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WHY AMERICA NEEDS SPACE

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COVER: America needs Space! Space is the ultimate high ground. With satellites on orbit we can monitor activities around the globe that are encompassed by our national security interests. By gaining and maintaining Space Superiority...we can encourage peace...and win wars. Space also provides the deterrent blanket that allows us to enjoy the many freedoms we do today.

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Why America Needs Space: The Prerequisites for Success

General Lance W. Lord
Commander, Air Force Space Command

The Doors of Wisdom are never shut.
- Benjamin Franklin

For space warriors and joint warfighters the theme for this *High Frontier* issue should seem all too elementary. We have seen firsthand the revolutionary changes brought about by the integration of space capabilities onto the modern battlefield. From the Cold War to the first Gulf War and to Operations ENDURING FREEDOM and IRAQI FREEDOM, we have witnessed a remarkable transformation. However, as space has become main stream we sometimes take for granted the capabilities it provides. This issue of *High Frontier* is devoted to the theme of "Why America Needs Space." It is vitally important for each of us to understand the answer and to continue fighting for the capabilities vital to the success of the joint warfighter.

In the simplest terms, America needs Space for its National Security and the survival of our way of life. We need space just as we need land, air, and sea forces. Removing one of those components of our National Security would render us incapable of defending the Nation. Removing space from the equation not only cripples our land, air and sea forces but it would have catastrophic consequences to our entire economy. In 1998, we saw firsthand what the loss of a satellite could do to our economy and way of life. Galaxy IV lost its Earth orientation, wiping out pager traffic for 40 million pagers in the US, halting credit card transactions and ATM machines, and knocking TV and radio stations off the air. Space is beyond a joint warfighting catalyst; it is a universal necessity and must be protected as such. It is important though, to recognize there are many different perspectives on the relevance of space.

Space makes us safer, makes warfare less likely, and less destructive. We have all witnessed the incredible images of a bomb going down an elevator shaft or bridge being destroyed with a single aircraft dropping multiple precision weapons. Those are vivid images of the awesome combat power of our armed forces. However, we should look beyond the combat effects for the true lesson in those images. The real story is about the destruction that didn't occur because we were so precise. The real story is about the troops on the ground that were not put in harm's way. The real story is also about the collateral damage that did not occur to civilian populations. The bottom line is our space capabilities save lives and minimize destruction, and for that reason we have a moral responsibility to maintain the world's preeminent space and missile force.

For many Americans, the most visible images of space are the Space Shuttle and the International Space Station. These programs have accomplished amazing things and have greatly contributed to our quality of life. However, that's just the tip of the iceberg. Most of what goes on in space is transparent to the average person. We do not see space at the Automatic Teller Machine or at the checkout counter in the supermarket, but it is there. Precise timing signals from the Global Positioning System synchronize financial transactions, making them possible. Most people probably don't think about space when they are cooking dinner, but it plays a role there too. Farmers use space assets to map the mineral and moisture content of their fields. The cost savings farmers achieve are then passed to consumers. Similarly, it takes space capabilities to get accurate weather forecasts and provide seamless world-wide communication connectivity. In total, today's space industry exceeds $100 billion annually world-wide, and is projected to exceed $150 billion per year by 2010. We could do without space capabilities, but only if we are willing to step back in time about 30 years.

> *Always bear in mind that your own resolution to succeed is more important than any other thing.*
>
> - Abraham Lincoln

On the modern battlefield space is enabling us to do things never accomplished before in human history. Navigation, missile warning, surveillance, weather, communications, and space control have been necessities to combat for more than a decade. Space capabilities are the lifeblood of our modern military. Space and space technologies are the horizontal integrators, connecting our forces around the globe. Space is shrinking the modern battlefield much like the technology boom has shrunk the world we live in. However, the enemy is paying attention and adapting to counter our strengths. We must fully appreciate this landscape in order to develop and build the proper space systems for the future.

While we talk about America's need for space it is also important to talk about what we need to do to ensure we are the best at what we do. We have devoted a great deal of energy to our Command's top three priorities:

#1) Continue our emphasis on ensuring Space Superiority and Provide Desired Combat Effects for Joint Warfighting
#2) Maintain a safe and secure Strategic Deterrent Capability and providing a means for Prompt Global Strike
#3) Continue efforts to develop Cost-Effective Assured Access to Space

Our priorities are important, but we can only make progress toward them by laying a solid foundation. This foundation is formed by three common prerequisites for success that cut across each of the priorities. First, we have the urgent need to develop our space professionals and prepare them for success. We are nothing without our space professionals. Our second prerequisite is space acquisition. We must strive to make space acquisition the model for the entire Department of Defense. Third, we must continue to demand nothing short of excellence in space and missile operations.

In these tight budget times, it is vital that we can clearly communicate the space message as informed professionals. That is where our Space Professional Development Program comes into play. If America needs space, it certainly needs space and missile professionals. It is not enough for space professionals to understand the technical specifications of their particular system and how to operate it. We must understand our complete environment, how we fit into it, and the impact we have on those around us. Anticipating the requirements of the joint warfighter is essential.

The professionals at the National Security Space Institute, in Colorado Springs, have made great strides. The foundation for success has been laid but the work is not finished. On 20 June 2005 we lost the father of space and missiles, General Bennie Schriever. He accomplished amazing feats in his life, but he did not do it by waiting for success. Similarly, as space professionals, we must take an active role in our future. We must seek out the knowledge we lack so that when an opportunity presents itself we will be prepared.

On the acquisition front we have learned important lessons the hard way. However, we never lost the recipe for success, we just didn't follow it. We must continue to persevere and battle through many of the congenital defects in our existing programs. Our goal is to become the model for acquisitions excellence DoD-wide. The joint warfighter's need for space demands nothing less. There will be bumps in the road along the way but that is our only option. If we are going to do something we need to do it right. General Schriever developed a brilliant engineering and manufacturing model during the 1950s and 1960s when we stood face to face with the Soviet Union. He faced monumental technical challenges. Today, we are also locked in a struggle with an enemy that wishes to destroy our way of life. The first step to securing our future is to efficiently and effectively acquire the space systems and capabilities required by the joint warfighter.

Excellence in operations has been the hallmark of Air Force Space Command for more than two decades. Our 3,000 plus space and missile operators can be counted on 24/7 around the globe. However, they are not alone. It takes a total team effort of the nearly 40,000 members of Air Force Space Command. In the current fight against terror and in future conflicts, America will continue to demand excellence in space and missile operations.

Finally, we should recognize that we are only effective as a fighting force when we are backed up by our ICBM warriors. In talking about our ICBMs, our former Chief of Staff, General Jumper described them as, "Top cover for the AEF." Our ICBMs assure our Allies, dissuade our foes, and deter attack. They are one of the fundamental reasons why we won the Cold War and why we haven't seen weapons of mass destruction used against us. America's space security starts with our ICBMs and the warriors operating, securing, and maintaining them. Recently, we closed the book on Peacekeeper by deactivating the 400th Missile Squadron at F.E. Warren AFB. However, that is in no way a reflection on the importance of strategic deterrence. Our Nation, and our Allies, are safer because of ICBMs.

This issue of *High Frontier* will highlight many success stories. I encourage Space Professionals and professionals in all disciplines to think critically about each article and enter the dialogue on how we can continue to evolve space support to the warfighter. Amazing things are going to happen in our next 50 years and it is our duty to be prepared. The need for space and the professionals that make it happen is only going to increase with time. Space was never the birthright of the Air Force, but it can be our destiny if we seize the opportunity.

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Transformational Technologies of the Early Space Age: Their Growth, Evolution and Improvements to Quality of Life

Mr. G. Thomas Marsh
Executive Vice President,
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At the dawn of the 21st century, we inhabit a world drenched by a steady rain of digital ones and zeros. This binary torrent is completely invisible to us, but it moves in two currents – from the sky down to Earth and back up again. It links us to satellites that serve us, and connects the world in a way that is difficult for even the most fertile imagination to grasp. The writer and visionary Arthur C. Clark postulated a law that, without doubt, applies here: "Any sufficiently advanced technology is indistinguishable from magic."[1]

It certainly seems like magic. Upon first waking, we have instant access to weather reports supported by decades of data carefully collected and analyzed in a way that can tell us, with unprecedented precision, whether we should wear a sweater or carry an umbrella. Walking to our car we can pull out a device and talk to a friend or business associate on the next block or continents away, while reading one e-mail and composing another. A few more buttons bring up a menu of destinations en route to work – to find our favorite cappuccino, or avoid a traffic snarl. As we prepare to retire for the evening, we can watch – in real-time – as events that will affect us the next morning unfold around the globe.

While pursuing our everyday activities, other satellites are scouring the most distant reaches of the universe, searching Mars for evidence of water, discovering volcanoes on Saturn's moon Titan, studying our Sun and assessing the health of the Earth's environment. Closer to home, still other satellites protect our security by quietly monitoring arms control agreements, protecting our warfighters and providing vital information to our leaders.

Nearly 50 years into the Space Age, the world is utterly transformed. But how did we get here? During the last half of the 20th century, our utilization and exploration of space represented the defining model for technological pre-eminence. But it was born of Cold War competition, beginning with an urgent search for solutions to questions of utmost national interest.

This article will focus on four space technologies that had their birth in the 1950s and 1960s – observation satellites, navigation satellites, communications satellites, and environmental satellites – their growth and evolution across the decades, and the benefits that have accrued from some of the missions that employ them today. The list is not all-inclusive, and there are commonalities among the categories, but it does provide us a baseline from which to view those basic capabilities and their impact on the world nearly a half-century later.

THE MOTHER OF INVENTION – AN END TO HISTORIC AMERICAN INVULNERABILITY

The American homeland – protected by great oceans to the east and west – had remained free from attack since the War of 1812. The dominant sentiment of American invulnerability persisted through the remainder of the 19th century and well into the 20th. A young Abraham Lincoln put voice to this shared feeling in a speech at Springfield, Illinois on 27 January 1838: "Shall we expect some transatlantic military giant, to step the Ocean, and crush us at a blow? Never! All the armies of Europe, Asia, and Africa combined, with all the treasure of the earth (our own excepted) in their military chest; with a Bonaparte for a commander, could not by force, take a drink from the Ohio, or make a track on the Blue Ridge, in a trial of a thousand years."[2]

As Americans read newspaper reports of the brutal fighting in World War I and prepared to send their sons to battle, they still believed that our wars would always be "Over There," as embodied in the popular song of the time by George M. Cohan.[3] World War II saw Americans engaged in epic battles in two theaters half a world apart – the Pacific and Europe – still ended with a victory that spared our own homeland.

However, hope and optimism soon gave way to uncertainty

"Shall we expect some transatlantic military giant, to step the Ocean, and crush us at a blow? Never! All the armies of Europe, Asia, and Africa combined, with all the treasure of the earth (our own excepted) in their military chest; with a Bonaparte for a commander, could not by force, take a drink from the Ohio, or make a track on the Blue Ridge, in a trial of a thousand years."

- Abraham Lincoln

and disquiet. The Soviet blockade of Berlin in 1948 was the first serious incident of the Cold War. One year later, the Russians successfully tested their first atomic bomb. A lingering fear of nuclear annihilation hung in the air. *Life* magazine published an article in December 1950 that detailed "How American Cities Can Prepare for Atomic War."[4] In 1952, the US successfully tested the first hydrogen bomb, but the Russians duplicated the feat barely nine months later. American students were soon crouching under their desks as schools regularly practiced nuclear attack drills.

Divining Russian intentions under such circumstances was exceedingly difficult because the highly disciplined, closed society they had created was nearly impossible to penetrate. One fact emerged: Soviet aims were not benign. They were in hot pursuit of an offensive nuclear capability and the US urgently needed good intelligence on their present and future capacity.

President Dwight D. Eisenhower, calling on experience as Supreme Commander of the Allied Expeditionary Force in World War II, thoroughly understood the importance of intelligence, as well as its limitations. Because he appreciated the danger of being caught off guard, in early 1954 he called upon the Nation's most eminent academicians and scientists to study the problem of surprise attack and return with recommendations on how best to protect the country.

The group, called the Technologies Capabilities Panel, reported back less than a year later with a document entitled "Meeting the Threat of Surprise Attack," providing a technological roadmap to a less dangerous world that served as a catalyst for the difficult work ahead.[5]

"In this period of explosive innovation, the nation would produce the U-2 spy plane, which could cruise at 75,000 feet, and started work on a successor aircraft so advanced that it would be considered a startling engineering feat if proposed today. In the late summer of 1960, the United States placed the first successful reconnaissance satellite in orbit. Along the way, scientists, engineers, businessmen and government officials who worked on these highly classified programs rewrote the book on airplane design and performance that led the nation into space. They transformed the world of intelligence by building machines that in a day could collect more information about a foreign enemy than an army of spies could assemble in a decade, and opened the way to a sea change in warfare made possible by the development of space-based reconnaissance, mapping, communications, and targeting systems. Altogether, it was a triumph of American ingenuity and technology, the Cold War equivalent of the Manhattan Project."[6]

During the same period the US was developing missiles that, if necessary, would carry nuclear weapons to the enemy. The Atlas ICBM led the way. Work began in January 1955, culminating in a successful launch just shy of three years later in December 1957. The Thor IRBM (later to be renamed Delta) also began development in 1955 and was launched successfully in late 1957.[7] The Titan ICBM was launched successfully in February 1959.[8] These rockets, and the launch vehicle families into which they evolved, continue to serve US launch requirements in the 21st century.

TRANSFORMATIONAL TECHNOLOGIES OF THE EARLY SPACE AGE

The necessity of protecting the Nation was the real genesis of the US space program. It was the search for solutions to life and death problems that drove American science and engineering to create the transformative technologies that would allow us to understand the threat and defend against it.

Many of the technologies that seeded our early efforts in space have grown exponentially across five decades, and in the process have spawned innovation resulting in previously unimagined capabilities. They have provided us with valuable tools that have enhanced our National Security and, at the same time, have had significant positive impact on the lives of the people of the planet.

Observation Satellites

It was the "need-to-know" that spawned Corona, the very first reconnaissance satellite. Corona's initial completely successful mission began with a launch into polar orbit from Vandenberg Air Force Base (AFB) aboard a United States Air Force (USAF) Thor booster on 17 August 1960. During the flight, the satellite exposed 3,000 feet of film, taking in a view of over 1.6 million square miles of territory previously inaccessible to the US. Corona acquired more overhead imagery of the Soviet Union than was accumulated on all of the U-2 flights to that date.[9] Former Director of Central Intelligence Richard Helms assessed the impact of this new technology: "The intelligence explosion of the century was on, a relentless stream of detailed data which turned analytical work on these so-called 'denied areas' from famine to feast."[10]

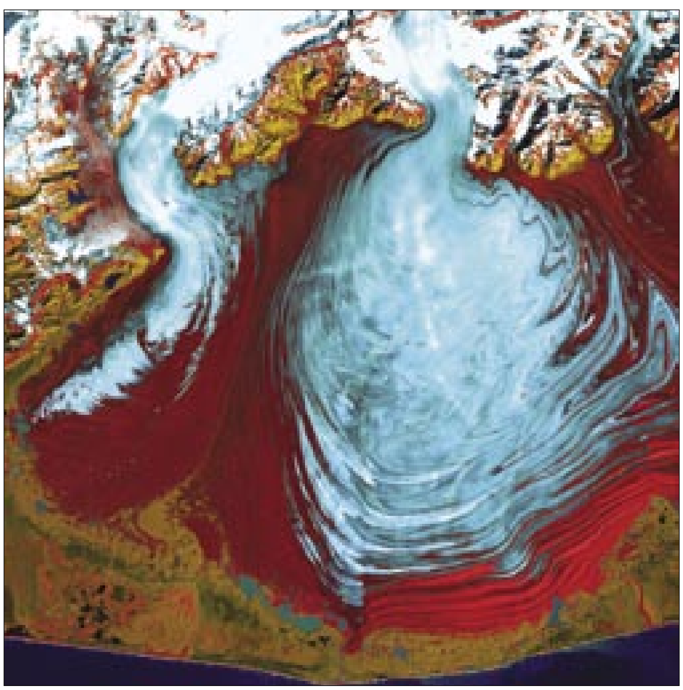
"The intelligence explosion of the century was on, a relentless stream of detailed data which turned analytical work on these so-called 'denied areas' from famine to feast." - Richard Helms

In service from 1959 to 1972, Corona was built by the Lockheed Martin Space Systems Company, formerly Lockheed Missiles & Space Company (LMSC), Space Systems Division. LMSC served as prime contractor, technical advisor and integrator for all Corona equipment other than the Thor booster. The company also developed the Agena upper stage and integrated and led the test, launching, and on-orbit control operations of Corona. Beyond Corona's distinction of being the first program to deliver intelligence from a satellite, it would be the first to pass the 100-mission mark, to recover an object from orbit, to utilize multiple reentry vehicles and the first to acquire stereoscopic imagery. But perhaps most impressive was the improvement in the quality of photographs provided to analysts. Over just 13 years, the resolution improved by greater than a factor of six – from an initial 40-foot capability to the means to discern objects just six feet across.[11]

Even as Corona was providing unprecedented access to areas previously denied, other more powerful satellites were under development. Because Corona captured its image on photographic film, it placed inherent limitations on the length of a mission. When the film was expended, the satellite's mission was over. The deorbit, capture, and processing of film consumed days before the real image made its way to the eyes of an intelligence analyst or decision-maker.

The need to view images in near real-time became the driver for a new technology. The Central Intelligence Agency (CIA) sponsored the development of what would later be called the Charge Coupled Device (CCD).[12] The CCD holds a variable charge that can be made proportional to the amount of light that falls on it, thus recording black, white, and many shades of gray in between. With light represented as electrons instead of silver molecules on a film, the CIA could collect and store images quickly and retrieve them digitally for manipulation and examination. The same CCD technology is now used in virtually all of our imaging satellites, and has made its way into such prosaic devices as consumer digital cameras, camcorders, and even cell phones.

The technologies and capabilities developed for Corona and its follow-on reconnaissance satellites not only made the Nation more secure, but supplied the US with potent means with which we have mapped and measured the Earth, explored other planets in our solar system, and begun to unravel the deepest mysteries of the universe.



USGS EDC

Figure 1. This Landsat 7 view, acquired on 31 August 2000, shows the tongue of the Malaspina Glacier, the largest glacier in Alaska, filling most of the frame. The Malaspina lies west of Yakutat Bay and covers 1,500 square miles (3,880 square km). The spectacular image demonstrates the superb ability of Landsat 7 to capture the lay of the land from space.

On 23 July 1972, the National Aeronautics and Space Administration (NASA) launched the first Earth Resources Technology Satellite (ERTS), later called Landsat. It was designed to provide high-quality moderate resolution data depicting the land and coastal regions of Earth. Five more Landsat spacecraft would reach orbit during the next 27 years, and two of them – Landsat 5 and Landsat 7 – remain operational.[13] All of the Landsat spacecraft were launched from Vandenberg AFB into near-polar orbits (inclined 98 degrees to the equator) that allowed them to image the entire Earth, one slice at a time as it rotated below. In 1975, NASA Administrator Dr. James Fletcher stated: "If I had to pick one spacecraft, one space development to save the world, I would pick ERTS and the satellites which I believe will be evolved from it late in this decade."[14]

Since that first launch, Landsat satellites have continuously supplied land surface images of the globe. Landsat's 33-year collection of land images serves those who observe and study the Earth, those who manage and utilize its natural resources and those who monitor the changes brought on by natural processes and human activities. The images provide information applicable to the broad and diverse needs of business, science, education, and government.

The data from Landsat spacecraft constitutes the longest, relatively high spatial resolution, multispectral record of Earth's continental surfaces as seen from space. The record is unmatched in quality, detail, coverage, and value. The Landsat program gave birth to an entirely new field of scientific study and application that we now call remote sensing.[15]

Farther afield, the US robotic exploration of the solar system has been under way for over 40 years. In that relatively short time, NASA has visited every planet in the solar system except Pluto, and NASA's Pluto-Kuiper Belt Mission will be on its way there upon launch in 2006.

As you read this, NASA's Cassini spacecraft is in orbit around Saturn and just recently discovered that the tiny satellite Enceladus -– once thought to be cold and dead – is displaying signs of active ice volcanism. An enormous cloud of water vapor has been found hovering over the little moon's south pole, with warm fractures nearby where evaporating ice probably supplies the vapor cloud.[16] The Cassini spacecraft was launched in October 1997 aboard a Titan IV rocket and arrived at Saturn in July 2004. In January of this year, it deployed the Huygens probe – developed by the European Space Agency – that successfully descended under parachute through the hazy atmosphere of Titan and settled on the surface, sending back data on a frozen, alien world of methane rivers, and orange skies. The Cassini orbiter will continue the reconnaissance of Saturn for at least three more years.

The robotic exploration of Mars began when NASA's Mariner 4 took the first close-up pictures of another planet in July 1965, and continues to this day. Mars is the most Earth-like planet in our solar system, and one day will be a destination for human exploration. Two spacecraft are orbiting the Red Planet and two rovers are exploring the surface half a planet apart.

Mars Global Surveyor (MGS) has been mapping the planet since 1998 and has completed over 28,000 orbits. Its suite of five scientific instruments analyzes infrared radiation from the surface, determines the height of surface features, measures the strength of any planetary magnetic field, records gravity variations and atmospheric temperature and pressure, and provides global imaging of Mars every day, as well as medium- and high-resolution images of selected areas.[17]

The 2001 Mars Odyssey spacecraft joined MGS to continue the scientific reconnaissance. Odyssey is collecting data used to analyze the global elemental composition of Mars, searching for evidence of ancient hot springs and mineral deposits, surveying the radiation environment and providing a communications link to the Mars Exploration Rovers – Spirit and Opportunity – that rolled out on the planet's surface in 2004.

Viewing at far greater distances, the Hubble Space Telescope (HST) has ushered in a golden age of astronomy. Since its launch in 1990, HST has taken over a half-million exposures that have generated more than 3,500 technical publications reporting science results.[18] Hubble has opened a window on the cosmos that has revolutionized – for both scientists and laypersons – our understanding of the evolution of galaxies, the birth of planets and the death of stars, the nature and existence of black holes, and the accelerating expansion rate of the universe that portends the existence of a mysterious "dark energy" in space.[19]

NASA, ESA, HEIC, and The Hubble Heritage Team (STScI/AURA)

Figure 2. This Hubble Space Telescope image of the Cat's Eye Nebula shows the glowing shells of gas from a dying star being expelled into space. The Cat's Eye, which can be found in the constellation Draco, lies 3,000 light years from Earth. The nebula itself is nearly one light year across.

In a field quite apart from astronomical research, a CCD for a Hubble instrument called the Space Telescope Imaging Spectrograph (STIS), has been put to use in the detection of breast cancer. The CCD is ideal because of its high resolution, low dynamic range and low light sensitivity that allow shorter exposure times.[20] The digital camera system is more efficient than previous methods, saves time and money, and reduces pain and radiation exposure. The serendipitous development, called Stereotactic Breast Biopsy Technology, was a 1997 Inductee to the Space Foundation Space Technology Hall of Fame.[21]

The launch of IKONOS in 1999 revolutionized the space-based imagery market with the placement on-orbit of the first commercial satellite that can resolve objects on the ground as small as one meter in diameter. IKONOS, built for Space Imaging in Denver, Colorado by Lockheed Martin Space Systems Company in Sunnyvale, is a direct descendent of Corona and offers high-resolution imagery of Earth to customers around the world.

The IKONOS spacecraft utilizes a three-axis stabilized platform. The main payload is a digital imaging sensor or "camera" that responds to tasking requests from ground stations. Altitude and speed give the camera a wide field of view and the ability to capture large quantities of data very quickly.

From managing natural disasters to facilitating city planning, the IKONOS commercial remote sensing system brings geographical information to everyday users and has dramatically changed businesses. For agriculture, such high-resolution imagery can improve harvest planning and monitoring of erosion and insect infestation as well as determine the impact of weather conditions on crops.

Utility companies, disaster relief organizations and civil engineers get a huge head start in responding to floods, hurricanes, and other environmental catastrophes. Within hours of an event, remote sensing imagery helps decision-makers assess damage and determine the extent and type of resources needed. And insurance companies can quantify damage more expeditiously and accurately.

Recently, Space Imaging released before and after IKONOS images of the areas in Southeast Asia devastated by the December 2004 tsunami (see figures 3 and 4, page 8). Their high resolution enabled relief workers to direct their efforts to those areas most directly affected. The United Nations has also used IKONOS imagery to survey the cultivation of illicit crops in the Middle East, Asia, and South America involved in the drug trade.[22]

Navigation Satellites

The notion of getting from here to there – while seemingly simple – imposes two basic requirements: knowing just where "here" is, and its position relative to "there." When traveling near home, recognizable landmarks guide us, but in unfamiliar terrain neither "here" nor "there" is obvious. For centuries, travelers and seafarers used the Sun and fixed stars as points of reference, but precision was elusive.

A more accurate form of "celestial" navigation became possible at the dawn of the Space Age. On 4 October 1957 the Soviet Union launched Sputnik, and two researchers at the Johns Hopkins Applied Physics Laboratory (APL) in Baltimore – William Guier and George Wiefenbach – determined how to calculate the new satellite's orbit by measuring the Doppler shift in the radio signal as it passed overhead. A few years later,

Space Imaging/CRISP-Singapore

Figure 3: The IKONOS view above, taken on 10 January 2003, shows an area of the western coast of Sumatra, Indonesia, and Lhoknga – a village near the capital city of Banda Aceh. A white colored mosque can be seen in the center of town. Almost a year later – on 26 December 2004 – the area would be devastated by a tsunami generated by a powerful undersea earthquake.

Space Imaging/CRISP-Singapore

Figure 4: The IKONOS post-tsunami view above, was taken on 29 December 2004, three days after the deluge. Lhoknga is completely destroyed, with the exception of the white mosque. Almost all trees, vegetation, and buildings were washed away. Behind the town, low-lying agricultural areas remained covered with water four days after the disaster, and sand on the nearby beaches was completely removed. According to news reports, the wave height might have exceeded 15 meters (50 feet) when it struck the shore.

APL scientist Frank McClure seeking a system that would enable Polaris submarines to precisely determine their locations reasoned that, conversely, a radio signal from a satellite in a known orbit could be used to determine the position of a receiver on Earth. Thus, satellite navigation was born. The US Navy's TRANSIT system would begin operation in 1964 with five satellites. Positional accuracy was about 25 meters, but it took 10 to 15 minutes for a submarine to determine accurately its location.[23]

The current generation of navigation satellites – the Global Positioning System (GPS) – comprises a constellation of 24 spacecraft in 11,000-mile circular orbits. The first operational GPS satellite was launched in 1978, and the constellation reached full operational capacity in 1995. The satellites are evenly spread across six orbital planes, so that from any place on Earth at least four will be above the horizon. Each satellite in the constellation continually broadcasts a digital radio signal that encodes its own position and the exact time, accurate to a billionth of a second. A GPS receiver decodes the information from four satellites, and then instantaneously calculates its own position in latitude, longitude, and altitude within 10 to 15 meters. The GPS Master Control Station, operated by the 50th Space Wing's 2nd Space Operations Squadron at Schriever AFB, Colorado, is responsible for monitoring and controlling the GPS satellite constellation.[24]

Figure 5: A modernized Global Positioning System IIRM satellite is inspected by a technician at the Lockheed Martin Space Systems Company facility in Valley Forge, Pa. These satellites incorporate two new military signals and a second civil signal, providing military and civilian users of the navigation system with improved capabilities much sooner than previously envisioned.

Russ Underwood, Lockheed Martin Space Systems Company

This breathtaking capability was designed for the US military and it has more than delivered on its potential. GPS first captured public attention in the 1991 Gulf War when US troops used the system extensively for navigation on land, sea, and in the air. Precise targeting of bombs and its use for on-board missile guidance were remarkable. During Operation IRAQI FREEDOM in 2003, the system allowed the delivery of some 5,500 GPS-aided Joint Direct Attack Munitions with high precision and with minimal collateral damage.[25] The ultimate compliment came from a US Special Operations soldier who, when asked how "space" enhanced his abilities in combat, responded, "Sir, I don't need 'space.' As long as I have my M-16 and this GPS box, I can do everything I need to."[26]

Civilian applications for use of the GPS system are exploding and seem certain to multiply over time as portable receivers continue to drop in price. Emergency vehicles use GPS to pinpoint destinations and map their routes. Pleasure boaters and owners of small commercial vehicles rely on GPS for navigation, as do civilian pilots who also use it for crop dusting, aerial photography, and surveying. Airlines have saved millions of dollars by using GPS to fine tune flight plans. Mapping roads, tracking forest fires, and guiding the blades of bulldozers in construction processes have also become more efficient and accurate with the use of GPS technology. Earth scientists use GPS to monitor earthquakes and the shifting of the earth's tectonic plates. GPS is being installed in ever-greater numbers of automobiles so that drivers can find out not only where they are, but can be given directions to where they are going.[27] These days, getting from here to there could not be any easier.

Communications Satellites

When historians look back on the first half-century of the Space Age, it is likely they will conclude that the technology having the greatest impact on the largest number of people was satellite communications. The history of early efforts is too voluminous to detail here, but it is safe to say that the building blocks of satellite communications came from directions both military and civilian.[28]

The notion of communication via satellite entered the public consciousness slowly. The first broadcast from space was a recorded Christmas message from President Eisenhower that was carried aboard the first orbital test flight of the USAF Atlas rocket, and beamed to Earth on 19 December 1958.[29] In 1960 NASA launched Echo, a 100 foot diameter Mylar balloon that inflated in space, and was tested as a passive reflector for radio communications.[30]

But it was the launch of a small satellite called Telstar that grabbed the attention of the world. Historian Walter McDougall describes its impact: "In July 1962 the United States had answered the Soviets with the orbital flights of [John] Glenn and Scott Carpenter. The race was not over but for the first time since Sputnik it all seemed less fearful. The wonder of spaceflight shouldered in beside Cold War emotions, and somehow a modest test comsat came along at this moment to pluck imaginations like no other unmanned satellite of the decade. *Telstar!* Built by AT&T, launched by NASA, it broadcast the first live television between continents and symbolized like nothing else the potential of space technology to unite the world."[31]

Telstar was launched into a highly elliptical orbit that allowed it to act as a transatlantic relay for only 102 minutes each day, and it could handle just 600 telephone calls or one television channel.[32] Nevertheless, the communications revolution had begun.

Later communications satellites would adopt the one very specific orbital position ideal for communications, first proposed by British science fiction writer Arthur C. Clarke. In the October 1945 issue of *Wireless World,* in an article entitled "Extra-Terrestrial Relays," Clarke wrote:

Russ Underwood, Lockheed Martin Space Systems Company

Figure 6: A modern communications satellite, the GE-4 is seen following a successful acoustic test at the Lockheed Martin Space Systems Company facility in Sunnyvale, Calif. The satellite, launched successfully in 1999, was built by Lockheed Martin for GE American Communications, and is serving North and South America.

> "It will be observed that one orbit, with a radius of 42,000 km, has a period of exactly 24 hours. A body in such an orbit, if its plane coincided with that of the earth's equator, would revolve with the earth and thus would be stationary above the same spot on the planet. It would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set."[33]

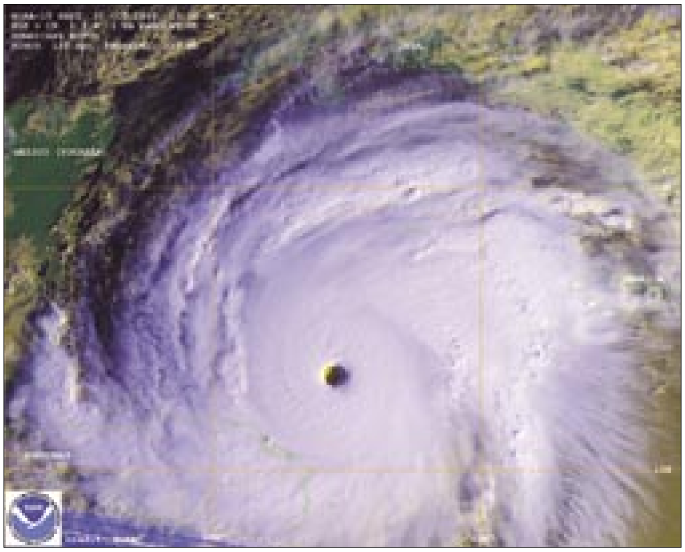
Today, hundreds of enormously sophisticated and powerful commercial communications satellites ring the Earth at the so-called Clarke Orbit. They have hundreds of times the capacity of Telstar. These switching stations in the sky receive digital streams of information from one source and relay it to another: Television, radio, telephony, high-speed data transmission, Internet, video conferencing, tele-medicine, cable, and Direct TV. The applications are limited only by one's imagination.

Environmental Satellites

"How's the weather?" is a question we hear every day, but 50 years ago about the best an ordinary person could do was look out the window and report back. It is a given that weather affects our daily lives, but it also impacts the global economy. Severe storms, excessive ice and other climatological conditions disrupt industrial productivity, consumer spending and property investment. We can not really change the weather, but we have created tools that allow us to prepare for it, or just get out of the way.

Weather and its impacts began to yield to reliable prediction with the launch on 1 April 1960 of the world's first meteorological satellite. The Television Infrared Observation Satellite (TIROS) demonstrated the advantage of mapping the Earth's cloud cover from satellite altitudes. The first views revealed clouds banded and clustered in unexpected ways. The mission also succeeded in verifying experimental television techniques designed to develop a worldwide meteorological satellite information system, and testing Sun angle and horizon sensor systems for spacecraft orientation. While the satellite operated for only 78 days, it paved the way for far more robust spacecraft that have made a lasting impact on weather prediction.[34]

The current generation of civilian weather satellites have a direct lineage to TIROS-1. The Advanced TIROS-N satellite



NOAA

Figure 7: This dramatic multi-spectral colorized image of Hurricane Mitch was generated from data captured by the NOAA-15 POES satellite on 26 October 1998. The powerful Category 5 storm, bearing winds of 155 mph, is seen plowing across the Caribbean Sea and into Honduras.

series are called Polar Operational Environmental Satellites (POES). The satellites are acquired and launched by NASA, and once on-orbit operated by the National Oceanic and Atmospheric Administration (NOAA).

A constellation consists of two POES satellites circling the planet in nearly north-south orbits. As the Earth rotates, the entire globe, one swath at a time rolls into view of the satellites' instruments. The satellites provide measurements of reflected solar and radiated thermal energy from land, sea, clouds, and the atmosphere in the visible and infrared spectrum, atmospheric soundings of temperature and humidity, measurements of global sea surface temperature, aerosol distribution data, ozone concentration data, soil moisture data, and measurements of orbital proton and electron flux.

Together these data comprise irreplaceable inputs to the numerical weather forecast model and are vital to medium and long-range forecasting. Separately or in combination, the data are utilized to produce sea-surface temperature maps, ice condition charts, vegetation maps, and other forecasting and management tools.

Data from the spacecraft also support a broad range of environmental monitoring applications including weather analysis and forecasting, climate research and prediction, ocean dynamics research, volcanic eruption monitoring, and forest fire detection. Additionally, POES satellites – and NOAA's Geostationary Operational Environmental Satellite (GOES) satellites cited below – detect distress signals from emergency locator beacons. More than 18,000 lives have been saved since the inception of this international program in 1982.[35] POES satellites also collect data from remote platforms and provide direct broadcast of environmental data worldwide.

The Defense Meteorological Satellite Program (DMSP) is the military counterpart of POES. Forty-three DMSP satellites have been launched successfully by the US Air Force since 1965. Equipped with a sophisticated sensor suite that can image visible and infrared cloud cover, the satellites collect specialized meteorological, oceanographic, and solar-geophysical information in all weather conditions, and are used for strategic and tactical weather prediction to aid the US military in planning operations at sea, on land, and in the air. The DMSP constellation comprises two spacecraft in near-polar orbits, C3 (command, control and communications), user terminals, and weather centers.

NOAA's GOES is the other crucial segment of the US civilian weather satellite constellation. GOES is the weather satellite most familiar to the American public, as its images and time-lapse sequences are the primary visual material of television weather forecasts. The GOES system, which has been operational since 1975, plays a critical role in short-term forecasting, or nowcasting. In orbit, high above the equator, GOES satellites are uniquely positioned to observe the development of hazardous weather, such as hurricanes and severe thunderstorms, and to track their movement and intensity so that major losses of life and property can be reduced or avoided.

Remote sensing from space also enables scientists to take a broader view and study the principal systems of this planet – air, land, water, and life – and how they interact. NASA's Earth Science Enterprise consists of a series of satellites, a science component and a data system that supports long-term global observation.[36] Questions posed and answers found in this grand scientific inquiry will likely yield knowledge of substantial practical value to society – in weather and climate forecasting, in agriculture, in natural resource management, in urban and regional planning, and elsewhere.

Conclusion

Observation, navigation, communication, and environmental satellites are linked by a common thread – the need for crucial information at a moment's notice – that first led our Nation's leaders to drive the pursuit of enabling technologies. Their prescience, and the awe-inspiring scientists and engineers who made these dreams a reality, have left us an invaluable legacy.

From the warfighter using GPS on an Afghan mountaintop, to the television reporter beaming her report to viewers from Hawaii, to the weather forecaster calling for residents to abandon their homes on the Gulf Coast, to the defense analyst observing increased troop training activity in North Korea, advanced satellite technologies are making our world smaller, but most importantly, much safer.

It is because of these amazing capabilities that we now live in the age of instant information, in a world that is forever changed. For the betterment of all.

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[18] This number is an extrapolation. It is based upon the figure for 2002 of 420,000 exposures over 12 years. "Hubble Space Telescope Servicing Mission 3B Media Reference Guide," 2002, prepared by Lockheed Martin for NASA, 1-1. The Guide is also available on the Internet at http://hubble.nasa.gov/a_pdf/news/sm3b_composite.pdf.

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Space Systems is one of five principal business areas of Lockheed Martin Corporation, with primary product lines encompassing launch vehicles, spacecraft, strategic and defensive missile systems, the Space Shuttle external tank, and other advanced technology space systems.

Senior Level Perspective

Successes and Challenges in Transforming National-Security Space

Dr. William F. Ballhaus Jr.
President and Chief Executive Officer,
The Aerospace Corporation

Introduction

During the conflicts in Afghanistan and Iraq, the US military has demonstrated its ability to leverage space capabilities to give Allied military forces unprecedented advantages in the areas of precision bombing, strategic and tactical communications, navigation, and situational awareness on the battlefield. Building on those successes, the US military is undertaking an ambitious effort to upgrade its space capabilities in all mission areas that will incorporate "transformational" capabilities, providing new levels of precision, agility and connectivity. This has made space systems development one of the most dynamic sectors in today's aerospace business. To be successful, government and industry must (1) continue to apply the lessons learned from acquisition failures in the late 1990s, which resulted in the loss of multiple launch vehicles and satellites, and caused multibillion-dollar cost overruns that emerged earlier this decade on major space system development programs, (2) assure continued access to space as the new Evolved Expendable Launch Vehicle (EELV) systems replace heritage launch vehicles and lay the groundwork for new generations of launch vehicles that will expand the future utility of space, and (3) maintain operations of current systems while transitioning to Internet-like, network-centric operations that will provide new levels of effectiveness.

15th Air Force Historical Archive, Maxwell AFB

Figure 1. WWII bombing "accuracy."

The Changing Roles of National-Security Space

National-security space capabilities have had a major effect on military operations. To begin, I would like to cite an eye-opening example of how warfare has changed. Figure 1 is a bomb-damage-assessment photo from World War II, following three weeks of bombing of the Lobau Refinery near Vienna, Austria. The photo shows the horrifying effects of bombing to the surrounding area, which included an adjoining town of civilians. Almost 10,000 bombs fell on this town over a period of three weeks to take out the single target. By contrast, approximately 10,000 munitions were dropped during the entire bombing campaign in Operation IRAQI FREEDOM. Today, a single precision weapon in the "sweet spot" of the refinery could likely have accomplished this type of mission.

Not only has this kind of precision revolutionized warfare, it has also changed in-country behavior. A good example is the Iraq conflict, where US military planners projected a significant refugee problem once hostilities began. That flood of refugees never materialized because the United States stated its intention to target the regime and not the people or the infrastructure—and then demonstrated it could strike with precision, incurring minimum collateral damage.

In fact, former Secretary of the Air Force Dr. James G. Roche described the growth of space capabilities by saying, "For the first time in our history, space has become an equal partner to air breathers." His quote says it concisely—space has become more important to military operations than ever before.

Sometimes space capabilities become so ingrained into the way people operate that users may not even be aware that the service is based on a space system. For example, former NASA Administrator Dan Goldin recalled the Congressman who once asked him, "Why are we building meteorological satellites when we have the Weather Channel?" This demonstrates a lack of understanding that I'm sure is shared by other members of the general public. And consider the soldier who was asked by a reporter how space has helped him. His reply: "Sir, I don't need 'space.' As long as I have my M-16 and this GPS box, I can do everything I need to."[1]

Today's military is on the verge of transforming space capabilities well beyond current capabilities. There have been many successes and challenges in reaching the current state, and many remain. First, let's step back in time. Early military space programs, such as Corona and the Defense Support Program, focused on strategic surveillance. They replaced U-2 aircraft overflight missions to watch for strategic missile tests and deployments (figure 2). These surveillance satellite systems provided value in two ways. First, they avoided increasing tensions—because observation from space was not viewed as provocative, while airplane overflight was seen as a violation of a nation's sovereign airspace. These systems also helped keep the peace during the Cold War by greatly reduced uncertainty about what the Soviet Union was doing militarily.

The late 1960s also marked the introduction of the first generation of communications and weather satellites. These systems seized the advantage of the high ground of space to demonstrate the potential of enhancing tactical warfighting capabilities (figure 3). By the late 1970s and early 1980s, the initial Global Positioning System (GPS) constellation was taking shape and provided

Photographs provided by US Air Force

Figure 2. Early military space programs focused on strategic surveillance.

Illustrations provided by US Air Force

Figure 3. Space also provides critical "utility" missions.

the first global space-based application of precision navigation. As we saw in Afghanistan and Iraq, these utility missions have revolutionized warfare.

Now let's fast-forward to today. Space has proven to be a "game changer." Whether in communications, precision weapons or surveillance—space has changed the way wars are fought. A great example is in military satellite communications. In Operation IRAQI FREEDOM, US forces used 30 times more bandwidth than in Operation DESERT STORM. With this greater bandwidth and smaller antennas, more information was made available from higher levels of command to the tactical level for forces on the move. As Vice Admiral Arthur Cebrowski, then Director of Force Transformation, Office of the Secretary of Defense, testified to Congress, it "provided the backbone for: *Blue Force Tracking* (i.e., tracking of Allied forces to avoid fratricide), *Shared Situational Awareness, Rapid Troop Maneuver, and Unprecedented Speed of Command*."[2]

At the same time, the government is in the midst of upgrading every space mission area to provide greater capability and integration—without skipping a beat on current operations. This includes major developments over the next 10 years (figure 4) in the following five mission areas:

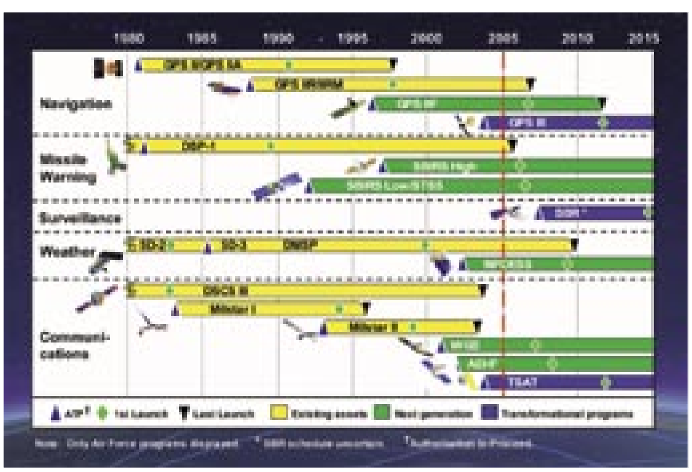
- Navigation—GPS Upgrades
- Missile Warning—Space Based Infrared System (SBIRS) and Space Tracking and Surveillance System
- Surveillance—Space Radar
- Weather —National Polar Orbiting Environmental Satellite System
- Communications—Wideband Gapfiller System, Advanced Extremely High Frequency satellites, and the Transformational Communications Satellite System

The remainder of this article focuses on three areas that I call an *Agenda for the Future:*

1. *Overcome the acquisition lapses of the 1990s.*
2. *Continue to improve reliable, operable and affordable access to space.*
3. *Transition to network-centric operations.*

Overcoming Acquisition Lapses of the 1990s

While users may take space for granted, many of us have felt the sting of failure in this business. "One strike and you're out" applies to few other industries as it does our own. In this business, thousands of people can do everything right, and one individual can make one mistake that, if not detected, can cause a multibillion-dollar mission failure (figure 5). Asset losses in military, civil and commercial space during the 1990s totaled $11 billion (figure 6).[3] Even more important than the financial losses are the other consequences of those failures. For the military it meant gaps in capabilities they were counting on. For NASA and commercial users it was the lost opportunity for exploration or business success.

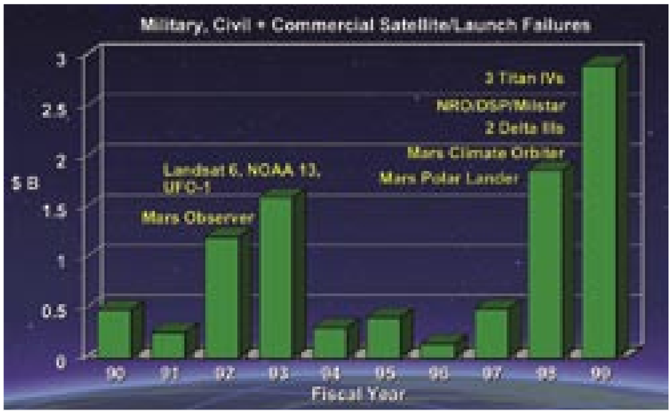


US Air Force/The Aerospace Corporation

Figure 4. Every mission area is being re-capitalized.

Photographs provided by US Air Force

Figure 5. An unforgiving business: "one strike and you're out."



W. Tosney, 45th International Symposium, Environmental Testing for Space Programmes, June 2001

Figure 6. Over $11 billion in lost space assets in 1990s.

Today, we're at a crossroads in national-security space. We're recovering from lapses in program execution and mission success from the 1990s while simultaneously building new, more complex systems in every space mission area. The space acquisition trends of the 1990s can be summed up in two concepts: (1) everyone wanted a share of "the peace dividend," which resulted in declining defense budgets, and (2) commercial space was ramping up for large constellations of telecommunications satellites (Teledesic, Iridium, and others) that would migrate communications and the Internet to space.

These two trends led to a lot of wishful thinking. Believing more could be done for less, both government and industry made some assumptions about how space programs could be conducted more cost effectively. The government would take on more risk to reduce cost but would manage that risk. It believed it could cut costs by leveraging a growing commercial space business and substantially reducing government involvement in the development process. Over time, this led to a serious erosion of government program management and systems engineering talent and experience and reduced the core capabilities the government needs to be a "smart buyer." The government also thought it could shift much of its role to the commercial sector, then populated with new defense giants that resulted from the defense-industry consolidations of the 1990s. The theory was that these global systems integration and technology companies could develop complex space systems with little government oversight and thereby save the government billions of dollars.

This was the era of Total System Performance Responsibility (TSPR) a concept that delegated total program responsibility to the contractor. The mantra was, "the contractor is in charge."

These new government approaches were ambitious and did reduce cost in the short term, but they led to problems that resulted in substantial cost consequences in the long term.

- *Defense "Acquisition Reform"*—Proven management and systems engineering practices were abandoned for unvalidated engineering and acquisition practices.
- *NASA: "Faster, Better, Cheaper"*—One-third of all missions (10 of 34) experienced failures.[4]
- *National Reconnaissance Office (NRO): "Maintain Performance; Reduce Cost"*—Proven management and systems engineering practices were abandoned for unvalidated engineering and acquisition practices.
- *Commercial "Best Practices"*—The commercial space market collapsed, and the anticipated leverage from riding the coattails of commercial space did not materialize.

The intent was noble, but the execution was flawed on a number of space system development programs. Some programs are still struggling to recover, including a number of advanced military space programs identified in recent Government Accountability Office findings.[5] In its efforts to reduce costs, government threw out most of its military specifications and standards. Government and industry also eliminated or failed to follow processes that incorporated many years worth of lessons learned. Well-defined processes are refined over many years and are intended to result in predictable, repeatable results. By stripping out elements essential for effective program management, the government artificially booked substantial cost savings up front and formulated programs that, in the case of SBIRS, for example, were unexecutable to defined baselines.

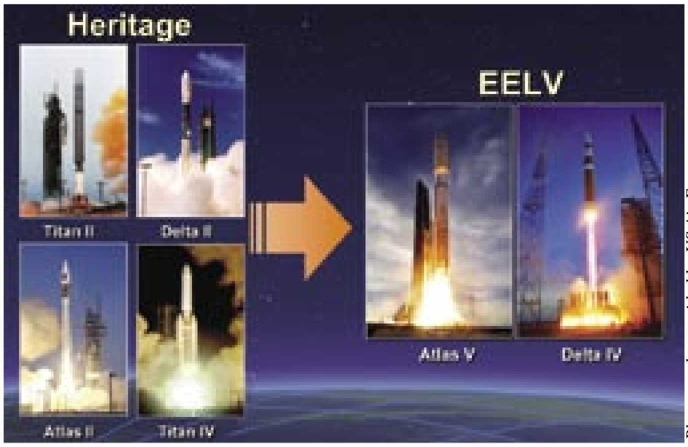
Recovering From Launch Failures

Six launch failures in 1998–1999 led to a major government-sponsored launch vehicle study, the Broad Area Review (BAR).[6] At that time, I was the Lockheed Martin representative on the BAR. The failures included three commercial launch vehicles/satellites (Athena-2/Ikonos-1, Delta III/Galaxy-10, Delta III/Orion-3), and three National Security Titan IV launch vehicles that carried Milstar 2 F-1, the Defense Support Program F-19, and a classified satellite for the NRO. The BAR made a number of recommendations for launch program recovery in 1999:

1. Reemphasize mission success, rather than cost. The BAR stressed that $20 billion of national assets were riding on inherently risky vehicles, and squeezing every nickel of cost out of launch programs could save only 2 - 4 percent of the value of the assets being launched—while substantially increasing the risk of a multibillion-dollar failure.
2. Instill more disciplined systems engineering practices into the process, with greater oversight and a formal risk management plan.
3. Reestablish thorough postflight analysis processes to improve reliability. This kind of analysis would look for anomalies or "out-of-family" performance parameters.
4. Make a successful transition from the heritage launch vehicles to the EELV, the next generation of space boosters. The BAR called for clear accountability for mission success and the need to gain greater visibility into, and control over, contractor processes.

Figure 7 shows the heritage launch vehicles that are being phased out as EELV ramps up. Those heritage programs (Atlas II, Delta II, Titan II, and Titan IV) represent decades of experience. Since the BAR recommendations were released, significant progress has been made in "getting back to the basics" on launch mission success by reestablishing rigorous mission assurance processes on heritage programs. The results have been 41 operational launch successes in a row since the recommendations were made.

Part of those successes is an eight-for-eight record for operational EELV launches, which is unprecedented for a new program.



Photographs provided by US Air Force

Figure 7. Launch evolution.

Historically, a new launch vehicle has experienced a failure during its first three missions about 40 percent of the time. At least part of EELV's success can be attributed to value-added activities instituted by the government, although late in the process, to supplement the original purely commercial approach. Those activities include hardware "pedigree" reviews of critical components, independent assessments of vehicle dynamic environments, and other mission assurance activities similar to those proven on the heritage launch vehicles.

While launch vehicle programs have been enjoying a string of successes, the same can not be said for all satellite acquisition programs. Earlier this decade cost overruns on two major satellite programs, SBIRS and the Future Imagery Architecture (FIA) program, led to a study on overall national-security space acquisition and how it could be improved. Both of these programs were initiated under the flawed acquisition policies of the 1990s. That study was conducted by a joint team of the Defense Science Board and the Air Force Scientific Advisory Board. This team became known as the Tom Young Panel, named for its chairman.[7] I also served on this panel.

The Young Report listed five major factors that contributed to acquisition failures:

1. Cost had replaced mission success as the primary driver in managing space development programs. Not unlike the launch vehicle problems, this has its genesis in the budget squeeze of the 1990s and the optimism that led to the acquisition experiments mentioned earlier.
2. Unrealistic estimates led to unrealistic budgets and to the formulation of programs like SBIRS and FIA that could not be executed successfully. The acquisition process was strongly biased to produce unrealistic cost estimates. Cost was typically minimized during the advocacy phase to fit constrained budgets. The contractors focused on the "price to win" and had bid aggressively on cost. In industry there was no excuse for losing a "cost-plus" contract competition on cost. The study also discovered that in source selections, the incumbent had lost 90 percent of the time, often because the nonincumbent was not burdened by actual costs of the ongoing program and could be far more optimistic.
3. Undisciplined definition and uncontrolled growth in system requirements increased cost and caused schedule delays. The space acquisition system lacked disciplined processes to control requirements. Tradeoffs among cost, schedule, and risk should be supported by rigorous systems engineering, budget, and program management processes. During program execution, requirements need to be under configuration control. The Air Force is now doing a much better job of controlling requirements growth since they instituted a more rigorous review process that goes through the Director of Space Requirements at Air Force Space Command for approval. This process has reduced the "requirements creep" that affected some past programs like SBIRS.
4. Government capabilities to lead and manage the space acquisition process had seriously eroded. The move to TSPR marginalized the roles of government agencies and federally funded research and development centers (i.e., nonprofit entities supporting the government, such as those at The MITRE Corporation and The Aerospace Corporation), and the program manager lost authority to execute effectively. The government experience base in program management and systems engineering eroded, which substantially damaged its ability to be a smart buyer. The government has a key role in setting requirements, assuring responsible management of risk, and assuring that proven practices are used by contractors.
5. Industry had failed to implement proven management and engineering practices on some programs. Industry should use proven practices, and government must incentivize industry to achieve program objectives, especially mission success.

Progress has been made in recovering from these problems, but, as in launch, we must continue reinstituting the proven "recipe" for acquisition and mission success while dealing with constrained budgets.

1. Validated processes and practices must be employed.
   - Validated processes are intended to produce predictable and repeatable results. They embody the lessons learned from past anomalies and failures.
   - Government and industry, with strong support from The Aerospace Corporation, are selectively putting a limited number of proven milspecs and standards on contract and improving process discipline.
2. Government must continue to improve its ability to be a smart buyer. In source selections it must know how to place value on key elements of success, such as systems engineering and mission assurance.
3. Government must attain a better understanding of how to assess the impact of risk on cost estimates. It must also budget for management reserve. Management reserve is an essential component of a program's budget and enables a program manager to take timely corrective action when confronting the kinds of unforeseen issues that always emerge in the development of new space systems. Lack of adequate management reserve can increase development cost and schedule.
4. As new systems are acquired, the government must validate adequate technology maturity before baselining these

technologies into new systems.

5. The experience base of space operators and acquisition professionals must be enhanced. It will take years of sustained effort to develop the numbers of experienced acquisition personnel needed. Air Force Space Command has a plan and is making inroads in this area.

The major challenge for ongoing programs begun in the 1990s is to institute these processes midstream. In some cases there are inadequate pedigree trails on hardware to establish its suitability, or there is insufficient testing at the unit or subsystem level. This is driving the need on programs like SBIRS, to conduct more extensive system-level testing to reduce risk and increase confidence before launch.

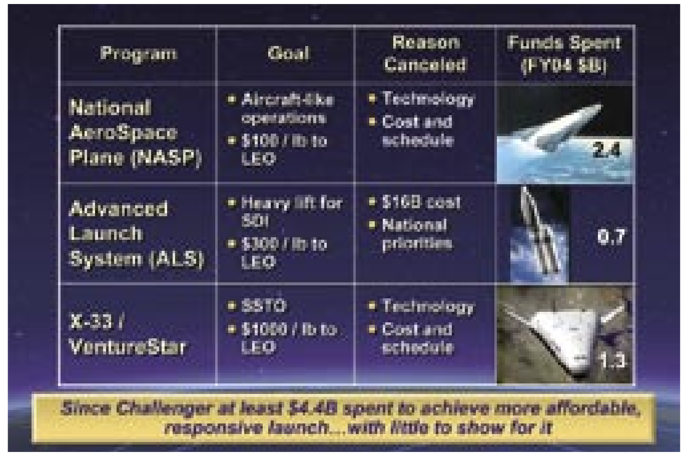
For new programs, the recipe is incorporated in National Security Space Acquisition Policy 03-01, which was issued by the Undersecretary of the Air Force in October 2003. It includes key decision points, an independent cost analysis process, expanded program reviews, and independent program assessments.

Significant progress made during the last few years can be attributed to three senior government officials, and I'd like to highlight their accomplishments. Peter B. Teets, who recently retired as undersecretary of Air Force and director of the NRO, drove the convergence of intelligence and military requirements where appropriate and revitalized the space acquisition process. *General Lance W. Lord,* commander of Air Force Space Command, has managed a significant ramp-up in space operations, established a rigorous requirements process, and is leading the "credentialed warfighters" concept to strengthen the government workforce. *Retired Lt Gen Brian A. Arnold,* who was commander of the Air Force Space and Missile Systems Center (SMC) and Air Force Program Executive Officer (PEO) for Space, achieved 100 percent mission success on operational launches and laid the foundation for the successful acquisition of future satellites and launch vehicles by revitalizing systems engineering, conducting benchmarking sessions with contractors to provide candid feedback on performance, and using independent reviews to assess and manage risk. *Lt Gen Michael A. Hamel* recently assumed command of SMC and, as the Air Force PEO for Space, is continuing to enhance program execution success and bring integrated capabilities to the warfighter.

Continue to Improve Reliable, Operable, and Affordable Access to Space

During the last two decades there have been a number of attempts to revolutionize space launch. Several are referenced in Figure 8. All had noble objectives, and each one could take a full paper to discuss. In short, each was cancelled because of cost or technology hurdles as summarized in figure 8. The bottom line is that since the space shuttle's development, at least $4.4 billion was spent on these programs, with little to show for it.

As Winston Churchill said, "The Americans will always do the right thing…after they've exhausted all the alternatives." What is needed is a technology roadmap for improving launch vehicle reliability, affordability, and operability that allows the benefits of the technology investment to be captured at each major roadmap milestone. For the time being, however, the major focus in launch

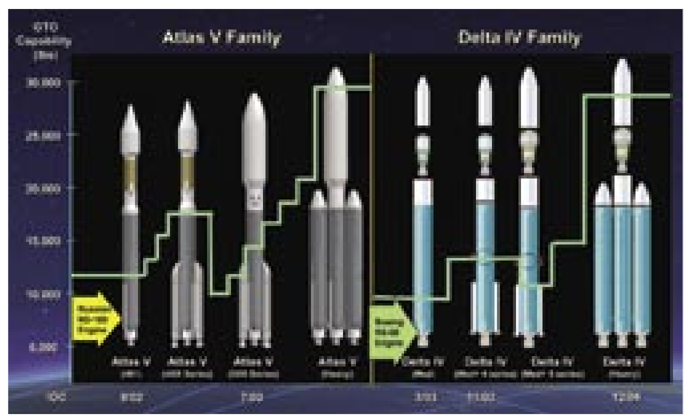


Illustrations provided by US Air Force

Figure 8. Post-shuttle attempts to revolutionize space launch.

will be to fully establish the reliability and viability of the EELV families of launch vehicles.

Figure 9 shows both the Atlas V and Delta IV EELV families and their capability to launch payloads to geosynchronous transfer orbit. They are largely seen as evolutionary vehicles, but they have incorporated some new technology as well, such as new engines for each. The Atlas V uses the proven RD-180 Russian engine. While it is not new technology in the strict sense, it is the



Illustrations provided by US Air Force

Figure 9. EELV families.

first time a US vehicle has used a Russian engine. The Delta IV uses the new Boeing RS-68 engine, developed by Rocketdyne, which is the first large liquid-fueled engine developed in the United States since the space shuttle main engine in the 1970s.

As mentioned earlier, the first eight operational EELV launches have been successful. On the initial block buy acquisition of 28 launch vehicles, the program has achieved the 25- to 50-percent cost reduction goal when compared with the heritage Titan, Atlas and Delta launch vehicles. As figure 10 shows, EELV has also greatly enhanced operations by reducing the processing time required both on and off the launch pad.

Although the initial launches have been successful, it's early in the program's life, and, with the current launch schedule, there will not be enough flights to demonstrate full reliability confidence until about 2010. It had been expected that a robust commercial market would allow a significant number of commercial launches prior to the launch of high-value US military and intelligence community assets. By the year 2000, it was clear that

The Aerospace Corporation

Figure 10. EELV accomplishments.

this was not going to be the case. The government would be the dominant customer. Realizing that the original assumption under which the program was formulated was no longer valid, the Air Force, The Aerospace Corporation, and the contractors instituted rigorous hardware pedigree reviews, strong mission assurance processes and independent launch readiness verification.

In 1998, a market sufficient to support two EELV families was projected, and development costs were to be shared between government and industry. Today the commercial market is mostly unaddressable because of very low-cost foreign competition. Both contractors are challenged with managing what, at best, is a marginally profitable launch business, while the government still needs two domestic launch providers to assure access to space.

Launch Industrial Base

There is extensive overcapacity at current launch rates, and a minimum number of launches per year is required for each EELV contractor to maintain capabilities. Hence, continued competition may not make sense in the current environment. Furthermore, if the business continues to be unprofitable, one or both contractors may exit the launch business. The government cannot reduce the overcapacity by downselecting to one provider because it currently does not have sufficient confidence that it will have assured access with just one provider. However, there are identifiable milestones for reducing uncertainty enough to enable a downselect decision. For instance, the milestone for confidence in system reliability is about seven successful flights of each configuration, goals expected to be reached by about 2010.

To address the industrial base issue, the government will incorporate two separate contracts for each launch provider: (1) a launch capability contract, which includes launch infrastructure and mission-related elements, and (2) a launch service contract. With this new contract structure, the government shares an appropriate level of risk with the launch service providers in addition to preserving the space launch industrial base and minimizing gaps in launch service operations. The revised acquisition strategy retains two EELV families of vehicles to maintain emphasis on assured access to space.

This approach is consistent with the new US Space Transportation Policy issued 6 January 2005, which addresses the EELV uncertainties short-term, and identifies 2010 as the time by which a long-term solution must be decided. It states: *"The DoD shall fund the annual fixed costs for both launch services providers unless or until such time as the Secretary of Defense, following coordination with the Director of Central Intelligence and the NASA Administrator, certifies to the President that a capability that reliably provides assured access to space can be maintained without two EELV providers.*

"Not later than 2010, the Secretary of Defense, the Director of Central Intelligence, and the NASA Administrator shall evaluate the long-term requirements, funding, and management responsibilities for the EELV system(s) and infrastructure."

The formation of a new company, United Launch Alliance, was announced on 2 May 2005 by Boeing and Lockheed Martin. This proposed joint venture for EELV launches will further address the industrial base overcapacity issue and help reduce costs. The venture will combine Boeing and Lockheed Martin production, engineering, test and launch operations associated with US government launches of Delta IV and Atlas V rockets, respectively. Under the terms of the venture, Boeing's Delta IV and Lockheed Martin's Atlas V rockets will continue to be available as alternatives for individual launch missions. United Launch Alliance headquarters will be established in Denver with most engineering activities consolidated there. Major manufacturing for both Delta IV and Atlas V, assembly and integration operations will be conducted at Boeing's facility in Decatur, Alabama. Completion of the transaction is expected in late 2005 upon approval by the Federal Trade Commission. It will be important to gain a fuller understanding of program impacts from this venture as we go forward.

The Future of Launch

As we look to the future of launch capability, there are some major open questions. Today there are a host of competing factions attempting to develop next-generation launch vehicles. That is especially true in the small-satellite launch market below 1,000 pounds, where at least eight companies are proposing vehicles. A major determining factor in how many of those vehicles, if any, succeed is how large the satellite market grows in that range. Many have predicted that satellites would shrink because of the continuing miniaturization of electronics. Yet some satellite segments continue to grow in weight because users add more payload instead of moving to smaller satellites.

The goal of these efforts is to develop "operationally responsive" access to and from space. The Space Transportation Policy also addresses this area as it directs that, *"Before 2010, the United States shall demonstrate an initial capability for operationally responsive access to and use of space to support national security requirements. In that regard, the Secretary of Defense, in coordination with the Director of Central Intelligence, shall:*

a) Develop the requirements and concept of operations for launch vehicles, infrastructure, and spacecraft to provide operationally responsive access to and use of space to support national security, including the ability to provide critical space capabilities in the event of a failure of launch or on-orbit capabilities; and

b) Identify the key modifications to space launch, spacecraft, or ground operations capabilities that will be required to *implement an operationally responsive space launch capability."*

Then there is the endless debate about the advantages of expendable versus reusable launch vehicles. Short of a space propulsion breakthrough comparable to the way the jet engine transformed aviation, we will not see substantial enhancements in performance because launch performance is subject to limitations of specific impulse and mass fraction as defined in the rocket equation. Until there is such a breakthrough, we will probably be limited to expendable or hybrid (i.e., partially reusable) launch vehicles.

Finally, there is the question of how to support NASA's initiatives to return astronauts to the moon and then to Mars. To achieve the vision laid out by President George W. Bush in January 2004, a new heavy-lift launch vehicle could be required. The Space Transportation Policy addresses this question in two ways. It says that, *"The US shall sustain a focused technology development program for next-generation space transportation capabilities to transform US access to and use of space. In that regard, the Secretary of Defense and the NASA Administrator, in cooperation with industry as appropriate, shall:*

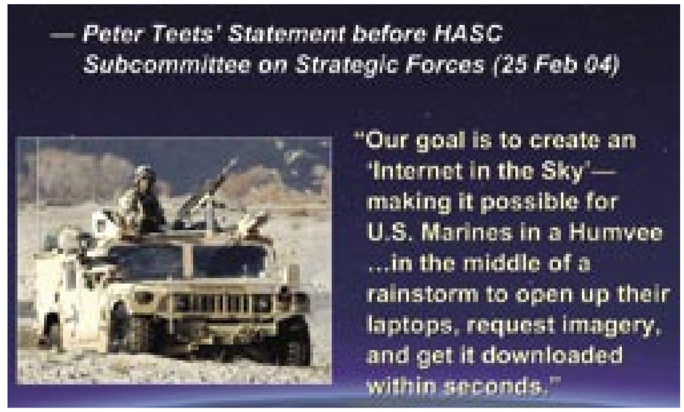
a) Within two years of the date of this policy, develop the requirements, concept of operations, technology roadmaps, and investment strategy for next-generation space transportation capabilities with the objective of dramatically improving the reliability, responsiveness, and cost of Earth-to-orbit space transportation for deployment of spacecraft and other payloads in Earth orbit, exclusive of human space flight; and

b) Pursue research and development of in-space transportation capabilities to enable responsive space transportation capabilities and the transformation of the Nation's ability to navigate in space. These efforts shall include, but not be limited to: automated rendezvous and docking, and the ability to deploy, service, and retrieve payloads or spacecraft in Earth orbit. The NASA Administrator, in cooperation with the Secretary of Energy and other departments and agencies as appropriate, shall pursue research and development of space nuclear power and advanced propulsion technologies to more quickly, affordably, and safely expand the reach of exploration into the solar system and beyond."

This multiagency consensus roadmap for development of next-generation launch vehicles could allow the government to continually capture the benefit of a sustained multiyear investment, and thus avoid the inefficient starts and stops illustrated in figure 8.

Transition to Network-Centric Operations

In figure 11, the quote by Peter Teets provides a good example of what the military is to do in the shift to network-centric operations: "Our goal is to create an 'Internet in the Sky'—making it possible for US Marines in a Humvee…in the middle of a rainstorm to open up their laptops, request imagery, and get it downloaded within seconds." The soldier does not care where the information comes from—he just wants to be sure he gets it



US Air Force/USMC

Figure 11. Peter Teets' statement.

when he needs it.

This goal highlights the point I made earlier about getting away from platform-centric weapon systems such as aircraft, spacecraft, ships, and tanks. Instead, the platforms become nodes on a network, and the user can pull the desired information as in an Internet search. The advantages of network-centric operations are:

- Global situation awareness—complete and persistent, and the ability to draw on non-organic assets for information.
- Fusion of multisource intelligence.
- Near-real-time sensor-to-shooter connectivity.
- "Reachback" to continental US sources for deployed forces worldwide.
- Secure global interoperable infrastructure—"any time, any place."
- All-terrain mobile operations.

This transformation will allow US forces to be the first to see, the first to understand, and the first to act—and then to quickly react to the results of the first act. Troops will be able to keep moving and "plan on the move," thereby defining the battle space on their own terms.

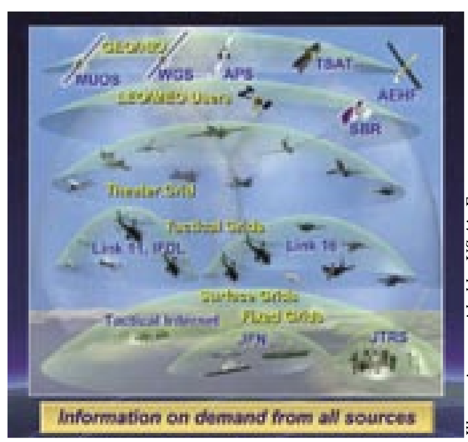


Illustration provided by US Air Force

Figure 12. Space: backbone for network-centric warfare.

The graphic in figure 12 shows how the goal is to tie all users together with an Internet-like architecture. It does not matter if an operator is at sea, on land, or in the air—he should be able to tap in to the network and get the information required. Some of the key features that will enable net-centric operations include the following:

- Universal Internet Protocol networking to allow the system to operate like the Internet.
- High-speed backbones using high-capacity optical communication. This will incorporate laser links with 30 to 60 times more capacity than current systems.

- Multiple security architecture levels, which allow highly classified information to be used at different levels without revealing its source.
- Dynamic resource allocation.
- Small robust terminals that allow access to more users.

Each of the military services is planning to make future forces network-centric. They all recognize the advantages. For them to be successful, the overall architecture must accommodate their needs. Following are some of the challenges to making that a reality:

- Maintaining current services while transitioning to Internet-based technologies—the same challenge telephone services have faced for decades, maintaining services while upgrading to incorporate new technologies.
- Realizing government and industry support of architecture-level integration that must endure and be capable of incorporating unanticipated new technologies.
- Planning long-lead-time space system developments while communications technologies are rapidly advancing; the time constants associated with developing space systems are much longer than those associated with advances in communications technology.
- Reconciling the Department of Defense (DoD) and intelligence community needs to achieve transparent interoperability. These two communities have different missions and requirements, and one issue is who controls use of the assets.

History has proven that as military capabilities provide greater advantage, adversaries will try to neutralize them. This is driving the growing need for space superiority. Potential adversaries recognize the advantages space provides—the military asymmetric advantage and the critical economic node for commercial communications, navigation and weather. As a nation, the US must be able to operate in space and deny an enemy the ability to do so when we choose—much like air or naval superiority. In the future we are likely to see a greater focus on increasing space situational awareness to identify threats to our space capabilities, as well as an increased focus on reducing the vulnerabilities of space systems.

Conclusion

As we look to the future we have the opportunity to truly transform national-security space. Success in that endeavor will take unrelenting pursuit of the three areas summarized here.

1. *Space Systems Acquisition Effectiveness*. Government and industry must fully implement the Young Panel recommendations and ensure that mission success remains job #1.
2. *Launch*. Government and industry must continue to focus on mission success for heritage launch vehicles until they fly out and in the transition to EELV. For follow-on systems, a roadmap must be established with sustained funding for more reliable, operable, responsive, and affordable future systems. The roadmap would allow the nation to capture the benefits of technology development investments while avoiding the zigzagging of the past.
3. *Network-Centric Operations*. The US military must maintain current capabilities while transitioning to Internet-based network-centric operations. This requires architectural designs that are enduring and capable of incorporating advances in technology.

At the end of the day, the overriding reason to develop these space capabilities is to support the warfighter. When Americans send their sons and daughters into harm's way, we want them equipped with tools that provide a decisive advantage, enabling them to accomplish their mission with minimum allied and civilian casualties and minimal collateral damage. Ideally, capabilities should be so overwhelming and precise that they serve as a deterrent to conflict.

Notes:

[1] Aviation Week & Space Technology, 21 April 2003, 26.

[2] Statement of Admiral Arthur K. Cebrowski to the Subcommittee on Strategic Forces, Armed Services Committee, US Senate, 25 March 2004.

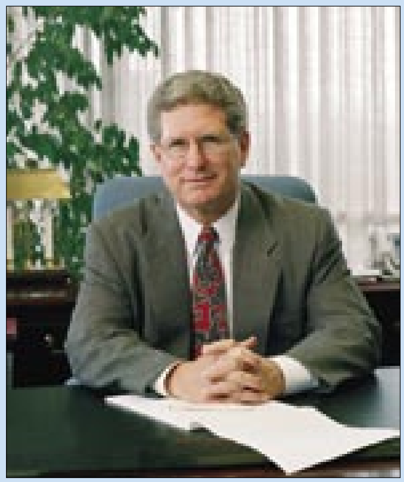
[3] William Tosney, The Aerospace Corporation, Proceedings of the 4th International Symposium on Environmental Testing for Space Programmes, June 2001 (ESA SP–467).

[4] David A. Bearden, The Aerospace Corporation, Fourth IAA International Conference on Low-Cost Planetary Missions, JHU/APL, Laurel, Md., 2-5 May 2000.

[5] Statement of Robert E. Levin, director, Acquisition and Sourcing Management, Government Accountability Office, to the Strategic Forces Subcommittee, Committee on Armed Services, US House of Representatives, 12 July 2005 (GAO-05-891T).

[6] Joseph Tomei, The Aerospace Corporation, 3rd Government/Industry Mission Assurance Forum, Chantilly, Va., 24–25 September 2002.

[7] Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs, May 2003, http://www.acq.osd.mil/dsb/reports/space.pdf.



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Dr. Ballhaus joined Aerospace in September 2000 after an 11-year career with Lockheed Martin Corporation, where he was a corporate officer and vice president of Engineering and Technology. Prior to his tenure with Lockheed Martin, Dr. Ballhaus was president of two Martin Marietta businesses, Aero and Naval Systems and Civil Space and Communications. He also was vice president of Martin Marietta's Titan IV Centaur operations.

Before joining Martin Marietta, Dr. Ballhaus was director of NASA Ames Research Center. He also served as acting associate administrator for Aeronautics and Space Technology at NASA Headquarters in Washington, D.C. Earlier at NASA he was director of Astronautics and chief of the Applied Computational Aerodynamics Branch.

He is a member of the Defense Science Board and the National Academy of Engineering and is a past president of the American Institute of Aeronautics and Astronautics.

Senior Level Perspective

Commercial Space: America and the World Reaping the Many Benefits of Technology

Maj Gen (Ret) Jeff Grime, USAF
President, Atlantic Systems Inc.

Almost a decade ago, General Howell Estes, then Commander of Air Force Space Command, opined that if petroleum provided the fuel for the engines of the industrial age, space would fuel the "engines" of the information age. He made this observation at a time when commercial investment in space -- for the first time -- surpassed military, intelligence, and civil-sector space expenditures. America's contributions to space technology have shown an amazing array of benefits, adding new opportunities for our economy, driving new technologies, and bettering lives for everyone around the world.

While the private sector did undertake some commercial space activities in the early 1960s, it was not until the 1980s and 1990s that commercial space began to dramatically expand. There were many reasons for this change -- risk reduction from massive initial investment by the government; technology advances; improved satellite manufacturing processes and techniques; and decreased launch costs. However, the creation of the internet has had perhaps the greatest impact, and an insatiable appetite for information-age services has ignited a myriad of new global technologies. If space is the fuel that drives the engine of the information age, the internet is the supercharger, creating a near-frenzied demand among a burgeoning worldwide consumer base.

Satellites have truly become a part of the world's critical infrastructure, and many satellite services have become essential "commodities" needed by nations and cultures in nearly every corner of the globe. In 2004, the Satellite Industry Association reported that the commercial satellite industry generated $97.2 billion in revenue, leading to new jobs and new growth with no limits in sight. However, in actuality, the true worth of space exploitation is virtually incalculable.

Communications Satellites

Within the satellite industry, the most dramatic performance has been in the communications sector. Space communications has reduced the size of the globe and arguably changed our daily lives more dramatically than any other technology in the world's history. Today, billions of financial transactions, inventory management assessments, and business decisions are now being conducted within a matter of minutes or seconds; communications satellites now provide the backbone for worldwide and national news media, permitting all of us instant access to information that affects our lives. The influence of satellite communication satellites is profound -- it is not affected by geography, it can be deployed anywhere, and it is becoming more cost-effective every day.

Possibly the most important transformation today is the dramatic impact space communications has on developing nations. Space industries are allowing people around the globe to jump-start their economies, enhance their standards of living, and reach new heights without being inhibited by ineffective governments or insufficient infrastructure. Further, because of space technologies, we are now witnessing the democratization of nations on a scale never seen before. Satellite television, for example, is revolutionizing politics in China and the Middle East. As our forefathers understood the value of a free press and free speech, communication satellites are providing unfettered access to information.

Theodore Roosevelt once said, "Free speech, exercised both individually and through a free press, is a necessity in any country where people are themselves free." Today, the internet has helped create a kind of "new press"; in so doing, democracies can best flourish and governments will be less likely to abuse power as people have the ability to form their own opinions based on the free-exchange of electrons and ideas.

Remote-Sensing Satellites

Remote-sensing satellites have come a long way from Cold War era days when defense satellites were employed to monitor the successes and failures of wheat crops in the Soviet Union. Clearly, during the Cold War, satellites such as DSP were one of the prime reasons why thermonuclear exchanges thankfully never occurred -- the Soviets knew that WE knew what they

Today, billions of financial transactions, inventory management assessments, and business decisions are now being conducted within a matter of minutes or seconds; communications satellites now provide the backbone for worldwide and national news media, permitting all of us instant access to information that affects our lives.

were doing with their arsenal.

"On-demand" imaging is also a part of the information age. Today, remote sensing provides high-resolution images for a wide variety of users, ranging from comprehensive views of the world's weather on a scale not possible by other means, to oil and gas exploration, to agricultural appraisals, to urban planning, and of course for National Security and emergency response to disasters.

Navigation Satellites

Ever since the public was given access to Global Positioning System (GPS) signals in the 1980s, the demand for precise location and navigation systems has been considerable. While GPS continues to bolster US warfighting capabilities, this military system is now a crucial resource for the public and industry. Its uses span the entire spectrum -- from determining tee-to-green distances on the golf course, to navigating highways and byways, to locating people in distress.

Applications in the transportation sector (rail, truck, ship) are continually improving efficiencies for both the supplier and the customer. Even the smallest of companies are now using GPS-enhanced systems to track their vehicles in an accurate and timely manner, ensuring that they have real-time knowledge of job progress throughout the day. Emergency dispatchers now have the ability to visualize the emergency location and determine the quickest way to respond, saving lives and protecting property.

Challenges Lie Ahead

We all benefit from this unobtrusive "space revolution." Indeed, our quality of life has improved; the world continues to get smaller; and our space systems will undoubtedly permit even greater opportunities in the future. From global person to person (P2P) communications; to GPS in our cars; to our ability to access images of major cities; to monitoring the traffic on our route of travel; to obtaining weather observations/predictions—our ability to manage our lives has changed significantly. Via the internet, we now have access to knowledge that enables us to accomplish tasks that were virtually unattainable in the past.

As is always the case, it is difficult to predict the next revolutionary technology that will provide additional benefits for the world. Alternative sources of energy from space, for example, could certainly alter our dependence on fossil fuels.

Perhaps the most important near-term challenge is developing low-cost, efficient access to space capabilities. Increased demand for communications and sensing satellites cannot be satisfied unless more affordable launch solutions are fielded. Another area that may have great potential is high-altitude long-endurance unmanned aerial vehicles (UAVs) that can operate at altitudes above 50,000 feet for weeks at a time. Systems such as Zephyr and Pegasus provide near-space platforms to fulfill this need, and can be employed as inexpensive geo-systems that can also move to new locations when required.

Space is critical to all elements of American's power: political, infrastructure, information, economic, social and military. Because of this, space systems will face threats from a wide variety of bad actors -- criminals, terrorists and nations opposing our views. Our country's space and missile professionals must stay focused in developing and executing strategies, policies and procedures to ensure the US and its Allies continue to reap the many tremendous benefits of the exploitation of space.

Maj Gen (Ret) Jeff Grime (BS USAFA, 1969; MS University of Illinois, 1970) is the President of Atlantic Systems Inc. in Arlington, Virginia. During his career, General Grime has had numerous assignments in the Pentagon to include positions in Air Force Plans/Programs, Operational Requirements, and Legislative liaison. A command pilot, he has commanded three fighter/composite wings in Air Combat Command, Pacific Air Forces and Southwest Asia. He is also a past commander of the Cheyenne Mountain Operations Center.

Missile Warning: A National Priority From Strategic to Tactical -- Past, Present, and Future

Dr. Michael M. Jacobs
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Dr. Ronald R. Herm
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The use of missiles during World War II, and the ensuing development of long-range ballistic missiles that threatened the United States, was clear motivation for development of a ballistic missile warning system alerting the US of an attack. The need for such a warning system became a National priority and was initially provided by a series of ground-based radars. As technology developed and use of space became a reality, the ability to remotely observe relevant areas of the earth and detect missile launches greatly expanded the Nation's missile warning capability. Remote sensing of ballistic missile launches from space is possible because radiation emitted from missile plumes can be distinguished from other natural features of the earth by carefully selecting the part of the electro-magnetic spectrum that is observed.

The space system eventually developed was comprised of Defense Support Program (DSP) satellites that operate in the infrared spectral region, and a ground segment, which provided surveillance of threat areas and conducted the missile warning mission, reporting on every important strategic event that occurred. Over time, this system has evolved in the satellite design and associated ground components, and the mission has also expanded to include reporting on tactical missiles to theater commanders, reporting on special events to other users, and providing cueing support to the Ballistic Missile Defense System (BMDS).

The follow-on Space Based Infrared System (SBIRS) satellites, with improved sensing capabilities, are in development and will begin joining the DSP satellites in space within the next few years. The mission will expand further with deployment of SBIRS, both in terms of planned and unplanned ways, as the sensor data is further exploited. SBIRS sensors are designed to provide key data for the BMDS to the intelligence community, and in support of the growing battlespace characterization mission. Beyond SBIRS, the Missile Defense Agency's Space Tracking and Surveillance System (STSS) is in the planning stages as a possible future addition to the system, which will extend tracking capabilities into the post-boost portion of the missile trajectory. As the threat continues to evolve, the Nation's intent to develop and maintain necessary warning capabilities remains strong.

EARLY HISTORY

The German missile attacks on England and Belgium during World War II, and the subsequent development of long-range ballistic missiles, were clear indications of the critical need for a ballistic missile warning system that could alert the Nation of an attack. Over 1,000 German V-2 missiles landed on London during the war causing significant loss of lives. When it was over, concern by the US and Soviet Union led to both sides to acquire the German technology and scientific manpower. The Soviets proceeded with a development program that led to a series of missiles, each with a longer-range capability. In August 1957, a Soviet R-7 missile lifted off from Tyuratam and successfully traveled a range of about 4,000 miles; this was followed by another successful launch in early September 1957. The Soviet boasted that it was now possible to send missiles to any part of the world, causing significant alarm in the United States, and initiating an effort to counter this capability. Advantages of intercontinental missiles included the possibility that the launchers could be mobile and they could be used in a surprise attack.[1]

The successful R-7 missile launches were followed almost immediately by the triumphant placement of the first man-made satellite into orbit on 4 October 1957, when Sputnik was launched. A new US intelligence assessment estimated that the Soviets could have an intercontinental ballistic missile operational capability as early as mid-1958.[2]

Efforts had been initiated earlier in the 1950s to place ground radars in position to warn of possible bomber attacks on the US. The Distant Early Warning (DEW) system was subsequently created in Canada by the US to provide Strategic Air Command advanced warning of a Soviet bomber attack. After Sputnik, an extended set of ground-based radars implemented and spread across a wide-range of the northern hemisphere; this was known as the ballistic missile warning system (BMEWS). These radar systems provided warning of incoming ballistic missiles by detecting the missiles during their post-boost phase. A missile launched from the Soviet Union could take up to 30 minutes to reach the US, and depending upon the relative location of the ground-based radar, warning might be provided many minutes into flight.[3]

As early as 1948, research in the US suggested that heat emitted from rocket plumes and hot metal might be detectable using detectors that sensed radiation in the infrared portion of the electro-magnetic spectrum. There was speculation that this could be conducted from long range, from a high altitude above the earth, even considering the effects of the earth's atmosphere.

Rocket plumes were determined to be very hot and bright, and heating caused by the atmosphere was thought to be beneficial. But the effect of atmospheric attenuation of the signal and the need to discriminate the rocket signal from natural earth signals were a concern. Key benefits of observations from space were thought to be the possibility of providing significantly earlier warning information, and the potential for covering a larger portion of the earth, as compared to the ground-based radars. In addition, it could be an independent second source of information to be used to confirm the data from the ground-based radar. This prompted a series of experimental flights to prove the concept of detection from space, and, if successful, leading to design details for an operational space warning system.[4]

The United States Air Force (USAF) was given responsibility for an infrared early warning project in 1958, which had earlier been initiated by the Advanced Research Projects Agency. This ultimately became the Missile Defense Alarm System (MIDAS) project. Nine MIDAS satellites were launched from 1960 to 1963; two of the satellites provided significant data collections on cooperative launches of US missiles, both solid- and liquid- fueled. Data on earth backgrounds were also collected. Real-time detection of missile launches from space was successfully demonstrated, even in the presence of clutter from the natural earth background. Three follow-on satellites of the then-called Project 461 were subsequently developed and launched in 1966. These produced additional data on Soviet-launched ballistic missiles, including launches from submarines, and proof that even dimmer and shorter-range missiles could be detected contrary to previous thought.[5]

The successful proof-of-concept, and the data collected from the MIDAS and Project 461 flights, led to an operational space-based missile warning system.[6] For over three decades, DSP satellites and the supporting ground segment have been the backbone of this missile warning system. Transition to the follow-on SBIRS is underway. The basic physics of ballistic missile detection is described in the next section, followed by a description of these satellite systems.

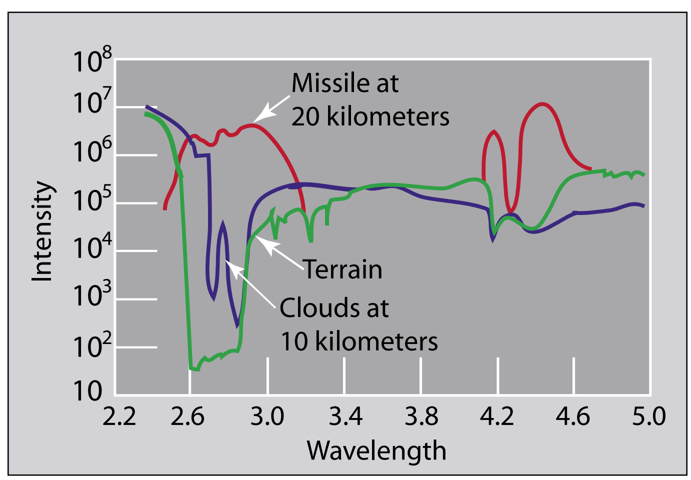
PHYSICS OF BALLISTIC MISSILE DETECTION FROM SPACE

In theory, observations in many different spectral regions might be used to detect ballistic missiles in flight by means of a passive space-based sensor. Indeed, over the years, concepts have been discussed for overhead ballistic missile detection using sensors operating in the ultra-violet, visible, infrared, millimeter wave, and even microwave regions of the electromagnetic spectrum. However, the discussion that follows indicates that the Short Wavelength Infrared (SWIR) has been the spectral region of choice for wide area missile warning (MW) surveillance from the early days of overhead MW surveillance by the DSP satellite up to the current development of the SBIRS program.[7] This is because selection of the proper SWIR spectral band provides a unique combination of attractive features for an MW system: a robust missile plume signature, ability to detect the plume early in flight, and a good ability to enhance the contrast between the signal from the plume and that from the background due to radiation from the earth and its atmosphere.

Missile Plume and Background Phenomenology

Although there has been some consideration at times (especially during the Strategic Defense Initiative Organization studies in the 1980s) of the possibility of using exotic bi-propellants (e.g., fluorine oxidizer), all existing ballistic missiles and space launch vehicles derive their thrust by combustion of a hydrogen-containing fuel with an oxygen-containing oxidizer. Thus, hot water vapor is a major constituent of the plumes of all of these missiles. With the exception of an engine burning only liquid hydrogen with liquid oxygen (e.g., the Space Shuttle's main engine), the fuel will also contain carbon, resulting in carbon monoxide and carbon dioxide as major constituents in the plume as well. The red curve in figure 1 illustrates the spectra of a hypothetical missile at 20 kilometer (km) altitude that is burning a hydrazine fuel with a nitrogen oxide oxidizer. The broad SWIR radiation emission from approximately 2.5 to 3.2 microns wavelength results primarily from radiation of hot water vapor in the plume. Similarly, the Medium Wavelength Infrared (MWIR) emissions result from radiation of hot carbon dioxide (near 4.2 microns wavelength) and carbon monoxide (near 4.5 microns). Because these are major plume species, these are robust plume signatures (i.e., these SWIR and MWIR emissions will always be present), although the ratio of carbon dioxide to carbon monoxide will vary with motor and altitude. Plume emissions in other spectral regions may or may not be present depending on specific propellant chemistry. For example, a solid rocket motor also burning aluminum will produce additional emission in the visible part of the spectrum and throughout the infrared due to emission from hot, solid aluminum oxide particles in the plume.[8]

The green and blue curves in figure 1 show the spectra of typical solar-illuminated earth terrain, and clouds at 10 km



Content: Northrop Grumman

Figure 1. Blue and green curves show background spectra of typical solar-illuminated terrain and 10 km-altitude clouds; red curve shows spectral emission of a hypothetical amine-fueled missile at 20 km altitudes. The x-axis covers a portion of the infrared spectrum, and the units are microns. Note that absolute intensity of the red curve cannot be compared with that of blue and green curves because the units differ.

altitude, respectively, as observed from space. In the SWIR spectral region, the observed earth background is primarily due to solar scatter (and the spectral intensity is much lower for nighttime viewing), whereas thermal emission from the earth/atmosphere system is an important contribution in the MWIR spectral region.[9] The missile plume is essentially a point source as observed by typical surveillance satellites, as compared to the earth background, which is an extended source. Hence, the plume spectral signature in figure 1 has different units from that of terrain and clouds. Depending on the physical size of the sensor footprint projected onto the terrain or cloud, the actual background intensity measured by the sensor may exceed the signal from the missile plume.

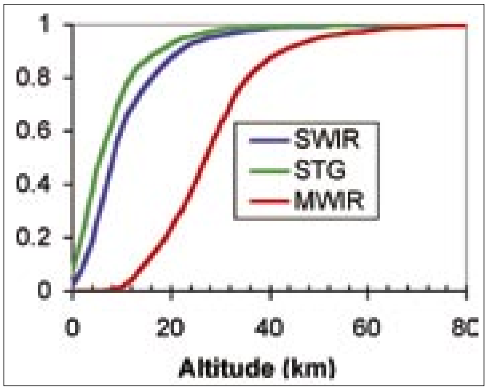


Figure 2. Atmospheric transmission to space from given altitude for nadir viewing in typical Missile Warning SWIR, MWIR, and STG bands.

Spectral Band Selection

For this reason, it is advantageous in an MW system to select a spectral band that favors plume emission over background. Another consideration is attenuation by the atmosphere of emission from low altitude plumes propagated to space.[10] While the MW system is typically not required to detect the missile at ground level, it is important to be able to detect missiles at relatively low altitude in order to provide earlier launch warning time, especially for theater ballistic missiles. Although the specific spectral band is classified, MW systems, including DSP and SBIRS, have chosen to provide wide-area surveillance in a spectral band around the SWIR "blocking band" discussed above and shown in figure 1. A careful selection of the spectral band provides a minimum signal from the terrain and cloud background, while still allowing adequate transmission of the missile plume through the earth's atmosphere. Figure 2 shows approximate atmospheric transmission from various altitudes above the earth, to space (i.e., well above the atmosphere), for a typical SWIR band, as well as other bands of interest.

As the missile reaches higher altitudes, the SWIR plume emission will begin to decrease and may become difficult to detect in the presence of the background, especially if the background exhibits spatial structure. SBIRS satellites will use a second spectral band, in the MWIR region, in some cases to track the missile to booster burnout. An MWIR band centered in the carbon dioxide absorption region is well suited for this task because carbon dioxide is uniformly distributed in the atmosphere, hence the atmosphere absorbs up to higher altitudes in the MWIR part of the spectrum, as compared to in the SWIR (water vapor band and water vapor is more concentrated at lower altitude). Figure 2 illustrates that transmission to space from a missile plume at a given altitude, even at the relatively high altitude of 10 km, is severely attenuated in such a band. Consequently, it had long been thought that such a "blocking" MWIR band is better suited to detection of weak plume emission at high altitudes because the expectation was that there would be very little spatial structure from the earth background in such a band. This was confirmed by background measurements in this spectral region by the Ballistic Missile Defense Organization's Midcourse Space Experiment (MSX) satellite in the 1990s. The specific SBIRS MWIR band was selected to balance the benefits of the benign background within a carbon dioxide band and atmospheric transmission properties to satisfy the mission.

Principles of Detection

Missile detection is achieved by processing infrared data collected by surveillance satellites, such as DSP or SBIRS satellites. Data from the sensor focal plane is processed in a way that attempts to eliminate nearly-static earth background radiation, leaving only exceedance-level data (meaning data above a certain threshold, and this is usually referred to as pre-processing) corresponding to point source targets from an extended underlying background scene. Different kinds of exceedance-processing algorithms are typically used for scanning sensors, as compared to staring sensor data, and the pre-processing might be done on the satellite or on the ground. If the intensity exceeds some threshold, the exceedance and a window of data points around the exceedance are forwarded to a representative return (rep return) centroiding algorithm, which computes unique location and intensity information for the infrared target by fitting the window of data to the Point Spread Function (PSF) of the sensor. The sensor PSF is a measure of the resulting distribution of energy from a point source target over the detector focal plane. Typically, the sensor is designed so that the signal from a point source is spread over more than one detector. This allows the location of the target signal to be determined to an accuracy that is better than the physical dimensions of the detector. This centroiding algorithm may also reject false exceedances when there is insufficient intensity in adjacent detector elements to correspond to a signal from a true infrared point source. Finally, the rep returns are forwarded to a tracker that attempts to assemble a track from a string in time of rep returns. If data from more than one sensor is collected on a target, the tracker will fuse the data from two or more sensors so as to produce a three dimensional track of the target.[11]

DEFENSE SUPPORT PROGRAM

DSP Mission

The Defense Support Program was initiated in the late 1960s with the primary missions of providing initial warning information on all strategic missile launches, and of reporting on nuclear detonations. The program consisted of a space segment of DSP satellites, a distributed ground segment, and communications support to route the data and messages. Warning messages were primarily sent to the National Military Command Authorities (the president and the Alternate Military Command Post), to the North American Aerospace Defense Command, and to the Strategic Air Command. DSP satellites and ground processing were initially designed to detect and report launches of relatively long-burning and bright missiles. Over time, the space and ground elements evolved to allow the system to detect and report on shorter-burning, and dimmer, sub-launched and theater ballistic missiles, and other special events. Evolution of the infrared sensor, and its associated mission processing, resulted in an expanded mission. During the Persian Gulf War in 1991, DSP demonstrated an ability to detect short-range theater missiles, but did not have the capability to describe such detections very accurately and did not have the communications capability to get its messages to theater war-fighters in time to provide adequate warning. These shortcomings were recognized and rectified after the war, and the requisite capabilities implemented by a combination of improved detection algorithms and fusion of data from multiple satellites, and eventually the use of dedicated tactical communication systems. This led to the development of a ground station dedicated to providing warning information to theater commanders. That system was called ALERT: Attack and Launch and Early Reporting to Theater, which became operational on 10 March 1995.

Northrop Grumman

Figure 3. DSP Satellite.

DSP Satellite

DSP is a spinning satellite deployed at geo-synchronous altitude and sweeps its detectors across the earth every 10 seconds. The satellite has undergone an evolution since the first launch in 1970, but the basic spinning design has remained the same. It has proved to be an effective and reliable design, with relatively few moving parts. A graphic of the current satellite is shown in figure 3.

There have been essentially five DSP satellite blocks, with increasing capabilities added over time. Initial DSP satellites weighed approximately 2,000 lbs, generated 400 watts of power, and contained 2,000 detector elements. Today's DSP-1 satellite has grown to over 5,000 lbs and 1,200 watts of power, and includes over 6,000 detector elements. Satellite reliability has generally increased with each block, and today's DSP-1 satellite has a lifetime significantly longer than those in the initial block. In addition, DSP satellite evolution has led to improved sensor sensitivity, providing enhanced capability in terms of the class of missiles and other events that can be detected. The primary spectral band used by DSP is an SWIR blocking band, as described in a previous section, for below-the-horizon surveillance of the earth. In addition, DSP sensors incorporate a wide window band that is used to observe above the earth's limb, as viewed from the satellite. That wide window band is extremely useful for detecting upper stages of boosting missiles, which are considerably dimmer than the typical first boost stage. Use of that wide window band is feasible for above-the-horizon applications, as compared to below-the-earth horizon, since for that application significant radiation from the earth background is not a factor. DSP sensor data is adaptively thresholded on board the satellite, and exceedance-level data is transmitted to ground stations.

Twenty-two DSP satellites have been launched since 1970. One last DSP satellite remains to be launched, and that launch is scheduled to occur in early 2006.

DSP Ground Segment

Ground stations were initially developed to receive and process DSP satellite data, and the stations were distributed around the world so as to be in direct communication with the on-orbit DSP satellites. Large processing sites were located in Australia (Overseas Ground Station-OGS), in Europe (European Ground Station-EGS), and in the Continental US (CONUS). Each site received data from satellites it could see, conducted data processing of data from each satellite, developed messages with missile warning information, and transmitted those messages on dedicated communication networks. Mission operators at the ground stations were employed to help reduce false reports occasionally generated by the automatic ground processing (false reports could result from exceedances in the data due to the earth background), and the system generally relied on a mission operator to release messages. As the system evolved, warning data became extremely reliable and accurate.

There were some limitations of the ground processing conducted by this distributed system. Data processing was performed on data from each individual satellite, without true fusion of data from different satellites, even when multiple satellite coverage was available. Multiple-satellite fusion had the potential to provide significant benefit in determining characteristics of the missile trajectory, and improving the accuracy of the launch and flight parameters. In addition, each ground station provided messages, and sometimes messages on the same event from different stations could have conflicting information, or it could be unclear that the information was on the same single event. Finally, each ground station required significant manpower to support mission operations and required significant funding to sustain.

As noted earlier, the ALERT ground station was developed in response to lessons learned from the 1991 Persian Gulf War to provide an operational system that would report on theater ballistic missiles. The ALERT ground station addressed some of the limitations discussed in the above paragraph. Fusion of data from multiple DSP satellites was developed and included in the data processing, and that resulted in improvement in the detection and description of the missiles and the associated trajectory estimates. Processing of the DSP data for theater warning was consolidated in a single ground station located in CONUS, and data from all DSP satellites was routed to this site. ALERT processing was conducted on satellite data that covered a limited area of the world, being those areas wherein theater missile events were anticipated. Processing of limited areas was due in part to command policy, and in part to limitations in data processing resources.

SPACE BASED INFRARED SYSTEM

SBIRS Mission

The SBIRS Program is the result of an initiative by the Air Force to improve the Nation's missile warning capability and continue to expand the mission set that is supported. A first objective of SBIRS was to effectively consolidate processing of DSP satellite data into a single ground station within CONUS. The second objective is to expand the mission requirements and provide capabilities in four mission areas: Missile Warning, Missile Defense, Technical Intelligence, and Battlespace Characterization. DSP had already evolved to support some of these additional mission areas. SBIRS satellites and ground elements are designed to satisfy operational requirements for these missions and expand the system capability beyond that which can be supported by the DSP satellite.

SBIRS Ground Segment Consolidation

In 1996, the SBIRS Program began the effort to consolidate and replace the existing ground segment infrastructure. Steps were initiated to develop and implement a new ground station in Australia, known as the Relay Ground Station-Pacific (RGS-P), which would replace the existing OGS. This new site would receive the DSP satellite data and relay it to the new SBIRS Mission Control Station (MCS) in CONUS, located at Buckley AFB, Colorado; processing of data would no longer be performed at the Australian site. Similarly, a new RGS in Europe is to be developed (RGS-E), which will serve as the ground entry point for several DSP satellites, and provide relay services back to the MCS. A third RGS at the MCS (RGS-M) would also be implemented to receive data from satellites located near CONUS. The MCS was to become the single site at which all data processing would be conducted, and from which all SBIRS warning messages would be released. In addition, mission processing capability that had been implemented in ALERT, which included the stereo fusion of data from multiple satellites within areas of interest, was to be implemented for the full earth. The intent was to reduce ground infrastructure, reduce required manpower support, eliminate duplicate reports issued by different ground sites, and very importantly, to improve the accuracy of the information that was provided in SBIRS messages. This ground consolidation was successfully achieved, and the new SBIRS MCS reached initial operational capability on 18 December 2001. These same SBIRS RGSs and MCS will be modified to also receive, relay, and process SBIRS satellite data as those satellites are deployed to replace the DSP satellites. Upgrades to SBIRS mission processing have continued and include enhancements that have been implemented to provide cueing messages to the Ballistic Missile Defense System.

SBIRS Satellites

While the SBIRS Ground Segment was being developed, design and development of new satellites that would ultimately replace the existing DSP satellites was also initiated. The SBIRS Space Segment will consist of satellites in geosynchronous earth orbit (GEO) and payloads in highly elliptical orbit (HEO) that fly on a Host spacecraft. SBIRS GEO satellites will have both a scanning sensor and a staring sensor. The scanning sensor will provide wide area surveillance of ballistic missile launches across the earth; the staring sensor will be used to observe smaller areas of interest with enhanced sensitivity and revisit time, for detection of theater missiles and other battlefield events, for tracking ballistic missiles to booster burnout for the missile defense mission, as well as for collection of technical intelligence data. Each SBIRS HEO payload will consist of a scanning sensor similar to the GEO scanning sensor and will be used to provide wide area surveillance of ballistic missiles for high-latitude launches, collection of technical intelligence data in smaller areas, and tracking of missiles to burnout in support of the missile defense mission. Figures 4 and 5 show the SBIRS HEO sensor, and a model of the GEO sensors, respectively.

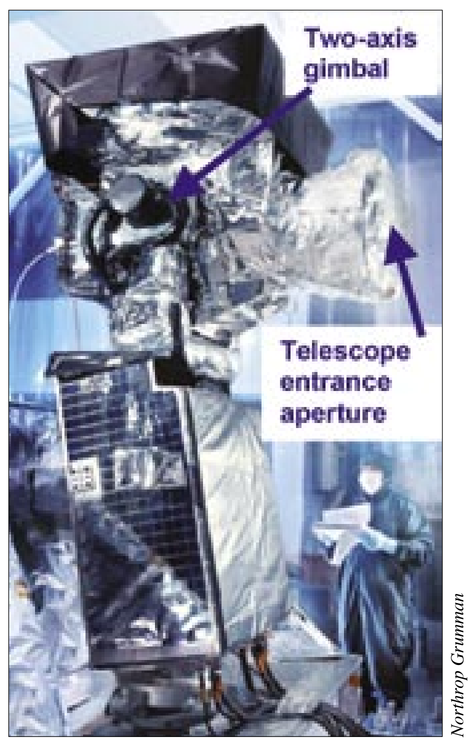
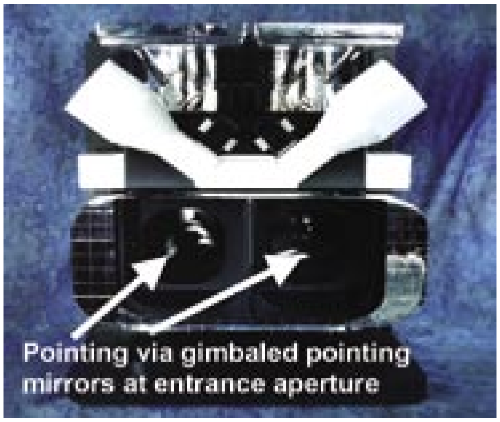


Figure 4. SBIRS HEO Scanning Sensor

GEO sensor data will be pre-processed on board the satellite to remove earth background data; the resulting exceedance-level data as well as raw data will be transmitted to the ground. HEO sensor raw data will be downlinked and pre-processed at the relay ground station.

SBIRS sensors include SWIR and MWIR spectral bands (discussed



Lockheed Martin

Figure 5. SBIRS GEO Scanning and Staring Sensors

earlier), as well as a third see-to-the-ground (STG) spectral band, which will be used to detect targets at or near ground level for the Technical Intelligence and Battlespace Characterization missions. As the Nation's operational Missile Warning system, SBIRS primarily will use data collected in the SWIR band to provide real-time missile warning reporting, since the system will need to meet performance requirements even during stressing solar background interference. This was considered the low risk approach because of experience acquired through the years with DSP data collection in this SWIR band. Atmospheric transmission in the SBIRS STG band is significantly better than in the SWIR band, and data collected in the STG band will mostly be used for off-line data exploitation opportunities. The SBIRS STG band was selected as a wide band near the SWIR spectral band, and its approximate transmission properties are indicated in figure 2.

This SBIRS capability will evolve over time as the HEO and GEO sensors are deployed. SBIRS sensors are designed to operate in different modes, with each mode providing a different combination of detection sensitivity and revisit rate. The better sensitivity and faster revisit rate of the SBIRS sensors will introduce capabilities that will allow earlier detection of targets that are currently detected and reported, as well as detection of new dimmer and shorter duration events. Figure 6 illustrates in a qualitative manner the evolution of capability against different event types as SBIRS sensors are deployed. Note that the chart is not intended to imply that event types below the nominal thresholds will never be detected.

The SBIRS GEO staring sensor will be tasked to step-stare over a theater major regional conflict area, or over smaller focused areas (FAs). Two step-stare FA coverage modes will be available; the Fast Revisit Focused Area mode will provide a faster revisit time to collect and report on short-duration events, and a high sensitivity focused area coverage mode will be used for collection and reporting on even dimmer targets. Finally, a dedicated stare mode will be available (called the Fast Frame Focused Area Mode) to provide a very fast revisit time over an FA, with the data available for off-line mission processing (discussed in the following section).

FUTURE MISSION GROWTH

SBIRS Data Exploitation

Growth in ability to process DSP data, as discussed earlier, led to improved trajectory estimation accuracy and the ability to report on shorter-range theater missiles and other special events. A mission set that has developed over the years and continues in the present, noted here but not discussed due to classification, are the "Walker" missions. Additionally, there is an evolving capability to use DSP observations for civilian applications in detecting fires and volcanic activity over the globe.[12] In the same way that DSP data was, and continues to be, exploited beyond its original intent, it is expected that SBIRS data will ultimately lead to applications well beyond the currently-defined mission capabilities.

As noted earlier and as illustrated in figure 6, deployment of SBIRS sensors will introduce better sensitivity and faster revisit times, thereby providing for earlier detection of targets currently reported, as well as higher confidence detection of new dimmer and shorter-duration events. The figure also in-

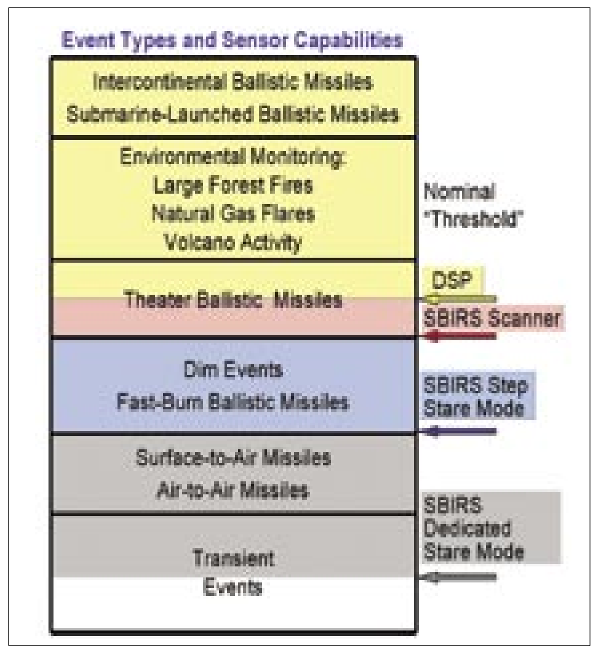


Figure 6. Nominal DSP and SBIRS sensor detection capabilities are illustrated for various types of events. Categories of events normally detected by DSP and SBIRS sensor modes are shown as the event types that fall above the specified nominal thresholds. The chart indicates that DSP is effective at detecting and reporting the bright and long-burning ICBMs and SLBMs for which it was originally designed, and that it has evolved over the years to be able to support some environmental monitoring as well as detection and reporting of some dimmer and shorter-burning theater ballistic missiles. The SBIRS scanning sensor will extend this capability to include more theater ballistic missiles. Finally, the SBIRS staring sensor will enhance the ability to detect and report on very short-burning theater missiles as well as SAMs, AAMs, important dim events of interest, and some transient sources of infrared signals. To remain unclassified, specific events and quantitative data are not included. In addition, the chart is not intended to imply that event types below the nominal thresholds will never be detected.

cludes a dedicated stare mode capability of the SBIRS staring sensor, which is intended to provide very high-frequency data for small areas of interest, that initially will be used for non-real-time, off-line, studies and applications. As indicated in the figure, this will extend collection capability to other kinds of targets. Real-time reporting on these events represents a future growth area for SBIRS, since this data will need to be examined in detail before confidence is gained in terms of how it can contribute to real-time mission processing and operations. Off-line processing and exploitation will be conducted to assess technical capabilities and tactics of foreign targets for the Technical Intelligence mission, as well as for the non-real-time situational awareness and intelligence preparation of the battlefield for the Battlespace Characterization mission.

Data collection for this off-line processing and exploitation mode is also expected to develop an appreciation for the added benefits of collection in the SBIRS STG spectral band, as compared to the SWIR mode. Although SBIRS is being designed to collect data for real-time missile reporting in the conventional SWIR band (which balances detection and false reporting rate, discussed earlier), there are advantages in collecting on targets at lower altitudes in the STG band. As more and more data is collected in this band under different background conditions, understanding the benefits and risks of using these data for real-time reporting will continue to evolve.

Future Evolution of SBIRS

Even as the Air Force's SBIRS System Program Office at the Space and Missile Systems Center (SMC) is acquiring and deploying the initial constellation of SBIRS GEO satellites and HEO sensors, it is continuing to work with the Development and Transformation Directorate at SMC (SMC/TD) and the Air Force Research Laboratory on technologies for the future generation of SBIRS. Technology planning is currently concentrated on a SBIRS Block II that would be initiated with the launch of the sixth GEO satellite in the mid to late 2010 century. Although a whole spectrum of technology opportunities is reviewed periodically, the highest priority has been and continues to be on development of a larger infrared sensor chip assembly (SCA) that could be incorporated as the detector focal plane of a staring sensor. The vision is to enlarge the field of view (FOV) of a staring sensor and to be able to simultaneously sample different regions of the FOV in different ways. For example, one FA region might be sampled at high sensitivity looking for dim targets, while a second is sampled at a fast revisit rate looking for transient events, and while the entire region is sampled at a lower frame rate for the conventional missile warning surveillance. Development of an SCA that would allow global surveillance without the need to step-stare the sensor would be a significant achievement, although the technology development may not reach that point by onset of SBIRS Block II.

During the late 1990s, the Air Force conducted studies of the benefits and cost of adding a low-altitude constellation to SBIRS, called SBIRS Low, which would be able to track missiles into the post-boost and midcourse phase of flight. In the end, SBIRS Low was assessed to be too expensive for immediate development. Currently, the Missile Defense Agency continues to study a low-altitude constellation, now called STSS, and two STSS demonstration satellites are in development, scheduled for launch in mid-2007. A constellation of high- and low-altitude satellites remains the ultimate long-term vision for evolution of the SBIRS constellation, and its performance was captured in a consolidated SBIRS Operational Requirements Document that was approved by the Joint Requirements Oversight Council in 2002. It describes performance of a consolidated constellation wherein the high- and low-altitude satellites work synergistically for detection and characterization of bright, hot infrared targets as well as missiles into post-boost, mid-course, and even intercept phase in support of an active missile defense system. This combined system would also provide improved performance in all SBIRS mission areas, while adding new missions in support of space surveillance and weather (primarily real-time cloud imagery).

Time will tell how the warning mission will continue to evolve as there are a myriad of growth paths which depend, in part, on how the global geo-political situation changes and how rapidly technology progresses. One thing that appears certain, however, is that the space-based missile warning surveillance capability has served the vital and changing needs of the Nation, and it is anticipated that the Nation's will to sustain and grow this capability will remain strong.

Notes:

[1] J. T. Richelson, America's Space Sentinels, DSP Satellites and National Security (Kansas: University Press, 1999), chapter 1.

[2] Ibid., chapter 1.

[3] Ibid., chapter 1.

[4] Ibid., chapter 1.

[5] Ibid., chapter 2.

[6] Ibid., chapter 3.

[7] F. Simmons and J. Creswell, "The Defense Support Program," *Crosslink,* The Aerospace Corporation magazine of advances in aerospace technology, 1, no. 2 (Summer 2000): 18-25.

[8] F. S. Simmons, "Rocket Exhaust Plume Phenomenology," *The Aerospace Press*, 2000. Unclassified indepth discussion of missile plume phenomenology.

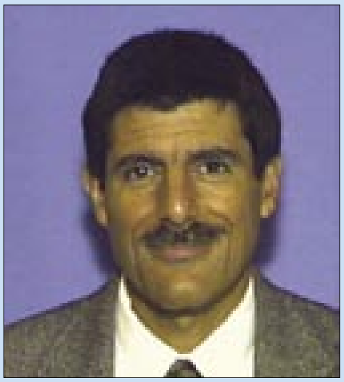
[9] G. J. Zissis, "Sources of Radiation, The Infrared & Electro-Optical Systems Handbook," *Infrared Information Analysis Center and SPIE Optical Engineering Press* 1 (1993). Details of background radiation.

[10] F. G. Smith, "Atmospheric Propagation of Radiation, The Infrared & Electro-Optical Systems Handbook," *Infrared Information Analysis Center and SPIE Optical Engineering Press* 2 (1993). Discussion of atmospheric transmission.

[11] "SDIO Handbook of Missile Launch Phenomenology," Aerospace TOR-92(2069)-3, 1-9 (1992). The Aerospace Corporation. A nine-volume classified set of documents with considerable detail relevant to this whole section.

[12] D. W. Pack et al., "Civilian Uses of Surveillance Satellites," *Crosslink*, The Aerospace Corporation magazine of advances in aerospace technology, 1, no. 1 (January 2000): 2-8. A discussion of this research area.

One thing that appears certain, however, is that the space-based missile warning surveillance capability has served the vital and changing needs of the Nation, and it is anticipated that the Nation's will to sustain and grow this capability will remain strong.



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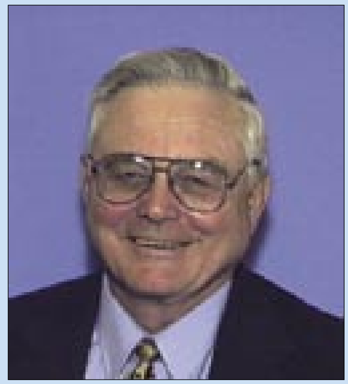

Dr. Ronald R. Herm (BS, Chemistry, University of Notre Dame, PhD, Chemical Physics, Harvard University) is a Distinguished Engineer in the Space Based Surveillance Division, The Aerospace Corporation, El Segundo, California. He serves as the Chief Scientist on the DSP and SBIRS Programs, in support of the SBIRS Program Office at the Space and Missile Systems Center. Dr. Herm is responsible for leading efforts that characterize the plume phenomenology and intelligence assessments of missiles and other threats of interest, defining, and implementing SBIRS support to the Technical Intelligence and Battlespace Characterization missions, supporting evaluation of SBIRS system performance, and planning for the future evolution of SBIRS. During his almost-30 years at The Aerospace Corporation, Dr. Herm has worked on Air Force satellite programs, Intelligence Community satellites, and also directed efforts within the Chemical Physics and Infrared Sciences Departments of The Aerospace Corporation Laboratory. Previously, he spent 10 years in academia on the faculty at UC Berkeley and at Iowa State University, and he also served as a Principal Investigator at the Lawrence Berkeley Laboratory and AMES DOE National Laboratory.

Space Systems - More Than Hardware and Hope

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Commander, 460th Security Force Squadron
Buckley AFB, Colorado

The service culture of the United States Air Force has always been characterized by a hunger for new technology that will aid in its mastery of the *high ground*. Nowhere is this service culture more apparent than in Air Force Space Command (AFSPC). Walking through the wide open spaces of AFSPC Headquarters, visitors are immediately impressed by hanging satellites and shuttles, and awed by models of rockets and Intercontinental Ballistic Missiles (ICBMs). Space operators are justifiably proud of their command of the *high ground,* and "ground-pounders" the world over are thankful for the benefits that come with US space dominance. As this volume of *High Frontier* clearly attests, America needs Space.

Rather than join the chorus of thousands already singing the praises of space and space utilization, this article focuses on a key, but often underrated ingredient in the maintenance of successful space operations: Space Systems Security. The unquestionable criticality of continued space exploitation demands an effective means of protecting American space operations. For this reason, Air Force Security Forces, or "Defenders", are regularly educated, enlightened, and reminded about the fundamental importance of the space mission; yet, when faced with the relatively low priority given to the provision of physical security, even the least astute Defender must question the veracity of these claims.

Billions of dollars and multiple years are spent researching, testing, launching, and maintaining a single space resource. When one compares these efforts to the relatively paltry amount of time and money spent securing them, the disparity is undeniable. Furthermore, when money is finally dedicated to physical security, it is usually after the fact—after the bulk of program money is spent and, much worse, after the resource is operational and beyond the capability for significant modification. Rather than find the appropriate amount of money to secure space resources effectively from the outset, too often the tendency is for budget-constrained decision-makers to scale down their assessments of the threat to match whatever degree of security can be afforded. The process is backwards. We rely too much on wishful thinking and the capabilities of inadequately manned Security Forces personnel to accomplish what should have been incorporated into the initial design process. The purpose of this article is not to criticize, vent frustrations, or fault the men and women who wear the SF shield. The purpose is simply to advocate for the full implementation of a new approach to fielding and securing critical space resources. After all, space systems without security are nothing but hardware and hope.

Within the Security Forces career field, there has recently been a paradigm shift when it comes to providing security. The old security paradigm was a regulation or compliance-based system. Somebody somewhere divided the resources into categories based upon their importance, uniqueness, cost, etc., then devised a set of security requirements he or she deemed adequate to protect each category. The requirements of compliance-based security were fairly easy to meet—simply count the cops, measure the fences, and test the alarms. If a base met the prescribed numbers, the resource was considered "protected" and security was deemed "adequate", irrespective of key, base-specific considerations such as mission, enemy, time, terrain, or troops (commonly abbreviated as METT-T). The primary advantages of the compliance-based approach lay in its simplistic consistency and low expense. Its primary disadvantages were its predictable consistency and shocking ineffectiveness. With the old system, a base could pass an operational readiness inspection with flying colors while failing to successfully secure the resource in a majority of realistic threat scenarios.

Partially as a result of the 2001 Air Force Audit Agency's *Report on Space-Related Ground Facility Security* which concluded that the "Air Force had no assurance that all space-related ground facilities were properly identified and safeguarded,"[1] the USAF Deputy Chief of Staff for Air and Space Operations, General Ronald Keys, issued guidance that all security planners and practitioners shift to a performance-based methodology in 2003.[2] General Keys recognized the risk associated with improper "selection and employment" of security technologies and stressed the need to consider the uniqueness of each base and resource when designing a security system.[3] Rather than using a cookie-cutter, one-size-fits-all approach, major commands (MAJCOMS) were directed to test the security at each base using a procedure that is commonly called a Systems Effectiveness Assessment (SEA). The SEA process "views detection, delay, and response as part of the overall system, and then matches technology, equipment, manpower, policy, tactics, techniques and procedures to identify the most effective system design through the use of modeling and simulation."[4] This new approach is far more effective, but understandably more costly, time consuming, and resource specific.

Quick to react to this new guidance, Lt Gen Robert C. Hinson, Vice Commander of AFSPC in May 2003, directed his staff to devise a way ahead that would "lay the groundwork for the security of all AFSPC satellite tracking, surveillance, warning, and space lift assets well into the future."[5] Under the leadership of previous AFSPC Director of Security Forces, Col Mike Hazen, and current Director, Col Pete Micale IV, AFSPC is leading the way with this new effectiveness-based approach. Every AFPSC base is now included in the "Space Roadmap"—a carefully considered and prioritized plan to ensure all bases undergo an SEA so that physical security upgrades can be devised and ultimately instituted. The problem with this approach is not in the planning process or in the resultant design, but rather in finding the dollars to implement the recommended solutions. How is it that the Air Force can spend billions of dollars building a new resource, only to balk at spending less than one percent of its cost to secure it? If the resource is important enough to build, it should be important enough to secure adequately. What is often forgotten in the pursuit of new space technologies is that without effective security, the Air Force really does not have a survivable wartime capability.

On 10 June 2005, the Defenders at headquarters (HQ) AFSPC briefed the Space Roadmap to General Lance W. Lord, commander of Air Force Space Command. Eager to move towards a more effective performance-based security system associated, General Lord directed his staff to factor Space System Security into the initial design stages of a new resource. Perhaps more importantly, he advocated that AFSPC fund the recommended changes for space system security within the next Future Years' Defense Plan.

With General Lord's backing, it is time for all Airmen in Air Force Space Command to re-examine the way we think about security. Security is often an inconvenience. While we all want to be secure, few of us appreciate the annoying hassle or high costs that accompany that security. How often do we grumble when we are delayed getting onto base because some bothersome gate guard is actually conducting 100% ID checks during rush hour? How many of us can say that our sense of gratitude outweighs our annoyance when just getting to our workplace requires a half-mile walk through multiple security checkpoints? Let's face it, security will never be popular, but it is important—especially in the post-9/11 world in which we live.

Rather than focusing all of our energy and funds on fielding a new resource and then compromising its security by settling for some stop-gap, piecemeal measure of protecting it after the fact, we should ensure that physical security becomes an integral part of the design process. Funds need to be allocated up front to prepare an area properly and to identify adequate numbers of security personnel to protect the new mission. As Airmen, we are quick to rally around the flag of technology when it comes to sexy new satellites or cosmic capabilities, but we constantly shy away from spending the necessary resources to invest in the technology that will improve that assets' chances of surviving an attack. We should constantly keep in mind that a high-tech satellite up in space is of little use to us on the ground without a secure, functioning ground station.

As our Nation grows more reliant on its space forces, we must constantly keep our eyes on the ground even though our heads are in space. Though technically not space operators, our Security Forces (SF) strive to fulfill the mission of securing the ultimate high ground every day with meager resources, limited manning, and inconsistent messages regarding USAF priorities. It is imperative that we, as members of the greatest space force in the world, consider carefully where our vulnerabilities lie and then take steps to mitigate them or eliminate them completely. The talented Defenders at AFSPC Headquarters are making great strides devising solutions to the many difficulties they face as a result of compliance-based security and zealously advocating for an effectiveness-based security approach to anyone who will listen. Nevertheless, it is every Airman's responsibility to seek out ways to incorporate security from the very beginning of a new system's design, or to retrofit adequate security onto our legacy systems. Rather than begrudge the SF for the relatively miniscule amounts of money they require to secure the mission, we should be eager to ensure they have what they need. After all, if they can't do their mission, what hope does anyone else have of doing theirs?

Notes:

[1] Air Force Audit Agency, "Report on Space-Related Ground Facility Security," Audit Report 00058014, 31 August 2001, i.

[2] General Ronald Keys (USAF), HQ USAF/XO, "Use of Leap Ahead Technologies," policy memorandum, 30 Apr 2003, paragraph 5E.

[3] Keys Memo, paragraph 3.

[4] Ibid.

[5] Lieutenant General Robert C. Hinson (USAF), HQ AFSPC/CV, "Space Security Roadmap," policy memorandum, May 2003, paragraph 3.

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Space, National Characteristics, and Revolutions in Thinking

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As we try to determine why the United States needs space capabilities, it might be instructive to look at space from the prism of history and what has caused nations to rise in prominence over time. In attempting to answer this question, we may share a perspective that will answer why the United States needs space capabilities and how we must continue to explore new realms of technological advancement far into the future.

National Characteristics

In the past, nations have risen to great power when their particular set of capabilities or characteristics were matched to the key developmental changes of the world as it developed. These characteristics could be anything from the size of the nation (geography or population), the nation's geographical location, the quantity of key natural resources, industrial skills to build ships, aircraft, or other assets, or technological advancements. Nations like China or the Soviet Union owed much of their power to the size of their countries and the size of their population. Invaders would find it impossible to occupy all of their country and these nations could always find more troops to fight an invader. Napoleon and Hitler found this out the hard way when they tried to subdue Russia in 1812 and 1941 respectively.[1] Great Britain, has had an advantage in its unique geography. It is strategically located off the coast of Continental Europe. It was isolated enough to effectively defend itself, but close enough to the economies of Europe to prosper. Great Britain also prospered in the age of sail because their island geography inherently led them to develop ship-building industry. For hundreds of years, its magnificent navy dominated the seas and allowed for Britain's security and economic mastery.[2] This confluence of characteristics, and others-such as the technological advancements of the industrial revolution-made Britain the most powerful nation on earth, controlling an empire with a quarter of the world's population and a third of its land mass.[3]

Another characteristic increasing national power is technological advancement. A clear case for national power through technological advancement comes from Portugal. In the 15th century, Portugal created a school for navigators, mapmakers, and geographers that grew into a technological base for exploration that propelled their ships to the rich spice trades of India and allowed them to lead the age of exploration. Portugal was a major economic and political power in the 15th and 16th centuries (a kind of silicon valley of its day). Portugal, despite its small size and relative lack of resources, made itself a powerful nation by being one step ahead of other nations with the capability to explore and navigate during a time when exploration was a key to national strength.[4] Their influence on the world was so strong at one time the world was divided into two halves, half was allotted to Portugese interests.[5] Today, their per capita gross domestic product is 31st in the world and their most prodigious industry is cork production.[6]

These general trends of history point to some conclusions that may affect how the United States looks at space and other new areas of world development. Sources of national power are always evolving and may change dramatically over time as the world creates new venues for commerce, industry and conflict.

In the United States' particular case, space is a key means of advancing its national strength. Utilizing and expanding America's space capabilities is one of the most efficient means of assuring national strength far into the future. It is an asymmetric advantage the United States has over many nations and to lose this benefit will mean a relative loss in national strength. Furthermore, if we keep this advantage over other nations, space will enable other advances our technology-based society creates to be highly optimized sources of national strength. An example of this enabling characteristic is the fusion of space-derived information with computer technology. Today, a missile launch can be detected by US satellites and the information can be sent around the world nearly instantaneously to alert US forces and protect US interests. Some nations have space systems that can detect missile launches, some nations have robust computer networks, only one nation can deliver key real-time battlefield information with the speed and fidelity needed for national leadership to make informed decisions vital to the survival of their way of life while giving battlefield combatants enough information to strike quickly at the source of the attack.

Space should not be seen as an end but rather as a means to consider how a nation deals with technology advances and other changes. National experience with technical innovations has shown that the best time for fostering these sources of power, such as space, is usually not during a time of conflict but rather during times of both conflict and peace and many times in areas of endeavor that are not originally intended to have military application. Stirrups, steam-powered ships, internal combustion engines, aircraft, wireless radios created revolutions within societies as well as revolutions in military affairs.[7] Nations that were not at the crest of these changes lost wars and lost political, and economic power as well. This happened despite the fact these innovations were many


Adam Faanes

Dejected French soldier-his nations inability to assimilate changes was a key to their defeat in World War II.

Emil Grimm

German tank and troops from early WWII — the ability of the German military to adapt and optimize the use of these battle instruments was a key to their early success.

times not intended to be a means of military supremacy. This situation reminds one of a quote from British scientist Michael Faraday. After attempting to explain one of his recent discoveries, Great Britain's Prime Minister, Sir Robert Peel, asked him what was the use of the scientific discovery. Mr. Faraday said, "Why sir, there is a probability that you will soon be able to tax it." On a parallel track, an equally valid response would be that scientific discoveries are a means of prospering the nation and defending it, even though at the time of an innovation its impact may not be understood at all.[8]

Revolution in Thinking

Not only does technology have to evolve but the people utilizing the technology have to change the way they think to allow for the greatest impact. Society is in a perpetual decision loop, much like the decision loop faced on the battlefield. On the battlefield, the US military tries to take in information, make decisions and act more quickly than an adversary. The time difference between our ability to take action and an adversaries ability to take action can leave the enemy vulnerable and allow them to be defeated decisively.[9] With respect to innovations, the United States will have to assimilate information about technology, decide how to employ it and take action with it faster than other nations. The time interval between this ability to utilize a capability brought on by innovation and another nations ability to utilize the same capability will give the United States a decisive advantage, for a time. As world events unfold however, this cycle of assimilating a technology, deciding how to use it and employing it must be seen as a perpetual process with a constantly compressing time element. A classic lesson from history on the importance of this strategic decision loop process is the battle for France in 1940. Both the Germans and the Allies had quality tanks. The Allies actually had a greater number of tanks.[10] The Germans, however, assimilated the capabilities of the tank into their military more effectively than the French or the British and were able to defeat France in 6 weeks.[11] While the Allies thought it was best to have tanks support an infantry advance, moving at the pace a person can walk; the Germans thought it was best to have infantry support a tank advance and move at the speed of armored vehicles.[12]

As you can see, the process of assimilating new capabilities can be seen in many of the past revolutions in military affairs. The technology advance was only part of the revolution. The military, as well as society, must determine how to employ innovations most effectively (doctrine) and adapt organizations or corporate culture, or how we think about the way do our jobs.

With the process for assimilating new capabilities taken into account, these concepts can be utilized to not only use space assets more effectively but experience from optimizing space can be used to guide how we approach other technology advances. Creating the technological advance is not enough, just as relying on current sources of national power whether based on geography or natural resources or technology are not enough. To secure the future strength of the United States, we must develop new technologies, determine how to use them most effectively, and adapt new ways of thinking and organizing to optimize technological advances.

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America Needs Space

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Throughout history, human activity has expanded into every medium that technology would allow. Technological improvements allowed human activity to expand from land to sea and then into the air. Improvements are always being made in the way in which people function within the different mediums—often driven by economic or military necessity. The pattern that history reveals is one of eager adoption of those improvements and rapid incorporation into our everyday lives. History suggests that increased economic and military activities in space are inevitable and that those activities will become increasingly interwoven into our daily lives, becoming indispensable. Once fully incorporated and relied on, these assets become worthy of defending militarily. The end result of this analysis is that military strategists and national political leadership must understand the importance of space in historical context because America needs space.

Mediums of human activity

The mediums of human activity have varied throughout history. The earliest people occupied and utilized just one land. With some creative thinking and desire for improvement in food gathering and basic transport, people took to the seas. This was followed by technological advances which permitted humans to take their activities into the skies. All of this exploration into the next unknown was for the same reason, to improve life for those who undertook it. The process did not stop in the air, however, and more technological advances allowed human activities to move into space, again to enhance quality of life.

Space: the new medium

Technology made it possible to adapt space for human activity. That activity has become part of our lives and space is now indispensable to that way of life. Space empowers the rapid transmission of a product that is in ever-increasing demand—information. Whether that information is business data, entertainment, or some other service, it has become a staple of our daily lives. We rely on the services that space provides in the same way that we have become dependent on previous improvements in the other mediums. In short, America needs space.

Space and the new product

The modern business or family does not live on material goods alone. Improved methods of shipment had a profound impact on people's lives when the acquisition of goods was difficult, if not impossible. That situation does not describe the modern world as transportation has allowed the movement of material goods to all but the most remote regions on the globe. There is a new product that we consume and demand in great quantities, but which does not require wheeled vehicles, ships, or airplanes. It is an electronic product we call information, entertainment, or data. Whatever its name, we want it, need it, demand it, and rely on it. It is an enormous part of our daily lives and has become essential to our way of life. Modern societies simply cannot live without it. As with transportation improvements previously described, space assets have improved the delivery of this information and subsequently the quality of our lives. Space has made much of this possible and we are as dependent on it now as on the more traditional mediums of transportation.

We spend a great deal of our day enjoying the benefits of space technology without even recognizing it as such. "For instance, most people know that direct broadcast TV comes from satellites, but are unaware that cable TV (from HBO to CNN) needs satellites to obtain most of its programming."[1] Space assets are used in banking, disaster warning, news services, trade, and transportation, to name a few.[2] These are all things that we use or benefit from daily—often without even recognizing the role space plays in making it possible. From paying at the pump for gas to watching our favorite 24-hour newscast, we have come to rely on space supported activities in our everyday lives. Space activities are a large and growing part of all economic activity. "Over the past decade, space activities have contributed nearly $1 trillion to the global economy."[3] Communications via satellite make up a large part of that revenue and "if one looks beyond the role of satellites (in narrow terms of telecommunications) and begins exploring the multiplier impact on the global economy, the overall impact is vastly more important on our planet as a whole."[4] Commercial space assets are not an insignificant part of our economy or our lives. In fact, America uses and needs space in exactly the same way that America uses and needs the previously adapted mediums of land, sea, and air. It enables us to engage more efficiently in economic activity, transport a high demand good—information, and conduct our daily business with greater ease than before. These are the same reasons that technology was employed to overcome obstacles presented by the previous mediums.

Space Conclusions

Some conclusions can be drawn by placing space in its rightful place as the next medium of human activity. It should be obvious by now that taking human activity into space was predictable, if not inevitable. All previous mediums had been explored and exploited. There was never a reason to believe that space would be any different. Another easily drawn conclusion is that space has been, and will continue to be, used to better the human condition here on earth. People seek to improve their condition, whether by gaining knowledge, pursuing economic gain, overcoming some obstacle to human activity, or enhancing power and prestige. This has been the case with previous mediums and space is no different. A final conclusion is that improvements to our quality of life, made possible by space assets, are eagerly incorporated into our daily lives and quickly become indispensable. The benefits of space have been pursued vigorously and will continue to be improved upon, just as with land, sea, and air before it. If we view space as yet another medium for human activity and accept the historical evidence that technological advances in the other mediums have become invaluable to our way of life, then it is easy to conclude that America needs space in the same way.

Military conflict enters each new medium

It is prudent to examine technologies impact on another realm of human activity—war. Just as certain as adapting technology to improve our daily lives is the certainty that it will also be adapted to military purposes. "Historically, whenever we traversed to a new medium (e.g., land to sea, land/sea to air, air to space) we brought conflict with us."[5] Technology provided advantages to early land forces engaged in conflict. "From Greek fire to the longbow, technological advantages have not stayed at home or been unilaterally set aside when armies have gone into battle."[6] The same process led to improvements in sea conflict and encouraged man to take to the skies to increase the advantage even more. This history suggests that entry into the medium of space will produce similar results on military activity. In fact, the 2001 Space Commission Report says that "We know from history that every medium—air, land and sea—has seen conflict. Reality indicates that space will be no different."[7] In reference to the predecessor mediums of land, sea, then air on strategy, one of space power's chief advocates, Everett C. Dolman writes that "Space power is their logical and apparent heir"[8] If this is true, then we should also look to space's predecessors for indications of what may lie ahead for space policy.

Lessons from sea and air

Space, as a medium, shares some characteristics with sea and air that are instructive. Like the oceans, space is not inhabited by humans. People don't actually live there except on a transient basis (rotational astronauts on the International Space Station or sailors traversing the seas). As a result of this, the oceans have not been claimed by any one group of people as their own. Nations have desired to claim them as their own, just that the practicality of possessing something so vast is a daunting, if not an impossible task. Rather, the ubiquity of ocean routes and its enormous accessibility has led to cooperative conventions on the use of the seas as a common medium. Nations have recognized the importance of free access to sea lanes and have sought to guarantee that openness. So important is this free access that any attempt at controlling sea lanes or blocking a "choke point" is considered a provocative act worthy of military response. Space, which overlies all terrestrial nations, certainly qualifies as a common medium for use in the same way. The importance of free access to space is directly analogous to that of sea lanes previously and all nations have an interest in maintaining that access. Like oceans before, " . . . the vastness of space has worked in favor of peaceful coexistence"[9] This does not imply that conflict has not occurred on the seas, but rather that the vastness of the oceans has necessitated some level of cooperation since complete control by one nation has been historically impossible. From this comparison we can predict that any attempt to control space or limit access to it would be seen as a provocative act potentially worthy of military response.

Military operations in the air also offer some insights for future space policy. The first has to do with issues of state sovereignty. Foreign aircraft, while not actually occupying the territory of another nation by flying over it, are seen as violating state sovereignty if the flight is not authorized. When one thinks of the potential intelligence gathering equipment or weapons employed aboard aircraft, it becomes obvious why nations choose to include airspace into their territorial sovereignty. This same concept can surely be applied to space where intelligence gathering assets can look down on any nation and weapons, if employed, could threaten multiple nations. It is equivalent to having an armed or spy aircraft flying over any nation on earth at any time. Intelligence gathering satellites are already in space and were an important asset through the Cold War and remain vital today. Nations have begrudgingly tolerated their existence because they could either do nothing about it or the information the satellites provided served to prevent a broader and devastating conflict. Opponents to weapons in space theorize that intelligence assets in space are "stabilizing" due to the information they provide while weapons in space are "overtly threatening and destabilizing."[10] Weapons in space do present the problem of directly threatening a nation, much as an armed aircraft does, but with little or no way to detect or prevent attack. The second lesson to remember from the development of air power is that countermeasures to any new technology are actively pursued by those nations threatened by the new technology. "Throughout the ages, it has been an iron law of weapons development for new concepts to be negated eventually by offsetting countermeasures."[11] The invention of radar by Great Britain to detect incoming German aircraft during WWII provides just one example. If space assets used for war are seen as threatening to a nation, that nation, or a coalition of similarly threatened nations, will seek to counter it. Finally, we learn from air power that the application of force from any one medium may not be decisive on its own. Early air power advocates, like Douhet, believed that the airplane would be decisive in military conflict by itself. This invincible airplane would spread a helpless fear in adversaries and destroy their will to resist. This proclamation proved unfounded as Great Britain and others endured bombardment from the air during WWII and continued to resist. True, air power is an enormously important part of our military arsenal—even more so now that true precision bombing has come of age—but it cannot win or stop wars alone. The same will likely be true of space power.

Sanctuary or High Ground?

With these historical lessons in mind, we can look at some of the debate surrounding the military use of space. This paper does not seek to explore the entire debate surrounding military uses of space or the weaponization of space, but rather to see if historical advances in previous mediums can offer any insight into the future course of space policy. To that end, we can first conclude that military operations in space have followed the historical pattern of previous mediums. Nations with the ability have pursued military advantages in space, just as our historical analysis predicts. What is less clear, however, is what direction future space policy should go. The current debate surrounding the future of space policy falls into one of two basic camps, "space as strategic *sanctuary* and space as the ultimate *high ground*."[12] Excellent arguments exist on both sides of the debate and this paper will certainly not end the discussion. What we can conclude, however, is that there is historical precedence that can be applied to each case. In the end, this author agrees with Lt Col Rinehart, writing in the Winter 2005 issue of *High Frontier,* that "Which course of action we advocate depends on whether we are pessimists or optimists about human nature, at least in the international environment."[13]

The "pessimists" are typically advocates of the military use of space as the ultimate high ground. Dolman claims not to conclude that a "harsh realist outlook is the only one for the future of space exploration and exploitation," but that "this has been the pattern."[14] Using sea power for comparison, space power advocates want to control space much as earlier sea powers sought to control oceanic choke points. Rinehart shows that sea analogies of potential "chokepoints" are applicable to space and believes that "we should not leave them open to exploitation by others."[15] The historical review of technological advance into every other medium supports this idea that nations will employ every conceivable technological advantage in space as they are able. As this applies to space, Dolman writes that "The militarization and weaponization of space is not only an historical fact, it is an ongoing process."[16] Taking this historic progress toward a conclusion, he writes that "the United States should seize control of outer space and become the shepherd (or perhaps watchdog) for all who would venture there, for if any one state must do so, it is the most likely to establish a benign hegemony."[17] While this sounds at first both bold and provocative, history does not judge it so harshly. When Great Britain was master of the seas, she moved to control key choke points on the oceans much as Dolman suggests for space. America's current dominant position in space compares easily with Great Britain's former domination of the seas. Unfortunately, the lessons from both sea and air power illustrate that nations will attempt to counter this move if it is carried out.

If we agree with Dolman and others that the US has an unprecedented advantage in space that will permit it to take such action, we ignore equally compelling historical evidence that other nations, no matter how outmatched, will seek to counterbalance any perceived American threat. "Once a nation embarks down the road to gain a huge asymmetric advantage, the natural tendency of others is to close that gap."[18] History also suggests that "Principal powers will simply not allow a space hegemon to emerge, and lesser powers may concede hegemony but will continue to seek asymmetric counters."[19] This was the case with Great Britain's taking of strategic choke points on the oceans. Great powers, while unable to force Britain to relinquish choke points, maintained a position as a credible counter force and the lesser powers sought what comparative advantage they could. One possible counter to American strength could be cooperative alliances. "History is full of examples of the emergence of one military power instigating coalitions against it."[20] If the principle powers are unable to counter American power alone, combined effort could be employed to balance the situation. The most instructive work for this line of reasoning could very well be that of Thucydides written more than two-thousand years ago describing the demise of Athens. That city-state, like America, was a dominant power, but she came to be resented by competing powers and a concerted effort on their part, coupled with Athens' own provocative and arrogant actions, led to her defeat.[21]

The "optimists," on the other hand, are advocates of ensuring space as a sanctuary free from weapons. They believe that putting weapons in space would be provocative, resisted, and ultimately bad policy. The idea that weapons in space are inevitable "is ultimately founded on a belief that the nature of people—their historical tendency to wage war—cannot change."[22] Our world and social attitudes have changed, however. "One has only to compare today's global attitudes toward slavery with those of 150 years ago."[23] Britain may have been able to take control of choke points without much global clamor in an age of colonization, but the same is not likely to be true today. The history of the oceans as a common medium does suggest that space may also remain a common area, implying some level of cooperation and international convention. What is not supported by history, however, is the belief that weapons can be restricted from space. History shows that all mediums of human activity have been adapted for military purposes as people seek to protect that which they see as vital to their way of life. Space, in this case, fits that bill since it is vital to America. This is not to say that weapons in space are inevitable. History is not determinative on human behavior—it is descriptive. Perhaps people are able to learn lessons from the past—as with the past century of war—and conclude that more of the same is not the answer. Unfortunately, Thucydides' timeless wisdom does not offer much hope for this view. He wrote for those "who want to understand clearly the events which happened in the past and which (human nature being what it is) will, at some time or other and in much the same ways, be repeated in the future."[24] These words have been accurate through the ages.

Conclusions

We cannot predict the future, but we must prepare for it. Military leaders are charged with defeating enemies and preserving their own force. To that end, they are obligated to seek every possible advantage on the battlefield. Current space assets, and maybe future space weapons, are part of that advantage. It is up to America's national level political leadership to formulate a long-range space strategy which takes into account the many factors in a complex world. "The decision to weaponize space does not lie within the military . . . but at the higher level of national policy."[25] While we can hope that humanity has found a less violent way to move forward, we must acknowledge the lessons that history has provided. Perhaps a dual approach space strategy that encompasses both an optimistic hope for a future without space weapons and a pessimistic backup capability that will enable their employment if required will emerge. In either case, military leaders must be prepared to attain and maintain a superior force. This currently includes an essential array of force enhancement space assets that must be maintained. If however, our political leadership decides that weapons in space are required, then military leaders must be in a position to deliver on that requirement.

Notes:

1 Joseph N. Pelton, Robert J. Oslund, Peter Marshall, eds., *Communications Satellites: Global Change Agents* (Mahwah: Lawrence Erlbaum Associates, Inc., 2004), 4.

2 Ibid., 275.

3 Ibid., 6.

4 Ibid., 6.

5 Lt Col G.W. Rinehart, "Toward Space War," *High Frontier* 1, no. 3 (Winter 2005): 47.

6 Col John Hyten and Dr. Robert Uy, "Moral and Ethical Decisions Regarding Space Warfare," *Air & Space Power Journal* 18, no. 2 (Summer 2004): 55.

7 *Report of the 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), vii, http://www.defenselink.mil/pubs/space20010111.html. p.10.

8 Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (Portland: Frank Cass, 2002), 7.

9 Rinehart, 49. (Lt Col Rinehart does not believe that this situation can last, however.)

10 Lt Col Bruce M. DeBlois, "Space Sanctuary: A Viable National Strategy," *Airpower Journal* 12, no. 4 (Winter 1998): 44.

11 Benjamin S. Lambeth "Air Power, Space Power and Geography," *The Journal of Strategic Studies* 22, no. 2/3 (June/September 1999): 72.

12 Dolman, 149.

13 Rinehart, 49.

14 Dolman, 2.

15 Rinehart, 49.

16 Dolman, 5.

17 Ibid., 157.

18 DeBlois, 50.

19 Ibid., 43.

20 Ibid., 47.

21 Thucydides, *History of the Peloponnesian War* (New York: Penguin Books, 1954), 400-8.

22 DeBlois, 55.

23 Ibid., 55.

24 Thucydides, 48.

25 DeBlois, 41.

1Lt Dwayne Liller (BS, Geography, University of Maryland) is a Peacekeeper instructor crew commander at F.E. Warren AFB, Wyoming. He develops training materials used to train 260 crewmembers/staff officers and conducts launch control center (LCC), missile procedures simulator, and classroom training. While on nuclear alert at the squadron command post, he is responsible to the President and CDRUSSTRATCOM for the offensive space force application of 50 nuclear missiles, directs missile crews, and oversees $5.4 billion in weapon system assets.

Lieutenant Liller is currently enrolled at Troy State University working toward a graduate degree in International Relations, National Security emphasis.

He enlisted in the US Navy in 1988 and served his first tour of duty at North Island Naval Air Station, San Diego, California, as an in-flight plane captain aboard the Grumman C-2A Greyhound. He retrained as a P-3C Orion flight engineer in 1992 and completed his second tour conducting anti-submarine warfare and counter-drug operations while stationed at Brunswick, Maine. He then continued to serve in the Navy Reserves as a C-130 Hercules flight engineer based at Andrews AFB, Maryland while attending the University of Maryland, College Park.

Lieutenant Liller earned a commission in the US Air Force through Officer Training School at Maxwell AFB, Alabama in December 2002.

Space Professional Development: Helping Make You Fit to Fight

Col Edward A. Fienga, USAF
Chief, Force Development and Readiness

In July of 2003, General John P. Jumper, chief of staff of the Air Force, announced via a Sight Picture the USAF's Fit to Fight program. Essentially, the cycle ergometry test was not the correct test to accurately gauge the fitness level of the world's greatest Air Force as it continued its rapid evolution toward being more expeditionary. Since that death knoll to couch potatoness, USAF fitness centers have, by some estimates, experienced an increase in usage of approximately 30 percent. In a testament to our institutional seriousness to this corporate fitness resolution, annual budgets have been amended to modernize, upgrade or add fitness equipment to afford Air Force members the maximum opportunity to prepare themselves for the physical demands of our expeditionary force. Most have already embarked on physical fitness programs to meet these physical demands and challenges. Recently, we have seen just where the bar has been set for being minimally physically ready: 12-hour shifts, 7 days per week, for 365 days while remotely deployed in support of our on-going operations. Compared to this benchmark, how physically ready are you? Simply stated, preparing for anything less is tantamount to preparing for failure. Around the same time, General Lance W. Lord, commander, Air Force Space Command, also recognized that being physically fit for the rigor of an expeditionary Air Force was, by itself, insufficient. Being solely physically fit could get you to and keep you at the dance, but it did not guarantee you would be escorted to the dance floor when the operational music started. As such, and based on the insights from the Commission to Assess United States National Security Space Management and Organization (The Space Commission), General Lord launched a "Fit to Fight" program to prepare the space community for the cerebral demands and challenges of an expeditionary Air Force supporting the needs of the joint warfighters, because being professionally unfit—or unprepared—would guarantee you would not have a seat (in the aerospace operations center) when the music stopped. Together, these Fit to Fight programs—the one which sculpts you for the physical strains and the one which chisels you for the cerebral challenges—are helping to define the minimum requirements for the Credentialed Space Professional (CSP).

Getting With the Program

Just as the Fit to Fight (FtF) program focused on your physical well-being has its component parts—aerobic, body composition, push-ups and crunches—so, too does the Space Professional Development Program (SPDP) have its components parts: education, training, and experience. For Air Force purposes, both programs more heavily weight one of the components: for the physical program, which translates directly into personal readiness to fight, the aerobic component counts for 50 percent of the total score. That is to say, the Air Force does not need a host of "power lifters." On the other hand, in order to maintain the robust ops-tempo while not sustaining injuries, sickness or stress failures, the Air Force, through the FtF scoring system, incentivizes your aerobic development, which translates directly to physical persistence. Similarly, the space community recognizes that when it comes to supporting the joint warfighters, nothing replaces actual space-related experience. Further, doing more repetitions of a similar mission builds professional stamina and strength. Said in other words, we have come to value the benefits rendered from developing technical depth (as opposed to placing a higher value on breadth of experience) in one of the space community's mission areas, because technical expertise—the prolonged concentration on a mission-muscle group—translates into increased senior-level opportunities such as operations group superintendent, operations officer, commander, command lead, branch or division chief. Briefly, our focus on technical depth is not to say we have discounted professional—or physical—cross training. The benefits to both FtF-physical and FtF-cerebral of cross training are clear: broader perspective, variety of experience for the individual and more mission-muscle groups get (some level of) development. All of these by-products of cross training are ostensibly "good," except if you are trying to develop a community of professionals qualified to overcome the rigor and demands of a highly technical, ever-evolving, weapon system-diverse Air Force competency. Which, of course, we are, and to ensure we have an inventory of properly developed individuals for the known demands, we know we must advocate for the development of technical experts as the foundation for long-term mission success in operations and acquisition. Additionally, we have all "done the math," and, once we have factored in the duration of mandatory training, deployments, professional military education and other schools, unfortunately, a typical career concludes too quickly for anyone to be a career-long cross trainer. Finally, in order to efficiently use each member of the space community and to enable the Air Force to effectively capitalize on the investments it makes on each individual, developing technical depth, the lifeblood of career longevity, is not only an institutional, but also an individual responsibility.

Individual Responsibility

The FtF-physical program has weekly formations of units conducting strength, endurance and morale-enhancing activities. These weekly events are not meant to be the sole level of effort. In fact, the unit activities are meant to complement the individual's physical fitness program. If individuals are relying on the weekly unit activities to deliver them to the appropriate level of personal readiness, then the individual's program is not robust enough. Similarly, the SPDP has created and funded education opportunities for the community of Credentialed Space Professionals. These career-long courses, which include Air Education and Training Command's Space 100 for space community accessions and Air Force Space Command's Space 200—for the 8-10 year

CSP—and soon-to-debut, Space 300—provided to the 13-15 year CSP and the capstone space professional course—are offered at strategic points in the career of a Credentialed Space Professional and are designed to prepare each of the CSPs for the next level of challenges and responsibilities they will face as they advance through the ranks. However, the institution-provided events are not meant to be the sole means for cerebral enhancement. For that reason, as the SPDP has been briefed to over 5,000 members of the space community at more than 37 different locations during the last year, we have stressed the importance of individual-initiated continuous space learning, and have designated the minimum necessary to keep in a fit fighting condition as 40 hours per year.

Professional Fitness Test

Tied to the completion of formal space education is the Space Professional Certification program. As CSPs accrue years of service in space-related positions, as briefly outlined above, they will be eligible for the various formal space education courses. Upon completion of the space education, coupled with the years of experience, CSPs will ascend through the certification levels and onto positions of higher responsibility. Specifically, Space Professional Certification Level I requires the completion of Space 100 and 12 months of duty in a space-related billet. Level II requires completion of Space 200 and six years of duty in any space-related—operations, acquisition or staff, within or outside of AFSPC—billets. Similarly, Level III requires completion of Space 300 and nine years of space-related duty. To reinforce our desire for the development of technical depth, and to more clearly define "depth" for the space community, of the nine years of space-related duty experience required for Level III certification, we have set six years of experience within any one of our 11 Space Experience Codes (SPEC) as an objective. Briefly, the 11 SPECs include: Satellite Systems, Nuclear, Space Lift, Warning, Space Control, ISR, Kinetic Effects, Space Warfare Command and Control, Space Test and Training, Space Staff, and Information Operations. The Headquarters Air Force Space Command Space Professional Management Office (SPMO) has identified over 8,700 officers and enlisted members of the Air Force who have served in space-related (again, in either operations, acquisition, or staff) positions and have categorized the experience they have accrued into one of the 11 areas.

"Bio-Feedback"

This gathered intelligence on the collective and individual inventory of experience of the space community is immediately actionable. The SPMO created a product which summarizes each individual's career-to-date totals of experience, space education and training. This biographical product, modeled after and using the same database as the Assignment Management System/Military Personnel Database SURF, is the Space Professional SURF. The Space Pro SURF is an "at-a-glance" summary and affords supervisors, commanders, career field development teams, assignment teams and special selection board members the ability to quickly decipher an individual's areas of strength, technical depth and, perhaps most importantly, placement into which jobs would be most appropriate based on that individual's specific record. Incumbent on each individual however, is the responsibility to ensure personnel records are accurate through a periodic review of your Space Pro SURF. To further underscore the importance of validating the data accumulated by SPMO, starting in the Fall of 2005, the new space badge will be tied to the Space Professional Certification program. Members of the CSP community must first attain Level I criteria to be authorized wear of the Basic Space Badge. Level II will equate to the Senior Space Badge and, for those who have achieved Level III, they will have earned the Master Space Badge. The credit for years of space-related experience will be derived directly from the Space Professional Database, which is used to produce the Space Pro SURF. Additionally, General Lord, in his role as the Air Force's Space Professional Functional Authority, can use the aggregate data of the space community to determine inventory shortages and overages of experience in each of the 11 SPEC categories. Consequently, he can direct segments of the space community into emerging mission areas or ensure pipelines of training and experience remain wide enough to accommodate increased requirements from one of the 11 areas.

As one would expect, and as each member of the space community deserves, a program to prepare for the cerebral challenges of joint warfighting is comprised of many moving and interacting components. And, just as making strides in your personal readiness—through FtF-physical—requires vision, dedication, patience and a little creativity, so too does the development of a program—FtF-cerebral—to enhance your intellectual strength. Rest assured, the institutional vision and dedication to creating within the Air Force a community of Credentialed Space Professionals who can continue to meet the Nation's security demands as they relate to space is crystal clear…is yours?

Col Edward A. Fienga (BS, The Citadel; MA, Webster University) is the Chief, Force Development and Readiness, Headquarters Air Force Space Command, Peterson AFB, Colorado. He is responsible for assignments of the Air Force Space Command's officer and enlisted space operators and space acquirers as well as the development, implementation and funding of the Air Force Space Professional Strategy to include education, training and certification development.

Colonel Fienga was commissioned through the ROTC program in May 1986. He has held a variety of operational and staff duty positions from the squadron to the Air Staff levels. He has controlled air activity as an Airborne Weapons Director on the E-3A Airborne Warning and Control System (AWACS), accumulating over 750 flight hours; operated the PAVE PAWS ground-based radar and commanded the 321st Missile Squadron at Francis E. Warren AFB, Wyoming. Colonel Fienga is a graduate of Squadron Officer's School, the Legislative Fellows Program (IDE) and the Belgian Defense College (SDE). He is a Senior Space and Missile Operator.

HQ National Security Space Institute: Answering the Space Commission's Call to Create Credentialed Space Professionals

Lt Col Frank Gallagher, USAF
Commander, National Security Space Institute

At the National Security Space Institute (NSSI), we have little trouble filling our classrooms with students; yet across the space community, NSSI is not a "household" word. The NSSI officially stood up October 2004 and we have been gaining mission responsibilities, hiring instructors, and building classrooms ever since. With this article, my aim is first to provide a short background covering the NSSI's roots. Second, I will add an overview of the courses we offer today. This overview will include brief course outlines and a description of the target audience. Third, I want to touch on our recent accomplishments and some near term challenges. Lastly, I will discuss our long range goals for Distance Learning and Advanced Space Training. All in all, this description should give *High Frontier* readers a better grasp of NSSI's role in developing Space Professionals and the steps we are taking to ensure our courses fill the needs of the National Security Space community.

BACKGROUND

After Operation DESERT STORM, the Space Warfare Center stood up the Space Tactics School (STS). Conceived by General Charles A. Horner and patterned after the United States Air Force (USAF) Weapons School, their mission was to foster inter-agency "cross-pollination" so the best techniques and experiences could be transferred among the different elements of the space community. The first course, offered in 1994, was eight weeks long. By 1996, it had grown to 20 weeks. Over this period, the STS graduated approximately 30 officers with technical expertise in all facets of space to include manufacturing, operations, management, and combat applications.

In 1996, the STS mission moved to Nellis AFB as a new division of the USAF Weapons School and the course expanded to 23 weeks. The mission of the new Space Division (now known as the 328th Weapons Squadron) is to integrate, train and enhance space capabilities in support of combat operations at the operational level of war. Space force enhancement missions and counterspace planning and execution are key themes. During the 23 weeks, space students work with other students from across the combat air forces to get a firm grasp on how all the pieces fit together. Over the last nine years, this course has graduated 146 Space Weapons Officers.

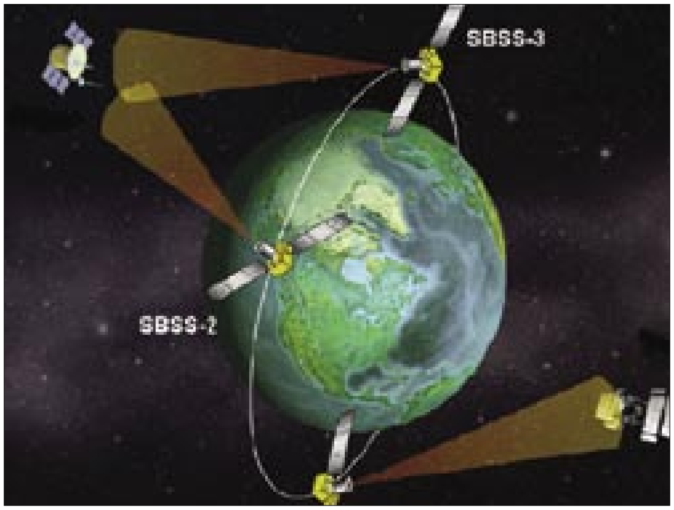
Tomorrow's space professionals need a broader understanding of operations across the range of space mission areas and the size of the space cadre will need to grow, as space becomes increasingly important to military operations. Perhaps more than other areas, space benefits from a unique and close relationship among research, development, acquisition and operations… -Space Commission

The Space Warfare Center's training branch continued to teach overview courses to help non-space personnel better understand how space systems support military operations. Due to a continuous demand for space education independent of the Weapons School concept, the Space Warfare Center formed the Space Operations School (SOPSC) in June 2001. The mission of SOPSC was to be the Air Force (AF) lead in the instruction of space concepts and systems as they relate to military operations and the development of space tactics, techniques and procedures.

In 2001, the Space Commission published their report assessing US National Security Space management and organization. Among the Commission's directives to ensure the Nation has the means to advance its interests in space was the need to create and sustain a cadre of space professionals. In August 2001, the Senate directed the Undersecretary of the Air Force to establish a space career management plan and directed the Secretary of the Air Force to assign the commander, Air Force Space Command (AFSPC) with responsibility for career management.

In 2003, SOPSC stepped up to build courses designed to address the key shortfalls of current Professional Military Education programs identified in the Space Commission report. Specifically, the courses stressed tactical, operational, and strategic application of space systems to combat operations. SOPSC went one step further to address another identified issue: breadth. To tackle this issue, SOPSC began development of courses to also emphasize space science, system design, and acquisition processes.

In late 2003, General Lance W. Lord made Space Professional Development the Command's #1 priority for 2004 and designated the SOPSC as the Command's execution arm for development



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of key courses in this effort. In October 2004, SOPSC was redesignated as Headquarters, National Security Space Institute and aligned directly under AFSPC. Today, our mission is to be the Department of Defense's (DoD's) center of excellence for space education throughout the National Security Space community and provide space power education and training required to prepare warfighters for Joint military operations. To develop Credentialed Space Professionals (CSPs), we research, develop and provide world-class space system instruction on technologies, acquisition principles, operational capabilities and employment concepts and tactics development. We anticipate forming several schools under the NSSI umbrella. Thus far, we have courses grouped under three – the Space Tactics School, Space Operations School, and Space Professional School. The courses offered by each school are summarized below.

COURSE DESCRIPTIONS

Space Tactics School. This school provides Advanced Space Training (AST) courses on specific mission areas. As pointed out by the Space Commission, "space leadership in the military will require highly trained and experienced personnel at the very senior positions and throughout all echelons of command. These leaders must provide the vision, the technological expertise and doctrine, concepts and tactics to generate and operate space forces in this new era of space…" We have designed our AST courses to cover future leader essentials:

- Acquisition—physics, concepts of operations, warfighter needs, etcetera.
- Operations—system architecture, tactics development, warfighter impact, etcetera.
- Sustainment—coupling maintenance & operational needs, decision making criteria, etcetera.
- Planning—current operations, crisis action planning, as well as future modernization

This education will be a foundational element that will be combined with specialized career management to meet the Space Commission's goal for depth of knowledge and experience among senior space leaders.

- *Navigation Operations Advanced Space Training*. This 12-week course provides in-depth education on Global Positioning System (GPS) operations. Topics include radio navigation physics, satellite components, ground architecture, navigation signal contents, navigation warfare, precision timing, warfighter applications, operational/tactical planning for combat operations, constellation modeling, and future concepts. It is intended for navigation operations CSPs with backgrounds in satellite/ground operations, system acquisitions, maintenance, and operational-level planning.
- *Missile Warning Advanced Space Training*. This course, projected to be 13 weeks, will provide in-depth education on Missile Warning and Defense with a focus on Space-based warning assets. Topics include sensor physics, enemy threat systems, warning architectures; air-, land-, sea-, and space-based sensors; missile warning and missile defense operation centers, warning processes, and tactics. Students will include missile warning space professionals with backgrounds in satellite/ground operations, system acquisitions, maintenance, and operational-level planning.

In the future, we are planning ASTs for several space mission areas: SATCOM, Command & Control of Space Forces, Nuclear Operations, Space Control, Intelligence-Surveillance-Reconnaissance and System Test & Evaluation.

Space Operations School. We conduct two types of courses in the Space Operations School: warfighter preparation and space familiarization. Warfighter prep courses provide education and training designed for CSPs eligible for theater deployment, intended to teach students how to integrate space capabilities into theater air, land, and sea operations. Space familiarization courses provide education at various levels of depth and classification. These courses support the needs of officers, enlisted, and DoD civilians for basic space concepts and operational capabilities, limitations, and vulnerabilities.

- *Weapons School Preparation Course (WSPC)*. This two-week course prepares AFSPC candidates for the USAF Weapons School program. The WSPC highlights the capabilities, limitations, vulnerabilities, applications and employment of space and Combat Air Forces (CAF) systems supporting the warfighter.
- *Director of Space Forces Course (DIRSPACEFOR)* is a five-day course that provides education and training to prepare CSPs for theater duty as the senior space advisor to the COMAFFOR or COMAFFOR/JFACC. It's intended for colonels and above in leadership positions identified by AFSPC.
- *Counterspace Planning and Integration Course* is a three-day program that provides MAJCOM, NAF, and theater level planners a comprehensive look into the counterspace mission area-- including up-to-date information on counterspace capabilities.

- *Space Operations Course (SOC)*. This course provides a basic knowledge of space operations and progresses to concepts involving DoD space resources and space initiatives by other nations. This two-week course highlights capabilities, limitations, vulnerabilities, applications, and employment considerations of the numerous space systems integrating space power into military operations and is an AFSPC AEF training resource. It is intended for all services, military and civilian (colonel and below and civilian equivalents). There are three- and five-day mobile versions of the SOC course, and a one-day executive version.
- *Space in the Air and Space Operations Center Course (SAOCC)*. SAOCC, two-weeks long, trains and educates CSPs with various backgrounds to effectively augment theater Air and Space Operations Centers (AOC) during exercise and real-world contingencies. It provides insights into the processes necessary to successfully integrate air and space power in support of theater military operations. SOC is a prerequisite for SAOCC.
- *Space Fundamentals Course (SFC)* is a two-week familiarization course that provides an educational and training bridge for new space support personnel or those within operations with little space exposure. It introduces students to doctrine, orbital dynamics, environment, space law, physical science aspects of space systems, force applications, and other related subjects to enhance student understanding of the operational aspects of space.

The next course to be added to the Space Operations School will be dedicated to hands-on skill training and Space Superiority academics to CSPs newly-assigned to the 14th Air Force Joint Space Operations Center at Vandenberg AFB, California.

Space Professional School. Courses in the Space Professional School are matched to the needs of CSPs at specific points in their career.

- *Space 200* is the first course specifically developed to address the Space Commission's recommendation to develop a cadre of space professionals. The four-week course emphasizes space power integration to Joint combat operations. It also provides education on space physics, satellite design, and space systems acquisition. The target audience is mid-career DoD civilians and military at their 8-10 year point.
- *Space 300* is the capstone course for space professional development at the NSSI. Space 300, four weeks, is a "thinker's course," primarily using guided discussion techniques to teach tomorrow's senior space leaders to solve problems within the space arena bearing on National Security. It expands the approach established during Space 200 to encompass a truly National perspective, to include considerations of Joint, National, Civil, Commercial, and even Foreign Space. It is designed for CSPs at the 13-15 year point.
- *Space Support Course* provides a one-week educational bridge for new space support personnel who have had no exposure to space. It is intended for officers, enlisted, and civilian personnel from all services assigned to the National Security Space community in a support capacity.


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The Space Professional School is also developing a series of computer-based lessons designed to provide students baseline knowledge prior to entry into Space 200 and 300. Since students arrive with a broad range of space-related knowledge—anywhere from high school physics to doctorate degrees, we need a way to get them all started at a known baseline.

RECENT ACCOMPLISHMENTS

Graduate Credit. Working through the American Council for Education (ACE), we are moving toward accreditation for many of our courses. Thus far, Space 200 and the Navigation Operations-Advanced Space Training (NAVOPS-AST) have completed this rigorous evaluation process. Based on ACE recommendations, Space 200 could earn five graduate credits (three for Space Mission Design, two for Space Systems). NAVOPS-AST could earn two undergraduate credits (Principles of Instruction) and 10 graduate credits (three for Space Based Navigation Systems, three for Space Operations Management, one for Space Issues, and three for Space Modeling and Simulation). One of our graduates has already applied his Space 200 credits to the completion of a master's degree in Space Systems Management with a university that fully accepted the ACE recommendations. It is worth noting that we are working to ensure NSSI courses earn credits toward graduate degrees, the NSSI does not offer graduate degree programs, as is the case with the Air Force Institute of Technology or the Naval Postgraduate School.

Space 200. We completed our first SP200 course last year. Since then, we have graduated approximately 500 space professionals. For each edition of the course, we blend students from several National agencies and all services. This blending sets up an environment for sharing experiences, ideas, and perspectives during group projects and wargame exercises. We have a very thorough critique program and the students and faculty members have generated hundreds of suggestions for course improvement. This volume of feedback highlights two points. First, we are providing an excellent course, but have many tasks to complete before we move beyond the development phase. Second, the students


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are intensely interested in the success of the Space Professional Development Program.

Army FA40 Training. Approximately 40 Army officers per year pursue the space career field, usually as majors. As part of a partnership with the Army, the NSSI offers seats in Space 200 for the FA40 candidates, which serves as the front-end of an 11-week FA40 training program. In exchange, the Army has added two instructors to the NSSI staff. These instructors provide valuable theater perspectives to several NSSI courses.

Space Power Lab. We completed work on a $1.4 million Space Power Lab (SPL), a state-of-the-art modeling and simulation facility, early in 2005. This 2,000 square foot facility features the full set of computer applications used in AOCs worldwide. The exercises conducted in the SPL give students an appreciation for the complexity of war planning, the situational dynamics involved with executing these plans, and the importance of integrating space capabilities. The SPL accommodates 30 students at a time and provides an interactive training environment via a classified internal network. Students receive high-fidelity, hands-on training covering every aspect of their duties as AOC augmentees during exercise and real-world contingencies. We plan to add SPL-based exercises to numerous space professional development courses.

AFSPC is dedicated to a program to develop CSPs who will lead the design, acquisition, operation, integration, and sustainment of current, emerging and future space systems.

Space 300. This year began with several challenges, including hiring course developers and instructors and the construction of a modern classroom. Currently, we have seven instructors dedicated to the effort and many more providing their expertise to research and development efforts. We expect to have many guest speakers from the National Security Space Community. Our invitation list includes General Lance W. Lord and Mr. Peter Teets, the former undersecretary of the Air Force. Construction of our classroom is underway and will be ready for the first prototype in September 2005.

Rank Structure. The NSSI will soon have a new rank structure--featuring a two-star "Chancellor" billet and Air Force colonel commandant, and Navy and Army colonel billets. Brigadier General Ericka C. Steuterman has been named to fill the Chancellor's position (which is dual-hatted as the mobilization assistant to the vice commander, AFSPC) and the Air Force commandant billet is in place and projected to be filled in CY 06. The new structure will match the expected growth and multi-service nature of the NSSI.

Reserve Associate Unit. In October 2005, a new reserve squadron will stand up to support the NSSI mission. This Reserve Associate Unit (RAU) will have 11 full-time and 44 part time reservists. The RAU will provide critical support to the NSSI mission by bringing expertise not readily available within the constraints of active duty manpower. This expertise includes pilots, navigators, engineers, and space operators with more than four years experience in specific space disciplines.

NEAR TERM CHALLENGES

Subject Matter Expertise. As the NSSI grows, so does its need for expert instructors. We have been fortunate to have a host of talented guest speakers. However, to best keep up with our development plans we need to have the experts assigned to the NSSI. To facilitate the recruiting process we have been campaigning to secure support from several external agencies. The Air National Guard (ANG), Space and Missile Systems Center (SMC) and the Army are already on board. Soon we will have staff support from the Defense Acquisition University, National Aeronautics and Space Administration, and the National Reconnaissance Office. We will continue working on various memorandums of agreement to increase our Joint and National expertise.

Space 300. A significant challenge ahead is to assemble the right group of students for our prototype courses in September 2005, January 2006, and May 2006. Since these students will help shape and design the final version of the course their inputs are critical. We need to ensure we have the right credentials represented. These students may be asked to remain after course completion to help refine course content.

Space Control Education. Among the conclusions identified in a recent space control Mission Area Review was the need for more rigorous education on counterspace systems, operational concepts, and policies. Our Counter Space Planning and Integration (CPIC) course presents an excellent one-week curriculum, but it does not address all the needs of the space control community. Our plan is to grow our CPIC course in two phases. First, we want to build a more in-depth counterspace planning course. This course would be tailored to educate operational-level planners at various headquarters. It may also address our goal of creating a Command & Control of Space Forces course. In the second phase, we plan to build an Advanced Space Training course with the same scope and depth as our NAVOPS-AST. Our vision is that this course will serve the needs of counterspace operators and planners from all services.

Joint Space AOC course. For at least two years, the leadership at 14th AF has pursued a training course for their new operators. More emphasis has been placed on building a training program since the "Space AOC" has received more responsibility from USSTRATCOM and was recently redesignated the Joint Space AOC (JSPOC). We are currently working with the 14th AF staff to form a course resource estimate for this training. Among the options is to establish an entry requirement that all JSPOC operators are certified a minimum of Level 2. This baseline would allow our education to focus on higher level concepts and skills associated with gaining and maintaining space superiority.


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LONG TERM GOALS

Distance Learning. For our Space Professional courses, we have limited our class sizes to 30 students due in part to facility limitations, but mainly because we want to ensure our courses remain interactive with labs, wargames, and guided discussions. This equates to approximately 390 seats per year. Attendance to Space 100, 200, and 300 are required to attain Space Professional Certification Levels I, II, and III respectively. Selection of attendees is monitored closely to ensure we provide enough slots for all our CSPs to attend and therefore attain the appropriate certification level. Because mission and ops tempo might limit an individual's ability to attend either Space 200 or 300, we are considering the feasibility of distance learning versions of these classes as a back-up means of meeting these requirements. Distance learning courses will prove to be valuable to Reserve and Guard CSPs who might not be able to attend a four-week course in residence. As we progress to the point when space billets will be filled only by those with required credentials, we must ensure all CSPs have an opportunity to attain those credentials. We will work with HQ AFSPC to determine the benefits of distance learning development costs versus the cost of additional instructors and facilities.

Advanced Space Training

Thus far, NSSI course development has emphasized the Space Commission's directive covering education breadth:

> Tomorrow's space professionals need a broader understanding of operations across the range of space mission areas and the size of the space cadre will need to grow, as space becomes increasingly important to military operations. Perhaps more than other areas, space benefits from a unique and close relationship among research, development, acquisition and operations…

Space 200 provides a series of lessons on space physics, satellite design, space system acquisition, and space power integration to Joint combat operations. To this baseline, Space 300 will add examinations of high level National Security space issues including space law and policy, acquisition strategy, and doctrine development. As mentioned earlier, to generate a Space 300 prototype this year, we have channeled all available resources to that task. With this level of effort we will rapidly answer the call for education breadth. In a parallel effort we are working to develop AST courses to increase knowledge depth within individual mission areas.

When the Space Commission described the education needs of space professionals, they emphasized the following:

> To ensure the highly skilled workforce needed, technical education programs will have to be enhanced. Space systems under development, such as the Space-Based Infrared System and the Global Positioning System III, and future systems envisioned, such as a space-based radar and a space-based laser, will be far more complex than today's systems. New concepts for space launch, offensive and defensive space control operations and projection of military power in, from and through space will give rise to increasing technology innovation. Other career fields, such as the Navy's nuclear submarine program, place strong emphasis on career-long technical education. This approach produces officers with a depth of understanding of the functions and underlying technologies of their systems that enables them to use the systems more efficiently in combat. The military's space force should follow this model.

In practical terms, we know it takes a great deal of system knowledge to develop new tactics that increase system performance, enhance/create combat capability, or prolong a satellite's useful lifespan. We also know that many future space systems will be taskable and operationally responsive—a dynamic that few space operators have experienced. Additionally, the Air Force is gradually shifting emphasis from space integration to understanding the enemy's use of space and their ability to deny our use of space. Space superiority is no longer a given and the next generation of space professionals will need far better education to understand the new complexities of military space operations.

A question we should ask is, "Will the Weapons School space curriculum meet these education needs?" Potentially, but only if additional courses are added that cover our future taskable assets to the level the current space curriculum covers counterspace contributions to theater operations. We believe developing ASTs at NSSI is a better alternative to meeting the broader needs of the National Security Space Community. Another question may be, "What is the NSSI doing to develop the new 'Wizards of Armageddon'?" In his April 2005 address to the National Defense University, General Lance W. Lord stated:

> We also have the newly created National Security Space Institute in

"…in-depth space-related science, engineering, application, theory and doctrine curricula should be developed and its study required for all military and government civilian space personnel…"

- Space Commission

> Colorado Springs and our consortium of colleges and universities led by the University of Colorado-Colorado Springs to help us generate thought provoking studies of some contemporary Strategic Deterrent and Global Strike issues. We're creating the "New Wizards."

This reference implies the NSSI will be a key element in providing the education necessary to develop future leaders of the evolving space community. Presently, our curriculum lacks such a course, but an AST for nuclear operations could well be the right answer.

We currently have an AST for Navigation Operations and we had planned to offer the first Missile Warning AST in summer 2005. However, subject matter expertise limitations and higher priority courseware development efforts have pushed this course's debut to the right. Looking ahead in this era of reduced budgets, AST development will compete with other programs for funding. To keep the momentum going, NSSI will need advocacy from each organization expecting to capitalize on AST graduates.

CONCLUSION

AFSPC is dedicated to a program to develop CSPs who will lead the design, acquisition, operation, integration, and sustainment of current, emerging and future space systems. The NSSI has a strong and improving curriculum that addresses the needs not only of those space operators who will deploy in support of Operations ENDURING FREEDOM and IRAQI FREEDOM, but also the directives of the Space Commission, which stated, "…in-depth space-related science, engineering, application, theory and doctrine curricula should be developed and its study required for all military and government civilian space personnel…" The men and women of the NSSI have made tremendous progress in our short history, but we have only just begun to develop the advanced academics future space leaders will require. Through investment across the DoD, the NSSI will continue on a growth path that will make us a household word inextricably connected to the development of space professionals.

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Previously, Lieutenant Colonel Gallagher served in a variety of space operator, instructor, and staff duty positions. His operations experience includes space surveillance, space-based missile warning, and navigation. He was the Space & Future Sensors Branch Chief at the AC2ISR Center and the Weapons and Tactics Branch Chief at AFSPC. Lieutenant Colonel Gallagher is a graduate of Squadron Officer's School, Air Command and Staff College, USAF Weapons School, and Air War College. He wears the Master Space and Missile Operator Badge.

The Reality of Space Warfare: A Chapter in Future War

Maj Robert J. Reiss Jr., USAF
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505 Exercising Control Squadron

Author's note: The purpose of this article is to generate serious discussion among all members of the military space community to consider a change in mindset concerning our collective outlook on how we impact our Nation's warfighting ability and dependence upon space superiority in future conflicts. As space professionals, it is our duty to honestly assess the critical role we have in the overall National Security construct. The spectrum of challenges we face (economics, technology, personnel, systems, etc) cannot be addressed in a single article nor at this classification level. Therefore, only one area, the realistic portrayal of threats to our space capabilities when we exercise, will be covered.

Defensive-Offensive Counterspace

Without space situational awareness, the rest won't happen.[1]

- USN RADM Thomas E. Zelibor, USSTRATCOM
Director of Global Operations

The space capabilities currently fielded by the United States comprise the leading technology shaping future 21st century military forces. US communications, detection, intelligence, surveillance, reconnaissance, weather, warning, and precision navigation capabilities have enhanced combat capabilities to the point that everything from force structure to the number of desired mean point of impact (DMPI) can be struck on each mission (for example: many aircraft using many bombs on one to few targets to one aircraft using one bomb per target to achieve a kill) must be recalculated and re-evaluated as we further integrate them throughout the joint warfighting spectrum. The synergistic effect of combining the aforementioned capabilities provided by space systems with air and surface weapons platforms has yielded results much greater than the sum of the individual parts. Additionally, effects based operations (EBO) can be implemented on a much wider scale and with greater efficiency and effectiveness than previously attainable without current space capabilities. This space power comes with a military as well as an economic price: it must be heavily protected. Civilian and military leadership accept the staggering economic cost of space power and appreciates the increased combat capability our space systems provide. Policymakers must now address the vulnerabilities of these space systems as we grow more dependent upon this technology. The great strength we draw from our space assets is also a great weakness because we rely so heavily on those capabilities. It is critical now and in the future to gain and maintain our space superiority if we are to prevail in future conflicts against adversaries who have access to space technology, understand our dependency on space and plan to negate our advantage. This, unfortunately, has not been an area where we train as we will fight.[2]

> *US Air Force counterspace operations are the ways and means by which the Air Force achieves and maintains space superiority. Space superiority is a distinctive capability of the Air Force.*
>
> - AFDD 2-2.1 Foundational Doctrine Statements

The US military does an excellent job of exercising at the tactical level and a satisfactory effort at the strategic level. It is at the operational level of war where the true measure of progress in joint warfighting capabilities must be seen to be believed. This area has not been neglected but has been overlooked by all of the services, yet this is the process that will be used to conduct war now and in the future. This fact is typified by exercises involving the Combined Air Operations Center (CAOC) where the Combined Forces Commander (CFC) and the Combined Forces Air Component Commander (CFACC) can see the entire theater of war (observe, orient, decide, and act) and based on this information shape the battlespace.

There are fundamental differences between war training and war gaming. In general, war training is when the expected war processes, tactics, and procedures are trained to everyone involved (from the leadership on down) in a sterile, nonviolent environment so the focus is upon learning. War gaming is when there are two distinct sides: the blue/good guys and red/opposing forces (OPFOR). Each is given a set of rules and objectives to follow. There is normally room for some experimentation, but the results are always the same: blue wins because blue has to win. We cannot afford to continue only using these two divergent ways of figuring out how we will fight. To fully integrate the diversity of space and information operation (IO), we must add a new third way: the joint force (purple) will meet not only the apparent red but also gray (commercial), orange (terror/guerilla groups and hostile countries), white w/red stripe (neutral country hiding/hosting hostile groups), light blue (ally nation, not quite w/US) among other categories.[3] This shift in mindset by adding more actors will push us closer to the reality we already face and the environment we will operate in future wars.

Top Air Force leaders have stated: "You can't go to war and win without space" and just as importantly, "If the opponent has any brains at all ... disrupt it to deny them (US) the use of space ..."[4] Therefore, it is incumbent upon space professionals in all services, with Air Force leading the way, to gain space supremacy by continuous maintenance of space superiority which occurs through vigilant counterspace operations.[5] Then why are there still problems with getting the 'message' through to non-space audiences concerning the importance of what space brings to the fight? Each service has unique hurdles to cross when it comes to education, just as each branch evolved their respective space mission areas. The Air Force has the preponderance of forces and therefore is expected to lead. Yet the overall mindset has not evolved past third dimensional air-centric thought. Space-centric thought is not needed to replace that, or merely to augment; we need to propagate a 'total' thought pattern that imbues all ground, air, naval, space, and IO combat power that efficiently provides the winning combination for future wars. The US military can neither afford to lose future conflicts nor the opportunity to capitalize on our current fortune.

The United States is the nation most heavily reliant on technology for its economy, defense and way of life.

- US Strategic Command, Fact Sheet

The United States is the nation most heavily reliant on technology for its economy, defense and way of life.[6] In addition to exploiting space for their own purposes, future adversaries will also likely seek to deny US Forces unimpeded access to space.[7]

Author's note: Multiple countries have invested in counter space technologies and have studied how the US military operates. They have a high level of confidence in their knowledge of how dependent we are upon our space capabilities. Unfortunately, we cannot go into specific countries and known/potential capabilities here due to classification.

Threats to Space Systems

A growing area (in terms of methods, systems, and knowledge) that has not been fully appreciated by the space community is the emerging specter of foreign offensive counterspace capabilities and the willingness to use them against US assets. The list of space faring nations continues to grow due to low-cost access to space enhancement capabilities verses the 'old' standard of indigenous launch capability only.

Adversaries can conduct attacks against our space capabilities using various methods both symmetric and asymmetric. Adversaries may have the capacity to develop counterspace capabilities but, in many cases, may simply acquire them from a third party. Near and far-term threats may include the following:

- Ground system attack and sabotage using conventional and unconventional means against terrestrial nodes and supporting infrastructure.
- Radio frequency (RF) jamming equipment capable of interfering with space system links.
- Laser systems capable of temporarily or permanently degrading or destroying satellite subsystems, thus interfering with satellite mission performance.
- Electromagnetic pulse (EMP) weapons capable of degrading or destroying satellite and/or ground system electronics.
- Kinetic antisatellite (ASAT) weapons capable of destroying spacecraft or degrading their ability to perform their missions.
- IO capabilities capable of corrupting space-based and terrestrial based computer systems utilized to control satellite functions and to collect, process, and disseminate mission data.

Adversaries do not need to be space-faring nations to exploit the benefits of space. Adversaries can purchase space products and services, such as imagery and communications, which often rival those available to US military forces. Adversaries may leverage US or friendly systems to their advantage as well. For example, an adversary may use the NAVSTAR Global Positioning System (GPS) constellation for navigation. In conflict, adversary access to space decreases US advantage and increases the threat to friendly military forces.[8]

The heavy reliance upon the commercial civilian sector for the bulk of satellite communication (SATCOM), 80 percent or more in some cases is a fact not lost on our adversaries.[9] Many of those same satellites are either owned (wholly or partially) or used by those whom we may come into conflict someday. Since these countries have the exact same access and/or capabilities that we utilize, does it not stand to reason that they also fully understand the advantages and vulnerabilities in this single slice of space power?[10]

The **gray space order of battle**, regarding US commercial and neutral foreign (commercial and government) space systems, can be difficult to develop and maintain. Status on US commercial providers requires their voluntary participation, as US law and policy strictly limit the ability of US intelligence agencies to collect, retain, or disseminate information concerning US persons and corporations. The importance of third party providers must not be understated as they provide space capabilities to numerous clients, including friendly and adversary military operations.[11]

By assuming away potential adversarial capabilities, we risk placing our future superiority, even our very survival, in grave peril. Space systems affect much more than the immediate joint space community. Space capabilities are interwoven throughout the enhanced combat operations spectrum enabling the near real-time intelligence gathering and dissemination, instantaneous worldwide communications, precise navigation, and level of situation awareness we are now accustomed to in the US military. These combined capabilities, plus the con-

Everything that can be invented has been invented.

- Charles H. Duell, Commissioner, US Patent Office, 1899

cepts called "reachback," are made possible by space assets and can be removed from the list of superiority assets by a determined enemy.

Closed Minds - Spacious Skies: Current attitude vs Current vulnerabilities

Currently, 'unrealistic' scenarios drive exercises. Resources are rejuvenated through models and simulations so overall exercise results may be inflated. However, even though exercise scenarios may seem unrealistic or appear as such, it stands to reason: 'war' in space has not happened to date, or not one we recognize as 'war.' We may think or believe we know what a space war would look like, but we do not. Will we recognize it when it does occur or will someone assume or dismiss it simply because it does not 'fit the model'? Just because an event or tactic did not originate from our think tanks or we never war-gamed it that particular way does not indicate whether anyone else thought of it or plans to attack us in such a manner. It is not in the realm of the impossible.

Exercises are conducted to achieve specific training objectives and to expose the training audience to a myriad of problems that may be encountered and continue the mission. For training to best prepare participants, exercises should be planned and conducted as close to real operations as possible. Yet, expectations should not be in the realm of 'flawless' performance of systems or crews and showcasing or grandstanding the latest innovation. Rather, the 'reality' test is based on how well space systems can overcome sustained attack on vulnerabilities and whether crews can recognize, understand, and solve the problems an enemy is forcing upon them. In some cases, it must be understood that certain aspects cannot be duplicated or somehow made 'realistic' due to either real world requirements or uniqueness of systems. Those simulations can only be presented as "you no longer have capabilities X and Y, what do you do?" Space forces must be exercised to the fullest extent possible consistent with operational requirements. To improve readiness, space forces should participate as a full partner with joint service and information assets in large-scale exercises overseas and in the Continental US (CONUS). Perhaps the best way to demonstrate exactly how integrated and crucial space systems are in the 'how we fight' mantra is to allow all those advantages to be 'removed' by plausible enemy action. Joint exercises can provide realistic training for in-theater and deployable space forces by all services, plus the added problems inherent in working with allied military forces. Valuable experience in integrating space systems will only occur if these opportunities are not squandered or beset by parochial bias. Instead, systems, processes and procedures should be tested to the breaking point with success measured by how fast recovery (restoration of expected capability or in the case of redundant systems, the speed of re-tasking) of systems or amount learned in the cause (the 'how' and 'why') of failures that will occur when faced with a determined knowledgeable space adversary.

Space Situation Awareness (SSA) is crucial for assessment of counterspace operations. SSA is an important source of battle damage assessment (BDA), particularly for counterspace operations against space nodes and links. Certain counterspace operations, particularly those with non-kinetic effects, may require focused, real-time BDA to effectively assess an adversary's defensive counterspace response.[12]

Opportunity to Excel

We can overcome the limitations and barriers. We have the tools and means available to us: professional journals, the Space Operations School (SOPSC), the implementation of Space Professional Development, Army (FA40) and Navy space career fields, space aggressor squadrons, the integration of space, and information operations into joint/combined exercises through the 505th Command and Control Wing to name a few. The final hurdle is mindset. If flexibility is the key to air power, then elasticity of the mind must open the door to space power. When we look back upon our short space faring history, we need to continue the leap of faith that the pioneers held. Looking into the future, we need not wait until capabilities are fielded to imagine what existing present day threats can do now and will do if we fail to identify and correct our vulnerabilities. The German Wermacht formulated a coherent combined arms doctrine and held experiments to test this doctrine in the 1920s yet did not possess a single armored fighting vehicle in their inventory.[13] These actions laid the groundwork for future panzer forces and blitzkreig tactics that shocked the world and conquered most of Europe in record time. We cannot continue to wait for our adversaries to drive the train and field capabilities before considering crisis action planning. This is how we will prevail: not by reaction to events, after being surprised by adversary actions, then having to explain to the American people that we did not foresee such things, but rather by embracing the reality of enemies who will use their full set of capabilities to win in future conflicts against us. We need to allow better exercise freedom by war gaming against a worthy opponent, against more than one space faring nation or even going a step further and fighting against a slightly 'superior' space enemy that will challenge us across the full spectrum of capabilities. Who learns more in a conflict: the winner or the loser? What about those countries that sat back and took notes of how we have conducted war since 1991? If we continue to script exercises so that we always win or never really push

The battle, sir, is not to the strong alone; it is to the vigilant, the active, the brave. . .

- Patrick Henry

the envelope to deal with a concerted effort to wipe away our space superiority, are we truly benefiting ourselves or are we inviting a recipe for disaster?

DODD 3100.10, *Department of Defense Space Policy,* states:

- "Space is a medium like the land, sea, and air within which military activities shall be conducted to achieve US national security objectives.
- Ensuring the freedom of space and protecting US national security interests in the medium are priorities for space and space-related activities.
- Purposeful interference with US space systems will be viewed as an infringement on our sovereign rights. The US may take all appropriate self-defense measures, including, if directed by the [President and/or SecDef], the use of force, to respond to such an infringement on US rights.
- Space activities shall contribute to the achievement of US national security objectives by countering, if necessary, space systems and services used for hostile purposes."

With the advent of space-based satellite systems, we can no longer base sea power on shipboard capabilities alone. Today, and increasingly tomorrow, a seafaring nation must also be a spacefaring nation.

- Admiral (Ret) James D. Watkins, USN, Chief of Naval Operations, July 1982-June 1986

"With the advent of space-based satellite systems, we can no longer base sea power on shipboard capabilities alone. Today, and increasingly tomorrow, a seafaring nation must also be a spacefaring nation."[14]

USSTRATCOM mission: Establish and provide full-spectrum global strike, coordinated space and information operations capabilities to meet both deterrent and decisive national security objectives. Provide operational space support, integrated missile defense, global C4ISR and specialized planning expertise to the joint warfighter.

The ability to utilize current space technology allows all of the services to employ true economy of force due to knowledge of weather, intelligence on enemy disposition, instant updates and communications. US military power, through the proper usage of space assets, has experienced combat enhancement and force multiplication. This power has the awesome potential to bring forces and weaponry to mass at the right point, multispectral vision and superior intelligence preparation of the battlespace. Technology is compensating for reduced numbers of platforms and troops (the age-old 'quality versus quantity' comparison). History is replete with examples of those who won with either the 'most' (quantity, such as US Sherman tanks versus German Panzers in World War II) or the 'best' (quality, such as ancient Roman expertise in engineering).[15] We do not want to be on the wrong side of history when struggle for national survival occurs. Rather, the capabilities that are in development should firmly remain in the US column and vulnerabilities to US systems mitigated by thorough testing and aggressive experimentation to find the weak points (doctrine, employment, processes, equipment) before our enemies do.

No Time to Waste

Unfortunately, it may already be too late to push advancements in technology further through the pipeline and be fielded before we engage in a space war. We have to rely upon the tactics, constellations, configurations and protections that currently exist and trust the assessments on how far behind our adversaries are in exploitative techniques. The slim technological superiority edge we currently enjoy is being eroded not only through our own inaction but also the leaps and gains by all actors in the counter space arena. Current space capabilities have laid the groundwork for EBO to be implemented on a wider scale with greater efficiency and economy of force. Doctrine, strategy, tactics, and exercises, while acknowledging threats, are only the baseline environment for adaptation of thought. They are not the final product or goal in the evolution of ideas. There has to be complete cooperation from all levels that touch space systems; to calculate the totality of US military might, all of the Department of Defense, certain civilian government agencies, and commercial entities must be in the equation.

However, there is hope for the immediate future if we recognize and address this problem now. What we must do is go beyond the 'jointness' revolution and push the knowledge of space capabilities below the highest leadership levels (as evidenced by the various quotes, leaders in many positions understand the advantage of space superiority) in the strategic realm to the operational and tactical leaders and operators. These are the personnel who work in the combat theater. Current exercises, including those involving the CAOC do not fully explore the extent of dealing with a space equal or superior foe. The consequences for not exposing potential leaders and operators, in a controlled environment, to the possible effects of severe losses of capability could lead to the very least reduced economy of force to the almost unimaginable tragedy of unrecoverable catastrophe for the deployed joint force. This is not alarmist, merely acceptance that the stakes are high and there is no prize for second place.

Notes:

[1] USN RADM Thomas E. Zelibor, USSTRATCOM Dir of Global Operations, *Space News*, 11 October 2004, A1.

[2] Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945*, (AU Press, 1983). Even during the height of WWII (Nov-Dec 1943 for example), the Luftwaffe conducted war games, assessed battle tested doctrine and tactics.

[3] Jennifer Reingold, "Hondas in Space," *Fast Company*, Feb 2005. This area is getting more complicated by the day. The article deals with a completely private venture to launch near-ton payloads into orbit. If

SpaceX is successful, individuals, corporations and any group or nation can launch payloads in the few millions of dollars.

[4] General Lance W. Lord, "Space Mission critical to Air Force success," *Air Force Print News,* 16 Sep 04

USAF Secretary James G. Roche, "Iraq Jamming Incident Underscores Lessons about Space," American Forces Press Service, 15 Sep 04

[5] AFDD 2.2-1, chapter 1, p 1, para 1.

[6] From the USSTRATCOM website Military Space Forces Fact File: Defending the Department of Defense computer and communication networks is vitally important to the nation. The United States is the Nation most heavily reliant on technology for its economy, defense, and way of life.

[7] *Quadrennial Defense Review Report*, 2001, 31.

[8] AFDD 2-2.1, 4.

[9] "Analyst: DOD Likely to Continue Reliance on Commercial Satellites," InsideDefense.com, 31 Aug 2004

[10] DISA briefing, DOD Use of Wideband Commercial SATCOM, slide 6, 4 Mar 2004, www.arrowhead.com, titled Commercial SATCOM Support to the GWOT.

[11] AFDD 2-2.1, 24.

[12] AFDD 2-2.1, 53.

[13] Williamson Murray, "Comparative Approaches to Interwar Innovation," *Joint Forces Quarterly*, Summer 2000.

[14] Admiral James D. Watkins, Chief of Naval Operations, October 1, 1983. Admiral Watkins was keynote speaker for the establishment ceremony, held aboard the Naval Surface Warfare Center at Dahlgren, Va., site of the NAVSPACECOM headquarters. In his remarks, Admiral Watkins emphasized the Navy's growing dependence on space technology. The Navy's critical "senses" - the ability of ships to communicate with each other, to monitor weather conditions, and to send and receive information about a potential enemy's movements - "are being sharpened by the movement of sensor from the masthead to the edge of space," he said.

[15] Dr. Christopher R. Gabel, "US Army Tank Destroyer Doctrine in WWII," Leavenworth Papers no. 12, September 1985. US M-4 Sherman tanks were death traps, but there were so many that the few high quality Panzer type VI Tigers lost when they ran out of ammo, fuel or both. It was not until the M-36 tank destroyer (an M-10 sporting a 90mm anti-aircraft gun) in Sep 1944 leveled the field in heavy firepower.

After years of studying all types of warfare, review of Roman legions, in my opinion had two distinct advantages over their contemporary enemies: engineering skills and reputation for being relentless. Even at their peak of power, there were probably never more than 30 true legions of 6,000 in the empire, total forces of no more than 350,000 to manage the known world. Suggested reading: Edward N. Luttwak, "The Grand Strategy of the Roman Empire," 6th printing, 1993.

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Weather Situation Awareness and Joint Space Effects

Lt Col Kelly Jon Hand, USAFR
IMA to Chief, Aerospace Weather Operations
Directorate of Air and Space Operations, HQ AFSPC
Col Martin E.B. "Marty" France, USAF
Deputy Director of Requirements, HQ AFSPC

Know yourself, know your enemy, your victory will never be endangered. Know the ground, know the weather, your victory will then be total…[1] - Sun Tzu, 500 B.C.

Successful military operations rely on our ability to effectively integrate weather information into the planning and execution of land, air, and sea operations, but does weather and its effects matter to space operations? On the terrestrial side, practical examples of weather's importance to the effectiveness of military operations are numerous. Successful air operations need to know the weather over the target but also to plan for the affect of weather conditions on ingress and egress routes to and from the target. Land force operations would certainly be at risk without understanding the actual and forecast soil conditions and its affect on land force traffic-ability. Naval and Marine operations must have accurate observations and forecasts of sea and littoral conditions in order to safely and effectively conduct their part in joint military operations. But, does weather matter to the effectiveness of space operations? Does it impact the ability of our space capabilities to bring desired effects to the joint warfighter? Because our National space capabilities are our military's center of gravity, Air Force Space Command (AFSPC) takes this question very seriously and, addresses it systematically, starting with doctrine.

Space Situation Awareness (SSA) Doctrine

US Strategic Command (USSTRATCOM) defines Space Situation Awareness (SSA) as "the requisite current and predictive knowledge of space events, threats, activities, conditions and space system (space, ground, link) status, capabilities, constraints and employment – to current and future, friendly and hostile – to enable commanders, decision makers, planners and operators to gain and maintain space superiority across the spectrum of conflict."[2]

Figure 1 illustrates the various components of this doctrine.[3] Ultimately, SSA information needs to be integrated into and made available through a Single Integrated Space Picture (SISP). From top to bottom in the figure, the SISP consists of relevant information from intelligence systems concerning threats to our space capabilities such characterizing red and gray space threats and courses of action (COA)—Space Intelligence Preparation of the Battlespace (SIPB). Additionally, space surveillance systems provide space system and object characterization to the SISP via the Space Surveillance Network (SSN). Weather information from space and ground-based weather sensors, models, and applications (such as the SSA Environmental Effects Fusion System—"SEEFS") provide actual and forecast environmental conditions and its impact on friendly and enemy space capabilities. Finally space force status information such as asset availability is provided by our blue space forces. Practically speaking, the SISP provides decision-makers and users at the strategic, operational, and tactical level an accurate, up-to-date, and intuitive understanding of the situation—what needs to be done and what can be done. Combined with military judgment, this allows identification of emerging patterns, discerns critical vulnerabilities, and concentrates space combat power where it can have its greatest effect.[4]

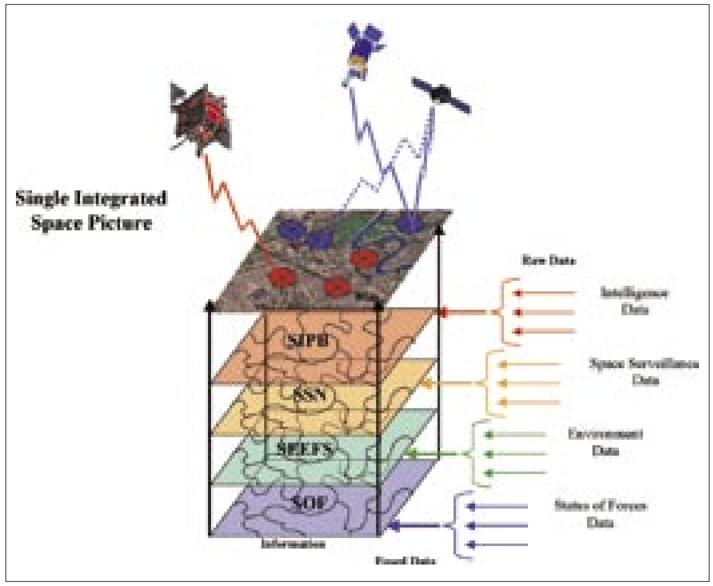


Figure 1. Single Integrated Space Picture (SISP).

Because the focus here is primarily on the environmental aspects of SSA, the following definition of "environmental SSA" is provided in the context of the USSTRATCOM SSA definition: "The requisite knowledge of current and predicted environmental conditions and the effects of those conditions on space events, threats, activities, and space systems to enable commanders, decision makers, planners, and operators to gain and maintain space superiority across the spectrum of conflict."[5]

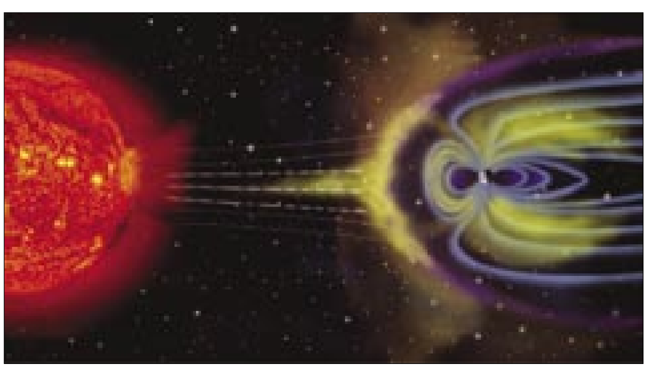
Needed Capabilities

The warfighter's environmental SSA needs are defined within the AFSPC Space Superiority Functional Concept.[6] The first capability below describes the need to gather information concerning environmental conditions relevant to effecting space systems and missions. The subsequent capabilities refer to the application of that information to military decision making or situation awareness:

- Monitor and characterize environmental conditions relevant to space system and mission effects. Access to actual and forecast terrestrial, near-space, and space environmental information to allow friendly forces to predict, respond to, mitigate, and exploit environmental effects on friendly and adversary operations.

- Assess and forecast natural environmental effects on blue/red/gray space systems and missions, including user impacts.
- Assess and predict effects of man-made changes (e.g., High Altitude Nuclear Detonation) to the environment on blue/red/gray space systems and missions, including user impacts.
- Support Munitions Effectiveness Assessments (MEA) related to environmental factors (e.g., scintillation effects on GPS-aided munitions accuracy).
- Support anomaly resolution/attack charaterization for blue space systems related to environmental factors (e.g., help DCS distinguish natural from hostile effects).
- Support development and execution of the environmental portion of the Space Tasking Order (S-T-O).
- Assess environmental vulnerabilities of blue, red, and gray space forces and assets

For effective SSA it is important to realize environmental conditions can significantly affect a space system's performance and survivability and therefore may impact its ability to bring intended space effects to the joint warfighter. For example, satellite systems, spacecraft components and their payloads, communication links for satellite command and control and mission data, and the satellite's respective ground sites can all be affected by the environmental conditions in which they operate. Likewise, ground-based space systems like surveillance or missile tracking radars that contribute to the space control and missile warning missions can also be affected by the environment. Thus, the degree to which the environment impacts these systems and how environmental information can be applied to improve performance or protect the systems defines the type on information needed for effective SSA. That said, relevant space system environmental information must include both terrestrial and outer space conditions—mud to sun. While most people are aware of the terrestrial environment such as rain, high winds, clouds, temperature, and pressure, fewer are aware of the outer space environment. So before discussing the linkage between environmental effects and warfighter impacts, and ultimately the desired effects of environmental SSA, it would be helpful to describe the outer space environment.



NASA

Figure 2. The Outer Space Environment.

The Outer Space Environment

The natural outer space environment illustrated in figure 2 consists of the Sun, the space between the Sun and near-Earth called interplanetary space, and the near-Earth space environment.

The Sun is basically a medium sized star with extreme mass made of mostly hydrogen and a little helium. Nuclear fusion takes place in the Sun's center resulting in the release of huge amounts of energy. The energy is emitted in two forms, electromagnetic and particle energy. Electromagnetic energy travels at the speed of light, taking about eight minutes to travel the 93 million mile distance from the Sun to the Earth. The form of electromagnetic energy includes the visible light you see, the infrared energy you feel and the ultraviolet energy that reacts with your skin's melanin (the sun also emits X-ray, gamma ray, and radio energy).

The second form of solar energy emitted is particle radiation. The same nuclear processes that produce the extreme amounts of electromagnetic energy described above push out massive amounts of hydrogen and helium nuclei called protons and alpha-particles and an equal number of electrons. This makes up solar wind. This solar wind travels straight out from the sun at about 800,000 miles per hour, plus or minus a few hundred thousand depending upon solar conditions. In addition to the solar wind, solar events known as solar flares and coronal mass ejections emit high energy solar particles that can impact spacecraft components. These particles can travel near the speed of light.

At the near-Earth environment, the solar wind first encounters the magnetic field of the Earth (the geomagnetic field) at about a million miles between the Earth and the sun. This creates a teardrop shaped magnetic shell surrounding the globe called the magnetosphere. This shell is formed due to the balance between the Earth's magnetic field pressure and the pressure exerted by the solar wind. The tail of this shell extends many millions of miles away from the sun. Contained within the magnetosphere are the radiation belts (Van Allen Belts) and other radiation phenomena that can affect spacecraft components. Down closer to Earth's upper atmosphere and the "ionized" upper atmosphere called the "ionosphere" that exists from about 1000 miles altitude down to about 50 miles.

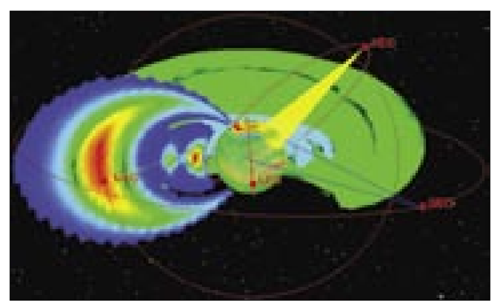


Figure 3. Complexity of near-Earth environment.

Figure 3 illustrates the complexity of this environment in the context of low-earth orbit (LEO), medium earth orbit (MEO), geosynchronous orbit (GEO) and highly elliptical orbit (HEO) satellites. High above the Earth, the figure shows a color cross section of the inner (1500-8000 miles altitude—just outside most LEO satellite orbits) and outer radiation belts (8000-25,000 miles altitude—affects MEO) above the earth. The variation in colors on the globe is meant to illustrate variations in conditions within the ionosphere and upper atmosphere.

Low Earth Orbiting (LEO) satellites such as the Defense Meteorological Satellite Program (DMSP) operate though the upper atmosphere (at about 600 miles) and are affected by atmospheric drag and sometimes trapped and solar particle radiation. Medium Earth Orbiting (MEO) satellites such as the Global Positioning Satellites (GPS) operate in the Van Allen radiation belts at about 11,000 miles, and are subject to constant bombardment by the highly energetic electrons that populate this region. These particles can cause anomalies in on-board computer systems and degrade inadequately shielded sensors, structures, and materials. Geostationary satellites, like the Defense Satellite Communication System (DSCS) satellites, are at the outside of the radiation belts, but operate in a region where charging and discharging can occur on the surface of the spacecraft. Also, GEO satellites experience effects from highly energetic cosmic and solar radiation not as prevalent at LEO altitudes. Finally, all satellites and some ground-base space systems must propagate their radio frequency (RF) signals through the ionosphere to reach terrestrial users. Depending upon the frequency of the radio signal, the ionosphere can significantly degrade the associated weapon system's performance because of the refractive effects of the ionosphere.

Environmental Impacts

Ultimately, it is the environment's effects on space systems that concern us. To effectively determine what environmental information matters to space operations and capabilities, the source of significant environmental effects need to be linked to system effects and, in turn, to associated warfighter impacts. It is the space system program office's responsibility to design space systems to operate within their specific operational environment as determined by their specific mission. But the environment can only be engineered away to a certain degree before additional costs begin to impinge on other priorities, and trades are made depending upon the desired system life time and performance requirements. For example, radiation hardening prevents parts from wearing out prematurely in the space environment, but add weight and, therefore, cost. Satellite Communication (SATCOM) power requirements account for the effects of some terrestrial conditions such as rain rate, but again add weight and complexity. Severe radiation or meteor events may require other means of system protection, such as shuttering or maneuvering that can best be enabled by timely and accurate operational, environmental SSA. The table at right provides some example linkages between environmental cause, effect, and warfighter impact.

This matrix (table 1) illustrates the linkages from mission to space environmental condition to system anomaly to warfighter impact from left to right. Ultimately, if we are completely ignorant of environmental stressing effects, the resulting potential warfighter impacts are described in the right hand column. For example, Comms-on-the-Move (OTM) is a capability provided by SATCOM. If space weather interferes with tactical SATCOM at certain times and the user has adequate warning, they can effectively plan for the disruption, switching to terrestrial communication or using more robust SATCOM. Another example is precision engagement. If the accuracy (Circular Error Probable or CEP) for certain GPS aided munitions is affected by space weather, the weapons planners need to know about it in order to more effectively plan for the type of weapon system to be employed—or they might delay the mission in order to avoid potential collateral damage. Still another example is satellite operations and the requirement to unambiguously determine the source of a spacecraft anomaly. For the warfighter, this is especially noticeable if the satellite in question is dedicated to their area of responsibility (AOR) for communications, navigation, weather, or missile warning. Having the ability to rapidly determine the source as environmental not only helps get the system back on line faster, it can also help distinguish from other sources such as hostile attack.

Space Capability Joint Effect	Environmental Cause	Environmental Effects	Warfighter Impacts
Comms on the Move	Ionospheric scintillation, ionospheric refraction	Degraded/broken communication link, anomalous radio wave propagation	Loss of command and control, lives/missions at risk
Intelligence, Surveillance and Reconnaissance (ISR)	Upper atmospheric density change, ionospheric refraction and scintillation	Inaccurate space object identification and tracking	Space object collision (e.g. shuttle), inaccurate enemy space force position
Missile Intercept	Aurora, upper atmospheric density change, ionospheric refraction and scintillation	Degraded warhead detection and tracking	Decreased probability of missile intercept, lives at risk
Precision Engagement	Ionospheric scintillation, ionospheric refraction	Degraded GPS system performance	GPS guided weapons miss target, increased collateral damage/civilian casualties
Intelligence	Aurora, upper atmospheric density change, ionospheric refraction and scintillation	Decreased intelligence system performance	Inaccurate enemy position data
Spacecraft anomaly assessment	Solar/Magnetospheric particle radiation, Upper atmospheric density change, ionospheric refraction and scintillation	Satellite system anomalies, increased operational downtime of space system	Decreased operational space system utility (GPS, Space-Base Infra-Red System (SBIRS), Space Radar (SR), etc.)
Attack Assessment	Solar/Magnetosphere particle radiation, auroral, upper atmospheric and ionospheric changes	Enemy and friendly weapon system performance degradation	Inability to meet attack assessment timelines, inability to distinguish hostile attack from natural effects

Table 1. Illustrates the linkages from mission to space environmental condition to system anomaly to warfighter impact.

Desired SSA Effects

The desired end state of environmental SSA is the effective application of environmental SSA information—that is, to mitigate negative impacts on and improve performance of our space systems, and exploit potential space environment impacts on enemy systems.

SSA is foundational to the success of the space superiority mission and effectively characterizing environmental effects is a critical part of that foundation. Space superiority operations ensure the continued delivery of space force enhancement to the military campaign, while denying those same advantages to the enemy. When SSA is successfully and sufficiently achieved, the following effects can be achieved:

- Maintenance of Space superiority
- Reduced "Fog of War" for commanders
- Lowered risk of space fratricide
- Rapid assessment of attacks on all blue, gray, or red space systems
- Shortened kill chain and targeting cycle
- Verification of space-related treaty compliance

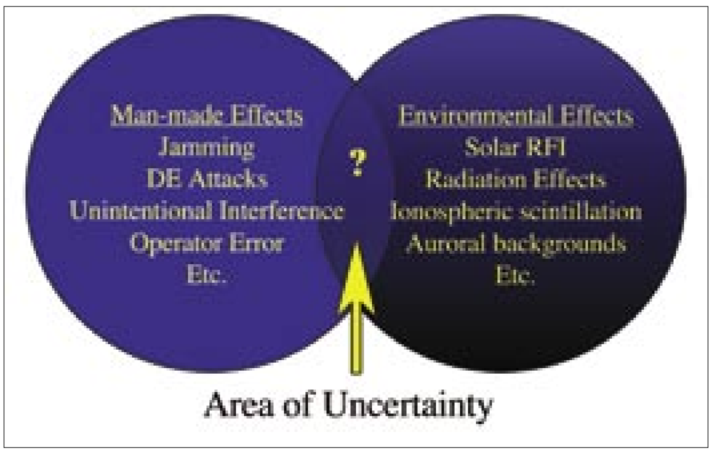


Figure 4. Desired effects using a satellite anomaly.

Figure 4 illustrates desired effects using a satellite anomaly as an example. The circle on the left represents the set of anomalies caused by sources other than the environment. The circle on the right represents anomalies characteristic of the environment. Where there is overlap in characteristic between the two, there is uncertainty (i.e., "fog of war").

Ultimately, superior knowledge of both circles will enhance advantages over an adversary from both an offensive and defensive perspective. From a DCS perspective, confirming or eliminating the environment as a factor enables us to respond in a much more

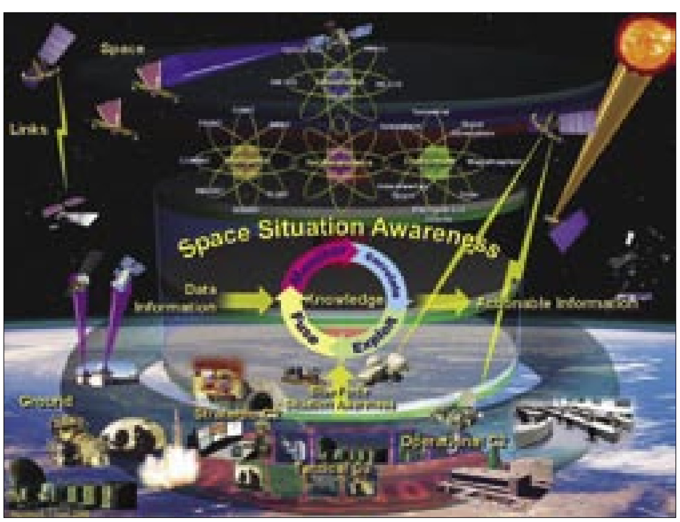


Figure 5. SSA OV-1.

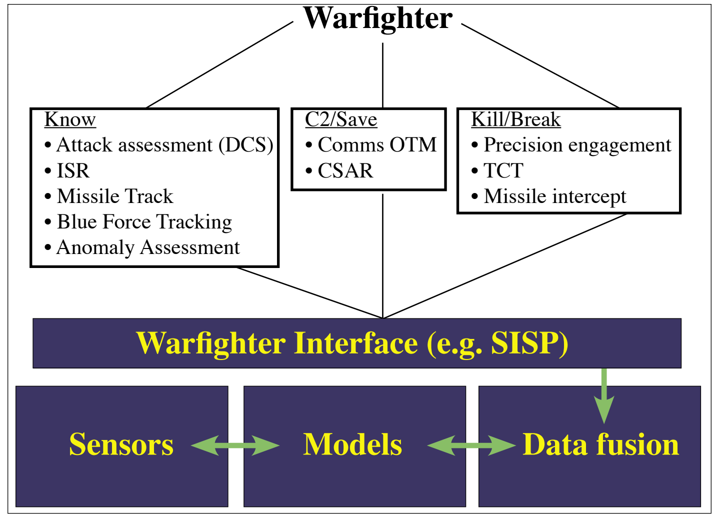


Figure 6. Environmental SSA Sensor to Shooter Context.

effective way to protect our systems. From an offensive perspective, superior knowledge provides potential to exploit environmental effects on enemy space capabilities.

Environmental SSA System of Systems

The list above describes what needs to be done but does not tell how to do it. To understand this, we need to look at what capabilities make up the environmental SSA System of Systems —their current status and how they are envisioned in the future to support space superiority and force enhancement operations. Figure 5 is the Operational View 1 (OV-1) of the SSA architecture. Figure 6 drills down deeper to show the three components of the environmental SSA.

Like a three legged stool, all legs are needed in order to meet SSA requirements. AFSPC has analyzed the current and desired state of these three components in the context of SSA task satisfaction. The current state shows a need to develop data fusion capabilities to effectively merge environmental information and system performance parameters in order to objectively characterize and forecast the effects of the environment on space systems and missions. The current program underway to perform this mission is the SSA Environmental Effects Fusion System (SEEFS). This network centric capability takes environmental information and merges it with system performance data (for mock-up see figure 7), then provides it to the SISP and other network centric user defined systems. In this example, the effects of solar radio noise are merged with SATCOM terminal performance to show the Sun as a source of radio frequency interference (RFI).

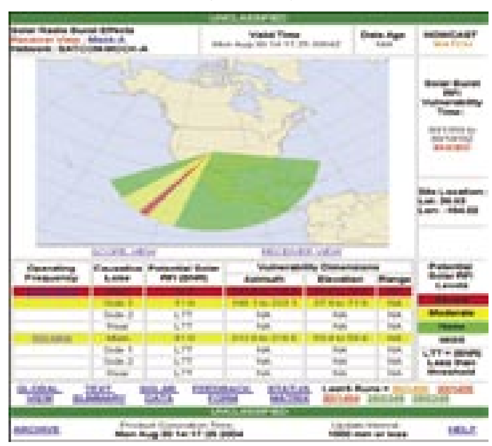


Figure 7. SATCOM RFI Analysis Display.

Referring back to figures 1 and 6, information like this can be used at the tactical and operational level. At the tactical level, one could objectively analyze equipment RFI issues. At the operational level this information could be aggregated from many users or operators to identify trends and potential vulnerabilities. Figure 7 is only one example of the capabilities SEEFS will bring. SEEFS will provide analogous support to example space capabilities and systems illustrated in table 1.

Conclusion

Because of the criticality of joint space effects to successful military operations, our adversaries will seek ways to degrade or destroy our space capabilities and ways to enhance their space capabilities. This elevates the importance of SSA within space superiority and makes its directly analogous to situational awareness for air superiority. Although not as well appreciated, environmental effects on space superiority must be on our radar screen. AFSPC is addressing this concern through careful analysis and is equipping our forces with the kind of environmental effects information that is relevant to maintaining and improving desired joint space effects.

Notes:

[1] Sun Tsu, *The Art of War.*
[2] USSTRATCOM Space Control CONOPS, 2004.
[3] Gary Barrette, SSA Fusion Concept, January 2005.
[4] Marine Corp Doctrine Publication 1-3, Tactics, 30 July 1997.
[5] AFSPC Counterspace Mission Area Plan for 2008 and Beyond.
[6] AFSPC Space Superiority Functional Concept, 2005.

Lt Col Kelly J. Hand (BS, Chemistry, Minnesota State University (Mankato); Meteorology, Texas A&M University; MS, Space Environmental Physics, Utah State University) is IMA to the Chief, Weather Operations Branch, Directorate of Air and Space Operations, Headquarters Air Force Space Command, Peterson AFB, Colorado. He assists the command in devising policy/directives in the execution of space and missile weather support operations, coordinating standardized weather operations policy with HQ USAF/XOO-W, directing development and integration of new technologies into daily space operations and assessing operational effectiveness and technical quality of weather systems, procedures and training used to support space operations; and initiating needed corrective actions and upgrade requirements. Lt Colonel Hand's experience includes 24 years in a variety of space weather related staff, technical, and operational positions supporting NORAD, USSTRATCOM, AFSPC and national program space systems and missions. He is an in-residence graduate of Air Command and Staff College and is a recent graduate of Air War College (correspondence). As a civilian, Lt Colonel Hand is a Project Engineer for The Aerospace Corporation.

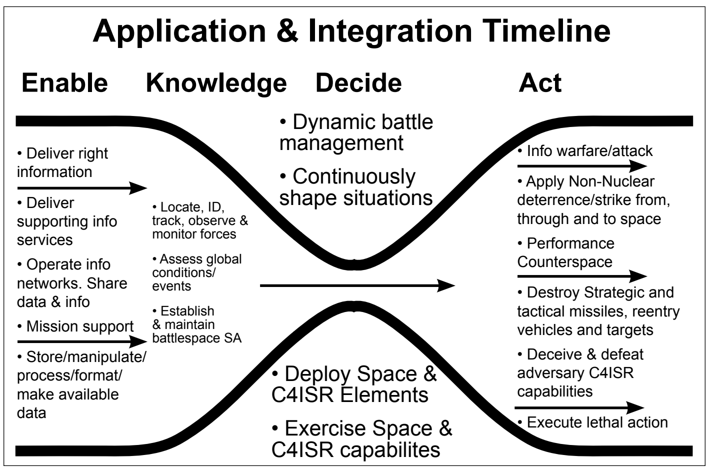
Col Marty E.B. "Marty" France (US Air Force Academy, 1981) is Deputy Director of Requirements, Headquarters Air Force Space Command, Peterson AFB, Colorado. He is responsible for ensuring future space and missile systems meet the needs of our joint forces into the 21st century.

Colonel France's experience includes research and development assignments with the Air Force Research Lab working on high energy laser systems, as the Air Force Engineer and Scientist Exchange Officer to France, assigned to the Office National d'Etudes et de Recherches Aérospatiale, Toulouse, France, and as a program manager at the Defense Advanced Research Projects Agency (DARPA). He served as an instructor, associate professor, and executive officer in the Astronautical Engineering Department, USAF Academy. Colonel France has also served as a staff officer at Air Force Space Command, the Air Staff, and on the Joint Chiefs of Staff, writing long range mission area plans for space forces and in a variety of requirements' positions for space support, force enhancement, and space superiority. He has published technical and strategy papers in several journals, is a fully qualified USAF Foreign Area Officer (fluent in French), Joint Specialty Officer, and is a Level III Certified Acquisition Professional (SPRDE).

Space-Based Joint Blue Force Situational Awareness for the Warfighter

Maj Randy "RT" Thompson, USAF
Chief, Blue Force Tracking Division

Since the dawn of conflict the "fog of war" has inherently reduced combat effectiveness. A major contributor to the "fog" is erroneous, incomplete or untimely information. The ability to have instant and accurate knowledge on the status and location of your forces and assets (as well as those of your adversary) is a vital factor in determining the victor of the conflict.[1]



Space and C4ISR Capabilities[2]

Blue Force Tracking (BFT) and Joint Blue Force Situational Awareness (JBFSA) are important tools at the commander's disposal to help cut through the fog. These two areas are critical growth industries in the Department of Defense (DoD) for improving battlespace awareness of ground personnel, vehicles, airdropped pallets, supply containers, and convoys. What are BFT and JBFSA? Why are they important? How are they accomplished today, and what are the future requirements for this capability from a space perspective?

What is Blue Force Tracking?

BFT is the ability to provide precise location, identification and movement of US, Allied, Coalition or Host Nation forces or assets (i.e., Blue Forces). BFT, a subset of JBFSA, is defined as the "employment of techniques to identify and track US, Allied, or Coalition forces for the purpose of providing the Combatant Commander enhanced battlespace situation awareness and reducing fratricide."[3]

The Air Force has been tracking Blue Force aircraft for years via radar, data links, and identification, friend or foe (IFF) systems to provide relatively precise location, identification, and movement data. For ground forces, BFT precise location and movement information is primarily derived from Global Positioning System (GPS) receivers such as the Army's precision lightweight GPS receiver (PLGR) or other military or commercial GPS products. This capability provides the user with very accurate position and movement (speed and heading) information. To tag this precise location and movement data to a specific user or unit, a GPS receiver is connected to or integrated into a device that allows a user or unit to enter their specific identification information. This packet of critical data is now available for transmission, via some medium, to higher echelon command and control elements. The "fog" thins when BFT information is provided to commanders.

What is Joint Blue Force Situational Awareness?

Joint Blue Force Situation Awareness is a key and unique contributor to the JV2010 and JV2020 specified end state of Full Spectrum Dominance.

- Director for Strategic Plans and Policy, JV2020

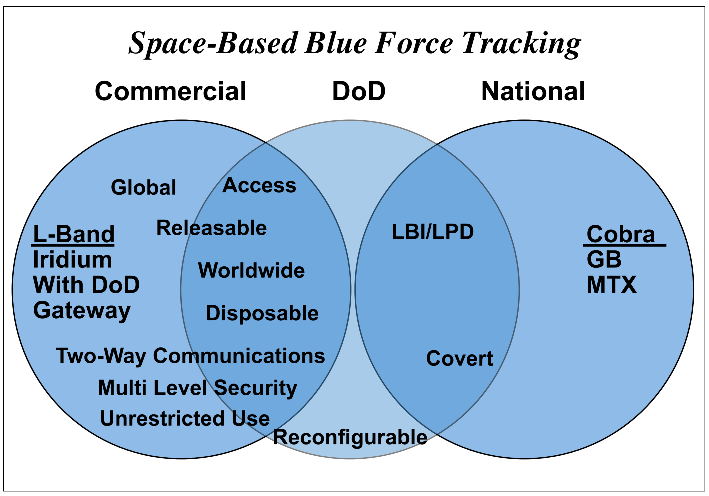
JBFSA is defined as the "collection of systems and capabilities used for the purpose of reporting and relaying blue force precise location, identification, movement, and intent and status information."[4] JBFSA uses the BFT elements of precise location, identification, and movement but also includes the elements of intent and status. Intent refers to future activities (i.e., mission progression as planned or any deviations) and status refers to the current status of the asset being tracked (e.g., supplies and health). BFT provides critical information to a commander on the disposition of his forces, while JBFSA provides the next level of information to a commander in the form of the near-term intention of those forces and the status of their "boots, bullets, and beans." BFT gives a commander "sight" of his forces, but JBFSA provides "insight" into those forces.

The same device that correlated BFT data to a user identification also provides that user the capability to add intent and status information to that same data packet. Intent is usually conveyed using a code word or a brevity code. For instance, a list of automobile names may be used with each one assigned a specific meaning, for example "Cadillac" may mean normal operations, and "Yugo" may mean mission abort. Status may include critical categories such as ammunition, food, fuel, and communications, which would be reported as green, yellow, or red. The "fog" starts to burn off when JBFSA information is available to the commander.

How are they accomplished today?

Once JBFSA information is generated on the battlefield, how is it transmitted to the proper command centers? Some BFT devices are connected to each other and their tactical operations center (TOC) via line of sight (LOS) communications architectures. The Army's Force XXI Battle Command Brigade and Below (FBCB2) system and the Marine Corps' Data Automated Communications Terminal (DACT) have leveraged these LOS types of architectures in the recent past. Both of these systems incorporate JBFSA information that is shared between units and their respective TOCs. But with the speed at which warfare moves today, LOS architectures can very quickly be outpaced by assets and units moving beyond line of sight (BLOS) of their communications infrastructure (e.g. Operation IRAQI FREEDOM). At the same time Blue Forces are spread all over the globe as US forces prosecute the Global War on Terrorism (GWOT). For example, Blue Forces may be conducting anti-terrorist operations in the Philippines with their rear echelon command and control (C2) element located in Hawaii, well beyond line-of-sight. Space provides the communications medium and architecture to transmit JBFSA over the horizon to a ground station so this critical information can be disseminated to the proper location anywhere in the world.

There are three types of space transmission capabilities for JBFSA; they are National Technical Means (NTM), DoD space systems and commercial space systems.



National Technical Means

For several years Special Operations Forces (SOF) have relied on NTM to collect their JBFSA data and disseminate it. It provides the SOF community with an established and covert collection and dissemination architecture. However, using NTM for this mission area presents some challenges for the user. The use of NTM requires a collection request to be submitted to national agencies. Even if this request is approved, NTM provides JBFSA coverage and collection as an adjunct mission, therefore support may not be provided if higher priority tasking is received prior to the user mission commencing. As an adjunct mission CJCSI 8910.01 addresses the use of NTM and the use of alternate means as follows:

"JBFSA systems and architectures may incorporate the use of national systems as part of their architectural designs to provide data required by the COP. However, before requesting the use of national Intelligence Community assets, JBFSA users will consider, evaluate, and coordinate the use of all other feasible alternatives first: e.g. theater, DoD space, commercial space, allied, commercial or DoD line-of-sight systems, and use of terrestrial data networks."[5]

DoD Space Systems

DoD space systems are virtually unused for JBFSA since these systems are perceived as low density/high demand assets in regard to bandwidth and allocation.

Commercial Space Systems

The US military has employed commercial space systems recently as on-orbit gap-fillers for JBFSA and for other roles. For JBFSA the Army's latest version of the FBCB2 system leases channels on commercial L-band satellites. These satellites are in geosynchronous earth orbit (GEO) so their ground station must be located within the satellite's footprint. Multi-national consortiums often own these satellites and the satellite ground station(s) may be located in countries that may or may not be an ally of the US posing a possible security concern for passing JBFSA data. Additionally, DoD must contract with different satellite providers for different theaters causing a delay in accessing the system or denied access to the system should the service provider choose to do so.

Iridium is another commercial space system, but with a DoD segment. Iridium is an L-band low Earth orbiting (LEO) satellite constellation consisting of 66 on-orbit satellites with 13 on-orbit spares providing pole-to-pole coverage for voice and data. Several years ago the Defense Information Services Agency (DISA) established a DoD Iridium ground station and gateway in Hawaii. All DoD Iridium users have their voice and data up-linked to a satellite, then cross-linked between satellites and then down-linked to the DoD ground station in Hawaii for dissemination. Iridium allows for a single satellite system to be used worldwide and the DISA ground station in Hawaii provides fenced use for DoD users. Additionally, Iridium's Short Burst Data (SBD) capability provides a very short on-air transmit capability for sending small data packets, to include two-way text messages, that is ideal for JBFSA. This asset provides the DoD and other government agencies an on-orbit global satellite communications (SATCOM) system without the launch and operational expense associated with National- or DoD- owned systems. Still there are some security concerns, although less than other purely commercial systems. The DoD needs to view the Iridium satellite system and its associated DoD segments as more than a super cell phone service, and leverage the capability and potential capability of the system for the warfighter.

What is the future requirement?

"We must continue to seek new, revolutionary, and imaginative ways to employ air and space power and continue to provide the United States with even more capability to pursue national and military objectives with reduced risk and cost in casualties, resources, and commitment."

- Air Force Doctrine Document (AFDD) 1,
Air Force Basic Doctrine

The primary contribution of space to JBFSA is beyond-line-of-sight coverage for collection and dissemination, and exchange of JBFSA information. Developers of JBFSA systems have leveraged any and all space capabilities available including NTM, DoD and commercial SATCOM. BLOS capability is critical to the modern, dynamic battlefield connecting fast-moving forward forces to rear echelon command and control and providing coverage in areas of denied access. The primary criticisms of the current state are; (1) JBFSA diverts NTM from its primary intelligence collection mission, (2) DoD military satellite communications (MILSATCOM) has been largely ignored due to perceived lack of availability and priority, and (3) JBFSA has become too reliant on potentially vulnerable pure-commercial SATCOM.

Currently, Air Force Space Command (AFSPC) assets supporting JBFSA consist only of GPS. The Air Force (i.e., AFSPC) is in the process of spinning up to fulfill their role as defined in Chairman of the Joint Chiefs of Staff instruction (CJCSI) 8910.01:

> "The Air Force, in their capacity as executive agent for space, will plan for and maintain adequate space-based assets to support evolving JBFSA needs. The Air Force will also plan for and maintain air-breathing assets and capabilities as necessary to support a future JBFSA architecture."[6]

AFSPC has had no dedicated funding to support existing or previous JBFSA efforts with respect to personnel, studies, and analysis. Currently no Air Force Program of Record is expected to impact the FY08 program objective memorandum (POM) with a DoD space-based JBFSA capability. However, the DoD requires near term, DoD, space-based JBFSA capability until a dedicated capability can be acquired.

For the near term (present - 2015) Iridium is a very good JBFSA capability for the DoD. An Iridium-based JBFSA capability has been developed and demonstrated by Air Force tactical exploitation of national capabilities program (AF TENCAP). Iridium is less vulnerable than other commercial space systems due primarily to the DoD Gateway in Hawaii and the short on-air time of the SBD.

AFSPC is in the very early stages of planning and programming for long-term DoD Space-based JBFSA capability in support of Joint Forces Command (JFCOM) and the Army as the JBFSA lead service. AFSPC/DR is conducting and supporting a space-based JBFSA analysis and study, and is planning for a near, mid and far term capability.

Maj Randy "RT" Thompson (BS, Geology, Southwest Missouri State University) is Chief, Blue Force Tracking Division, Air Force Tactical Exploitation of National Capabilities (AF TENCAP), Space Warfare Center, Schriever AFB, Colorado. The Space Warfare Center is the centerpiece of the Air Force Space Command's efforts to fully integrate space into the daily operational Air Force. The center develops new techniques and procedures to apply space-based capabilities to military training, exercises, plans, and operations in support of Department of Defense front-line warfighters. AF TENCAP leads the Air Force in National Technical Means and emerging technologies exploitation for the tactical warrior and provides innovative integrating capabilities and concepts to increase efficiency and effectiveness of the tactical warfighter
Major Thompson received his regular commission after completing Officer Training School as a distinguished graduate. He was equally honored after completing undergraduate navigator training, and was the top graduate and Col Mike Gilroy Award winner from the Electronic Warfare Officer Training program. Major Thompson is a Master Navigator with more than 2,100 flying hours, primarily in the F-15E/I and F-4E/G.

Summary/Conclusion

JBFSA, and its subset BFT, is a rapidly emerging capability providing significant enhancements to command and control, battlespace awareness, and ultimately, force application. It is a capability provided by numerous systems, some of which are fielded, some of which are in development, some of which are yet to be defined. JBFSA is an inherently joint capability, enabling joint and coalition forces to operate more effectively together, contributing to almost every mission area.

The cornerstone to the United States' warfighting success is the ability to integrate the unique core competencies and functions of each Service (the joint team). The Air Force, as a key contributor to the joint team, integrates its Air and Space core competencies with the other team members to prosecute and win the fight. Joint Vision 2020 describes how integrating each team member's competencies and functions will allow the US to fight and win. Joint Vision 2020 defines four operational concepts necessary to successfully fight as a joint team and achieve full spectrum dominance. These four operational concepts are Dominant Maneuver, Precision Engagement, Focused Logistics, and Full Dimensional Protection, all tied together by Information Superiority. Blue Force Situation Awareness supports each of these joint operational concepts thus implying BFT will support, to varying degrees, the Air Force's Air and Space core competencies and functions.

Notes:

[1] Air Force Joint Blue Force Situational Awareness Enabling Concept, 1 April 2004, draft, p. 2, para. 1.2.1 Fog of War.

[2] Space and C4ISR Capabilities CONOPS, 2 May 2003, draft, version 7.1.

[3] Chairman Joint Chiefs of Staff Instruction - CJCSI 8910.01, Blue Force Tracking Collection and Dissemination Policy, 27 July 1999, enclosure A, A-1.

[4] Capstone Requirements Document for Combat Identification, 19 March 2001, I-1.

[5] Chairman Joint Chiefs of Staff Instruction - CJCSI 8910.01, Blue Force Tracking Collection and Dissemination Policy, 30 Apr 2004.

[6] Chairman Joint Chiefs of Staff Instruction - CJCSI 8910.01, Blue Force Tracking Collection and Dissemination Policy, 30 April 2004, enclosure B, pg. B-1, para. 2.

Satellite Communications and the Future of American Expeditionary Warfare

Maj Rory D. Welch, USAF
Chief, Strategy and Policy Section,
Directorate of Plans and Programs, AFSPC

Future warriors must arrive in their area of responsibility (AOR) with a "basic load" of communications as well as munitions. - Alan D. Campen, The First Information War, 1992

If military success depends on an abundance of *beans, bullets, and band-aids,* then in the Information Age one must add something else to that list – *bits*.[1] Timely, accurate information has always been important in war. But in the modern era, fast and reliable collection, processing, and dissemination of abundant information have become even more vital.

The American defense establishment must communicate that information rapidly and reliably among highly mobile air, land, sea, and space forces deployed around the world. Space assets, particularly satellite communication (SATCOM) systems, provide the global information capabilities necessary to deploy, employ, and sustain US military forces anywhere in the world and under any conditions. Such capabilities provide the United States with a tremendous military advantage. Yet, there is significant and growing concern that current and planned SATCOM capabilities will not be sufficient to meet the ever-burgeoning information demands of future expeditionary warfare. A lack of understanding of SATCOM's unique importance to America's defense strategy could lead policy makers to pursue cheaper, but less capable alternatives.

SATCOM Capabilities are Essential to America's Defense Strategy

America's National Security depends on the ability to project its military power anytime, anywhere around the world. Forward-deployed air, land, sea, and space forces help ensure international peace and security. With a smaller military presence overseas, however, American policy makers are increasingly reliant on smaller, rapidly deployable, highly flexible, and sustainable expeditionary forces. Such forces, and their ability for prompt global action, permit the United States to assure Allies and friends, dissuade potential adversaries, and deter or defeat potential threats far from its shores.[2]

To project American combat power around the globe requires an expeditionary support infrastructure. Just as air, land, sea, and space transport assets are needed to lift people and equipment, so are communication systems needed to 'lift' information to the fight. American military operations are heavily information-dependent. US Forces require mountains of precise information concerning the enemy, friendly forces, the environment, and a variety of other factors in order to plan, execute, and assess military operations. Collecting, processing, and disseminating this information when and where it is needed demands "a telecommunications infrastructure that has flexible capacity (bandwidth on demand), does not encumber force mobility (wireless), is easily deployable (light, small), is self-organizing, has global coverage (reach back), provides integrated services (voice, video, data), is secure and survivable, and provides assured access to the warfighter."[3]

Meeting the communication needs of expeditionary warfare is the purpose of the Global Information Grid (GIG). The Department of Defense (DoD) is developing the GIG to provide warfighters, policy makers, and support personnel with ubiquitous access to high-quality communications, computing, and information management services.[4] The GIG will be built upon a robust and responsive communications infrastructure that includes an integrated mix of optical fiber, wireless radio, and SATCOM capabilities.

SATCOM systems form the expeditionary backbone of the GIG. Optical fiber networks can provide high capacity links to fixed command centers in rear areas, but they are unsuitable for communications among mobile forces. Also, expanding fiber coverage into a theater of operations is difficult. Mobile tactical forces generally employ wireless radio communication systems, though their range is relatively limited. SATCOM provides US military forces with the coverage, deployability, mobility, and reach necessary to bridge the gap between fixed fiber and mobile radio networks.

There is a high risk to US military advantage that the right kinds and right amounts of SATCOM bandwidth will not be available in time to meet the US military's ever-burgeoning requirements for connectivity.

- Colonel David Anhalt, "Why Bandwidth Matters," 2002

Representative User Types	Location	Major Characteristics
Major Commands, Intel, Support Organizations, Gateways and Teleports, DISN, DTS, NISN, NCN	CONUS/OCONUS	- Widely distributed worldwide; enduring - Fixed sites; many with large terminals - Large, high-capacity needs; full period - Low to some specialized protection needs
JTF and Component Commands Major Tactical Commands Rear Area Units	MTW/SSC Areas	- Deploy into/support theaters of operation - Relocatable and mobile platforms - Short-to-mid term durations - Small-to-medium, some large terminals - Many high capacity needs -- common user, C2, intel, support - Some protection required
Forward Area Tactical Units Extended/Remote Tactical (Aircraft, Detached Units, SOF, Sensors)	Theater and Dispersed	- Concentrations into crisis/conflict areas -- Also many globally dispersed users - Small, mobile, and relocatable terminals - Short- to mid-term durations - Wide range of needs in-theater & enroute - Protection sought against tactical threats - Short notice access; quick reconfiguration
National Command, Senior Leadership, Strategic Forces		- Fixed HQs plus mobile platforms; dual use - High capacity C4ISR; high protection - Survivable C2, force direction, report-back, and assessments - Missile Defense communications
Space Exploration & Earth Observation		- Earth orbiting spacecraft, space station - Data relay communications satellites - Centralized ground stations - Multiple, dispersed processing/analysis
Inter-Agency & Civil Support Activities		- First responders, emergency services - DoD & Federal, State, Local Government - Non-governmental service agencies

Table 1. Types of SATCOM Users. Source: US Strategic Command, Satellite Communications Systems Capstone Requirements Document, 25 May 2003, 56.

The Role of SATCOM in Expeditionary Warfare

SATCOM systems represent a significant US military advantage. They enable American forces "to gather, process, and disseminate an uninterrupted flow of reliable and precise information anywhere in the world and under any conditions."[5] As table 1 illustrates, a variety of US military users rely on SATCOM, often as their only practical means of communication. Such systems provide secure and survivable communications for national leaders and strategic forces. SATCOM supports naval vessels at sea, aircraft in flight, and mobile ground forces operating at extended distances. Weather, intelligence, and other information are broadcast globally via SATCOM. Early entry forces or units in austere locations often depend on SATCOM due to the lack of a supporting infrastructure. Many fixed facilities also use SATCOM as an alternate long-distance communications mode.[6]

SATCOM systems provide US military commanders with assured access to a variety of critical information services, including command and control (C2), intelligence, warning, and weather. However, SATCOM access can be disrupted by many threats, such as jamming, interference, interception, exploitation, intrusion, nuclear explosions, and environmental effects. To mitigate these threats, many military SATCOM systems have built-in protection capabilities, such as hardening, anti-jam, and low-probability of intercept or detection. Commercial SATCOM systems generally have only rudimentary protection. Nevertheless, they are quite useful in low threat environments.

Communication satellites can relay information instantly to and from locations around the world. From geosynchronous orbit, SATCOM systems can rapidly shift their focus between theaters, or support multiple theaters simultaneously. Other communication modes have a much more limited reach. The coverage of optical fiber networks extends only to the end of the wire. Many terrestrial wireless systems require multiple relay nodes to reach beyond line of sight (LOS) distances. Also, airborne radio networks are generally limited to theater-level coverage. SATCOM enables expeditionary forces to connect to the GIG from virtually anywhere, whether on land, at sea, or in the air.

Use of SATCOM provides rapidly deployable capabilities to US military forces who often must operate from austere locations with little or no existing infrastructure. In many contingencies, extensive support elements must be brought in, requiring additional time and strategic lift assets. SATCOM can reduce the communications infrastructure that must be deployed in such situations, since the satellites are already on orbit. The size and scope of SATCOM networks are also readily scalable, based on the number of terminals and channels allocated to an operation. In contrast, it is generally much more difficult to extend the reach of terrestrial networks, especially wired systems.

SATCOM systems enhance the C2 of mobile tactical forces. Rapidly moving maneuver forces may outrun the reach of terrestrial communication systems. SATCOM systems, on the other hand, provide tactical forces with a communications infrastructure that can move with them. For example, most US military aircraft and ships have built-in SATCOM terminals that can be used in flight or at sea. Relocatable antennae that can be quickly set up or taken down also give mobile ground forces access to SATCOM. However, such terminals generally can only be used when units pause for some period.[7] Furthermore, some commercial systems provide mobile SATCOM services through man-portable terminals or handheld telephones similar to cellular systems.[8]

Compared with terrestrial communication networks, SATCOM systems give tactical forces a high degree of freedom from terrain and distance. With terrestrial systems, forces must remain stationary to maintain contact with a wired network or control high ground to provide LOS relay nodes. With SATCOM, users can instantly communicate with each other even when dispersed across hundreds or thousands of miles. This permits forces deployed around the world to reach back to elements in the United States and elsewhere for C2, intelligence, sustainment, and other support. SATCOM also enables senior civilian and military leaders to collaborate in real-time with operational and tactical commanders deployed in remote theaters.

The 2003 Iraq War illustrated the essential role of military and commercial SATCOM capabilities in expeditionary warfare. The DoD leveraged the deployability of SATCOM to significantly expand its in-theater communications infrastructure, in order to support the 235,000 troops deployed for Operation IRAQI FREEDOM (OIF). Military SATCOM systems – including four Defense Satellite Communications System (DSCS) III, two ultrahigh frequency follow-on (UFO), and two MILSTAR satellites – provided 520 Megabytes per second (Mbps) of bandwidth capacity.[9] Leased commercial SATCOM links supplied an additional 1,880 Mbps.[10] Moreover, the DoD leased over 550 Mbps of optical fiber bandwidth, accounting for nearly 19 percent of the communications capacity for OIF. Overall, OIF major combat operations required nearly three Gigabits per second (Gbps) of communications bandwidth.[11]

Increased use of SATCOM also facilitated the planning and execution of coalition air operations. SATCOM enabled transmission of instantaneous targeting updates to strike aircraft while en route. As a result, the days-long targeting cycle typical of the first Gulf War was reduced to hours and sometimes minutes in OIF. According to one commentator, "A soldier using a laser range finder linked to Global Positioning System (GPS) could send via satellite the coordinates of a target to a command site hundreds of miles away, which fed those coordinates onto the GPS-enabled bombs of an aircraft in another locale – and even change them in flight."[12]

SATCOM also enabled widespread use of split-base operations, in which deployed forces reached back to intelligence and other support elements in the United States and elsewhere. Senior US civilian and military leaders also used SATCOM to reach forward and coordinate with operational and tactical units half-a-world away in Iraq. Moreover, Predator and Global Hawk unmanned aerial vehicle (UAV) operations relied heavily on SATCOM. Wideband SATCOM data links allowed UAV pilots in the United States to fly surveillance missions over Iraq. There was even at least one case of a Predator pilot so situated firing a Hellfire missile at a target in Iraq.[13] Predator and Global Hawk sensor data from Iraq was also sent via SATCOM to analysts in distant intelligence centers.

Furthermore, SATCOM links allowed dispersed ground commanders to synchronize their operations across the noncontiguous battle space. In OIF, direct LOS radio communications were often impossible between rapidly moving ground units separated by hundreds of miles. As a partial solution, the Army distributed over 1,200 new Force XXI Battle Command, Brigade and Below (FBCB2) systems to US and British ground forces in Iraq.[14] With it, commanders accessed digital maps and imagery, noted intelligence reports of enemy activity, tracked the GPS-reported location of friendly forces, and communicated with each other – all via commercial SATCOM. Army and Marine Corps forces frequently depended on the FBCB2 system, as well as the DoD-financed Iridium satellite service, as their only reliable means of communication.[15]

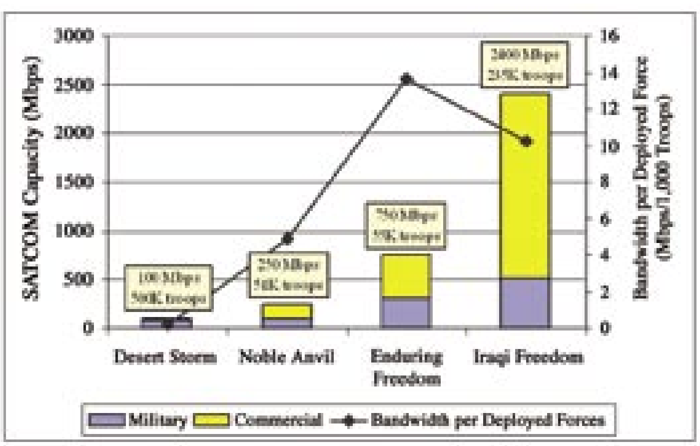


Figure 1. Increasing Demand for SATCOM in Major US Military Operations, 1991-2003. Data from Col Patrick Rayermann, USA, "Exploiting Commercial SATCOM: A Better Way," Parameters 33, no. 4 (Winter 2003-2004), 55; Pravin Jain, "SATCOM Support to the War Fighter: An Overview," (briefing, DISA Satellite Communications Division, 17 November 2003), n.p., e-mail to the author, 12 February 2004; Joseph S. Toma, "Desert Storm Communications," in The First Information War, ed. Alan D. Campen (Fairfax, VA: AFCEA International Press, October 2002), 2; Gen Ralph E. Eberhart, USAF, Commander-in-Chief, US Space Command, statement to the Senate Committee on Armed Services, Strategic Subcommittee, 106th Cong., 2nd sess., 8 March 2000, 13-14.

The high demand for SATCOM in OIF reflects several general trends in US expeditionary operations during the past 15 years (see figure 1). First, SATCOM capacity demands have grown substantially. OIF required 24 times as much SATCOM capacity as in Operation DESERT STORM. This in turn has led to a marked increase in the use of commercial SATCOM, as military systems have been unable to keep pace with the growing demand. In the first Gulf War, the ratio of military to commercial SATCOM was approximately 80:20. The situation was reversed in OIF, where commercial systems provided over 78 percent of the available SATCOM capacity. Furthermore, the deployment of smaller and leaner, yet more agile and lethal expeditionary forces has made US military commanders more dependent on precise knowledge and high-capacity C2 capabilities. To illustrate this last point, consider the increasing demand for bandwidth when it is normalized using a standard 1,000-man force package. Fewer than half as many troops deployed for OIF as for Operation DESERT STORM. Thus, the growing use of SATCOM bandwidth shown in figure 1 translates into a 50-fold rise in the demand for information by US Expeditionary Forces.

Emerging Concerns with Military SATCOM

Evolution of America's military SATCOM architecture has not kept pace with the requirements of expeditionary warfare. Designed to meet the needs of a superpower Cold War, it was intended to support a largely garrison force operating in a few known locations on a linear battlefield. That architecture is no longer sufficient for US Expeditionary Forces that deploy to many unforeseen locations and fight in an often non-contiguous battle space. Warfighters' growing demand for bandwidth has far outstripped the capabilities of current US military SATCOM systems.

Furthermore, the American defense establishment's demand for communications capacity is growing faster than its ability to field new military SATCOM systems. New warfighting systems, concepts, and applications drove a huge increase in the use of SATCOM by US forces in the 13 years from Operarion DESERT STORM to OIF. Furthermore, the DoD's worldwide demand for SATCOM is projected to jump from 13.6 Gbps in 2006 to more than 160 Gbps in 2015 (See figure 2).[16] That already far exceeds the total capacity – approximately 1.2 Gbps – of current military SATCOM systems. The launch of follow-on systems, like the Wideband Gapfiller Satellite (WGS) program, will increase available bandwidth over the next several

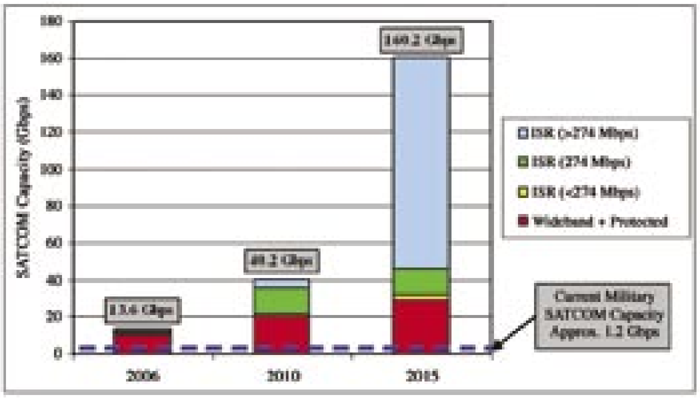


Figure 2. Projected DoD SATCOM Requirements Growth. Data from DISA, SATCOM Database, 1-4-2-1 Scenario, August 2003, e-mail from Paul M. Chapell, Science Applications International Corporation, Chantilly, VA.

years, but they will not close the gap significantly.

The strain of military SATCOM capacity shortfalls is particularly acute in the wideband category. The bulk of military SATCOM bandwidth is provided by the DSCS program. Yet, its capacity is already far short of demand. The four DSCS satellites that supported combat operations in Afghanistan and Iraq provided less that 17 percent of the total wideband SATCOM requirement.[17] WGS will have 10 times the capacity of DSCS.[18] Yet, it will still lag well behind the demand for bandwidth being driven by the employment of enhanced airborne and space-based intelligence, surveillance, and reconnaissance (ISR) systems. An example of one such system is the high-altitude Global Hawk UAV, each of which will require at least 548 Mbps of SATCOM bandwidth in the near future for long-range C2 and for relaying imagery, signals intelligence, and other sensor data to ground processing stations.[19]

The lack of military SATCOM capacity is also a pressing problem for mobile tactical users. Most SATCOM-capable mobile platforms are equipped with some sort of ultrahigh frequency (UHF) terminal. These narrowband terminals are typically constrained to voice and data rates of less than 20 kbps.[20] The problem is that with nearly 20,000 narrowband SATCOM terminals deployed across the US armed forces, the current UFO constellation is heavily oversubscribed.[21] Too many users are competing for too few channels, limiting throughput and often causing interference. The problem will get worse over the next several years, as the DoD fields more SATCOM-enabled weapon, sensor, and support systems. The next-generation Multi-User Objective System (MUOS) will have a total worldwide capacity of up to 39.2 Mbps and be able to support nearly 2,000 simultaneous narrowband accesses.[22] Yet, it will be overwhelmed by the almost 100,000 narrowband SATCOM terminals that are projected for the US military inventory by 2015.[23]

Bridging the Gap

SATCOM systems are fundamental elements of America's expeditionary warfare strategy. The accessibility, coverage, deployability, mobility, and reach of SATCOM give the United States a significant military advantage. However, existing military SATCOM capabilities fall well short of meeting current warfighting needs; and next-generation systems are not likely to close the gap significantly. The DoD must bridge that gap to ensure that the right SATCOM capabilities are available to support future American expeditionary warfighters.

One proven method is to continue to use commercial SATCOM to augment the capabilities of military systems. American armed forces spend $200-400 million annually to lease more than 60 percent of their total worldwide SATCOM capacity from the commercial sector.[24] Moreover, commercial systems supplied the vast bulk of the SATCOM bandwidth used in OIF. Given projected military SATCOM shortfalls, US Expeditionary Forces will depend on commercial augmentation for the foreseeable future. However, American defense policy makers should understand the risks associated with continued military reliance on the commercial SATCOM marketplace.

Access to commercial SATCOM may be limited in future conflicts. Though commercial service providers are normally reliable, they may not be able or willing to expand support to US military forces in wartime. Many other users, including potential adversaries, will compete with the DoD for SATCOM services. Also, international SATCOM providers may be unwilling to extend service to US forces during controversial conflicts.[25]

Commercial SATCOM systems do not have the protection features required by US Expeditionary Forces. Most commercial SATCOM systems have rudimentary protection against nuisance interference. However, market forces largely dissuade commercial service providers from investing in more costly military protection features, such as encryption, hardening, jam resistance, or low probability of interception.[26]

Market fluctuations make the commercial SATCOM industry's future uncertain. New commercial SATCOM providers cropped up almost overnight to meet the demand for bandwidth during the 1990s telecommunications boom. Yet when the telecom bubble burst, many commercial SATCOM companies were forced into bankruptcy.[27] Commercial SATCOM providers also face stiff competition from terrestrial communication systems. The spread of cellular telephone coverage greatly reduced commercial demand for mobile satellite telephone services, as the market failures of Iridium and Globalstar indicate.[28] Moreover, optical fiber networks, with capacity costs about one-tenth that of commercial SATCOM, have nearly cornered the market on high capacity fixed communications within and between major urban areas.[29]

The good news is that despite recent declines, the commercial SATCOM market will likely remain viable for the foreseeable future. Eutelsat, Intelsat, PanAmSat, SES Global, and other large providers of fixed satellite services weathered the industry's decline fairly well. A few mobile SATCOM service providers, like Inmarsat and Thuraya, are also thriving. Even Iridium emerged from bankruptcy, largely thanks to its contract with the DoD.[30] Industry analysts predict that the next few years are a critical period as commercial SATCOM providers adjust to new market realities.[31]

Unfortunately, the DoD's procurement practices exacerbate the risks associated with commercial SATCOM. With about 30 percent of the market, the American defense establishment is the single largest commercial SATCOM customer.[32] Yet rather than exploiting its buying power, the DoD acquires commercial SATCOM services as if it were a disadvantaged user. SATCOM requirements are presented to commercial service providers in a piecemeal manner and normally under the urgency of emerging crises. US military forces are also generally unable to enter into commercial SATCOM leases longer that a year at a time.[33] This not only causes the DoD to spend nearly three times more than necessary for commercial SATCOM, but it also limits service providers' insight into the demand dynamics of their largest customer.[34] If the DoD does not alter its procurement practices, surplus commercial SATCOM capacity may not be available to support future US military operations.

Another option is to develop and employ *near-space* platforms to supplement the DoD's intra-theater and tactical SATCOM capabilities. Near space has been defined as the atmo-

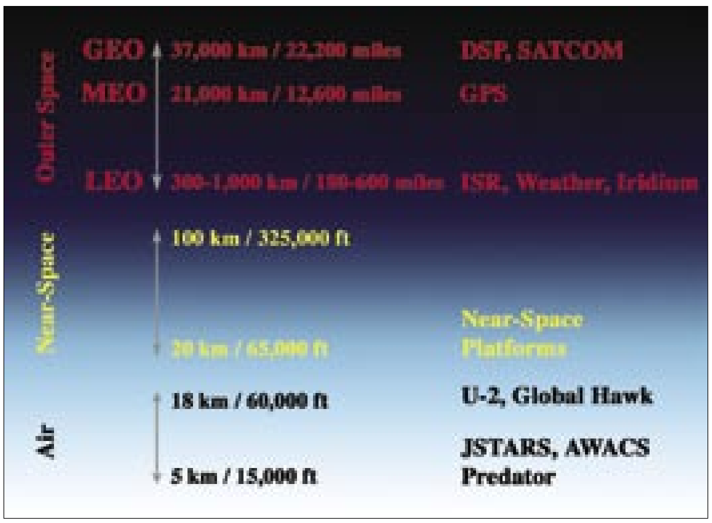


Figure 3. Air, Near Space, and Outer Space Regions. Adapted from Lt Col Edward B. Tomme, USAF, The Paradigm Shift to Effects-Based Space: Near-Space as a Combat Effects Enabler, Research Paper 2005-01 (Maxwell AFB, AL: Airpower Research Institute, 2005), 9.

spheric region from about 20 kilometer (km)/65,000 ft to 100 km/325,000 feet (ft) above the Earth's surface (See figure 3). Thus, it is sandwiched between the upper limit of internationally controlled airspace and the loosely defined lower limit of outer space.[35] Currently, very little operates there, as the atmosphere is too thin to support flight by most aircraft and yet too thick for satellites to sustain orbit. Near space has recently become a hot topic, however, as the Air Force, Army, Navy, and other agencies are all seeking ways to provide cost-effective, persistent, tailored, tactical-level space effects to American expeditionary warfighters.[36] Several types of lighter than air near-space platforms are being studied, developed, or employed.

The simplest and most mature near-space platforms are *free-floaters*, which are akin to weather balloons. They are very inexpensive and straightforward to construct and launch; but their speed and direction of travel is completely dependent on the winds aloft. Limited steering is possible by altering the balloon's altitude, but free-floaters have no station-keeping ability.[37] Thus, multiple balloon launches are required to maintain persistent coverage over an area. These balloons can lift payloads of tens to thousands of pounds to well over 30 km/100,000 ft, depending on their volume.[38] Free-floating balloons have demonstrated utility as communications platforms. Space Data Corporation, for example, uses such systems to collect and transmit data from oil platforms throughout the southwestern United States. The Air Force Space Battlelab is also exploring how balloons can be used to improve tactical communications by relaying radio broadcasts from forces on the ground and in the air. In March 2005, the Battlelab's Combat SkySat system successfully used a small, free-floating balloon with an expendable relay payload to extend the range of tactical LOS radio communications from about 10 miles to over 400 miles. The Battlelab is now developing the free-floating Talon TOPPER system, which will use an autonomous glider to recover and reuse more expensive payloads.[39]

Steered free-floaters are more complex and potentially more useful near-space platforms. Using a high altitude balloon with a wing suspended far below, such a platform could be steered by exploiting speed and direction differentials between winds at separate altitudes.[40] According to one expert, "such platforms could be navigated with a fairly high degree of precision, generally going with the flow of the prevailing latitudinal winds but being able to speed up, slow down, and move perpendicular to those winds to various degrees."[41]

The most sophisticated type of near-space platforms being studied are *maneuvering vehicles*. They are designed to use a variety of propulsion mechanisms, such as propellers or variable buoyancy, to fly or keep station over specified areas of interest for days to months at a time.[42] One example under study is the Naval Research Laboratory's propeller-driven High Altitude Airborne Relay and Router airship. It is envisioned as a high-capacity communications link between Navy ships and deployed ground forces.[43] Maneuvering vehicles are potentially the most useful type for communications; but they are also the most expensive and technologically challenging.

Near-space communication systems cannot replace SATCOM, but they could deliver effects similar to space systems at the theater and tactical levels. Near-space platforms have much smaller coverage areas than satellites, due to their lower altitude. But, they can still increase the range of terrestrial LOS networks by hundreds of miles and provide persistent, cost-effective communication services to mobile forces. Near-space systems could also extend communications connectivity into areas with limited or no access to SATCOM.[44] That would be especially useful in upper latitudes, mountainous terrain, urban areas, or similar environments. In those situations, a geosynchronous satellite may be below the horizon or otherwise masked by the terrain. Yet, a near-space platform could drift or keep station over the area to maintain LOS with the user(s). Given their operational flexibility, near-space communication systems would make valuable adjuncts to the DoD's military SATCOM capabilities.

Ultimately, the DoD must field new military SATCOM systems with much greater capacity and ability to support mobile users. Commercial SATCOM assets will necessarily continue to augment military capacity, but they lack the protection and certain availability required for many warfighting missions. Similarly, near-space systems could offset theater communication shortfalls by expanding connectivity among mobile forces, and by covering gaps in SATCOM coverage. However, they will not have the global coverage or reach of SATCOM. And, it will take considerable time and effort to develop the necessary technologies and to assess the real capabilities of such platforms.

As previously explained, the DoD is developing several new military SATCOM programs. It plans to spend nearly $11 billion on new satellites and over $2 billion on SATCOM ground terminals through 2009.[45] The most capable of the DoD's new SATCOM programs is the Transformational Communications Architecture (TCA). At its heart is the Transformational Satellite (TSAT) system. The full TSAT constellation will consist of six geo-synchronous satellites plus an on-orbit spare, with the first launch scheduled for 2013.[46] Each satellite will have at least 2 Gbps of radio frequency capacity and support laser communication data rates from 10 to100s of Gbps.[47] TSAT will also provide protected, wideband, and on-the-move communication services through smaller, more mobile terminals. Moreover, TSAT will act as a virtual Internet router in space, dynamically adjusting resource allocations according to user demand, network loading, and environmental factors.

The current TCA plan is very ambitious. It will provide significant new capabilities, far beyond those of other military SATCOM systems. However, building the TCA will be enormously expensive. The seven-satellite TSAT program will cost an estimated $22 billion, which is almost four times the combined price of the WGS and Advanced Extremely-High Frequency SATCOM programs.[48] The TCA will also face stiff competition for limited defense dollars from other major defense acquisition programs. Furthermore, the history of other space acquisition programs illustrates the potential cost, schedule, and performance risks in the TCA program. Despite these concerns, the DoD must proceed with the TCA as scheduled in order to meet the ever-burgeoning SATCOM capacity demands of US military operations.

Closing Observations

Solving the problem addressed in this article is central to the future of expeditionary warfare. New weapon systems and war-fighting concepts are predicated on the availability of ubiquitous information, all provided by robust, reliable, deployable, and mobile communication systems. For many expeditionary warfare missions, SATCOM is, and will continue to be, the communications mode of choice. Yet, SATCOM systems are scarce, high-demand resources. There is a significant risk that the right military and commercial SATCOM capabilities will not be available to satisfy American warfighters' growing information needs.

Solving the problem will be a challenge. There already is a large and growing gap between the American defense establishment's SATCOM needs and capabilities. To close the gap will require development of new technologies, systems, and procedures both in and outside the DoD. That will be very expensive. Defense policy makers will have to make tough choices between many competing priorities. However, without an understanding of SATCOM's importance to the United States' defense strategy, policy makers may choose to pursue cheaper, but less capable alternatives. Doing so will jeopardize America's military advantage.

Notes:

1 SSgt Bill Lisbon, USMC, "1st FSSG Paving the Way for Iraq-bound Marines," *Marine OnLine*, 10 February 2004, http://www.usmc.mil/marinelink/mcn2000.nsf/lookupstoryref/200421015291 (accessed 10 May 2004). The Army and Marine Corps commonly use the phrase "beans, bullets, and band-aids" to refer to the combat service support requirements of modern mechanized warfare. It typically includes supply, transportation, maintenance, engineering, medical, and other support services.

Notes:

2 Department of Defense, *The National Defense Strategy of the United States of America* (Washington, D.C.: March 2005), 13, 17-18.

3 Defense Science Board, *Task Force on Tactical Battlefield Communications Final Report* (Washington, D.C.: Office of the Under Secretary of Defense for Acquisition and Technology, December 1999), viii.

4 *Enabling the Joint Vision,* the Joint Staff, C4 Systems Directorate, Information Superiority Division, Pentagon, Washington, D.C., May 2000, 2.

5 United States Strategic Command, *Transformational Communications Architecture Concept of Operations,* 24 October 2003, 41.

6 Booz-Allen & Hamilton (BAH), "Global Information Grid Support to CINC Requirements," study task #01-05 (Washington, D.C.: Joint C4ISR Decision Support Center, 15 May 2001), 66.

7 United States Strategic Command, *Satellite Communications Systems Capstone Requirements Document,* 25 May 2003, 67.

8 For example, the Inmarsat Mini-M terminal is about the size of a laptop computer. The Iridium, Globalstar, and Thuraya systems all offer handheld terminals that are slightly larger than a cellular phone.

9 Eric Silbaugh, "USCENTCOM OIF/OEF SATCOM Overview" (U) (briefing, US Central Command, 30 January 2004), 19-20. (Secret) Information extracted is unclassified.

10 COL Patrick Rayermann, USA, "Exploiting Commercial SATCOM: A Better Way," *Parameters* 33, no. 4 (Winter 2003-04), 55.

11 LG Harry D. Raduege, Jr., USA, Director, Defense Information Systems Agency (DISA), "Net-Centricity: The Core of DoD Transformation" (briefing, DISA, 19 February 2004), 3.

12 John Ferris, "A New American Way of War? C4ISR in Operation Iraqi Freedom, A Provisional Assessment," *Journal of Military and Strategic Studies* (Spring-Summer 2003) http://www.jmss.org/2003/spring-summer/documents/ferris-infops.pdf (accessed 27 October 2003).

13 Richard J. Newman, "War from Afar," *Air Force Magazine* (August 2003), 60.

14 Nick Johnson, "IFF Systems Needed to Complement Blue Force Tracking, Officials Say," *Aerospace Daily* (22 October 2003) http://ebird.afis.osd.mil/ebfiles/s20031022226774.html.

15 Marine Corps Systems Command (MCSC) Liaison Team, "Field Report: Central Iraq" (20-25 April 2003), 2, http://www.urbanoperations.com/usmcfieldreport.pdf (accessed 28 October 2003).

16 The American defense establishment's SATCOM requirements are compiled by DISA on behalf of the Joint Staff and US Strategic Command. The services, combatant commands, and defense agencies submit their requirements to the Joint SATCOM Panel, which validates and consolidates them in the SATCOM Database (SDB). Current needs are based on existing operations or contingency plans. Future requirements are estimated from doctrine and concept developments, systems studies, and on-going acquisition programs. The SDB supports the development of SATCOM systems and strategies by linking users' needs to specific op-

erational scenarios identified in the DoD's Strategic Planning Guidance. For more detailed information on the SATCOM requirements process, see CJCSI 6250.01B, *Satellite Communications,* 28 May 2004.

[17] Richard Williams, "MILSATCOM and Commercial SATCOM Systems in 2006," 20 January 2004, e-mail to author, 12 February 2004.

[18] United States Space Command (USSPACECOM), "SATCOM Capabilities & Operations in FY10 Prior to TCS," 14 February 2002, 7.

[19] Department of Defense, *Unmanned Aerial Vehicles Roadmap,* 2002-2027 (Washington, D.C.: December 2002), 8, 102.

[20] USSPACECOM, 4.

[21] DFI International, "Global MILSATCOM Augmentation" (Washington, D.C.: Joint C4ISR Decision Support Center, 11 December 2002), 25; SATCOM Systems CRD, 41.

[22] USSPACECOM, 3.

[23] DFI International, 25.

[24] DFI International, 72.

[25] Committee on Evolution of Untethered Communications, National Research Council, *The Evolution of Untethered Communications* (Washington, D.C.: National Academy Press, 1997), 121.

[26] SATCOM Systems CRD, 43.

[27] Futron Corporation, *US Government Market Opportunity for Commercial Satellite Operators: For Today or Here to Stay?* (Bethesda, MD: 29 April 2003), 2.

[28] Col David Anhalt, USAF, "Why Bandwidth Matters: The Changing Nature of US Military Advantage in the Information Age" (point paper, Office of the Under Secretary of the Air Force, Directorate of Space Acquisition, Space Control & Advanced Technology Division, Washington, D.C., 24 September 2002), 4.

[29] Futron Corporation, 3.

[30] Ira Brodsky, "Making Good on Colossal Mistakes," *America's Network* 106, no. 13 (1 September 2002): 32, on-line, Proquest, 11 May 2004.

[31] ViaSatellite.com, "2003 Satellite Survey: Via Satellite's Global Satellite Survey," 1 July 2003, http://www.telecomweb.com/satellite/viasatellite/survey/survey2003.htm (accessed 6 January 2004).

[32] Rich Williams, Chief, DISA Global Information Grid Enterprise Services Transport Engineering Division, Falls Church, VA, interviewed by author, 30 January 2004.

[33] Rayermann, 58-59.

[34] Satellite Industry Association, "Government use of Commercial Satellite Capacity," 10, http://www.sia.org (9 February 2004).

[35] Lt Col Edward B. Tomme, USAF, *The Paradigm Shift to Effects-Based Space: Near-Space as a Combat Effects Enabler,* Research Paper 2005-01 (Maxwell AFB, AL: Airpower Research Institute, 2005), 9.

[36] Hampton Stephens, "Near-Space," *Air Force Magazine* 88, no. 7 (July 2005): 37

[37] Tomme, 18.

[38] Richard Gong, "Near Space" (study, The Aerospace Corporation, 8 March 2005), 6. Small balloons, a few cubic meters in volume, can lift about 22 lbs to 60,000-80,000 ft. At the other extreme is NASA's Long Duration Balloon, which can lift 3,000-4,000 lbs to 130,000 ft and remain aloft for 40 days. Its volume is 830,000 cubic meters, with an inflated diameter of 129 meters.

[39] Stephens, 38-39.

[40] Tomme, 47.

[41] Tomme, 19.

[42] Tomme, 19. Propeller-driven platforms would be most effective at lower near-space altitudes. Propeller efficiency progressively decreases as altitude increases and the atmosphere thins. On the other hand, variable buoyancy and similar propulsion techniques become more efficient at higher altitudes. A vehicle using variable buoyancy would fly almost like a glider, moving forward as it ascended and descended.

[43] Tomme, 48.

[44] *Unmanned Aerial Vehicles (UAVs) as Communications Platforms,* vol 1 (Washington, D.C.: Joint C4ISR Decision Support Center, 4 November 1997), 6-4.

[45] Department of Defense, *FY04 President's Budget Request,* Descriptive Summaries, http://www.dtic.mil/descriptivesum (accessed 11 February 2004).

[46] Kam Lee, "TSAT Satellite Constellation" (briefing, The Aerospace Corporation, 11 March 2005), 3, email to author from Maj David Holz, USAF, Headquarters Air Force Space Command, 11 July 2005.

[47] "Transformational Communications Architecture Fact Sheet," draft, 12 August 2003, 1-2, http://www.globalsecurity.org/space/library/report/2003/TCA-Factsheet-Draft-15-August-2003.pdf (accessed 8 February 2004)

[48] Maj David Holz, USAF, "TSAT SBR Support," 16 March 2005, n.p., e-mail to author, 11 July 2005; GAO, *Satellite Acquisition Programs* (Washington, D.C.: 2 June 2003), 17-18, 24-26.

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Future Security in Space: Charting a Cooperative Course

Future Security in Space: Charting a Cooperative Course. By Theresa Hitchens. Washington, D.C.: Center for Defense Information, 2004. Notes. Glossary. Index. Pp. 107. $25.00 Paperback.

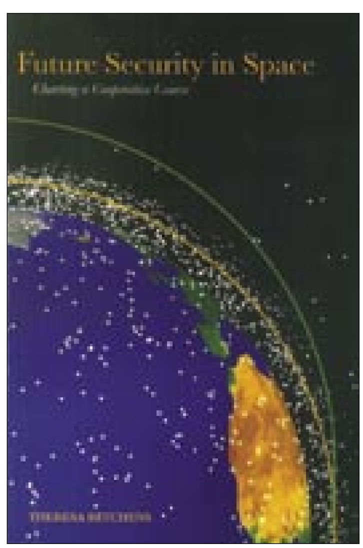
Whoever said, "It's not the size of the hammer, it's the nail you're throwing it at" was right. This diminutive paperback hits you over the head with its thesis from the get-go and continues to hammer away throughout its brief 107 pages. Using a very well-written and well-researched argument, including references to many notable civilian and military space power theorists, authors, and historians, Hitchens prescribes a liberal – with a small "l" – solution to the problems of space, that is, through the application and enforcement of international control regimes. Particularly readable is the 13 page Executive Summary that leads off the book. The Center for Defense Information is dedicated to strengthening security through: international cooperation; reduced reliance on unilateral military power to resolve conflict; reduced reliance on nuclear weapons; a transformed and reformed military establishment.

This monograph covers three major issues and offers possible solutions. The issues are space environment, space tracking and surveillance, and space traffic management. The goal of the book is to "address these interlinked issues and develop the outlines of what could be thought of as a framework for international cooperation in space…in order to ensure future space security and dampen prospects for conflict in space" (p. 22). Hitchen's book prescriptive approach is certainly one way to do it.

The first chapter deals with the space environment by looking at debris, spectrum interference, and crowding problems in the geo belt and efforts to mitigate them. According to the author, the two key environmental issues are the threat of "space pollution" from orbital debris and the growing saturation of the RF spectrum. This chapter begins, as do they all, with very interesting background material on the history of the problem. While claiming this is an important issue, Hitchens also points out "Scientists widely agree that the current hazards to space operations from debris are low" (p. 29). In a sense, then, this discussion is a "sky is falling" argument, which she admits: "preventive measures are best taken well in advance of a 'crisis,' but without the [threat] of an immediate 'crisis,' most stakeholders are loathe to take actions…" (p. 25). Core to Hitchens argument, though, is her basically negative belief that "It is unlikely that voluntary application of mitigation measures will solve the space debris problem" (p. 36), although she never makes it clear why. Therefore, she recommends lots of "could's" and "should's" for solving the problem, centered on the United Nations and other international organizations. This regulatory theme runs throughout.

In chapter two, Hitchens offers what she feels is a solution to the environmental problem, and by extension with the international space situation more generally. In the author's view, mitigating the space debris problem will come through "increased transparency in space." In her opinion, "the ability to 'see' what is going on in space is a precursor to international cooperation and future security in space" (p. 53). She is particularly concerned about her belief that "the trend-line in the United States toward more secrecy" (p. 62) may only make her solution more difficult to achieve but she admits that the problem "is compounded by China's routine secrecy [in] its space program" (p. 70). Hitchens offers an interesting description of the space surveillance capabilities of other nations, including the Europeans, China, Japan, and Canada. This discussion provides both background (e.g., the Chinese spend only $3.63 million on their space tracking budget, including sites in Pakistan and Namibia [p. 59]) and a key to her solution to this problem: wider sharing of the space tracking, surveillance, and situation awareness data, centered on international institutions, a solution that is most likely unachievable. Space power is likely where air power was around 1908 and Hitchens is trying to bring order to chaos. But in one respect, the chaos currently serves a purpose.

The third chapter, "Rules of the Road," is the most prescriptive. This chapter is highly critical of on-going efforts to develop a space traffic regime to prevent collisions in space and, more generally, conflict in space. Hitchens is convinced that it will remain "impossible for space operations to remain safe and relatively conflict-free" without the adoption of her proposals (p. 81). Clearly coming out against weapons in space, while acknowledging that current treaties do not prevent weapons in space other than weapons of mass destruction, Hitchens believes that leaders would imbue on-orbit weapon systems, by virtue of their location and constant presence, with a "use 'em or lose 'em" nature, creating "dangerous new instabilities in international relations" (p. 83). However, US ICBMs have stood alert for decades in essentially the same posture, actually adding stability to the international political environment, not subtracting from it. And given that space weapons do not have to actually be in space (e.g., ground-based lasers or Global Positioning System jammers), Hitchens' argument is somewhat incomplete.



What is the value of this book for the space professional? First, the book provides some interesting background, in one place, on topics like space environmental issues and space control issues. Second, it is useful and in fact important for members of any profession to be aware of arguments and proposals from all sides, whether or not these positions are similar to their own. The Center for Defense Information, for whom Hitchens writes, is dedicated to strengthening security through international cooperation and reduced reliance on military power, among other goals. This book certainly offers some proposals that are outside the typical military approach to these problems. Whether or not you agree with Hitchens' proposals, space professionals should certainly be aware of them.

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