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National Security Space in the Twenty-First Century

HON. PETER B. TEETS

FIFTY YEARS AGO, US defense and intelligence experts imagined the benefits possible from space-based surveillance, reconnaissance, communications, mapping, and environmental monitoring. Forty years ago, American ingenuity and industrial prowess made those possibilities a reality. Since then, space systems have brought better intelligence and stronger defenses by enabling the collection of new types of data and information; significantly increasing communications capabilities and capacities; revolutionizing precision navigation and timing; enriching science; establishing new markets; providing safer air, land, and sea transportation; and enabling faster disaster relief as well as more effective civil planning. These benefits and more were the reward of steadfast leadership, a vibrant industrial base, and the energies of talented people.

During the past 10 years, space-based systems have enabled dramatic improvement in military and intelligence operations. Thanks to those systems, our leaders have more accurate and current information on developments, issues, and crises in virtually all parts of the world. Due in large part to space systems, US military forces know more about their adversaries, see the battlefield more clearly, and can strike more quickly and precisely than any other military in history. Space systems are inextricably woven into the fabric of America's national security.

Space Power Is America's Decisive, Asymmetric Advantage

Today, space power represents a decisive, asymmetric advantage for the US government and, in particular, for military and intelligence organizations. The space systems themselves are technologically superior and, when fused with other air-, sea-, and land-based systems, provide the data and information to produce the knowledge and effects needed for successful diplomatic activities, negotiations, deterrence, or warfare.

Our unprecedented global situational awareness, global connectivity, strategic reach, and precision strike are largely enabled by our space systems. Capabilities such as those provided by global positioning system (GPS) satellites and by the military strategic and tactical relay system (MILSTAR)—our most advanced communications constellation currently in orbit—proved vitally critical to the war fighter during recent conflicts. Further, the successful application of space capabilities has enabled significantly changed concepts of power projection, decisive force, overseas presence, strategic agility, and forcible entry. For example, a combat air controller on horseback in Afghanistan used space capabilities to direct bombs on target. The successful application of space power has fundamentally changed our view of the age-old military precepts about mass, movement, fog, and friction.

However, retaining this decisive, asymmetric space advantage is becoming increasingly difficult. Yesterday's highly successful strategies resulted in space systems optimized to enhance the deterrent posture of our strategic forces by providing information about the military and economic status of a closed, hostile superpower. These systems focused on monitoring the long-term strategic posture while guaranteeing strategic warning—they were perfectly suited for knowing what was happening inside the borders of the Soviet Union.

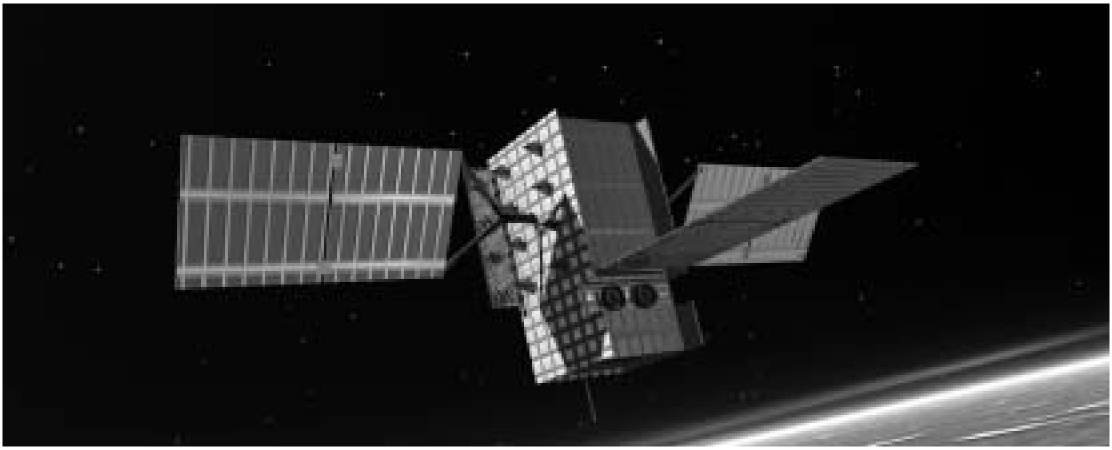
Today's security challenges are more diverse and dispersed. We must still protect Americans and American interests from hostile armies and strategic threats, as well as from new, emerging threats from nonstate actors—particularly those posed by globally organized terrorists who may be fleeting and nearly invisible. These new threats—smaller and scattered globally—may strike anywhere, at any time.

Meanwhile, space is not solely an American domain. Countries worldwide continue vigorous civil, defense, and commercial space programs that provide highly accurate reconnaissance imaging, precision navigation and timing, and near-instantaneous global-communications capabilities. Using the Internet and commercially available products, countries, groups, or individuals may acquire high-quality, space-based products and services, thus reaping the operational benefits without the heavy financial burden of investment. All of this is occurring while the industrial base of American space power has narrowed over the past decade, and its formidable talent pool has shrunk due to corporate mergers, acquisitions, and a decrease in government-funded research and development.

Our challenge lies in shaping a future which will ensure that our space capabilities support tomorrow's successes. To meet that challenge, we will focus on five top priorities: achieving mission success in operations and acquisition, developing and maintaining a team of space professionals, integrating space capabilities for national intelligence and war fighting, producing innovative solutions for the most challenging national security problems, and ensuring freedom of action in space.

Achieving Mission Success in Operations and Acquisition

We will select and develop tomorrow's space systems differently than we do today. Decisions about what we need to acquire will consider not only satellites and all the components needed to make them useful—such as launch vehicles, facilities, communications, and end-user equipment—but also their role as part of a portfolio of systems. Trade-offs will be based on a broad understanding of desired capabilities and effects, as well as the comple-



ment of space, air, manned, and unmanned elements needed to achieve them.

To attain the desired capabilities, we must assure that mission success in operations is accompanied by mission success in acquisitions. We have benefited greatly from the recommendations of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs, led by Mr. A. Thomas Young. One of their recommendations, with which I strongly agree, is that mission success should be the primary driver of a program—not cost and schedule.

As we establish programs, we need to employ strong systems-engineering practices. Management of requirements; early risk-reduction activity; rigorous design discipline; periodic, independent program assessment; and thorough component, subsystem, and system-level test activities need to be built into the program at the onset. Program managers must have unencumbered schedules and financial reserves at their disposal to solve problems that arise during program execution. Most importantly, we will nurture a culture focused on mission success as the prevailing vision.

We will also adopt a system-of-systems approach in our planning, designing, and fielding of new capabilities. Such an approach will require us to increase our investment in integrated solutions that capture the complementary advantages and dependencies of both space and nonspace systems. To further this objective, we will also look to integrate space enterprises wherever possible and continue to integrate space capabilities throughout national security endeavors.

Finally, we will explore new opportunities for cooperative endeavors between national security space and the US civil and commercial space sectors. Internationally, working with our friends and allies, we will seek out opportunities for partnerships that enhance US and coalition space capabilities and operations.

Developing and Maintaining a Team of Space Professionals

In order to preserve our advantage as the leading spacefaring nation, we must ensure that we have a strategy to guarantee availability of the most crucial element of space power—our space professionals. People remain central to our success in space, and meeting the serious challenges of today, as well as the future, requires a Total Force approach. We will continue to develop well-educated, motivated, and competent people skilled in the demands of the space medium.

Operationally, they must understand the tactical environment they support, together with the needed space-unique tactics, techniques, and procedures. Technically, they must be schooled in the acquisition of space systems, the requirements of the vehicles that operate in space, and the development of space-related research, science, and technology. Our space professionals must remain sensitive to the needs of the many and varied end users of space capabilities; further, they must formulate and articulate new space doctrine to fully control and exploit the medium of space in support of our nation's security objectives.

Space professionals must develop new technologies, systems, training methods, concepts of operations, and organizations that will continue to sustain the United States as a world leader in space. The new systems they develop must achieve desirable effects at all levels of conflict. Furthermore, they must see to it that these systems are interoperable with and integrated into architectures that support the creation of lethal and nonlethal effects. The backbone of our joint and interagency space-operations capabilities will continue to consist of individuals of exceptional dedication and ability.

Integrating Space Capabilities for National Intelligence and War Fighting

America's space superiority and the resultant advantages depend on continued synergy among strategy, leadership, industry, and the talent of our people. Our space superiority also requires unity of effort among the defense, intelligence, and civil-government communities, as well as collaboration with the US private-sector enterprise.

We must emphasize the integration of capabilities and the production of space systems that help enhance both our long-term global perspective and our near-term understanding of events to shape our responses. Two particular efforts that we are pursuing across the national security space community demand horizontal integration of war-fighter and intelligence community needs and capabilities: space-based radar (SBR) and transformational communications.

SBR will act as the forward eyes for strike platforms and other intelligence assets by detecting surface movers and rapidly imaging stationary targets. With a day/night, all-weather capability, SBR will achieve persistent collection over denied areas, thereby benefiting intelligence collection and the war fighter in ways we are only beginning to recognize.

With space leading the way, we may single out communications as the other area ripe for transformation. The demand for communications bandwidth and access across all sectors of our society continues to increase geometrically. By their very nature, our armed forces operate in exactly those places where no ground-based networks exist—not only remote locations on land, but also on the sea, in the sky, and in space. With transformational communications, we will create an entirely new infrastructure to support future war fighting. We will exploit known technologies such as optical communications, Internet protocol networks, and packetized data switching in new ways to vastly improve our information-dissemination capabilities.

Future war fighting will demand more responsive and integrated operational concepts and the acquisition of flexible, innovative systems and capabilities. Together, these assets will meet the needs of a wide variety of traditional and nontraditional space users quickly and simultaneously—we are on the path to meet those needs.

Producing Innovative Solutions for the Most Challenging National Security Problems

Technological and industrial dominance has remained the prevailing theme in many US victories during the past century. The strategy of using technological and industrial capabilities to redress tactical disadvantages has proved spectacularly successful. This focus on maintaining both the technological edge and the means to nurture innovative approaches must continue.

Innovation defies efforts to reduce it to a recipe, but two factors favor its growth: (1) the existence of an important strategic problem and (2) the sustainment of talent and resources. A new strategic opportunity clearly exists. The reality of the current world situation demands that we provide new means, concepts, and processes to exploit the space medium in better and different ways in order to provide US decision makers the data and information necessary to help solve the toughest military and intelligence problems. We must, therefore, invest in skilled and dedicated people, leading-edge science and technology, and a healthy industrial base as the foundations of producing and delivering national security space capabilities.

Our toughest challenges demand new capabilities to improve and transform our space forces. We seek to create a synergistic and integrated mix of land, sea, air, cyber, and space power that provides additional options: (1) to warn of threats to our homeland and US interests; (2) to deter aggression, dissuade adversaries, and prevent coercion; and (3) to fight and win decisively, as necessary. In particular, we will significantly increase our investment in breakthrough technologies that underpin our transformational space programs—specifically, on-orbit sensors to detect traditional and nontraditional observables; access to and collection of intelligence, surveillance, and reconnaissance that is persistent, undeniable, and deep; and high-capacity, dynamic, high-speed communications.

Sustaining talented people and technical resources presents additional challenges. Not only will we stimulate the industrial base by investing in transformational capabilities, but also we will partner with civil agencies, industry, and academia to form a national science-and-technology program fueled by sufficient investment to encourage innovation. In doing so, we will preserve US leadership in critical technologies and bolster areas of research where the American lead is diminishing. We will also press to fund space programs at a level commensurate with their importance.

Ensuring Freedom of Action in Space

Having come to rely on the unhindered use of space, Americans will demand no less in the future. This reliance demands the continuance of robust capabilities for assured launch and space control. Although the United States supports the peaceful use of space by all countries, prudence demands that we ensure the use of space for us, our allies, and coalition partners, while denying that use to adversaries. To guarantee freedom of action, we will pursue complementary approaches for assured access to space in the near term with two providers of the evolved expendable launch vehicle, as we simultaneously investigate entirely new, operationally responsive space-lift capabilities.

Today's space-surveillance capability must evolve into integrated space situational awareness. Space-control activities—while taking advantage of improvements in such awareness—will emphasize, most importantly, the protection of our national security interests against known vulnerabilities and credible threats. We will also pursue a mix of reversible, nonlethal effects to limit any adversary's ability to deny us free access to space or to use space against us for hostile purposes.

Conclusion: Sustaining Our Space Advantage

Space systems and capabilities are critical components of our national security. Their importance demands that we guarantee a continued and enduring advantage in space. Toward that end, we must apply our most innovative thinking to exploit the inherent advantages of the space medium, enhancing our space capabilities to help solve the national security challenges of today and tomorrow. □

Commanding the Future

The Transformation of Air Force Space Command

Gen Lance W. Lord, USAF

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after changes occur.

—Giulio Douhet

No one would deny that the character of war has changed over the past century. The twentieth century saw a transition from attrition warfare in both world wars to guerilla warfare in Vietnam. The global-security situation has evolved from a standoff between superpowers throughout the Cold War to regional conflicts in the Balkans and Southwest Asia, humanitarian operations, and the global war on terrorism. The latest evolution of Air Force basic doctrine reminds us of the necessity to remain "aware of the lessons of the past—alert and receptive to future technologies and paradigms" because they may, in some manner or another, "alter the art of air and space warfare."[1] Air Force Space Command is on a path today that takes these words of wisdom to heart. This article outlines that path by looking first at some key lessons learned from recent conflicts, the foundation laid early on in military space operations, and, finally, the vision for the Air Force Space Command of the future.

Space Today

Today, events unfold before our eyes around the world as if we were there. We have advance warning of adverse weather as it develops. We can communicate with people 10 or 10,000 miles away with equal ease, and a small receiver tells us our exact position and how fast we are moving in the air, on land, or at sea.

New technologies move large amounts of data around the world at the speed of light. Although a century ago people would have considered such feats science fiction, modern space capabilities make these, and so many more things, unquestionable facts. Space power has transformed our society and our military. Today, at the outset of the twenty-first century, we simply cannot live—or fight and win—without it.

Although many people refer to Operation Desert Storm as the first space war, it did not mark the first use of space capabilities during conflict. During the war in Vietnam, space systems—communications and meteorological satellites—provided near-real-time data that was essential for combat operations.[2] The Gulf War of 1991, however, was the "first conflict in history to make comprehensive use of space systems support."[3] Since then, we have worked hard to integrate the high-tech advantages provided by speed-of-light space capabilities into all our forces—air, land, and sea. Those efforts significantly improved our American joint way of war, and they paid off during Operation Iraqi Freedom.

American forces led a coalition that set benchmarks for speed, precision, lethality, reach, and flexibility. As President George W. Bush said on 1 May 2003 aboard the USS *Abraham Lincoln*, "Operation Iraqi Freedom was carried out with a combination of precision and speed and boldness the enemy did not expect, and the world had not seen before. From distant bases or ships at sea, we sent planes and missiles that could destroy an enemy division, or strike a single bunker."[4] In a matter of minutes—not hours, days, or weeks as in past wars—commanders identified and engaged targets and received timely battle damage assessment. Lt Gen T. Michael "Buzz" Moseley, the combined force air component commander, reinforced the role that space capabilities played when he said, "The satellites have been just unbelievably capable . . . supporting conventional surface, naval, special ops and air forces. They've made a huge difference for us."[5]

Space warriors deployed to the coalition's air and space operations centers (AOC); some served as expert advisors to the combined force land component commander; and others deployed to wing-level units where they integrated, facilitated, and generated space-combat effects. In the evolving nature of warfare, though, not all of our space warriors need to deploy. Space forces operating from home stations backed up those deployed experts and in many cases provided direct support and information to joint and coalition forces in the field. Throughout the conflict, our space AOC orchestrated and integrated this time-critical reachback support with theater operations.[6]

Working with other highly trained, highly skilled, highly connected, and highly integrated combat warriors, we can generate unprecedented combat synergy on the battlefield. This synergy—something we have come to expect—is aided immeasurably by eyes, ears, links, and beacons from the "high ground" of space.

There is a face to space—space capabilities and their effects touch every facet of our combat operations, but not until we start looking at specific examples does the impact of those effects really hit home. Lt Gen Dan Leaf describes this impact: "Space systems were woven through every bit of [the] moving, shooting, and communicating our land forces did."[7] He likes to share a story from Iraqi Freedom that illustrates the synergy of our forces today.

In late March 2003, the lead elements of the 3rd Infantry Division engaged enemy forces just south of the Iraqi city of Najaf. Members of Charlie Troop of the 3rd Squadron, 7th Cavalry, encountered Iraqi forces at night in a dust storm and were surrounded. They had sporadic contact on the east and on the south as well as fairly persistent contact with a large, armored enemy force on the west while another enemy force was moving down from Hallah towards Najaf. This contact was so close that Iraqi rocket-propelled grenades ricocheting off US armored tracks were killing Iraqi soldiers. The severe weather forced the Iraqis to pack their T-72 tanks and other armored vehicles very tightly together. During the intense fighting, US Army soldiers dismounted their tracks and picked up enemy AK-47 rifles from the dead and wounded to fire back at the enemy.

During this engagement, an Air Force tactical air controller engaged a reported 20 T-72s and some 10 to 15 other armored vehicles with four 2000-pound global positioning system (GPS)-aided Joint Direct Attack Munitions (JDAM) from an Air Force B-1 bomber. The bomber received the tasking via satellite communications and, because of GPS navigation satellites, put its weapons precisely on the enemy, destroying the Iraqi force. When the dust cleared, Charlie Troop had not suffered any casualties. Coalition forces turned a potential disaster into a decisive defeat of the enemy while visibly demonstrating the asymmetric advantage that integrated air and space capabilities can bring to the fight.

Another example that puts the "face to space" comes from World War II and the daylight bombing raids on Schweinfurt, Germany, in 1943. The targets were five ball-bearing factories essential to German fighter production. On the first mission, which took place on 17 August, 200 B-17 Flying Fortresses dropped 760,000 pounds of ordnance. Thirty-six aircraft were lost on that mission alone. On 14 October, America lost an additional 60 aircraft, and another 138 were damaged out of 291 sent on the raid, for a two-mission total of 68 percent damaged or destroyed! The United States Army Air Forces could not sustain deep-penetration missions without fighter escorts—the damages were too severe. As a result, the Allies suspended attacks for four months, and German production returned to preraid levels.

Today a single B-2 or B-52 mission with five GPS-guided JDAMs (10,000 pounds of ordnance) would have much better effects versus the 24 million pounds dropped on Schweinfurt that destroyed the targets but caused significant collateral damage and numerous civilian deaths. Once again, this example illustrates the asymmetric effect of integrated air and space forces. The lessons learned from every contingency operation since Desert Storm highlight the importance and urgency to fully integrate space into the fight. Today, our integrated team of dedicated space professionals and the space and missile capabilities they bring are essential to any fight and, maybe more importantly, to deterring conflict before it begins. Military space is not in the back room behind the secret door anymore.

Although we rightfully tout our recent combat successes, Air Force Space Command must move forward to face even greater challenges in the future. Space capabilities provide an ever-increasing asymmetric advantage for our nation's military. We must not let that significant advantage become a disabling vulnerability. Future adversaries understand the importance of space and the advantage it offers our forces. We have to assume that those same potential adversaries are developing methods to challenge our capabilities. It has been said that "you never really know what you have until it is gone." Imagine the effects of tugging on the string of space—a string tightly interwoven into the fabric of our joint force. Our capabilities would quickly begin to unwind. We have enjoyed a period of unchallenged dominance in military space that has enabled our success since Desert Storm. Our jobs would become much easier if we could expect this trend to continue, but we would be living a dream.

Space Yesterday

These concerns and recent lessons learned will significantly influence that future, but Air Force Space Command also has to look to the past as it develops the space force of the future.

Foundation for the Future

A small group of visionaries played key roles in establishing the foundation of our nation's military space power. These space pioneers led the technical innovations that pushed America through—and helped us win—the Cold War. In 1954 the Air Force Research and Development Command established the Western Development Division and named Bernard A. Schriever, a brigadier general at that time, the first commander.[8] General

Schriever and his team developed the systems that formed the basis of every one of our current space and missile capabilities. They provided a momentous beginning to the Air Force's leadership in military space power.

The Western Development Division developed the nation's intercontinental ballistic missile (ICBM) program, the Corona/Discoverer satellite-imagery program, and our launch programs. The division was the home for communications, weather, and navigation satellites as well as for MIDAS, the first missile-detection program. Technical competency and technological superiority laid the groundwork for amazing progress—progress absolutely essential to keep pace with, and ultimately surpass, the Soviets in a race for survival. Then, like now, the key to that progress—the key to that technical competency and superiority—was not the systems themselves, but the people who took those systems from concepts on a drawing board and made them a reality.

Space and Missile Pioneers

Each year Air Force Space Command recognizes individuals who played a significant role in the history of the Air Force's space and missile programs. The achievements of these pioneers are nothing short of astounding. Their effort formed the capabilities that are still the best in the world. With a depth of technical expertise and unfailing determination, they did something that no one had done before. The United States placed unparalleled trust in these pioneers at a time when failure was simply not an option. This past year, the inductees included Brig Gen Martin Menter, who, from the late 1950s onward, was an international leader in the fields of aeronautical and space law. His legal treatises on space law were the first of their kind anywhere in the world.[9] Another inductee in the class of 2003, Col Albert J. "Red" Wetzel, directed the Titan ICBM program from its concept stage to operational readiness in 1961.[10] Lt John C. "Jack" Herther designed a three-axis stabilization system during the late 1950s that enabled Lockheed's Agena space vehicle to become the workhorse of the Corona reconnaissance program.[11] Finally, Capt Robert C. "Bob" Truax, US Navy, played an instrumental role over the course of three years in the early stages of the Thor intermediate-range ballistic missile and WS-117L, the Air Force's advanced reconnaissance system, at the Western Development Division.[12] These innovative pioneers designed, launched, and overcame all obstacles. They laid the foundation and set Air Force Space Command on a success-oriented path that served the nation well in the decades which followed. Our successes in recent contingency and combat operations were also enabled by a concerted effort to more fully "operationalize" our space operations.

Operationalizing Space Operations

Over the last 12 years, operationalizing space operations served as a central tenet of the Air Force Space Command agenda, and that emphasis paid off. Taking advantage of lessons learned from air- and missile-operations missions, the command emphasized disciplined and structured space operations based on sound technical data coupled with robust crew-force training, evaluations, and inspections. As a result, operational success, readiness, and competency soared. Air Force Space Command built an extensive knowledge base for space systems founded on expertise in operational weapon systems while pushing responsibility down from midgrade officers and senior noncommissioned officers to lieutenants and junior Airmen.

These lessons from the past—the technical foundation laid by the men and women of the Western Development Division, the examples set by our space pioneers, and the significant progress in operationalizing space operations within Air Force Space Command—point clearly to the next step in space power. As our nation's dependence on space capabilities grows, it is critical that we create and then develop a cadre of space warriors who are equally skilled in operational art and technical expertise. Military space operations must have a depth of technical and operational expertise in each mission and weapon system in order to face increased and even more uncertain threats than our nation confronted during the Cold War.

These lessons from the past, when coupled with the uncertain threats looming in the dynamic and changing security environment of the twenty-first century, necessitate a change in focus for military space operations: "Defending the United States of America through the control and exploitation of space."[13] To that end, our charter for the future of Air Force Space Command is to maintain the highly successful force-enhancement roles the command provides our joint forces today and to increase its focus on producing warfighting effects with space superiority and strike capabilities—in short, to become a full-spectrum space-combat command.

Space Tomorrow

Space capabilities are inherently global in nature and joint in terms of the effects they produce. Air Force Space Command must develop and deliver the full spectrum of space-combat effects. To do that, command and control capabilities must deliver the right combat effect to the right place at the right time. Doing so requires a fundamental shift in our thinking. In the past, we focused largely on the force-enhancement role of our space systems and the deterrence role of our nuclear forces. The space and missile operations of tomorrow will focus on developing and projecting combat power. To make that vision a reality, Air Force Space Command has implemented a strategy we call "Commanding the Future"—our flight plan for transformation.

Space Professionals

One of the key components of that flight plan is the human aspect of this crucial business—space professionals. World-class scientists, engineers, and operators can be found in academic institutions, industry, government agencies, and all our military services.[14] Sustained excellence in the scientific and engineering disciplines is essential to the future of the nation's national-security space program. As the Space Commission pointed out, we cannot take it for granted: "Military space professionals will have to master highly complex technology; develop new doctrine and concepts of operations for space launch, offensive and defensive space operations, power projection in, from, and through space, and other military uses of space; and operate some of the most complex systems ever built and deployed."[15]

To shape the future, the team of tomorrow—made up of these space professionals—must build on the success of today as well as the immense legacy of the space and missile pioneers. Last fall I had the opportunity to speak about officership to cadets at the Air Force Academy; I was impressed. Their technical and professional military education is truly second to none, and their leadership's "Agenda for Change" is really making great progress. These outstanding young men and women, along with those of the Reserve Officer Training Corps and Officer Training School, are the future leaders and pioneers of our Air Force. They will operate, employ, and sustain the systems we are designing and building today. The space professionals of today are working hard to define and shape the future—but these young people will live it!

Warrior Culture

Culture, another key component of our Commanding the Future flight plan, is directly related to the space-professional concept. Members of the Space Commission cited in their report the importance of culture and recommended that the Air Force "take steps to create a culture within the Service dedicated to developing new space system concepts, doctrine and operational capabilities."[16] It is the duty and fundamental responsibility of Air Force Space Command to generate, maintain, and ensure space superiority. We must see to it that our nation and allies can operate in space and deny that same advantage to our adversaries. Air Force Space Command is developing a warrior culture, a warrior ethos, to meet that responsibility.

As Airmen, we recognize the importance of gaining and maintaining air superiority in all conflicts. We design and build aircraft and weapon systems to this requirement and emphasize this point throughout our professional military education as we train our warriors and leaders to achieve it. It is the sum total of our service culture. Space should be no different. Space superiority is our mandate, and space superiority must roll off our tongues as easily as air superiority. The world today is much more unsettled than it was during the Cold War. Threats are more unpredictable, and adversaries have increasingly more technological savvy. Space capabilities have become both a military and economic center of gravity for our nation and our allies.[17] We assume that these capabilities will always be available and deem them more critical than ever before.

Space Superiority

Just as we gain and maintain air superiority through offensive and defensive counterair operations, so do we achieve space superiority through offensive and defensive counterspace operations. Air Force Doctrine Document 2-2, *Space Operations*, tells us that "space situational awareness (SSA) forms the foundation for all counterspace and other space actions."[18] In other words, robust situational awareness is absolutely essential to our mandate of ensuring space superiority. Historically, the command has focused efforts in this area around space surveillance; although that is still important, there is more to SSA than simply space surveillance.

Based on data from the 1st Space Control Squadron, located in Cheyenne Mountain Air Force Station, Colorado, there are over 1,150 satellites in space today—over 300 of those are US satellites, about 60 of which are military. We also track over 13,500 objects in space for collision avoidance.[19] Although we know and track what's up there, we must know more. We need to know what capabilities are available to potential adversaries and need to understand what natural or hostile events can disrupt our use of space or present threats against our interests on Earth. Adversaries know the value and benefit we derive from space—a value that enhances, improves, and transforms our military operations. We must assume they will increasingly try to deny us the asymmetric advantage that space provides. This assumption proved accurate during Operation Iraqi Freedom when coalition forces faced a GPS jamming threat—and that is only the tip of the iceberg for what lies in store for the future. We simply must have the ways and means of detecting, characterizing, reporting, and responding to attacks in the medium of space. Space is no longer a sanctuary, and our vision—our culture—must transform appropriately. Space superiority must be our first thought. It must become our way of life.

Conclusion

In Air Force Space Command, our Commanding the Future efforts are on track to realize our vision of a full-spectrum space-combat command that is preeminent in the application of space power for national security and joint warfare.[20] Key to that thought is the idea of full-spectrum capabilities—kinetic through nonkinetic—across the entire spectrum of conflict. We will be able to rapidly bring the full weight of space power to bear globally, generating war-fighting effects when and where needed. We will also be aware of, and be able to counter, an adversary's attempt to exploit this same set of advantages.

What is the key to making this vision a reality? Actually, it is very simple—people! Our space professionals will be warriors—they must have that focus. Space professionals must understand the comprehensive set of space capabilities and the effects they can deliver, but they must also understand how those effects are integrated with those generated in the air, on land, or at sea. They will be experts—not only in operations but also in the acquisition process. The new space cadre will have a broad space-education background with in-depth expertise in weapon systems. Why so many requirements? Are we asking them to be space pioneers? Well, in a word, yes. The next generation of our space capabilities, which we are developing today, will be more complex, more dynamic, more integrated, and more responsive to both theater and global requirements.[21] The space professionals of the future must take advantage of those capabilities.

If this seems like a lot of change, it is, but there should be no question that this process is absolutely necessary. Air Force Space Command must focus on the future and be ready for whatever it brings. If our past experiences have taught us anything, it is that we must be ready for new and unexpected challenges—we must be ready for surprises. To do that, we have to transform our way of doing business. Through this transformation, though, some things will remain the same. In a speech to the National Defense University in January 2002, Secretary of Defense Donald Rumsfeld reminded America's military of another time of such dramatic changes: "In 1962, during a similar time of upheaval and transformation, as our forces prepared to meet the new challenges of the Cold War, General MacArthur addressed the cadets at West Point, and he said, 'Through all this welter of change, your mission remains fixed, determined, inviolable: It is to win wars.' The mission of the armed forces remains equally fixed today, equally determined and inviolable."[22]

The evolution of Air Force Space Command over the next few years will make certain that we continue to meet that goal and accomplish our mission. The character of war is truly dynamic, and our anticipation of those changes will ensure that victory continues to smile on us all. □

Notes

1. Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, 17 November 2003, 105.
2. David N. Spiers et al., eds., *Beyond Horizons: A Half Century of Air Force Space Leadership* (Peterson AFB, CO: Air Force Space Command, 1997), 169.
3. *Conduct of the Persian Gulf War: Final Report to Congress* (Washington, DC: Department of Defense, April 1992).
4. "President Bush Announces Major Combat Operations in Iraq Have Ended: Remarks by the President from the USS *Abraham Lincoln* at Sea Off the Coast of San Diego, California," 1 May 2003, http://www.whitehouse.gov/news/releases/2003/05/iraq/20030501-15.html.
5. Lt Gen Michael Moseley, "Coalition Forces Air Component Command Briefing," United States Department of Defense, *News Transcript*, 5 April 2003, http:/www.defenselink.mil/news/Apr2003/t04052003_t405mose.html.
6. This AOC is located at Vandenberg AFB, CA.
7. Lt Gen Daniel P. Leaf, Air Force Space Command, Peterson AFB, CO, interview by Maj John Wagner, 14 August 2003. Currently the vice-commander of Air Force Space Command, General Leaf served as director of the Air Component Coordination Element for the combined force land component commander during Operation Iraqi Freedom.
8. Gen Bernard A. Schriever, "Military Space Activities: Recollections and Observations," in *The U.S. Air Force in Space: 1945 to the Twenty-first Century*, ed. R. Cargill Hall and Jacob Neufeld (Washington, DC: Air Force History and Museums Program, 1998), 15.
9. Air Force Space Command Historian's Office, "Brigadier General Martin Menter," *Air Force Space and Missile Pioneers*, http://www.peterson.af.mil/hqafspc/history/menter.htm.
10. Air Force Space Command Historian's Office, "Colonel Albert J. Wetzel," *Air Force Space and Missile Pioneers*, http://www.peterson.af.mil/hqafspc/history/Wetzel.htm.
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12. Air Force Space Command Historian's Office, "Captain Robert C. Truax (USN)," *Air Force Space and Missile Pioneers*, http://www.peterson.af.mil/hqafspc/history/Truax.htm.
13. *Annual Performance Plan* (Peterson AFB, CO: Headquarters Air Force Space Command, 2003), 2.
14. *Report of the Commission to Assess United States National Security Space Management and Organization: Executive Summary* (Washington, DC: The Commission, 11 January 2001), 18.
15. Ibid. *Space Commission* is the term commonly used to refer to the Commission to Assess United States National Security Space Management and Organization.
16. Ibid., 23.
17. *Air Force Space Command Strategic Master Plan, FY06 and Beyond* (Colorado Springs, CO: Headquarters Air Force Space Command/XPXP, 1 October 2003), 23.
18. AFDD 2-2, *Space Operations*, 27 November 2001, 14.
19. The 1st Space Control Squadron tracks objects down to about 10 cm (softball size), which could do extensive damage to a manned or unmanned spacecraft.
20. *Air Force Space Command Strategic Master Plan*, 3.
21. These capabilities include, but are not limited to, space-based space surveillance (SBSS), space-based radar (SBR), space-based infrared system (SBIRS), and transformational communications.
22. Donald Rumsfeld, US secretary of defense (address, National Defense University, Fort Lesley J. McNair, Washington, DC, 31 January 2002).

LT COL PAUL D. BERG, EDITOR

A Changing of the Guard

COL CHRIS CAIN has served with distinction as editor of *Air and Space Power Journal* for nearly two years, but all good things must end. He is moving to a new assignment. Chris brought numerous innovations to the *Journal*. He developed a thematic construct that paid dividends in the Centennial of Flight issue, recognized by many readers as his finest effort. During his tenure, he produced seven issues on such topics as leadership, weapons of mass destruction, transformation, and technology. He has built upon the *Journal*'s already strong reputation as a leading air and space power forum by introducing a new e-mail subscription service in late 2003 to meet the needs of deployed Airmen; by including "NOTAMs" about changing doctrinal concepts and vignettes that feature important people and events from our service's history; and by laying the foundation for an upcoming joint US Air Force / British Royal Air Force issue, just to mention a few of his initiatives. We wish him continued success in his new job—but we will miss him.

The free e-mail subscription to the online version of the English-language *Air and Space Power Journal* has been such a resounding success—now boasting over 2,500 users—that we've expanded the service to include the Spanish-language *Journal*. We add subscribers' e-mail addresses to our electronic distribution list so that we can automatically send them a table of contents with links to full-text articles in each new quarterly issue of either the English or Spanish *ASPJ*, thus ensuring that they don't miss any of our informative features.

E-mail subscription is easy. For the English *Journal*, all you have to do is log on to the "Subscription Center" at the *Air Force Link* Web site http://www.af.mil/subscribe, select the "sub[scribe]" radio button for *Air and Space Power Journal*, enter your name and e-mail address, and then click on the "submit" button. For the Spanish *Journal*, select "Air and Space Power Journal (en español)." We will notify you of your subscription via e-mail and ask that you confirm it. Of course, you may subscribe to the *Journal* in both languages if you wish.

We on the *ASPJ* editorial staff are always looking for new, insightful articles and book reviews in our quest to publish *the best in air and space power thought*. We offer both hard-copy and electronic-publication opportunities. If you are interested in submitting an article for publication, please refer to our guidelines in the "Mission Debrief" section of this issue, or check the submission instructions on our Web site: http://www.airpower.maxwell.af.mil/airchronicles/howto.html. If you're interested in the latest books about airpower, space power, and other military topics, see our book-review section, both in the published version of *ASPJ* and online at http://www.airpower.maxwell.af.mil/airchronicles/bookmain.html. If you would like to write a book review for us, please refer to the guidelines on our Web site. As you can see, you have many opportunities to contribute to your *Journal*. □

Space Power

SPACE POWER IS becoming an increasingly important aspect of national strength, but experts disagree about how best to develop its potential. Like airpower, space power relies heavily upon advanced technology, but technology is useless unless space professionals apply it properly. Air Force leaders recognize that the service needs to nurture a team of highly dedicated space professionals who are prepared to exploit advanced technologies and operating concepts. Today, space power provides supporting functions such as communications, reconnaissance, and signals from global positioning system (GPS) satellites—tomorrow, space may become the site of combat operations. Concern about the future direction of military activities in space has spurred debate over which technologies to produce and how best to develop space professionals. Moral, theoretical, and doctrinal questions also loom large. Underlying all of these considerations are political and diplomatic factors.

Morality poses unique challenges for space power. People have fought on land and at sea for millennia, but some see space as a pristine domain, unsullied by human conflict, and want to keep it that way. Others see space power as a critical, asymmetric military advantage ripe for exploitation by technologically advanced nations. The way political forces adjudicate this ethical issue will strongly influence the future military use of space.

Like airpower, space power lacks an overarching theory. Some professionals view theory as a type of Holy Grail; others take a more pragmatic approach. Space theories have traditionally featured derivatives of seapower and airpower thought. Space-power theory generally considers the control of space analogous to the vital task of regulating the sea and air. Fleshing out the details of how to gain control of space and what to do afterward, however, has proven difficult. Pragmatic space professionals might point out that space power has already achieved a great deal without the benefit of a completely satisfying theory.

Efforts to formulate space doctrine—derived from theory, previous experience, and other sources—inspire especially active and varied commentary. Current Air Force doctrine addresses everything from fundamental "tenets of space power" to more specific guidance about integrating space into the combined air and space operations center (CAOC). The issue of "weaponizing" space poses questions that may alter the relationship between operations in space and those in the air, on the ground, and at sea. Air Force space professionals continue to grapple with such important doctrinal questions.

The high cost of space technology drives the need to develop cogent moral, theoretical, and doctrinal underpinnings for space power. By doing so, we can persuade our political leaders to spend money on the right technologies and force-development initiatives, thereby assuring the United States the maximum benefit from space power. □

Doctrine NOTAM

Effects-Based Operations

CHARLES TUSTIN KAMPS

THE *JOINT FORCES Command Glossary* defines effects-based operations (EBO) as "a process for obtaining a desired strategic outcome or 'effect' on the enemy, through the synergistic, multiplicative, and cumulative application of the full range of military and nonmilitary capabilities at the tactical, operational, and strategic levels" (http://www.jfcom.mil/about/glossary.htm). As such, all types of armed forces have performed EBO for centuries—albeit without the same dynamics as have appeared since the beginning of practical airpower in the early twentieth century.

During World War I, ground forces proved adept at killing the enemy in large numbers but equally *unable* to achieve a decision. Postwar air theorists, including Italy's Giulio Douhet, Britain's Hugh Trenchard, and America's William "Billy" Mitchell, championed an alternative to attrition in the form of what we now call EBO. Using "strategical" bombardment, they envisioned achieving the "effect" of destroying the enemy's army by attacking his population centers, critical industries, or logistical infrastructure.

These ideas, developed during the 1930s by the US Army's Air Corps Tactical School and the Royal Air Force's Bomber Command, formed the basis for the Combined Bomber Offensive of World War II. EBO conducted by "strategic" air arms in that war received mixed reviews but undoubtedly affected the outcome of the conflict. In truth, although the theory was sound, interdiction by tactical aviation and submarines may have proved the concept more convincingly than did heavy bombers.

Nevertheless, EBO and the ability to strike directly at enemy centers of gravity were instrumental in securing an independent US Air Force in the postwar era. After an institutional hiatus in strategic thinking during the nuclear-dominated Cold War, the application of airpower in a conventional EBO role reemerged in the 1980s in the writings of John Warden and later under his protégé, David Deptula. This reemergence of EBO invoked the advantages promoted by early airpower visionaries; however, the emphasis shifted away from populations and industry toward targets such as electrical grids and command and control networks. The Warden model of analyzing the enemy as a "system of systems" has become a definite factor in Air Force planning thought since the Gulf War of 1991.

The proverbial "long pole in the tent" for EBO has always been accurate assessment, which, in turn, has depended upon imperfect intelligence. By their very nature, second- and third-order effects from military operations can take time to come to fruition and may be difficult to discern. Ironically, even though the Air Force has fully embraced the modern interpretation of EBO, after-action reports from Operation Iraqi Freedom indicate that, for the most part, the service measured "success" by traditional attrition methods because of the high tempo of operations and the resultant inability of headquarters to gauge or assess effects.

In the final analysis, EBO has indeed transformed modern military thought, thanks in part to the latest generation of weapons and platforms that facilitate its execution. The Air Force and the joint community now look forward to a future in which decisive action takes place directly against an enemy's critical vulnerabilities and centers of gravity in order to achieve "effects" formerly attainable only after long periods of tactical and operational attrition.

To Learn More . . .

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At the rate science proceeds, rockets and missiles will one day seem like buffalo-slow, endangered grazers in the black pasture of outer space.

—Bernard Cooper, physicist

The Air Force of the Future

Thoughts from the Future Capabilities War Game of 2004

THOMAS R. SEARLE*

MANY OF THE strengths and weaknesses we see in the US Air Force today reflect decisions made decades ago during the Cold War to meet the Soviet challenge. For example, to stop huge, fast-moving Soviet ground forces protected by state-of-the-art aircraft and air-defense systems before they overran Western Europe, the Air Force knew it would have to gain air superiority immediately and then rapidly destroy an enormous number of ground targets, all the while suffering severe attrition. Toward that end, the Air Force built an impressive fleet of F-15C air-superiority fighters and a very large force of strike assets (A-10s, F-16s, and F-15Es). Because Soviet offensive doctrine sacrificed concealment for speed and mass, making Soviet forces easy to find, the Air Force did not invest so heavily in tactical intelligence, surveillance, and reconnaissance (ISR). Since the end of the Cold War, however, the actual foes attacked by the Air Force have neither seriously contested US air superiority nor tried to overwhelm US forces rapidly with an enormous number of armored vehicles; instead, they have attempted to conceal themselves from us. As a result, the Air Force has entered recent conflicts with a surplus of strike assets—both air-to-air and ground—but a shortage of ISR assets.

Just as decisions made 20 or more years ago shape our current forces, so will the decisions we make today shape the Air Force for decades to come. In an effort to help us build the Air Force we will need, the recently

*The author is a military defense analyst with the Airpower Research Institute, College of Aerospace Doctrine, Research and Education, Maxwell AFB, Alabama.

completed Future Capabilities War Game of 2004 looked at alternative, hypothetical force structures in conflict with a notional adversary in the year 2020. The game players came away with clearer questions but not necessarily with clear answers to all of them—and that was by design. Without discussing any classified research or detailed risk-versus-reward calculations on investment options for weapons development, this article raises certain fundamental questions about the future of the Air Force that all Airmen need to consider.

How Will Our Sister Services Transform Themselves in the Coming Decades?

The Air Force will fight as a member of a joint, combined, and interagency team in the future. Therefore, to achieve the maximum possible synergy, we must stay abreast of thinking in the other services. The single most striking aspect of how the Army, Navy, and Marine Corps plan to transform themselves is that they all intend to dramatically change the way they get to the fight. The Army's future combat systems and its shift to smaller, more carefully task-organized units of employment and units of action are driven by the belief that these changes will insert effective and sustainable land power into the fight faster. Similarly, the sea services have embraced concepts of "sea basing" and "ship-to-objective maneuver" that will transform the way they fight by radically changing their means of getting to and sustaining the fight. The Air Force, on the other hand, got a head start on these sorts of reforms with the expeditionary air and space force and related efforts to make the force more expeditionary, dating back to the late 1990s. The Air Force is currently less focused on changing the way it reaches the fight than the other services are.

All of the other services also have become heavily involved in developing unmanned aerial vehicles (UAV). The ground services in particular are looking at using a large number of very small, cheap UAVs swarming over the battlefield in support of the tactical and operational surface fight. If these systems are in fact inexpensive, the enemy will likely field significant numbers of them as well. Consequently, the Air Force will have to figure out how to sort friend from foe in this cloud of small UAVs, tap into the intelligence provided by the friendly ones, and manage the airspace.

How Much of the Force Needs to Be Transformed—and How Quickly?

Transformation has replaced *revolution in military affairs* as the most popular term for describing future forces. Most of the discussion deals with what to transform, but one must also consider how much of the force needs transforming and how quickly. To frame the problem, let's consider some historical examples. In 1940 Germany invaded France, Belgium, Luxemburg, and the Netherlands with air and ground forces smaller than the Allied forces opposing them. However, about 7 percent of the German forces had “transformed” after receiving armored tracked vehicles, motorized logistical support, and effective close air support and air interdiction. These Panzer forces, though only a small part of the entire German force, enabled the Germans to conquer all four of the countries they invaded in about six weeks, despite the fact that the opposition was just as good as the German troops and comparably equipped. This “blitzkrieg” was possible because the Allies had not transformed a major part of their forces.

However, as the war continued, the Germans’ industry could not produce enough vehicles to transform their entire army. The United States, on the other hand, had vastly more industrial capacity than Germany, allowing it to transform its entire force. As a result, when the US Army entered France on 6 June 1944, American infantry divisions had more tanks and trucks than did the German Panzer divisions while the untransformed German infantry divisions still relied on horse carts. Once the Allies broke out of the Normandy peninsula, their fully transformed forces outmaneuvered and overwhelmed the partially transformed German forces. But at the same time that transformed US Army forces were liberating France, the blitzkrieg transformation was having only minimal impact on the way the US Army fought the Japanese in the Pacific. Thus, any specific kind of transformation will yield greater dividends in some environments than others (the blitzkrieg transformation proved decisive on the European continent but much less important on the Pacific islands). Furthermore, although transforming the entire force is not necessary to trounce outdated forces, complete transformation becomes important in defeating a near-peer that has updated parts of its force.

Consider a more recent example. The development of stealth aircraft has had some transformational effects on airpower. In stealth terms, the Air Force is partially transformed. The service’s stealth assets were very important against Iraq in 1991 and Serbia in 1999 but largely irrelevant in Afghanistan in 2001. While the Soviet Union existed, the Air Force planned to transform its entire manned bomber force to a stealth force with hundreds of B-2 bombers. The dissolution of the USSR, however, prompted the Air Force to build a small B-2 force and retain untransformed, nonstealthy manned bombers. Because this partially transformed bomber force has proved affordable and highly effective, the Air Force intends to retain a partially transformed bomber force for decades. Thus, the basic questions about how much of the force needs transformation, in what way, and how fast, hinge on the sort of fight we expect to be in (e.g., continental Europe or Pacific island), what sort of enemy we expect to fight (e.g., Afghans, Serbs, or Soviets), and what sorts of capabilities we want to have (e.g., stopping a huge, rapid armored invasion or finding a small, hidden enemy force).

What Threat Will We Face in the Future?

War planning is based upon a known objective that forces must achieve against a specific enemy using a certain force structure. However, considering the time required to field new weapons; develop doctrine as well as tactics, techniques, and procedures (TTP) to employ them; recruit and train personnel to execute the TTPs; and so forth, planners have to make important force-structure decisions very far in advance, when our objectives and enemy are not at all clear. In spite of our best efforts, we have not done very well at predicting the wars we would have to fight. For example, we did not see the Korean War coming; we did not expect the Vietnam War to grow nearly as big as it did; and we did not expect to invade Afghanistan. Other nations have not done much better at predicting their future foes, and—given the fluid nature of the post–Cold War world—it seems unlikely that we will suddenly become dramatically better at doing so. Under conditions of such great uncertainty, we need to consider several alternative threats.

In recent conflicts in Panama, Haiti, Bosnia, and Afghanistan, we had the luxury of fighting enemy forces designed to meet a very different threat than the one posed by the US military, giving us an enormous advantage. We can reasonably expect that some of our future foes will be similarly designed to meet only a local threat and prove just as unable to cope with our capabilities as Manuel Noriega's Panamanian forces in 1989 or the Taliban's Afghan forces in 2001. Assuming, however, that some future adversaries will devote serious thought and effort to countering US forces, what sorts of threats will they probably pose?

The cheapest and most obvious approach to attacking the United States and its allies calls for terrorism and guerrilla warfare. We already find ourselves fighting a global war on terrorism as well as guerrillas in Iraq and Afghanistan, so we do not have to wait for 2020 for these threats to arrive. Presumably, daily combat with guerrillas and terrorists over the coming decades will improve our ability to meet these asymmetric threats, but the threats will still exist. Similarly, our computer networks have come under attack, and although decades of cyber combat should enhance our capabilities, we can expect future foes to continue their assault on our networks.

If some future foe tries to meet us in more traditional combat, how might he do that? Clearly, he will not build imitation F-15s and F-16s. To build a force comparable to the one we already have would be prohibitively expensive; moreover, by the time an adversary fielded it, we would have a force of F/A-22s and F-35s, decisively more effective than his imitation F-15/16 force. In fact, given our advantage in manned aircraft and stealth technology, no enemy is likely to challenge us directly in those areas. Similarly, our national and theater anti-ballistic-missile programs make ballistic missiles a bad long-term investment for potential foes. The fact that we can cope with enemy aircraft, together with our growing ability to handle ballistic missiles, will also create problems for enemies who attempt to deliver weapons of mass destruction against us. Since we expect to maintain overwhelming, long-term superiority in nuclear weapons, using weapons of mass destruction against the United States would invite disastrous US retaliation. Of course, terrorists' willingness to face the consequences of employing such weapons makes them a particularly important long-term threat.

Although traditional weapons do not offer a potential foe the opportunity to leap ahead of us by 2020, some other technologies might. Directed-energy (DE) weapons, which can travel at the speed of light and achieve a variety of effects, might represent that sort of leap-ahead technology. Additionally, a technologically sophisticated and well-resourced adversary might also gain an advantage with nanotechnology and present the United States with a vast number of tiny threats. Since anyone with the technological and economic wherewithal to develop these technologies and the intention of opposing us is probably working hard in these areas, we need to think seriously about how we will counter these threats.

What Will the "Network" Really Do for Us?

A great deal has appeared in print about "netcentric warfare" and what a truly networked system would provide. According to the basic idea, the same types of technology that enable cellular phone calls to take any of a large number of different routes from one phone to another would create a communications system that would be very hard to take down, if mounted on a mix of air, surface, and space vehicles. Further, if the data-transfer rates between the various elements on the network were sufficient, every system in the network would know anything known by any other system anywhere in the network in real time. This capability would make even the smallest, most remote elements of the network (an individual soldier, aircraft, bomb, etc.) incredibly "smart," achieving an otherwise unimaginable level of speed and synergy throughout the system.

One of the attractions of this kind of networking is that it radically improves the intelligence of the different nodes and thus helps address our existing ISR weakness. From the perspective of the observe-orient-decide-act (OODA) loop, the network should radically tighten our loop, putting us inside the decision cycle of anyone less networked (less "transformed") than ourselves. One major challenge would involve trying to achieve this sort of real-time universal omniscience without simply overwhelming our personnel and machines with irrelevant information.

The Air Force and its sister services have been heading in the direction of networked warfare for some years now, but predicting how far we will go and how fast is very difficult. Perhaps the most daunting challenge lies in transforming our doctrine, training, education, and TTPs to take full advantage of the network without getting ahead of our actual capabilities and relying on something that does not yet work. For example, in a fully networked force, we would not publish a daily air tasking order (ATO) but produce a sort of living ATO that would continuously evolve in real time. But if we have switched to the living ATO with no published, daily version and the network crashes, what will we fall back on? At one point during the Vietnam War, the Air Force put too much faith in air-to-air missiles too soon and had to reinstall guns in fighter aircraft because the missiles were not actually ready to replace guns completely.

What Do Unmanned Aerial Vehicles Offer Us?

The successes of Predator and Global Hawk have taken UAVs off the drawing board and into the battlespace to stay. In 2020, however, the F/A-22, F-35, and B-2 will give the Air Force an extremely powerful, stealthy manned capability, both air-to-air and air-to-ground. Even if the F-35 is the last manned combat aircraft the United States develops, we probably will not need an unmanned replacement for it and the F/A-22 before the middle of the century. What do UAVs have to offer in the meantime?

By leaving out the human element, UAVs save weight and space and are not subject to a need for sleep. Development and testing also become faster and cheaper because there is no risk of killing the aircrew if things go wrong. Bolstered by air refueling and uninhibited by a need to swap out aircrews, UAVs can conduct extremely long-duration ISR missions, providing persistent surveillance that would prove quite expensive with manned systems. UAVs are also ideal for certain kinds of electronic-warfare missions because harmful radiation or shootdowns of the jamming aircraft no longer loom as threats. Traditional strike missions run out of munitions before human-endurance factors come into play, so UAVs offer fewer advantages in that regard although for certain high-risk strike missions, UAVs could attack without risk to an Airman. The obvious advantages of UAVs for ISR purposes and our current weakness in that area suggest that ISR should become the immediate focus of UAV development, with other applications to follow. And taking humans out of the aircraft does not mean that they disappear. UAVs have heavy crew and maintenance requirements that must be met through some combination of home-station and forward-based personnel.

What Does Directed Energy Offer Us?

The fielding of the airborne laser in the next few years will take destructive DE weapons out of science fiction and onto the battlefield. But how far should we go down this road? With such weapons still in their infancy, it is hard to foresee exactly what types of weapons will achieve what sorts of effects, at what cost. Their advantage over missiles (DE weapons reach their targets at the speed of light) makes them attractive for engaging incoming missiles before the latter reach their targets (hence the airborne laser). In space, these weapons may prove effective at very long ranges, but the atmosphere limits their reach against most targets. Because some types of DE weapons can run off aircraft power and because we can air-refuel aircraft, some of these weapons will never run out of ammunition—a situation that produces obvious advantages against a large number of enemy targets. By varying the power and dwell time on the target, these weapons offer a "dial-a-yield" capability that can provide nonlethal effects as well as varying levels of destruction which could help commanders carefully manage collateral damage. The future looks bright for DE, but the Air Force will have to pursue a variety of different research projects for some time before that future really comes into focus.

What Does "Persistent Area Dominance" Offer Us?

The Predator UAV has always served primarily as an ISR platform, but recently we have mounted two small Hellfire missiles on the vehicle. These armed UAVs have had some success as strike platforms because they already had line-of-sight view of the enemy and could attack more quickly than a manned platform not already in the area. We should consider expanding this approach to one of sending out a large number of small, unmanned systems that can loiter in an area and attack targets as they appear. If these systems become cheap enough to procure and use in large numbers, then we could use them to flood and dominate an area for as long as their flight time allowed. This concept, known as persistent area dominance, represents a radical change from our long-held paradigm of sending in a strike package to put a specific weapon on a preplanned target at a preplanned time. Traditionally, we have achieved such dominance only with surface forces. If UAVs, the network, and new munitions enable persistent area dominance from the air, it could revolutionize the way we think about airpower.

Is Space the Wave of the Future or Just Another Niche Capability?

Space vehicles have a major political advantage over air and surface systems because they can legally fly over every spot on Earth. During the Cold War, only space systems could monitor military activities deep inside the Soviet Union—the largest country in the world—from outside Soviet territory. For other areas, particularly those close to international waters, space systems offer fewer advantages. Unfortunately, the cost of launching space systems remains quite high, and once they are in place, they are expensive to repair, upgrade, or replace. Could we migrate some space capabilities—such as communications and ISR—down to very high altitudes (e.g., 100,000 feet), putting them on high-altitude airships or some other sort of extremely long-duration UAV? Doing so would radically cut the launch cost of these systems; facilitate surge launches; focus these capabilities on a particular crisis area; and allow us to upgrade, repair, or replace these systems.

The global role of the United States will always make space more attractive to us than to most other nations. But the cost of launching space systems and their vulnerability to attack make them less attractive than other unmanned systems. A few years ago, a popular saying described the Air Force as "an air and space force transitioning to a space and air force." But high-altitude unmanned systems may in fact take some of the burden off space systems, making space an important part of the force—but not the main force.

Conclusion

These are exciting times for the US Air Force. Our legacy systems remain the best in the world. The fielding of new systems such as the F/A-22 and airborne laser will give us amazing capabilities. The entire joint and interagency community is in the early stages of transformation. New technologies show great promise and may offer us dramatic new capabilities in the near future. All this while we find ourselves locked in a global war on terrorism as well as tough guerrilla fights in Iraq and Afghanistan. As busy as we are today, we still need to pause and make sure that we are building the right force for both the present and the future. The Future Capabilities War Game of 2004 forced us to think hard about tough questions. □

Maxwell AFB, Alabama

Our Air Force is the finest air and space force in the world because of the generations of professional Airmen who have devoted their lives to dominating the skies. Capitalizing the word "Airman" recognizes their historic achievements and signifies our unique contributions to fighting and winning America's wars. It shows we have earned the respect a proper name imparts. We are one Air Force and we are Airmen.

—Gen John P. Jumper
Air Force Chief of Staff

PIREP

Editor's Note: PIREP *is aviation shorthand for* pilot report. *It's a means for one pilot to pass on current, potentially useful information to other pilots. In the same fashion, we intend to use this department to let readers know about air and space power items of interest.*

Developing Space Professionals

COL CAL HUTTO, USAF*

We need space professionals in all services and agencies . . . to exploit space effectively in the interests of national security. Development of a space cadre is one of our top agenda items for national security space programs.

—Hon. Peter B. Teets
Undersecretary of the Air Force

ENGAGED IN A deadly firefight in central Iraq in March 2003, lead units of the 3rd Infantry Division mysteriously lost their primary communication link with the military strategic and tactical relay system (MILSTAR) satellite network. In an instant, critical targeting coordinates being transmitted to rear fire-support elements were completely cut off. Fortunately, an alert crew from the 4th Satellite Operations Squadron at Schriever AFB, Colorado, quickly determined that another user had inadvertently moved the satellite spot beam away from the combat zone. After initiating override procedures, personnel immediately repositioned the beam back to the fight, restoring the important link. The 3rd Infantry Division then resumed its coordinated attack and went on to win this key battle.[1]

This story represents just one of many recent examples of the critical wartime role played by military space assets and the dedicated space professionals who wield them. Make no mistake—the victorious outcome of this engagement, along with numerous other battles in Operation Iraqi Freedom, would have remained uncertain without dominant US military space power. Over the past 20 years, space systems and the people who develop and operate them have repeatedly demonstrated their indispensable contribution on the battlefield. We can rest assured that this decisive role for space will continue to expand in future conflicts.

But this is no time for complacency. The acquisition pipeline is filling up with increasingly complex space systems, such as space-based radar, that will provide unprecedented capabilities. These systems will integrate space with air, land, and sea battle arenas more than ever before. Battlefield integration and situational awareness will become vital to exploiting these new capabilities, and people are the key to that success. Specialized space expertise will play a critical role in the design and integration of these new systems. Similarly, space

*Colonel Hutto is director of the Space Professional Task Force, Peterson AFB, Colorado.

operators and support personnel will also require more in-depth knowledge of how these systems support military operations. This level of human interaction will dramatically enhance space effects as compared to today's space capabilities, which are much more static in nature.

As a result, the Air Force must redouble its efforts in recruiting and training talented people to design, acquire, operate, plan, integrate, and sustain a completely new generation of space weapon systems. In its final report, the Space Commission clearly spelled out this imperative: "The DoD is not yet on course to develop the space cadre the nation needs." Commission members further asserted that space operators and acquirers must "master highly complex technology . . . and operate some of the most complex systems ever built and deployed." This conclusion led the commission to call for initiatives to "create and sustain a cadre of Space Professionals . . . within which the space leaders for the future can be developed."[2]

Agreeing with the commission's findings, Secretary of Defense Donald Rumsfeld tasked Secretary of the Air Force James Roche to prepare a comprehensive space career-management plan.[3] As a first step, Air Force Space Command built an Air Force space-professional strategy that lays out a sound approach for developing and sustaining space professionals. Approved by Secretary Roche in July 2003, the strategy identifies the specialties and disciplines required to take space systems from *concept* to *employment*. Additionally, Secretary Roche designated the commander of Air Force Space Command the space-professional functional authority, responsible for "managing the space career field."[4] The space cadre includes nearly 10,000 officers, enlisted members, and government civilians, as well as National Guard and Reserve personnel, who serve as scientists, engineers, program managers, and space operators.

Another group of space professionals—the space-support community—is equally critical to space activities. They serve in the intelligence, maintenance, communications, weather, contracting, finance, and other functional areas. To ensure mission success, these individuals must receive similar training and development whenever they perform space-support duties. Currently, most space professionals are assigned to Air Force Space Command and the National Reconnaissance Office, but many also work at the Air Force Research Laboratory, Air Staff, Joint Staff, and air logistics centers, as well as at other major commands, unified commands, and government agencies.

Implementation of the space-professional strategy will lead to more purposeful career development for the entire space community. The strategy, already under way, includes six major initiatives: (1) identify every individual in the Air Force's space cadre and track his or her unique "space experiences," (2) develop new and improved space education and training courses, (3) institute a three-level certification program to monitor the health and status of the most junior to the most senior members of the cadre, (4) review all Air Force space billets and establish minimum space experience and certification standards for each position, (5) coordinate space-professional guidance with the appropriate force-development teams to ensure a more deliberate assignment process, and (6) establish a permanent Space Professional Management Office under the space-professional functional authority.

Because of our tighter budgets and smaller fighting force, we must constantly strive to sustain the right number of people, with the right education and training, to fill the right jobs, at the proper time in their careers. The Space Professional Implementation Plan gives us a clear road map for achieving this mandate, and it is flexible enough to accommodate changes along the way should they prove necessary. Although we are already making big strides, a number of challenges remain. Cultural shifts and change are sometimes met with apprehension and skepticism. However, we need these initiatives, which have the full support of the Air Force's senior leadership. Working individually with the thousands of space professionals throughout the Air Force is a monumental task, but it is necessary to ensure that each one understands how the new program interacts with force development. We are confident we can accomplish all of our goals, and we are working hard to implement the program as smoothly as possible. Finally, we should also note that the initiatives under space-professional development are in concert with the Air Force's evolving force-development program, so space professionals will be able to leverage an even wider range of career-development programs and resources.

Since the Space Commission first published its findings and recommendation in January 2001, we have made considerable progress, but much work remains. Space-professional development is designed to identify the opportunities and deliberately prepare our people to meet and take advantage of the operational and technical challenges of the future with the purpose of securing the ultimate high ground. The goal is to assemble a world-class team of scientists, engineers, program managers, operators, and support personnel skilled and knowledgeable in the development, acquisition, operation, sustainment, and integration of space capabilities to avoid conflict but, if necessary, provide overwhelming air and space power to guarantee victory.[5] □

Notes

1. Capt Ryan Stalnaker, 4th Satellite Operations Squadron, Schriever AFB, CO, excerpt from 50th Operations Support Squadron interview for "The Space Power Survey in Draft," January 2004.
2. *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington, DC: [Space] Commission, 11 January 2001), viii, xiii, xviii, 27, 42.
3. Hon. Donald H. Rumsfeld, secretary of defense, to secretaries of the military departments, memorandum, 18 October 2001.
4. Hon. James G. Roche, secretary of the Air Force, to Gen Lance Lord, commander, Air Force Space Command, memorandum, 15 July 2003.
5. For additional information, see *Space Professional Development*, 27 February 2004, https://halfway.peterson.af.mil/spacepro.

Psychological Operations

MAJ PAUL R. GUEVIN, USAF

JOINT PUBLICATION 1-02, *Department of Defense Dictionary of Military and Associated Terms*, defines psychological operations (PSYOP) as "planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals." PSYOP has become a mainstay of US government efforts at the strategic, operational, and tactical levels to exert such influence in a manner favorable to military operations.

PSYOP played a significant role in recent operations such as Enduring Freedom, in which air-mobility missions delivered humanitarian rations at the same time air-combat sorties struck militarily significant targets in other parts of Afghanistan. Furthermore, during Iraqi Freedom, we dropped both leaflets and ordnance to prompt enemy soldiers to surrender; we also broadcast messages to them over their own radio systems. These transmissions had the complementary effect of denying the Iraqis use of their own radios.

Air Force doctrine for information operations (see the NOTAM on info ops elsewhere in this issue) and PSYOP is evolving, a fact reflected in the Air Force Doctrine Center's realigning and renumbering of some publications. *Intelligence, Surveillance, and Reconnaissance Operations*, formerly Air Force Doctrine Document (AFDD) 2-5.2, will become AFDD 2-9, and *Psychological Operations*, formerly 2-5.3, will become 2-5.2. The next approved revision of the published documents will incorporate these changes. In addition, Air Combat Command (ACC) is currently defining a new concept of operations for "influence operations" as an element of the revised concept of information operations. As ACC's and the Air Force's center of excellence for Air Force PSYOP, the Air Intelligence Agency has taken the lead in refining the focus of PSYOP to include psychological effects.

The Air Force now believes that air, space, and information power are all psychological instruments that can influence an adversary's perception, behavior, and morale. For this reason, Air Force PSYOP activities serve as an integral part of air-operations planning and targeting processes, rather than as mere adjuncts. US aircraft, by their dynamic presence and actions, transmit an unmistakable psychological message to most adversaries. The mere threat or presence of superior aircraft can ground an enemy's air force, demoralize his army and civilian population, or promote stability.

Through the production of certain effects, our service is exploiting the psychological element of warfare by creating conditions that drive an adversary to perceive events and behave in ways favorable to friendly interests. It is in this vein that the Air Force ponders the place and direction of PSYOP doctrine.

To Learn More . . .

Air Force Doctrine Document (AFDD) 2-5.3. *Psychological Operations*, 27 August 1999. https://www.doctrine.af.mil/ Main.asp?. (This document will become AFDD 2-5.2 upon approval of its revision.)

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Hosmer, Stephen T. *Psychological Effects of U.S. Air Operations in Four Wars, 1941–1991*. Santa Monica, CA: RAND, 1996.

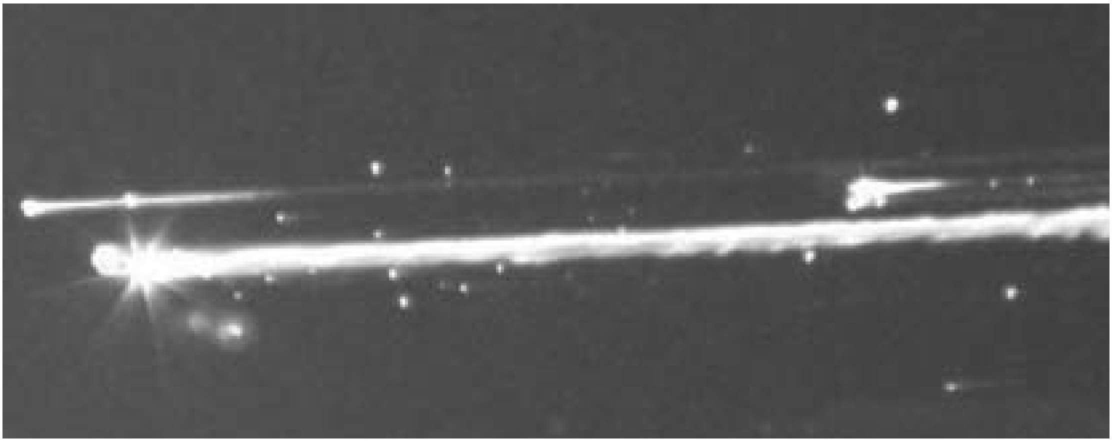
Huss, Maj Jon. "Exploiting the Psychological Effects of Airpower: A Guide for the Operational Commander." *Aerospace Power Journal* 13, no. 4 (Winter 1999): 23–32. http://www.airpower.maxwell.af.mil/airchronicles/apj/apj99/win99/ huss.pdf.

Editorial Abstract: Circumstances surrounding the loss of the space shuttle Columbia *affirm multiple lessons that emerged from analyses of similar tragedies of the past 40 years. General Deal takes a hard look at the findings of the* Columbia *Accident Investigation Board so that senior leaders of other high-risk operations can prevent similar mishaps and promote healthy organizational environments.*

Beyond the Widget

Columbia Accident Lessons Affirmed

BRIG GEN DUANE W. DEAL, USAF*



THE DATE 1 February 2003 presented the world with images that will be forever seared in memories of all viewing them—images of the space shuttle *Columbia*'s final moments as it broke apart in the skies over Texas. As tragic as the *Columbia* accident was, multiple lessons to prevent future accidents can be "affirmed" from the circumstances surrounding this accident. The emphasis is on "affirmed," because all of those lessons had been previously learned during the past 40 years through the analysis of other tragedies:

- April 1963, loss of the USS *Thresher*, while operating at the edge of several envelopes
- January 1967, *Apollo I* capsule fire on launchpad

*The author was a member of the *Columbia* Accident Investigation Board and would like to acknowledge the support and ideas contributed by many of its members and staff, particularly Maj Gen Ken Hess, Lt Col Rick Burgess, Lt Col Larry Butkus, Cdr Johnny Wolfe, and Dennis Jenkins.

- December 1984, Union Carbide pesticide factory tragedy in Bophal, India, resulting from insufficient attention to maintenance and training, and its leadership ignoring internal audits
- January 1986, loss of the space shuttle *Challenger*
- April 1986, Chernobyl disaster, where safety procedures were ignored during reactor testing
- July 2000, crash of a Concorde supersonic passenger plane in Paris after multiple prior incidents
- September 2001, al-Qaeda attacks on the United States despite more than a decade of uncorrelated signals and warnings
- October 2001, Enron collapse, despite multiple warnings and indications

The lessons gleaned from these and other prominent accidents and disasters, management and leadership primers, and raw experience are the same lessons that should have prevented the *Columbia* accident. The saddest part is that some in the National Aeronautics and Space Administration (NASA) had simply not absorbed, or had forgotten, these lessons; the result was the deaths of seven astronauts and two helicopter search team members, as well as the intense scrutiny of a formerly exalted agency.

This article highlights many of the major lessons affirmed by the *Columbia* Accident Investigation Board (CAIB)—lessons that senior leaders in other high-risk operations should consider to prevent similar mishaps and to promote healthy organizational environments. Admittedly NASA-specific and greatly condensed, the specific *Columbia*-related vignettes and perspectives presented here are intended to provide the reader an opportunity to step back and contemplate how his or her organization has the potential to fall into the same type of traps that ensnared NASA. Due to NASA's size, complexity, mission uniqueness, and geographically separated structure, some specific lessons may not be applicable to all organizations; however, the fundamental principles apply universally, as many of these same conditions may be present in any organization.

Effective leaders recognize that every organization must periodically review its operations to avoid falling into complacency as NASA had done. They also recognize that it is far better to prevent, rather than investigate, accidents. To assist with that prevention, readers should carefully examine the situations in which NASA found itself, perhaps drawing relevance by substituting their own organization's name for "NASA," and affirm those lessons once again. These situations are organized and examined in the three categories of basics, safety, and organizational self-examination.

> *We are what we repeatedly do. Excellence, then, is not an act, but a habit.*
>
> —Aristotle

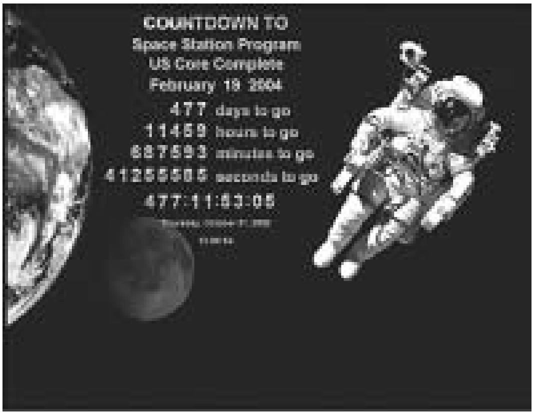
Sticking to the Basics

The reason basics are called *basics* is that they *form the foundation for an organization's success* in every field from plumbing to accounting to technology-intensive space launches. As NASA and the world shockingly discovered, deviating from basics *can form the foundation for disaster*.

Keep Principles Principal

Avoid Compromising Principles. In the 1990s, the NASA top-down mantra became "Faster, Better, Cheaper." The coffee-bar chat around the organization quickly became, "Faster, Better, Cheaper? We can deliver two of the three—which two do you want?" While the intent of the mantra was to improve efficiency and effectiveness, the result was a decrease in resources from which the institution has yet to recover.

Leaders must contemplate the impact of their "vision" and its unforeseen consequences. Many must also decide whether operations should be primarily designed for efficiency or



More than a year before the event, NASA headquarters provided everyone in NASA a screen saver that displayed the days, hours, minutes, and seconds to go until the planned launch of the final United States Node for the International Space Station. Although well-meaning, it had the unintended consequence of driving overtime, prompting questionable schedule decisions, and promoting a mind-set of meeting the goal at all costs.

reliability. The organization and workforce must then be effectively structured to support that decision, each having a clear understanding of its role.

Leaders must remember that what they emphasize can change an organization's stated goals and objectives. If reliability and safety are preached as "organizational bumper stickers," but leaders constantly emphasize keeping on schedule and saving money, workers will soon realize what is deemed important and change accordingly. Such was the case with the shuttle program. NASA's entire human spaceflight component became focused on an arbitrary goal set for launching the final United States Node for the International Space Station. They were so focused, in fact, that a computer screen saver was distributed throughout NASA depicting a countdown clock with the months, days, hours, minutes, and seconds remaining till the launch of the Node—even though that date was more than a year away. This emphasis did not *intend* to change or alter practices, but in *reality* the launch-schedule goal drove a preoccupation with the steps needed to meet the schedule, resulting in an enormous amount of government and contractor schedule-driven overtime. This preoccupation clouded the institution's primary focus—was it to meet that date, or to follow the basic principles of taking all necessary precautions and ensuring that nothing was rushed?

Don't Migrate to Mediocrity. A glaring example of backing off of basics was in the foreign object damage (FOD) prevention program at Kennedy Space Center (KSC). KSC and its prime contractor agreed to devise an aberrant approach to their FOD prevention program, creating definitions not consistent with other NASA centers, Naval reactor programs, Department of Defense aviation, commercial aviation, or the National Aerospace FOD Prevention, Incorporated, guidelines. In the KSC approach, NASA implied there was a distinction between the by-products of maintenance operations, labeled *processing debris*, and FOD-causing *foreign object debris*. Such a distinction is dangerous to make since it is impossible to determine if any debris is truly benign. Consequently, this improper and nonstandard distinction resulted in a FOD prevention program that lacked credibility among KSC workers and one that allowed stray foreign objects to remain present throughout shuttle processing.

In devising a process that ignored basics, they created conditions that could lead to a disaster. Their new definitions ignored the reality that the danger generated by debris begins while the job is in progress. Although the contractor espoused a "clean as you go" policy, the elimination of debris discovered during processing was not considered critical, causing inconsistent adherence to that policy. Both contractor and KSC inspectors reported debris items left behind on numerous occasions. The laxity of this approach was underscored by the loss of accountability for 18 tools used in the processing of the *Columbia* orbiter for its doomed Space Transportation System (STS) mission STS-107. In the aviation world, the concern lies with foreign object ingestion into jet engines, interference with mechanical control mechanisms, and the like. If such items remain undetected aboard a shuttle, which is then launched into a microgravity environment, they create a great potential for harming shuttle systems or other objects in orbit—regardless of whether those items are classified as *process* or *foreign object* debris—their KSC-assigned terrestrial definitions. The assumption that all debris would be found before flight failed to underscore the destructive potential of FOD and created a mind-set of debris acceptance.

In another migration to mediocrity, NASA had retreated from its supposedly routine analysis of shuttle-ascent videos. After noting that foam from the external tank's left bipod ramp had struck the *Columbia* during its launch, part of dismissing the danger resulted from the NASA statement that this loss marked only the fifth time in 113 missions that foam has been lost, roughly a one in 23 chance of occurrence. The CAIB, however, directed a full review of all existing shuttle-ascent videos, revealing two previously undiscovered foam losses from the left bipod ramp. Peeling the onion back even further, the CAIB evaluated how many missions actually produced usable images of the external tank during launch. Due to night launches, visibility, and external-tank orientation, images were available to document only 72 of the 113 missions. Thus, the failure to perform the "basic" and routine imagery analysis hid the actual severity of the problem; the seven left bipod ramp foam losses in 72 observed missions more than doubled the previously stated NASA odds of one in 23 to one in 10. Had the film-analysis program been consistent over the history of the shuttle program, perhaps NASA would have detected and fixed the foam-loss problem sooner.

Maintain Checks and Balances. A glaring example of where KSC faltered in its checks and balances lay in the administration of its government quality assurance (QA) program as maintenance changed to a contractor-run operation. Hardware inspections by government inspectors had been reduced from more than 40,000 per launch to just over 8,000. If properly managed, this level of inspection *should* suffice, as the contractor assumed more responsibility and had a strong program that relied heavily on the technicians' skill. However, that was not the case. For example, government QA inspectors were not permitted to perform some of the basics in their job descriptions—to include unscheduled "walk around surveillance." Indeed, one technician, having completed such surveillance, discovered a "Ground Test Only" (not-for-flight) component installed on an orbiter main engine mount prior to flight. Although his job description called for such inspections, that technician was threatened for working "out of his box." An attempt to confine such surveillance to statistically driven sampling parameters underscored a lack of experience and a lack of understanding of the purpose for such surveillance. It also served to handcuff the QA inspectors and the program's effectiveness.

While other examples exist, it suffices to say that checks and balances using "healthy tensions" are vital to establish and maintain system integrity in programs from the federal government to aviation. High-risk operations dictate the need for *independent* checks and balances. To further this approach, leaders must establish and maintain a culture where a commitment to pursue problems is expected—at all levels of the program and by all of its participants.

> *Mere precedent is a dangerous source of authority.*
>
> —Andrew Jackson

Avoid an Atrophy to Apathy. An organization should not invent clever ways of working around processes. For example, NASA created an ad hoc view of the anomalies it had experienced and then deemed subsequent anomalies as either "in family" or "out of family," depending on whether an anomaly had been previously observed. This led to "a family that grew and grew"—until it was out of control. This ad hoc view led to an apathy and acceptance of items such as the *Challenger*'s solid rocket booster O-ring leakage and the foam strikes that had plagued the shuttle since its first mission but, until *Columbia*'s demise, had never brought down an orbiter.

Control Configuration Control. The space shuttle is a magnificent system that has produced six orbiters—each differing from the others in multiple aspects. With only six orbiters, one might expect the use of an intricate method for tracking configuration changes of such things as wiring systems, control systems, and mounting hardware, likely augmented with extensive digital photos. That was not the case with the shuttle program, calling into question everything from the condition of orbiter components to the assumptions made on the shuttle's center-of-gravity calculations.

Leaders must insist on processes that retain a historical knowledge base for complex, legacy, and long-lived systems. Configuration waivers must be limited and based on a disciplined process that adheres to configuration control, updated requirements, and hardware fixes. If workers at the lower level observe senior leaders ignoring this path, routinely waiving requirements and making exceptions to well-thought-out standing rules, they too will join the culture of their seniors and begin accepting deviations at their level—adding significant risk to the overall system. Senior leaders must also ensure the steps required to alter or waive standing rules are clearly understood.

Avoid "Fads"—Question Their Applicability. Although bombarded by "management by objectives"; Deming-driven, off-site quality thrusts; and "one-minute-management" techniques, leaders must ensure that the latest "organizational fad" does not negatively influence their operations. For example, the ISO-9000/9001 sampling processes mandated in the NASA–United Space Alliance (USA) contract are based on solid principles and are appropriate for many processes and organizations worldwide. These principles would work well in a manufacturing process producing 10,000 bolts a day, or at a scheduled airline where a technician may perform the same steps dozens of times per week. However, the same principles do not necessarily apply in an environment where only three to six flights are flown each year, and workers may accomplish certain processes just as infrequently. Process verification must be augmented when critical operations take place with an "eyes-on, hands-on" approach, which was not happening in the shuttle program.

The KSC approach also had an emphasis on *process* over *product*; that emphasis was exemplified by employees, unaffectionately labeled *Palm Nazis*, who wandered the Orbiter Processing Facilities with personal digital assistant devices, sampling to verify that every step of a maintenance process was followed. This sampling approach certainly ensured the steps they checked were completed, which created a false sense of security with an equally false assumption—that verifying a process was followed would ensure that the product was perfect. Nothing could be further from the truth—the steps may have been insufficient, lacking required definition and depth, or improperly accomplished.

Keep Proper Focus. When launching a space shuttle or conducting any operations where safety is paramount, every operation should be unique; there is no such thing as routine. The CAIB discovered many within NASA had the attitude that putting a shuttle into orbit was just something that NASA did. In fact, the attitude should have been that "putting a shuttle into orbit is not something we do, it **IS** what we do." In testimony before the CAIB, Dr. Harry McDonald, who headed the 1999 Shuttle Independent Assessment Team, stated that NASA had drifted, and his conviction that NASA should go back to its previous days of excellence and toward a shuttle focus. He underscored his position by saying, "Each launch should be treated as the first launch, each orbit as the first orbit, and each reentry as the first reentry."[1]

When an organization adopts a mind-set that allows the most important thing that they do—their primary and most visible reason for existence—to become "just another operation," the focus of that portion of the organization is lost. An organization cannot let this happen, particularly when dealing with the safety of human lives or national assets such as the shuttle fleet. In an era of declining budgets, and with organizations looking for ways to compete for other business, organizations should avoid removing focus from the real goal or the "thing" that they are expected to do. When this happens, organizational focus can be lost and "what" they do simply becomes "something" they do.

> *A primary task in taking a company from good to great is to create a culture wherein people have a tremendous opportunity to be heard and, ultimately, for the truth to be heard.*
>
> —Jim Collins
> *Good to Great*

Communicate, Communicate, Communicate

Leaders Must Insist on Discussion. NASA's heavy-handed management of meetings, using a rigid protocol, discouraged an open discussion of concerns, resulting in a failure to properly investigate those concerns. The senior executive service (SES) leaders at the meeting table did not seriously encourage inputs from the lower-ranking government service (GS) engineers on the room's periphery; however, it was these GS engineers who saw the potential danger from a foam strike to the *Columbia*.

Leaders not only must ask for inputs, but also must place a heavy emphasis on communication and encourage both consent and dissent. In fact, certain successful leaders of risky operations admit that they are uncomfortable if there are no dissenting opinions when important and far-reaching decisions are considered.

Encourage Minority Opinions. The minutes and audiotapes of NASA's Mission Management Team reflect little discussion other than that emanating from the head of the conference-room table. Expressions of concern that the foam impact might affect the integrity of the orbiter were quickly refocused to a discussion of how much additional maintenance might now be needed to prepare *Columbia* for its next flight.

Successful and highly reliable organizations promote and encourage the airing of minority opinions, such as those of the NASA engineers seeking to express their concerns with the foam strike. Leaders must acknowledge and exercise their own responsibility to conduct a thorough and critical examination, and remain cautious so as not to create an environment where they are perceived as ignoring inputs or no longer willing to hear about problems.

> *Leaders should listen and listen and listen. Only through listening can they find out what's really going on. If someone comes in to raise an issue with the leader and the leader does not allow the individual to state the full case and to get emotions out in the open, the leader is likely to understand only a piece of the story and the problem probably will not be solved.*
>
> —Maj Gen Perry M. Smith
> *Taking Charge*

Conduct Effective Meetings—*Transmit* and *Receive*. Transcribed and audio evidence revealed that many NASA meetings were inconsistent and ineffective. For example, a critical meeting that was required to occur daily when a shuttle was on orbit was held only five times during the 16 days *Columbia*'s astronauts were aloft. The heavy-handed management of many meetings limited input and discussion; voice tapes also revealed the tone of the leader's voice could be intimidating. The perfunctory, matter-of-course requests for inputs were often phrased more as a statement than as a solicitation, akin to, "Then there is no dissent on that point, is there." Period.

To be effective, meetings should have agendas and satisfy the requirements of a governing directive (such as their frequency when a shuttle is on orbit). An effective leader will elicit and listen to all opinions, evaluating carefully the possible substance. Leaders should promote respect for each participant's independence and value his or her contributions. An effective meeting leader will ensure each attendee the opportunity to contribute and not allow the person with the loudest voice to dominate the discussion. The leader should be inquisitive and ask questions about items that are not clearly presented, penetrating below the surface of glib marketing presentations—that emphasize the *medium* over the *message*, using fancy graphics, transitions, and so forth—and demanding backup data or facts. An effective meeting leader should encourage others to ask questions—knowing that if the leader doesn't understand something, the chances are others may have the same questions. Indeed, participants observing a leader who is comfortable enough to ask questions may be prompted to do the same.

During NASA meetings, a final problem occurred when an individual with expertise in one arena was incorrectly purported to have expertise in another critical arena. His forceful personality and familiarity with the meeting's leaders tended to quash dissent. It is the responsibility of the meeting leader to ensure its integrity—particularly during decision sessions—being aware of those with false or presumed expertise, and instead seeking out and listening to actual authorities with expertise.

Ensure Management-Information Systems Matter. As the CAIB discovered across NASA and its centers, older, legacy management information systems that did not interface with each other made problem identification very difficult. These systems had become dysfunctional databases—too burdensome to be effective, too difficult for average workers to use and interpret data, and, in the case of foam loss, simply nonexistent. Although the CAIB found that NASA tracked multiple metrics, the impression was that many of these simply served as "eyewash" or as one small piece of a huge pie that was irrelevant to or uncorrelated with the total picture. With multiple information centers, systems, and databases for trend analysis, senior leaders could not ensure appropriate metrics were tracked or, more importantly, that they were even used.

To avoid developing a focus on metrics for metrics' sake, the quantity being measured *must* be understandable, applicable, measurable, and the goal must be attainable. Ideally, there should exist a process that consolidates and assimilates data from multiple databases, providing a comprehensive picture of system performance, costs, malfunctions, and other trends of utility to management.

Avoid "Organizational Arrogance." The CAIB conducted a review of more than 80 past reports of studies that related to the shuttle program and its management, focusing on the reports' findings, recommendations, and NASA's response.[2] The revelations from that review were disturbing—NASA would essentially pick and choose the third-party inputs to which it would listen and respond. It made only incremental changes and then only to those things it saw fit to change, rarely letting such third-party concerns filter down to its line workers. NASA seemed to say, "We know what we're doing, so thanks for your input to human spaceflight." At a more grassroots level, evidence revealed that KSC decision makers had routinely ignored or shelved inputs from KSC line workers with 15 to 20 years of shuttle program experience. This often created dysfunctional situations—line workers redirected their ignored inputs to NASA Headquarters using the NASA Safety Reporting System (NSRS). The NSRS was established in 1987 after the *Challenger* shuttle mishap, and is an anonymous, voluntary, and responsive reporting channel to notify NASA's upper management of concerns about hazards. Those previously ignored concerns were often validated, mandating a headquarters-directed fix rather than one locally implemented and managed. More than a year after the *Columbia* accident, NASA had still not come to grips with ensuring experts' opinions were acknowledged—a March 2004 145-page report that included employee surveys reflected open communication was not the norm within NASA, that employees did not yet feel comfortable raising safety concerns to management, and that the raising of issues was still not welcomed.

Senior leaders must avoid insulating themselves (or even giving the perception of insulating themselves) from third-party inputs, workers, engineers, and operators—regardless of their position in or with the organization. Everyone's opinions deserve respect and should be given consideration. However, there must obviously be balance. The more hazardous the operation, particularly when lives are at risk, people will naturally examine every facet of the operation more closely and see more reason for concern. In NASA's case, for example, it is entirely conceivable that endless concerns could be raised through internal questions and outside reviews, allowing operations to be halted while every minute safety question is addressed in perpetuity. If this were allowed to become the norm, NASA might never again fly an aircraft test sortie, much less a shuttle mission. Thus, the key lies in accurately assessing and accepting *calculated* risks for such research and development systems—not reacting to every conceivable, abstract safety concern in a manner more appropriate to airliners that are expected to routinely and safely fly families and cargoes.

Be Thorough and Inquisitive

Avoid Leadership by PowerPoint. In our "sound bite" world, short and concise briefings have increasingly become the order of the day, especially the higher in the management echelon one resides. NASA management meetings were found to have greatly condensed briefings, sometimes boiling a 40-slide engineering analysis down to a single slide (the potential impact of a foam strike on the orbiter is one notable example). In other instances, the slide(s) presented would have factual errors or errors in assumptions that an expanded briefing or technical data may have eliminated (the case of the history of foam strikes and external tank modifications is one such example). Multiple examples of key NASA decision briefings were lacking in the rigor to explain or even identify key assumptions, ranges of error and variability, or alternative views.

Used properly, briefings and slides are certainly suitable tools for high-level summaries and decisions, but as a complement to and not a replacement for thorough analytical research and processes. Leaders must avoid using briefing slides as the sole means of transferring information during critical operations or for formal management decisions.

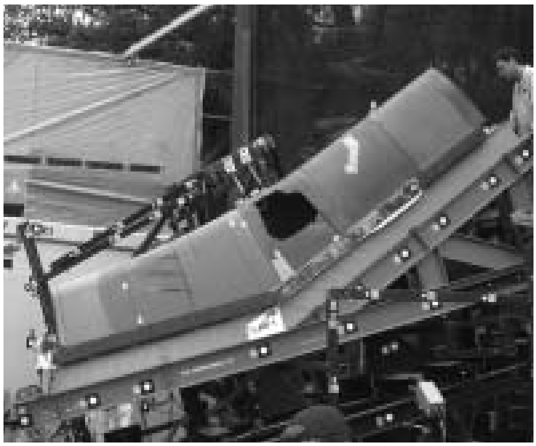
Leaders who have adopted a 10-slide briefing limitation for presentations may have done so because it was "how they were brought up," and it is their belief that it adds discipline and removes unnecessary information. However, they must also realize that they are not getting the full story—rather, they are getting a distilled view of what their subordinates have chosen to present to them. This practice could be acceptable if the decision maker were certain that a rigorous process had preceded the briefing—one that had thoroughly examined the issues and asked all the correct questions. That, however, was not the case with NASA. In some instances, the necessary data had been cast aside, or, worse, not even sought. Competent leaders realize that they are accountable for the results of the actions of their organization and realize that if there's any doubt, they must insist on getting enough information (even the com-

Left to right: *Air Force astronaut Col Mike Bloomfield, Brig Gen Duane W. Deal, and NASA test coordinator Dan Bell review test preparations in front of the wing prior to the foam impact test. The posttest photo, below, dramatically revealed the capability of the foam to damage an orbiter wing's leading edge.*

plete story) to convince themselves of the integrity of their processes.

Mandate Missouri Mind-Sets ("Show Me!"). A healthy pessimism is required in high-risk operations. During prelaunch operations, NASA seemed to demonstrate a healthy pessimism, questioning deficiencies that could affect the mission and exhibiting an attitude of "prove to me this is safe." However, after launch, that attitude seemed to be recast to "prove to me it's unsafe," meaning that if the engineers and managers did not produce solid evidence to support their concerns, those concerns were quickly subordinated to mission accomplishment.

Disregarding engineers' concerns also subdued a healthy curiosity. Although the external tank was known to shed large chunks of foam, the postlaunch, debris-strike damage assessment done for *Columbia* while it was on orbit relied on test data and analytical models for relatively miniscule foam projectiles. However, "what if large pieces of foam hit the



Foam can *hurt. It was not until a 1.67-pound chunk of foam was propelled at 500 mph against an orbiter wing panel that naysayers in NASA came to realize that foam could indeed damage the leading edge. In this dramatic test, a piece of foam using the same impact conditions (foam type, size, weight, angle, and speed) that it would have had when it broke away from the bipod ramp and hit the* Columbia, *created a hole approximately 16 x 17 inches.*

orbiter?" was a question no one had been motivated to ask or answer—not after the first loss of a large piece of foam on STS-7, and not after the loss of a much larger piece during STS-112's October 2002 ascent that hit and damaged the solid-rocket booster. As a result, no viable analytical models had been developed or test data collected for large foam-debris strikes.

After the *Columbia* tragedy, NASA was originally entrapped into believing and even evangelizing that foam could not hurt the orbiter. One reason was that NASA became enamored with an "analysis by analogy," publicly stating that a foam strike was akin to the Styrofoam lid on a cooler in the bed of a pickup that is traveling on the road ahead of you suddenly flying off, striking your car, and harmlessly breaking apart. Although making superficial sense, it was an approach proven dramatically and tragically faulty. As an analogy, it ignored the basic physics—kinetic energy (KE) of the foam ($KE = \frac{1}{2}mv^2$)—of a 1.67-pound piece of foam breaking off a rocket body traveling at nearly Mach 2.5 and decelerating to a differential speed of approximately 500 mph before encountering *Columbia*'s wing. Indeed, there were those who were not convinced until 7 July 2003, when a test replicated those conditions.

In that "show me" test, the engineers at the Southwest Research Institute fired a 1.67-pound piece of foam at 500 mph, shattering a hole in an orbiter's wing panel. In short, a preference for a clever analogy can serve as a recipe for repeating catastrophic mistakes, whereas insistence on analysis over analogy can prevent potentially disastrous situations.

Can't get an "ought" out of an "is."

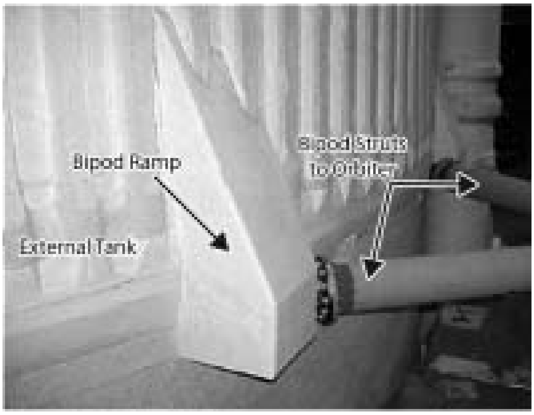
—G. E. Moore

Question Untested Assumptions. Leaders must be careful not to rely on untested basic system certification as the "end-all solution" to approaching problems. Originally, the space shuttle's leading-edge, reinforced carbon-carbon (RCC) panels were arbitrarily certified for 100 missions; therefore, there was no perceived integrity problem due to the aging of the panels. While engineering and design criteria were exhaustively incorporated into the shuttle, no similar system existed to revalidate and recertify the RCC design assumptions or to check the progression of unforeseen problems, such as micrometeoroid strikes, pinholes, corrosion, oxidation, and other effects detrimental to those critical leading-edge RCC panels.

In another example of untested components, the faulty external tank foam had never been dissected—especially the foam applied in the bipod ramp area that came apart and hit *Columbia*'s leading edge. The dissection of several different bipod ramps, accomplished at the direction of the CAIB, revealed voids, gaps, and even debris—any one of which could have contributed to the bipod-ramp foam losses that occurred roughly once in every 10 missions. However, NASA had never pursued evaluating the foam beyond simple pull tests to check adherence to the external tank, eddy current tests to verify the foam thickness, and chemical composition checks.

To ensure it employs technology over technique, an organization must, if possible, certify all critical hardware through testing—not just analysis. However, if analysis must be used, it should be verified by testing. For example, even today's computerized aircraft-design process does not eliminate the necessity for flight-testing. Using certified test techniques to inspect critical hardware during maintenance turnaround and upgrading those techniques as new test technologies emerge, should be standard procedure. Examples were found of NASA failing to use modern technology to facilitate its testing. CAIB members were astonished to find 1960s- and 1970s-era test equipment while visiting NASA work centers. Although it might still work for its original purpose, today's digital equipment offers a more accurate, maintainable, reliable, and economical methodology.

Ensure Taskings and Resources Balance. Leaders must be willing to stand up and say "No" when tasked to operate or function without sufficient resources, risking their own careers, if necessary. Perhaps former



***The Culprit—the External Tank's Bipod Ramp**. The bipod ramp covers the bipod struts that connect the orbiter's nose to the external tank. The investigation revealed that portions of the ramp would dislodge approximately one in every 10 flights. Because it had not sustained any major damage from such losses, NASA pursued no further testing to determine the potential danger of such a loss—then a 1.67-pound chunk dislodged and struck* Columbia *on STS-107, dooming the crew and craft.*

***If You Test, You May Discover Something**. The CAIB directed that the external tank bipod ramps be dissected to understand why they might periodically dislodge chunks. This testing had not previously been conducted. It revealed inconsistent foam application, resulting in voids, delaminations, and even debris—any one of which could have contributed to foam losses.*

shuttle program managers and center directors should have resigned in protest years ago for being unable to safely support the shuttle and International Space Station (ISS) programs with congressionally approved budgets, personnel, and resources. When leaders become convinced, using objective measures, that their taskings and resources are out of balance, it is their duty to make their concerns known, act appropriately on their convictions, and ensure those concerns are consciously addressed. Such objective measures are critical, however, for NASA has shown—as recently documented in an April 2004 General Accounting Office report to Congress—that it could not provide detailed support for the amounts it had obligated in its budget requests.

Safety First—and Always

Discovering these vulnerabilities and making them visible to the organization is crucial if we are to anticipate future failures and institute change to head them off.

—D. D. Woods and R. I. Cook
Nine Steps to Move Forward from Error

Illuminate Blind Spots

A key to safe operations is to eliminate all potential blind spots—areas that are not seen or subject to examination and from which unforeseen problems might arise. Their danger is that they are invisible until identified by someone with a different vantage point or opinion. NASA allowed itself to evolve into an organization with inconsistent authority and responsibility in its safety structure, exhibiting marked differences between and even within its centers. Along the way, it had also transferred some of this inherent safety responsibility to contractors—creating governmental blind spots.

Leaders must always be on the lookout for these weaknesses and other safety shortfalls. It is imperative to have a safety organization, or similar office, whose goal is to search out and identify blind spots—those potential problem areas that could become catastrophic.

> *You need an established system for ongoing checks designed to spot expected as well as unexpected safety problems. . . . Non-HROs* [non–high-reliability organizations] *reject early warning signs of quality degradation.*
>
> —Karlene H. Roberts
> *High Reliability Organizations*

Stop Stop-Gap Safety

While NASA can boast some of the most effective industrial safety programs in the world—the industrial safety world of "trips and falls, hard hats, and safety goggles"—its effectiveness in institutional safety (programs and processes) was found lacking. Waivers that even experienced astronauts found startling had become the order of the day and were accepted as a matter of course. *Columbia*, for example, was flying STS-107 with 3,233 waivers—36 percent of which had not been reviewed in 10 years. The number of waivers remained a sore spot with technicians and some engineers, but this had become an accepted practice by management. No one knew the extent of the waivers, how one waiver might contraindicate others, or how certain combinations might have a cumulative failure potential. Safety personnel silently observed, if they noticed at all.

An *involved and independent* safety structure is vital, especially in high-risk organizations like NASA. Safety managers must have an equal voice in decision making, the authority to stop operations, the ability to question waivers and similiar items, and direct access to key decision makers. Further, employees and contractors at all levels must never feel threatened to bring "bad-news" safety issues to their bosses. Overconfidence in organizational safety processes must be avoided since unexpected events require "out-of-the-box" solutions—solutions that generally come from workers in the trenches and not senior management.

Leaders of high-risk organizations must ensure that key program leaders do not unilaterally waive operational or technical requirements, a problem illustrated by NASA's excessive number of waivers. Clearly defined technical requirements and thorough and independent processes for safety and verification can do much to achieve this objective. Such an approach can be bolstered if leaders ensure risk-assessment capabilities are quantitatively based, centralized, and given programwide access for simpler, organizationwide hazard assessments.

Additionally, in complex organizations dealing with high-risk technologies, there must be clarity, uniformity, and consistency of safety responsibilities. Tailoring by program managers or directors should never be permitted unless approval is granted by both the organization having final authority for technical requirements and by the organization having oversight of compliance.

Put Safety First—Safety People, Too

NASA seemed unconcerned about staffing some of its centers' key safety organizations with the right people, and also relegated those activities to back shops that had a minor supporting role and limited authority. This practice must change to ensure a viable first line of defense—safety organizations must be empowered, and safety personnel certainly cannot be treated as second-class citizens in the eyes of others or themselves. Unless this advice is followed, in-line safety organizations will not be the first line of defense they are expected to be.

Keep It Pertinent—and Attractive

Results speak for themselves that organizations should spend a significant amount of energy on safety awareness—not just simple posters, bumper stickers, and doodads. The Navy, for example, has done an admirable job of producing lesson-packed but entertaining articles that appear after every serious accident. These articles allow all sailors to learn from the mishap; indeed, many are enticed to learn through the presentation of the material. Organizations should be committed to the communication of safety lessons, and those that follow such an approach will help their members stay a step ahead in safety awareness.

Third-Party Review Caveats

Be Alert for "Pet Pigs." One of NASA's previous approaches to safety was to form a focus group, relegating safety to the back row of key decision-making meetings. Formed in the wake of the 1967 *Apollo 1* fire, the Aerospace Safety Advisory Panel (ASAP) was a solid concept, but it had no authority. The panel was designed to spot neither the smaller, regularly occurring events that happened on the shop floor every day, nor the larger, looming deficiencies waiting to strike.

The ASAP got into a vicious circle with NASA. Its members used the tenure of their position to focus on their "pet pigs," the aspects of the program with which they had familiarity or which were on the members' personal agenda. NASA, in turn, grew to ignore the ASAP, considering nearly everything it did as simply a championing of their pet pigs versus providing safety insights with operational value to NASA. The ASAP and other such panels NASA chartered were rendered ineffective.

The lessons to remember from NASA's experiences are to ensure that the charters of future safety organizations are clear, the qualifications for membership are appropriate for the task, and they have the authority to act. Operations requiring high levels of safety and mission assurance should have full-time safety engineers involved—people or teams who understand systems theory and systems safety. Simply forming another group and naming high-profile members, or getting one more outside assessment, will neither identify systemic safety problems nor cause senior leaders to change the way they do business.

Routinely Review. Successful organizations must have a review process that addresses the findings and recommendations from third-party reviews and then tracks how that organization addresses those findings. As previously discussed, NASA's response to such reviews was, at best, sporadic. That was, in part, because of a mind-set that had grown from their experience with the ASAP—a vicious circle of ignoring pet pigs. However, if a disciplined review process existed to evaluate such inputs, a record would exist to document how review findings were resolved or, perhaps, why they were justifiably ignored.

> *Err on the side of providing too much rather than too little information in the aftermath of a mistake or failure.*
>
> —James M. Strock
> *Reagan on Leadership*

Go "Beyond the Widget"

Rarely is there a mishap caused by a single event or a broken widget. Therefore, after major mishaps—such as aviation and naval accidents—senior leaders must use that opportunity to look at the "whole" organization. Even if the apparent cause of a flight accident is a broken part or an obvious pilot error, there are usually several other contributing factors. Those factors range from design and manufacturing processes to crew training deficiencies and operational employment. For *Columbia*, the CAIB did not simply conclude that "the foam did it." The CAIB examined NASA's entire organizational and safety structure and found that to be as much at fault as the foam-shedding event. By going beyond the widget, the CAIB in effect said, "The foam did it. . . . The institution allowed it."

Make Benchmarking Bedrock

Leaders of large organizations should consider cross-organizational benchmarking to learn how other like agencies or services implement operational safety into their operations. Benchmarking should also include sharing techniques and procedures for investigating mishaps, with the objective of applying lessons learned toward mishap prevention. For example, spacecraft, aircraft, and submarines have sealed pressure vessels that operate in hazardous environments. Each system requires the integration of complex and dangerous systems, and they all must maintain the highest levels of safety and reliability to perform their nationally significant missions. Each community has something to learn from the others.

> *Over the years, these organizations [HROs] have learned that there are particular kinds of error, often quite minor, that can escalate rapidly into major, system-threatening failures.*
>
> —James T. Reason
> *Managing the Risks of Organizational Accidents*

Track Flaws through Closure

The KSC's discrepancy tracking system was a glaring example of a failure to track flaws. KSC had moved away from a previously effective closed-loop tracking system. In that system, an inspector or engineer who observed a failure or problem documented the discrepancy. The problem was then verified with appropriate analysis. The root cause was established, and the appropriate corrective action was determined and incorporated. Finally, the inspector or engineer who had originally discovered the problem evaluated the effectiveness of the corrective action. This ensured the proper disposition of the discrepancy, as well as ensuring that the "fix" was shared with others working on the same or similar systems (in the case of the orbiter at the KSC, the "fix" information would be shared with the personnel at the Orbiter Processing Facilities, the Vehicle Assembly Building, and the launchpad). With these closed-loop and information-sharing processes eliminated, there no longer existed a path to ensure discrepancies were properly resolved or a method to ensure that all who needed to know about the discrepancy were actually informed. The elimination of those processes created the potential for repeat problems.

Organizations must take discrepancy tracking seriously and view inspections as valuable—especially since they can identify deficiencies, force positive change, and make improvements. Inspections may also spur findings and recommendations, and leaders must ensure the organization is responsive to those findings and recommendations within the specified period.

Organizational Self-Examination

> *It's extremely important to see the smoke before the barn burns down.*
>
> —Bill Creech
> *The Five Pillars of TQM*

A major strength of organizations that successfully deal with high-risk operations is their ability to critically self-evaluate problems as they are identified. Reporting good news is easy and often useful. However, the reporting of bad news is critical and should be encouraged, and it must be accompanied by a discussion of what will be done about it. The culture within these successful organizations recognizes that simply reporting bad news does not relieve the individual or department of the responsibility to fix it.

Teaming

Develop the Team. As large as NASA is and as unified as the shuttle-related workforce is behind each mission, it had not developed an institutionalized program to identify and nurture a stable of thoroughbreds from which to develop its future senior leadership. As a result, much of NASA's managerial hierarchy, from GS-14 to associate administrator levels, had assumed their positions without having received a prescribed standard of education, career-broadening, leadership experience, or managerial training that collectively would prepare them for their roles of ever-increasing responsibility. In short, NASA found itself with some relatively junior "stars" thrust into positions of immense responsibility for which they were unprepared.

Leaders and organizations that emphasize people over and above organizational processes or products will be able to recruit and retain the very best people—people who will be trained, developed, and rewarded during their careers in the organization. This philosophy not only produces positive results in those directly affected, but also positively influences their coworkers and subordinates who can see, early in their careers, the potential for education and career-broadening opportunities in their future. Organizational leaders should consider executive development programs, such as those followed in the Air Force, to provide professional development and "sabbaticals" at appropriate career phase points.

> *We train together . . . we fight together . . . we win together.*
>
> —Gen Colin Powell

Train for Worst-Case Scenarios. The CAIB found NASA ill prepared for worst-case scenarios. Indeed, evidence revealed that NASA's complacency caused it not to pursue worst-case events or practice using the scenarios those events would generate. For example, despite the tragic *Challenger* launch accident, NASA still routinely aimed its launch-anomaly practice at emergencies, such as losing a main engine, that resulted in the shuttle not being able to achieve orbit and having to land at an emergency recovery field on the far side of the Atlantic. While this is indeed a serious scenario, the prior failure to pursue and practice orbiter integrity problems, with their potential crew-loss implications, proved to be a continuing blind spot, resulting in the failure to request imagery that could have revealed *Columbia*'s damage from the foam impact.

Safety analyses should evaluate unlikely, worst-case, event-failure scenarios, and then training events should be developed and scheduled, simulating potential catastrophic events. Senior leaders must lead these worst-case training and failure scenarios, which produce an experience base similar to that gained by aircrews during intensive simulator sessions or via Red Flag exercise scenarios. They will develop the ability to make critical decisions during time-sensitive crises, using the experience gained from worst-case exercises. Such an approach to the worst-case scenario will force decision makers to resolve problems using tested and fail-safe processes, thus reducing the chance they could break down

A lack of inquisitiveness eliminated the possibility of rescue. An ill-conceived conviction that foam could not hurt the orbiter prevented NASA management from requesting imagery or directing a spacewalk—either one could have revealed the damage. NASA initially declared and then maintained that, "Even if we had known of the damage, there's nothing we could have done about it anyway." Not until after the CAIB directed NASA to execute a "What-if?" scenario that contained an assumption that damage had been detected did NASA discover several alternative courses of action. The Columbia *could have been repaired on orbit; or, as pictured,* Atlantis*—only weeks from being ready to launch—could have been sent on a rescue mission. Although either mission would have been risky, NASA afforded neither one the chance to succeed.*

in the "fog of war" or during the stress of real-time malfunctions, anomalies, or events.

> *Those who ignore the past are condemned to repeat it.*
>
> —George Santayana

Educate Past Hiccups. Since 1996, over 5,000 Naval Nuclear Propulsion Program members have been educated in lessons learned from the *Challenger* accident, primarily through the lessons documented in Diane Vaughn's *The Challenger Launch Decision*.[3] NASA, however, seemed to continue to assert its organizational arrogance with a "we know what we're doing" attitude. NASA did not train on the landmark *Challenger* lessons and never invited Ms. Vaughn to address any of its gatherings.

Senior leaders must ensure that their organization's key members are fully educated on past mistakes, with a focus on lessons learned. That is especially important when its own organizational structure has been at fault in those mistakes. Large, high-risk organizations that act as though they are in denial risk repeating past mishaps. A successful organization must remain a "learning organization," internalizing the lessons from big and small mistakes and continuously improving.

In the Air Force's SR-71 program, for example, past incidents and accidents were studied by all new crew members in an elemental block of instruction. During that block, the crews would review every reportable incident that had occurred during that specialized program's existence—beginning with its first operational sortie in 1968. This program continued through the SR-71's retirement in the 1990s, and contributed to its remarkably strong safety record—a considerable accomplishment for such a unique aircraft, the only one capable of operating in its hostile and unforgiving environment.

Avoid Promoting Unintended Conflicts. The requirement to support the International Space Station had an indirect and detrimental influence on mission preparation for *Columbia* and STS-107, its final mission. Just as these external factors altered the organizational goals and objectives for *Columbia*, other factors will affect future operations if management does not recognize those pressures and consciously take measures to counter their influence. The external factors of cost and schedule pressures, for example, can have a negative influence on safety and reliability. Leaders must ensure that their support of other programs and management tools is not allowed to cause "unintended consequences" which may force subordinate operators and leaders to make questionable decisions.

> *In discussing such organizations [HROs], it's emphasized that, "The people in these organizations . . . are driven to use a proactive, preventive decision making strategy. Analysis and search come before as well as after errors . . . [and] encourage:*
>
> - *Initiative to identify flaws in SOPs [standard operating procedures] and nominate and validate changes in those that prove to be inadequate;*
> - *Error avoidance without stifling initiative or (creating) operator rigidity"*
>
> —T. R. LaPorte and P. M. Consolini
> James Reason, *Managing the Risks of Organizational Accidents*

Seek to "Connect the Dots." Within NASA, the machine was talking, and no one was listening—neither program management nor maintenance process owners recognized the early warning signs of their defects. For example, the tile damage caused by foam impact was a maintenance problem that repeated itself on every flight. However, maintenance process owners did not present that information as a preventable problem above midlevel personnel. More often, the emphasis was on how to repair and improve an orbiter's tile adhesion and resiliency versus finding the *sources* of the tile's damage—the lack of the external tank's foam adhesion.

Although these errors can occur in any large organization, successful organizations are sensitive to "weak signals" and make improvements by investigating and acting on the occasional small indicator. These organizations must be sensitive enough to learn from—and not overlook—"small" incidents; its members must be encouraged to highlight such incidents. Leaders cannot wait until a major catastrophe occurs to fix internal operations issues or safety shortfalls.

Sustain Sustainment. Although the shuttle was altered from a system originally programmed and designed to fly 100 flights in 10 years, to one to last until 2006, then 2012, then 2020, no viable sustainment plan was built.

Should a need arise to continue to operate a system beyond its initially designed service life, as happened with the shuttle program, an extended lifetime must be carefully calculated, and plans must be developed and executed to permit the system to reach its new service life safely. Initial program planning must include sustainment mechanisms for the duration of its planned existence; those mechanisms must be modifiable and then adjusted to properly sustain the program when the life of that program is extended. Air Force system sustainment and service life extension programs (SLEP), for example, provide a benchmark for the level of excellence other organizations (including NASA) could emulate. The concept of having lifelong sustainment as an equal-to or more-important goal than the original certification, keeps the Air Force a step ahead by strongly encouraging the design of systems with maintenance in mind, and the building of data and processes that monitor the fleet's health. Such an approach attempts to anticipate the need and then adjust the sustainment measures to reflect the unavoidable, changing environment that accompanies aging products.

> *Except in poker, bridge, and similar play-period activities, don't con anyone—especially yourself.*
>
> —Robert Townsend
> *Further Up the Organization*

Don't Confuse Tomorrow's Dream with Today's Reality. NASA allowed the shuttle to effectively transition from a research and development system to operational status, despite the fact that prior to the *Columbia* tragedy there had only been 111 successful shuttle flights. In contrast, the Air Force's F/A-22 is programmed for 2,500 flights, nearly 4,600 test hours, before being deemed operational. Although the space shuttle should be considered experimental because of the nature of its mission profiles, it was, due to its commitments and ISS obligations, processed and operated as an operational vehicle.

Senior leaders must ensure that a vehicle or program still in the R&D stage is not treated as operational and fielded—an experimental vehicle or program must be treated as such. Although the loss of *Columbia* cannot be directly tied to the confusion between R&D and operational, it did influence certain decisions that may have changed the fate of the crew; a decision not to pursue imagery eliminated the consideration of an on-orbit repair or rescue mission.

Outsourcing Caveats

Retain and Exercise Accountability? In many ways, NASA is a victim of the same government financial reform initiatives that many organizations face. For example, turning work over to a contractor and then reducing the size of the government staff charged with monitoring the contractor is not unique to NASA.

Often, government reform initiatives can blur the lines of accountability or even violate Federal Acquisition Regulations—they certainly did within NASA. Although the government's responsibility and authority roles were diminished in the shuttle program, the accountability role clearly should not have been—just as it should not diminish in *any* organization.

Contracting Caution: Expertise Loss Ahead. The United Space Alliance's Space Flight Operations Contract (SFOC) with NASA and the resulting loss of technical expertise within NASA are good examples of diminishing government expertise. In NASA, senior management often evolved to the point of being uninformed when compared to the expertise of its prime contractor, United Space Alliance, and the prime's subcontractors.

Leaders must ensure that appropriate organizational expertise is retained as processes and programs are contracted out. If not, the organization itself will wilt; it will merely have individuals overseeing contracts and matters in which they have very little technical expertise. When considering organization and contractor interface, the question becomes, "How much technical expertise should reside with the contractors on an operational system?" If contractors are given too much independence, over time, they may begin to drive new requirements—something that *should* be done only by the owning organization. Successful organizations cannot afford to lose their corporate knowledge and must avoid the easy and economically tempting solution of privatizing technical expertise. Finally, just as warriors must understand their commander's intent, contract structures must ensure that organizational goals are fully understood and met by the people who have been contracted to carry them out. Unfortunately for the shuttle, incentives were weighted more toward launching shuttles and meeting interim schedule milestones than correcting problems, which had significant safety implications.

Outlaw Normalization of Deviance. The space shuttle travels through arguably the most hostile environment on or above Earth—and NASA made it look easy. However, in clear violation of written design specifications, foam and debris were falling off and hitting the orbiter during its launches. Nevertheless, as more and more flights landed successfully, the perception of danger from debris and foam strikes continued to diminish as a concern. Successful flights, despite failing to satisfy the design requirements that prohibited foam strikes, serve as examples of how success can set an organization up for future failure. When such unplanned-for occurrences are ignored, left unresolved, or shortcut fixes are accepted today—the consequences may be catastrophic results tomorrow. As this tragedy underscored, past successes—or lack of failures—helped create and expand blind spots, bureaucratic complacency, and "group think" when approaching anomalies such as debris strikes.

Due to the normalization of prior shuttle debris events, when foam was seen striking *Columbia* on STS-107, senior leaders and decision makers were already convinced that foam could not bring down an orbiter, and viewed this as nothing more than a maintenance turnaround issue. By letting "the *unexpected* become the *expected* that became the *accepted*," NASA had achieved what Diane Vaughn termed the *normalization of deviance*.[4]

Uncorrected minor and seemingly insignificant deviations from accepted norms and technical requirements can lead to catastrophic failure—an unacceptable and often predictable consequence of normalizing deviance. Leaders must maintain a constant vigilance to avoid complacency and acceptance of anomalies, regardless of how risky the technology may be.

A Closing Thought

A total of 16 people—two space-shuttle crews and two helicopter-crew members—perished because NASA failed to go "beyond the widget." If NASA will now absorb the hard lessons from this tragedy, it can remove the conditions that make it ripe for another disaster. Likewise, any organization not abiding by the lessons to be learned from this tragedy may be creating its own recipe for disaster, for these cancerous conditions may be present in any organization.

These lessons, affirmed by *Columbia*'s loss, are summarized in the 20 primary questions below—questions all organizations should periodically ask of themselves to prevent complacency and forgo the potential calamities complacency could facilitate. As you review these questions, you might consider, "The foam did it. . . . The institution allowed it." The questions to ask yourself are, "What foam do *you* have . . . and what are *you* allowing?"

An Organizational Self-Examination Checklist

Basics

1. Do you "keep principles principal"?
    - Avoid compromising principles?
    - Avoid clouding principles?
    - Avoid migrating to mediocrity?
    - Maintain checks and balances?
    - Avoid an atrophy to apathy?
    - Control "configuration control"?
    - Avoid "fads"? Question their applicability?
    - Keep proper focus?
2. Do you communicate, communicate, and communicate?
    - Insist on discussion?
    - Encourage minority opinions?
    - Conduct effective meetings?
3. Do you affirm that management information systems matter?
4. Do you avoid "organizational arrogance"?
5. Do you remain thorough and inquisitive?
    - Avoid leadership by PowerPoint?
    - Mandate "Missouri show-me mind-sets"?
    - Question untested assumptions?
6. Do you ensure taskings and resources balance?

Safety

7. Do you stop stopgap safety?
8. Is safety first . . . safety people, too?
9. Are you keeping safety pertinent—and attractive?
10. Are you aware of third-party review caveats?
    - Watching for "pet pigs"?
    - Routinely reviewing inputs?
11. Do you go "beyond the widget"?
12. Is benchmarking bedrock?
13. Are you tracking flaws through closure?

Organizational Examination

14. Are you promoting teaming?
    - Developing the team?
    - Training for worst-case scenarios?
    - Educating past hiccups—others' and your own?
15. Do you avoid promoting unintended conflicts?
16. Do you seek and attack signals to "connect the dots"?
17. Are you sustaining sustainment?
18. Does tomorrow's dream distort today's reality?
19. Are you aware of outsourcing caveats?
    - Outsourcing accountability?
    - Outsourcing expertise?
20. Are you outlawing "normalization of deviance"?

Notes

1. Testimony of Harry McDonald before the CAIB, 6 March 2003, Houston, TX, transcript, *Columbia Accident Investigation Board Report*, vol. 6, appendix H.1 (Washington, DC: National Aeronautics and Space Administration, 2003).

2. *Columbia Accident Investigation Board Report*, vol. 1, chap. 5, 112–13; and vol. 2, appendix D, 18.

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Moral and Ethical Decisions Regarding Space Warfare

Col John Hyten, USAF
Dr. Robert Uy

Editorial Abstract: The possibility of warfare in space not only reshapes the traditional view of conflict, but also challenges national leaders and military commanders. Outlining the moral and ethical dimension of determining the right course of action in space, the authors consider the consequences of moral and ethical choices in the context of the appropriate and measured development of certain space weapons.

The big, red line we all have is the weaponization of outer space, which would be immoral, illegal, and a bad mistake.

—Bill Graham
Canadian foreign
affairs minister, 2001

In combat today, United States military commanders face many difficult moral and ethical decisions. The nation has entrusted them with her most precious resource—her sons and daughters—to fulfill their obligation to protect and defend her vital interests. Commanders' decisions have life-and-death consequences for Americans, allies, enemy forces, and, unfortunately, sometimes noncombatants. Without a doubt, these decisions are among the most difficult any human being could ever face.

The potential for warfare in space adds a new dimension to our traditional view of war and further challenges national leaders and military commanders. The debate over weapons in space continues to be vigorous and controversial; both sides are entrenched in their own positions, asserting that only their judgements are buttressed by "moral" and correct arguments. The purpose of this article is to highlight the moral and ethical challenges that surround space warfare in a way that helps clarify the issues for all who must examine these choices and make appropriate decisions in future combat situations. Ethics and morality issues are often not clear-cut, and future decision makers must be open to the possibility that the *greater good*—a means to measure the consequences of moral and ethical choices—may be served through an appropriate and measured development of certain space weapons.

The Dichotomy: Who is Right?

It would be a disaster for us to put weapons in space of any kind under any circumstances. It only invites other countries to do the same thing.

—Senator Tom Daschle, 2001

We know from history that every medium—air, land and sea—has seen conflict. Reality indicates that space will be no different.

—*Report of the Commission to Assess United States National Security Space Management and Organization*, 2001

Defining Space Weapons

It is essential to first define the term *space weapon* and the nature of *space warfare*; doing so will clarify this discussion, since the number of definitions for space weapons is nearly as infinite as space itself. Many authors have defined the term using slightly different criteria. In general, the most significant difference between these definitions reflects the weapon's basing mode; specifically, must the weapon be based in space to be a space weapon? If the answer is yes, then ground-based lasers or ground-based antisatellite (ASAT) weapons would not be considered space weapons. This article will, however, use a more inclusive definition.

Wulf von Kries, a member of the German Space Agency, addressed the difficult topic of defining space weapons at a Berlin conference in June 2002. He noted that "nothing can, might, and will stop the routine use of space for military activities." Since the existing legal framework dates from and uses the body of knowledge that existed over 40 years ago, he suggested that "the discussion on space weapons should not be limited to deployment in space but include those weapons on Earth that can be directed into space."[1] This article will follow his suggestion and use a broader definition of a space weapon, which is (1) a ground-based or space-based weapon that can attack and negate the capability of space systems on orbit or (2) a weapon based in space that can attack targets on the earth.[2]

Defining Space Superiority

The purpose for employing space weapons in space warfare is to achieve space superiority and, along with air and surface capabilities, establish a battlespace in which we can satisfy our national security objectives. Today, space capabilities are integral to the way our nation fights wars, and their enhancement of air and surface capabilities has given our nation's military tremendous advantages in recent conflicts.

Joint pubs define space superiority as "the degree of dominance in space of one force over another that permits the conduct of operations by the former and its related land, sea, air, space, and special operations forces at a given time and place without prohibitive interference by the opposing force."[3] The *Air*

Force Glossary adds that space superiority is the "degree of control necessary to employ, maneuver, and engage space forces while denying the same capability to an adversary."[4] Although neither of these space superiority definitions requires the development or deployment of space weapons, the ideas of space sanctuary and weaponization need further exploration.

The Debate: Sanctuary versus Weaponization

Numerous think tanks, educational institutions, and individuals have put a great amount of thought and effort into defining the debate between space sanctuary and weaponization. In the winter 1998 issue of *Airpower Journal*, Lt Col Bruce DeBlois published an article that has become a lightning rod for debate on both sides of the issue. His article, "Space Sanctuary: A Viable National Strategy," argued that it was in the best interest of the United States to pursue a sanctuary strategy and that a strategy of weaponization was flawed in a number of ways. He outlined four strategy-implementation elements that he felt would best position the United States for dealing with the future challenges in space. Specifically, DeBlois argued that the United States should (1) pursue intense diplomatic efforts to develop treaties and agreements to preserve the sanctuary of space, (2) develop strategic alternatives to our current force structure to reduce our dependence on a relatively small number of critical space systems that inherently provide a vulnerability, (3) develop passive hide-and-seek protective measures to protect our critical space assets, and (4) maintain the technical ability to develop and deploy space weapons should the need arise, preferably beginning with "the lesser provocative earth-to-space weapons."[5]

The *Report of the Commission to Assess United States National Security Space Management and Organization*, chaired by Secretary of Defense Donald Rumsfeld, voiced a different view when it summarized America's interests in space. Those interests are to (1) promote the peaceful use of space, (2) use the nation's potential in space to support US domestic, economic, diplomatic, and national security objectives, and (3) develop and deploy the means to deter and defend against hostile acts directed at US space assets and against the hostile use of space toward American interests.[6] This succinct statement is also in line with the 1996 National Space Policy developed under the Clinton administration and continued into the current Bush administration.[7] This statement of policy clearly allows for the development of the space weapons necessary to meet those objectives—with no limitation on basing modes. In practical application, however, the United States has not aggressively developed a significant space weapon capability.[8]

One of the more overused statements—bordering on myth—in discussions of the current state of military space is that space has been *militarized* but not yet *weaponized*. Proponents of this argument contend that today's military space force structure is postured to provide force enhancement effects on the battlefield; space has no weapons that directly impact targets—either in space or in the terrestrial environment.

The Taliban and Iraqi Republican Guard forces, who were on the receiving end of global positioning system (GPS)–guided weapons, likely have a different impression. Many of the targets attacked by today's Army, Navy, Air Force, and Marines are targeted using overhead space systems commanded through the use of space connectivity and guided by precision, space-based navigation systems. Space systems are an essential element of our current intelligence, command and control, and weapon systems inventory. This fundamental nature of modern warfare is a critical element driving the moral and ethical decisions regarding "space weapons."

Although modern capabilities have developed over the past 50 years in a de facto sanctuary environment, the fundamental nature of space in modern warfare has not been lost on the sanctuary proponents like Bruce Gagnon, head of the Global Network against Weapons and Nuclear Power in Space:

> It's an important distinction. . . . Weaponization I think is clear. Our position is no weapons in space, at any level, period. Militarization is more complicated. . . . While we accept some aspects of the militarization of space for treaty verification, confidence building measures, etc., we are firmly against military space technologies that are used for conventional war fighting. . . . Satellite systems that identify and direct war on the earth, which essentially allow for "full spectrum dominance" are not acceptable in our view. . . . We want a de-escalation of all military systems for fighting war on Earth or in space. We'd like to see the stabilizing, treaty verifying satellite technologies commonly shared globally.[9]

Morality and Ethics

This is where conflicting principles of the moral and ethical beliefs held by various groups within our nation begin to create a dilemma. Many believe that preserving space as a sanctuary from weapons is in the United States's and the world's best interests. If, as President Bush said earlier this year, the United States desires to work with international partners—returning to the moon and then proceeding on to Mars—then it may truly be in America's national interest to preserve the sanctuary. A contrary argument is based upon the US military's reliance on space to achieve an asymmetric advantage, which increases its effectiveness and reduces its own casualties but creates the need for space superiority. Hon. James Schlesinger, former secretary of defense and secretary of energy, states that "we are dependent on public support to sustain an ambitious foreign policy. That public support is, in turn, dependent upon very low, if not zero, casualties, and a high degree, a very high degree, of effectiveness of our forces, an exemplary display of those conventional forces. And that, in turn, is dependent on space."[10] The conflict between moral and ethical principles revolves around whether, on the one hand, space should be held as a sanctuary from weapons or, on the other, whether our nation has a moral duty to furnish those it asks to go in harm's way with the tools that will increase their effectiveness and reduce their casualties. Would the United States be willing to let its men and women in uniform fight in the future without that asymmetric advantage? Or, as a nation, do we believe that military space capabilities should be protected and developed further, expanding the asymmetric advantage that our nation's fighting forces currently enjoy?

The Morality of Asymmetric Advantage

One example of asymmetric advantage can be found in a quick examination of the US special operations forces (SOF)—the troops that "own the night." Through high levels of training in the application of night vision and other technologies, these forces have developed a capability that gives them enormous tactical advantage in the field. However, this advantage is increasingly being challenged by the sale of low-cost night vision devices that are available on the commercial market. Is this bad? Is it necessary for America to take every opportunity to apply technology to gain and maintain a battlefield advantage over potential adversaries? Or are there circumstances where it would be in the best interests of the United States not to pursue such an advantage?

Some might argue that vast advantages in capabilities make it easier to engage in an "electronic stay-at-home war," neither suffering combat losses nor sharing sacrifice. A more level playing field, one that puts American forces at greater risk, might make the United States think twice before engaging in hostilities and having to pay that terrible price. It has been argued that shared sacrifice and the loss of untold lives on both sides of a conflict make for an easier peace at the cessation of hostilities. However, as evidenced by the conflicts of the twentieth century, shared sacrifice and loss have not made people more averse to war and have not made the world a "kinder, gentler" place. A lasting peace has been, and remains, elusive.

The United States has not always pursued an asymmetric advantage. Although America recently celebrated the centennial of the Wright brothers' first flight, it should be remembered that just 15 years after that American first, the air forces of every other major nation that participated in the First World War were numerically and technically superior.[11] In 1904 an American, Benjamin Holt, implemented the first use of Caterpillar tracks; his application was for farm machinery, but it was the British who applied his innovation to armored vehicles.[12] Both the airplane and the tank eventually helped break the stalemate and mass slaughter of trench warfare—few have questioned the morality and ethics of incorporating these new technologies.

On the other hand, the First World War also saw the first widespread use of chemical weapons. International abhorrence to their indiscriminate nature later resulted in a ban on their use—a repudiation that, with a few notable exceptions, has been observed by the international community ever since.[13] Although chemical weapons were a new technology, they did not lead to a significant advantage for either side. Their employment relied on favorable atmospheric conditions for success, an element over which neither side had any control. A global ban on the use of chemical weapons has not deprived any country of a significant advantage with respect to its adversaries.

There have been numerous proposals at the United Nations Conference on Disarmament to expand the 1967 Outer Space Treaty to ban all types of space weapons.[14] But space is different. For all the goodwill that might result from an agreement to ban weapons in space, the United States would be disproportionately affected by the loss of a key asymmetric advantage.

The bottom-line issue that remains for our nation's leadership is, Should America, when it calls its sons and daughters to arms, ensure that they have every advantage in the field so that they may prevail? From Greek fire to the longbow, technological advantages have not stayed home or been unilaterally set aside when armies have gone to battle. Should we agree to limit ourselves to a "fair" fight? Losing space superiority could put our nation on a level playing field with our adversaries. This diminished capability can also have consequences beyond the combatants involved. Even after leveling the playing field and after thinking twice, there will still be situations where our national interests require that we enter into combat. Without space-based, warmaking capabilities—intelligence gathering, providing improved situational awareness, networking forces using secure space communications capabilities, and enabling precision-guided munitions (PGM) to enhance fire superiority—Baghdad today might resemble Grozny. While the objective of capturing both cities was the same, technology and overwhelming advantage spared the noncombatants and structures of Baghdad the massive casualty tolls and destruction that were seen in Chechnya.

Case Studies

Engaging an enemy in conflict and contesting each other's use of space is new in modern warfare. In fact, the enemy's use of space in the recent conflicts of Operation Allied Force (OAF) and Operation Iraqi Freedom (OIF) has presented us with a direct challenge to our space superiority. There are space-warfare lessons that can be learned from dealing with the challenges of those engagements.

Operation Allied Force. The Serbs, under President Slobodan Milosevic, used satellite television to provide command and control, among other means, to transmit propaganda. Col Konrad Freytag, NATO spokesman, reported on 23 April 1999 to the world press that "last night, NATO continued to disrupt the national command network and to degrade the Federal Republic of Yugoslavia's propaganda apparatus; our forces struck at the regime leadership's ability to transmit their version of the news and to transmit their instructions to the troops in the field prosecuting their campaign of repression and destruction in Kosovo. . . . The building also housed a large multipurpose communications satellite antenna dish."[15] News reports from three days before had stated that "Mount Zlatibor, a ski resort 120 miles south of Belgrade, was hit by eight explosions. . . .

Hilltops in Yugoslavia are often sites for communications links. The news agency also said NATO had fired four missiles at a satellite ground station in Prilike near Ivanjica."[16]

This picture, courtesy of NATO, documents the damage to the satellite antenna and the surrounding infrastructure at Ivanjica satellite ground station.

NATO military planners could not know if civilians would be in the target area when the Ivanjica satellite ground station was attacked; therefore it is not clear if, or how many, civilian casualties occurred, but the possibility certainly existed. Although arguments about whether this was a legitimate target continue to this day, NATO attacked this target with the best precision weapons available, ensuring the target was eliminated while minimizing, but not eliminating, collateral damage.[17]

Operation Iraqi Freedom. Satellite communications were again a target for allied forces during OIF, and the enemy, for the first time, attempted to employ GPS jammers to deny coalition forces the use of GPS-enabled precision weapons. The methods for countering each of these threats provide interesting lessons.

One of the coalition's countersatellite communications objectives in Iraq was to get the Iraqi state-run television off the air to keep Saddam Hussein from communicating instructions to his forces and providing propaganda to the world. The *Washington Times* reported the following:

> In a March 25 strike, the unmanned Predator fired a laser-guided Hellfire missile at a TV satellite dish in downtown Baghdad, as part of the United States Air Force's dogged effort to take Iraq's state-run television off the air. The Predator, controlled by Air Force personnel at a base elsewhere in the Persian Gulf area, scored a direct hit. Yet Saddam Hussein's regime continues to keep the signal on. "We're still trying to take Iraq TV off the air," a senior allied officer said this week. "He's been preparing for something like this for 12 years. He's got redundancy into redundancy. But it's getting harder and harder for him to bring it back." In the Predator flight, air planners decided its 100-pound Hellfire was better suited for some downtown targets than a 1,000-pound-warhead Tomahawk cruise missile or a one-ton satellite guided bomb. The TV dish sat near a school and other civilian buildings. "A 2,000-pound bomb probably would have caused more damage, so the Predator took it out," said a senior allied officer, who asked not to be identified. "We really do worry about collateral damage. We target and we choose the weapons in a very deliberate way. You try never, never to use any more weapon than you actually need."[18]

The mission was similar to the one against Ivanjica during OAF, but different methods were chosen, reflecting a desire to minimize collateral damage. The effect in Iraq, however, was not as complete as it had been in Serbia. The Iraqi regime had learned from OAF and built redundancy into all its communications, which included its satellites' ground infrastructure. That made it much more difficult for allied forces to eliminate the ground segment of their space capability.

The Iraqis also understood that the PGMs that were using GPS guidance provided the allies with a big advantage; they attempted to jam the GPS signal, hoping to force allied airpower to use other weapons that would not be as effective. Their extremely crude attempts were easily identified and destroyed. As reported by Maj Gen Victor Renuart, USAF, United States Central Command (CENTCOM) director of operations at the time,

> We have noticed some attempts by the Iraqis to use a GPS-jamming system that they have pro-

> cured from another nation. . . . Actually, we've been able to identify the location of each of those jammers, and I'm happy to report that we have destroyed all six of those jammers in the last two nights' air strikes. The jammers had no effect. . . . In fact, we destroyed one of the GPS jammers with a GPS [-guided] weapon.[19]

It is interesting to note that the Iraqis actually used, or at least tried to use, a space weapon (by the definition arrived at earlier in this article) against the US GPS system, attempting to deny the allies the use of their precise-navigation capabilities.

A Better Way?

The method chosen to gain space superiority in recent conflicts has been a lethal attack on the enemy's ground stations and/or ground systems. What will be our preferred method to establish our control of space in the next conflict? The answer to this question must include more than the perspective of just what is most effective. Leaders and planners must also consider the moral and ethical issues of asymmetric advantage and their effects on the idea of space sanctuary.

What kind of military response would allied commanders prefer? The traditional answer is to respond with lethal force against ground targets in a way that eliminates an enemy's access to space and preserves the sanctuary of space. However, this is fraught with many problems, as evidenced in the previous examples.

First, attacking the ground system will not guarantee the desired effect on the battlefield. Today, before a conflict begins, enemies can implement redundancy into their infrastructure, making it difficult to destroy the network's ability to function; the Iraqis built in infrastructure redundancy and preserved access to their satellite communication network during OIF. Although coalition forces identified and destroyed, with little collateral damage, what they believed to be the Iraqi satellite system's critical antenna, the Iraqis stayed on the air; Saddam Hussein continued to communicate propaganda to the world and directions to his army, putting our forces at risk. Another risk was illustrated by the OAF example previously discussed in this article: no matter how good the intelligence and how careful the military planning, the employment of lethal force runs the risk of inflicting collateral damage and causing noncombatant civilian casualties. The political fallout from those casualties—lost domestic support, lost international support, split coalitions, legal complaints, and so forth—may be more damaging than the possible gains that would accrue from a successful attack.

That attack on the satellite ground station near Ivanjica is, in fact, one of a number of events cited in a war-crimes complaint filed with the International Criminal Tribunal for the former Yugoslavia at The Hague. That complaint was filed by a group of lawyers from several countries; half of them are residents of Canada while others, one each, live in Argentina, France, Nicaragua, Spain, and the United States. It targets the political leaders of the NATO countries along with their military commanders and is based on the additional protocols to the Geneva Convention that are concerned with the protection of civilian populations.[20] Those protocols prohibit "an attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated."[21] Although it is unlikely that anything will come of this complaint, the fact that an attack on a satellite ground station was included in a "war crime" complaint emphasizes the need to limit collateral damage, even when attacking targets of this kind. The military commanders that were involved in OAF have stated in discussions that they would have preferred to have eliminated that satellite ground station's capability without using traditional blast and fragmentation weapons—if a capability had been available that would have given them as high or higher a probability of succeeding. Although not available to commanders during OAF in 1999, in 2004 the Air Force will begin to test and evaluate a new capability for subsequent operational use—the Counter Communication System (CCS).

The CCS is a ground-based deployable system designed to deny a potential enemy the use of a satellite communications system with effects employing temporary and reversible methods. It will be classified as a space weapon, using the same definition that was applied to the Iraqi GPS jammer; however, it will likely be much more effective.

When the CCS becomes part of the operational inventory, a military commander will be able to consider both lethal and nonlethal methods for accomplishing the same effect. However, since the CCS will have some operational limitations and does not have a guarantee for mission success, that decision will not be as straightforward as it might have first appeared. Depending on the circumstances, commanders may once again be forced to resort to lethal options to accomplish the mission. The CCS also opens the theoretical possibility for further space-control options, which include different basing modes that will address newer threats and mitigate operational limitations.

Sanctuary Lost?

Unfortunately, the events of the last few years clearly demonstrate that war and conflict will be with us for some time. The current American way of war is heavily dependent on controlling space and establishing space superiority. In seeking a moral and ethical high ground, we could assert that our nation should needlessly risk neither the lives of its sons and daughters nor the lives of noncombatants. We have seen how an asymmetric space advantage improves our effectiveness, reduces our casualties, and helps us satisfy the intent of the Geneva Convention's principle of proportionality by precisely targeting and guiding weapons, thereby avoiding most collateral noncombatant casualties. In light of these observations, can this nation, as Colonel DeBlois has suggested, embrace a national security strategy that maintains space as a sanctuary free of weapons?

That question will be addressed using Colonel DeBlois's four elements of a *space sanctuary strategy* as a framework:

1. *Pursue intense diplomatic efforts to develop treaties and agreements for preserving the sanctuary of space.* This is possible only when dealing with rational state actors that have self-interests similar to those of the United States. This leads us to recognize two problems in today's world: (1) the majority of threats to the United States come from nonrational or nonstate actors and (2) no one is as dependent on space as is the United States, which would have to give up much more than the other signatories would have to surrender.

2. *Develop strategic alternatives to our current force structure to reduce our dependence on a relatively small number of critical space systems that inherently provide a vulnerability.* We are now dependent on a great number (rather than DeBlois's "relatively small number") of crucial space systems for our military and economic well-being. In fact, neither the US military nor the US government owns or operates many of the systems on which we are currently dependent. In OIF, for example, commercial carriers provided over 80 percent of our required satellite communications connectivity.[22]

3. *Develop passive hide-and-seek protective measures to protect our critical space assets.* Although this may be possible with a small number of critical assets, it is much more difficult with the large space infrastructure we use today. This trend will only continue, and hiding our assets will become increasingly difficult, particularly as our potential adversaries pursue more robust space surveillance capabilities.

4. *Maintain the technical ability to develop and deploy space weapons should the need arise, preferably beginning with "the lesser provocative earth-to-space weapons."* The

need has arisen. Nevertheless, it is important for the United States to move slowly down this path. The CCS is an example of a less-provocative, Earth-to-space weapon that employs temporary and reversible effects, providing an essential first step.

Conclusion

Clearly, the world would be a much better place if the causes of war could be abolished. War is a nasty business, and leaders should always choose it as a last resort. Sadly, however, various world problems seem to arise on a fairly regular basis that only the use of military force can solve. We must be successful when we choose to use military force, and our nation has made space essential to that success. Space superiority is now critical to the American way of war, but the United States should proceed very carefully down any path to develop space weapons. America clearly has a desire to continue its exploration of space for peaceful purposes. An international approach that preserves the sanctuary as much as possible would facilitate the nation's efforts to return to the moon and proceed on to Mars. Nevertheless, our leaders must balance sanctuary considerations with the critical contribution that the control of space makes to the security of the United States and the effectiveness of our economic, diplomatic, and military elements of national power when threatened by adversaries around the world.

A national debate is needed to examine the merits and trade-offs between our various objectives: winning the nation's wars with the fewest casualties, fighting those wars with the greatest possible effectiveness, following a Geneva Convention principle of proportionality that helps protect noncombatants, supporting space as a sanctuary free of weapons, and fielding and using space weapons. That debate will influence future decisions such as developing capabilities like the CCS, answering the question about whether or not our military commanders, charged with removing an enemy's space capability, should have a nonlethal means to accomplish that objective, even if that capability would be classified as a "space weapon." Would it be better, more moral, for that commander to be limited to the use of air-deliverable lethal weapons, potentially causing many more noncombatant deaths? In many of today's cases, the use of space weapons and systems provides a better moral and ethical choice for military commanders because those systems can potentially provide him or her with better options for fighting and winning the nation's wars while reducing collateral damage and noncombatant deaths.

Will this one step necessarily lead to the employment of weapons based in space and space weapons with lethal capabilities? Not necessarily. The same moral and ethical arguments that have been discussed in this article can be used to help evaluate future requirements. If and when the United States moves weapons into space, the desired effects should once again be temporary and reversible, and space basing should be required only if ground basing cannot handle the threat. Upon resolution of the conflict, the "sanctuary" of space, or more appropriately the commons of space, can then be restored. Likewise, permanent lethal effects would be required only when terrestrially based solutions cannot effectively meet the needs of the military and the nation.

This article has outlined the moral and ethical challenges facing the country as it decides the right course of action in space. The weaponization of space does not necessarily mean crossing a "big, red line"; neither is it "immoral, illegal, and a bad mistake." The appropriate, measured development and use of certain space weapons will allow the United States, in circumstances where the nation is forced into war, to conduct warfare in ways that increase combat effectiveness while at the same time limiting collateral damage here on Earth—a more moral and ethical decision. □

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The Space Campaign

Space-Power Theory Applied to Counterspace Operations

2D LT BRENT D. ZIARNICK, USAF

Editorial Abstract: Despite the importance of space to current and future military operations, one seldom hears discussions about the importance of establishing space superiority. Drawing on James Oberg's elements of space power, Lieutenant Ziarnick describes an operational space-superiority targeting doctrine, offers a foundation for fighting a space campaign, and suggests the adaptation of a model widely known to air strategists.

EVEN THOUGH SPACE operations receive wide recognition as an important part of present military operations and will likely play a dominant role in future conflict, one hears remarkably little discussion about achieving space superiority. Part of the reason for this apparent indifference is the common notion that we have no general theory of the relationship of space activity to both military operations and the national interest on which to base ideas. Therefore, thinking about military space either limits itself to loose generalizations based on established theory, such as that dealing with air operations, or emphasizes defeating specific systems/capabilities rather than producing a general doctrine applicable to all space systems, based upon a space perspective. James E. Oberg, however, in his book *Space Power Theory*, does make a notable attempt to form a coherent system for explaining space power.[1]

This article describes an operational space-superiority targeting doctrine based on Oberg's elements of space power. The proposed doctrine has immediate applicability to current space doctrine, relies on current or near-term military systems for execution, and includes sufficient flexibility to apply to any space scenario faced by a spacefaring nation. After introducing Oberg's theory of space power, the article explores the military utility of his space-power elements and considers the effect of conflict duration on the nature of space campaigns. It also offers a foundation for fighting a space campaign, culminating in a model familiar to modern air strategists.

Oberg's Theory of Space Power

Oberg defines space power as "the combination of technology, demographic, economic, industrial, military, national will, and other factors that contribute to the coercive and persuasive ability of a country to politically influence the actions of other states and other kinds of players, or to otherwise achieve national goals through space activity."[2] From this definition, he derives a list of space-power elements—factors necessary for a nation or other entity to acquire and sustain space power—that includes facilities, technology, industry, hardware (space vehicles), economy, populace, education, tradition and intellectual climate, geography, and exclusivity of capabilities/knowledge.[3] From a military standpoint, we can consider these elements essential centers of gravity for an adversary's space efforts. However, some of the more esoteric ones do not constitute viable military targets. For the military professional, the important attackable elements consist of an enemy's facilities, industry, hardware, economy, and—potentially—populace and exclusivity of capabilities/knowledge.

Facilities

The "hardware with which to conduct space operations," facilities include sites for manufacturing, launch (referred to here as spaceports), command and control (C^2), and laboratories—all of them normally ground-based structures subject to attack and destruction by a variety of conventional means.[4] We can also assume that they are finite in number and quite valuable to the adversary's space power. Successful elimination of a single facility could devastate an adversary's space capabilities, and complete destruction of a class of facilities (i.e., spaceports or C^2 centers) could prove fatal. We should consider facilities an attractive target for attacking an enemy's space power because of ease of strike as well as their high utility and cost of replacement in terms of both money and time.

Industry

"Modern and efficient production facilities" for producing space equipment and other technologies with space-related applications, industry includes firms or operations that provide raw materials to facilities.[5] That is, industry offers "support services" such as components and materials essential for the operation of space facilities, thus resembling the petroleum/oil/lubricants concept used in US strategic-bombing theory during World War II. Unfortunately, industry may not lend itself to successful attack due to the redundancy of operations (e.g., if one ore field or power plant supplying a facility element is destroyed, then another can take its place relatively easily and quickly), and crippling an enemy's space power by means of attacks on industry may prove impractical. However, doing so may also assist friendly ground, air, or sea operations, thereby elevating the total war-fighting utility of such attacks. They may also serve to defeat an enemy through attrition, beyond their ability to degrade his space power. For these reasons, we should consider industry a space-power target.

Hardware

Actual space systems such as satellites and launch boosters comprise the hardware element, whose utility to a nation's space power is obvious. Attacking this element poses unique opportunities as well as challenges and risks. Significant technological hurdles limit antisatellite (ASAT) capabilities, and perceived political limitations make such endeavors unpopular. Furthermore, the physical destruction of satellites might cause orbiting debris that could possibly render that orbit or space itself unsuitable for operations. However, alternatives to physical destruction include attacking subsystems (blinding the satellite) or forcibly moving the system outside of acceptable parameters. Attacking space boosters does not share the risks associated with targeting satellites, and any national missile-defense capability fielded to engage ballistic missiles in the boost phase could also destroy a space booster. Hitting space-lift systems during boost can result in the complete destruction or neutralization of the payload; moreover, debris would either fail to reach orbit, burning up harmlessly in the atmosphere, or rain down on the adversary.

Economy and Populace

Their function as sources of funds and manpower for a nation's space effort makes the economy and populace essential elements of space power. Although subject to attack, they should not be considered direct targets of space power because of ethical concerns, aside from the fact that their utility is not concentrated in a certain area. A space warrior, however, should keep in mind their possible impact on a nation's space power in long-term conflicts.

Exclusivity of Capabilities/Knowledge

Oberg describes the capabilities/knowledge element—the spread of technical space knowledge in the host nation—as "the most volatile aspect of power in general."[6] If the nation has only a small cadre of space professionals, such as engineers and scientists, they become an important target with very high utility. However, if space expertise is so widespread that enemy space systems do not rely on a small, easily targeted group of individuals, this element lessens in importance. Eliminating or incapacitating exclusivity targets warrants careful consideration in military planning since it could become a decisive factor in destroying an enemy's ability to project space power.

These elements comprise the target list of a campaign to destroy enemy space power. Destruction or degradation of any of them could be devastating to an adversary. Identification of these targets and examination of their strengths and weaknesses allow us to develop methods for their negation.

Time Span of Space Conflict

The length of the conflict becomes a factor in a nation's plans for defeating an enemy's space power. By nature, space power is difficult to deploy and, under current military realities, relatively fixed. Satellite constellations that one normally needs to produce a significant military capability take years or even decades for major spacefaring nations to construct. Even single satellite systems may prove difficult for minor spacefaring nations or private companies to deploy. In low-intensity, short-duration campaigns, destroying a system without attacking the space-power infrastructure may effectively eliminate all of a nation's space capabilities for the remainder of hostilities. However, longer engagements may allow the enemy to rebuild destroyed elements, requiring the military commander to reengage in counterspace operations. The enemy's ability to regenerate space systems serves as the primary factor in categorizing the relative time span of a space conflict. This model considers three such durations: short, medium, and long.

In a short-duration space conflict, the enemy nation has little or no ability to regenerate space assets damaged or destroyed by physical action. Regeneration involves rebuilding a terrestrial command center or relaunching a space asset. This time span can vary, depending on the maturity of the adversary's space power. For example, Russia could restore a destroyed ground station in less time than could a nation like North Korea, which might not be able to launch a replacement space asset at all. In a space conflict of short duration, the utility of attacking the ground or space nodes of active space systems increases since one can achieve space superiority by this means alone. Attacking support structures such as industry or spaceports is pointless since these elements would be of no use to the opponent's space power during the conflict. Striking the enemy's space power fast and early in order to produce maximum results makes the establishment of space superiority relatively easy. By eliminating the effectiveness of the adversary's space systems immediately in the short-duration space conflict, one can forgo attacks designed to severely damage his space infrastructure. However, when an enemy has the ability to regenerate space assets, the conflict becomes more complex.

A medium-duration conflict gives a nation limited ability to regenerate space assets—for example, rebuilding a ground station, reconnecting with debilitated space nodes, and perhaps even replenishing satellites to some extent. Thus, simply destroying a ground station may not permanently (at least for the duration of the conflict) eliminate the targeted space capability, so one must turn to attacking space nodes or continuously allocating resources to attack ground stations as they become operational. Also, a spaceport may become a worthwhile target during this time span. In other words, in a conflict of medium duration, one must use more permanent means to disable enemy space systems while targeting infrastructure that the enemy might use to quickly replenish lost assets.

In a long-duration space conflict—the most advanced and complex of the space-superiority scenarios—an enemy has enough time to replace any and all space systems destroyed. Therefore, permanently destroying a space capability is unlikely, and achieving space superiority becomes a function of delaying or disabling the enemy's space power as long as possible with as little effort as possible. In this scenario, all elements of space power are effective targets because the conflict is likely to last long enough for the adversary to feel all effects. Whereas during the short- and medium-term time spans, one focuses on attacking current space systems, the long-term conflict requires destruction of both the enemy's space systems and space infrastructure. Thus, counterspace operations become more numerous and must be strategically planned to balance the needs of air, land, and sea superiority.

Assumptions and Beliefs

The model offered here operates on a number of fundamental assumptions. First, space power is and will remain a major factor in deciding military conflict and will become the decisive factor in the future. Second, a nation's space power should be a primary target in any engagement. Third, one should attack space power by targeting its elements as defined by Oberg. Fourth, political and economic factors will determine the counterspace methods used and the effects desired. Fifth, counterspace doctrine should adapt to any situation and should maintain effectiveness. Sixth, counterspace operations should be characterized by their political, economic, military, physical, and temporal effects.

Targets and Methods of Engagement

Regardless of the type or length of an engagement, attacking the elements of space power is essential to effective counterspace operations. Military commanders have a number of options available for directing force against the variety of targets presented by these elements. The two primary categories of attacks—physical and informational—concentrate on the space system and the data it provides, respectively.

Physical attack, the most common form of military operation, involves inflicting actual damage in order to degrade or destroy the target. Because effects are usually permanent (unless the enemy can rebuild) and normally involve loss of property and, more importantly, loss of life, political factors come into play. Physical attacks can negatively affect public opinion both domestically and internationally, can escalate a situation beyond the intended purpose, and can cause unrest as television broadcasts images of bodies and carnage worldwide. However, once a system is destroyed, it could take the enemy weeks, months, or even years to rebuild and restore his lost capabilities, making physical attack an attractive military option. Commanders charged with adapting counterspace operations to function in all possible scenarios must carefully consider this method of attack because of its volatility. Due to the unique qualities of space power, information operations avoid the pitfalls of physical attack yet still deny the enemy his space capabilities.

Information attack (IA) can fulfill offensive-counterspace goals without causing destruction of property or casualties, thereby lessening concern about escalation or adverse international opinion. IA takes many forms, including jamming the communications link between a satellite and its ground station, sending a confusing signal to a hostile satellite, or infecting a ground station with a computer virus to impair its ability to process telemetry (satellite data). However, because IA usually produces only temporary effects, its utility depends upon continuous application (e.g., constantly broadcasting electronic jamming signals to assure impairment of a space system). Since it does not cause physical destruction, an enemy can normally recover quickly (within days) from a virus attack or some other isolated assault. Furthermore, the enemy can defeat IA by destroying signal jammers or boosting his own signal to negate the signal (antijam). An adversary can also restore services denied by IA once he determines how to counter the attack, a situation that could prove disastrous to friendly military operations if it occurs at a critical time. IA operations, therefore, have diminished military utility because one successful application does not guarantee a permanent effect on a nation's space power, as would destruction of an enemy command center. A successful space-superiority campaign must unite physical attack and IA operations to destroy any opposing space capability. Thus, we must match the unique characteristics of the space-power elements to the strengths and weaknesses of each attack option, enhancing the former and limiting the latter.

Attacking Facilities

Two subcategories of facilities—satellite C^2 sites (including remote tracking antennas) and spaceports—are terrestrially based and, therefore, targetable by traditional weaponry. Destruction of C^2 facilities, essential to space operations, would eliminate an active space system. Destroying an enemy spaceport, however, which allows a nation to replenish or expand its space assets, will not eliminate current in-orbit capabilities but will ensure that the enemy cannot augment his space systems if they come under attack. Therefore, targeting C^2 facilities is a form of space-force attack, while targeting space lift is a form of logistical assault or interdiction. One can easily conduct either type of attack by using terrestrial weapons systems with conventional tactics. In essence, a space facility is just another building—like any other strategic target.

Facilities offer an attractive target to a contemporary space-control campaign because they are rare, fixed, and susceptible to conventional engagement. These circumstances, however, will likely change in the near future. New space-lift capabilities such as single-stage-to-orbit, reusable, aircraft-like launch systems could make traditional spaceports obsolete and eliminate the need for isolating these systems from populated areas. Such technologies might also preclude spaceport latitude as a factor for determining inclination insertion limits. Eventually, these facilities will likely be located throughout a nation, decreasing the importance of individual spaceports. Also, research into light, mobile ground stations for satellites could make easy ground-link targets a thing of the past. Therefore, a space-control campaign based on eliminating ground elements or facilities may be feasible today but will encounter serious difficulties tomorrow.

IA operations permit a variety of attacks on facilities. One can strike a computer system with a virus or computer-network attack, perhaps disabling the entire facility for an extended time, and electronic jamming of the communications node can terminate the utility of the space asset. Because the facility is stationary, unlike spaceborne assets not in geosynchronous orbit, a jamming system would not have to retarget it continually in order to produce the desired effect. Unfortunately, IA operations share the limitations of physical attack in that ground facilities may become less important as technology evolves.

Attacking Industry

Attacking industrial support of a nation's space power affects its space effort indirectly. Whereas attacks on facilities or hardware can eliminate systems directly, attacking industry has an effect only in a long-duration space campaign in which the regeneration of space assets comes into play. Because a swift space campaign is not well served by attacking industry, a space planner should not commit forces for this purpose if they could be used against facilities or hardware. Industry is important to the planner because of its strategic and long-term campaign implications as well as its potential as a by-product of an air campaign.

Space operations rely on chemicals (propellants, coatings, etc.), electrical equipment (circuit boards, silicon, semiconductors, etc.), and many other resources. Thus, attacks on virtually any industrial center could have a detrimental effect on the space efforts of a particular country.

Attacking Hardware

Hardware attacks entail targeting space systems either in use or on the ground. Currently, even though options for physical attack on active space systems are very limited, such a course of action can still prove useful. In fact, for many reasons this option represents a very desirable way to eliminate space capability. First, space segments are generally more difficult to replace or repair than are link or ground segments. Second, attacking space systems generally does not put lives at risk, as would an assault against an occupied ground station. Possible objections include political lack of will and the effect of space debris. Although direct-ascent, kinetic ASAT weapons may be the easiest to deploy and use, they will produce a great deal of debris. Directed-energy weapons, either ground- or space-based, may be more practical since energy can target onboard computer systems by imparting enough radiation to cause electronic systems to fail without physical damage to the satellite or by causing terminal damage without explosive action. Attacking spaceborne hardware with proper ASAT systems can sidestep the issue of space debris.

Attacking hardware with IA operations can also produce results. Jamming satellites in orbit renders them useless for the duration of the jamming. Geostationary satellites remain in the same position with respect to a position on Earth, so targeting is relatively easy and jamming can take place continuously from the same location. However, the extreme distance of the geostationary belt from Earth might create complications with power requirements, not to mention the fact that jamming may inadvertently have an effect on other satellites near the target. Targeting satellites in other orbits closer to Earth introduces the problem of targeting a moving object. Also, jamming from one area on Earth can affect a space object over its line of sight (e.g., preventing a reconnaissance satellite from collecting useful intelligence over a specific area) but cannot disable a satellite indefinitely.

Another IA attack option involves transmitting false orders to a hostile satellite that will either disable or destroy it. One can tailor this type of attack to almost any purpose—for example, "turning off" a satellite for the duration of hostilities or ordering it to expend its reserves of fuel. However, this option—usually available in only a few instances—can prove extremely difficult to conduct successfully.

Attacking Exclusivity of Capabilities/Knowledge

Obviously, one can compromise an enemy's space systems by incapacitating the personnel responsible for operating them. If, for example, only a very few space professionals run a secret space program in a Third World country, destroying that capability (and perhaps all of that nation's space power) may be as easy as killing them, taking them prisoner, or otherwise denying their ability to command the system. Physically attacking a manned C^2 facility may also affect the exclusivity element. Even though the enemy might rebuild it, he cannot as easily replace the chief scientist or seasoned operators lost in the assault. Although one can target this element with aerial/space bombardment or ground assault, using special operations forces focused on eliminating important human players in an adversary's space forces may prove very effective in quick campaigns against an unsophisticated opponent.

Again, the effect of an exclusivity attack is directly related to the sophistication of the adversary's space program. Advanced nations that frequently use space assets have considerable knowledge of space and technical matters. Exclusivity assaults on the United States, Russia, or other nations with substantial space programs would prove largely futile because their programs do not rely on a select few personnel. Because any technical manager or engineer can be replaced with someone equally competent, the loss of a few people—even exceptionally gifted ones—will have little or no effect on the space program.

A recent, tragic accident in Brazil, however, reinforces the fact that the loss of qualified personnel can prove disastrous to a small, fledgling space effort. On 22 August 2003—mere days before launch—a Brazilian VLS-1 V03 rocket exploded on the pad due to a booster-engine malfunction, killing 21 engineers and technicians. Physicist Francisco Conde notes that "Brazil's space program . . . lost its professional elite" and that 18 of the 21 people killed had over 20 years of experience.[7] The destruction of two satellites, a booster rocket, and the launch facility was a serious setback, but the loss of so many space professionals has caused many to wonder if Brazil's space efforts will ever recover. At the least, the accident set back that country four years or more. Clearly, space professionals are of inestimable value to small space efforts, making exclusivity a vitally important element of space power and thus a prime target.

Considering the possible time spans of space conflict, multiple space-power targets, and various methods of attack available, one can wage a space campaign in a variety of ways. Even though no country has ever initiated direct military action to systematically destroy another's space capability, when it does occur, the issues raised in this article will likely become factors in the process. That is, some methods of attacking space-power elements are better than others, depending upon the length of the conflict (fig. 1).[8] One can then make use of the concepts explored so far to develop a space-campaign strategy.

A Space-Campaign Strategy

At the beginning of any military campaign that contests space superiority, one must eliminate the enemy's space abilities as quickly as possible—specifically, by directly attacking the nodes (hardware and facilities elements) of his operational space systems. However, if an exclusivity target exists, it becomes the most important target to the space campaign because eliminating it will have a quick and decisive effect on the enemy's space power. These opportunities, however, may never present themselves.

The decision to attack either hardware or facilities with greater zeal depends upon the particulars of the campaign. If it involves a third-party remote-sensing system, such as a "neutral" satellite selling imagery to the enemy, physical attacks on the satellite, its personnel, or its ground station will likely be out of the question, making IA attacks the best course of action. For a projected combat operation of only a few days, IA operations against space systems owned by the enemy could produce all the desired results for space superiority and would be especially attractive in terms of tactical flexibility. However, physical attacks on the elements of space power produce permanent results for the short-duration campaign. Attacks on hardware do not put lives at risk, and this particular element is more difficult to replace

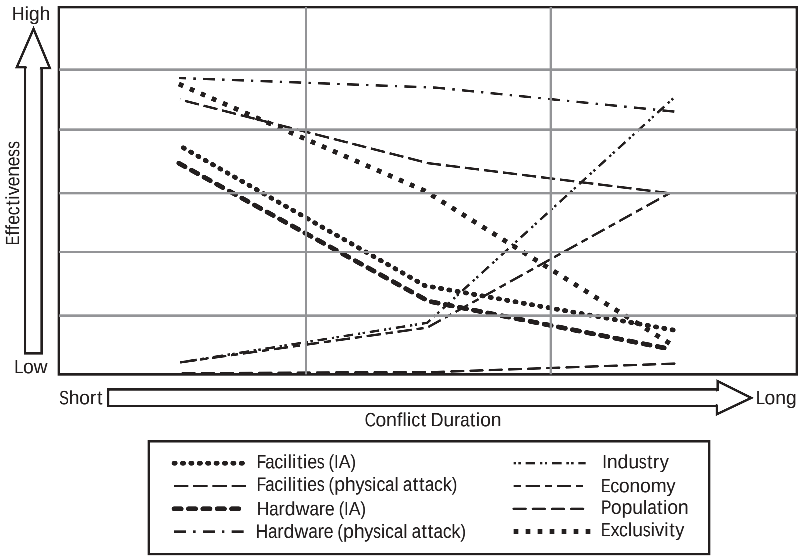


Figure 1. Effectiveness of attacking elements of space power. Attacking fielded systems is of key importance in a conflict of short duration. As duration increases, IA loses its utility, so the emphasis shifts to attacking the enemy's ability to field replacements for destroyed systems. In a long-duration conflict, attacking hardware, facilities, and exclusivity is effective only if the adversary's ability to replace them is also attacked.

than a facility. However, attacks on facilities require only traditional weapons and are almost as effective at destroying space power as hardware attacks. Before choosing, one must understand that the enemy can replace facilities such as C^2 complexes with mobile units or new fixed positions, given the time and resources, while he would have difficulty replacing hardware, which is also vulnerable to interdiction during preparation or launch. When the enemy's hardware and facilities are sufficiently damaged to destroy the usefulness of his space systems, the short-duration space campaign ends in victory. In a medium- or long-duration space conflict, the emphasis shifts from eliminating the enemy's space assets to eliminating his ability to rebuild them, which is essential to the establishment of space superiority.

One cannot rely on destroying each new fielded system as it comes online—that is simply too difficult. Therefore, enemy spaceports may become important targets. If the opposition has no spare satellites or launch-on-demand capability, then destroying spaceports may not be necessary for short-duration space superiority. For a medium-duration space conflict, however, spaceports become a top priority because even if the adversary has spare satellites and available rockets, they are useless without a launch facility, which is easily targeted, easily reattacked, and difficult to replace. Their destruction can lead to victory in the medium-duration campaign.

After defeating the fielded space systems in a long-duration campaign, friendly forces should then shift their primary focus to disabling the industry and economy of the adversary to restrict or eliminate his ability to replace lost hardware and facilities. Attacks on chemical plants, heavy industry, electrical-component manufacturing, and other concerns can cripple the enemy's ability to rebuild satellites, rockets, C^2 platforms, and spaceports. Without damaging the industry and economy elements of space power, friendly forces would experience a constant drain of materiel and personnel by employing them to destroy newly fielded space systems. Furthermore, the enemy might produce some small space capability in the interim while a new system is targeted and destroyed. The only way to achieve space superiority is to eliminate the enemy's ability to do anything in space, and that entails destroying his industrial base. Attacking the economy and populace elements might also disrupt a space program, but doing so would make inefficient use of resources dedicated to winning the space campaign. Also, ethical considerations regarding people and their means of survival (food, water, sanitation, etc.) make these elements the least desirable targets of the space campaign.

Graphically, one may depict a space campaign directed against the elements of space power as six concentric circles, similar to the model for John Warden's five-ring theory (fig. 2).[9] The exclusivity element occupies the inner circle—the position of most importance—followed by hardware, which should be attacked if exclusivity is too diffused, and the facilities element. These three rings, representing fielded space power and encompassing the space-forces zone, are the primary targets of the short-duration campaign and the first targets of any campaign. The industry ring—which, along with economy and populace, is part of the foundation component—is extremely important because it determines the difference between short-, medium-, and long-duration space campaigns. The four inner rings—exclusivity, hardware, facilities, and industry—embody the main target groups of interest to the space-campaign planner, whereas the outer rings—economy and populace—are not targets of choice. This model, together with the options for attacking the elements of space power, provide a strategic, theoretical base for planning a successful space-superiority campaign.

For the United States, space superiority is not a given now—nor will it be in the future. Civilian and military leadership must take

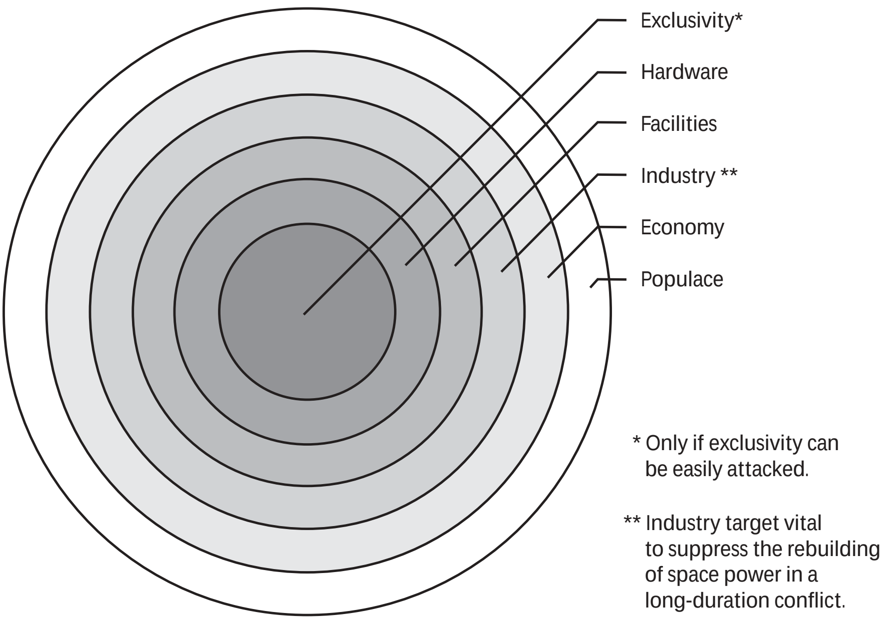


Figure 2. Space-campaign targeting model. Inner rings are the most effective targets. As a space campaign increases in duration, targets further away from the center become more important. (Adapted from Col John A. Warden III, "The Enemy as a System," *Airpower Journal* 9, no. 1 [Spring 1995]: 47.)

steps to ensure that it becomes a national objective of the highest priority. When an adversary seeks to contest that superiority, it will fall to the US military to understand the elements of his space power and the ways of dealing with them. Perhaps the strategies outlined here will assist those who are called to defend our space superiority in the future. □

Notes

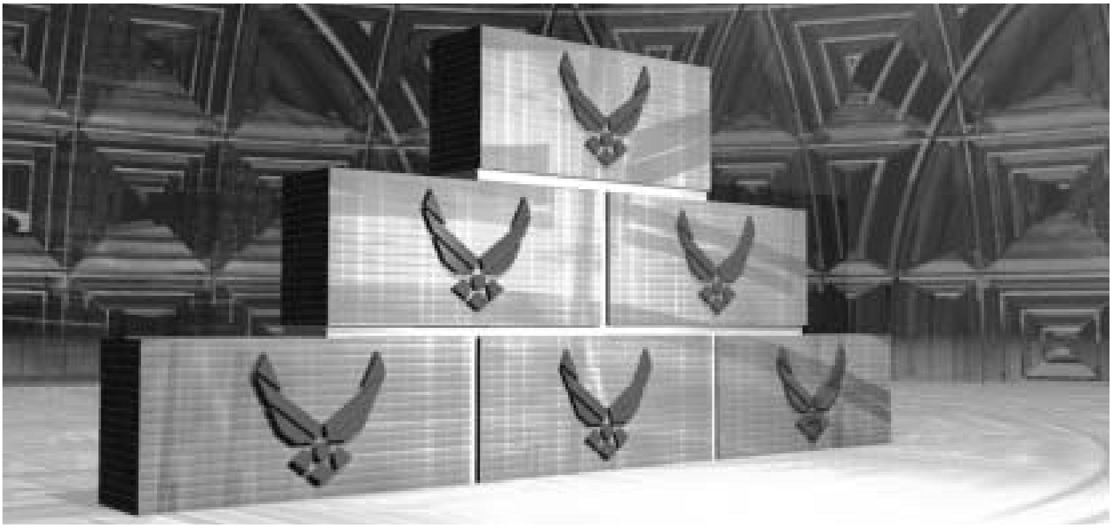
1. James E. Oberg, *Space Power Theory* (Colorado Springs, CO: US Air Force Academy, [1999]).
2. Ibid., 10.
3. Ibid., 44.
4. Ibid. Oberg includes laboratories as part of the technology element, but for simplicity's sake, this article considers them facilities.
5. Ibid.
6. Ibid., 47.
7. Stan Lehman, "Brazil's Space Dreams Are Now in Limbo," *SPACE.com*, 20 October 2003, http://www.space.com/missionlaunches/brazil_future_031020.html.
8. Figure 1's graphical representation has no mathematical basis. It reflects only the author's opinion regarding the relative effectiveness of attacking the elements of space power.
9. I am heavily indebted to Colonel Warden and Maj Jay Billups, 34th Education Squadron, USAFA, for providing me with the inspiration to adapt a similar ring concept to a space campaign.

Proposed Tenets of Space Power

Six Enduring Truths

Maj Samuel L. McNiel, USAF

Editorial Abstract: The Air Force has a policy of using space as the high ground and has funded programs for building responsive launch vehicles and applying force directly from space. At the same time, the service continues to improve its current space capabilities. However, the Air Force has no tenets about how best to employ space power. Major McNiel stipulates that without guiding, enduring truths about space power, there is no doctrinal foundation to build upon, and the Air Force risks building systems and developing tactics, techniques, and procedures that do not ensure the most efficient and effective use of space power. He proposes six such tenets for consideration.



But if we limit our efforts only to applying space technologies to existing modes of war fighting, we have undershot. . . . It is no different than all the ways our armed forces once found for airpower to support ground operations—and do no more.

—Hon. Peter B. Teets
Undersecretary of the Air Force

THE TENETS OF space power presented in this article address the necessity of developing doctrine for conducting military operations in space. Maj M. V. Smith's study *Ten Propositions Regarding Spacepower* concisely articulates the nature of space power by conclusively showing that it is a unique form of military power—not an extension of airpower.[1] If, as Smith demonstrates, space power is unique, then enduring truths must exist regarding the employment of that power. This article proposes six such truths with the hope that the Air Force community will examine, discuss, and incorporate them into our service's doctrine.

Tenets Are Appropriate at This Time

We have heard legitimate discussion about the appropriateness of developing tenets of space power. Because many people believe that space power's primary mission today is force enhancement and further believe that it should integrate as closely as possible with air operations, they argue that the tenets of airpower provide sufficient guidance. However, since the Air Force now has policy and programs calling for space power to do much more than force enhancement, the service needs doctrine to guide the development and employment of space forces. Furthermore, we can now draw on experience in space matters and a wealth of research to form a basis for articulating the tenets of space power in doctrine.

Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, notes that "the application of air and space power is refined by several fundamental guiding truths . . . known as tenets."[2] This article builds upon Smith's propositions, focuses on truths about employment as we now understand them, and suggests their inclusion into doctrine. With these truths as a starting point, as space power matures the tenets of space power will also evolve—just as AFDD 1 says they should.[3]

The idea that we do not have enough experience in space flight to develop space doctrine does not stand up. Mankind's dream to reach into space is almost as old as the dream to fly.[4] Only 13 years after the Wright brothers' first flight, Robert H. Goddard launched the first liquid-fueled rocket—the direct antecedent of modern space-launch vehicles.[5] Dating from the launch of Sputnik in the 1950s, we now have over 46 years of operating experience in space.[6] The National Reconnaissance Office was created in 1960.[7] An Air Force major command has assumed responsibility for space forces for over 21 years.[8] Furthermore, a unified command responsible for war fighting with space forces has existed for over 18 years.[9] The nearly half century of experience includes major utilization of space power in the Vietnam war; the Cold War; Operations Desert Storm, Allied Force, and Enduring Freedom; and now the ongoing Iraqi Freedom. After hundreds of years of thinking about going to space and five decades of operating in space, we obviously have plenty of experience to write tenets about space power. In addition to experience that spans a timeframe longer than that between the Wright brothers' first flight until Chuck Yeager broke the sound barrier, we have witnessed a plethora of academic writing about space power and some doctrine development.[10] Given the lengthy experience base, the extensive number of publications about space power, and the policy and programs for the application of force in, to, and from space, it is not only appropriate but also necessary to codify the tenets of space power in doctrine.

Current Air and Space Doctrine and Policy

National safety would be endangered by an Air Force whose doctrines and techniques are tied solely on the equipment and process of the moment. Present equipment is but a stop in progress, and any Air Force which does not keep its doctrine ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.

—Gen Henry H. "Hap" Arnold

Today's Air Force doctrine claims to articulate the tenets of space power, but this seems the result of an attempt to include space in air operations rather than an honest assessment of space-power doctrine in its own right. Such a situation is problematic because, as Lt Col Peter Hays observes, since few concepts of sea-power theory directly translate to airpower theory and since space is as unique as sea or air, there is no reason to assume that either sea-power or airpower theory should directly translate into space-power theory.[11]

The idea of an *aerospace* force still drives Air Force doctrine, even if the term has fallen out of favor. Colonel Hays and Dr. Karl Mueller point out that "Air Force chief of staff Gen Thomas D. White first used the word *aerospace* in 1958, and the concept that air and space form a seamless operational medium has been the foundational component of Air Force thinking about space ever since."[12]

AFDD 2-2, *Space Operations*, made significant steps towards formulating a mature space doctrine by pointing out that space is a "physical environment—like land, sea, and air."[13] AFDD 1 continues this evolution of doctrine: "Air and space are separate domains requiring exploitation of different sets of physical laws to operate in, but are linked by the effects they can produce together."[14]

Even though current doctrine recognizes the differences between the air and space mediums, it does not explain how the linkage of effects between space and air forces is any greater than that between air and ground forces or space and naval forces. So the idea that space power operates as an extension of airpower seems an underlying assumption.

Also, current Air Force doctrine does not consider tenets of space power apart from the tenets of air and space power as articulated in AFDD 1.[15] If interpreted very generally, those tenets may also have applicability to space power. However, to be useful in guiding future programs; tactics, techniques, and procedures (TTP); and the development of combat theory, they should be restated with further specificity as they apply to space power—if not in AFDD 1, then in some subordinate doctrine document.

The latest revision of AFDD 2-2 not only draws some distinction between the mediums of air and space, but also distinguishes between air and space power: "Airmen, however, should not assume airpower and space power are interchangeable. Applying the operational art of war requires an understanding of the similarities and unique qualities of each."[16] Representing a significant departure from previous Air Force doctrine, AFDD 2-2 goes so far as to rename the joint force air component commander (JFACC) the joint force air and space component commander (JFASCC): "A JFASCC may require a space officer dedicated to carry out the detailed responsibilities associated with the [space forces] coordination role."[17] Central Air Forces used this concept of a senior space officer in Operations Enduring Freedom and Iraqi Freedom, successfully incorporating space into air operations.

AFDD 2-2 explains how to integrate space into air operations but not how to employ space forces as either a supporting or supported military power. It also does not address how synergy between air and space forces makes them suitable for remaining a single component. Synergy exists between all components of a joint force, yet we would not consider placing either land and air forces or sea and land forces under a single component commander. Given that the differences between space and air forces are just as great as—in many ways, even greater than—those between air and ground forces, it is no more appropriate to have space forces commanded by the air commander than to have air forces commanded by the ground commander.

Some people have argued against the push by space-power advocates to change the focus of the Air Force's space-power doctrine from force enhancement towards a more complete force package, including force application. Maj John Grenier comments that "the essence of [offensive counterspace] and [defensive counterspace] has less to do with force application and more to do with supporting, enabling, and enhancing other air and space operations."[18] He, along with others, believes that until the fielding of technology that allows space to apply force, the Air Force should continue to focus on using space power as a force enhancer.

If this same argument were applied to airpower prior to World War II, then the work of the Air Corps Tactical School's strategic-bombing advocates in developing the theory (what was, in effect, doctrine at the time) of high-altitude, precision daylight bombing before the advent of high-performance bombers was completely misguided.[19] They should have waited until after the B-17 and B-24 bombers became operational to develop doctrine about how to use them.[20] Had they done so, the United States might never have had a four-engine heavy bomber capable of bombing Germany or Japan. The fallacy of this "wait for the capability" argument is that without the development of doctrine, there is nothing to guide the requirements for new systems or their TTPs. Technology does not limit the development of space power today; the culprit is the lack of doctrine that results in ill-defined, incomplete space-power requirements.

Major Grenier points out that the high classification of many space systems and the lack of integration of counterspace plans represent substantial obstacles to helping the air-breathing part of the Air Force understand what space brings to the fight. However, he says that those factors are just excuses for the "inability of space operators, space weapons officers, and space experts to tell in-theater aviators what counterspace brings to the fight."[21] Although counterspace is only one portion of space power, if his argument is correct, it is actually doctrine that has failed to articulate what space power contributes to the fight. That failing partially results from the lack of space-power tenets that could serve as building blocks for doctrine on applying space power. Although we have made some progress towards recognizing space power as the equal of airpower, current Air Force doctrine views space power as an extension of airpower, having a primary mission of force enhancement. Disappointingly, many people believe it should stay that way.

Space as the High Ground

In *On Space Warfare: A Space Power Doctrine*, David E. Lupton proposes four schools of thought—actually four doctrinal approaches—regarding military activity in space.[22] Each of the four schools—sanctuary, survivability, control, and high ground—suggests a focus, employment strategy, wartime mission, and preferred organization for space forces.

The United States Air Force is now part of the "space as the high ground" school of thought. It is important to view space power through this frame of reference because then we can clearly see that space forces will become directly engaged in traditional combat—killing targets and receiving hostile fire—adapted for the unique environment of space, along with conducting space power's traditional role in command, control, intelligence, surveillance, and reconnaissance. If that is true, then the need for a solid doctrinal basis for space power becomes imperative. This move to the high-ground school was a significant departure from historical practice, occurring as recently as Desert Storm, when the United States began moving from a sanctuary doctrine towards a survivability doctrine.[23]

The formal beginning of the move to space as the high ground began with publication of US Space Command's *Long-Range Plan*. The plan envisions a robust, fully integrated suite of space and terrestrial capabilities by 2020 that provides dominant battlespace awareness enabling on-demand targeting and engagement of all ballistic and cruise missiles. If so directed by the president and secretary of defense, these assets can also identify, track, and hold at risk designated high-value terrestrial targets.[24]

The report of the Space Commission sees space as the high ground as well:

> Finally, space offers advantages for basing systems intended to affect air, land and sea operations. Many think of space only as a place for passive collection of images or signals or a switchboard that can quickly pass information back and forth over long distances. It is also possible to project power through and from space in response to events anywhere in the world. . . . Having this capability would give the U.S. a much stronger deterrent and, in a conflict, an extraordinary military advantage.[25]

The commission also warns of the need to deal with satellite vulnerability and to negate enemy spacecraft.[26] The fact that the Department of Defense accepted the recommendations of the report indicates that military policy is clearly in line with the high-ground school of thought.

Realization of a high-ground policy continued with Air Force Space Command's applying financial resources to implement parts of a high-ground doctrine. On 1 March 2003, the command launched an $8 million Analysis of Alternatives for Operationally Responsive Spacelift program based on a mission-needs statement validated by the Joint Requirements Oversight Council. Projected for initial operational capability in 2014, the program's payloads include the common aero vehicle, a munition that can be delivered from or through space, along with counterspace payloads.[27] The command also recently launched the Counter Surveillance and Reconnaissance System (CSRS); Counter Communications System (CCS); and Rapid Attack, Identification, Detection, and Reporting System (RAIDRS)—all designed for space combat. Finally, AFDD 1 describes the counterspace function of air and space power: "Counterspace involves those kinetic and nonkinetic operations conducted to attain and maintain a desired degree of space superiority."[28] Taken as a whole, these indicators show that the Air Force is responsible for a high-ground approach to space power, even if its current doctrine still treats space power as an extension of airpower.

Tenets of Space Power

Few concepts from sea power theory translate directly into airpower theory—why should we expect either sea power or airpower theory to apply directly to the distinct medium of space?

—Lt Col Peter Hays
United States Military Space: Into the Twenty-First Century

Although the Air Force has plans and programs for using space to do more than move large amounts of data over long distances and observe terrestrial activities, it has no guiding, fundamental truths about how to employ space power. The following proposed tenets of space power attempt to represent enduring truths about such employment. Although in some cases existent capabilities may be "lead-turning," without doctrine to help shape thinking and requirements, how will the Air Force see to it that programs and TTPs develop in ways that ensure the most efficient and effective use of space power?

Tenet One: Space Operators Should Understand the Advantages and Limitations of Operating in, to, and from Space

Space is a distinct medium, both physically and politically. As is the case with land, sea, and air, one finds both advantages and disadvantages associated with operating in, to, and from this medium. Understanding these benefits and limitations is critical to the proper employment of space forces.

Although some people consider space operations similar to air operations, space is no less unique than any of the other three mediums.[29] Space's physical characteristics make it distinctive.[30] Even though no universally accepted dividing line exists between air and space, we should consider the following: the highest altitude obtainable by an air-breathing aircraft is about 28 miles; somewhere around an altitude of 62 miles, the conditions for aerodynamic flight cease, even if we had some form of sustainable propulsion; and the lowest altitude of a sustainable satellite orbit is 93 miles.[31] Therefore, in between the two mediums lies a region 65 miles wide which cannot sustain flight without tremendous expenditures of fuel.[32]

This boundary layer divides two dissimilar environments. Air is a medium of substance, and space is a vacuum. AFDD 2-2 quotes Gen Thomas White as saying, "There is no division . . . between air and space. Air and Space are an indivisible field of operations."[33] As shown above, General White—as well as anyone else who believes that space power is an indivisible, natural extension of airpower—is wrong.

The existence of a synergy of effects between forces operating in different mediums does not suggest that one of those forces is an extension of the other. For example, one would certainly not claim that a C-17 delivering Army troops or a B-52 dropping bombs on enemy troop positions represents ground power; obviously, airpower operates in a different medium and can do more than support Army troops. Similarly, when space power delivers effects that benefit other forces, it does not act as an extension of those forces; space power operates in a different medium and can do more than perform force-enhancement missions.

The value of knowing the difference between air and space resides in understanding how the different mediums affect operations. Some of the differences concern the operation of vehicles—the dissipation of heat in space or the effect of a change in velocity on the ground trace of a spacecraft's orbit. Others have to do with the effect of phenomena in the medium, such as electromagnetic-energy storms in space.

The most important differences are what the physical distinctions permit. For example, spacecraft travel at very high speed (about 17,500 mph in low Earth orbit), allowing them to cover distances very quickly or have a tremendous amount of kinetic energy. However, there is much distance to traverse in the vastness of space. Changing direction at orbital speeds is very difficult or impossible given the very limited fuel supplies available. Also, orbiting at a very high altitude allows a wide field of view and, at a geosynchronous altitude, a continuous presence over an area. However, electromagnetic energy and physical objects are affected in many ways as they pass through the entire depth of the atmosphere. Clearly, one must have considerable operational expertise to understand how to use the peculiarities of operating in space for military advantage.

In addition to the physical differences, other differences exist. Unlike operations in any other medium, those in space observe no political boundaries. Much like a ship in international waters, spacecraft can go anywhere at any time, but space has no shores to impede travel. The unprotested orbits of the first Sputnik established the right of spacecraft to unimpeded orbits over any country.[34]

Related to the right of unrestricted orbits is the idea of vehicular sovereignty. That is, sovereignty resides with the vehicle—not its position, as is the case with ships operating in international waters. The disadvantage of vehicular sovereignty is that there are no safe sanctuaries in which to seek refuge for refitting or resupplying. Once hostilities towards a spacecraft commence, it cannot (with the exception of transatmospheric vehicles) seek protection by returning to friendly territory.[35]

As with other mediums, treaties limit some activities in space. In very broad terms, we have treaties against placing weapons of mass destruction in orbit or on the moon, establishing military bases on celestial bodies, or interfering with the verification of arms-control treaties from space. Causing long-lasting environmental effects is also prohibited.[36] Most importantly, almost everything is legally permissible except for the few specific cases mentioned above.[37] In this sense, space is like other mediums: some activities therein are subject to agreed-upon political limitations, but such restrictions are unique to space.[38] Given its distinctive physical and political environments, we can reasonably conclude that space is a unique medium and that the need to understand the advantages and limitations of operating in, to, and from that environment is the first tenet of employing space forces.

Tenet Two: Space Power Should Be Prioritized and Coordinated by a Space Professional with a Global Perspective

Because of their global impact, tremendous capabilities, very high cost, difficulties of operating in space, and extreme sensitivity to technology advances, space forces may be the ultimate low-density/high-demand asset, thus requiring prioritization by a commander with a global perspective. The speed and altitude of orbiting spacecraft almost always give space forces the potential to produce effects in multiple theaters, often simultaneously. For example, a communications satellite may provide support to European Command and Central Command at the same time, or an imaging satellite may image targets in multiple theaters within a few minutes of each other. Similarly, terrestrial forces executing space-control missions would almost always produce effects on systems used by an adversary in multiple theaters. The organization of US military forces allows combatant commanders to command all the forces in their theater for good reasons. In the current command plan, the commander of US Strategic Command provides the required global perspective.

The combatant commander with a global perspective should have command authority of all military space forces. Additionally, because the space forces selected to execute any major regional-contingency operations plan will require significant commercial and intelligence augmentation, the combatant commander should be able to obtain and coordinate additional forces from the civil, commercial, and intelligence space sectors.[39]

In this organizational scheme, tactical control and, sometimes, operational control of assets would be allocated to a theater. However, the theater commander would never have control over a satellite—only mission payloads. Either a deployment order or space tasking order would clearly define the time and scope of a theater's control of an asset. This could entail complete dedication of a satellite to a theater (e.g., a communications satellite supporting only that theater) or continuous dedication of a certain number of transponders on a communications satellite. In the case of satellites in low Earth orbit, it could involve certain windows of time for each mission payload, based on when resources would become useful to that theater.

The joint force space commander in a theater should have direct liaison authority with whatever organization controls the payload, and that organization would have a direct supporting relationship with the commander while its payload remained allocated to the theater. This arrangement allows the commander to coordinate as necessary to ensure that the operations crews fully understand what effects the theater needs during the time the resources are allocated. In effect, the satellite- and payload-operations crews would work under that theater commander for the duration of the direct-support relationship. The same arrangement should also hold for terrestrial space forces. Even though tactical control passes to the theater, combatant command should reside with a commander having a global perspective because of that person's ability to regularly create effects in multiple theaters.

The theater commander would have authority to "pull the trigger" on systems that affect only his or her theater. However, for missions that would create effects in multiple theaters, execution authority remains with the space combatant commander. Clearly defining the extent of this authority for each system allocated to a theater, based either in space or terrestrially, becomes extremely important to avoid confusion and maintain unity of both command and effort.

Space forces not allocated to a theater would remain under the operational and tactical control of the space combatant commander, even if they affect a theater. The commander must remain fully aware of theater commanders' needs and requirements to see that space forces respond to these supported commanders. A single space-tasking-order process would transmit orders from the theater commander and combatant commander to the executing forces.

Future systems will present greater challenges to this system but will make it even more important. For example, should a microsatellite "space-predator" constellation launched solely to support a single theater be under theater combatant command? In this scheme, the answer is no because, even though the constellation may be optimized to provide imagery coverage of specific gaps in one theater, it would still have value to other theaters. The same is true of theater missile defense from space. Those missiles may or may not impact in the theater from which they were launched, so a commander with a global perspective should pull the trigger for those systems. Processes such as training and exercising, which ensure close coordination between the theater's space staffs and the space combatant commander's staff, should be adopted to assure that space remains integrated with the theater's campaign plans.

Tenet Three: A Space Professional Should Centrally Control Space Power in a Theater

Being a good operator in any one environment is difficult. Becoming expert on how to employ military instruments at the operational or strategic level of war in any medium takes a career of learning.[40] Space is no different; only professionals with a deep pool of experience in space operations should command space forces.

Because space power in a theater is a very limited resource, a space commander with a theaterwide perspective should control its allocation within that theater. Failing to do so runs the risk of repeating the mistakes made in the early years of airpower—specifically, forces spent inefficiently in "penny packets." A joint force space component commander (JFSCC) should fill this role.

During the research for this article, this tenet and the preceding one received the most criticism of all the tenets proposed; interestingly, they were also the most strongly defended. The most often voiced concern was that space power, for the most part, has done a good job of becoming relevant to the fight through force enhancement—especially force enhancement of the Air Force—and is well integrated into air and space operations centers (AOC). Many leaders who provided comments felt strongly that this situation should not be reversed, thereby avoiding the segregation and marginalization of space power. This tenet in no way suggests reversing any of those advancements in the utilization of space power.

It does not call for the removal of space weapons officers or other space operators from the AOC, although they may need renaming. Their primary function should remain the optimizing of space support for air operations and ensuring that the JFACC has experts who can see to it that airpower uses space to its fullest advantage. Sometimes they also help other services integrate space power into their operations. We should continue to use space power to enhance air, land, and sea power; however, it can do much more.

The JFSCC would have responsibility for planning the employment of all space forces allocated to the theater by the space combatant commander. He or she would do this coequally with the other component commanders and would answer to the joint force commander (JFC) for the employment of space power to accomplish effects for the campaign plan, either as the main effort or in support of that effort, as directed. Currently, no one is tasked to think about how to use joint space forces in this way. As long as the senior space operator remains part of the JFACC's staff, the focus for the employment of space forces will not likely shift away from providing support to air operations.

Today's situation resembles the one during the early days of airpower when Gen Carl Spaatz said in exasperation that soldiers and sailors talked about the years of experience that went into training a surface commander, which made it impossible for outsiders to understand their calling. Yet, they all felt capable of running an air force.[41] Today's equivalent to General Spaatz's comments would have pilots speaking in awe of the complexities of running eight-ship formations and designing strategic air campaigns, insisting that a person can master the required skills only after spending years in the cockpit and commanding air forces. Yet, the Air Force considers pilots almost instantly capable of mastering the intricacies of optimizing space power.[42] That statement does not denigrate pilots; it merely emphasizes the idea that learning how to use space power in a fight—like using any other form of military power—is a complex, difficult process which requires years of learning.

Although it did not consider space power, Joint Publication 3-0, *Doctrine for Joint Operations*, points out that "any dimension of combat power can be dominant—and even decisive—in certain aspects of an operation or phase of campaign and each force can support or be supported by other forces."[43] True, space power would be hard pressed to demonstrate decisive effects today, but such capability is only about 10 years away (see tenet six).

Decisive or not, space forces in a theater should remain under the command of a JFSCC. Fully integrating space power's potential into the JFC's plan while simultaneously providing support to other forces can become a very complex task. It is a mission for a JFSCC—a commander with enough experience in space operations to make those judgments, the staff to employ space power to full advantage, and a coequal position on the JFC's staff.

Tenet Four: Space Power Is Flexible and Versatile

Space power, much like airpower, is flexible and versatile. Although these attributes are not unique to space power, they nevertheless constitute a valid tenet of space power. Flexibility allows space power to shift from one campaign objective to another very quickly.[44] For example, a photoreconnaissance satellite may image targets on two different fronts of a campaign within a very short period of time. Today's legacy satellite systems are not easily reconfigured or maneuvered;[45] however, they can shift between different objectives within the limits of the platform. In this respect, they resemble all weapon systems: they must operate within their limitations.

Future systems may provide much more flexibility in the form of responsive launch systems using common microsatellite buses. Addition of a "space predator"—a small, cheap, expendable satellite with limited life, launched for a single purpose—enhances flexibility, as do on-orbit refueling capabilities. The latter reduce the mission-limiting impact of deciding to maneuver a satellite.[46] Some critics say that space systems will never become cheap enough to make short-lived satellites such as space predators practical. However, considering the fact that a Tomahawk cruise missile costs $600,000 and is completely expended in a single mission, it seems reasonable to spend $1.1 million on microsatellites (not including some of the one-time infrastructure costs) that are launched for a single mission but provide a few months of useful life.[47]

Space power is versatile in that it can prove equally effective at the strategic, operational, and tactical levels of war—sometimes simultaneously. For example, a Defense Support Program satellite has the ability to watch for strategic-missile launches at the same time it looks for much shorter-range theater missiles. The common aero vehicle or space-based lasers planned for the future will attack targets across the spectrum of war and do so nearly simultaneously. Furthermore, counterspace systems will attack space systems used by the enemy to achieve tactical and strategic effects.

Some critics may charge that this tenet dwells on future systems that may never develop into weapon systems. But that is precisely the point of writing tenets now: to help guide the development of those systems—which are actual programs, not just vaporware—and their TTPs. If we do not design flexibility and versatility into systems, they will not have it.

Tenet Five: Space Power Should Capitalize on Its Unique Advantages

As a unique operating environment, space provides advantages that we should capitalize on and limitations that we should minimize. Thus, the best use of space power requires choices about what mission to perform in, to, and from space. Just as it makes sense to conduct some missions from a tank rather than an airplane, it also makes sense to do some things from ships or airplanes instead of space. By the same token, we should use space rather than terrestrial forces for certain missions. As the often-repeated mantra of the space-integration school of thought goes, some airpower missions will migrate to space when it becomes reasonable; however, in addition to such migration, we can probably use space to execute entirely new sets of missions.[48]

What, then, are the most important characteristics of space power? First, the "global" nature of space power allows us to reach any place on Earth in much less time than with any other system. It also gives us access to all locations on Earth simultaneously with relatively few assets, unlike any other form of military power.[49]

Second, because of the persistence of space power, we can not only reach all spots on Earth with great speed and / or do so simultaneously, but also continue to provide access to those areas for as long as required. Together, *global access and global presence are the essence of space power*.[50]

Third, space power is unobtrusive. Its ability to create effects over an area is not always apparent. As launch systems become more responsive and as satellites require less on-orbit checkout prior to becoming operational, this characteristic will become increasingly prominent. One has to deal with fewer political and public-opinion considerations when deploying space-based forces rather than strike aircraft or unmanned aerial vehicles. As stated above, even when the presence of space power is well known, no laws prohibit it from conducting operations over any spot on Earth.

Finally, the vacuum of space allows some weapons to travel very long distances with no disruption by atmospheric conditions. Although this principle applies mostly to space-to-space engagements, it makes space-based missile defense and space-based counterspace missions practical.

These four attributes—*global access, global presence, unobtrusiveness,* and *the vacuum of space*—constitute unique advantages that space-power missions should capitalize on. If a mission does not require any of these attributes, using some other form of military power may be preferable. But if a mission does lend itself to any of these four, we would do well to consider conducting it in, to, or from space.

Space power will never replace airpower, and airpower will never do everything space power can do; the two are unique and complementary. As Maj M. V. Smith observes, "Airpower should continue to provide theater-focused forces; space power provides globally focused forces. The two complement each other as joint partners with land and sea forces."[51]

Tenet Six: Space Power Can Support, Be Supported, or Operate Independently

Like all other forms of military power, space power can support other forces, receive support from other forces, or act independently. Today, space assets are the first forces over a theater and remain there after the termination of conflict. For much of its history, space power has supported terrestrial forces. Both experience and books that forecast how space power will support forces in the future speak for themselves—they don't require repeating here.

One case, however, is worth mentioning. The Air Force's Global Strike Task Force (GSTF) and Global Response Task Force (GRTF) will rely on space for traditional support, but space power may also play a major role in helping "kick down the door" and rapidly striking fleeting targets with precision.[52] With the fielding of the Force Application and Launch from the Continental United States (FALCON) program and other strike systems in the next 10–15 years, force application from space may soon become possible against targets very deep in enemy territory or against very well defended targets. Gen John P. Jumper, the Air Force chief of staff, did not present space-power force application as part of either the GSTF or GRTF, even though he addressed other capabilities not yet available. As soon as space forces demonstrate an attack capability, we should include them as force appliers in these task forces. Space assets can reach the theater faster, strike with greater impunity, and remain over the area longer than other forces. That is not to say they will ever replace the cost-effectiveness or mission flexibility of aircraft—only to point out the existence of some specialized missions the GSTF will execute that can take advantage of the unique characteristics of space forces.

Terrestrial forces can also support space power—most obviously when terrestrial forces strike ground segments of an adversary's space systems.[53] Other less apparent support may include making efforts to mask the actual capabilities of some space forces, designating targets for munitions delivered from space, transporting space forces to forward locations, and providing security for terrestrially based space forces—to name just a few.

Additionally, space and terrestrial forces should be able to create synergistic effects. For example, terrestrial forces may cause an adversary to shift communications from a fiber-optic network to a space-based system. Space forces may then deny use of that system. The two forces working together would thus create an effect that neither could produce independently. Space power should never think of itself as operating in the vacuum of space; it should always be integrated into the JFC's plan to create effects in any way required. Space forces should stay flexible enough and sufficiently integrated into joint war fighting to support other forces, even if doing so is not part of an ideal space mission. In turn, space forces may need assistance from other forces to cover their shortfalls.

Space power can also act independently of terrestrial forces. Only a very specific set of circumstances would allow space power to act decisively today, but as new systems become available, those circumstances will expand. That is not to say we should ever consider space power an answer to every problem or even useful in every circumstance. Like every other form of military power, in the right circumstances when an adversary has a critical vulnerability in a center of gravity that space power can affect, then it can be decisive. Major Smith points out that

> force application from space will take many forms; but it seems likely space-based weapons will fill specific niches, ideal for a handful of missions during certain phases of operations. No claim is made that space power by itself can be decisive in conventional warfare, but it may help set the conditions for victory by friendly forces in certain circumstances. . . . There may be certain forms of limited warfare wherein information gleaned from space or strikes delivered from space may achieve the political and military aims of an operation.[54]

James Oberg argues that, at least for the next several decades, space power alone "is insufficient to control the outcome of terrestrial conflict or ensure the attainment of terrestrial political objectives."[55] He fails to consider that some national centers of gravity might have a vulnerability that space power can affect. As Smith says, such weaknesses would probably occur in limited warfare with limited objectives and only in unique circumstances. The fact that they are uncommon, however, does not place them outside the realm of possibility. For example, space power may succeed in coercing some leaders by holding high-value, well-defended targets at risk from a space-based attack that neither puts a pilot in jeopardy nor requires overflight permissions from any other country.

Even if space power is not decisive, it may still take action independently of other forces—for example, by signaling US intent through temporarily denying some satellite-based services in a country or by striking a high-value, well-defended target. Many other attack options may remain independent of terrestrial forces, even if they produce synergistic effects with those forces to create a decisive outcome. Although we have not yet fielded some of these capabilities, they should become available during the careers of space operators on duty today.

Nothing here suggests that space power will ever prove decisive in all, or even many, situations or will ever replace airpower. However, a JFC's plan should always include space power and its ability to support other forces, be supported by other forces, or act independently to produce whatever effects the commander requires.

Conclusions

This article has depicted space as a unique medium with its own physical and political attributes. That uniqueness gives space its own operational characteristics—with the corresponding advantages and limitations. Therefore, one must concede the existence of enduring truths about how to employ space power.

The Air Force has policies that require space power to create effects in, to, and from space. Air Force Space Command has funded programs to enact that policy. However, Air Force doctrine includes no enduring truths about how to employ space power that could guide the development of space-power vision, operating concepts, programs, or TTPs. To remedy that deficiency, this article has proposed six tenets of space power and has demonstrated the validity of each.

Acceptance of these tenets by Air Force doctrine and, more importantly, by members across the services will put to rest discussion about whether space should be "weaponized." That argument is long since over: space is already being weaponized. The tenets will also help change the paradigm that many people use to view space by allowing them to see it as a coequal component of a joint force capable of supporting other forces, receiving support from other forces, or taking independent action.

To incorporate these tenets would require some organizational changes. Creation of a JFSCC will call for additional expertise in joint war fighting and a knowledge of how space can contribute directly to a JFC's plan. Deciding whether or not to collocate this staff with AOCs will require considerable thought and discussion. The processes, training, and exercising for these space staffs will become critical. We can apply all the lessons learned about incorporating space into air operations to making it part of the joint-force campaign plan, but the process will still take considerable time. The Space Division of the Air Force Weapons School may have to break into multiple sections—one focusing on support to air operations and another on creating direct effects.

Most importantly, adopting these tenets permits the presentation of space power to JFCs as a power in its own right—not just as a supporting function of airpower. Only a few people envisioned how applications of the global positioning system would eventually permeate society. It is just as difficult to predict the many ways space operators will use space power to create effects for the joint campaign plan.

Above all, this article has attempted to capture truths about space power yet to be codified. Regardless of a reader's stance on these specific tenets, few could argue that we do not need to articulate tenets. Space power has emerged as a force able to stand on its own. If the Air Force does not codify enduring truths about how to fight with this power effectively, its maturation will become a long and painful process. The next step requires us to discuss these tenets, modify them if necessary, capture them in doctrine, and apply them throughout the Air Force. □

Notes

1. Maj M. V. Smith, *Ten Propositions Regarding Spacepower*, Fairchild Paper (Maxwell AFB, AL: Air University Press, October 2002).

2. Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, 17 November 2003, 27.

3. Ibid., 3.

4. According to legend, during the Ming Dynasty in ancient China, Wan Hoo attempted to reach space by mounting 47 large rockets on a wicker chair. "Wan Hoo and His Space Vehicle," http://history.msfc.nasa.gov/rocketry/06.html.

5. Goddard's first successful liquid-fueled flight occurred on 16 March 1926, in Auburn, Massachusetts.

6. *Sputnik I*—the first artificial, Earth-orbiting satellite—was launched on 4 October 1957.

7. Lt Col Peter L. Hays et al., "Space Power for a New Millennium: Examining Current U.S. Capabilities and Policies," in *Spacepower for a New Millennium: Space and U.S. National Security*, ed. Peter L. Hays et al. (New York, NY: McGraw-Hill, 2000), 8.

8. Air Force Space Command was created on 1 September 1982.

9. United States Space Command was formed in September 1985.

10. The Wright brothers first flew on 17 December 1903, and Chuck Yeager broke the sound barrier on 14 October 1947, almost 44 years apart.

11. Lt Col Peter L. Hays, *United Sates Military Space into the Twenty-First Century*, INSS Occasional Paper 42 (Maxwell AFB, AL: Air University Press, 2002), pt. 1, 25–26.

12. Lt Col Peter Hays and Dr. Karl Mueller, "Going Boldly—Where? Aerospace Integration, the Space Commission, and the Air Force's Vision for Space," *Aerospace Power Journal* 15, no. 1 (Spring 2001): 36.

13. AFDD 2-2, *Space Operations*, 27 November 2001, 4.

14. AFDD 1, *Air Force Basic Doctrine*, 4.

15. Ibid., 27.

16. AFDD 2-2, *Space Operations*, 8.

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32. Ibid.
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We have the best space and missile operators and acquirers in the world, and we will continue to improve on that standard of excellence.

—Gen Lance W. Lord
Commander, Air Force Space Command

Tenets of Air and Space Power
A Space Perspective

Lt Col Paula Flavell, USAF

SEVEN FUNDAMENTAL TRUTHS set air and space power apart from surface-force capabilities. As noted by Air Force Doctrine Document (AFDD) 2-2, *Space Operations* (27 November 2001), Airmen "should not assume airpower and space power are interchangeable. Applying the operational art of war requires an understanding of the similarities and unique qualities of each" (p. 8). Understanding how space ops fits within these tenets helps Airmen employ the correct mix of forces to achieve desired effects. AFDD 2-2 outlines the following space power tenets:

Tenet One: Centralized Control and Decentralized Execution. This tenet provides the commander "oversight and ability to direct and coordinate component space forces through mission-type orders, while allowing component forces the flexibility to determine how they will employ their resources to achieve the mission" (p. 8). Once established in-theater, the director of space forces (DIRSPACEFOR), who holds the delegated position of space control authority, facilitates coordination between the joint force commander's (JFC) operational/tactical needs and national global/strategic requirements.

Tenet Two: Flexibility and Versatility. These characteristics of space capabilities increase the JFC's options. "Air and space forces [allow exploitation of] mass and maneuver simultaneously to a far greater extent than surface forces" (p. 9). "Space forces, like air forces, operate simultaneously at the strategic, operational, and tactical levels of war, increasing their versatility across the range of military operations" (p. 10). During Operation Iraqi Freedom, US forces conducted preemptive strikes on Iraqi leadership based on real-time satellite feeds to the cockpit, sent warning/execution orders over satellite communication links, and delivered precision-guided munitions (PGM) using global positioning system (GPS) navigation and timing.

Tenet Three: Synergistic Effects. "Space forces enable synergistic effects that increase the capability of our forces" (p. 10). GPS receivers fitted to munitions transform "dumb bombs" into accurate, all-weather weapons. Operation Allied Force highlighted the synergy of these new "space-aided" weapons; the enemy could no longer rely on weather as a sanctuary.

Tenet Four: Persistence. "Space-based forces hold the ultimate high ground, offering the potential for permanent presence over any part of the globe" (p. 11). Satellites placed in specific orbits to produce required effects provide unmatched information collection and dissemination on a constant or recurring basis. Though a critical advantage for US forces, orbit predictability remains subject to passive defensive measures (such as cover, concealment, and deception) or active defensive measures (such as satellite jamming) by adversarial forces.

Tenet Five: Concentration. "Space forces contribute to the military's ability to concentrate effects" (p. 11). Space-based intelligence, surveillance, and reconnaissance, as well as information systems—combined with the effects of PGMs—have exponentially increased the effectiveness of war fighters. Although attacking one target in World War II required multiple bomber sorties, the use of space now enables one aircraft to strike multiple targets. But like other low-density/high-demand assets, space systems require strict attention to asset utilization to ensure the concentration of effects.

Tenet Six: Priority. "The use of space forces must be prioritized because the assets are finite and are exceeded by requirements" (p. 12). We must employ space forces to make the greatest contribution to both national and theater requirements. Space asset prioritization grows increasingly complex as the demand for these critical space capabilities (communications, weather, imagery, etc.) continues to rise.

Tenet Seven: Balance. "Space forces must be balanced against competing priorities" (p. 12). The global nature of space assets, as well as the responsibility for command and control, must reside in a commander who has a global perspective and the means to execute this responsibility. US Strategic Command fills this role for global space forces.

These seven tenets are applicable to *both* air and space. As our understanding of space capabilities evolves and the US military transforms, should we develop separate and distinct tenets for space power? Time will tell . . . as of 1 April 2004, AFDD 2-2 was reopened for revision.

Space Power in Joint Operations

Evolving Concepts

LT COL BRIAN E. FREDRIKSSON, USAF

Editorial Abstract: Space power is now an integral part of joint operations, without which our nation's forces can conduct few operations. Colonel Fredriksson discusses how space can be better integrated into the joint fight using evolving and transformational constructs, including the space coordinating authority, director of space forces, and space air and space operations center (Space AOC).

OPERATION DESERT STORM, dubbed the "first space war," witnessed an unprecedented integration of space into joint operations. An even greater dependence on space was demonstrated in the more recent conflicts in Iraq and Afghanistan. Maj Gen Robert Dickman, USAF, retired, now deputy for military space in the Office of the Undersecretary of the Air Force noted, "We had very few weapon systems then [during Desert Storm] that could not have been used without space assets. It was very different in Operation Iraqi Freedom [OIF]. The way we planned our campaign—things like GPS [global positioning system]—were not a force enhancement but embedded in how we operate our forces. And that was a very fundamental difference."[1]

With the ever-increasing importance of space, the need for an effective command and control (C2) construct to integrate space forces globally—across multiple areas of operations—is increasingly apparent. The secretary of the Air Force, as the Department of Defense's executive agent for space, and the Air Force, as the lead service with the preponderance of space assets, need a comprehensive and fully integrated C2 methodology for space forces—a C2 system that takes into account the unique nature of space power and effectively integrates it into the joint warfighting environment.[2] Quite simply, we need a C2 construct that optimizes and leverages the application of space power at the operational level of employment.

The Nature of Space Power

Space power is "the total strength of a nation's capabilities to conduct and influence activities to, in, through, and from space to achieve its objectives."[3] For our joint forces, this means exercising the military instrument of national power more effectively through the control and exploitation of the medium of space. Space power's contribution to the military instrument has grown dramatically. Nearly all our forces rely on the GPS for precise navigation and timing, and much of the global information grid uses the medium of space to link units around the world. In addition, blue force tracking and space surveillance and reconnaissance have become integral parts of the common operating picture.

Before examining how to integrate space forces in joint operations, one must understand the unique nature of space power. Doctrine for both the joint community and the Air Force recognizes the differences in the mediums.[4] In changing the name of this journal to *Air and Space Power Journal* (from *Aerospace Power Journal*), Gen John Jumper, the Air Force chief of staff, noted that "we will respect the fact that space is its own culture, and that space has different operating principles."[5] This is not just to say that space is different than air, though indeed it is, as the laws of aerodynamics and orbital mechanics attest: the control and exploitation of these mediums also differ. The argument is not that air and space forces need be independent. To the contrary, in many respects they are complementary and synergistic. While Earth-imaging spy satellites can examine great swaths of terra firma, manned and unmanned airbreathing vehicles are arguably more responsive, can loiter at a specific location much longer, and can get much closer to the action.

But space power is indeed unique. Why else would we spend exorbitant sums to go there? The reason is that space power provides distinct advantages, which include global presence, perspective, persistence, responsiveness, and destructive potential.[6] These attributes are a function of the unique character of space power. Understanding the nature of space power is the first step toward effectively integrating space into joint war fighting. So, then, what is unique about space power?

Space Power Is Inherently Global in Nature

First, space power's inherently global nature provides for simultaneous, real-time effects in multiple theaters from numerous operating locations. Satellite constellations like the GPS can provide a pervasive, worldwide utility. Ground stations can downlink or uplink information collected on the other side of the globe nearly instantaneously. For example, a joint tactical ground station for the Defense Support Program can downlink missile warning information for a primary user in the United States Central Command (USCENTCOM) area of responsibility (AOR) and share this information with users in other AORs. Moreover, space systems operate and can provide effects continuously—24 hours a day, 365 days a year—across the entire spectrum of conflict from peace to crisis to war. Unlike expeditionary forces, many space forces operate from "forward deployed" locations all of the time. Some, like navigation support and early warning, provide services even during periods of relative peacefulness.

Global Space Forces Produce Theater Effects

While it is useful to think about the global nature of space power, the application of this power in joint operations occurs at the theater level—these global forces create theater or local effects. Whether it is precision GPS guidance for aircraft and their bombs or imagery for targeting or battle damage assessment, the pointy end of the spear pierces the enemy at the tactical level. For example, although a Joint Direct Attack Munition is guided by a global GPS system, it produces a distinctly local effect. It is for this reason that space power must be integrated with air, land, and sea power at the operational level across the spectrum of conflict from peace to crisis to war.

Space Power Is Joint and Interagency

Space supports war fighters in all mediums—air, land, sea, and cyberspace. Each military service operates space forces of its own, although the Air Force is recognized as the lead service for military space.[7] The Defense Satellite Communications System is an example of service cooperation; the Army operates the payload while the Air Force flies the satellite. In another example, the Navy operates its Fleet Satellite Communications and UHF Follow-On satellites utilizing the Air Force Satellite Control Network. Additionally, space missions are normally fragmented across many agencies—the National Reconnaissance Office, National Aeronautics and Space Administration, National Security Agency, National Geospatial-Intelligence Agency (formerly

NIMA), and Defense Information Systems Agency, to a name a few. These missions, therefore, are particularly dependent on joint and interagency cooperation and coordination. In fact, the military relies on commercial space systems for a majority of its wideband communications and garners much of its imagery through these agencies.[8]

The Rules of Engagement Are Different for Space

Ever since the Eisenhower administration declared that the use of space should be for peaceful purposes, the medium has developed as a global commons.[9] International treaty and national policy have sought to preserve space as a sanctuary for the common use of all nations. Accordingly, there is a common perception that space is a peaceful place. Forces operating in space do so without constraint from political and geographic boundaries. Although treaty bans prohibit the deployment of weapons of mass destruction to space, they do not forbid other weapons or the militarization of space.[10] With a few historical exceptions, space has not been weaponized—however, it has been militarized.[11] Indeed, given the dependence of the American way of war on space, one cannot deny its strategic significance.

Requirements for the Command and Control of Space Forces

Current C2 constructs for air, land, or sea might suffice if space power were not different from other forms of military power. Just as airpower developed its own principles and methods for the application of its unique attributes, so must space power. Airpower evolved from an auxiliary air service under the province of the Army to a fully independent force. As it matured, so did its means to command and control the forces using that medium. From flags and radios to flying command posts and expansive air and space operations centers (AOC), the C2 of air forces has revolutionized its impact on war fighting.

An important step toward realizing space power's potential in joint war fighting is to identify the requirements for C2—a necessary space-power evolution that mirrors that of airpower. Airpower and space power share many characteristics. With their ability to influence large areas and their limited force structure, both are most effective when centrally controlled.

Space power, even more than airpower, is inherently global in nature, and its limited force structure is in high demand. Therefore, unless capabilities exceed requirements, the effective application of space power first requires that a central authority prioritize, apportion, and allocate space forces. That commander should be able to balance global space responsibilities with theater requirements to properly prioritize space assets and provide positive theater effects. For example, during OIF, the USCENTCOM staff made six separate requests for support for Constant Vigilance, the capability to provide dedicated, space-based, infrared monitoring for a particular area of operations. Those requirements had to be prioritized and deconflicted with requests from other AORs and then balanced against the requirements for strategic early warning. However, execution can be centralized or decentralized, depending on the circumstances.

Second, integration of space forces must occur at the strategic, operational, and tactical levels. Although the distinction between strategic, operational, and tactical effects is often blurred—a single tactical attack, for example, can have strategic consequences—these rubrics remain useful for organizing, planning, commanding, and controlling military forces. A statement of a nation's grand strategy reflects its national policies and objectives, which, in turn, dictate its military strategy. Or, in the words of Carl von Clausewitz, "War is not merely an act of policy but a true political instrument, a continuation of political intercourse, carried on with other means."[12] Military strategies dictate operational campaigns, in which forces are mobilized, deployed, and engaged. In those engagements, tactical units employ specific assets to achieve specific objectives, which, in turn, contribute to accomplishment of campaign objectives. In planning terms, national strategy dictates military strategy, military strategy dictates operational objectives, and operational objectives determine tactical tasks. This, applied in a joint construct, is how the US military organizes, trains, plans, and fights. And we must integrate space power accordingly.

Third, space power must be integrated into the joint C2 structures. Joint forces are organized to fight in joint task forces (JTF) under the command of a joint force commander (JFC). Joint operations doctrine states that the JTF can be comprised of both service components (Army, Air Force, Marine, and Navy) and joint functional components for air, land, maritime, and special operations (joint force air component commander [JFACC], joint force land component commander [JFLCC], joint force maritime component commander [JFMCC], and joint force special operations component commander [JFSOCC]) (fig. 1).[13] All Air Force air and space forces are organized under the authority of commander, Air Force forces (COMAFFOR). Air Force doctrine also recommends that the COMAFFOR serve as the JFACC in most cases.[14]

Finally, as stated earlier, the employment of military force occurs at the operational level. The Air Force supplies the preponderance of air and space power forces and the capability to exercise C2. Generally, the Air Force employs theater forces through air and space expeditionary task forces with an AOC as the C2 element.[15] The Air Force relies on this construct for the integration of air, space, and information power. Integration of air, space, and information operations is certainly necessary. For too long, stovepiped organizations hampered effective integration of these different but synergistic functions.

Organizations for Space Forces

United States Strategic Command (USSTRATCOM) is the organization responsible for global space operations. On 30 July 2002, President George W. Bush signed a new Unified Command Plan directing the merging of US Space Command with USSTRATCOM and designating it as the combatant command for space, effective 1 October 2002.[16] As such, USSTRATCOM is responsible for executing space operations to provide effects to theater commanders worldwide and for conducting continuous space services that support global missions. USSTRATCOM can be both *supporting*, as in the case of support to a regional combatant commander, and *supported*, as in the case of the space-superiority mission.

Air Force Space Command (AFSPC) is the force provider and currently the operational component to USSTRATCOM for Air Force space forces. Fourteenth Air Force exercises

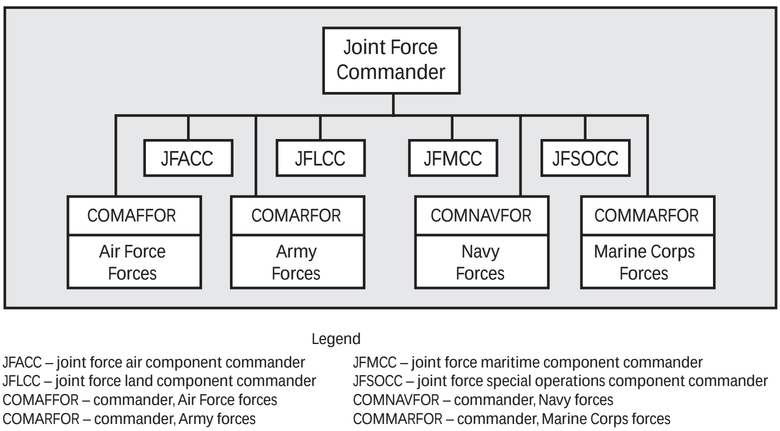


Figure 1. A joint task force organization with functional and service component commanders, representing the Air Force's preferred joint force organization. (Reprinted from Air Force Doctrine Document 1, *Air Force Basic Doctrine*, 17 November 2003, fig. 5.2, 65.)

operational C2 of Air Force and attached forces through the Fourteenth Air Force AOC on behalf of AFSPC and for USSTRATCOM. At the time of this writing, discussions were under way on how to combine all of the forces that the Air Force provides to USSTRATCOM—intercontinental ballistic missiles; space forces; information operations; intelligence, surveillance, and reconnaissance (ISR); and global strike—into a single component, which will be called Air Forces Strategic Command (AFSTRAT).[17] The details of this arrangement are relevant to the employment of space forces; the general principles prescribed in this article are valid regardless.

Current Constructs for Integrating Space into Theater Operations

Based on the complexity and scope of operations, the JFC can either retain authority or designate a component commander to coordinate and integrate space operations. The JFC considers (among other things) the mission, nature, and duration of the operation; preponderance of space-force capabilities; and the C2 capabilities (including reachback) in selecting the appropriate option. Joint and Air Force doctrines provide guidance for how the JFC coordinates and integrates space forces.

Space Coordinating Authority

Joint Publication (JP) 3-14, *Joint Doctrine for Space Operations*, establishes the concept of a coordinating authority for space, stating that "a supported JFC normally designates a single authority to coordinate joint theater space operations and integrate space capabilities. The space authority will coordinate space operations, integrate space capabilities, and have primary responsibility for in-theater joint space operations planning."[18] This authority, dubbed the *space coordinating authority* (SCA), has been tested in practice. For the first time in OIF, the JFC designated the JFACC to function also as the joint space coordinating authority, and a senior space officer was deployed to assist the JFACC in that role.[19] Table 1 provides a more complete list of that person's responsibilities.

Air Force doctrine provides specific guidance regarding the C2 of space forces. Air Force Doctrine Document (AFDD) 2-2 states that the JFACC should be the *coordinating authority* for space and that this officer "may require a space officer dedicated to carry out the detailed responsibilities associated with the coordination role."[20]

Senior Space Officer

In recent operations, a senior space officer (SSO) has served as the space advisor to the COMAFFOR, JFACC, or other JFC. In Operation Enduring Freedom (OEF), for example, senior Air Force officers deployed to the theater to support the COMAFFOR and the JFACC.[21] Typically, a senior colonel or brigadier general with current space experience serves as the SSO and becomes the senior space expert and advisor to the COMMAFFOR, combined force air component commander

Table 1. Responsibilities of the space coordinating authority

- Deconflict and/or prioritize military space requirements for the JTF
- Recommend appropriate command relationships for space to the JFC
- Help facilitate space-target nomination
- Maintain space situational awareness for the JFC
- Request space inputs from the Joint Staff and components during planning
- Ensure optimum interoperability of space assets with coalition forces
- Recommend priorities for military space requirements to the JFC

Adapted from Air Force Doctrine Document 2-2, *Space Operations*, 27 November 2001, fig. 2.3, 32.

(CFACC), or JFACC. Responsibilities of the SSO are listed in table 2.

The "Space AOC"

The Fourteenth Air Force AOC, often referred to as the "Space AOC," at Vandenberg AFB, California, is the central C2 node for Air Force and attached space forces. The Space AOC conducts space-strategy development and combat planning; it also directs space operations across the spectrum of conflict. In concert with the planning efforts of USSTRATCOM and service components, it provides theater AOCs reachback capability as it simultaneously allocates, prioritizes, and develops the Air Force space operations plans to exploit the full range of space-combat capabilities in multiple theaters. These capabilities include gaining and maintaining space superiority, enabling and enhancing terrestrial operations, providing assured access and operations in space, and, eventually, delivering conventional strike capabilities from and through space. It is also the primary node for collecting, integrating, and fusing numerous information streams into a single integrated space picture as part of the overall common operating picture. The Space AOC operates 24 hours a day, 365 days a year, planning, synchronizing, tasking, integrating, and assessing execution of assigned and attached space forces.

The Space AOC provides and integrates theater space effects with Falconer AOCs through the air tasking order (ATO) process. The "Falconer AOC" designation is applied to those five AOCs that have fully integrated space into their operations centers. During this process, the JFACC determines the objectives, targets, timing, and tempo of effects for the JFC. Embedded space personnel in the Falconer AOC divisions ensure that space activities and effects are integrated into ATO development and execution. The ATO process, in turn, drives the development of the space tasking order (STO), which is developed in parallel at the Space AOC. The STO tasks the right combination of operational in-place and deployed space units to synchronize space operations and provide the effects that theater and global commanders require (fig. 2).[22]

Support Teams

Service components and supporting commands provide support teams to assist theater commanders with integrating space in-theater. USSTRATCOM has created SSTs that are prepared to support theater commanders with integrated space, information operations, computer network operations, missile defense,

Table 2. Responsibilities of the senior space officer

- Provide senior space perspective to the COMAFFOR or JFACC, including guidance development, target selection, force enhancement to terrestrial operations, and special technical operations activities
- Facilitate AFSPC, USSTRATCOM, and national support to the COMAFFOR or JFACC
- Provide assistance to the COMAFFOR or JFACC in establishing military space requirements
- Assist the AOC or the staff of the joint air operations center in developing and staffing space-related operational requirements and policy matters
- Coordinate with liaisons in other components to ensure responsive space support
- Recommend appropriate command relationships for space to the COMAFFOR or JFACC
- Coordinate with strategic support teams on behalf of the COMAFFOR or JFACC when the JFC retains SCA
- Coordinate the space effects for the theater commander
- Direct strategic support teams (SST) on behalf of the COMAFFOR or JFACC when SCA is designated to the COMAFFOR or JFACC, respectively

Adapted from briefing, subject: Senior Space Officer, Doctrine Summit 4, Air Force Doctrine Center, Maxwell AFB, AL, 17–18 November 2003.

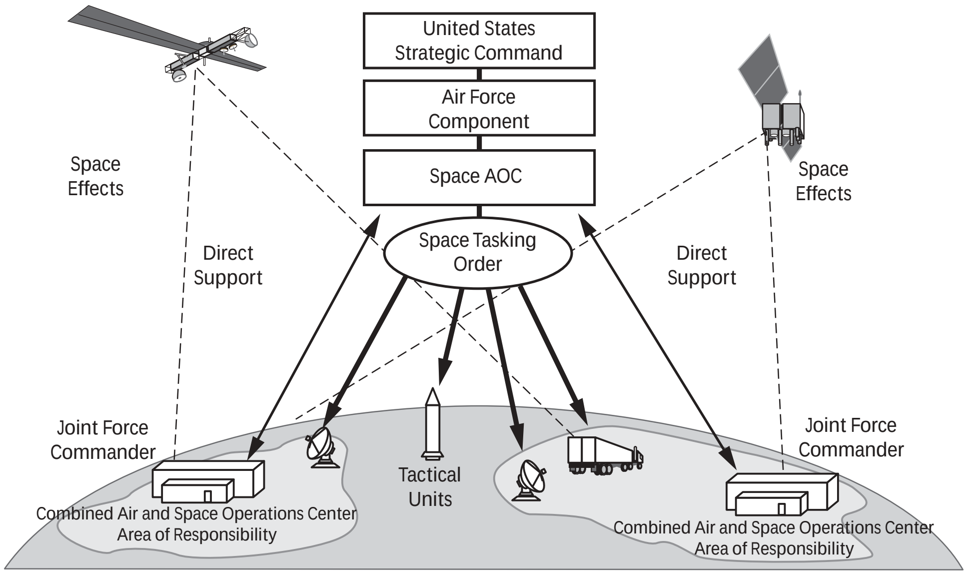


Figure 2. Integrating global and theater space effects

and global strike capabilities. Several SSTs have been formed, each with a distinct theater focus. When needed, the SSTs will deploy to the theater to support the JFC. The teams will include space personnel that will work closely with the SSOs, space operations officers assigned to the theater, and reachback organizations such as the Space AOC.

Looking Forward: Director of Space Forces

Space forces resemble mobility forces in that they have both global and theater responsibilities. Senior officers attending a recent doctrine summit recognized this similarity and recommended that a *director of space forces* (DIRSPACEFOR) concept, modeled after the *director of mobility forces* (DIRMOBFOR), be examined as a C2 option for in-theater space forces (fig. 3).[23] This recommendation became a summit action item which led the Air Force Doctrine Center and AFSPC to convene a "red team" whose purpose would be to examine that concept. That team recommended adopting a DIRSPACEFOR construct based on a modified DIRMOBFOR model, which was subsequently approved at Corona South, the Air Force's periodic senior-leadership conference.[24]

Essentially, the team recommended evolving the SSO construct to a more defined role as a DIRSPACEFOR. The DIRSPACEFOR would serve primarily as an advisor to the COMMAFFOR/JFACC as part of this commander's special staff. The DIRSPACEFOR would coordinate and integrate space support for the Air Force under the COMMAFFOR or for the JFC under the JFACC. The DIRSPACEFOR's responsibilities (table 3) would closely mirror those of the SSO, which he or she would replace. The DIRSPACEFOR concept builds on both the DIRMOBFOR and the SSO positions. This individual would serve as a senior advisor to the air component commander and help ensure space support's unity of effort. It is a position with wide horizontal, vertical, and reachback responsibility but with only limited authority under the current proposal. The DIRSPACEFOR would have to rely on his or her moral authority and skills of coordination to get the job done. Unlike the DIRMOBFOR, the DIRSPACEFOR would not have a dedicated space division in the AOC

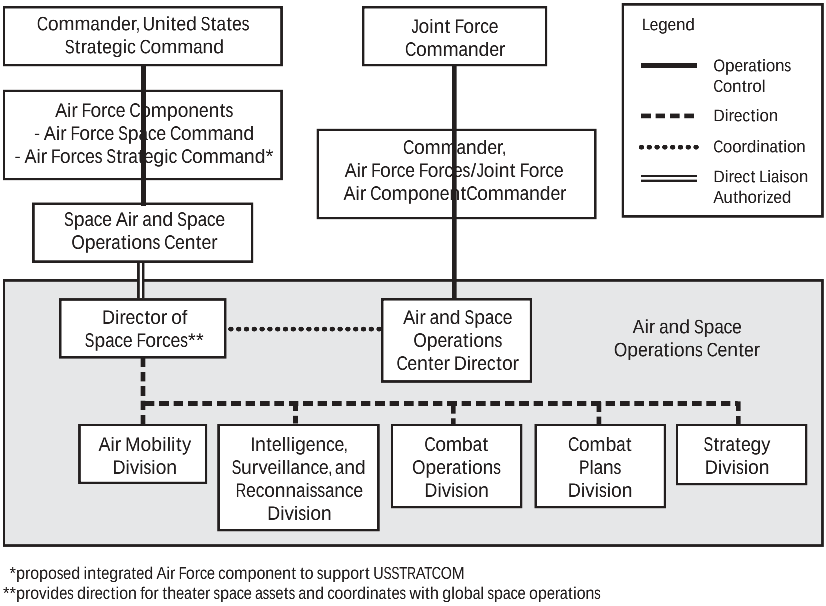


Figure 3. Director of space forces concept. (*Adapted from* Headquarters Air Force Space Command, Directorate of Plans and Programs [HQ AFSPC/XPXS] briefing, subject: DIRSPACEFOR, 1 February 2004.)

but would rely on a small staff, personnel embedded in all AOC divisions, and reachback capabilities to execute his or her responsibilities. Whereas a DIRSPACEFOR would provide coordination at the JFACC and AOC levels, it is essential to address integration at the JFC level if SCA is retained, or to determine the coordination of joint space forces if the SCA is delegated to another joint force component commander—say, the JFMCC. Although neither optimal nor complete, the DIRSPACEFOR model for integrating space power into joint operations is a useful evolutionary step toward a more robust C2 construct for theater space forces. In fact, the construct was successfully employed during Austere Challenge 04, United States Air Forces in Europe's annual exercise in March 2004.

Table 3. Responsibilities of the director of space forces

- Recommend appropriate command relationships for space for the COMAFFOR/JFACC
- Assist in establishing and prioritizing military space requirements and policy
- Provide senior space perspective for the development of strategy guidance, target selection, and the employment of space forces
- Direct and monitor, on behalf of the COMAFFOR/JFACC, assigned and attached space forces and capabilities, including space-related special technical operations
- Facilitate and coordinate AFSPC, USSTRATCOM, service, and agency support
- Coordinate horizontal reachback activities with the Space AOC, SSTs, and liaisons
- Execute and direct day-to-day SCA responsibilities on behalf of the COMAFFOR/JFACC
- Act as the COMAFFOR'S/JFACC'S representative to the SCA if authority resides with another component
- Perform other duties as assigned

Adapted from Air Force Doctrine Document 2-2.1, "Counterspace Operations," draft, 12 February 2004, 21–22.

Recommendations for Transformation

The Air Force is on an evolutionary path toward developing a C2 mechanism that will most effectively integrate space into joint war fighting. The processes in place today are a vast improvement over those of the past. Still, we can do better. The following recommendations are offered to maximize space power's contributions to joint war fighting.

The in-theater SSO or DIRSPACEFOR should be empowered with a robust reachback capability. The Space AOC function, under AFSTRAT or another component of USSTRATCOM, is that capability. The Space AOC must provide an automated, machine-to-machine-correlated, single, integrated space picture as part of the family of common operating pictures to commanders at all echelons. Regardless of the evolution of in-theater space C2, this decision-making capability will provide centralized and effective C2 of our space power.

An alternative C2 approach would empower the theater AOCs with an ability to plan, task, and execute inherently global space forces. That approach, however, has several drawbacks. First, although some space forces are deployable and could, in theory, be fully dedicated to a single JFC, breaking our space forces into penny packets is not an efficient way to allocate these scarce resources.[25] Second, resource limitations prevent duplicating the planning and tasking functions for each AOR, especially in an era when the Air Force is seeking to reduce the forward footprint of its AOCs. Finally, with such a modus operandi, space units would field a multitude of requests for effects—sometimes conflicting—from multiple areas of operation. The lack of a central, operational-level adjudication and tasking authority would result in a splintered chain of command for these tactical units.

Rather, the Air Force should integrate joint space capabilities at the operational level of conflict. As the lead service for space and the one with the preponderance of its capabilities and the ability to command and control through the Space AOC, the Air Force is uniquely postured to assume this role. However, as long as the presentation of space effects remains fragmented across multiple agencies and services, the United States will fail to realize space power's full effectiveness or achieve its full potential.

A small space coordinating element (SCE), with perhaps 10 personnel, would enhance the integration of space within in-theater Falconer AOCs. It would include specialists in the various space-combat capabilities: navigation, warfare, missile warning, space control, surveillance, and targeting. In addition to giving the DIRSPACEFOR or SSO a dedicated and robust staff, an SCE would also provide additional resources for horizontal and vertical coordination with the JFC and other components. In contrast, the first responsibility of space personnel who are embedded in the AOC's other divisions is that division's respective portion of the ATO process—strategy, combat plans, combat operations—rather than providing dedicated space oversight and expertise. The perception of *stovepiping* space is chief among the arguments against an SCE, as is the desire to limit the AOC's footprint. However, a relatively small staff reliant on the reachback capability resident in the Space AOC would be a minimal addition to the AOC staffing and considerably less than that of the AOC's mobility and ISR divisions. The SCE would not serve as a stand-alone planning and tasking organization—the Space AOC should do that—but would provide a staff with specialized space expertise for the DIRSPACEFOR or SSO.

Eventually, space forces will do more than transmit information in support of air, land, and sea forces. Countersatellite operations and kinetic-kill capabilities are under development. Additional capabilities that can be tasked on platforms like space-based radar, space-based infrared systems, and GPS will further exacerbate the need for C2 of space forces. As these capabilities mature, the need for a dedicated joint force component commander for space will increase.

A single joint force space component commander (JFSCC) could also serve as global space coordinating authority (GSCA) for USSTRATCOM, the global combatant commander. Accordingly, joint doctrine should designate a GSCA as an inherent responsibility of the commander of US Strategic Command (CDRUSSTRATCOM).[26] As the combatant commander responsible for global space operations, the CDRUSSTRATCOM would delegate GSCA to USSTRATCOM's functional component for space, be it AFSTRAT, Fourteenth Air Force, a JTF for space, or another organization. The JFSCC should exercise operational control over the resources of all the services and government agencies charged with providing space support to the war fighter.[27] This will provide a single point of contact for JFCs and unity of command for space forces supporting them.[28]

Conclusion

The Air Force is the right organization to integrate space effects in joint war fighting. It provides the preponderance of military space capabilities and the ability to command and control them. JFCs should delegate SCA to the JFACC or COMAFFOR to provide air and space power to the joint fight. The JFACC, through the SSO or DIRSPACEFOR, would exercise SCA, coordinating space effects for all functional component commanders in the AOR. The Falconer AOC ensures that space effects are integrated and synchronized with the JFC's campaign plan through the ATO process. This process, in turn, provides the guidance for the one global STO, which prioritizes and integrates all theaters' requests for space support. The commander of USSTRATCOM and the combatant commander for space delegate the responsibility for providing space effects to his or her Air Force component, which exercises this responsibility through the Space AOC, which in turn provides the requisite centralized C2 function for global and theater space operations. This approach ensures that a single commander commands space forces at the operational level of war. Just as an Airman provides airpower to the joint fight, so should a *space Airman* provide space power. □

Notes

1. Quoted in J. R. Wilson, "The Ultimate High Ground," *Armed Forces Journal*, January 2004, 28.

2. DOD Directive (DODD) 5101.2, *DOD Executive Agent for Space*, 3 June 2003, http://www.dtic.mil/whs/directives/corres/pdf/d51012_060303/d51012p.pdf.

3. Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 12 April 2001, updated through 23 March 2004, 489, http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf.

4. JP 3-14, *Joint Doctrine for Space Operations*, 9 August 2002, on page I-2, identifies characteristics of space that include no geographical boundaries, motion not affected by the earth's surface, and unique (physical) characteristics; other special characteristics include global access, persistence, predictive orbits, and unique legal considerations. Older Air Force doctrine documents (Air Force Doctrine Document [AFDD] 2-8, *Command and Control*, 16 February 2001, for example) still use the term *aerospace* and with it the implication of a seamless operating medium. However, the current doctrinal idiom refers to the terms *air* and *space* as separate and unique mediums.

5. Gen John P. Jumper, "A Word from the Chief: Why 'Air and Space'?" *Air and Space Power Journal* 16, no. 3 (Fall 2002): 5, http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/fal02/jumper.html.

6. Brian E. Fredriksson, "Globalness: Toward a Space Power Theory" (master's thesis, School of Advanced Air and Space Studies, Maxwell AFB, AL, June 2003), 37–45. Other sources and authors that have also characterized the attributes of space and space power include *SPACECAST 2020 Executive Summary* (Maxwell AFB, AL: Air University, June 1994); Christian C. Daehnick, "Blueprints for the Future: Comparing National Security Space Architectures," in *Beyond the Paths of Heaven: The Emergence of Space Power Thought*, ed. Col Bruce M. DeBlois (Maxwell AFB, AL: Air University Press, September 1999); Bob Preston et al., *Space Weapons: Earth Wars*, RAND Report MR01209 (Santa Monica, CA: RAND, 2002); Bruce M. DeBlois, "Ascendant Realms: Characteristics of Airpower and Space Power," in *The Paths of Heaven: The Evolution of Airpower Theory*, ed. Col Phillip Meilinger (Maxwell AFB, AL: Air University Press, August 1997); Gregory Billman, "The Inherent Limitations of Space Power: Fact or Fiction?" in *Beyond the Paths of Heaven*; and Colin S. Gray, *Modern Strategy* (Oxford: Oxford University Press, 1999).

7. *Report of the Commission to Assess United States National Security Space Management and Organization, Commission to Assess United States National Security Space Management and Organization*, Pursuant to Public Law 106-65 (Washington, DC: The [Space] Commission, 11 January 2001), chap. 4, 56–57, http://www.space.gov/docs/fullreport.pdf; and DODD 5101.2, *DOD Executive Agent for Space*.

8. Commercial systems provided approximately 60 percent of satellite communications in OEF and 80 percent in OIF. See "US Government Market Opportunity for Commercial Satellite Operators: For Today or Here to Stay?"

Futron Corporation Report (Bethesda, MD: Futron Corporation, 29 April 2003), http://www.futron.com/pdf/governmentwhitepaper.pdf; and Robert K. Ackerman, "Military Users Boost Commercial Imagery," *SIGNAL Magazine*, December 2003, http://www.us.net/signal/Archive/Dec03/Archive-dec03.html.

9. Col David W. Ziegler provides a thorough review of the "sanctuary perspective" in "Safe Heavens: Military Strategy and Space Sanctuary," in *Beyond the Paths of Heaven*.

10. See P. K. Menon, *The United Nations' Efforts to Outlaw the Arms Race in Outer Space: A Brief History with Key Documents* (Lewiston, NY: Edwin Mellen Press, 1988); Peter L. Hays, *United States Military Space: Into the Twenty-First Century* (Maxwell AFB, AL: Air University Press, September 2002); and Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London and Portland, OR: Frank Cass Publishers, 2002), 113–44, for excellent surveys of space-related arms-control treaties and regulations. The most prominent space treaty is the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," 27 January 1967, and usually referenced as simply the "Outer Space Treaty" (OST). Contrary to popular perception, the treaty regime, to include the OST, does not prohibit weapons other than "weapons of mass destruction" in space. Article IV of the OST declares, "States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner." See http://www.oosa.unvienna.org/SpaceLaw/outersptxt.htm. Two additional treaties include (1) the now defunct Anti-Ballistic Missile (ABM) Treaty of 1972, which limited the development, testing, or deployment of land, air, sea or space-based ABM systems or components (http://www.fas.org/nuke/control/abmt); and (2) the Agreement on Activities of States on the Moon and Other Celestial Bodies (United Nations General Assembly Resolution 34/68, 1979), which declared that the moon be developed "exclusively for peaceful purposes," and prohibits nuclear weapons, weapons of mass destruction, and military facilities or maneuvers on or in orbit around the moon. See http://www.unog.ch/frames/disarm/distreat/moon.htm.

11. Although weapons do not orbit in space, capabilities exist that can threaten space assets. Examples of those capabilities include nuclear weapons launched by ballistic missiles; ground-based lasers; electronic countermeasures, like GPS jammers; ABM systems, like the Russian Galosh deployed around Moscow; the old SL-11-launched co-orbital ASAT, which may still be operational; as well as the American space shuttle. Paul B. Stares, *Space and National Security* (Washington, DC: Brookings Institute, 1987), 111–13, provides a dated but still relevant discussion.

12. Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 87.

13. JP 3-0, *Doctrine for Joint Operations*, 10 September 2001.

14. AFDD 1, *Air Force Basic Doctrine*, 17 November 2003, 78, https://www.doctrine.af.mil/Main.asp.

15. Ibid., 79.

16. Unified Command Plan, change 1, 30 July 2002; and "US Strategic Command History," USSTRATCOM Fact File, http://www.stratcom.mil/factsheetshtml/history.htm.

17. Gen John P. Jumper, USAF chief of staff, to Adm James O. Ellis, Jr., letter, 23 February 2004, http://www.55srwa.org/0403/04-03011454.html.

18. JP 3-14, *Joint Doctrine for Space Operations*, 9 August 2002, http://jdeis.cornerstoneindustry.com/servlet/page?_dad=portal30&_schema=PORTAL30&7865629.58.211_J7_JDISBROWSEPUBS_CLS_7865629.next_page=browsePubs/tblContents.jsp&_pageid=56&d=3&pubId=43&pubNum=null&bol=1&searchType=0&pubOne=0.

19. CFC FRAGORD 09-004, 180548Z Mar 03, as cited in Maj Mark Main, "An Examination of Space Coordinating Authority and Command Relationships for Space Forces" (unpublished paper, Fourteenth Air Force Weapons and Tactics Division, Vandenberg AFB, CA). On 19 March 2003, Gen Tommy Franks, commander, USCENTCOM, invoked his authority and issued an order that designated the *combined force air component commander* (CFACC) as the *space coordinating authority* for OIF with responsibility to "coordinate all joint theater space operations and integrate space capabilities."

20. AFDD 2-2, *Space Operations*, 27 November 2001, 24.

21. Brig Gen Richard Webber served as the deputy JFACC for space at the combined air operations center at Al Udeid Air Base, Qatar. Brig Gen William Shelton served as the chief, space and information operations element at Headquarters USCENTCOM at Tyndall AFB, FL.

22. "Doctrine Watch no. 21: Space Tasking Order," 12 March 2004, https://www.doctrine.af.mil/Main.asp.

23. Doctrine Summit 4, Air Force Doctrine Center, Maxwell AFB, AL, 17–18 November 2003.

24. Maj Scott Patton, Headquarters Air Force Space Command, Directorate of Plans, point paper, subject: Director of Space Forces, 9 January 2004; and Headquarters Air Force Space Command, Directorate of Plans, briefing, subject: DIRSPACEFOR, 1 February 2004.

25. Similar arguments were made by early airpower advocates, including Mitchell and Trenchard, to justify separate air services—and subsequently in debates about close air support for the Army.

26. Maj Mark Main, deputy to the SSO during OIF, "An Examination of Space Coordinating Authority (SCA) and Command Relationships for Space Forces" (unpublished paper, Fourteenth Air Force Weapons and Tactics Division, n.d.).

27. Myron Hura et al., *Integration of Air and Space: Focus on Command and Control*, RAND Project Air Force Report MR-1521-AF (Santa Monica, CA: RAND, 2002), xiii. These authors observed that "only a fraction of space systems that support military operations are commanded and controlled by the military."

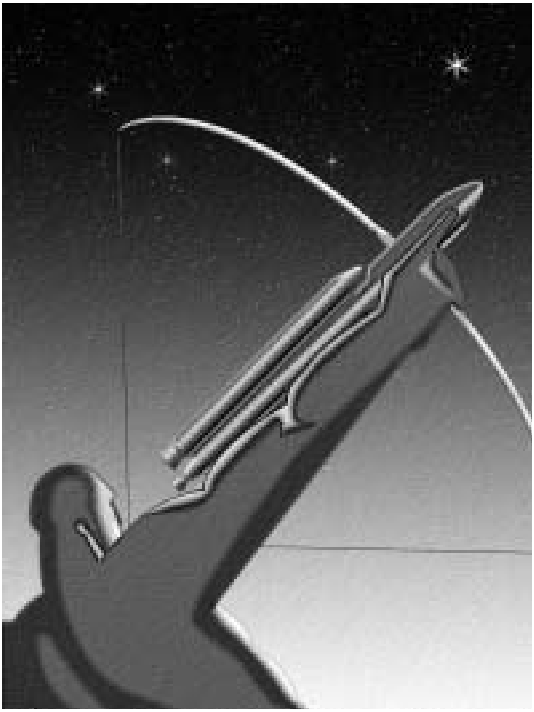
28. Benjamin Lambeth, *Mastering the Ultimate High Ground: Next Steps in the Military Uses of Space*, RAND Project Air Force Report MR-1649-AF (Santa Monica, CA: RAND, 2003), 158.

Space-Operations Doctrine

The Way Ahead

Maj Todd C. Shull, USAF

Editorial Abstract: To continue the asymmetric advantage that our "high-demand, low-density" space systems provide US war fighters, we must develop efficient, smart guidance for their employment. After evaluating current space doctrine in light of lessons learned in Operations Enduring Freedom and Iraqi Freedom, Major Shull offers suggestions to enhance and expand the current body of space-operations doctrine.



THE RECENT CONFLICTS in Afghanistan and Iraq demonstrated the asymmetric advantage provided by space systems and their significant contribution to the most flexible, precise, and lethal military the world has ever seen. To ensure that our "high-demand, low-density" space systems continue to provide an asymmetric advantage for us, we must employ them as efficiently and smartly as possible to meet war-fighter needs. The foundation for such employment lies in well-developed, comprehensive space-operations doctrine.

In every major conflict since Operation Desert Storm, space capabilities have provided increasing levels of support to combat operations. Command relationships continue to evolve to maximize theater commanders' ability to integrate space effects into their campaigns. Similarly, space-operations doctrine has grown and matured by continually capturing the lessons learned and best practices discovered in each successive conflict. We are now at a point where we can evaluate our current space doctrine in light of the lessons learned in Operations Enduring Freedom and Iraqi Freedom. How should our space-operations doctrine build on these lessons? What, if any, new such doctrine is necessary? This article examines these questions and proposes a course for enhancing and expanding the body of space-operations doctrine. However, before we proceed, a short discussion on existing operational-level space doctrine is appropriate.

Current Space-Operations Doctrine

The Air Force and the joint community have codified operational-level space-operations doctrine in Air Force Doctrine Document (AFDD) 2-2, *Space Operations*, and Joint Publication (JP) 3-14, *Joint Doctrine for Space Operations*, respectively. (A rather dated Army document—Field Manual 100-18, *Space Support to*

Army Operations, 20 July 1995—is not discussed here.) AFDD 2-2 and JP 3-14 are similar in both scope and content.

Current Air Force operational-level space doctrine resides in AFDD 2-2, last revised in 2001.[1] This document provides significant detail in the areas of command and control (C^2) of space forces as well as the planning and execution of space operations. The first chapter serves as a primer on the contribution of space operations to air and space power, examining the relevance and contribution of these operations to the principles of war, tenets of air and space power, Air Force functions, and Air Force distinctive capabilities (formerly known as core competencies). The second chapter offers guidance for the C^2 of both global and theater space forces. It introduces the construct of a joint force air and space component commander (JFASCC) although this entity has not found acceptance with the other military services. The third and fourth chapters discuss planning and execution of space operations, respectively. The planning chapter covers campaign planning and highlights development of the Air Force Space Operations Plan. The execution chapter provides guidance for conducting both global and theater space operations. Of particular note are sections that cover the integration of civil, commercial, and foreign space assets into operations and development of the space tasking order. The final chapter addresses training and education for space operations in the context of developing space warriors. AFDD 2-2 provides a solid doctrinal foundation for Air Force space operations, but as we will see later, it needs updating to incorporate the lessons of Enduring Freedom and Iraqi Freedom.

JP 3-14, which treats joint space-operations doctrine, finally saw publication in 2002 after undergoing development for well over 10 years.[2] Even though a fairly recent document, it needed revision as soon as it appeared due to the merger of US Strategic Command (USSTRATCOM) and US Space Command (USSPACECOM). Divided into five chapters and eight appendices, JP 3-14 includes material similar to that of its service counterparts. The first chapter provides an overview of military space operations and the operational considerations for space. The second, which covers space organizations and their responsibilities, requires significant revision because of the creation of the new USSTRATCOM. The third chapter offers guidance for the C^2 of space forces, focusing primarily on global space forces but including limited guidance on command and support relationships for theater space operations. The fourth discusses military space operations in the context of the principles of war and the four mission areas for space (control, force enhancement, support, and force application). The final chapter discusses deliberate and crisis-action planning for space operations. The appendices provide a tutorial on several topics, including intelligence, surveillance, and reconnaissance (ISR); integrated tactical warning and attack assessment; environmental monitoring; communications; position, velocity, time, and navigation; and orbital characteristics. Although lacking detail in some areas, JP 3-14's guidance for joint space operations serves as a good primer for familiarizing the joint community with what space brings to the fight.

The Way Ahead

Two thousand four promises to be a banner year for space-operations doctrine. AFDD 2-2.1, *Counterspace Operations*, currently in draft, should see publication in 2004, and a revised version of AFDD 2-2 should appear by spring 2005. Additionally, JP 3-14 may begin an out-of-cycle revision this year as well. Standup of the new USSTRATCOM and experiences from Enduring Freedom and Iraqi Freedom have provided significant rationale for updating existing Air Force and joint space-operations doctrine and have reinforced the need for additional space doctrine, particularly for counterspace operations. One should also explore any possible rationale for developing new Air Force space doctrine to cover the other space-related functions or mission areas.

The New USSTRATCOM

The merger of USSPACECOM and USSTRATCOM to form the new USSTRATCOM necessitates many changes to both Air Force and joint space-operations doctrine. A number of these alterations are only cosmetic, requiring nothing more than a simple "find and replace" of *USSTRATCOM* for *USSPACECOM*, but others are more substantial. Of particular significance to JP 3-14 is the transition of USSPACECOM's joint space-support teams into STRATCOM support teams, which involves more than a simple name change. Whereas the joint space-support team provided space support to joint theater operations, the STRATCOM support team works with all STRATCOM-assigned missions (space, global strike, global ISR, information operations, and integrated missile defense). One concern raises the question of how the space portion of the STRATCOM support team will interface with the designated coordinating authority for space, especially if that authority is delegated to one of the functional component commanders (e.g., the joint force air, land, or maritime component commanders), as was the case during Iraqi Freedom and several subsequent major exercises.

The USSPACECOM-USSTRATCOM merger also drove changes to the service-component structure. Army Space Command became Army Strategic Command, and Naval Space Command merged with Naval Network Warfare Command. The Air Force component to USSTRATCOM is still evolving, faced with the difficult task of presenting space, ICBM, ISR, information operations, and global strike capabilities that are distributed across two separate Air Force major commands (MAJCOM) (Air Force Space Command and Air Combat Command). The likely solution will involve establishing a Warfighting Headquarters, a "STRATAF" that will draw forces from both MAJCOMs to accomplish USSTRATCOM-assigned missions. The exact structure of the STRATAF and the ways it will affect the Fourteenth Air Force air and space operations centers (AOC) remain undetermined, but we expect resolution by mid-2004. The appropriate sections of AFDD 2-2 and JP 3-14 should be updated to include these new service components.

Space Lessons from Enduring Freedom and Iraqi Freedom

The recent conflicts in Afghanistan and Iraq provide ample opportunity to assess the effectiveness and utility of current space-operations doctrine in the crucible of actual combat. The lessons from these conflicts fall into two areas. First, experience shows that existing space-operations doctrine, both Air Force and joint, lacks sufficient detail regarding the coordination and integration of space forces supporting theater operations.[3] This is particularly true of the roles and responsibilities associated with the coordinating authority for space (JP 3-14) and the Air Force's senior space officer (SSO) (AFDD 2-2). Second, Iraq's use of global positioning system (GPS) jamming demonstrates a new reality of warfare: our adversaries have recognized how much US war fighters rely on space systems and will attempt to disrupt our ability to use them. This combat experience reinforces the need for dedicated Air Force counterspace-operations doctrine.[4]

Integration and Coordination of Theater Space Support. When Enduring Freedom began, we had no approved joint space-operations doctrine to guide the joint force (US Central Command) as it established command relationships for space forces. The joint force commander (JFC) elected to retain authority for theater space operations. The lack of doctrinal guidance led to suboptimal command relationships, resulting in confusion and duplication of effort among the JFC's staff, theater functional components, and reachback organizations.[5] The Air Force later proposed a possible solution, as codified in AFDD 2-2, that involved redesignating the JFACC as the JFASCC, taking on the roles of coordinating authority for space and supported commander for joint space operations.[6] This proposal was not well received by the other services, eventually prompting the compromise wording found in JP 3-14, which states that a JFC will normally designate a single authority "to coordinate joint theater space operations and integrate space capabilities."[7] The JFC can either retain space coordinating authority or delegate it to a component commander.[8] The publication includes a general list of space-authority responsibilities such as coordinating space operations, integrating space capabilities, and having primary responsibility for joint, in-theater space-operations planning.[9]

During Iraqi Freedom, the JFC delegated space coordinating authority to the combined force air component commander (CFACC). In that operation, as in Enduring Freedom, an SSO served on the special staff of the commander, Air Force forces (COMAFFOR)/CFACC as an assistant/advisor on space matters. During Iraqi Freedom, this individual assisted the CFACC with execution of space coordinating authority, and, though consistent with the position stated in Air Force doctrine, some problems arose in the execution of this authority.

Two primary causes contributed to this situation. The first resulted from the late-breaking decision, made only two days before hostilities began, to delegate responsibility for space coordinating authority to the JFACC.[10] This arrangement, which differed from the one exercised prior to the conflict, required last-minute changes to coordination plans and procedures. The second contributor resulted from the lack of any real detail in joint doctrine that would identify the exact responsibilities of the space coordinating authority and a similar lack of detail in Air Force doctrine regarding the roles and responsibilities of the SSO.[11]

As a result of the difficulties experienced during Iraqi Freedom, Headquarters Air Force Space Command and the Air Force Doctrine Center were directed to flesh out the SSO construct and brief the proposal at Air Force Doctrine Summit IV in November 2003. The proposed construct refined the roles and responsibilities of the SSO in situations in which the JFC retains space coordinating authority or delegates it to the JFACC or a different component. Although briefed at the doctrine summit, the SSO construct resulted in a new action item for Headquarters Air Force Space Command to develop and form a "red team" to explore an alternative director of space forces (DIRSPACEFOR) construct for presentation at Corona South in February 2004.

Red team representatives from Headquarters Air Force Space Command, Air Mobility Command, Air Force Director of Space Operations and Integration, Fourteenth Air Force, Air Force Command and Control Training and Integration Group, Space Warfare Center, and Air Force Doctrine Center met in early January 2004. The proposed DIRSPACEFOR construct, consisting of a five-person unit type code attached to the COMAFFOR's special staff, facilitates execution of space coordinating authority on behalf of the JFACC (when designated) or coordinates Air Force theater space requirements with the designated space coordinating authority. Personnel familiar with the director of air mobility operations will have a fairly accurate sense of the type and scope of responsibilities held by the DIRSPACEFOR. However, although the director of air mobility operations has the authority to direct the Air Mobility Division in the AOC, the DIRSPACEFOR has no corresponding Space Division within the AOC to direct. Therefore, the DIRSPACEFOR is a director in name only, simply acting on behalf of the COMAFFOR/JFACC.

Because attendees at Corona South 2004 decided to press ahead with the DIRSPACEFOR construct, the draft of AFDD 2-2.1 now includes information on the detailed roles and responsibilities of the DIRSPACEFOR and space coordinating authority; AFDD 2-2 and JP 3-14 must do likewise when they are revised. This updating is essential to ensuring that we employ space capabilities and establish C^2 relationships as efficiently and smartly as possible to meet the needs of our war fighters.

Doctrine for Counterspace Operations. Iraq's employment of GPS jamming in Iraqi Freedom emphasizes the need to get serious about counterspace operations. Although Iraq's efforts proved militarily ineffective—defeated by GPS-aided munitions—they show that our adversaries recognize US dependence on space and will attempt to disrupt our ability to exploit the asymmetric advantage that space capabilities give us. Obviously, we need detailed counterspace-operations doctrine to ensure that campaign planners consider such operations and that we properly conduct them in combat.

The Air Force's current counterspace doctrine is inadequate for the task at hand, existing entirely as single-page descriptions in AFDD 1, *Air Force Basic Doctrine*, and AFDD 2-2. The former defines counterspace operations as "those kinetic and nonkinetic operations conducted to attain and maintain a desired degree of space superiority by the destruction, degradation, or disruption of enemy space capability."[12] These operations have both offensive and defensive components.

Offensive counterspace (OCS) operations deny, degrade, disrupt, destroy, or deceive ("the five Ds") an adversary's space capability.[13] AFDD 2-2's more detailed discussion of OCS seems inconsistent with the one in AFDD 1 in at least one respect. As Maj John Grenier points out, AFDD 1 handles the five Ds as effects while AFDD 2-2 describes them as methods.[14] The revision to AFDD 2-2 should correct this problem, emphasizing effects, as does AFDD 1.

According to AFDD 1, defensive counterspace (DCS) operations preserve space capabilities, withstand enemy attack, restore/recover space capabilities after an attack, and reconstitute space forces.[15] AFDD 2-2 adds a discussion of active and passive defenses and includes a single-paragraph introduction to space situational awareness.[16] Technically, such awareness is not part of counterspace operations, but it functions as the foundation of counterspace and other space actions.[17]

The need for detailed, stand-alone Air Force counterspace-operations doctrine gained formal recognition when the Air Force Doctrine Working Group voted unanimously in April 2002 to approve development of AFDD 2-2.1, *Counterspace Operations*.[18] Currently in final draft, the document likely will appear in mid-2004. On a related note, because of pressure to reduce the number of joint publications, a plan to develop JP 3-14.1, *Joint Tactics Techniques and Procedures for Space Control*, will probably be scrapped and the material combined with JP 3-14 when it is revised.

The draft of AFDD 2-2.1 includes six chapters. The first provides an overview of counterspace operations, threats to space systems, and space-policy considerations, as well as a discussion on the linkage between Air Force counterspace operations and the space-control mission area. This chapter alone offers greater insight into counterspace operations than do the existing references in AFDD 1 and AFDD 2-2. The second chapter devotes itself to discussion of the C^2 of counterspace operations, significantly detailing command relationships, roles and responsibilities, and the C^2 of theater and global counterspace operations. The new command relationships and roles/responsibilities resulting from the standup of the new USSTRATCOM and lessons from Enduring Freedom and Iraqi Freedom will be incorporated prior to publication. The third chapter includes a detailed discussion of the tasks and components of space situational awareness, which, as noted before, is not part of counterspace operations exclusively but is a fundamental enabler of counterspace operations. The fourth chapter greatly expands the DCS construct found in AFDD 2-2 by presenting it in terms of deterrence, defense, and recovery. The fifth chapter covers OCS, includes the five Ds (as effects, not methods), discusses OCS targets (nodes and links), and lists forces capable of contributing to OCS operations. The final chapter outlines detailed guidance for planning and executing counterspace operations. AFDD 2-2.1 should embody the guidance necessary to assure that counterspace operations effectively contribute to achieving campaign objectives in future conflicts.

Candidates for New Air Force Space-Operations Doctrine

AFDD 2-2 is the space equivalent of AFDD 2-1, *Air Warfare*. The publication of AFDD 2-2.1 will give us a single subordinate doctrine document to AFDD 2-2, in contrast to the nine such documents for AFDD 2-1. Given the proliferation of air doctrine, is a similar proliferation of space doctrine likely? One should examine the possibilities for new Air Force operational-level space doctrine, keeping in mind that Air Force doctrine focuses on the desired effect rather than the platform that creates the effect or the location of the target.

For example, some individuals believe that space-based missile defense should be a part of counterspace operations. But consider the hypothetical launch of an ICBM against a target in the United States, which a space-based system intercepts while the missile is in space. Surely this occurrence belongs in the realm of counterspace. Right? Wrong. The adversary launched the missile against a terrestrial target—defense of terrestrial targets against air or missile attack constitutes defensive counterair. If we change the scenario slightly to make the missile a direct-ascent antisatellite weapon, it now becomes a case of DCS.

Most AFDDs are associated with the 17 Air Force functions identified in AFDD 1.[19] In fact, only two of the functions—space lift and navigation and positioning—do not have counterpart doctrine documents, making them candidates for new AFDDs. Navigation and positioning, though predominantly space-related functions in the form of GPS, are not exclusively provided by space systems. Additionally, the effect produced primarily enhances terrestrial operations. If we ever develop a doctrine of navigation and positioning, it would likely become a subordinate document to AFDD 2-1. The space-specific tactics, techniques, and procedures should be captured in the tactical space doctrine found in Air Force Tactics, Techniques, and Procedures (AFTTP) 3-1, volume 28, *Tactical Employment, Space*.

The subelements of the four space-mission areas represent another possible source for new space-operations doctrine. One finds these mission areas in JP 3-14 but not in Air Force space doctrine.[20] The space-control mission area and its subordinate elements of surveillance, prevention, protection, and negation are adequately covered by the counterspace doctrine publication in development. As for the space force-application mission area, existing documents include both subordinate elements—missile defense and strikes against terrestrial targets. Missile defense is an integral part of defensive counterair, and terrestrial strike would fall under strategic attack or counterland / counterair / countersea, depending upon the target. The space force-enhancement mission area has five subordinate elements: integrated tactical warning and attack assessment; communications; ISR; environmental monitoring; and positioning, navigation, and timing. These elements are not likely candidates for new space doctrine because (1) none is exclusively space related or produces primarily space effects and (2) several are associated with existing Air Force doctrine publications. Nevertheless, the relevant space-specific tactics, techniques, and procedures should be captured in AFTTP 3-1, volume 28. The space-support mission area, however, contains the subordinate elements of space lift and satellite operations, both of which are potential candidates for future stand-alone doctrine documents.

The Air Force Doctrine Center has three criteria for judging new doctrine proposals: appropriateness, distinctiveness, and sufficiency.[21] As for appropriateness, the center determines whether the proposal applies to the operational level of war and whether a validated need for the new doctrine exists. It then examines the proposal for sufficient distinctiveness to warrant a stand-alone document. Finally, the center judges the proposal to ascertain the availability of sufficient material to develop a stand-alone document. It is instructive to examine how the two possible contenders might fare against the Air Force Doctrine Center's criteria.

Space lift, which allows us to place spacecraft into orbit, is fundamentally important for space operations. However, the close linkage of current space-lift capabilities to acquisition and its schedule-driven nature make space lift's appropriateness for operational-level doctrine questionable. Space lift is certainly a distinctive capability not easily combined with air-mobility operations. Given the nature of current space-lift operations, sufficiency of material may also pose a problem. Overall, space lift is probably not quite mature enough to justify a stand-alone doctrine document. This assessment could certainly change in the future as operationally responsive space-lift capabilities come online and launch-on-demand becomes a reality.

Satellite operations control and monitor on-orbit satellites. As with space lift, the current state of satellite operations may not pass the appropriateness test. Since our satellites are relatively nonmaneuverable, most satellite operations concern themselves with status monitoring and updates. These operations are distinctive, but sufficient operational-level material may not be available. This situation could change drastically in the future as operationally responsive satellites, microsatellites, and, potentially, space-based weapon platforms enter the Air Force inventory.

Based on the rationale above, augmenting the counterspace-operations document now in development with additional stand-alone space-operations doctrine may be 10–15 years away. In the meantime, the US military must ensure that existing space doctrine provides the best guidance possible to the war fighter and permits the proper incorporation of space equities into other Air Force or joint doctrine, as appropriate.

Conclusion

After establishing a baseline of what constitutes doctrine, as opposed to policy and strategy, and exploring the content and scope of current space-operations doctrine, this article examined the way ahead for that doctrine. As noted previously, 2004 promises to be a banner year for space-operations doctrine, and the standup of the new USSTRATCOM and our experience in Operations Enduring Freedom and Iraqi Freedom have given us ample justification for updating and expanding the body of that doctrine. Furthermore, although dedicated doctrines for space lift or satellite operations will not likely appear in the near future, their time will come. Our growing body of space-operations doctrine reflects the increasingly important role that space plays in US military operations. The future of space operations and space-operations doctrine is limited only by our imagination. □

Notes

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Space Reform

DOUGLAS E. LEE

Editorial Abstract: Leaders responsible for making decisions about space acquisition have recently confronted two critical problems with this process: increases in program costs and schedule slips. Mr. Lee addresses three additional factors that will affect the competitiveness of space acquisition in the information age: accommodating technological change, reducing system complexity, and basing the acquisition process on a plug-and-play strategy.

Space is unforgiving; thousands of good decisions can be undone by a single engineering flaw or workmanship error, and these flaws and errors can result in catastrophe.

—Defense Science Board

THE CURRENT satellite-acquisition process is broken. Space-acquisition decision makers recently made policy changes in the hope of solving two critical problems: increases in program costs and schedule slips. Their primary change accelerated the decision to build, test, and launch the satellite system. Although this change improved management oversight, the process remains flawed and needs overhauling to reduce cost overruns and schedule problems. The current acquisition process could significantly improve by using common satellite components and by addressing the overall process as a "system of systems" featuring a "plug and play" strategy similar to today's personal-computing environment.

In 2003 the Defense Science Board (DSB)/Air Force Scientific Advisory Board (AFSAB) task force and the General Accounting Office (GAO) published reports critical of the space-acquisition process.[1] Both reports expressed concerns about system-cost overruns and schedule slippages, especially in two vital space systems: the advanced extremely high frequency (AEHF) military-communication program and the space-based infrared systems (SBIRS) early-warning satellite program. Combined, both programs are more than $8 billion over budget. Both reports cite several underlying factors for these programmatic issues and provide viable solutions; however, neither confronts the fundamental issue, which mandates a revamped space-acquisition process. The current acquisition method increases program oversight and compresses decision milestones at the beginning of a program, but it does not exploit principal concepts from other information-age technologies. The current initiative to redefine transformation also provides an opportunity to change the process of satellite acquisition.

Background

Operating in space requires highly robust, autonomous systems. Space does not offer the natural protections found within Earth's atmosphere, thus forcing systems to function in extreme—both hot and cold—temperatures while combating greater radiation exposure. Mechanical failures considered minor in terrestrially based equipment can prove catastrophic in space because we cannot service the system hardware. Unfortunately, we must balance both system protection and redundancy with operational capability to meet the constricted weight limits required for spaceflight. By way of comparison, the military strategic and tactical relay system (MILSTAR)—our heaviest communication satellite—weighs 10,500 pounds while the F-15E's maximum takeoff weight is 81,000 pounds. Another obstacle to fielding a reliable space system involves minimizing the traditionally high failure rates associated with "bleeding-edge" (the phase beyond "leading-edge") technology developed for many satellite systems.

By its very nature, military satellite communications (MILSATCOM) provide an asymmetric advantage to US military forces and, as with other Department of Defense (DOD) space programs, can benefit from transformation initiatives. Satellite communications also figure prominently in the Quadrennial Defense Review's operational goals as an information-technology backbone for command and control, especially in areas where more traditional infrastructure does not exist (e.g., landlines and line-of-sight communications). Recent reviews by the DSB joint task force and GAO highlighted several shortfalls with ongoing space-system acquisitions that include the AEHF program, SBIRS, the future imaging architecture (FIA), and the evolved expendable launch vehicle (EELV). Although the observations from these reviews are insightful, many of them focus on symptomatic issues rather than the core acquisition problem.

The DOD's recent space-acquisition track record has been spotty at best. Originally envisioned in 1998 as a $2.8 billion, five-satellite buy with the first launch projected for 2006, the AEHF program has grown to $5.6 billion with a two-year launch delay for the first satellite.[2] Costs for SBIRS High almost doubled—from $2.4 to $4 billion—before the program restructured; estimates now approach $8 billion.[3] The DSB report states that SBIRS "could be considered a case study for how not to execute a space program."[4] FIA capabilities have been significantly scaled back, program cost has increased from $6 to $10 billion, and production has slipped by more than a year.[5] These examples underscore the need for transformation initiatives not based exclusively on technology. In these cases, procurement "doctrine" and "concept of acquisition" qualify as transformation candidates.

Transformation is not new. A major milestone in air and space transformation began the day Orville and Wilbur Wright began designing their Flyer. The F/A-22 Raptor, B-2 Spirit, and C-17 Globemaster III evolved from that fateful endeavor. However, transformation has become more complex with the advent of the integrated circuit in the late 1950s and the Atanasoff-Berry digital computer in the late 1930s, both intrinsic elements in the information age. Further complications occurred on 11 September 2001, when an asymmetric attack took place on US soil. Currently, developing and fielding a weapon system can take longer than a decade; consequently, the transformation strategy initiated earlier this year will reach steady state within the next 15 to 20 years. During this transition, we must provide for today's national security while we develop capabilities that assure our future.

Both the Air Force's and the DOD's transformation strategies[6] use as their foundation the six critical operational goals described in the Quadrennial Defense Review's report of 30 September 2001, with military satellite systems playing a role in each of them: (1) protecting the American homeland while defending forces abroad, allies, and friendly bases of operation; an additional objective involves deterring the threat from and defeating the delivery means for chemical, biological, radiological, and nuclear weapons; (2) "assuring information systems in the face of attack and conducting effective information operations"; (3) "projecting and sustaining U.S. forces in distant anti-access or area-denial environments"; (4) "denying enemies sanctuary by providing persistent surveillance, tracking, and rapid engagement"; (5) "enhancing the capability and survivability of space systems"; and (6) benefiting from "information technology and innovative concepts to develop interoperable joint C4ISR [command, control, communications, computers, intelligence, surveillance, and reconnaissance]."[7] These goals help focus transformation efforts, ensuring that US military superiority—at a minimum—is maintained in an asymmetric, nonlinear strategic environment.

Independent Reviews of Space-System Acquisition

The DSB/AFSAB joint task force and the GAO reports, published in May 2003 and September 2003, respectively, highlight shortfalls in the DOD's space-system acquisition process. The task force, which analyzed three space programs—SBIRS, FIA, and EELV—was charged with assessing the nation's dependence on space, recommending improvements to space acquisition, and looking at underlying causes for increases in system costs and schedule slippages. It found that the nation is "critically and increasingly dependent upon space systems."[8] Moreover, many capabilities—early warning, weather, communications, navigation, imagery intelligence, and launch—have replacement programs under way. The task force also notes five key issues that increase program cost, suggesting that any one of them could have a significantly negative impact on a program's success.

The first cause of program growth and delays involves using cost instead of mission success as the primary driver in space-system development. The task-force report concludes that managing quality and doing things right the first time can contain program cost. Second, unrealistically low cost estimates lead to dubious budgets and unexecutable programs. The task force found that one could predict a 50 to 100 percent growth in cost for most programs. Third, according to the report, the space-acquisition process lacks a disciplined management process to vet requirements—especially critical in a time when the user base and corresponding requirements have grown considerably. Fourth, the task force attributes the government's inability to lead and manage the acquisition process, in part, to the acquisition-reform environment of the 1990s that weakened accountability and management effectiveness. Finally, the report cites industry's failure to implement proven practices in some programs.[9]

Another key observation regarding space acquisition deals with the industrial base's long-term prognosis. Although the prime contract workforce can adequately support planned space programs in the near term, second- and third-tier contractors are experiencing problems with low demand for their components. In the long term, significant concerns exist with a large retirement-eligible workforce and a relatively smaller replacement pool.

The report of the DSB task force provides several recommendations that blunt those factors affecting program cost and schedule. These include realigning the measure of success from cost to mission capability, reformulating cost estimates to an 80/20 ratio (i.e., estimating program cost so that it has an 80 percent chance of coming in under budget), tightening the requirements process, revamping government leadership, and reestablishing organic-engineering capability.[10]

The GAO used its experience from the past 20 years to assess space acquisition, finding that the majority of the programs reviewed experienced cost increases and schedule slips and concluding that those problems were "largely rooted in a failure to match the customer's needs with the developer's resources . . . when starting program development." Its report also states that the DOD's new space policy may increase awareness about the gaps between requirements and resources but that the policy's effectiveness will depend largely on how that information is used. The GAO's basic premise maintains that the DOD advances leading-edge technology as part of system acquisition but should separate the technology and product-development processes to reduce program risk. The report also notes that every acquisition program should undergo evaluation at three critical decision points to ensure success: (1) before product development, when user needs and available resources—technical and engineering knowledge, time, and funding—must match; (2) midway through development, at which point the product's design must remain stable and prove its ability to meet requirements; and (3) prior to production, when the developer must provide assurance of reliable production within cost and schedule.[11]

The GAO believes that in most programs, user requirements will eventually match system resources but that programs balanced at these decision points will have a better chance of delivering a product on time and within budget. To achieve that balance between requirements and resources, users may have to reduce their expectations if the technology associated with a specific resource is not mature and must be deferred in the ongoing production-development cycle.

The Technology Paradox

The DOD disagreed with the GAO's position on separating technology and program development, stating that a more deliberate process would delay acquisition programs. In its updated space-acquisition process, the DOD provides more senior-level oversight and, contrary to the GAO's recommendation, accelerates key decision points—committing earlier in the acquisition process to accommodate technology-development times. The fact that technology appears to be the key driver in space-system acquisition presents an interesting paradox: any technical advantage a program gains is lost before launch of the first satellite. In 1965 Dr. Gordon Moore made a prediction about integrated circuits that eventually came to be known as Moore's Law: the number of transistors in an integrated circuit will double every of couple years.[12] That prediction has held true and will probably continue to apply in the foreseeable future.

Using Moore's Law as a technology standard, one finds that a system with a 10-year development cycle and a design "freeze" at the five-year point would fall at least one generation behind technologically before the first launch. If that same program produces six satellites, each with a 10-year mean mission duration, the technology used to develop those satellites could lag another four to six generations before a newer system replaces any of those satellites (fig. 1).

Transformation and the Acquisition Process

Three recently published regulations that reflect current transformation initiatives will play key roles in shaping future MILSATCOM acquisitions. First, the DOD's newest acquisition regulation simplifies the acquisition process, emphasizing an evolutionary approach.[13] Second, the Joint Staff's Joint Capabilities Integration and Development System (JCIDS) revamps the requirements-generation process, using a capabilities-based approach that focuses on shortfalls and redundancies, assesses shortfall risks and priorities, and recommends the best approach to mitigate those deficiencies.[14] Third, the DOD's space executive agent acquisition policy emphasizes guiding principles that endured over the first 50 years of space. Those principles include mission success, management accountability, realistic cost estimates, a stable environment, and disciplined process—issues identified by the recent DSB/AFSAB task force as affecting

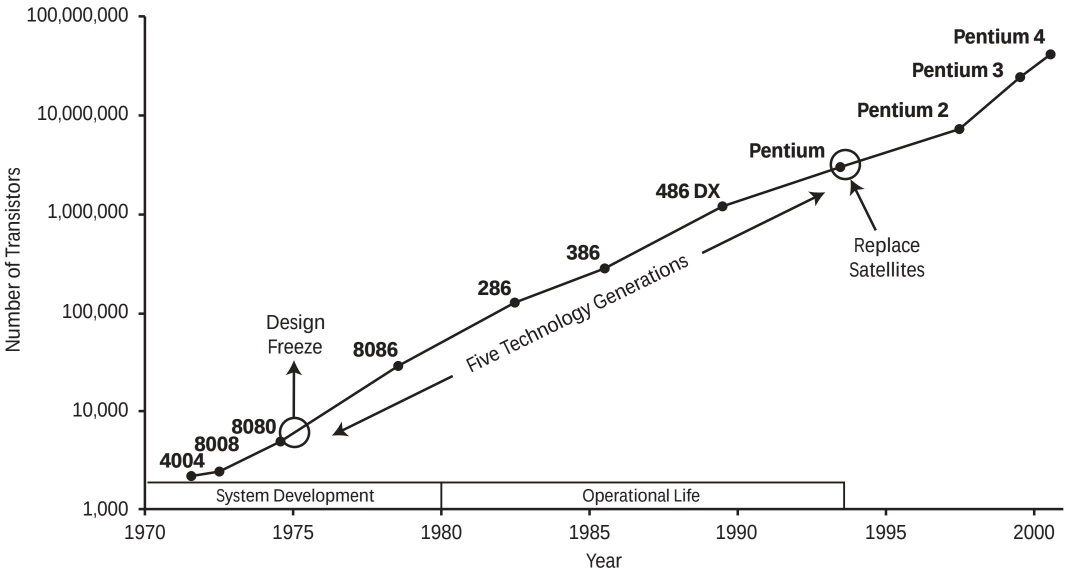


Figure 1. Development timeline for computer central processing unit (CPU). This figure overlays a generic satellite-development program on actual computer CPU fielding dates. In this example, the generic program has components that are five generations behind technology when a replacement system begins fielding. (Adapted from "Moore's Law," *Intel*, 2003, http://www.intel.com/research/silicon/mooreslaw.htm.)

current space-system acquisitions.[15] That policy also contrasts small-quantity space programs, using those disparities as a basis for accelerating the decision to build, test, and launch the satellite system.

The reports of the joint task force and GAO focus on the causes that drive satellite-system cost and schedule slips. Both highlight user requirements as an issue—the DSB/AFSAB addresses uncontrolled requirements growth while the GAO examines the disparity between requirements and proven technology. The task force's other findings are also symptomatic of a deeper acquisition problem. Those findings include unrealistic cost estimates, the government's ability to lead, and the use of program cost as a success metric. The Defense Space Acquisition Board, mandated in the guidance of the DOD's space-system acquisition process, provides a good start for resolving issues.[16] However, in the current environment, more control may exacerbate acquisition problems if we do not introduce more stability into the process. Similarly, the Joint Staff's JCIDS capabilities process will have little effect if a program cannot rein in costs.

Both the DSB/AFSAB and GAO provide excellent recommendations to help contain costs and schedule; furthermore, recent DOD refinements to the acquisition and requirements-generation processes will improve space acquisition. However, current strategy does not provide an optimal foundation to build upon and will require constant supervision to function properly. The key to success lies with a stable acquisition model that can easily accommodate transformation. Current space strategy focuses on low-quantity buys that produce up to 25 satellites, but the average program usually procures six satellites.[17] Within current strategic communications, new programs are revolutionary by necessity. The AEHF program—MILSTAR's successor—does not use any of its predecessor's hardware; in today's environment, that makes sense considering the time that has elapsed between the two programs. However, a revolutionary process increases program complexity and managerial responsibility because there is no starting point to build upon—a situation contrary to evolutionary development, which does have a foundation.

An Alternative to the Current Space-Acquisition Process

The myriad issues associated with space-system acquisition are well documented, but potential solutions do not have similar fidelity. The underlying issue in many papers appears to be program risk and the resulting uncontrolled cost increases. Although one might argue that space-related acquisitions are unique and that successes from other programs are not transferable, the current acquisition process remains broken. For that reason, as a means of reducing billion-dollar cost overruns, we must evaluate solutions that have worked in similar areas. Regardless of the solution, we should concentrate on methods that transform the current process into a better setting that permits management of risk. Such solutions include revamping the roles and responsibilities of the program office and using standardized, common components as well as plug-and-play architecture—prominent techniques in information-age computing.

In an optimal environment, the best acquisition process would allow ample time and funding to develop emerging technology while minimizing program risk. Additionally, resources would be readily available to produce highly qualified managers and engineers. Unfortunately, today's environment is not optimal. Constraints and conflicts associated with schedules, funding, and resources will always be an issue. However, we can make changes to the current acquisition process that will minimize risk yet nurture an atmosphere that allows managers to oversee their acquisition programs more easily. Changing the current process would also allow implementation of a framework that assists the acquisition community with system development. The proposed process addresses the most problematic issue with space acquisition—technology development. It is not feasible to expand the timelines associated with technology development in a satellite's highly compressed acquisition schedule. This method attacks the development problem from a different angle, narrowing the focus on core capabilities and reducing the technological "leap" required to field a system. It reduces an acquisition program's complexity, permitting a program manager to spend more time on a critical issue without increasing the time allotted in the overall procurement schedule.

Although individual space-system acquisitions are small scale, we can realize several benefits by addressing the overall process as a system of systems using a plug-and-play strategy. Managing space acquisition as a larger-scale system that emphasizes a common-component baseline not only benefits from economy of scale, but also adds more stability to the process. A properly controlled process will naturally resolve the issues highlighted by the DSB and GAO because it does not "force" a specific fix, which will have a higher propensity for failure. A successful program will minimize distractions, allowing management to concentrate on the critical paths that contain system components most sensitive to cost and schedule. Addressing space as a system of systems establishes a broad foundation with a process that allows the acquisition community to separate technology drivers from established capability. But it goes a step further. Standardizing common components—such as system platform, power distribution, satellite control, heating and cooling, and cryptography—helps stabilize an acquisition program. The cost and schedule for developing basic satellite functions become known quantities, thereby reducing the number of issues that a program manager must consider.

Establishing a plug-and-play strategy creates a structured design process by default. Plug and play—the micro (versus macro) aspect within a system of systems—uses a system-of-subsystems approach. Any subsystem developer will have to conform to a common set of standards that includes interface specifications, power limitations, and volume constraints. The advantages to this approach resemble those in personal computing. Like a PC user, a space-system program manager can integrate technology during the satellite-production phase as that technology emerges, adding components to improve or add capability. Thus, one can target technological advances without having to "buy" an entire system. For example, a PC user can increase memory or upgrade processors, replace other components (e.g., hard or CD drives, video or sound cards, and monitors), or add new capabilities (e.g., DVD drives and common-access card readers) without replacing the basic system. By the same token, the space community could develop "bare bone" configurations (built with standard, modularized "housekeeping" essentials such as control infrastructure, power, stabilization, cooling, etc.) that would serve as the foundation for any new system.

A further refinement to this acquisition approach would establish a satellite-support office responsible for developing and procuring the basic satellite "shell" for the "production" programs. This strategy allows a production program manager to focus on the satellite's core mission components (e.g., communications, intelligence, and early warning). The basic satellite design is not "one size fits all." On the contrary, this concept resembles the EELV program in that a basic set of resources exists to support common attributes. In the launch program, booster configuration depends upon payload weight and orbital parameters. Similar capability would reside in the support office—tailoring basic satellite configurations to mission, payload weight and volume, and orbital parameters. As in other long-term programs, at times the standard configuration may not support emerging capability. Creating a program office accountable for basic satellite functions, however, can minimize those occurrences and ensure a more orderly transition if emerging capability outpaces support infrastructure. Analogous to the EELV concept, the support office would provide a satellite shell, using a building-block approach with off-the-shelf components for many mission types.

Requirements that exceed current capability will signal the need for greater corresponding support. For example, if a new mission requires more power than is available, the support office can develop that new component while the production office concurrently builds new communications capability. This concept allows the production manager to focus on a system's mission capabilities while the support manager oversees the peripheral needs common to all satellite programs. Other programs with similar power requirements benefit, saving the time and resources needed to develop comparable, redundant support capability.

Although the nexus of this concept shifts acquisition to a common plug-and-play system, another change assimilates the DOD's evolutionary acquisition paradigm, thus reducing the technology paradox by modifying a system with updated technology *during* its life. Currently, many satellites are upgraded with software, but the proposed approach makes hardware upgrades more feasible as well. Plug and play allows for a more adaptable and, in turn, more flexible acquisition process. Using that flexibility, a program manager can "evolve" technology during system development. Specifically, instead of pursuing immature technology at the outset, the program can use more mature technology during initial system development. As technology matures, one can integrate it into satellites prior to launch. This concept may increase initial program cost by keeping satellite production lines open past the traditional production phase, but in the long run, it could significantly lower major cost overruns as well as program risk by utilizing more current, stable technology.

This proposal offers a framework that will naturally redress the concerns presented in the reports of the joint task force and GAO. However, this solution—like any other comprehensive alternative—will cost more to implement and maintain than will recent proposals, but in the long term, expenditures should prove significantly less than those generated by shortfalls encountered in existing programs. Until we achieve steady state, we will have to devote additional time to the process. We can minimize such phase-in time if we implement the process by using concurrent and consecutive satellite programs.

Assessing the Proposed Alternative

Both the DSB/AFSAB and GAO studies point to the requirements-generation process as a major concern. Traditionally, we develop a communications-satellite initiative from the ground up and do not use technology from previous efforts. A process that addresses a space system as a group of components reduces the number of unknowns in requirements generation by providing a basic satellite platform to build upon, allowing the acquisition community to concentrate solely on operational capabilities. As an ongoing process, performance requirements become more stable because users do not develop a system that must stay viable for the next 20 years—rather, the system evolves as the next satellite in the production line is manufactured. Compared to the current process and its resulting technology paradox, the proposed process reduces the technology gap from multiple generations to a generation or two. With plug and play, users assure themselves of capabilities commensurate with the technological time frame during which the system will operate.

In a fiscally constrained environment, cost remains the dominant factor. However, after the establishment of cost parameters, mission success should become the first and foremost concern. Once a sound program experiences a significant cost issue, recovery is difficult. Several cascading factors come into play—especially in a small-quantity program with little idle time. Any near-term funding shortfall will affect the overall schedule, and such schedule slips disrupt future funding. At this point, the total program cost probably exceeds the projected shortfall and the original estimates. On the outside, the program's viability may become suspect, and, in turn, vulnerable to budget cuts—a situation that brings about an exponential cost increase and a corresponding schedule slip. Mission success then becomes secondary to cost containment. The proposed alternative reduces unknown costs at the start, allowing the community to realistically capture costs associated with the basic satellite because those components exist. An evolutionary-design approach also reduces cost estimates for future technology because the technology gap from the most recent satellite amounts to only years instead of decades. After the process attains steady state, one can reduce the overall system costs even further as future generations not only build on basic satellite capability, but also use previous mission capability. Furthermore, the fact that this process dovetails with the JCIDS allows developers to logically correlate capability shortfalls with satellite design.

Ensuring that a program manager remains in place through a system's acquisition cycle also becomes an issue, especially in an environment requiring personnel movement for career success. The best solution entails retaining a static management team from system conceptualization through production; however, several factors could affect that strategy. To achieve program success, we must simplify the acquisition process to assure a seamless transition in the event management changes. Dividing a system's acquisition into support and production program offices reduces the volume of data that one must relay in a move, and using a building-block approach provides a structured syllabus that logically presents that information to an incoming manager.

This process also provides residual benefits that help resolve other concerns of the joint task force, whose report identifies industry's failure to implement proven practices and provides a long-term prognosis for space's industrial base. The report highlights solid leadership and sound management processes—in both government and industry—as attributes of a successful space program. Although leadership qualities depend upon the particular individuals, one can implement management processes that cultivate program success. The proposed plug-and-play process could help promote program success by cultivating an atmosphere for applying best business practices by reducing a highly complex issue into its fundamental, more manageable components.

The DSB/AFSAB also assesses the industrial base as adequate for the near term but expresses concerns about the future. Primary issues include the modest demand for lower-tier components, the loss of the experience base to retirement, and the relatively small pool of engineering professionals to serve as a replacement. These matters lie beyond a restructured acquisition process; nevertheless, the simplicity of the process presented here can help mitigate concerns associated with a dwindling industrial base and an inexperienced engineering pool. Use of common components in basic satellite platforms by the commercial sector would help sustain constant demand from the industrial base. Moreover, the structure associated with a plug-and-play environment could help reduce the learning curve for new engineers, who could focus on distinct, specialized areas and expand as needed rather than learn a complete system all at once.

This proposed process also has the potential to provide a capability inconceivable today: on-orbit maintenance in the geosynchronous region.[18] Satellite programs are becoming increasingly expensive; indeed, systems such as the AEHF program exceed $1 billion per satellite. Today, system repairs require hands-on fixes similar to those performed during the space-shuttle mission that corrected the Hubble telescope's "vision," but we could use robotic technology to maintain or upgrade satellites that utilize modularized plug-and-play components.

Conclusion

The recent transformation initiative is the cornerstone for several changes within the DOD. A more responsive acquisition strategy and a capabilities-based requirements-generation process are critical tools for the quickly evolving environment characteristic of the information age. Key issues affecting the acquisition of space systems include technology and its current procurement process. Other than the personality-driven issues (i.e., leadership, management, and recruiting), all remaining concerns defined by both the DSB/AFSAB task force and GAO are affected by technology and acquisition strategy. Technology and procurement issues force decisions on highly complex programs that have not matured sufficiently to assess risk properly. One can measure the results in terms of funding shortfalls that have doubled or tripled the original program costs. To put these shortfalls in perspective, one need only note that the additional funding currently required for the AEHF program and SBIRS is enough to fund 50 F/A-22s.

This article has addressed three factors that we must consider if space acquisition is to remain competitive in the information age. First, future systems must readily accommodate technological advances. For example, integrated circuits in the 1970s had 30,000 transistors; 300,000 in the 1980s; and 42 million in the 1990s. The technology gap created during the life cycle of a system fielded in the 1970s and 1980s seems minor compared to the one today with transistor counts approaching 100 million and doubling every couple of years. To lower risk and maintain state-of-the-art capability, acquisition programs should not pursue technology that is generations away from maturity and then freeze the system design prior to fielding. Rather, we should use current technology and upgrade individual systems prior to launch.

Second, we must reduce system complexity. Restructuring space acquisition into a program office responsible for the basic satellite shell and corresponding offices for mission capability allows a "production" program manager to focus on a satellite's mission-related components. Splitting space programs into these distinct areas not only lessens system complexity, but also reduces the issues a production manager must consider.

Finally, to easily exploit technological advances and reduce system complexity, we must base the acquisition process on a plug-and-play strategy, using modular components. This strategy—used successfully in the personal-computing environment—provides a framework for effortlessly upgrading components or adding capability without redesigning an entire system.

Space-based systems are key force enablers that give us the asymmetric advantage which underpins the transformation process. Nevertheless, we must make significant changes in the acquisition process if space is to remain a viable contributor. Three major space programs have more than doubled in cost—from $11.2 to $23 billion—since their inception. These unforeseen increases are indicative of a broken acquisition system. However, robust solutions do not mature quickly. Reform of space-system acquisition will span generations, as does transformation. The time is right to develop a solid foundation. Myriad space-based capabilities now find themselves in transition—the ideal time to exploit economies of scale. The Air Force's mission is to fly and fight; anything else constitutes support. In today's fiscally constrained environment, support functions such as spaced-based capabilities will have difficulty competing with the primary needs of war fighters. This is especially true when there is no legitimacy associated with cost and schedule and when program shortfalls amount to billions of dollars. □

Notes

1. The Defense Science Board includes experts from the civilian sector who advise the secretary of defense on scientific, technical, manufacturing, acquisition process, and other matters of special interest to the Department of Defense. Similarly, the Air Force Scientific Advisory Board counsels Air Force senior leadership on science and technology for continued air and space dominance. Department of Defense, *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs* (Washington, DC: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, May 2003), http://www.acq.osd.mil/dsb/space.pdf (hereafter DSB/AFSAB report); and United States General Accounting Office, *Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives: Defense Acquisitions, Improvements Needed in Space Systems Acquisition Management Policy* (Washington, DC: General Accounting Office, September 2003), http://www.fas.org/spp/military/gao/gao-03-1073.pdf (hereafter GAO report).

2. GAO report, 8.

3. Ibid. The Air Force manages SBIRS-High and SBIRS-Low—the two components of SBIRS. In 2000 the new Missile Defense Agency took over SBIRS-Low, which became the Space Tracking and Surveillance System (STSS) in 2002. The STSS focuses on missile defense while SBIRS-High concentrates on missile warning, missile defense, technical intelligence, and battlespace characterization. Jeremy Singer, "Air Force Says New SBIRS High Problems Are Manageable," *Space News*, 20 October 2003.

4. DSB/AFSAB report, 6.

5. Douglas Jehl, "Boeing Lags in Building Spy Satellites," *New York Times*, 4 December 2003.

6. The Air Force defines transformation as "a process by which the military achieves and maintains asymmetric advantage through changes in operational concepts, organizational structure, and/or technologies that significantly improve warfighting capabilities or ability to meet the demands of a changing security environment." Air Force Policy Directive 10-23, *Operational Innovation Program*, 20 June 2003, 9.

7. Department of Defense, *Quadrennial Defense Review Report*, 30 September 2001, 30, http://www.defenselink.mil/pubs/qdr2001.pdf.

8. DSB/AFSAB report, 12.

9. Ibid. 2–4.

10. Ibid., 5, 14. In cost-estimating terminology, an 80/20 ratio refers to the point at which a program has an 80 percent chance of being under budget and a 20 percent chance of being over budget. The task force believed that the contracts using contractor proposals to establish cost estimates were more likely to have a 20/80 ratio. Additionally, the task force recommended a 20–25 percent management reserve for development programs that would not be used for new requirements.

11. GAO report, 6–7.

12. For a more detailed discussion as well as Dr. Moore's original paper, see "Moore's Law," *Intel*, 2003, http://www.intel.com/research/silicon/mooreslaw.htm.

13. Department of Defense Instruction 5000.2, *Operation of the Defense Acquisition System*, 12 May 2003.

14. Chairman of the Joint Chiefs of Staff Instruction 3170.01C, *Joint Capabilities Integration and Development System*, 24 June 2003.

15. National Security Space Acquisition Policy 03-01, *Guidance for DOD Space Acquisition Process*, 6 October 2003.

16. Ibid., 6. The DOD Space Milestone Decision Authority convenes the Defense Space Acquisition Board at each key decision point, inviting the appropriate representatives to provide advice.

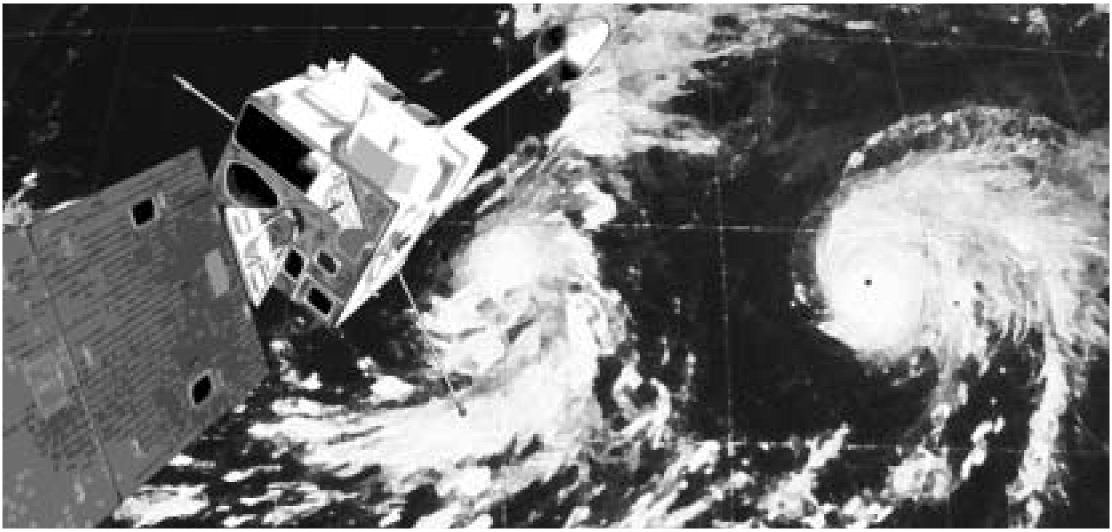
17. GAO report, 25.

18. Mr. James Fitzgerald, support contractor, MILSTAR System Sustainment Office, interview by the author, 14 November 2003.

Using Space-Based Radar to Derive Fully Integrated, Real-Time Weather Information

MAJ STEVEN T. FIORINO, USAF

Editorial Abstract: Generally, space-based radars (SBR) used in weather and other military/civilian aviation operations have been designed and fielded separately. This practice has prevented the integration of time-sensitive, mission-critical, radar-derived meteorological information with other key radar-derived data. Major Fiorino argues that the collection of weather data from future SBR platforms would significantly benefit operational- and tactical-level war fighters. Toward that end, he proposes techniques for integrating weather data within the SBR platform.



In any combat operation or any conflict, weather's probably your number one concern.

—Gen Richard B. Myers
Chairman, Joint Chiefs of Staff

CURRENT PLANS FOR the fielding of a space-based radar (SBR) capability in 2010 include developing and testing a space platform that can provide a ground moving target indicator (GMTI); precision geolocating; single-pass, digital, terrain-elevation data collection; electronic protection; single-pass, synthetic aperture radar (SAR) imaging; and high-data-rate, secure communications. The plans, presentations, and news releases concerning SBR, however, do not specifically address the collection of meteorological data. The history of radar development suggests that despite many hardware similarities, radars for weather and other military/civilian aviation operations have generally been designed and fielded separately, probably due to the human-intensive analysis required to process the distinctive radar data generated by each function. Thus, the integration of time-sensitive, mission-critical, radar-derived meteorological information with other key radar-derived parameters has historically suffered from a cumbersome manual-fusing process, often involving different equipment and different organizations.

This article hypothesizes that modern communications and electronic signal-processing capabilities would allow the derivation of fully integrated meteorological information from the proposed SBR constellation without significant additional costs or program delays. It presents previously proven techniques for obtaining weather information from this constellation, along with evidence that minor additions of equipment could greatly enhance SBR's "see-through" capability in weather-clutter areas. One could expect the integration of real-time weather information into the SBR data stream to benefit operational- and tactical-level war fighters significantly. Collection of weather data from SBR would also provide a vast source of observational information about global weather, thus improving numerical weather forecasts for military and civilian endeavors alike.

Uses of Modern Weather and Tracking Radars

Active surface microwave sensors (ground radars) have monitored precipitation for research and operational purposes for decades—and one space-based version has operated since 1997. Radars that employ the Doppler principle in their signal processing first emerged during World War II to better detect aircraft and other moving objects in the presence of "cluttering" background echoes created by the radar beam's sidelobe emissions. The earliest Doppler (moving target indicator [MTI]) radars detected only relative motions of objects rather than quantifying velocities, as do modern pulsed-Doppler radars. The MTI designation has persisted to the present day, as is apparent in the GMTI radar equipment used aboard Joint Surveillance Target Attack Radar System (JSTARS) aircraft. The rapid development of pulsed-Doppler radar was impeded by the formidable amount of signal processing required to extract quantitative estimates of the Doppler shift at each of the thousands of range locations a radar can survey. Not until the late 1960s and early 1970s did solid-state devices make the implementation of Doppler measurements practical at all resolvable ranges.[1] Thus, the first 25 years of operational radar were dominated by manual signal processing of fleeting cathode-ray-tube images.

The early reliance on manual signal processing of radar measurements strongly influenced the development of separate fields (both equipment and personnel) of radar meteorology and operations for military/aviation tracking radars. Yet, even before the launch of Sputnik in 1957, both fields recognized the satellite as the ideal platform for global radar observations. The scientific, civilian, and military need for such data is as great as the applications are varied.[2] Despite the need for SBR, the radiometer (microwave, infrared, and visible) provided the only space-based observations of the earth's surface and its enveloping clouds and precipitation until the launch of precipitation radar aboard the Tropical Rainfall Measuring Mission (TRMM) satellite in 1997. Until recently, insufficient technology and high development costs have hampered efforts to field an effective spaceborne radar for military purposes. But advancements demonstrated by the TRMM precipitation radar—combined with improvements in power-amplifier efficiency and reliability, low-noise receivers, and antenna technology—have yielded new concepts that could be exploited by a military SBR capability in the 2010 to 2020 time frame.

Because radars are principally dependent on scattering, an SBR does not suffer problems caused by the lack of a homogeneous background, which hinders the use of passive microwave sensors over land surfaces. At this point, it is instructive to review the TRMM satellite since it is the only operational satellite flying both a radar and radiometer that concurrently monitor the same volumes of the terrestrial environment. The TRMM is the first Earth satellite equipped with a precipitation radar (a 13.8 gigahertz [GHz] [2.2 cm], non-Doppler radar), the only instrument on the TRMM that can directly observe the vertical distribution of rainfall rate and provide an unambiguous estimation of this measurement over land as well as water. The radar's footprint is small enough to allow study of inhomogeneous rainfall effects relative to the comparatively coarser resolution of the lower-frequency TRMM radiometer emission channels.[3]

The TRMM also carries a passive microwave radiometer, the TRMM microwave imager (TMI), which takes observations in nine channels at five frequencies—10.7, 19.35, 21.3, 37.0, and 85.5 GHz. Similar in design to the Defense Meteorological Satellite Program's (DMSP) special sensor microwave imager (SSM/I), the TMI has an additional pair of channels at 10.7 GHz and approximately two and one-half times better spatial resolution due to the TRMM's lower orbit altitude of about 350–400 km versus SSM/I's altitude of about 800 km.[4] The TMI is the TRMM's main workhorse for retrieving wide-swath, radiometer-based, instantaneous rates of rainfall from space since the precipitation radar's surface coverage is swath-limited and only about one-third the size of the TMI swath. The major role of the precipitation radar on the TRMM is to provide details on the vertical structure of rain; these help refine the radiometer-based retrievals.[5] However, the roles could be reversed, with the wide-swath, emission-based TMI retrievals providing a first-guess field for the higher-resolution, background-independent precipitation radar. For a primarily military-use satellite, the advantage of such a role reversal is that one could use the first-guess radiometer field to optimize the radar-retrieval algorithms for any obscuring meteorological phenomena. In other words, coupling a radar with a radiometer could reduce the effects of adverse weather on radar detection and tracking.

Presently, the operational employment of radar remains divided, both in terms of fielded equipment and trained personnel to analyze and process the remotely observed data. However, advances in signal-processing capabilities, radar-hardware technology, and the meteorological successes of the TRMM satellite program suggest a merging of meteorological and military radar equipment and data processing from an SBR platform. Clearly, one should explore the feasibility and possible benefits of such an idea.

Space-Based Radar: A Battlespace-Data Integrator?

Existing plans for fielding an SBR capability in 2010 focus on developing both technology and an intelligence, surveillance, and reconnaissance (ISR) system capable of providing continuous GMTI, SAR, and digital terrain and elevation data (DTED) over a large portion of the earth. The system should incorporate battlefield tasking and control to facilitate near-real-time availability of SBR products to the theater. It should also allow military forces a "deep look" into denied areas of interest on a nonintrusive basis without risk to personnel or resources. One could utilize this capability—not currently available via existing assets—before, during, and after hostilities.[6]

A constellation of SBR satellites would satisfy these requirements. Concept developers expect the constellation to offer day/night, all-weather, near-continuous, global GMTI search/track and high-resolution imagery; near-real-time, direct downlink of overhead GMTI and imagery collection to the theater; and collection of precision DTED.[7] The Air Force's command, control, intelligence, surveillance, and reconnaissance (C2ISR) center has a specific vision for the employment of SBR (fig. 1, the fifth in a series of six illustrations depicting the activities of various surface, air, and spacecraft linked with air-and-ground control centers during the find, fix, track, target, engage, and assess time-critical targeting [TCT] cycle).[8] One sees that SBR is a major contributor of key decision-making

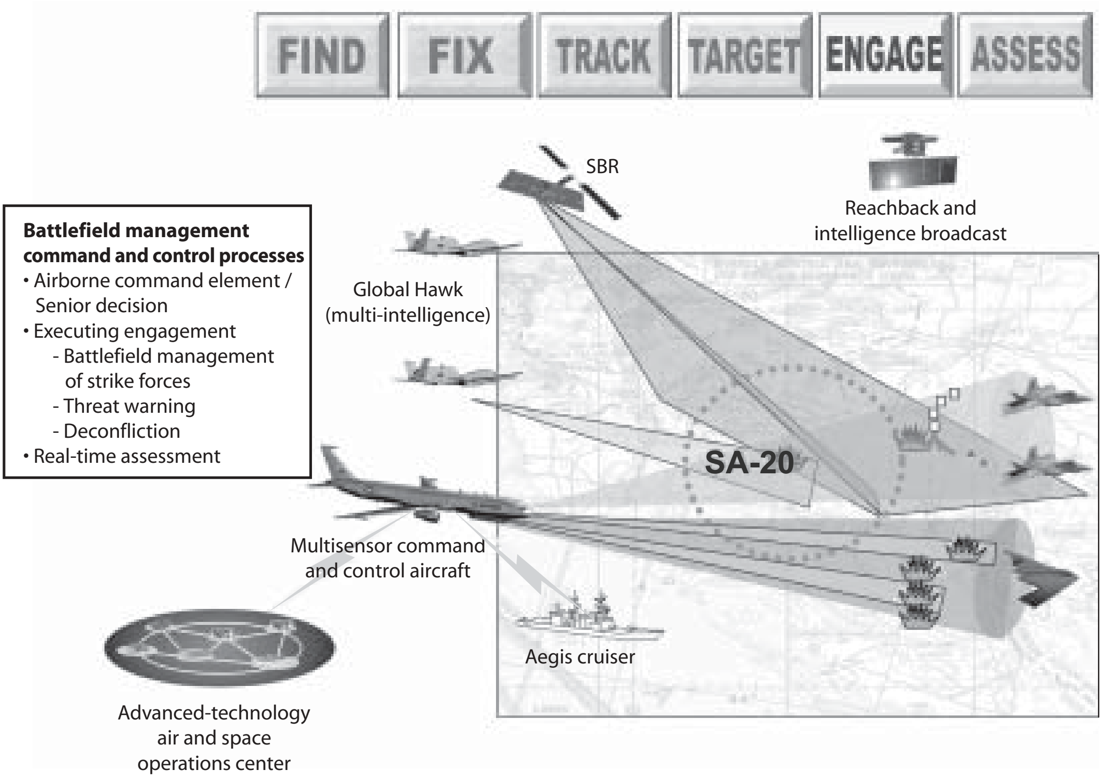


Figure 1. Visualization of future battlespace command and control, including SBR; various other surface, air-, and spacecraft; airborne and ground control centers; and their utilization in the find, fix, track, target, engage, and assess TCT cycle. (From Maj Gen Robert F. Behler, "Transformational Command and Control for Your Generation" [lecture, Air Command and Staff College, Maxwell AFB, AL, January 2003].)

data in all portions of the TCT cycle except the targeting phase. Interestingly, no SBR plans or reports describe the collection and analysis of meteorological data, despite the fact that atmospheric phenomena quantifiably affect all aspects of SBR measurements throughout the TCT cycle.

The collection of quantifiable and operationally "exploitable" weather data from a future SBR platform is both possible and feasible. One of the more dominant concept designs for an SBR platform under consideration uses a SAR approach. The Air Force Research Laboratory is planning a flight experiment, dubbed TechSat 21 and scheduled for launch in 2006, to demonstrate a formation of three lightweight, high-performance microsatellites.[9] The formation will operate together as a "virtual satellite" with a single, large radar-antenna aperture.[10] Although this configuration differs from current ground-based weather-radar configurations and the current precipitation radar aboard the TRMM satellite, described above, the 1970s saw a demonstration of the detection of rainfall and other meteorological parameters by airborne SAR.[11] Thus, without the costly addition of, or modification to, any planned equipment/sensors for the SBR, weather-signal processing—for meteorological and operations-enhancement purposes—could be integrated into the analysis processing of the SBR data stream.

Weather Data from Space-Based Radar: Advantages and Benefits

As noted previously, radars for the collection of meteorological data and those for predominantly military purposes have generally been funded and developed separately, despite their similarities in basic equipment, frequencies, and even operations supported. The duplication of fielded equipment not only has greatly (and unnecessarily) increased the cost of radar support to military (and civilian) aviation operations, but also has fragmented the accounting of the single most significant physical variable affecting both the radar equipment and military operations supported by the radar: the weather. The fact that radars that produce a digitized, electronic data stream can have multiple uses—including the collection of weather data integrated with military tracking data—offers a clear opportunity for improvement.

Examples of the cross-applicability of weather, military, and/or aviation radars include the routine capture of precipitation and wind-shear areas on airport air-traffic-control radars (often not passed on to local weather forecasters) and the detection of chaff from military exercises in WSR-88 NEXRAD imagery (the National Weather Service's network of Doppler radars). Additionally, the ground-based NEXRAD weather radars provided perhaps the best radar tracking of the fallout of debris from the space-shuttle *Columbia* disaster (fig. 2).

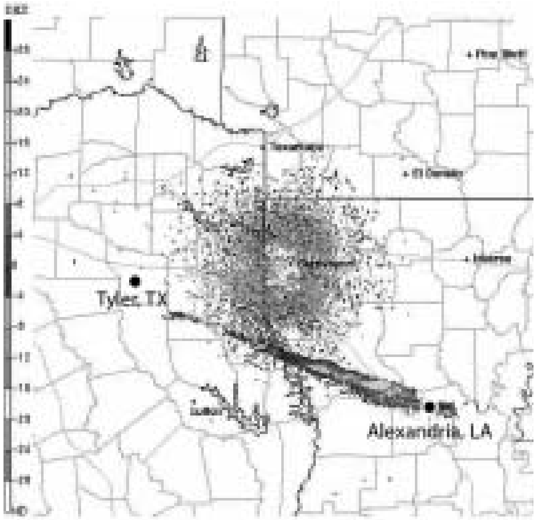


Figure 2. National Weather Service (Shreveport, Louisiana) radar image from 1 February 2003. The line of echoes from Tyler, Texas, to Alexandria, Louisiana, represents the fallout of debris from space-shuttle *Columbia*. The doughnut-shaped pattern of echoes around Shreveport represents ground clutter.

Regardless of the final configuration and operating frequencies of the SBR constellation, one will have to take into account the meteorological aspects of the earth's atmosphere—specifically clouds, cloud microphysics, and precipitation—if the platform is to provide a consistent, reliable, and "all-weather" capability. Thus, an SBR platform will conduct some meteorological-data collection, whether a stated objective or not, even if only to designate many obscured areas as "weather cluttered."

Furthermore, downward-looking SBRs offer a viewing angle advantageous to both military and meteorological applications. Specifically, vertical-looking radars provide an alternative way to illuminate objects that present a small cross section when viewed horizontally but a much larger one vertically. Illustrating this principle is the difference one notes in cross-sectional areas when looking straight-on at a B-2 bomber in flight—as a ground-based radar would when the aircraft is many miles away—and then looking straight down at the same aircraft, as an SBR would. Vertical-looking radars have the distinct meteorological advantage of providing much greater resolution along the axis in which weather parameters change the most over the shortest distances (e.g., consider how far one would have to travel horizontally to undergo the same weather change experienced in going up a mountain 10,000 feet high). Moreover, downward-looking meteorological radars can be designed to consume much less power and use much smaller antennas since their vertical radar beams travel through significantly less attenuating "weather" than their horizontally looking counterparts.

As a major ISR asset of the future, SBR offers huge benefits not only because of its space-based, vertical-look angle, but also due to its potential as a data integrator. The concurrent processing of weather information—such as precipitation, humidity, and wind velocities—would fuse mission-critical environmental effects into the find, fix, track, target, engage, and assess TCT process in real time. Currently, weather information is manually integrated into this TCT process through imagery and weather-analysis overlays. Due to the cumbersome nature of this fusing process, a significant amount of valuable weather information collected with separate ISR assets (such as the DMSP or geostationary operational environmental satellites) is not included in the TCT process.

The fact that government and military platforms such as radars and defense-support satellites may collect critical information that is either unused or unnecessarily and expensively collected by another platform is not completely lost on today's military leaders and visionaries. Gen Lance Lord, commander of Air Force Space Command, stated that "we get a lot of data. . . . We're collecting it more and enjoying it less"; he agreed that using an SBR platform to provide integrated meteorological data along with the intended GMTI information would constitute an example of "enjoying the data more."[12] General Lord also noted that although "many are looking to purchase and field more platforms, few are looking for ways to more fully exploit data from existing and future platforms—we need more data exploitation."[13]

Space-based collection and exploitation of meteorological data, such as the capability provided by the DMSP satellites, have long been considered a significant force multiplier—mainly at the strategic and operational levels of war. Incorporation of fused, real-time weather information with GMTI information would make the space-based collection of meteorological data a force multiplier at the tactical level as well. Indeed, SBR-derived, real-time weather data could provide the key, quick-decision (perhaps automated) information one needs for weapons and tactics selection (fig. 3). This highly perishable targeting information clearly resides at the tactical level of war, offering an excellent example of how integrating meteorological data collection with SBR data processing would make SBR a critical part of all six steps—find, fix, track, target, engage, and assess—in the TCT process.

Figure 3 also demonstrates that the joint and/or combined air and space operations center (JAOC/CAOC) would become a focal point for the beneficial effects of SBR-derived and integrated meteorological and oceanographic data. Automated, real-time, and fused SBR-derived weather would greatly enhance the CAOC weather team's ability to immediately and concurrently support the operations of all five CAOC divisions (strategy, plans, current operations, ISR, and air mobility) at all levels of warfare. Such operationally entwined, space-based weather information would strongly support the assertion of Brig Gen David L. Johnson, past Air Force director of weather, that weather is *the* critical ISR component (a point he makes by using the acronym "WISR" ["weather" plus "ISR," pronounced "wiser"]).[14]

Exploiting the SBR data stream for weather analysis would make "wiser" military commanders and command-and-control centers privy to the information and could improve worldwide numerical weather forecasting—for both military and civilian activities. Meteorological data collection by SBR and the resultant signal processing would undoubtedly provide atmospheric information about vast areas not now regularly sampled. Simply incorporating such data into the meteorological global data-assimilation system in a timely man-

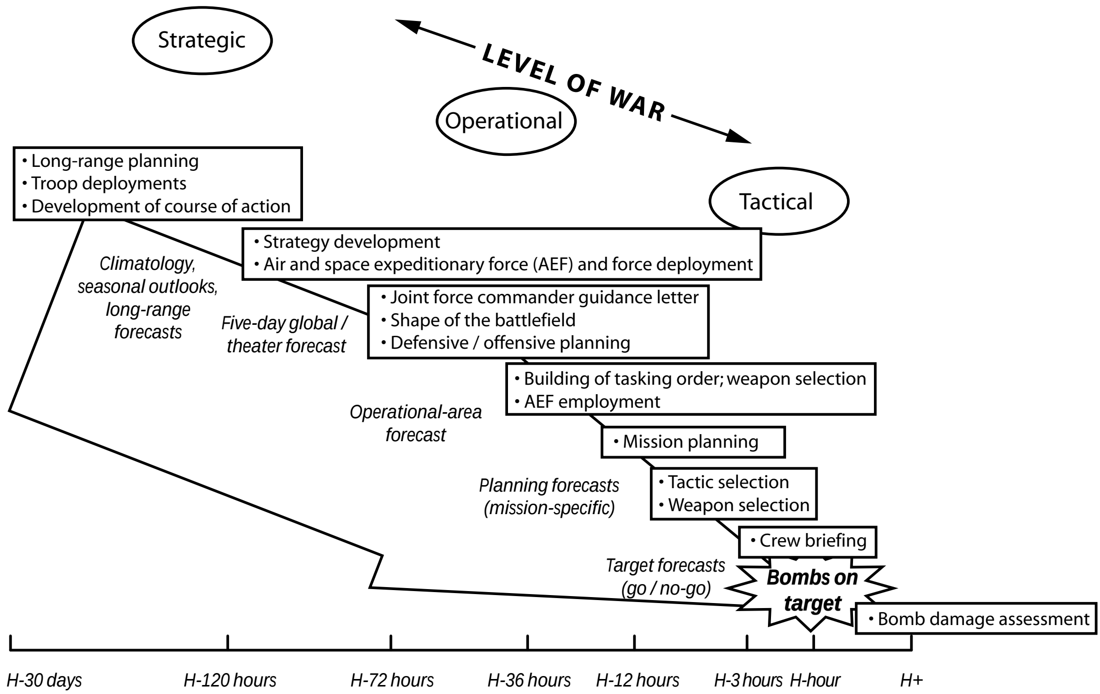


Figure 3. Impact of weather on operations at the strategic, operational, and tactical levels of war. (Adaptation of AF/XOW slide, Brig Gen David L. Johnson, "Environmental Situational Awareness" [preview of Joint Force Air and Space Component Commander Course weather lecture, Air War College, Maxwell AFB, AL, 8 February 2003].)

ner could greatly enhance short- and medium-range numerical weather prediction. A recent study showed that the incorporation of more than 170,000 automated observations from commercial aircraft worldwide resulted in a 10 percent reduction in forecasted wind errors in the rapid-update-cycle model used in the United States.[15] Notably, the automated observations from commercial aircraft were primarily recorded at one level near 30,000 feet rather than throughout the atmosphere. The SBR could collect atmospheric-profile data (at numerous, regularly spaced vertical intervals over each surface point), providing much greater data richness that, in turn, would likely result in significantly improved numerical weather forecasts.

Techniques developed to perform signal processing of SBR-derived meteorological information could subsequently lead to methods for extracting fused weather data from JSTARS and Global Hawk SARs. Fully exploiting all space-based and airborne radar assets for all GMTI, DTED, and meteorological information is fully consistent with the Transformation Flight Plan's networkcentric collaborative targeting (NCCT) concept, an operating system designed to fully integrate air, space, and surface ISR assets at the digital level.[16] The plan goes on to state that "by providing a seamless, machine-to-machine interface, NCCT can dramatically improve the geo-distributed processing environment by leveraging existing sensors, communications, and processing systems."[17]

Lastly, current meteorological research using the TRMM precipitation radar, combined with passive microwave radiometers such as those aboard the DMSP satellites, suggests that the obscuring effects of weather could eventually be reduced or nearly eliminated during signal processing ("weather clutter" removal). Another advantage of adding a radiometer to each of the SBR constellation satellites is the tripling in size of ground-area coverage (see the previous discussion of the TRMM satellite). Radiometer measurements would allow a more complete weather characterization because the radar/radiometer sensor combination would better account for the scattering and emission properties of the atmosphere and its natural and manmade constituents. Such a characterization of the weather environment through which the SBR operates would better permit removal of ambient adverse conditions that an adversary might use as cover.

Of course, the addition of a radiometer aboard an SBR satellite would add weight and cost. However, radiometers currently operating on board the DMSP and TRMM satellites are reliable, scientifically sound, and readily available via "commercial, off-the-shelf" means. Their cost would pale in comparison to the overall development costs of SBR.

Conclusions

As mentioned previously, weather data is not operationally collected and processed from virtually all radar equipment because of the vast amount of signal processing required to obtain useful and rapidly communicable information from those systems. Until the advent of solid-state electronics in the late 1960s and subsequent advances in computer technology, the amount of necessary radar signal processing forced a reliance on separate equipment and separately trained analysts for each radar discipline. Despite the modern capabilities that now allow automated, integrated signal processing, this split in the fields of military and meteorological radars persists to the present day—witness the lack of consideration given weather in the SBR proposal.

This article has asserted that the collection of quantifiable and operationally exploitable weather data from a future SBR platform appears both possible and feasible. Techniques for deriving meteorological information from the methods and equipment proposed for SBR have long been established. Integrated, SBR-derived weather information is feasible because it involves a signal-processing problem, not one requiring costly new equipment. However, we must conduct much additional research to develop specific weather-retrieval algorithms for use on the SBR data stream. Thus, the SBR program office should work closely with graduate-level military academic institutions such as the Air Force Institute of Technology and the Naval Postgraduate School to spearhead the algorithm effort. Using military academic institutions should keep research costs below those one might incur with civilian institutions.

By deriving real-time, fused weather data from the SBR platform, one would realize the benefit and advantage of fully entwining that data in the TCT cycle, thereby immediately incorporating key, perishable weather information into all parts of the find, fix, track, target, engage, and assess TCT cycle. Doing so would squeeze even more utility out of the SBR system and ensure that real-time (not forecasted) weather is fully considered in time-critical decisions concerning the selection of weapons and tactics. Thus, SBR-derived meteorological information would effectively embed valuable weather information from a spaceborne asset into the tactical level of war, as well as the strategic and operational levels.

Exploiting weather data from SBR would also provide a vast source of observational data on weather worldwide, consequently improving numerical weather forecasts for military and civilian endeavors alike. In addition to the Doppler-derived wind information, SBR would also provide microphysical—precipitation, clouds, and humidity—profile information, which could significantly improve numerical forecasts. To more specifically quantify how much SBR-derived weather data could improve forecasts for both military and civilian activities, the SBR program office should establish a cooperative study with the Air Force Weather Agency, which is uniquely positioned to consider the effects of additional weather observations on weather models. This agency operationally provides fine-scale, numerical-model forecasts for different regions of the world up to four times daily.

The exploitation of weather data could reap even greater benefits for the SBR program if the higher costs associated with additional equipment become acceptable. Therefore, a full cost-analysis study of the need for, benefits of, and justification for SBR weather-exploitation initiatives is very much in order. Such a study—perhaps best suited for the Air Force Institute of Technology, the Naval Postgraduate School, or a combination of the two—could highlight both a minimal-cost solution with no additional equipment and a higher-cost/greater-benefit project involving some addition to the SBR platform.

This article has argued that concurrently processing meteorological data from the proposed SBR data stream would prove militarily advantageous, cost-effective, and beneficial to civilian activities. Given the effect of weather on all aspects of military operations and its status as the medium through which SBR will operate, perhaps the strongest argument one can make is that the SBR program cannot meet its goal of "develop[ing] an integrated and interoperable architecture for theater and national information management" without incorporating weather signal processing.[18] □

Notes

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Doctrine NOTAM

Information Operations

Maj Paul R. Guevin, USAF

INFORMATION OPERATIONS (IO) doctrine has evolved from age-old concepts of influencing and shaping battles through deception and control of information to more recent methods based on advanced communications and electronic warfare (EW). Sun Tzu suggested the possibility of victory through bloodless battles by not fighting at all. IO could serve as a means to this end, presenting operational commanders capabilities to significantly affect an enemy's operations. Current and emerging doctrine has formalized and refined these IO concepts, with significant adjustments based on recent operational experience and analysis of our capabilities.

Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, 17 November 2003, defines IO as the integrated employment of three operational elements—EW operations, network-warfare (NW) operations, and influence operations—to affect or defend decision makers and their decision-making process (p. 46). These three interdependent elements focus on military actions in the electromagnetic, digital, and cognitive target domains, respectively, to achieve integrated effects across the battlespace and throughout the spectrum of conflict. We orchestrate such capabilities to influence the adversary's observe-orient-decide-act (OODA) loop while simultaneously defending our own loop.

EW operations employ electromagnetic and directed energy within the electromagnetic battlespace to support operational objectives. This battlespace includes the full range of the spectrum, from extremely low-frequency radio waves, through the infrared and visible bands, to gamma rays. Planning, execution, and assessment of EW operations enable electronic attack, electronic protection, and EW support activities.

NW operations support operational objectives by affecting and defending systems that transmit or receive information. The digital or information domain is composed of hardware, software, data, and human components. Planning, execution, and assessment of NW operations enable network attack, network protection, and NW support activities.

Influence operations support operational objectives by affecting behaviors, protecting operations, and projecting accurate information to achieve desired effects across the cognitive battlespace. Influence operations include the integrated military activities of counterpropaganda operations, psychological operations, military deception, operations security, counterintelligence operations, and public-affairs operations.

In concert with diplomatic, economic, and other information activities, IO becomes an essential function of air and space power that can influence leaders and populations to resolve conflicts. IO should precede and subsequently integrate with offensive air, land, sea, and space operations to shape and prepare the battlespace for decisive combat operations. Furthermore, it can set the stage for follow-on diplomatic, economic, and military activities.

The Air Force's senior leadership has crafted a refined vision for IO, affirmed through Corona South 2003 and published in our service's *Concept of Operations for Information Operations*. This document addresses the three operational elements described above and defines their capabilities in the context of integrated-control enablers, which harmonize air, space, and information operations to produce integrated effects for the joint fight. This IO concept of operations is the foundation for the forthcoming, completely revised version of AFDD 2-5, *Information Operations*.

To Learn More . . .

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Net Assessment

Airpower alone does not guarantee America's security. But I believe it best exploits the nation's greatest asset—our technical skill.

—Gen Hoyt S. Vandenberg

Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation by Lynn Eden. Cornell University Press (http://www.cornellpress.cornell.edu), Sage House, 512 East State Street, Ithaca, New York 14850, 2003, 384 pages, $32.50 (hardcover).

Lynn Eden's book examines the devastating firestorms that would follow the detonation of nuclear weapons, a topic largely ignored in the prodigious literature on nuclear policy and strategy. She begins her quest by raising an intriguing question: how and why did the US government ignore the possibility of catastrophic atomic firestorms as it developed plans for nuclear war fighting, especially in light of its World War II experience with firebombing and the atomic bombings of Hiroshima and Nagasaki?

The author begins her search for an answer with an empirical inquiry into why the US government routinely underestimated the damage caused by nuclear weapons. Her methodology compares damage predictions of the combined effects of blast and fire with much lower levels of damage expected if only blast effects are measured. Eden discusses and critiques alternative explanations of organizational routines that have seen use in predicting only blast damage. Her research shows that frames used by organizations, particularly the Air Force, to define problems and seek solutions lead to the acquisition of certain types of expertise as well as the emergence of both specialized research programs and knowledge-laden routines. In sum, this process of organizational problem solving causes actors to make critical choices about predictions of blast damage but not fire damage—predictions divorced from attributes of the actual physical environment.

Eden's inquiry into this organizational phenomenon begins with US bombing doctrine shaped in the 1930s and applied during World War II. US Army Air Corps officers believed that bomb damage resulted primarily from blast effects. Although American planners did not entirely ignore the potential for fire damage, they paid far greater attention and applied more resources to predicting and optimizing blast damage.

The blast-damage frame, which carried over into the post–World War II era, strongly influenced the earliest attempts in 1947 and 1948 to predict damage from atomic bombing. Because of the historical association of blast damage with bombing and because analysts and planners believed it more predictable than fire damage, experts, research programs, and knowledge-laden routines focused exclusively on understanding blast damage. By the early 1950s, an extensive research program had arisen for the purpose of acquiring detailed knowledge about the effects of an atomic blast. Consultants hired to conduct this research helped shape the agenda, interpreted data, and developed analytical tools to better predict blast damage. However, no comparable activity sought to understand fire damage from atomic attacks.

US nuclear tests conducted in the early 1950s generated new data that verified and expanded the Vulnerability Number system, a blast-damage model developed in 1951. Although the Air Force commissioned a single study during this period to predict atomic fire damage, the effort did not yield compelling predictions. Other government organizations concerned with civil defense and the protection of equipment during war performed extensive experiments, but none studied or predicted damage from mass fires. Detonation of the first hydrogen bomb by the United States in 1952 created new problems for measuring blast effects due to the longer duration of the blast wave. Accordingly, by the mid-1950s analysts had devised a new method for calculating blast damage for higher-yield weapons. By the late 1950s, they had incorporated this method into a new knowledge-laden routine for predicting blast damage: the VNTK system (VN = vulnerability number, T = type of structure attacked, and K = sensitivity to the duration of the blast wave). Although fire damage increased dramatically compared to blast damage for higher-yield weapons, no one attempted to measure this effect.

From the mid-1950s through the 1970s, a small fire-research community funded by US government agencies interested in civil defense produced computer models of house fires, forest fires, and nuclear mass fires; however, their research failed to produce consistent, reliable predictions. Thus, this work effectively confirmed the organizational beliefs and knowledge-laden routines of individuals oriented toward asserting blast damage as the key metric for understanding the effects of nuclear weapons.

In the 1980s, the Defense Nuclear Agency undertook an effort to predict mass fires for use in nuclear war planning. This study was based on the work of Harold Brode, a scientist at the Pacific-Sierra Corporation, who used an approach which differed markedly from that of the fire-research community. By the early 1990s, Brode and his collaborators had developed a method for predicting both blast and fire damage, and the US government nearly adopted this model for its nuclear war plans. Despite Brode's conclusions, the fire-research community continued to claim that mass fire damage could not be predicted accurately. The group's view, which coincided with the end of the Cold War, proved influential in government circles. This confluence of organizational choice, bureaucratic influence, and historical change halted the US government's interest in developing models to incorporate both blast- and fire-damage models into its nuclear strategy.

As a study of the interplay among science, technology, organizations, and history, Lynn Eden's book makes a valuable contribution to the literature. Importantly, her study raises questions about whether the US nuclear arsenal during the Cold War exceeded actual requirements because it neglected a potentially important metric for measuring overall nuclear effects. Furthermore, it draws parallels to failures caused by misinformed experts and faulty knowledge-laden routines. For example, experts wrongly understood the brittleness of the steel plates used in the *Titanic* and did not fully understand the O-ring problem that caused the *Challenger* disaster. Nor did the designers of the World Trade Center grasp the critical difference between the effect of an impact from a Boeing 707 and that of thousands of gallons of jet fuel burning inside the buildings.

Whole World on Fire is thoroughly researched and well documented. Despite Eden's occasionally abstruse and sermonizing prose, her work reminds us of the importance of applying critical thinking to solving problems. Otherwise, we risk the danger of casually applying historically framed organizational routines as though every problem conforms neatly to the past and is amenable to the same set of solutions. Although the author acknowledges that "precaution can be mind-bogglingly expensive" and seems inclined to err in favor of having precaution influence policy and strategy, I suggest that excessive caution can lead to thinking and outcomes just as muddled and wrong as those shaped and influenced by dogmatically applied, knowledge-laden routines.

Lt Col Charles E. Costanzo, PhD, USAF, Retired
Maxwell AFB, Alabama

Contemporary Nuclear Debates: Missile Defenses, Arms Control, and Arms Races in the Twenty-First Century edited by Alexander T. J. Lennon. MIT Press (http://www-mitpress.mit.edu), Five Cambridge Center, Cambridge, Massachusetts 02142-1493, 2002, 344 pages, $24.95 (softcover).

Who cares about nuclear missiles? They're *so* eighties. We won the Cold War. Terrorists, suitcase bombs, anthrax, radiological dirty bombs, and improvised explosive devices dominate the new strategic lexicon. We have to worry about terrorists now. Russia isn't going to attack; we're allies. China doesn't have a reason to do so; it's concentrating on economic reform and embracing capitalism, if not democracy. North Korea? Well, next year our new ground-based missile-defense system will reduce that threat. Right?

On the other hand, although the Cold War is over, thousands of nuclear weapons remain in the depots of several nations. With them lie the seeds for a new crop of deterrence, missile-defense, and arms-control pundits. That's where *Contemporary Nuclear Debates* comes in, filling the gap—let's call it the dialog gap—where advocates for post–Cold War missile defense, arms control, nuclear testing, and their opponents square off.

In reality, the stakes today are a bit different. Cold Warriors remember the air-raid drills in school and the threat of a "nuclear winter" or apocalyptic film and television fantasies like *Dr. Strangelove* and *The Day After*. Tomorrow's leaders will remember the twin towers coming down and terrorist-attack evacuations from school. Yet, the Cold War threats never really went away—they're just obscured behind the dust of the falling Wall, less likely to occur but potentially much worse if they do. Although terrorists remain the most likely threat, they aren't necessarily the *only* "worst case" scenario.

An anthology of essays, pro and con, *Contemporary Nuclear Debates* helps frame the current nuclear discussion, considering a number of pretty bad scenarios. Its contributors are well known in national-security circles; some are or were high-ranking officials in the US government. The scope and breadth of its analyses make the book worthwhile reading. Its 25 essays fall into four parts: (1) "National Missile Defense: When and How?" (2) "Global Perceptions of Missile Defense," (3) "Do Arms Races Matter Anymore?" and (4) "Is Arms Control Dead?" Despite the book's publication date of 2002, the essays were obviously written earlier—some before withdrawal from the Anti–Ballistic Missile Treaty in May 2002. Consequently, the inclusion of some anachronistic artifacts, such as debates over that treaty, are distracting.

Two essays are particularly striking. In "Toward Missile Defense from the Sea" by Dr. Hans Binnendijk and Dr. George Stewart, we learn that Secretary of Defense Donald Rumsfeld changed the missile-defense world in 2002, exchanging the "theater ballistic missile" and "national missile defense" nomenclature and substituting a new philosophy: we defend against a spectrum of missile threats with a multilayer missile defense. This spectrum includes prelaunch, boost, midcourse, and terminal stages.

The authors assert that sea-based defenses are better focused on the boost threat rather than the midcourse and terminal threats (p. 64). Furthermore, sea-based radar provides many advantages, not the least of which is the fact that it is not destabilizing (pp. 58–59). This discussion of missile defense and sea-based radar has importance to Airmen because the joint aspect of missile defense affects the Air Force tremendously. Air Force and selected long-range naval assets such as Tomahawk missiles represent America's knock-down-the-door force. Furthermore, the prelaunch and boost phases offer the perfect times to hit enemy missiles, so they can blow up on or over enemy territory—not over the heads of friendly troops or allies. (This is precisely the problem with waiting until the midcourse or terminal stages. To be fair, though, a nominal threat of collateral damage may exist, depending upon the missile's payload and trajectory, as well as the point in the boost phase when it is hit. But that threat seems much more severe if the debris lands on friendlies.) The authors also present well-thought-out pros and cons for sea-based radars, especially as part of a defense system using intercontinental missiles (pp. 50–61).

Another noteworthy essay, "Action-Reaction Metaphysics and Negligence" by Dr. Keith Payne, formerly the assistant secretary of defense for force policy, at first just sounded bad to an old fighter pilot. However, the article gets to the heart of many assumptions thrown around as facts in current defense debates, such as "defense encourages attack" or "missile defense encourages an arms race" (pp. 197–207).

According to Dr. Payne, critics of missile defense would argue that "the Salt I and II negotiations were premised on the assumption that limitations on strategic offensive forces would not be possible without extensive constraints on strategic defenses" (p. 198). However, he points out that President Bush's "call for both nuclear force reductions and missile defense deployment poses a direct challenge to this foundation of Cold War thinking" (p. 198). This notion remains very important for today's policy discussions, especially since missile defense will soon become reality.

Dr. Payne offers a short, historical argument on the issue of defense: "From the late 1960s to the present, the first order response to US missile defense initiatives by political opponents has been to assert . . . the 'inevitable' superiority of the offense"; Payne calls such a response "nonsense" (p. 202). He's right; otherwise, why do we even attempt to do defensive counterair or force protection? Why put a losing doctrine in print? Why even try? Dr. Payne supports his assertion with good evidence of defenses that have worked quite well, including Athens's defensive walls in the Peloponnesian War; Constantinople's walls, which provided almost a millennium's worth of security; and British air and naval defenses that prevented Operation Sea Lion in World War II. He even brings up Clausewitz, who considered defense generally stronger than offense. Obviously, each situation is different, but it's hard to argue that we shouldn't defend the United States from missile attacks because the task is too difficult or will provoke someone to attack who otherwise would not. Perhaps defense alone won't win, but that isn't how we propose to defend our nation; arguments against defense on a historical basis are weak.

Contemporary Nuclear Debates includes many more great essays, a few of which seem a bit dated. Overall, I heartily recommend this book to readers interested in both missile defense and the nuances of *Dr. Strangelove*. It is also an important book for students of strategy—both current and future decision makers—who want to get their arms around the security dilemma posed by nuclear weapons and their defenses.

Lt Col Merrick E. Krause, USAF
Washington, DC

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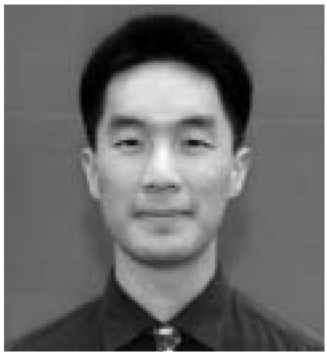
The Editor

The Honorable Peter B. Teets (BS, MS, University of Colorado; MS, Massachusetts Institute of Technology) is undersecretary of the Air Force, responsible for all actions of the Air Force on behalf of the secretary of the Air Force; he is acting secretary in the secretary's absence. In that capacity, he oversees the recruiting, training, and equipping of more than 710,000 people and a budget of approximately $68 billion. Designated the Department of Defense executive agent for space, Mr. Teets develops, coordinates, and integrates plans and programs for space systems and the acquisition of all the department's major space-defense acquisition programs. As director of the National Reconnaissance Office, he is responsible for the acquisition and operation of all US space-based reconnaissance and intelligence systems. This position includes managing the National Reconnaissance Program and reporting directly to the secretary of defense and the director of central intelligence. He is the retired president and chief operating officer of Lockheed Martin Corporation, a position he held from 1997 through 1999. Mr. Teets is a Fellow of both the American Institute of Aeronautics and Astronautics and the American Astronautical Society, as well as a member of the National Academy of Engineering.

Gen Lance W. Lord (BS, Otterbein College; MS, University of North Dakota) is commander of Air Force Space Command, Peterson AFB, Colorado. He is responsible for the development, acquisition, and operation of the Air Force's space and missile systems. The general oversees a global network of satellite command and control, communications, missile warning, and launch facilities and ensures the combat readiness of America's intercontinental ballistic missile force. He leads more than 39,700 space professionals who provide combat forces and capabilities to North American Aerospace Defense Command and US Strategic Command.

Col John E. Hyten (BA, Harvard University; MBA, Auburn University) is the director of the Commander's Action Group, Air Force Space Command. Previously he served in a variety of Air Force space-related engineering and acquisition positions, unified commands, joint positions in the Army, and commanded the 6th Space Operations Squadron, Offutt AFB, Nebraska. Colonel Hyten also served on the senior staff of the Air Force Secretariat where he worked sensitive technology programs and was a member of the 1992 Air Force Blue Ribbon Panel on Space. He is the only military recipient of the prestigious William Jump Award for outstanding public service. Colonel Hyten is a distinguished graduate of both Squadron Officer School and Air Command and Staff College and served as an Air Force National Defense Fellow at the University of Illinois at Urbana-Champaign.

Brig Gen Duane W. Deal (BS, MS, Mississippi State University; MS, University of Southern California) is the commander of the Cheyenne Mountain Operations Center, Cheyenne Mountain Air Force Station, Colorado. He has commanded four squadrons, one group, and three wings. General Deal had served as a president or member of a dozen aircraft and space-launch accident investigations before being appointed to serve as a member of the *Columbia* Accident Investigation Board on 1 February 2003, hours after the tragic shuttle loss. He is a graduate of Squadron Officer School, Air Command and Staff College, Air War College, and Marine Corps Command and Staff College. He completed the Executive Development Program of Dartmouth College and served as a fellow at the Harvard Center for International Affairs and also as a fellow at the RAND Corporation. He has piloted seven aircraft types, including the SR-71 Blackbird, and served as crew commander in two Air Force space systems. The general has authored more than 20 published articles on aviation, leadership, and technical subjects.



Dr. Robert V. Uy (BSE, University of Michigan; BA, University of Canterbury; MS and PhD, California Institute of Technology [Caltech]) is a member of the Institute for Defense Analysis's research staff and was previously the RAND intern, Commander's Action Group, Air Force Space Command. He has 14 years of experience with civil, commercial, and military space programs. Dr. Uy has authored and coauthored numerous RAND publications and other technical articles.

2d Lt Brent D. Ziarnick (USAFA) is a satellite vehicle officer with the 2d Space Operations Squadron (GPS), Schriever AFB, Colorado. Previously, Lieutenant Ziarnick underwent Officer Space Prerequisite Training and Initial Qualification Training at Vandenberg AFB, California.

Maj Samuel L. McNiel (BA, Baylor University; MA, George Washington University; MMOAS, Air Command and Staff College) is the executive officer in the National Security Space Integration Directorate, Office of the Undersecretary of the Air Force. In addition to staff experience in Headquarters Air Force, he has commanded a space-surveillance detachment, served as an operations officer in a space-surveillance squadron, and held various instructor-qualified space and missile operations and staff positions. Major McNiel is a graduate of Squadron Officer School and Air Command and Staff College.

Lt Col Brian E. Fredriksson (BS and MS, Lehigh University; MS, Troy State University; MMOAS, Air Command and Staff College; MAAS, School of Advanced Air and Space Studies) is the chief of plans, Fourteenth Air Force, Vandenberg AFB, California. Previously, he served in a variety of missile- and space-related operational and staff positions at the squadron, wing, and command levels. Colonel Fredriksson is a graduate of Squadron Officer School, Air Command and Staff College, School of Advanced Air and Space Studies, and Air War College.

Maj Todd C. Shull (BA, Colorado State University; MS, University of North Dakota) is chief of the Policy and Strategy Section, Headquarters Air Force Space Command (AFSPC), Peterson AFB, Colorado. He has previously served as chief of the Doctrine Section, Headquarters AFSPC; executive officer for the 30th Space Wing and current-operations plans officer for the 30th Operations Support Squadron, Vandenberg AFB, California; missile-warning test manager for the 721st Support Group, Cheyenne Mountain Air Force Station, Colorado; and ICBM instructor crew commander with the 446th Missile Squadron, Grand Forks AFB, North Dakota. Major Shull is a graduate of Squadron Officer School.

Douglas E. Lee (USAFA; MS, Air Force Institute of Technology) is a military defense analyst with the Airpower Research Institute, College of Aerospace Doctrine, Research and Education, Maxwell AFB, Alabama. Before retiring as an Air Force lieutenant colonel in 1999, he served as chief of the Operational Communications Branch, US Strategic Command; chief of the Space Branch, Air Force Studies and Analyses Agency; operations research analyst with US Southern Command; and ballistic missile trajectory engineer with Strategic Air Command. Mr. Lee is a graduate of Squadron Officer School, Air Command and Staff College, and Marine Corps Command and Staff College.

Maj Steven T. Fiorino (BS, MS, Ohio State University; MMOAS, Air Command and Staff College; BS, PhD, Florida State University) is an assistant professor of atmospheric physics at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio. During his career, he has served as wing weather officer, 319th Bomb Wing, Grand Forks AFB, North Dakota; officer in charge, Weather Flight, 806th Bomb Wing (Provisional), during Operation Desert Storm; acquisition systems meteorologist, Wright Laboratory (now the Air Force Research Laboratory), Wright-Patterson AFB; Weather Flight commander, 1st Fighter Wing, Langley AFB, Virginia; and joint meteorological and oceanographic officer, joint task force, Southwest Asia. Major Fiorino is a graduate of Squadron Officer School and Air Command and Staff College.

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