), one of our most valuable assets, is critical not only for urban, stability, and support operations, but also for humanitarian and shaping operations. US armed forces did not have enough tactical HUMINT teams, and combat-arms commanders did not understand how to use them.[70] We lacked even simple HUMINT functions (e.g., interpreters). If the sources prove credible, this asset provides the catalyst for all-source intelligence in determining the adversary's intent. Adding more collection systems will not solve this problem.

Though not as critical as HUMINT, bandwidth and connectivity are essential for network-centric operations. According to Lt Gen Harry D. Raduege Jr., USAF, retired, former director of the Defense Information Systems Agency, US and coalition forces had 30 percent more bandwidth supporting 45 percent fewer troops than they did in the first Gulf War. Even with this increase, commanders demanded more, claiming that the bandwidth restriction limited the numbers of targets war fighters could engage.[71] Sufficient bandwidth seemed available at the operational level but clearly not enough to push the network down to the tactical level.[72] The large size of the weapon-system video demanded high bandwidth not available to many tactical units.[73] Units then e-mailed video using the Secret Internet Protocol Router Network or file transfer protocol to the combined air operations center and then to CENTCOM's Joint Intelligence Center in Tampa via file transfer protocol. These file transfers eventually hindered collection and targeting efforts due to overlapping and duplicative requirements and analyses.[74] For example, the combined air operations center imaged one target with three different ISR assets on one day even though intelligence did not exploit the previous day's image of the same target and could have satisfied the requirement.[75] Adding collection systems could help support this

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increased demand but could also compound it by pushing more data and information "in the pipe."

Since we may never have enough bandwidth, we need bandwidth management and synergistic connectivity. Again, the military rushes to solve problems with technology and then pushes it to the war fighter without integration and optimization. For example, according to a member of the 1st Marine Division,

> members of my force often had to use a helmet headset, four radios and two laptop computers—all crammed into a light armored vehicle—all at once. . . . We were overwhelmed with communications systems for every eventuality, but these did not really integrate with each other. For example, a Marine commander riding aboard a [light armored vehicle] had to use a headset to use the intercom to talk to his driver and gunner, answer his squad leaders by grabbing [a] hand-held radio and speak to accompanying infantry by another radio, all this while monitoring two laptop positions of friendly and hostile forces![76]

As one senior commander mentions in his report, "No matter how perfect a future network and CP [mobile command-post operations] we build, it won't do us much good until we fix the overarching problem of bandwidth management."[77] Adding collection or repeater systems will not solve this problem.

Caution

Elevated bandwidth alone is not the answer. More and faster does not always equate to better. Seeing everything all the time is a lofty but unrealistic goal. What value is raw imagery data to a pilot, tank driver, or Marine infantryman? Such data provides no value-added intelligence information, especially to a nonimagery analyst. C4ISR, probably the most complex mission area, requires balanced solutions that provide the best return on limited dollars. Given the need to recapitalize the Army, Marines, and special forces, the Air Force will have to make some tough budget decisions.

Should the DOD continue to pursue near space? Yes, the Air Force should explore its entire realm and exploit any opportunity. Near space could provide persistence over a given area, but it will not solve all communication or ISR shortfalls. Near space could augment other mission areas as well as expand to other roles, such as force application.

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Should AFSPC take the lead and invest heavily in near space? Before answering, advocates should consider the C4ISR trade space.

First, the DOD (especially the Air Force) invests heavily in UAVs. For the Predator, Global Hawk, and Joint Unmanned Combat Air System, the Air Force has budgeted $1.4 billion for fiscal year 2006 and about $9.6 billion for years 2007 to 2011.[78] This translates to fielding and operating 120 Predators, 58 Global Hawks, and six Joint Unmanned Combat Air Systems. Combined with the other services' UAV investments, the DOD could control close to 900 UAVs.[79] Interestingly, of the airships listed in the *Unmanned Aircraft Systems Roadmap, 2005–2030*, only the Avenger airship operates in the near-space realm, and the Air Force cancelled the program in November 2004.[80] The Missile Defense Agency's high-altitude airship operates within UAV altitudes.

Second, the DOD (especially the Air Force, with AFSPC as lead) invests heavily in the operationally responsive space program, which has both congressional support and the full backing of the secretary of defense's Office of Force Transformation. Examples of this program include the Tactical Microsatellite Experiment (TacSat) program sponsored by the Office of Force Transformation, the Naval Research Laboratory, the Air Force's Space and Missile Systems Center, and several other agencies. The program has four satellites in various stages of development. The Office of the Secretary of Defense has such confidence in this program that it funded the first experiment—TacSat-1.[81] The experiments run from exploitation of the Secret Internet Protocol Router Network, through tactical and hyperspectral imaging, to an all-communications payload. The space segment of ORS offers unique capabilities (fig. 1).

Third, the Air Force and AFSPC invest in optimizing existing capabilities—another segment of ORS. Recent examples from Iraqi Freedom include improving accuracy by means of the global positioning system's enhanced theater support and the Defense Support Program's backing of combat-search-and-rescue missions.[82] Also included are increasing military-satellite theater communications by repositioning the Defense Satellite Communication System and accelerating early checkout of that system's new satellites and Milstar satellites.[83]

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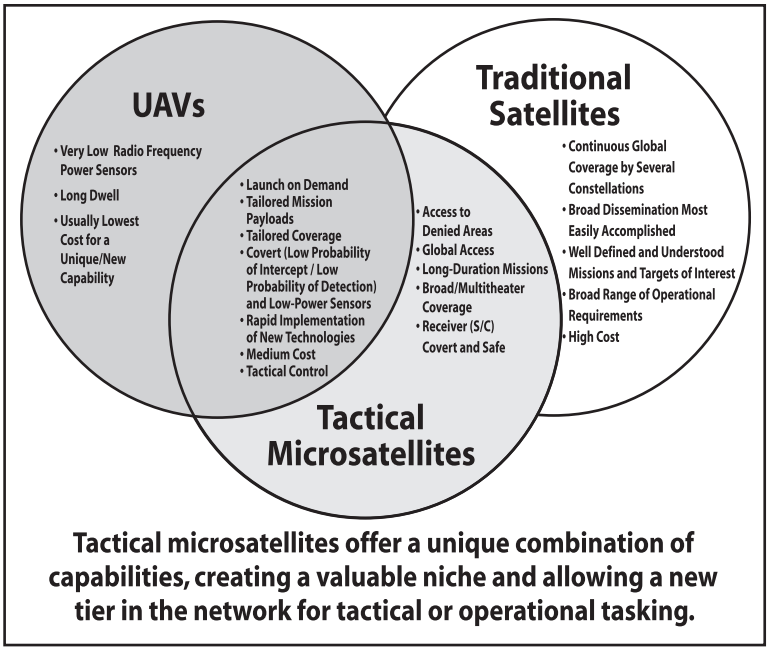

Figure 1. Proposed capabilities set for tactical microsatellites. (From briefing, Office of the Secretary of Defense, Applied Physics Laboratory, Naval Research Laboratory, subject: A TacSat Update and the ORS/JWS Standard Bus, Third Responsive Space Conference, 26 April 2005.)

Even with the planned reduction in Air Force personnel to help increase the service's investment, operations, and maintenance portfolios, it still faces tough decisions on future programs. Based on heavy investments in UAVs, congressional support for ORS, and the optimizing of existing space systems (coupled with the Air Force's substantial commitments to air and space systems), we may have no room left for a multiyear, multibillion-dollar program.

Recommendations

Stability and reconstruction operations in Iraq and Afghanistan, hurricane-relief efforts in the United States, and force transformation are creating a fiscally constrained environment for new investments. Tight budgets are projected, and General Moseley believes that trade-offs are inevitable

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for the Air Force's strike, mobility, and space/C4ISR portfolios: "If we have programs that have had exponential [cost] growth and we need to roll that money back, it's time to be killing some things."[84] Space radar and the transformational communications satellite program fall into this category of trade-offs due to large cost overruns.[85] According to the Congressional Budget Office, financing the current space portfolio for "unclassified space systems" will require an increase of 40 percent, estimated at $6.9 billion. By 2010 the budget will almost double to over $10 billion.[86] With increases this large, further trade-offs are inevitable. Thus, the Air Force will have two internal competitions: one between Air Combat Command and AFSPC concerning manned and unmanned aerial systems versus space-based ISR (what the author calls "big space" programs) and another within AFSPC concerning near-space airships and tactical microsatellites.

With regard to the first competition, the Air Force is clearly investing in UAVs, HUMINT, and the Joint Surveillance Target Attack Radar System (JSTARS). The assistant deputy chief of staff for air and space operations believes that contributions made by UAVs during Iraqi Freedom were the most significant made by the Air Force.[87] Almost all the airships and aerostats within the *Unmanned Aircraft Systems Roadmap, 2005–2030* operate in the air regime although some operate slightly above controlled airspace. The CSAF commented that the JSTARS could track the Iraqi Republican Guard in a sandstorm and that it provided "a tremendous asymmetric advantage."[88] Almost every Army lesson learned praised this system's achievements. General Moseley also stated that the Air Force needs more HUMINT resources to keep pace with technology.[89]

With regard to the second competition, ORS has the highest level of support, resembling the joint/multiagency consolidation required to focus effort and save money. The JWS office claims that this initiative involves ORS plus near space, each complementing the other. However, near space does not appear to have the same support as ORS, nor have near-space experiments and demonstrations of the past been truly joint. A search of briefings and papers in the Responsive Space Web site (http://www.responsivespace.com)—which includes a collection of material from the first three ORS conferences—found no detailed concepts that

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link ORS and near-space capabilities operationally. Given these issues, AFSPC should keep near-space investment low in the short term to midterm.

This paper offers a way ahead. First, AFSPC should participate in STRATCOM's Joint Functional Component Command ISR process, one of whose primary functions calls for adapting ISR collection strategies to satisfy revolving requirements.[90] As the joint community demonstrates, tests, and fields ISR solutions, AFSPC can continue to assess shortfalls and weaknesses against near-space benefits. Second, we should ensure that the joint community engages in near-space concepts and demonstrations. The Space Battlelab is moving in the right direction by participating in JFCOM's Joint Experimentation, Test, and Evaluation Advanced Concept Technology Demonstration for fiscal year 2006.[91] By not participating in the JFCOM experimentation process, near-space demonstrations such as Combat SkySat require independent and close coordination with the Army's new doctrine for battle command on the move, the Joint Tactical Radio System, changes in Marine and special forces doctrine, and the J6 communications community on architecture and interference issues—and a service-specific capability would emerge.

For example, the Space Battlelab's Combat SkySat project claims it can help close-air-support controllers in the tactical air control party. The demonstration uses a PRC-148 tactical radio; however, units already have the AN/PRC-150 high-frequency and low-band very-high-frequency tactical radios, capable of automatically selecting the correct frequency to bounce off the ionosphere and thus offering BLOS communications.[92] The radio uses a transmission technique called near-vertical-incident sky wave, which launches signal energy toward the sky at angles between 45 degrees and the zenith and returns to Earth after ionospheric reflection. The returning signal comes down from above at high angles in an omnidirectional pattern that has no gaps and a radius of hundreds of miles. The DOD must weigh the benefits of continuously launching balloons to extend range against new fielded capabilities that offer the same advantage.

Third, the Air Force intends to establish a program office in 2008, based on demonstrations of Combat SkySat.[93] But

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we should delay establishing such an office for near space until the commercial and civil communities bring the technology to maturity, which will take a number of years. Since near-space systems in the *Unmanned Aircraft Systems Roadmap, 2005–2030* operate in the air regime, the Aeronautical Systems Center's Reconnaissance Office would be the best program office—an established organization that manages the Air Force's UAV programs.

As stated earlier, AFSPC appears to have an internal competition between near space and ORS. Both initiatives offer significant organic capabilities to the theater commander. The fourth recommendation calls for using ORS conferences to vigorously debate the capabilities of near space versus those of tactical satellites. Even with a significant level of support and the potential for early success, it may prove difficult for AFSPC to receive procurement authority for ORS capabilities due to fiscal realities. However, the command must consider the United States' space race with Asia and Europe. Investing in lower-cost access to space as well as lower operations from space offers a much greater return.

AFSPC's Detachment 12 can continue as the command's virtual program office, coordinating efforts from the Air Force Research Laboratory and Space Battlelab. Detachment 12 can monitor commercial, civil, and Missile Defense Agency development efforts until a controllable vehicle can operate successfully at altitudes at or above 100,000 feet. It may take five to seven years to attain this level of maturity. Until then the primary focus should remain on ORS lift and operations.

One finds a good many resource issues with space even in doctrine. Air Staff experts disapproved using the term *near space* in space-operations doctrine, evidently because they feared that such inclusion, combined with the overselling of its capabilities and potential in the press, might drive unwanted resources decisions.[94] Near space must wait for the next decade, when the DOD fields sister services' recapitalization and current Air Force investments.

Summary and Conclusion

US armed forces demonstrated new technologies and approaches to conducting military operations in Afghanistan and Iraq. They also supported disaster relief and humani-

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tarian efforts both in the continental United States and abroad. From the myriad of lessons learned, the Joint Chiefs of Staff developed a capstone document to guide the services on how to integrate their competencies across the full spectrum of military efforts for a truly joint effect.

Shortfalls in capability drove new doctrines, new technologies, and the optimization of existing capabilities. The key lies in balancing these drives and prioritizing which technology investments can offer the greatest benefit. Although the US military saw unprecedented capability in C4ISR during the last five years, it also experienced its share of shortfalls. General Jumper, former CSAF, responded to theater commanders' feedback by articulating the need for a JWS initiative to make space more tailored and responsive and by directing AFSPC to lead this effort. The JWS team focused on near space due to the potential advantage of achieving spacelike C4ISR capabilities at a lower cost—near space's greatest benefit.

This paper has urged that AFSPC exercise caution in investing in near space for the near term. The technical challenges of developing a UAV-like capability for airships are daunting. An examination of HAE UAV cost data suggests that estimates for airship development approach $2 billion and that the process would require nearly a decade to achieve capabilities similar to those of UAVs. Unit costs for airships are comparable to those for Global Hawks.

After defining persistence accurately and analyzing lessons learned in greater detail, one can realize cheaper investments with a quicker return. Those investments include better training of intelligence officers as well as more HUMINT, bandwidth management, and connectivity. Adding more collectors and repeaters will neither determine an adversary's intent nor necessarily place actionable intelligence down to the tactical level. By better integrating the mosaics of all forms of space intelligence in near real time with airborne-platform coverage, combined with HUMINT and data from open sources, one could create a new form of space-centered joint intelligence that would lead to improved situational awareness and targeting capability.[95]

All services invest heavily in C4ISR. By 2011 the inventory will swarm with close to 900 UAVs. The Office of the Secretary of Defense, AFSPC, and other agencies have in-

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vested in ORS in a truly joint effort. Developing low-cost access to space and operations from space not only will provide tailored, responsive support to the theater but also will help the United States maintain its global lead in space. Finally, AFSPC continues to optimize existing space capabilities to meet the theater commander's needs. All big-space programs currently in development must do the same.

Since these investments—combined synergistically with the training, bandwidth management, and connectivity investments outlined above—could better solve persistence, AFSPC should exercise caution when investing in near space. The author has offered several recommendations for monitoring near-space development and preparing the joint community for its integration when the technology matures. Participating in STRATCOM's ISR process as well as JFCOM's experimentation regime, allowing commercial and civil organizations together with the Missile Defense Agency to bring the technology to maturity, and debating the merits of near space with ORS will ensure a fully vetted and fully joint C4ISR capability. Given the Air Force's investments in ORS and significant increases in the cost of big-space programs expected over the next five years, the Air Force cannot afford any other large obligations. AFSPC should control its shore—but at a distance for the near term. That is, it should let commerical companies and universities mature the technology and monitor their progress rather than invest large budgets and man-hours. When the technology reaches maturity (most likely 10–15 years from now), then AFSPC should begin investing.

Notes

1. Gen Richard B. Myers, *Capstone Concept for Joint Operations*, version 2.0 (Washington, DC: Joint Chiefs of Staff, August 2005), vii, http://www.dtic.mil/futurejointwarfare/concepts/approved_ccjov2.pdf.

2. Ibid.

3. According to Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3151.01A, *Global Command and Control System Common Operational Picture Reporting Requirements*, 19 January 2003, command, control, communications, computers, and intelligence systems consist of "integrated systems of doctrine, procedures, organizational structures, personnel, equipment, facilities, and communications designed to support a commander's exercise of command and control across the range of military operations" (GL-7). Joint Publication 1-02, *Department of Defense*

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Dictionary of Military and Associated Terms, 12 April 2001 (as amended through 14 April 2006), defines intelligence, surveillance, and reconnaissance as "an activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and future operations" (269). Thus, C4ISR entails an integrated intelligence, command, control, and operations function.

4. Final briefing, Air Force Space Command, subject: National Defense Industrial Association (NDIA) Near-Space Summer Study, 9 November 2005.

5. TSgt Jennifer Thibault, "Near-Space Programs to Provide Persistent Space Capability," *SpaceWar*, 15 March 2005, http://www.spacewar.com/news/milspace-05g.html.

6. Ibid.

7. Ibid.

8. House, *Statement by Admiral Edmund P. Giambastiani, Jr., Commander, United States Joint Forces Command and Supreme Allied Commander Transformation (NATO) before the House Armed Services Committee*, 108th Cong., 1st sess., 2 October 2003, http://armedservices.house.gov/openingstatementsandpressreleases/108thcongress/03-10-02giambastiani.html.

9. Lt Gen T. Michael Moseley, *Operation Iraqi Freedom: By the Numbers* (Shaw AFB, SC: Combined Forces Air Component, Assessment and Analysis Division, 30 April 2003), 4.

10. Ibid., 3.

11. Ibid.

12. Ibid., 4.

13. Patrick E. Clarke, "Nerve Centers for Air Warfare," *Military Information Technology Online Edition* 7, no. 7 (1 September 2003), http://www.military-information-technology.com/article.cfm?DocID=183.

14. Maj Gen Ronald F. Sams, USAF, director of intelligence, surveillance, and reconnaissance, "Presentation to the Senate Armed Services Committee, United States Senate" [testimony on Air Force fiscal year 2005 ISR programs], 7 April 2004, 3, http://www.fas.org/irp/congress/2004_hr/040704sams.pdf.

15. Bill Yenne, *Attack of the Drones: A History of Unmanned Aerial Combat* (Saint Paul, MN: MBI Publishing Co., 2004), 97.

16. Ibid., 99.

17. Ibid., 101.

18. Ibid., 102.

19. Ibid., 103.

20. General Accounting Office, *Force Structure: Improved Strategic Planning Can Enhance DOD's Unmanned Aerial Vehicle Efforts*, GAO-04-342 (Washington, DC: GAO, 17 March 2004), 1, http://www.gao.gov/new.items/d04342.pdf.

21. 3d Infantry Division (Mechanized), After Action Report, Operation Iraqi Freedom, chap. 17, "Communications," http://www.strategypage.com/articles/3IDAAR/default.asp.

22. Ibid.

23. House, *Statement by Admiral Edmund P. Giambastiani, Jr.*

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24. Sams, "Presentation," 13.

25. 3d Infantry Division (Mechanized), After Action Report, Operation Iraqi Freedom, chap. 9, "Intelligence," http://www.strategypage.com/articles/3IDAAR/default.asp.

26. Lt Col Daniel R. Johnson, *Enabling Intelligence, Surveillance, and Reconnaissance Effects for Effects-Based Operations Conditions*, Maxwell Paper no. 34 (Maxwell AFB, AL: Air University Press, June 2005), 5, http://www.maxwell.af.mil/au/aul/aupress/Maxwell_Papers/Text/Johnson_MP34.pdf.

27. [1st Marine Division, G-2], "Operation Iraqi Freedom (OIF): Lessons Learned" [May 2003], 4–5, http://www.globalsecurity.org/military/library/report/2003/1mardiv_oif_lessons_learned.doc; and idem, "Brief on 1 MARDIV Operations" [May 2003], 3, http://www.globalsecurity.org/military/library/report/2003/1mardiv_brief.doc.

28. House, *Statement by Admiral Edmund P. Giambastiani, Jr.*

29. Senate, *Statement of General Tommy R. Franks, Former Commander, US Central Command, before the Senate Armed Services Committee*, 108th Cong., 1st sess., 9 July 2003, 6, http://www.au.af.mil/au/awc/awcgate/congress/franks_09july03.pdf.

30. Although the author could not find an official statement of what altitudes define near space, the International Aeronautics Federation was likely the first official organization to set limits, which the Air Force then adopted under AFSPC's Joint Warfighting Space initiative. For more information, see "Near Space: The Shore of Our New Ocean," *HobbySpace.com*, http://www.hobbyspace.com/NearSpace/index.html.

31. Hampton Stephens, "Near-Space," *Air Force Magazine* 88, no. 7 (July 2005): 37, http://www.afa.org/magazine/july2005/0705near.pdf.

32. Ibid., 38.

33. Ibid.

34. Taylor Dinerman, "Near Space: Balloons, Satellites, and Suborbital Rockets," *Space Review*, 25 July 2005, http://www.thespacereview.com/article/416/1.

35. Ibid.

36. The author worked at the North American Aerospace Defense Command (NORAD) Plans Branch from June 1999 to May 2002, inside the Cheyenne Mountain Complex, supporting the US Coast Guard and the Drug Enforcement Agency. Aerostats are tethered, balloonborne radar systems that operate at 15,000 feet. NORAD has used aerostats from eight sites around the United States since 1980.

37. "Students Steer a Blimp to Test Near Space Military Technology," *ScienceDaily*, 21 July 2005, http://www.sciencedaily.com/releases/2005/07/050720065446.htm.

38. Deputy commandant for plans, policies, and operations, to deputy commandant, Marine Corps Combat Development Center, memorandum, 22 November 2004, 2.

39. Lt Col Edward B. Tomme, *The Paradigm Shift to Effects-Based Space: Near-Space as a Combat Space Effects Enabler*, Research Paper 2005-01 (Maxwell AFB, AL: Airpower Research Institute, College of Aerospace Doctrine, Research and Education, Air University, 2005), 13–15, http://www.au.af.mil/au/awc/awcgate/cadre/ari_2005-01.pdf.

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40. "Tactical Operations Center Performance: Operation Iraqi Freedom C4ISR Lessons Learned/VI," *Defense Update* [25 October 2005], http://www.defense-update.com/features/du-1-05/oif-c4-6.htm.

41. Combat SkySat is a "proof of concept" demonstration that carries commercial off-the-shelf two-way radios, potentially boosting communications capability BLOS for forces on the ground.

42. Tomme, *Paradigm Shift to Effects-Based Space*, 23.

43. Ibid., 24.

44. Ibid.

45. The ionosphere is an electrically charged portion of the atmosphere that is also affected by Earth's magnetic field. Phenomena known as Faraday rotation and scintillation can have a significant effect on ground-to-satellite signal paths. Faraday rotation (discovered as an interaction between light and a magnetic field) occurs when elements of a signal travel in different ways, causing the signal to decompose into two circularly polarized rays traveling at different speeds with a phased offset. Ionospheric scintillation, caused by electron density in the ionosphere, can also change signals. For more information about these phenomena, see "The Ionosphere Explained," *Project Horizontal E-Region Experiment*, http://www.uaf.edu/asgp/hex/ionosphere.htm; and "Satellite Signal Propagation," *Radio Electronics.com*, http://www.radio-electronics.com/info/satellite/satellite_sig_prop/satellite_signal_propagation.php.

46. Strict use of terminology requires making a distinction between reconnaissance and surveillance. According to Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, 17 November 2003, "surveillance is a continuing process, not oriented to a specific target. . . . Reconnaissance complements surveillance by obtaining specific information . . . through visual observation and other detection methods" (55–56).

47. Lewis Jamison, Geoffrey S. Sommer, and Isaac R. Porche III, *High-Altitude Airships for the Future Force Army* (Santa Monica, CA: RAND, 2005), 2, http://www.rand.org/pubs/technical_reports/2005/RAND_TR234.pdf.

48. Ibid., 17.

49. Ibid., 19.

50. Ibid., 22.

51. Ibid., 23.

52. High-altitude airships are superpressure helium vessels. Temperature variations can alter internal pressures and place added stress on the hull. A RAND report suggests that this avoids flight-path and gas-management problems but at the expense of higher stresses in the hull fabric. For more information, see Jamison, Sommer, and Porche, *High-Altitude Airships*.

53. Mass fraction for airships is the design criterion between the system weight (airframe, support/control systems, and fuel) versus the payload weight. The more the system weight increases, the less weight allowed for the payload. One may trade decreasing altitude for increased weight.

54. Jamison, Sommer, and Porche, *High-Altitude Airships*, 24.

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