3

Space Weaponry Development

THIS CHAPTER SEEKS to describe the multifaceted variety of space weapons and related applications being developed by the U.S. military. Emphasis is being placed on U.S. military research and development efforts in this arena because the United States is the principal nation conducting substantive scientific technological research in this area and because significant portions of this research are publicly accessible on U.S. military and government websites. This research is produced by a variety of U.S. military agencies including the Missile Defense Agency (MDA) and U.S. Air Force component organizations including AFSPACOM, the Air Force Space and Missile Systems Center, and the Air Force Office of Scientific Research.

Programs described in subsequent sections of this chapter include information about program capabilities and historical organization if available and relevant.

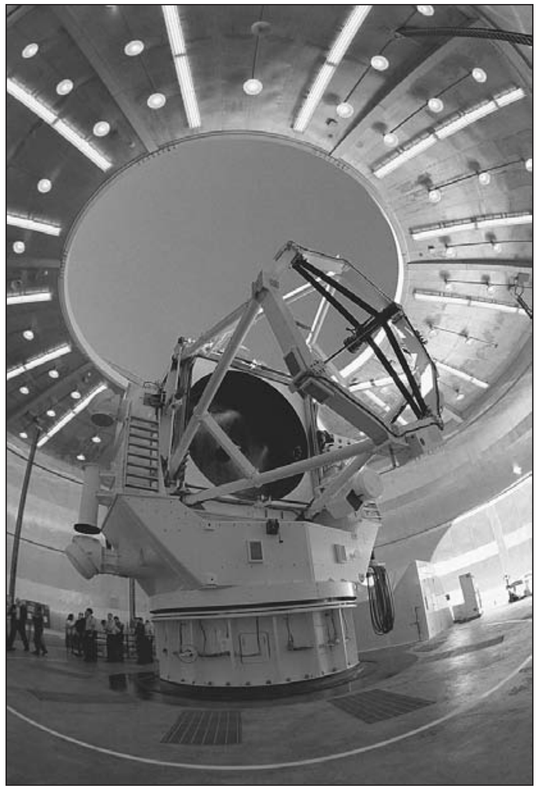
Active Denial System

The Active Denial System (ADS) is an Advanced Concept Technology Demonstration program conducted under the joint auspices of the Air Force Research Laboratory (AFRL) at Kirtland, AFB, New Mexico and the DOD Joint Non-Lethal Weapons Directorate. Using cutting edge technology, ADS seeks to provide unprecedented nonlethal striking power with a range greater than that provided by small arms. ADS works by projecting a focused beam of millimeter waves to produce an unbearable heating sensation on an enemy's skin repelling the individual without causing injury. These waves are produced at a frequency of 95 gigahertz traveling at light speed to penetrate skin to a depth of less than 1/64th of an inch. Such capability enables U.S. forces to stop, deter, and repel advancing forces using nonlethal force while also minimizing collateral damage.

Advanced Electro-Optical System

The Advanced Electro-Optical System (AEOS) is a 3.67-meter telescope space surveillance system that seeks to enhance the collection and quality of space data at Hawaii's Maui Space Surveillance Complex facility. AEOS is used primarily for DOD space surveillance missions, but the telescope is also used by the U.S. academic and scientific community.

Its origins began in the middle 1980s when the Air Force was attempting to develop a ground-based laser ASAT capability. The Maui location proved attractive to facility



The Phillips Laboratory Advanced Electro-Optical System (AEOS) is the Department of Defense's largest optical telescope supporting the Air Force Space Command space surveillance mission. *(U.S. Department of Defense)*

planners due to its maritime location, 10,000-foot altitude, clear visibility, near equatorial location, and a stable physical environment as an ideal site for observing space objects. Collaborative work in support of Vandenberg AFB (California) Western Test Range, the Barking Sands Missile Range on Kauai Island, Hawaii, and restricted airspace in this section of the Pacific Ocean further enhanced the site's ability to meet its space tracking mission. The 3.67-meter telescope was added to previously existing Maui Space Surveillance Complex facilities including a 1.6-meter telescope, 1.2-meter twin telescopes, a laser beam director, a beam director/tracker, and the ground-based Electro-Optical Deep Space Surveillance System, whose capabilities were augmented by close proximity to the Maui High Performance Computing Center.

At its inception, AEOS's mission was supporting space testing and tracking missions for SPACECOM, which had historically favored radar-based imaging techniques over electro-optical methods. The latter systems could produce photographic images, unlike radar, and these images are more user friendly to human eyes than images produced through radar signatures. Anticipated benefits from AEOS and the enhanced Maui Space Surveillance System included mission payload assessment and space object identification for AFSPACOM, adaptive optic research for AFRL, and use by government agencies and national and international astronomy communities.

Effective in fall 1995, AEOS retained its research and development mission for Air Force Material Command, while its AFSPACOM mission emphasized space intelligence, space tracking, and space control. The space tracking responsibilities required detecting and tracking space objects that would produce metrics of space objects for a catalog being developed of these objects by the Air Force. AEOS space control activities demand high-resolution imagery and good signature data to ensure positive identification of individual space objects.

Advanced Extremely High Frequency System

The Advanced Extremely High Frequency System (AEHF) is a joint-service satellite communications system providing secure, survivable, and jam-resistant communications for high-priority military land, sea, and air assets. AEHF is among the newest generation of military satellites, and its first launch is expected in April 2007.

Once fully deployed, AEHF will consist of three satellites in geosynchronous earth orbit that will be capable of servicing up to 4,000 networks and 6,000 terminals and have 100 times the capacity of 1990's vintage MILSTAR satellites. AEHF satellites will provide continual 24-hour coverage of the earth between altitudes of 65° N and 65° S. It will allow NSC and Unified Combatant Commanders to contact their tactical and strategic forces at all conflict levels through nuclear war and support their attaining information superiority. AEHF provides connectivity throughout the spectrum of combat missions including land, air, and naval warfare; special operations; strategic nuclear operations; strategic defense; and space operations and intelligence. It also gives war fighters broadcasting, data networking, voice conferencing, and strategic reporting capabilities, and represents a multinational effort involving British, Canadian, and Dutch partners.

Additional AEHF attributes include consisting of three segments: space (satellites), terminals (users), and mission control and associated communications links. These particular links provide communications in specified data speeds from 75 bits per second to nearly 8 megabits per second. AEHF satellites are capable of responding directly to service requests from operational commanders and user terminals while providing real-time point-to-point connectivity and network services on a priority basis.

Lockheed Martin Space and Strategic Missiles serves as the primary contractor. An AEHF satellite will weigh 13,500 pounds at launch and 9,000 pounds in orbit, and each satellite has an estimated 14-year design life and costs approximately $477 million.

Advanced Research and Global Observation Satellite

The Advanced Research and Global Observation Satellite (ARGOS) is the largest Air Force research and development satellite. Weighing almost three tons, ARGOS is responsible for handling DOD payloads that cannot be flown on the space shuttle or smaller launch vehicles due to complexity, size, and mission duration constraints. ARGOS's mission is spending three years in orbit collecting crucial science data on the earth's global environment for top military space programs.

Examples of research functions performed by ARGOS include investigating electric propulsion, orbital debris distribution, space radiation effects, the effect of upper atmospheric conditions on the security of Army communication systems design, magnetic storm prediction, and identification of plumes and atmospheric wakes of launch and orbital vehicles.

Aegis Ballistic Missile Defense

Aegis Ballistic Missile Defense (ABMD) serves as the sea-based component of the MDA's ballistic missile defense system. Aegis destroyers patrol, detect, and track ICBMs and report tracking data to the missile defense system. Such capability shares tracking data to inform other missile defense sensors and provides fire control data to ground-based midcourse defense interceptors at Fort Greeley, Alaska and Vandenberg AFB, California. It is possible for Aegis to reliably track data across eight time zones to enhance missile defense situational awareness and missile targeting and engagement capabilities.

Aegis cruisers and long-range surveillance and track destroyers are given the capability to intercept short- and medium-range ballistic missiles and to distinguish between missiles carrying individual and multiple warheads. Operational capability for Aegis cruisers is scheduled for late 2006.

As of July 2006, 11 of 15 long-range surveillance and track destroyer installations have been completed and all Aegis long-range surveillance and track destroyers are expected to be upgraded with engagement capability by 2009. Anticipated future capabilities include increasing precision track data from radar signal processing upgrades to augment long-range surveillance and track and engagement capabilities and gaining the ability to defend against Intermediate Range Ballistic Missiles (IRBMs) and ICBMs.

Aerospace Engineering Facility

The Air Force's Aerospace Engineering Facility (AEF) is located at Kirtland AFB, New Mexico. AEF's mission is serving as a single facility for space experiment integration, verification, and testing. AEF personnel test components and payloads, integrating them for space flights, and near space flights such as high altitude balloons.

Encompassing 16,500 square feet, AEF is designed to provide vibration, shock, acceleration, environmental, and thermal variation testing for flight components and their payloads under realistic launch and orbital environments. AEF includes a 60-foot tall, 4,500-square-foot laboratory for assembling and testing space flight hardware, three environmental chambers, and a thermal vacuum chamber capable of housing components up to 9 feet long. Additional facility capabilities consist of three vibration tables capable of exerting 42,000 pounds of force on small satellites of up to 500 pounds, and the ability to conduct electromagnetic compatibility and susceptibility testing within a copper screen room to determine whether satellites and space experiments can survive launch and orbit.

Airborne Laser

The Airborne Laser (ABL) is a collaborative program between the MDA, the Air Force, the AFRL's Directed Energy Directorate, Boeing, Lockheed Martin, and Northrop Grumman Space Technologies. The ABL program office was formed in 1993, and in November 1996 the Air Force awarded a $1.1 billion contract to the three companies listed above to develop a laser capable of finding, tracking, and hitting targets such as ballistic missiles.

Air Force testing with lasers dates back to the 1960s and has produced mixed results. During 1967 scientists invented the first gas dynamic laser, which used nitrogen and water vapor and influenced the belief that a laser could be used as an antimissile system,

Airborne Laser aircraft in flight. *(Missile Defense Agency)* although testing this belief would prove to be a protracted process. Between October and December 1972, technicians fired a ground-based 100-kilowatt carbon dioxide laser propagating 10.6 microns against various stationary targets. Successful results from these tests saw the Air Force look at firing a laser at a moving airborne target. On November 13, 1973, the laser was shot at a 12-foot-long radio-controlled aerial drone in attempt to knock it out of the air. The drone fell but the results were not as intended since the laser beam burned the drone's aluminum skin frying the control system instead of igniting the drone's fuel tank.

Continued testing occurred throughout the 1970s and early 1980s when an ABL Laboratory plane (a KC-135) shot down a Sidewinder air-to-air missile over California's China Lake on May 26, 1983. Concern that these tests did not reflect real world battle conditions and that the laser was impractical resulted in it being ignored during the late 1980s.

ABL's fortunes revived during the 1990–1991 Persian Gulf War when Iraqi forces began firing Scud theater ballistic missiles at U.S. troops and their allies. Intervening technological advances also facilitated enhancements in ABL capabilities as the gas dynamic laser was replaced by a Chemical Oxygen Iodine Laser (COIL) that was more powerful than the gas dynamic laser, more compact in size, and capable of producing a lethal beam over long distances. The Air Force decided to replace the gas dynamic laser with COIL, whose modules are installed on the rear of a Boeing 747–400 plane. ABL is also enhanced by having an optical system capable of projecting a beam over hundreds of kilometers and compensating for atmospheric disturbances potentially existing between the aircraft and its target. Between July and December 2002, ABL aircraft made 14 flights logging over 60 flight hours, and it is based at Edwards AFB, California.

ABL continues to undergo research and development. Effective system requirements continue to include:

- Being housed aboard a stable platform capable of staying aloft for hours above weather systems whose clouds could refract its laser beams and nullify its effectiveness;
- Having sensors capable of locating a ballistic missile just after launch and holding the missile's track long enough for other missile defense system operations to become active;
- Possessing a computer system capable of tracking dozens of missiles and prioritizing them so the most threatening is targeted first;
- Possessing a highly developed optical system capable of measuring the thermal disturbance between the aircraft and target and being capable of directing an energy beam capable of compensating for clear-air obstacles;
- Having the ability to focus the killer beam on a rapidly rising target that may be traveling at speeds of Mach 6 or greater, and keeping the energy shaft in place long enough to burn a hole in the missile's metal skin; and
- Having a laser powerful enough to be lethal at distances of hundreds of kilometers.

Air Force Research Laboratory Directed Energy Directorate

The Air Force Research Laboratory Directed Energy Directorate (AFRLDED) is located at Kirtland AFB, New Mexico. DED employs over 800 people and develops directed energies such as high-energy lasers and high-powered microwaves while also working with advanced optics and imaging technologies. During 2004, these DED employees worked with a budget of approximately $309 million in a 670,000-square-foot working space, focusing on integration and transition research technologies in military systems used by various operational commands.

DED work focuses on six major emphasis areas. These include directed energy technologies protecting the U.S. population and resources; giving military field commanders more information about space assets; exploiting the global advantages and uses of high-power lasers; emphasizing the tactical roles of lasers; using radio frequency and high-power microwave technologies for electronic attacks capable of eliminating enemy threats without causing physical destruction, and examining "exotic" directed energy research that doesn't fall into the preceding five areas.

DED research is carried out by three technical divisions focusing on high-power microwaves, lasers, and optics. The High-power Microwave Division manages the research and development of high-power microwave technologies including those capable of protecting against hostile microwave systems. Such systems can identify weapons concealed in buildings or turn away attacking forces without using lethal force. The Laser Division performs cutting edge research and development of transformational technologies including semiconductor, gas, chemical, and solid-state lasers such as the COIL laser used by the ABL. Optics Division research stresses improving optical and imaging systems and improving the United States' ability to view space objects along with developing high-energy technologies to accurately direct high-energy lasers to their targets. This particular division operates DOD's largest and most sophisticated telescope facilities conducting experiments at Kirtland's Starfire Optical Range, the North Obscura Peak on White Sands Missile Range, New Mexico, and Hawaii's Maui Space Surveillance Site.

Work done by these three divisions is then taken over by DED's Technology Applications Division, which takes the developed technologies and transitions to other war-fighting organizations, while also looking for potential DOD needs and developing opportunities for transferring directed energy systems to relevant DOD entities.

Antisatellite (ASAT) Weapons

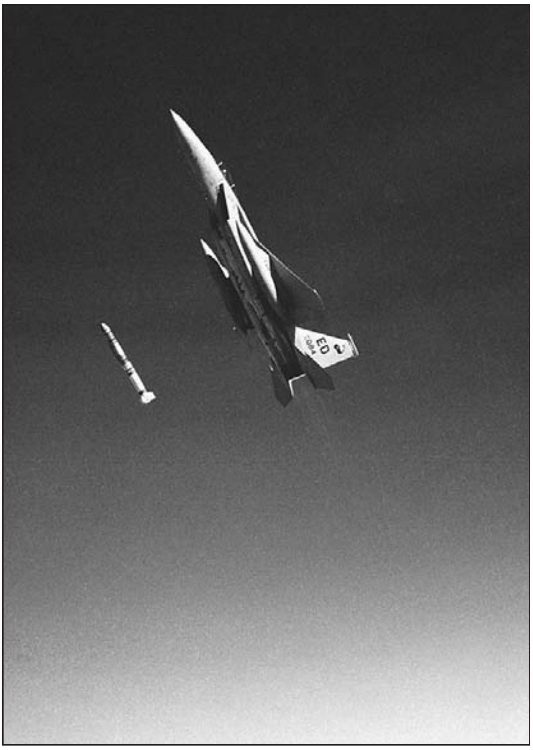
ASAT weapons are generally designed to destroy or disable satellites of hostile powers. The initial objective of U.S. ASAT weapons was to counter orbiting nuclear weapons, which was a threat that failed to materialize. Initial problems with planned early ASAT weapons were that since they were nuclear-armed they would likely damage U.S. satellites as well as their intended Soviet targets. Limitations on early ASAT guidance systems made it possible to place such weapons only within a few miles of their target. An additional complication from this inaccurate ASAT targeting and dependence on nuclear armament was the widespread impact of electromagnetic pulse from the detonation of these weapons. An upper atmospheric ASAT test in 1962 activated burglar alarms and darkened streetlights in Hawaii several hundred miles from the test site while also disabling several U.S. satellites in the area.

A number of ASAT weapon systems were tested by various branches of the U.S. military during the 1950s and 1960s. Beginning in 1959, the Air Force's Bold Orion program launched rockets from a B-47 bomber as part of an ASAT program. During 1962, the Navy conducted two Hi-Ho ASAT weapons tests from an F-4 jet fighter. The Army's Nike-Zeus program during this period initially began as an ABM system but evolved into more of an ASAT system because of its ineffectiveness as an ABM. The United States' first ASAT intercept occurred on May 23, 1963 from Kwajalein Island in the Pacific Ocean. The Air Force tested and deployed several THOR rockets for ASAT tests, and these became operational on Johnston Island in the Pacific in 1964 and had greater range than Nike-Zeus. These tests occurred at least 16 times between 1964–1970 before the system was retired in 1976.

The Air-Launched Miniature Vehicle (ALMV) was the principal U.S. ASAT program during the early 1980s. ALMV was launched from an F-15 fighter by a small two-stage rocket and carried a heat-seeking miniature homing vehicle that would destroy its target by direct impact at high speed. An advantage of this system was its enabling the F-15 to bring the ALMV under its targets ground track, as opposed to a ground-based ASAT, which must wait for a target satellite to overfly its launch site. An operational force of over 100 interceptors was originally planned for the ALMV program but cost overruns by 1986 had seen the program's estimated cost skyrocket from $500 million to $5.3 billion. The Air Force scaled the program back by two-thirds in 1987, and it was cancelled by the Reagan administration in 1988 after encountering continuing cost overruns, testing delays, and homing guidance system problems.

In February 1989, the Kinetic Energy Anti-Satellite Joint Program Office was established and the Army was given leadership of this program in December 1989. The purpose of this program was developing a ground-based interceptor capable of destroying satellites by homing in and colliding with them. This interceptor would reach satellites in low earth orbit at ranges of up to several thousand kilometers. Upon reaching the target, the interceptor would extend a sheet of Mylar plastic, called a "kill enhancement device," that would strike the target and neutralize it without destroying the satellite.

In August 1992 a Kinetic Energy integrated technology experiment demonstrated the ability to intercept reentry vehicles in the atmosphere using a homing seeker and non-nuclear warhead, and in August 1997 a successful hover test of a prototype kinetic energy ASAT kill vehicle occurred.



An air-to-air left side view of an F-15 Eagle aircraft releasing an anti-satellite (ASAT) missile during a test, 1985. *(U.S. Department of Defense)*

Air Force officials have expressed concern that the kinetic energy ASAT could create debris and endanger other U.S. space assets. DOD has not requested funding for this program for several years, but Congress added money for this program into the defense budget for fiscal years 1996–1998, 2000–2001, and 2004.

There has been renewed congressional interest in ASAT weapons since the 104th Congress (1995–1996), and some funding for such programs has occurred even though there are variant viewpoints within DOD and individual armed services on the suitability of these programs for U.S. national security interests. A May 18, 2005 *New York Times* article asserted that a forthcoming national space policy being developed by the Bush administration was bringing the United States closer to deploying offensive and defensive space weapons. A legislative amendment introduced by Representative Dennis Kucinich (Democrat from Ohio) to ban the use of weapons to damage or destroy objects in orbit was rejected by the House by a vote of 302–124 on July 20, 2005.

Despite supporting some ASAT programs, Congress has been skeptical about the ability of the Air Force to manage the costs and goal schedules of these programs and expressed concern about relationships between classified and unclassified space activities and about defense space acquisition programs.

U.S. ASAT research programs are likely to continue but with acute skepticism about their viability and costs, Congress is likely to keep a tight rein on their funding.

Atlas II Launch Vehicle

The Atlas II is designed to launch payloads into low earth orbit, geosynchronous transfer orbit, or geosynchronous orbit. Atlas vehicles have been used by NASA as a space launch vehicle since 1958 and by the U.S. Army Signals Corps since the Eisenhower administration. Atlas was also initially deployed as an ICBM with the first vehicle being placed on alert at Vandenberg AFB, California by the 576th Strategic Missile Squadron on October 31, 1959. In May 1988, the Air Force selected General Dynamics (now Lockheed Martin) to develop the Atlas II to carry Defense Satellite Communications Systems payloads for commercial users because of Atlas I launch failures in the late 1980s.

The final West Coast Atlas II launch occurred in December 2003 by the 30th Space Wing at Vandenberg AFB, and subsequent launches are carried out by the 45th Space Wing at Cape Canaveral AFS, Florida.

Ballistic Missile Defense System

The U.S. Ballistic Missile Defense System (BMDS) is directed by the MDA within DOD. On December 17, 2002, President George W. Bush directed DOD to field a defense system capable of countering the ballistic missile threat to the U.S. homeland and to forces deployed by the United States and its allies. MDA is charged with developing a BMDS that will eventually address all three phases of a hostile ballistic missile's flight path and defend against ballistic missiles of all ranges.

The three phases of a ballistic missile's flight trajectory are the boost phase, midcourse phase, and terminal phase. During the boost phase, which occurs just after launch, the missile is easiest to detect and track because missile exhaust fumes are bright and hot. This phase, however, is the most difficult phase in which to engage a missile because the intercept window is only 1–5 minutes. The midcourse phase occurs when the hostile missile's booster burns out and it begins coasting in space toward its target. This phase may last as long as 20 minutes, which allows several opportunities to destroy the incoming missile before it reenters the atmosphere, and debris remaining after the intercept burns up after entering the atmosphere. During the terminal phase, the missile reenters the atmosphere. This is the last opportunity to intercept the warhead before it reaches its target. Intercepting a warhead is difficult and the least desirable time because there is little margin for error and because the intercept will occur so close to the intended missile target.

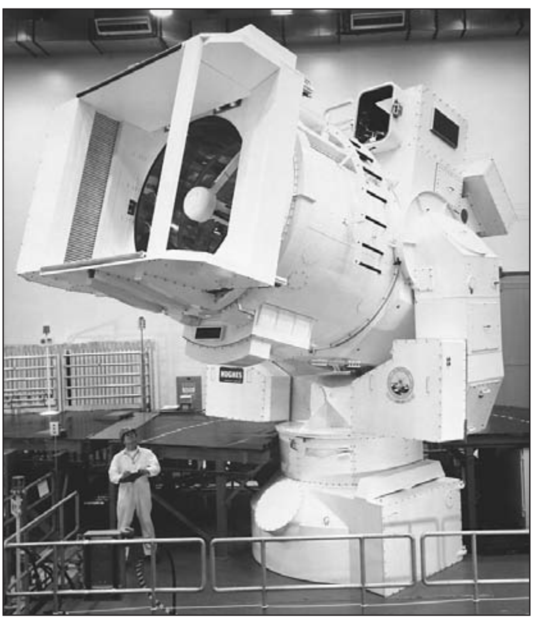
Ballistic Missile Defense System Interceptors

This capability has been developed by MDA to provide a next-generation mobile, multi-use intercept capability to destroy medium-range ballistic missiles, intermediate-range ballistic missiles, and ICBMs during their boost, ascent, and midcourse flight phases. The interceptor's mobile capability is used during the boost and ascent phases where hostile missiles are destroyed shortly after launch before they can release their weaponized payloads and countermeasures. This interception capability may also be used during the midcourse phase when the missile is no longer thrusting and follows a more predictable glide path, allowing for a longer time to track and engage the target.

This particular system is deployed close to threats on mobile land launchers or on sea-based platforms including surface ships and submarines. Interceptor system design and performance approach are for booster, kill vehicle, and mobile fire control. System risk is reduced through demonstration testing and robust engineering and integration, while interceptor fire control equipment interfaces with the overall BMDS. The interceptor uses existing BMDS sensors as well as additional overhead sensors to obtain threat-tracking data. Deployment for these interceptors is estimated in 2014 and 2015.

Beam Weapons

Beam weapons are also called directed energy weapons and they consist of lasers, high-powered microwaves, and particle beams. They can be used for air, ground, sea, and space warfare. The ABL, described earlier in this chapter, is one example of a beam weapon. An additional example of beam weapons researched by the United States for over two decades includes the Army's Tactical High Energy Laser (THEL) at White Sands, New Mexico, which has demonstrated the ability to heat high-flying rocket warheads and blast them with enough energy to make them self-detonate using a high-energy deuterium fluoride chemical laser.



The Navy's high energy laser beam director built by Hughes Aircraft Company for use in high energy laser research and development. The experimental pointing and tracking system is designed to track targets in flight and direct a high power laser beam to selected aimpoints. *(U.S. Department of Defense)*

Active Denial Technology is another example of beam weapons and it presents a nonlethal way for using millimeter-wave electromagnetic energy to stop, deter, and turn back advancing adversaries. Such technology has been supported by the Marine Corps and seeks to use millimeter wave beams to heat an enemy's skin and cause severe pain and make them flee the area. Work at Los Alamos National Laboratory involving the Navy also uses free-electron laser work in the terahertz frequency range.

U.S. military beam research initiatives continue although limited funding and uncertain political support for these programs makes their future uncertain.

Chemical Oxygen-Iodine Laser

The Chemical Oxygen-Iodine Laser (COIL) is the world's shortest wavelength and high-power chemical laser-emitting light with a wavelength of 1.315 micrometers and a power range of 1–40 kilowatts. It is used in the ABL laser described earlier. COIL is developed at the AFRL's DED facility and was invented in 1977. Other significant milestones in COIL's development include the 1982 demonstration of the world's highest power subsonic gas flow, the 1984 demonstration of supersonic gas flow, the 1989 demonstration of a high-power (700 watts) continuous wave frequency doubling capability, and the 1992 demonstration of high-power COIL pulsing using magnetic gain switching.

Command, Control, Battle Management, and Communications

Command, Control, Battle Management, and Communications (CCBMS) are essential characteristics of the U.S. BMDS program. They deliver layered defense through networking and unifying individual element components (sensors, weapons systems, and fire control) with military commands globally. CCBMS also allows the president, secretary of Defense, and tactical and strategic level combatant commanders to systematically plan battles, watch conflicts unfold, and dynamically direct or adjust networked sensors and weapons to systems to effectively engage ballistic missile threats at any time and place.

MDA successfully delivered an introductory foundation for an integrated-layered defense emphasizing situational awareness, basic planning, and network architecture at the end of 2005. Ongoing and future MDA goals for CCBMS include completing the foundation for fielding common situational awareness, deliberative planning capability for all leadership levels, advanced battle management capability to control and direct sensor weapon-system combinations and global network management by late 2007, expanding geographically, and incorporating additional sensors and weapons capable of planning and adjusting real-time fighting ability to attain highest kill probability against any range of threats between now and 2009.

Communication/Navigation Outage Forecasting System

The Communications/Navigation Outage Forecasting System (CNOFS) is produced by the AFRL's Space Vehicles Directorate. CNOFS's objective is detecting active scintillations in the ionosphere that are naturally occurring irregularities leading to communication signal fluctuations. Such scintillations are responsible for decreased satellite-to-ground message work capacity and delayed signal acquisition. CNOFS alerts users of impending UHF and L-band satellite communication outages that affect certain satellite communication frequencies and terrestrial communications between satellite equipment.

CNOFS collaborative partners include NASA, the Naval Research Laboratory, the University of Texas, the National Polar Orbiting Environmental Satellite System, General Dynamics, and Orbital Sciences. CNOFS satellite assets include a radio beacon, GPS receiver for remote ionospheric sensing, ion velocity and neutral wind monitors, vector electric field instrument, and planner Langmuir Probe.

Communications Satellite Sabotage

Communications satellite sabotage occurs when satellites are attacked through the use of nuclear explosions or more targeted attacks such as space mines, which occur when nations or terrorist organizations target satellites used for civilian or military communications or intelligence purposes by seeking to destroy or disable them. Responses to such potential attacks and sabotage include producing a variety of satellite platforms for system redundancy against potential targeters, giving satellites substantial operational autonomy, choosing satellite orbits beyond the reach of most threats, having satellite orbits go through several orbital planes to preclude predictable targeting, hardening the satellites, installing ASAT attack warning sensors, and making the satellites orbit frequencies and paths irregular.

Cryocoolers: Cool Infrared Sensors to Enable Space Intelligence, Surveillance, Reconnaissance and Situation Awareness

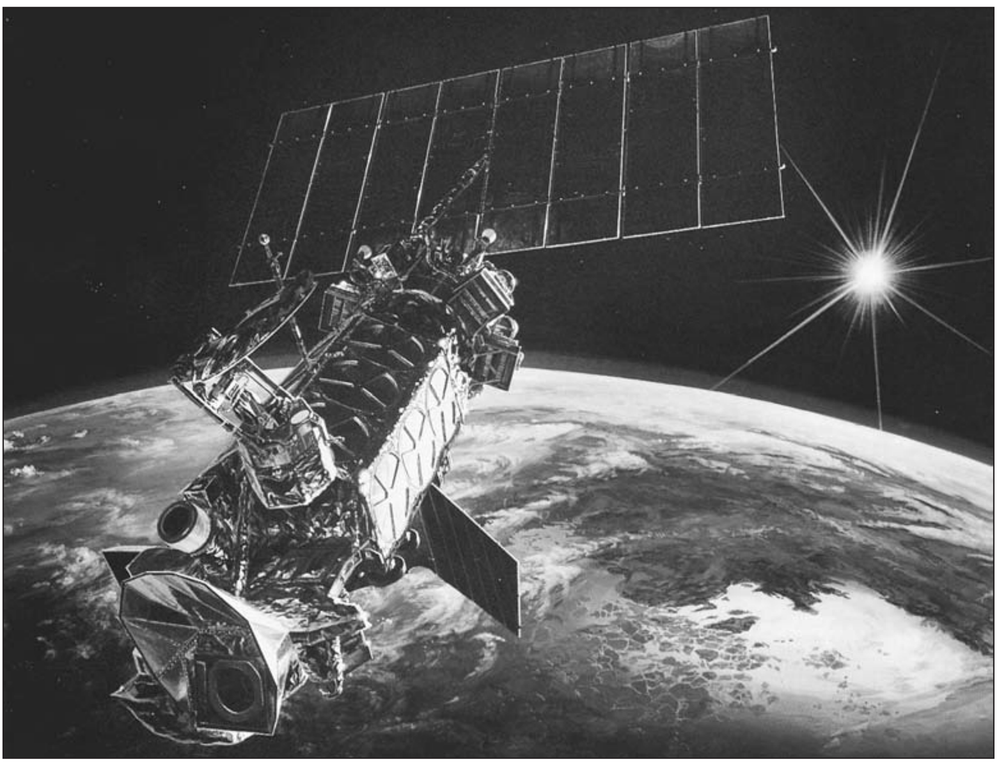
Cryocoolers are small simply designed refrigerators operating at very low temperatures, which compress and expand gas such as helium to lower the temperature of critical satellite payload elements such as sensors. AFRL's Space Vehicles Directorate conducts cryocooler research to develop cryogenic refrigeration technology so satellite infrared sensors can be cool enough to enhance missile detection, conduct intelligence gathering, and enable space situational awareness. Cryocoolers help these sensors function in space's cold environment by enabling them to accurately identify distant objects in space or on the land through their heat signatures, which are often referred to as spectral footprints.

Historical satellite refrigerators had an approximate 1-year lifespan, weighed around 1,000 pounds, and could only generate approximately 0.5 watts cooling. In contrast, the Cryocooler has an estimated 10-year lifespan, weighs approximately 11 pounds, and can generate up to 20 watts cooling power.

Defense Meteorological Satellite Program (DMSP)

The Defense Meteorological Satellite Program (DMSP) has been responsible for collecting military data for U.S. military operations for four decades. Two operational DMSP satellites are in polar orbits of about 458 nautical miles at all times. DMSP's Operational Linescan System serves as the primary weather sensor providing continuous visual and infrared imagery of cloud cover covering 1,600 nautical miles. Other satellite sensors measure atmospheric vertical profiles of moisture and temperature. Military weather forecasters use this data to detect developing weather patterns and track existing weather systems such as severe thunderstorms and hurricanes over remote areas.

DMSP satellites also measure local charged particles and electromagnetic fields to examine the ionospheric impact of ballistic missile early warning radar systems and long-



Defense Meteorological Satellite Program (DMSP) illustration. *(U.S. Air Force)* range communications. Such data is also used to monitor global auroral activity and to predict space-environment effects on satellite operations.

President Clinton directed DOD and the Commerce Department to consolidate their previously separate polar-orbiting weather satellite programs in July 1994. DMSP operations were transferred to the Commerce Department in Suitland, Maryland in June 1998. The National Oceanic and Atmospheric Administration's Office of Satellite Operations provides command, control, and communication support for DMSP and the Space and Missile Systems Center of Los Angeles AFB is responsible for developing and acquiring DMSP systems.

DMSP-derived data is received by tracking stations at New Boston AFS, New Hampshire; Thule AFB, Greenland; Fairbanks, Alaska; and Kaena Point, Hawaii who transfer this electronically to the Air Force Weather Agency at Offutt AFB, Nebraska. Specially equipped tactical units can also receive this data directly from satellites. DMSP satellites weigh approximately 2,545 pounds including a sensor payload of 592 pounds, are just over 14 feet long without the solar panels deployed, have a power plant of 10 panels generating 2,200 watts of power, and are launched by a medium evolved expendable launch vehicle. Lockheed Martin Missiles and Space is the primary DMSP contractor.

Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) is used for high priority command and control communication including wartime information exchange between defense officials and battlefield commanders. DSCS is also used by the military to transmit space operations and early warning data to various systems and users.

The system has been in use since its first launch in 1982. DSCS is built with single and multiple beam antennas that provide highly flexible coverage. A single steerable dish antenna provides an increased power spot beam that can be customized to suit the needs of different size user terminals. DSCS Phase III satellites can resist jamming and consistently exceed their projected ten-year design life.

Members of the Air Force's 50th Space Wing's 3rd Space Operations Squadron at Schriever AFB, Colorado provide satellite command and control for all DSCS satellites. AFSPACOM operates 13 Phase III DSCS satellites orbiting at an altitude of over 22,000 miles. Each satellite uses six super high-frequency transponder channels capable of delivering secure voice and high-rate data communications. DSCS III assets also include a single-channel transponder capable of disseminating emergency-action and force-direction messages to nuclear capable forces.

Lockheed Martin Missiles and Space is the primary contractor for this 2,716-pound satellite, which costs $200 million per unit. DSCS's power plant consists of solar arrays generating an average of 1,500 watts, its dimensions are 6 six feet long and high, 7 feet wide, and an overall 38-foot span with solar arrays deployed.

Defense Support Program

The Defense Support Program (DSP) satellites provide early warning of ballistic missile launches, space launches, and nuclear detonations from their geosynchronous orbits. DSP satellites use an infrared sensor to detect heat from missile and booster plumes against the earth's background. During 1995 technological enhancements were made to ground processing systems, increasing their ability to detect smaller missiles to give enhanced warning of attack by short-range missiles against U.S. and allied forces overseas. These enhanced features have been incorporated into the DSP's successor Space-Based Infrared System (SBIRS).

The first DSP satellite was launched in 1970. Over the years, DSP has become an important part of the U.S. early warning defenses. During Operation Desert Storm, DSP detected the launch of Iraqi Scud missiles and warned coalition forces in Saudi Arabia and Israel along with Israel's civilian population. The 460th Space Wing at Buckley AFB, Colorado with affiliate units elsewhere is responsible for operating DSP satellites and providing warning to appropriate authorities.

Delta II Launch Vehicle

The Delta II Launch Vehicle serves as an expendable launch medium-lift vehicle for launching Navstar GPS satellites into orbit so these satellites can provide navigational data to military users. The Delta II also launches civil and commercial payloads into low-earth, polar, geosynchronous transfer, and stationary orbits.

Delta's launch vehicle history began in 1959 when NASA's Goddard Space Flight Center awarded a contract to the Douglas Aircraft Company to produce and integrate 12 space launch vehicles. Delta component parts included the Air Force's Thor IRBM for its first stage and the Navy's Vanguard launch vehicle for the second stage. The inaugural Delta launch occurred from Cape Canaveral AFS, Florida, on May 13, 1960. In January 1987 the Air Force awarded a contract to McDonnell Douglas, now Boeing, to construct 18 Delta IIs for launching Navstars, which had originally been designed to be launched on the space shuttle, and the Delta remains the Air Force's only launch platform for launching and orbiting GPS satellites.

The first Delta II was successfully launched at Cape Canaveral on February 14, 1989 and Delta has successfully launched over 270 military, civil, and commercial craft since 1960. Historically significant Delta launches include the Telstar I international satellite in 1962, the first geosynchronous orbit satellite Syncorn II in 1973, and the first commercial communications satellite COMSAT 1 in 1965.

Delta II is launched primarily from Cape Canaveral, but it is also launched at Vandenberg AFB, California. The AFSPACOM's 45th Space Wing headquartered at Patrick AFB, Florida and the 30th Space Wing at Vandenberg AFB are the military organizations responsible for Delta II launches.

Demonstration and Science Experiments (DSX) Satellite

The Demonstration and Science Experiments (DSX) Satellite is being produced by AFRL's Space Vehicles Directorate. Scheduled for launch in 2008, DSX is being designed to conduct basic research to enable DOD spacecraft to successfully operate in medium earth orbit (MEO) with its harsh radiation environment. This satellite's military benefits include enhancing understanding of MEO and its "slot region," which is a highly desirable area for future space surveillance and high-speed communication. It will also perform research needed to evaluate DOD's ability to actively regulate agitations in the space meteorological environmental that cause accelerated degrading of critical space assets.

Areas of DSX experimentation include:

- Wave Particle Interaction, which researches the physics of very low frequency (VLF) transmissions in the magnetosphere and characterizes the capability of natural and man-made VLF waves to reduce space radiation;
- Space Weather Experiment, which characterizes and models the space radiation environment in MEO, which is a desirable orbital area for future DOD and commercial missions;
- Space Environmental Effects, which investigates and characterizes space weather effects on spacecraft electronics and materials.

Directed Energy Weapons

See Beam Weapons

Early Warning Radar Service Life Extension Program

The Early Warning Radar Service Life Extension Program (EWRSLEP) is an Air Force program to replace 1970s–1980s era computer systems used in the Solid State Phased Array Radar System (SSPARS) providing the military with missile early warning and space surveillance capabilities. These mission capabilities are provided by the PAVE Phased Array Warning System (PAWS) at Cape Cod AFS, Massachusetts; Beale AFB, California; Clear AFS, Alaska; and by Ballistic Missile Early Warning System Radars at Thule AFB, Greenland and the British Royal Air Force Base at Flyingdales, UK. A key factor prompting this program is the increasing inability of original equipment managers to repair or produce spare parts for original SSPARS equipment.

Solid state module tests, the Flyingdales' radio control computer, the network-processing unit 8-Mb micromemory instruction board, tape and disk drive peripherals for the digital module test set/radar controller and main mission processor, and the solid state phased-array radar-training system will be the main EWRSLEP parts replaced as a result of this program.

Electromagnetic Pulse

Electromagnetic pulse (EMP) involves the electromagnetic radiation from a nuclear explosion caused by recoiling electrons and photoelectrons from photons scattered in a nuclear devices materials or a surrounding medium. Resulting electric and magnetic fields can combine with electrical/electronic systems to produce damaging current and voltage surges, which can also be produced by nonnuclear means.

EMP attacks could disrupt or destroy the electric, electronics, energy, financial, telecommunications, transportation and other infrastructures in the United States or other countries. Concern over this possibility caused Congress to create an EMP Commission in 2000, and this commission's report issued in 2004 recommended that the United States take aggressive steps to harden civilian and military infrastructures that could be vulnerable to EMP including space-based assets while also using intelligence, interdiction, and deterrence to thwart EMP attacks against U.S. national interests.

Evolved Expendable Launch Vehicle (EELV)

The EELV seeks to enhance the reliability of U.S. space access by making space launch vehicles more affordable and reliable. Boeing Delta IV and Lockheed Martin Atlas V

Atlas V expendable launch vehicle with the New Horizons spacecraft poised for launch. *(NASA)* launchers are the chief EELV component parts, and their operability improvements over predecessor systems include a standardized payload interface, standardized launch pads, and increased off-pad processing.

Initial EELV program activity dates from the November 1996 completion of the Low Cost Concept Validation program emphasizing competition in preliminary design and risk reduction demonstration. Four $30-million contracts were awarded to companies such as Boeing and Lockheed Martin during this period. Two $60-million 17-month contracts were awarded to Boeing and Lockheed Martin after this initial phase and subsequent development agreements with these contractors run through September 30, 2007 with launch agreements lasting until September 30, 2012.

Forward Deployable Radars

These radars are part of BMDS's efforts to detect ballistic missiles in their early flight stages and provide precise tracking information for missile defense system use. Radar will provide high-resolution, X-band class, phased-array radar that will acquire, track, discriminate, classify, identify, and estimate the trajectory parameters of hostile missiles and missile components, and pass this information to other BMDS tracking assets downstream. These radars can be transported by air, ship, or rail and are also deployed with command and control interface, a radar support trailer, generators, and supply containers.

Development plans for this system include four forward deployed units to protect the United States from ICBM and IRBM threats with an initial search and track capability being available in 2006 and discrimination enhancements being added in 2007.

Global Positioning System (GPS)

The GPS is one of the key elements in the U.S. military space arsenal as well as serving as a system with significant civilian applications. Its involvement in U.S. military activities dates from its testing period from approximately 1978–1985, and its influence on U.S. military operations has continually increased.

GPS is a series of orbiting satellites providing navigation data to military and civilian users globally, and it is operated by the 50th Space Wing at Schriever AFB, Colorado. These satellites orbit the earth every 12 hours emitting continual navigational signals. Users with proper equipment can receive these signals to determine time, location, and velocity. The accuracy of GPS signals is such that time can be calculated to within a millionth of a second, velocity within a fraction of a mile per hour, and location to within 100 feet. GPS receivers can be used in aircraft, ships, land vehicles, and be hand carried.

Around-the-clock navigation services provided by GPS include:

- Extremely accurate three-dimensional location information including latitude, longitude, and altitude with velocity and precise time

- A common global grid, which can easily be converted to any local grid
- Passive all-weather operational capability
- Support of an unlimited numbers of users and areas
- Support of civilian users at slightly lower accuracy levels.

GPS includes a suite of 24 satellites consisting of six planes with a minimum of four satellites per plane. Delta II expendable launch vehicles are used to launch GPS satellites from Cape Canaveral into circular orbits nearly 11,000 miles above the earth. GPS's design life is 7.5 years, and it transmits signals on two different L-band frequencies.

During its recent history, GPS has already had significant impact on U.S. military operational activities. During the 1990–1991 Persian Gulf War, U.S. and allied troops made heavy use of GPS to navigate the featureless Arabian Desert. Use of GPS increased substantially during Operations Enduring Freedom and Iraqi Freedom. During Iraqi Freedom, GPS satellites facilitated the delivery of 5,500 GPS-guided Joint Direct Attack Munitions to within 10 feet of their targets and with minimal collateral damage. This represented nearly one-fourth of the 29,199 bombs and missiles released against Iraqi targets by coalition forces during the course of this campaign. GPS continues to play a crucial role in air, ground, or sea operations by helping ensure military personnel that they and their equipment are on time and accurately on target.

Rockwell International, Lockheed Martin, and Boeing serve as GPS's largest contractors. GPS power plant includes solar panels generating 800 watts and Block IIF panels generating 2,450 watts. The height and weight ranges of individual GPS systems are 2.4–3.4 meters and 1,705–2,217 kilograms.

Ground-Based Electro-Optical Deep Space Surveillance

Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) is carried out by AFSPACOM's Joint Space Operations Center Mountain (JPSOC-MTN) within Cheyenne Mountain AFS near Colorado Springs. GEODSS is responsible for tracking nearly 10,000 man-made objects in Earth orbit. These objects consist of active satellites and debris from rocket bodies or historical satellite breakups. More than 2,500 of these objects, including geostationary communication satellites, are in deep-space orbits ranging from 10,000–45,000 kilometers from the earth.

GEODSS missions are performed using a one-meter telescope equipped with highly sensitive digital camera technology called "Deep STARE." Each GEODSS detachment has three telescopes that can be used individually or collectively. Individual telescopes are able to view objects under conditions 10,000 times dimmer than the human eye can detect. Deep STARE can track multiple satellites in its viewing field, and the telescopes take rapid electronic snapshots that show up as tiny streaks on the monitoring recipient's console. Computers measure these streaks and use the data to calculate the current position of an orbiting satellite and this information is sent instantaneously to JPSOC-MTN. Beginning in 2004, Deep STARE began upgrading its capabilities so GEODSS can track objects as small as a basketball more than 20,000 miles from the earth.

Ground-Based Midcourse Defense

Ground-Based Midcourse Defense (GBMD) is part of the BMDS system of sensors, radars, and ground-based interceptors capable of shooting down ICBMs during their midcourse flight phase. GBMD hits the incoming missile by ramming the warhead at a speed of approximately 15,000 miles per hour to destroy it, which has proven successful in flight tests.

The three system components are sensors, ground-based interceptors, and fire control and communications. GBMD uses various sensors and radars to acquire information on missile launches and track, discriminate, and target incoming warheads. Such information is provided to the ground-based interceptor prior to launch and during flight to help find the missile and close in on it.

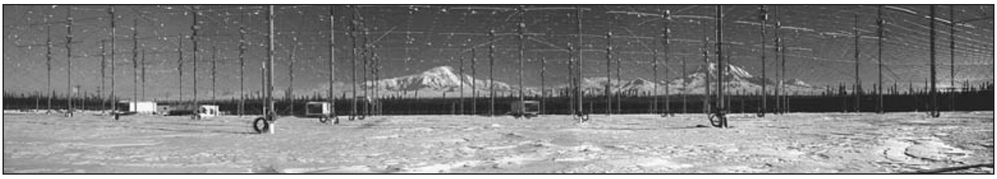
A ground-based interceptor consists of a three-stage solid fuel booster and exoatmospheric kill vehicle. Once launched, the booster missile carries the kill vehicle to the target's predicted location in space. Upon release from the booster, the 152-pound kill vehicle uses in-flight data received from ground-based radars and its own on-board sensors to close in and destroy the target using the force of impact.

Fire control and communications serves as GBMD's central nervous system connecting the hardware, software, and communications systems required for planning, tasking, and controlling GBMD.

Interceptor missiles are deployed at Fort Greely, Alaska, and Vandenberg, AFB, California with more deployments planned for 2006. Fire control centers have been established in Alaska and Colorado and a global system of existing early warning radars, including one at Shemya Island in Alaska's Aleutian Islands, has been upgraded to support flight tests and provide tracking information if a hostile missile attack occurs. A powerful mobile sea-based X-Band radar is nearly complete and expected to be fully incorporated into BMDS during 2006.

Ground Station Attacks

Ground station attacks are military attacks made from space or other venues on land-based satellite tracking stations by lasers, or assaults against these facilities by natural disasters or man-made weapons systems such as cruise missiles, ground attacks, bombs, artillery, and sabotage. The consequences of attacks on satellite ground stations would have severe military and civilian repercussions. It would not be possible for the military to get early warning information and track hostile missile launches, and the ability to get



High-Frequency Active Auroral Research Program array in Alaska. *(U.S. Department of Defense)*

accurate battlefield intelligence information and assessment would be severely compromised. The ability to do precision strikes would be restricted and increased collateral i.e., civilian, damage would likely occur, and mapping would have to revert to paper maps and compasses.

Civilian consequences of attacks or sabotage on satellite ground stations or their spaceborne infrastructure would include not being able to use pagers, cell phones, personal digital assistants, radio, or television. Land, sea, and aircraft using GPS for precise location and navigation information would not have the most current information, mapmakers could not update maps with current information, weather satellite information could not be updated, emergency responders could not respond as quickly to disasters, and many credit card transactions would no longer be possible since businesses could not verify personal credit quality.

High-Frequency Active Auroral Research Program

The High-Frequency Active Auroral Research Program (HAARP) is jointly managed by AFRL's Space Vehicles Directorate and the Navy's Office of Naval Research. HAARP is responsible for providing expanded new capabilities for conducting experimental research involving high-power radiowave interactions in the ionosphere and space and related military system applications.

Relevant programs involve assessing the possibility of exploiting emerging ionosphere-radio technology for next generation communications, radar, and navigation systems. HAARP radio and optical diagnostic instruments give real-time data on geophysical parameters characterizing the ionosphere and magnetosphere and include observations of the earth's magnetic field, electron densities, and radio wave absorption under normal conditions and solar-related disturbances. Facility diagnostic instruments ultimately provide a ground-based space weather station. Further information on HAARP can be found at www.haarp.alaska.edu.

High-Power Microwaves

Air Force high-power microwave research focusing on the weapons potential of this technology is centered in the High Power Microwave Division (HPMD) of AFRL/DED at Kirtland AFB, New Mexico. Research conducted here sees scientists exploring ways for generating high-power microwave energy and accurately delivering that energy to intended targets. Applications of this research include efforts assessing the effects of high-power microwaves on various targets and reviewing the feasibility of installing high-power microwave systems on various Air Force platforms.

While a typical household microwave oven generates less than 1,500 watts of power, AFRL's HPMD works with equipment generating millions of watts of power. Once microwaves encounter modern microelectronic systems, the microwave's heat and power can cause these systems to burn out or function incorrectly and such heavy reliance on electronic components in contemporary weaponry enhances the desirability of high-power microwave weapons.

High-power microwaves can be used in command and control warfare to suppress hostile air defenses, tactical aircraft, or unmanned aerial vehicles. HPMD research focuses on the following technology areas: source and antenna development, beam development, vulnerability efforts, high-power microwave modeling and simulation efforts, active denial technology, and the vehicle stopper program. Source and antenna research and development emphasizes narrow and wide-band high-powered microwaves capable of focusing ultrawide radiation into a conical beam with a single degree beam width.

Beam development initiatives seek to produce technology making it possible to steer microwave beams into an extremely narrow region. Division vulnerability efforts evaluate the effects of high-power microwaves on U.S. weapons and seek to protect these systems from microwave threats. High-power microwave modeling and simulation efforts seek to investigate the effectiveness of this technology in disabling targets. Active denial technology involves high-power microwaves that penetrate less than 1/64th of an inch into human skin to stimulate individual pain sensors enough to deter them from aggressive action. The vehicle stopper program works with the Justice Department to explore how radio frequency devices can stop vehicles without using lethal force and without injuring suspects or bystanders.

Innovative Space-Based Radar Antenna Technology (ISAT) Flight Demonstrator

The Innovative Space-Based Radar Antenna Technology (ISAT) Flight Demonstrator is a collaborative program between AFRL, DARPA, NASA's Langley Research Center and Jet Propulsion Laboratory, and private sector contractors Boeing, Raytheon, Lockheed Martin, and Harris Corporation. ISAT's anticipated launch date is 2010, and the program seeks to deploy a large system (up to 300 yards) of electronically scanning radar antennas flying 5,700 miles above the earth's surface and providing ground target detection for U.S. forces. It will weigh over five tons and serve as the forerunner of next generation U.S. intelligence, surveillance, and reconnaissance (ISR) space assets. These ISR capabilities will facilitate tracking and identifying targets with precise resolution and scanning in multiple areas of interest to warfighters.

Joint Surveillance Target Attack Radar (JSTAR)

Joint Surveillance Target Attack Radar (JSTAR) is an airborne battle management, command and control, and ISR platform housed on a Boeing EC-8 aircraft. JSTAR's mission is providing theater ground and air commanders with ground surveillance to support offensive operations and facilitate the delay, disruption, and destruction of enemy forces.

EC-8 radar and computer subsystems gather and display detailed battlefield ground force information, which is relayed in almost real time to Army and Marine Corps ground stations and other command, control, computers, communications, and intelligence (C4I) nodes. System antenna can be tilted on either side of the aircraft to develop a 120°-viewing field covering nearly 50,000 square kilometers and detecting targets at more than 250 kilometers.

JSTAR originated with Air Force and Army programs to develop, detect, locate, and attack enemy armor beyond the range of forward area troops. The first two JSTARs were deployed in Operation Desert Storm in 1991 with later deployments including supporting NATO troops over Bosnia-Herzegovina in 1996, Operation Enduring Freedom, and Operation Iraqi Freedom. Northrop Grumman serves as JSTARS's primary contractor. The aircraft has a flight ceiling of 12,802 meters, optimum orbit speed of 390–510 knots, can fly for nine hours without refueling, and has a flight crew of 4, plus 15 Air Force and 3 Army specialists, although the crew size varies depending on the mission.

Large Membrane Mirrors

Large membrane mirrors are another research focus of AFRL/DED. This program seeks to explore the use of new lightweight membrane materials in large optical quality telescope designs. The program seeks to develop a large aperture, high-resolution, space-deployable laser projection system capable of reducing optic payload weights by at least 50% and with comparable launch cost decreases. The principal applications of these mirrors will be on a space-based surveillance satellite or high-altitude imaging platform on aircraft such as dirigibles to enhance battlefield situational awareness for military commanders (U.S. Air Force Research Laboratory 2004(b), 1–2).

Laser Effects Test Facility

The Laser Effects Test Facility (LETF) is part of AFRL/DED and conducts experiments for the laboratory, DOD, the Energy Department, other government agencies, U.S. industry, and universities. LETF has a variety of laser capabilities including a 50,000-watt carbon dioxide electric discharge coaxial laser and other lasers covering the electromagnetic spectrum from ultraviolet to far infrared wavelengths.

Facility optic inventory capabilities permit tailoring laser beam spot size and irradiance to various configurations. Data acquisition systems can record more than 64 data channels per computer at rates exceeding 300 kilohertz per channel. These systems are augmented by cutting edge diagnostic equipment such as infrared cameras measuring spatial and temporal temperature distributions in interested targets.

LETF's Reflectance Laboratory analyzes physics laser-material interactions and makes it possible to acquire accurate coupling data during the laser's interaction with a target and resulting target surface property changes. This laboratory also can perform coupling measurements in a vacuum, which reduces target surface oxidation during laser interactions.

LG-118A Peacekeeper

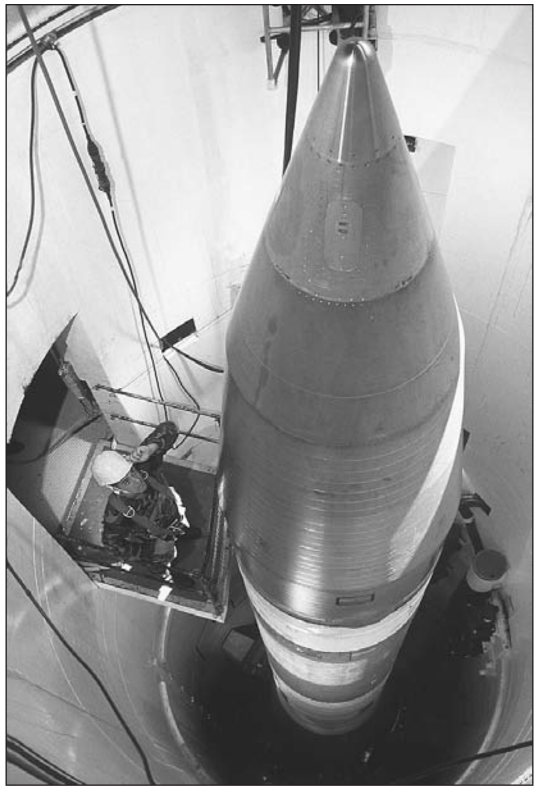
The LG-118A Peacekeeper ICBM served as one of the United States' key nuclear weapons systems from its December 1986 deployment until it was deactivated on September 19, 2005. The Peacekeeper's first successful test flight saw it travel 4,190 miles from Vandenberg AFB, California to drop six unarmed reentry vehicles at the Kwajalein Missile Test Range in the Pacific Ocean. The first Peacekeepers were deployed at Warren AFB, Wyoming in December 1986 and reached a full operational capability of 50 missiles in December 1988.

Missile capabilities included delivering 10 independently targeted warheads on a four-stage rocket system consisting of a boost system, post-boost vehicle system, and reentry system. The boost system contained four rocket stages launching the missile into space. Each of these stages were mounted atop one another and fired successively. The post-boost vehicle system consisted of a maneuvering rocket and a guidance and control system riding atop the boost system. The reentry system at the top of the missile included the deployment module, up to 10 cone-shaped reentry vehicles, and a shroud responsible for protecting the reentry vehicles during ascent. The shroud was topped with a nose cap containing a rocket motor separating it from the deployment module.

LGM-30G Minuteman III Missile

The LGM-30G Minuteman III Missile has served as the primary land-based ICBM of the U.S. nuclear missile arsenal since the early 1960s. (L is a DOD designation for a silo-launched missile, G refers to surface attack, and M refers to guided missile). The Minuteman arsenal was created in response to the weaknesses of slow reacting, liquid-fueled, remotely controlled ICBMs used previously. In contrast, the Minuteman is quick reacting, inertia guided, and a highly survivable part of the United States' nuclear weapons triad of land, air, and sea-based missiles.

These weapons are dispersed in hardened silos to protect against attack and connected to an underground launch control center through a hardened cable system. Two-member launch crews perform constant alert in the launch control systems, and various communication systems provide the U.S. National Command Authority with reliable and almost instantaneous contact with the launch crew. If command capability is lost between



Sgt. Stephen M. Kravitsky inspects an LGM-30G Minuteman III missile inside a silo about 60 miles from Grand Forks Air Force Base, North Dakota, 1989. *(U.S. Department of Defense)*

the launch control center and remote missile launch facilities, specially designed E-6B airborne launch control center aircraft automatically assume command and control of the isolated missile(s).

The current Minuteman force has 500 ICBMs located at Warren AFB, Wyoming; Malstrom AFB, Missouri; and Minot AFB, North Dakota. A life extension program focusing on replacing the aging guidance system, remanufacturing rocket propellant motors, replacing standby power systems, repairing launch facilities, and installing updated survivable communications and command and control capabilities is expected to maintain Minuteman reliability into the 21st century.

The Minuteman's range exceeds 6,000 miles, its flight ceiling is 1,120 kilometers, its top speed is 24,000 kilometer per hour, Boeing is the primary contractor, Thikol, Aerojet-General, and United Technologies Chemical Systems Division are rocket motor stage contractors, and Minuteman's prelaunch height is 18 meters.

MILSTAR Satellite Communications System

The MILSTAR Satellite Communications System serves as a joint-service satellite communications system providing secure, jam resistant, and global communications for meeting crucial wartime requirements for high priority military users. MILSTAR satellites link command authorities with various resources including ships, submarines, aircraft, and ground stations.

The five operational MILSTAR satellites are positioned in geosynchronous orbits, weigh approximately 4,536 kilograms, and have a projected 10-year life span. Individual MILSTAR satellites serve as a smart space switchboard directing traffic from terminal to terminal anywhere significantly reducing ground control switching requirements. MILSTAR establishes, maintains, reconfigures, and disassembles required communications circuits as needed by users. Satellite terminals provide encrypted voice, data, teletype, or fax communications while striving to provide interoperable communications among Air Force, Army, and Navy MILSTAR terminals.

The first MILSTAR launch was February 7, 1994 aboard a Titan IV EELV and the most recent launch was April 8, 2003. AFSPACOM's Space and Missile Systems Center at Los Angeles AFB, California is responsible for developing and acquiring MILSTAR space and mission control components. The Electronics Systems Center at Hanscom AFB, Massachusetts handles the Air Force portion of MILSTAR terminal segment development and acquisition. The 4th Space Operations Squadron at Schriever AFB, Colorado is responsible for providing real-time satellite platform control and communications payload management.

Lockheed Martin Missiles and Space serves as MILSTAR's primary contractor. Each satellite is powered by solar panels generating 8,000 watts, weighs about 4,536 kilograms, and costs $800 million each. MILSTAR payloads include low data rate communications delivery capabilities ranging from 75 bits per second to 2,400 bits per second and medium data rate communications ranging from 4.8 kilobits per second to 1,544 megabits per second.

Minotaur Space Launch Vehicle

The Minotaur space launch vehicle is produced for the Air Force's Space and Missile Center by Orbital Sciences Corporation. Minotaur seeks to provide low-cost and reliable solutions for launch services for government-sponsored payloads. System features include inertia-guided four-stage solid rocket propulsion, comprehensive payload support including power, telemetry, sequencing, deployment, attitude control and recovery, horizontal satellite integration to simplify launch operations, 18-month mission response including payload integration and launch by Orbital crews, and the ability to launch from sites in Alaska, California, Florida, and Virginia.

Near-Space Access Program: High-Altitude Balloons and Tethered Aerostats

The Near-Space Access Program uses high-altitude balloons and aerostats such as dirigibles to conduct research, development, testing, and evaluation for the Air Force, DOD, additional government agencies, universities, and industries. The Near-Space Access

Program is run by the High-Altitude Balloon and Tethered Aerostat Group in AFRL's Space Vehicles Directorate. High-altitude balloons and aerostats are useful instruments for space environment qualification; meteorological measuring; optical, infrared, ultraviolet, and radar surveillance; radio and laser communications; and target simulation.

These instruments provide low-cost, nonpolluting, vibration-free, and highly reliable platforms capable of delivering quick response times, long-duration flights, limitless configurations, nearly unlimited launch sites, and completely recoverable payloads. Balloons may be used for simulating low-earth orbit and geosynchronous satellites by utilizing repeatable stratospheric wind patterns.

North Oscura Peak

North Oscura Peak is an AFRL facility in the northern part of the Army's White Sands Missile Range, New Mexico. North Oscura is designed to assemble and evaluate advanced sensor, tracking, and atmospheric compensation systems. From the summit of this 8,000-foot-high peak, a 30-inch telescope is used to send and receive laser light to and from the Salinas Peak about 35 miles away. Instrumentation is then used to measure the degree to which the earth's atmosphere distorts this laser light. Mirrors capable of changing their shapes can be used to compensate for any distortions that may occur during the laser light transmission.

Research gained from this testing benefits the ABL. While the ABL is designed to operate at altitudes around 40,000 feet, North Oscura Peak tests occur between 8,000–9,000 feet. Denser air at these lower test elevations makes it possible to take acquired data and scale it to the higher altitudes and longer ranges envisioned for the ABL. Lasers used at North Oscura include a 30-watt tracking laser, a 30-watt adaptive optics beacon laser, and a 3-watt scoring laser.

Nuclear Weapons in Space

From a strictly scientific technical standpoint, the explosion of a nuclear weapon in space would result in the fallout being dispersed over the universe instead of on the earth. Since there is no air in space, electromagnetic waves would be freed with radioactive particles, and the intensity of this effect decreases the farther away one gets from the explosion (U.S. Department of Energy, Argonne National Laboratory, n.d., 1). During the early years of the space age, both the United States and Soviet Union showed some interest in the possibility of placing nuclear weapons in space. International political sentiment was strongly against this and resulted in both these countries signing the United Nations Treaty on Outer Space in 1967, which banned the positioning and use of nuclear weapons and other weapons of mass destruction in outer space. Although this treaty has been in existence for nearly four decades, its enforcement provisions are nonexistent, and it remains possible for a nation or terrorist organization to use EMP or other means to place mass destruction weapons in orbit.

Patriot Advanced Capability–3

The Patriot Advanced Capability–3 is an Army weapons program that is part of the U.S. BMDS system. Patriot is capable of countering ballistic missiles and airborne threats including aircraft, unmanned aerial vehicles, and cruise missiles. It provides short-range point defense for crucial civilian and military assets, defends deployed troops, and provides ongoing missile defense coverage for rapidly maneuvering forces.

Patriot is mounted on wheeled vehicles and includes launchers carrying several interceptors along with advanced radars providing 360° battlefield coverage. It directly hits targets to destroy them, is linked to BMDS's CCBMS infrastructure, and can be rapidly deployed to global hotspots.

The Army is responsible for producing and further development of Patriot and the Medium Extended Air Defense System, which is a cooperative venture between the United States, Germany, and Italy to develop a mobile and transportable air and missile defense system. The MDA maintains responsibility for ensuring Patriot's interoperability and integration into BMDS.

PAVE PAWS Radar System

The PAVE PAWS Radar System is an AFSPACOM radar system. PAVE is an Air Force program name while PAWS refers to "Phased Array Warning System." Three 21st Space

Mike Badman, a security policeman with the 6th Space Warning Squadron, Cape Cod Air Station, Massachusetts, patrols the perimeter of the PAVE PAWS facility in 1996. *(U.S. Department of Defense)*

Wing squadrons are responsible for operating this system's missile warning and space surveillance capabilities. PAVE PAWS radars are located at Cape Cod AFS, Massachusetts; Beale AFB, California; and Clear AFS, Alaska. PAVE PAWS is also responsible for earth-orbiting satellite detection and tracking and information concerning ballistic missile and satellite detection is forwarded from PAVE PAWS to U.S. Strategic Command's Missile Warning and Space Control Center at Cheyenne Mountain Air Station, Colorado, the National Military Command Center, and U.S. Strategic Command.

Mechanical radar must be physically aimed at a space object to track and observe it. PAVE PAWS uses phased array antenna technology, which is in a fixed position and part of an exterior building wall. Aiming this kind of radar is done by electronically controlling the timing/phase of incoming and outgoing signals. By controlling the signal phasing through the many segments of the antenna system it is possible to allow the beam to be quickly projected in different directions. This drastically reduces the time required to change beam direction from one point to another, which permits nearly simultaneous tracking of multiple targets without losing surveillance responsibility. The large fixed antenna array enhances system sensitivity and tracking accuracy through a better quality beam.

Overall operational activity is automated, only requiring human involvement for monitoring, maintenance, and final checking on warning validity before the information is transferred to Cheyenne Mountain.

Personnel Halting and Stimulation Response

Personnel Halting and Stimulation Response (PHASR) is a rifle-sized laser weapon system using two nonlethal laser wavelengths to deter, prevent, or limit an opponent's effectiveness. This is accomplished by a laser light illuminating hostile forces and temporarily limiting their ability to see the laser source. PHASR can be operated by a single individual and includes a self-contained power source. This weapon uses one visible wavelength diode-powered laser and one mid-infrared wavelength.

ScorpWorks, which is part of AFRL/DED, designed PHASR for military and law enforcement applications, and AFRL/DED's Human Effectiveness Directorate works to ensure its safe operation and study its biological effects.

RAD6000 Computer

This computer is used by AFRL's Space Vehicles Directorate, and it serves as the first radiation-hardened 32-bit microprocessor containing over one million transistors. The RAD600 is capable of withstanding the harsh space radiation environment and operating reliably over long-term missions focusing on controlling data stream telemetry between spacecraft and ground controllers.

Ongoing radiation bombardment produces unwanted electrical charges inside transistors and can reach the point where the transistor can no longer control electron flow.

This can cause overcharged transistors to shut down and the resulting electronics failures can terminate missions and cost millions of dollars. Both DOD and NASA used to pay \$50–\$100 million in development and manufacturing costs for each processor. RAD6000 processing module costs, in contrast, range from \$500,000–\$2 million and is available as off-the-shelf hardware.

Air Force and industry collaboration on this system has increased the lifespan of spacecraft electronic systems. More than 60 Air Force, DOD, NASA, and commercial space systems use this technology and over 90% of satellites launched today rely on these radiation-hardened processors.

Relay Mirror Technology

Relay Mirror Technology program research is conducted at AFRL/DED and seeks to use a dual-mirror instrument in air or space to transfer laser energy from one part of the earth to another. Low earth orbit relay-mirror satellites can be used to relay laser energy from one point to another providing global light speed capability to war fighters. This works by directing a laser beam at a “receive mirror,” which collects the beam, passes it to a beam control system that optically refines the beam, then refocuses and retransmits it to a second mirror transcending the limits of Earth’s curvature.

Program goals include identifying and developing crucial technologies required to produce a relay demonstration mirror in the near future. Relay mirror technology and technical synergy with other airborne or space-based directed energy systems are key program emphases instead of laser source development. Technologies that must be examined to achieve program objectives include space vehicle design, vibration and thermal management, attitude control, large-angle slewing and momentum control of a multibody system. The system must be able to precisely point, acquire, and track the laser source and targets, and large, lightweight, and potentially deployable mirrors must be developed along with optical coatings and techniques to control jitter and optical aberrations.

Satellite Countermeasures

Satellites may take a variety of actions to deter, defeat, or reduce the effects of hostile actions taken against them by hostile weapon systems. These include increasing the number of satellites in orbit (although this is more costly than other mitigating measures), redesigning satellites to reflect radar signals weakly or evade such signals, taking electronic countermeasures such as jamming or blinding hostile satellites, using nuclear weapons such as ICBMs and Submarine Launched Ballistic Missiles (SLBMs), developing non-nuclear interceptor spacecraft, space mines, developing ground-based directed energy or kinetic energy weapons to use, establishing and defending protected zones around specific satellites, and giving individual satellites self-defense capabilities.

Possible diplomatic satellite countermeasures include negotiating limitations on the hostile use of satellites and establishing restrictions on potentially provocative activities in space such as unexplained close approaches to foreign satellites and irradiating foreign satellites with direct energy beams.

Scintillation Network Decision Aid

The Scintillation Network Decision Aid (SCINDA) is a computer program developed by AFRL's Ionospheric Hazards Branch for AFSPACOM. SCINDA predicts communication satellite outages in the equatorial region caused by naturally occurring ionospheric disruptions. These disruptions can cause satellite signals to rapidly fluctuate or scintillate at or near the earth's surface. This development is most intense during the night within 20° of the earth's magnetic equator, which occupies over one-third of the earth's surface. Such scintillation affects radio signals and seriously disrupts communication and navigation satellites.

SCINDA has been developed to inform operational users when and where scintillation is likely to take place. Fourteen SCINDA sensors are installed in South America, southeast Asia, and southwest Asia. These sensors measure scintillation data from existing GPS and geostationary beacon satellite links and ionospheric drift speeds are measured and stored at remote sites. AFRL researchers retrieve this information via the Internet every 15 minutes, and this information is compiled to make simple bicolor maps of equatorial disturbances and related areas of likely communication outages. These maps provide scientists with enhanced understanding of how such scintillation structures develop and provide situational awareness to satellite communication operators.

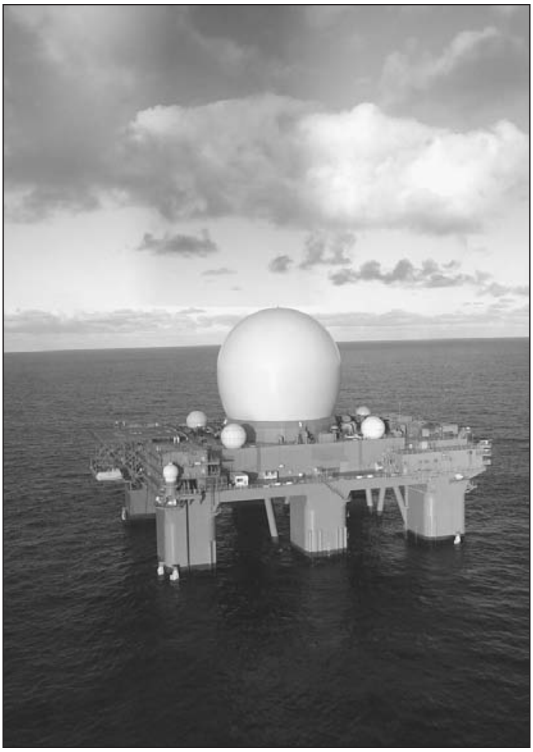
An additional four to six stations are planned during 2006–2007, and these will be concentrated primarily in Africa's equatorial regions where AFRL is participating in a United Nations Basic Space Science Initiative to deploy space weather sensors for the International Heliophysical Year.

Sea-Based X-Band Radar

Upon integration into the U.S. BMDS, Sea-Based X-Band radar will track, discriminate, and assess incoming target missiles and enhance the MDA's ability to conduct vigorous and operationally realistic tests of BMDS's GBMD.

Sea-Based X-Band radar includes advanced X-band radar with a mobile oceanic and semisubmersible platform giving BMDS a discrimination capability to cover anywhere in the world. It is located on a high-tech semisubmersible oil drilling platform, which is twin-hulled, self-propelled, and remains stable in high winds and unsettled sea conditions. The radar's ocean-spanning mobility allows it to be positioned as needed to provide radar coverage of possible threat launches from any location.

This system is 240 feet wide and 390 feet long, covers more than 289 feet from keel to the top of its radar dome, and displaces nearly 50,000 tons. It will be staffed by an approx-



Sea-Based X-Band radar is a U.S. system designed to track, discriminate, and assess characteristics of hostile ballistic missiles. *(Missile Defense Agency)*

imately 75-person crew who will live and work in an area housing living quarters, work areas, storage, power generation, a bridge, and control rooms while also providing requisite floor space and infrastructure for supporting the radar antenna array, command, control, and communication assets, and an In-Flight Interceptor Communication System Data Terminal.

System construction and assembly were completed in two Texas shipyards and sea-trials were conducted in the Gulf of Mexico. It will be based at Adak, Alaska upon deployment.

Solar Mass Ejection Imager

The Solar Mass Ejection Imager (SMEI) was produced to detect, track, and forecast the arrival at Earth of coronal mass ejections (CMEs), which are responsible for all severe space weather. Since the January 2003 launch of the Coriolis satellite, which carries SMEI, it is possible to track CMEs from sun to Earth orbit and beyond from an orbit 840 kilometers above the earth. SMEI provides scientists with enhanced understanding of CMEs and longer lead times to predict and understand their detrimental effects on spacecraft and ground systems.

SMEI was designed and constructed by scientists and engineers from AFRL, the University of California-San Diego, Boston College, Boston University, and the United

Kingdom's University of Birmingham with additional financial support provided by the Air Force and NASA. Imagery produced by SMEI is available on the National Solar Observatory Web site, www.nso.edu.

Space-Based Infrared Systems (SBIRS)

The SBIRS is one of AFSPACOM's highest priority space systems and is intended to provide the United States with critical missile defense and early warning capability for the 21st century. SBIRS includes three individual space constellations and an evolving ground component: the existing DSP, SBIRS High, and the Space Tracking and Surveillance System (STSS). The four mission areas supported by SBIRS include missile warning, missile defense, technical intelligence, and battle-space characterization.

DSP was described earlier in this chapter and has served the United States for over 30 years and for approximately the past decade has given military theater commanders missile-warning notification. This notification, initially, occurred through the Attack Launch and Early Reporting to Theater (ALERT) system before transitioning to SBIRS. The SBIRS Missile Control Station at Buckley AFB, Colorado became operational on December 18, 2001 and enhances national infrared space capability by consolidating command and control and data-processing elements from divergent legacy systems into a centralized and modern facility.

SBIRS High consists of four geosynchronous satellites, two highly elliptical orbit satellites, and associated ground hardware and software. It is expected to have greater sensor flexibility and sensitivity than DSP since it possesses scanning and staring sensors while DSP only has scanning sensors. This enhanced capability means SBIRS High is expected to take only 10–20 seconds to detect a missile launch, determine its course, and warn appropriate ground forces while DSP would take 40–50 seconds to accomplish these tasks.

STSS is a capabilities-based system managed by MDA, which will track tactical and strategic ballistic missiles. STSS sensors are designed to operate across long- and short-wave infrared and the visible light spectrum. These wavebands are intended to allow STSS sensors to acquire and track missiles during their boost and midcourse phases. Launch of the first satellite is expected in 2006.

Space-Based Radar

Space-Based Radar (SBR) is a defense acquisition program inaugurated in 2001 whose objective is deploying by 2008 space-borne ability for theater military commanders to track moving targets. SBR emphasizes maturing technology and developing an ISR system capable of offering Ground Moving Target Identification (GMTI), Synthetic Aperture Radar (SDR), and Digital Terrain and Elevation Data (DTED) covering large portions of the earth (land and sea) on an ongoing basis. An SBR system incorporates battlefield tasking and control to enhance near real-time SBR product availability to the theater. SBR gives military forces a deep look and nonintrusive access to currently inaccessible areas of interest without jeopardizing personnel or resources.

A constellation of SBR satellites is needed to satisfy these demanding operational requirements. These satellites must offer day/night, all-weather, near continuous, global GMTI search/track and high-resolution imagery, direct theater downlink of overhead GMTI and imagery collection, and precision DTED collection.

Space Countermeasures Hands On Program (Space CHOP)

Space Countermeasures Hands On Program (Space CHOP) is a DOD program designed to emulate terrorist and asymmetric threats to U.S. military and critical national infrastructure systems. The program occurs three to four times per year at Kirtland AFB, New Mexico and involves a select group of junior military officers and civilian federal employees using open source Internet databases and libraries to seek out potential weaknesses in current and future DOD space systems or other critical government agency systems.

The beginning of each of these sessions sees Space CHOP identify rules of engagement to participants, and client and events are coordinated, for precautionary reasons, with the customer's security organization and other relevant security entities. The stimulated terrorist team gives a status briefing for the customer halfway through the mission. Upon mission completion, the customer agency receives a formal and classified presentation and report including a listing of simulated terrorist team findings in open source resources.

Governmental and military entities providing consultation to CHOP include U.S. Strategic Command, the Air Force's Space Warfare Center and Space Battlelab, the Navy's Space and Warfare Systems Center, MDA, NASA, Naval Postgraduate School, the FBI, and U.S. Customs and Border Protection.

Space Mines

Space mines are microsatellites capable of having military and non-military uses. Military applications of space mines would allow a satellite with maneuver capability to approach a target satellite at varying ranges and explode to destroy or disable a satellite. Peaceful uses of these microsatellites include observation and communication. It is technologically easy to produce these weapons but using space mines to destroy or disable space assets such as satellites can create space debris along with having serious political, diplomatic, and international security repercussions.

Space Tracking and Surveillance System (STSS)

The STSS is a MDA program using space-based sensors that are part of BMDS for detecting visible and infrared light such as that produced by a ballistic missile.

STSS will initially consist of two research and development satellites that are scheduled to be launched into low earth orbit in 2007, and a ground segment will be developed to operate these satellites. System requirements include passing missile-tracking data to missile defense interceptors with requisite accuracy and timeliness so they can intercept incoming missile targets. Later program components include taking lessons learned from the initial deployment and testing in 2008 to make necessary STSS upgrades, fielding a constellation of operational STSS satellites for global missile tracking beginning in 2012, and achieving enhancements in satellite lifetime, producibility, and the ability to process and communicate missile tracking data to interceptors in 2012.

TacSat–2 Micro Satellite

The TacSat–2 Micro Satellite is produced by AFRL's Space Vehicles Directorate and is designed to demonstrate and meet TacSat–2 objectives including being able to test a ready-launch spacecraft within 15 months of receiving the authority to begin the project, launching within one week of being called from storage, performing on-orbit checkout within a day, conducting efficient operations and downlinking data directly to the required theater, and providing this theater with images containing tactically significant resolution.

This satellite is scheduled for 2006 launch into a sun-synchronous orbit of 350-kilometer altitude at a 97.3° circular inclination. Besides AFRL, participating organizations include DOD's Space Test Program, Naval Research Laboratory, Army Space Program Office, AFSPACOM, and NASA components including the Jet Propulsion Laboratory.

Artist's rendition of the TacSat-2 Micro Satellite. *(U.S. Air Force)*

Telescope and Atmospheric Compensation Laboratory

The Telescope and Atmospheric Compensation Laboratory (TACLAB) is part of the Starfire Optical Range at Kirtland AFB, New Mexico. This facility features optics, electronics, computer, and mechanical laboratory space emphasizing equipment design, construction, and testing before integrating with telescopes and other experimental hardware. The laboratory houses a series of optical mounts such as telescopes and beam directors capable of tracking low-earth orbit satellites, and these mounts possess large-scale, high-performance adaptive optical systems.

Additional system instrumentation includes smaller telescopes, beam directors, multiple laser systems, and assorted optic, electronic, and mechanical laboratories. TACLAB work specialties include technological experimentation in real-time atmospheric compensation, atmospheric turbulence physics, and target acquisition, pointing, and tracking.

Terrorism

Space may become a forum for terrorism just as terrorist activities occur in the ground, air, and sea. Possible examples of space terrorism could include destroying satellites and other space-based objects or creating obstacles that hinder their normal operations and seizing and using space-based objects to enhance communications among terrorists. Terrorists may use space-based assets to attack urban targets such as high-rise apartments and major transportation and economic hubs including drinking water infrastructures, postal delivery, computer networks, research centers located near large urban areas, chemical facilities, nuclear reactors, and petroleum storage facilities.

Providing security for these facilities against such scenarios must become part of the homeland security, critical infrastructure planning, and antiterrorism responsibilities policymakers engage in during the years to come.

Theater or Terminal High-Altitude Area Defense (THAAD)

Theater or Terminal High-Altitude Area Defense (THAAD) is the BMDS component responsible for providing a rapidly transportable and forward deployable capability of intercepting and destroying ballistic missiles inside or outside of the atmosphere when they are in the final or terminal phase of their flight.

THAAD system characteristics include truck-mounted launchers, interceptors containing eight interceptors per launcher, x-band radars, and fire control and communication units. The launchers are highly mobile and capable of storing, transportation, and firing interceptors and reloading rapidly. The interceptor is designed to intercept targets in and out of the atmosphere using hit-to-kill lethality. The x-band radar is the world's largest mobile band and provides searching, tracking, discrimination, and fire control updates to the interceptor. The fire control and communications units serve as a data management backbone linking THAAD components together and to external BMDS units. The entire system can be transported by land, sea, and air and be airlifted anywhere within hours.

During 2006, the MDA hopes to build, test, and verify THAAD's initial capability, conduct four tests at White Sands Missile Range, New Mexico by the end of 2006, continue system planning and conducting soldier training, and continue planning for transitioning system operations to the Army.

310th Space Group

The 310th Space Group is the Air Force Reserve's sole space organization and is located at Schriever AFB, Colorado, where it was activated on September 4, 1997 and reports to the 10th Air Force. The mission of the 310th is providing command and control for DOD and Commerce Department satellites, supporting the Air Operations Center and the Commander, Space Air Forces (COMSPACEAF), supporting space asset testing and evaluation, and providing security for terrestrial based 14th Air Force assets. Additional 310th responsibilities include supporting GPS, DSP, and DMSP operations.

Organizational components of the 310th include the 6th Space Operations Squadron at Schriever responsible for operating DMSP satellites, the 7th Space Operations Squadron at Schriever responsible for supporting GPS and DSP satellites, the 8th Space Warning Squadron at Buckley AFB whose responsibilities include SBIRS, and the 9th Space Operations Squadron at Vandenberg AFB, which gives COMSPACEAF the ability to command and control space forces by providing force status, intelligence data, and battle space awareness.

Additional 310th components include the 14th Test Squadron at Schriever, which supports the Space Warfare Center by testing and evaluating space assets, Schiever's 19th Space Operations Squadron, which supports GPS launch, modernization, and operation, Schriever's 26th Space Aggressor Squadron, which is responsible for supporting adversary space capability simulations and conducting exercises, training, and testing to increase US space force quality, the 310th Security Forces Squadron at Schriever, which is responsible for providing AFSPACOM ground asset security, and the 310th Communications Flight at Peterson AFB, which enhances AFSPC's Network Operations and Security Center by providing command, control, and situational awareness for AFSPC communications system and assets.

Titan IVB

The Titan IVB is a space booster used by the Air Force and launched from Vandenberg AFB, California and Cape Canaveral, Florida. It consists of a liquid-fueled core and two large solid rocket boosters, and the liquid core ignites approximately two minutes after launch.

A seven-year journey to the ringed planet Saturn begins with the liftoff of a Titan IVB/Centaur carrying the Cassini orbiter and its attached Huygens probe, October 15, 1997. *(NASA)*

System origins date back to October 1955 when the Air Force awarded the Glenn L. Martin Company (now Lockheed Martin) a contract to build an ICBM, which became known as the Titan I becoming the United States' first two-stage ICBM. Additional system upgrades occurred over ensuing decades and the Titan IVB first flew on February 23, 1997 with an upgraded rocket possessing a new guidance system, flight termination system, ground checkout system, solid rocket motor upgrade, and 25% thrust capability increase.

Titan IVB has a height of just over 62 meters, its motors provide 1.7 pounds of thrust per motor at liftoff, it can carry up to 21,682 kilograms into low-earth orbit, 5,761 kilograms into geosynchronous orbit when launched from Cape Canaveral, and up to 17,599 kilograms into low-earth polar orbit when launched from Vandenberg. The Titan IVB can also carry up to 2,381 kilograms into geosynchronous orbit if it uses an inertial upper stage.

Wideband Gapfiller Satellites

Wideband Gapfiller Satellites (WGS) were scheduled to be first launched between October 1, 2005–September 30, 2006 though the first launch did not occur until October 10, 2007. WGS is responsible for providing flexible and high-capacity military communications and drastically increased communications bandwidth available to U.S. forces.

This capability will be compatible with terrestrial portions of the Defense Information Systems Network while also being compatible with existing and programmed x and Ka-band terminals. WGS will eventually consist of five satellites in geosynchronous orbit. Boeing Satellite Systems serves as the primary contractor and each of these satellites has an approximate cost of $300 million.

XSS-10 Microsatellite

The XSS-10 Microsatellite is an AFRL experimental microsatellite first launched on January 29, 2003 from Cape Canaveral. It weighs about 65 pounds and is the first in a series of future microsatellites the Air Force wants to use for inspection, rendezvous, docking, and up-close maneuvering around space objects. Key XSS technologies include a lightweight propulsion system, guidance, navigation, and control capability, a miniaturized communications system, using primary lithium polymer batteries, and an integrated camera and star sensor.

XSS-11 Microsatellite

The XSS-11 Microsatellite is also produced by AFRL and was launched for the first time on April 11, 2005. It weighs approximately 100 kilograms and program goals include giving the XSS-11 military applications such as space servicing, diagnostics, maintenance, space support, and performing efficient space operations. The XSS-11 is expected to increase AFSPACOM's future missions by reducing the size and complexity of future space ground stations.

YAL-1A Attack Laser

The YAL-1A Attack Laser is the world's first laser-armed combat aircraft, and it is a conversion of a Boeing 747–400F aircraft. This project, involving the MDA, the Air Force, Boeing, Lockheed, and TRW, has been under development since 1992, and its goal is creating a laser to destroy hostile ballistic missiles during their vulnerable boost phase. Unique YAL-1A features include infrared heat detectors first used on the Navy's F-14 Tomcat jet fighter; a turbopump, capable of filling a household swimming pool in ten minutes, circulating laser fuel through a megawatt class laser; two solid-state kilowatt class lasers; the COIL liquid and gas-fueled high-energy laser; and a beam-steering configuration incorporating adaptive optics science. YAL-1A marks the first time these systems are installed and used as an integrated weapons system, and system testing occurred at Edwards AFB, California during 2004 and 2005.

References and Further Reading

Beason, D. 2005. *The E-Bomb: How America's New Directed Energy Weapons Will Change the Way Future Wars Will Be Fought.* Cambridge, MA: Da Capo Press.

Bingham, T. P. 2004. "Ground Radar Surveillance and Targeting." *Joint Force Quarterly* 35 (October): 88–94.

Boeing Corporation. 2007. "Boeing Advanced Military Satellite Begins On-Orbit Checkout." [Online article or information; retrieved 10/25/07.] www.boeing.com/news/releases/2007/q4/071011a_nr.html.

Bolkcom, C. and S. A. Hildreth. 2005. *Airborne Laser (ABL): Issues for Congress.* Washington, D.C.: Library of Congress, Congressional Research Service.

Bouchard, J. F. 1999. "Guarding the Cold War Ramparts: The U.S. Navy's Role in Continental Air Defense." *Naval War College Review* 52 (3): 111–135.

Brearley, A. 2005. "Faster Than A Speeding Bullet." *Astropolitics* 3 (1): 1–34.

Cady, S. E. 1982. "Beam Weapons in Space." *Air University Review* 33 (4): 33–39.

Covault, C. 2003. "USAF Technology Satellite Plays Tag With GPS Delta." *Aviation Week and Space Technology* 158 (5): 39.

David, L. 2006. *Beam Weapons Almost Ready for Battle,* MSNBC, January 11, 2006. [Online article or information; retrieved 8/1/06.] www.msnbc.msn.com/id/10805240/.

Dunn, D. H. 1997. *The Politics of Threat: Minuteman Vulnerability in American National Security Policy.* New York: St. Martin's.

Engel, J. A. 2003. *The Missile Plains: Frontline of America's Cold War: Historic Resource Study, Minuteman Missile National Historic Site, South Dakota.* Omaha: National Park Service.

Evans, D.L. ed. 1995. *Spaceborne Synthetic Aperture Radar: Current Status and Future Directions.* Washington, D.C.: NASA Scientific and Technical Information Office.

Fabey, M. 2006. "Spy Sats Seek Relevance in War on Terror." *Defense News* 21 (14): 1.

Ferguson, J. 2002. "NATO, Europe, and Theater Missile Defense." *Canadian Military Journal* 3 (1): 45–52.

Fernandez, A. J. 2004. *Military Role in Space Control: A Primer,* 9, 13. Washington, D.C.: Library of Congress, Congressional Research Service.

"Frontlines." 2005. *Air Force Times,* 66 (4) 6–7.

Globalsecurity.org, *Anti-Satellite Weapons-Overview,* (1993?): 1–9; [Online article or information; retrieved 7/27/06.] www.globalsecurity.org/space/systems/asat-overview.htm.

Goodman, Jr., G. W. 2000. "Layered Protection: New US Theater Missile Defense Systems Will Be a Far Cry From the Patriots of the Gulf War." *Armed Forces Journal International* 138 (4): 44–49.

Gray, C. 1993. "Space Power Survivability." *Airpower Journal* 7 (4): 27–42.

Gregorian, R. 1993. "Global Positioning Systems: A Military Revolution for the Third World?" *SAIS Review* 13 (1): 133–148.

Lacomme, P., Hardange, J.P., Marchais, J.C., and Normant, E. 2001. *Air and Spaceborne Radar Systems: An Introduction.* Norwich, NY: William Andrew Publishing.

Lambakis, S. 2001. "Space Weapons: Refuting the Critics." *Policy Review* 105 (February-March): 41–51.

Lawes, I. 2006. "Land Force Air and Missile Defence: Dealing With the Complexities of Future Warfighting." *Australian Army Journal,* 3 (2): 109–122.

McKenna, T. 2005. "Lost in Space: Could Space-Based Weapons Help Protect Military Satellite Capability?" *Journal of Electronic Defense* 28 (1) 40–48.

Moltz, J. C., ed. 2003. *New Challenges in Missile Proliferation, Missile Defense, and Space.* Monterey, CA: Center for Nonproliferation Studies.

Neufeld, J. 1990. *The Development of Ballistic Missiles in the United States Air Force, 1945–1960.* Washington, D.C.: Office of Air Force History, United States Air Force.

Neufeld, M. J. 2006. "'Space Superiority': Werner von Braun's Campaign for a Nuclear-Armed Space Station, 1946–1956." *Space Policy* 22(1): 52–62.

Orbital Sciences Corporation. 2006. *Fact Sheet: FORMOSAT-3/COSMIC: Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC),* 2; [Online article or information; retrieved 10/25/07.] www.orbital.com/NewsInfo/Publications/FORMOSAT-3_Fact.pdf.

Reiss, Major R. J., Jr. 2005. "Space Games: Scripted Exercises Fail to Address Threats to U.S. Satellite Capabilities." *Armed Forces Journal* 142 (12): 28–30.

Richelson, J. T. 1999. *America's Space Sentinels: DSP Satellites and National Security.* Lawrence, KS: University Press of Kansas.

Rip, M. R. and J. M. Hasik. 2002. *The Precision Revolution: GPS and the Future of Aerial Warfare.* Annapolis, MD: Naval Institute Press.

Roberd, R. M. 1984. "Introducing the Particle-Beam Weapon." *Air University Review* 35 (5): 74–84.

Rogers, M. E. 1997. *Lasers in Space: Technological Options for Enhancing U.S. Military Capabilities.* Maxwell Air Force Base, AL: Air War College, Center for Strategy and Technology.

Singer, J. 2003. "U.S. Seeks to Target Satellites From Ground." *Defense News* 18 (29): 38.

Smith, M. S. 2005. *U.S. Space Programs: Civilian, Military, and Commercial,* 9, 13–14. Washington, D.C.: Library of Congress, Congressional Research Service.

Smith, M. S. 2006. *Military Space Programs: Issues Concerning DOD's SBIRS and STSS Programs,* 3–4. Washington, D.C.: Library of Congress, Congressional Research Service.

Spires, D. N. and R. W. Sturdevant. 1997. "From Advent to Milstar: The U.S. Air Force and the Challenges of Military Satellite Communications." In *Beyond the Ionosphere: Fifty Years of Satellite Communication,* edited by A. J. Butrica, 65–78. Washington, D.C.: NASA.

U.S. Air Force. 2003. *The Airborne Laser: Frequently Asked Questions,* 1–6. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-23.pdf.

U.S. Air Force. 2005(b). *Fact Sheet: Defense Meteorological Satellite Program,* 1–2. [Online article or information; retrieved 8/2/06.] www.af.mil/factsheets/factsheet_print.asp?fsID=94&page=1.

U.S. Air Force. 2005(c). *Fact Sheet: Defense Satellite Communications System,* 1.[Online article or information; retrieved 8/2/06.] www.af.mil/factsheets/factsheet_print.asp?fsID=95 &page=1.

U.S. Air Force. 2005(d). *Delta II Launch Vehicle,* 1–2. [Online article or information; retrieved 8/3/06.] www.af.mil/factsheets/factsheet.asp?fsID=97.

U.S. Air Force. 2005(e). *Global Positioning System,* 1. [Online article or information; retrieved 8/8/06.] www.af.mil/factsheets/factsheet_print.asp?fsID=119&page=1.

U.S. Air Force. 2005(f). *Fact Sheet: E-8C Joint Stars,* 1–2. [Online article or information; retrieved 4/24/00.] www.af.mil/factsheets/factsheet_print.asp?fsID=100&page=1.

U.S. Air Force. 2005(g). *Milstar Satellite Communications System,* 1–2. [Online article or information; retrieved 8/21/06.] www.af.mil/factsheets/factsheet_print.asp?fsID=118&page=1.

U.S. Air Force. 2006. *Defense Support Program Satellites,* 1–2. [Online article or information; retrieved 8/24/06.] www.af.mil/factsheets/factsheet.asp?id=96.

U.S. Air Force. Operations Analysis Office. 1962. *100 MT Weapons in an Orbital Bombardment System.* Washington, D.C.: Headquarters, United States Air Force, Operations Analysis Office.

U.S. Air Force Research Laboratory. 1999. *New Space Propulsion System Launched.* [Online article or information; retrieved 10/25/07.] www.pr.afrl.af.mil/press/articles/esex991a.htm.

U.S. Air Force Research Laboratory. 2002(a). *Advanced Electro-Optical System,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-030.pdf.

U.S. Air Force Research Laboratory. 2002(b). *Chemical Oxygen-Iodine Laser (COIL).* 1–2. [Online article or information; retrieved 10/25/07.] www.de.afrl.af.mil/Factsheets/COIL.pdfkirtland.af.mil/shared/media/document/AFD-070404-034.pdf.

U.S. Air Force Research Laboratory. 2002(c). *High power Microwave,* 1–3. [Online article or information; retrieved 8/18/06.] www.de.afrl.Factsheets/HPM.pdf.

U.S. Air Force Research Laboratory. 2002(d). *Laser Effects Test Facility.* [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-037.pdf.

U.S. Air Force Research Laboratory. 2002(e). *North Oscura Peak,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-041.pdf.

U.S. Air Force Research Laboratory. 2003. *Telescope & Atmospheric Compensation Laboratory (TACLab),* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-046.pdf.

U.S. Air Force Research Laboratory. 2004(a). *Directed Energy Directorate,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-035.pdf.

U.S. Air Force Research Laboratory. 2004(b). *Large Membrane Mirrors,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-038.pdf.

U.S. Air Force Research Laboratory. 2005(a). *Active Denial System: Advanced Concept Technology Demonstration,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-026.pdf..

U.S. Air Force Research Laboratory. 2005(b). *Aerospace Engineering Facility,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-093.pdf..

U.S. Air Force Research Laboratory. 2006(a). *Personnel Halting and Stimulation Response (PHaSR),* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-043.pdf.

U.S. Air Force Research Laboratory. 2006(b). *Relay Mirror Technology,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-044.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2003. *Near-Space Access Program: High-Altitude Balloons and Tethered Aerostats,* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/library/factsheets/factsheet.asp?id=7890.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(a). *Demonstration and Science Experiments (DSX) Satellite,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-096.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(b). *High Frequency Active Auroral Research Program,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-097.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(c). *AFRL's RAD6000 Computer,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-100.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(d). *Solar Mass Ejection Imager: New Tool for Space Weather!.* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-102.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(e). *XSS-10 Micro Satellite,* 1. [Online article or information; retrieved 10/2507.] www.kirtland.af.mil/shared/media/document/AFD-070404-107.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2005(f). *XSS-11 Micro Satellite,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-108.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(a). *The Communications/Navigation Outage Forecasting System (C/NOFS),* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-094.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(b). *Cryocoolers: Cool Infrared Sensors to Enable Space Intelligence, Surveillance, Reconnaissance and Situational Awareness,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-095.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(c), *Innovative Space-Based Radar Antenna Technology (ISAT) Flight Demonstrator,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-098.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(d). *Scintillation Network Decision Aid (SCINDA),* 1–2. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-101.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(e). *The Space Countermeasures Hands On Program (Space CHOP),* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-103.pdf.

U.S. Air Force Research Laboratory. Space Vehicles Directorate. 2006(f). *TacsSat–2 Micro Satellite,* 1. [Online article or information; retrieved 10/25/07.] www.kirtland.af.mil/shared/media/document/AFD-070404-105.pdf.

U.S. Air Force Space and Missile System Command. 2001. *Space-Based Radar (SBR),* 1. [Online article or information; retrieved 10/25/07.] www.losangeles.af.mil/library/factsheets/factsheet.asp?ID=5308.

U.S. Air Force Space and Missile Command. 2004. *Factsheet: Advanced Extremely High Frequency System,* 1–3. [Online article or information; retrieved 10/25/07.] www.losangeles.af.mil/library/factsheets/factsheet.asp?id=5319.

U.S. Air Force Space Command. 2003. *Early Warning Radar Service Life Extension Program,* 1. [Online article or information; retrieved 10/25/07.] www.afspc.af.mil/news/story_print.asp?id=123071186.

U.S. Air Force Space Command. 2004(a). *LGM-30G Minuteman III,* 1–2. [Online article or information; retrieved 10/25/07.] www.afspc.af.mil/libary/factsheets/factsheet.asp?id=3655.

U.S. Air Force Space Command. 2004(b). *310*th *Space Group,* 1–2. [Online article or information; retrieved 10/25/07.] www.afspc.af.mil/library/factsheets/factsheet.asp?id=3644.

U.S. Air Force Space Command. 2005(a). *Evolved Expendable Launch Vehicle,* 1. [Online article or information; retrieved 8/8/06.] www.afspc.af.mil/library/factsheets/factsheet_print.asp?fsID=3643&page=1.

U.S. Air Force Space Command. 2005(b). *LG-118A Peacekeeper,* 1–2. [Online article or information; retrieved 10/25/07.] http://space.au.af.mil/factsheets/peacekeeper.htm.

U.S. Air Force Space Command. 2006. *Ground-Based Electro-Optical Deep Space Surveillance,* 1. [Online article or information; retrieved 10/25/07.] www.af.mil/factsheets/factsheet.asp?ID=170.

U.S. Air Force Space Command. n.d.(a). *Pave Paws Radar System,* 1–2. [Online article or information; retrieved 8/22/06.] www.afspc.af.mil/library/factsheets/factsheet.asp?id=3656.

U.S. Air Force Space Command. n.d.(b). *Space Based Infrared Systems (SBIRS),* 1–2. [Online article or information; retrieved 8/24/06.] www.afspc.af.mil/library/factsheets/factsheet.asp?id=3675.

U.S. Air Force Space Command. n.d.(c). *Wideband Global Satcom Satellite (WGS),* 1–2. [Online article or information; retrieved 10/25/07.] www.afspc.af.mil/library/factsheets/factsheet.asp?id=5582.

U.S. Army. Space and Missile Defense Command. 1998. *SMDC History-New Frontiers,* 1, 4. [Online article or information; retrieved 7/28/06.] www.smdc.army.mil/Historical/SMDCTimeline3_NewFrontiers.doc.

U.S. Army. Space and Missile Defense Command. 2002. "A Day Without Space: Ensuring It Doesn't Happen." [Online article or information; retrieved 8/17/06.] www.smdc-armyforces.army.mil/SpaceJournal/Article.asp?AID=15.

U.S. Army. Space and Missile Defense Command. n.d. *SMDC History: A Non-Nuclear Approach,* 2. [Online article or information; retrieved 7/28/06.] www.smdc.army.mil/Historical/SMDCTimeline2_ANon-NuclearApproach.doc.

U.S. Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack. 2004. *Volume I: Executive Report,* 1: 11–13, 15, 28. 32, 40, 44, 46–48.

U.S. Congress. House Committee on Government Operations. Subcommittee on Legislation and National Security. 1993. *Performance of the Patriot Missile in the Gulf War.* Washington, D.C.: U.S. Government Printing Office.

U.S. Congress. House Committee on Science and Technology. Subcommittee on Science, Space, and Technology. 1994. *The Global Positioning System: What Can't It Do?* Washington, D.C.: U.S. Government Printing Office.

U.S. Congress. Office of Technology Assessment. 1984. *Directed Energy Missile Defense in Space.* Washington, D.C.: U.S. Government Printing Office.

U.S. Congress. Office of Technology Assessment. 1985. *Anti-Satellite Weapons, Countermeasures, and Arms Control.* Washington, D.C.: U.S. Government Printing Office.

U.S. Congress, Senate Committee on Commerce, Science, and Transportation. 1994. *Weather Satellite Convergence.* Washington, D.C.: U.S. Government Printing Office.

U.S. Congressional Budget Office. 2004. *Alternatives for Boost-Phase Missile Defense.* Washington, D.C.: U.S. Congressional Budget Office.

U.S. Defense Science Board. 2003. *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs,* 30–31. Washington, D.C.: U.S. Defense Science Board.

U.S. Department of Commerce. National Telecommunications Information Administration. 1996. *A Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Services.* Boulder, CO and Washington, D.C.: National Telecommunications and Information Administration and U.S. Department of Transportation.

U.S. Department of Energy. Argonne National Laboratory. n.d. *Nuclear Weapons in Space.* [Online article or information; retrieved 8/22/06.] www.newton.dep.anl.gov/askasci/gen01/gen01086.htm.

U.S. Department of State. Bureau of Arms Control. n.d. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies,* 1–2; [Online article or information; retrieved 8/22/06.] www.state.gov/t/ac/trt/5181.htm.

U.S. Government Accountability Office. 2004. *Defense Acquisitions: Space-Based Radar Needs Additional Knowledge Before Starting Development.* Washington, D.C.: U.S. Government Accountability Office.

U.S. Missile Defense Agency. 2006(a). *Fact Sheet: Aegis Ballistic Missile Defense,* 1. [Online article or information; retrieved 7/27/06.] www.mda.mil/mdalink/pdf/aegis.pdf.

U.S. Missile Defense Agency. 2006(b). *The Ballistic Missile Defense System,* 1. [Online article or information; retrieved 8/1/06.] www.mda.mil/mdalink/pdf/bmds.pdf.

U.S. Missile Defense Agency. 2006(c). *Ballistic Missile Defense System Interceptors,* 1. [Online article or information; retrieved 8/1/06.] www.mda.mil/mdalink/pdf/bmdint.pdf.

U.S. Missile Defense Agency. 2006(d). *Command, Control, Battle Management, and Communications,* 1. [Online article or information; retrieved 8/2/06.] www.mda.mil/mdalink/pdf/c2bmc.pdf.

U.S. Missile Defense Agency. 2006(e). *Forward Deployable Radars,* 1. [Online article or information; retrieved 8/8/06.] www.mda.mil/mdalink/pdf/fdr.pdf.

U.S. Missile Defense Agency. 2006(f). *Ground-Based Midcourse Defense,* 1. [Online article or information; retrieved 8/17/06.] www.mda.mil/mdalink/pdf/gmd06.pdf.

U.S. Missile Defense Agency. 2006(g). *PATRIOT Advanced Capability–3,* 1. [Online article or information; retrieved 8/22/06.] www.mda.mil/mdalink/pdf/pac3meads.pdf.

U.S. Missile Defense Agency. 2006(h). *Sea-Based X-Band Radar,* 1. [Online article or information; retrieved 8/24/06.] www.mda.mil/mdalink/pdf/sbx.pdf.

U.S. Missile Defense Agency. 2006(i). *Space Tracking and Surveillance System,* 1. [Online article or information; retrieved 8/25/06.] www.mda.mil/mdalink/pdf/stss06.pdf.

U.S. Missile Defense Agency. 2006(j). *Terminal High Altitude Area Defense,* 1. [Online article or information; retrieved 8/28/06.] www.mda.mil/mdalink/pdf/thaad.pdf.

U.S. National Research Council. 2004. *Terrorism: Reducing Vulnerabilities and Improving Responses: U.S.-Russian Workshop Proceedings,* 6–7. Washington, D.C.: The National Academies Press. [Online article or information; retrieved 8/28/06.] www.nap.edu/openbook/0309089719/html.