10. Space Control

Area Description

Space control is defined as:

> Combat and combat support operations to ensure freedom of action in space for the United States and its allies and, when directed, deny an adversary freedom of action in space. *

Space control itself is dependent on assured access, consisting of space launch and satellite operations and now considered part of the space support mission area by the operational community. Space support provides communication to, through and from space.

Space control includes a mix of defensive and offensive measures to achieve its objectives. Capabilities required to accomplish the mission fall within key interrelated tasks of surveillance, protection, prevention, and negation.

Space control requires a systematic approach:

- Initially, our ability to sustain the capabilities considered essential to support single-Service, joint and combined operations across the spectrum of conflict depends on our ability to protect existing ground and on-orbit space assets and their associated data links.
- Second, enhanced protection for future space systems is fundamental to ensure that continuity of space products and services to friendly forces is maintained and improved.
- Third, these assets must be capable of surveying their own space environment, both for self-protection against natural and man-made threats and to determine if they are under attack.
- Should hostile use of friendly systems' products or services be attempted, or an attack be mounted against them, the next step would be to defend against such exploitation or assault.
- Finally, the ability to negate hostile activity may be necessary. Clearly these space control tasks will depend on national policy decisions; meanwhile, their enabling technologies must be defined and pursued to assure timely acquisition of required capabilities;

The space control mission/technology area requires a phased approach to achieve its goals, to include:

- Interim improvements to surface-based and airborne assets while the long-term migration of the space surveillance mission to space-based assets takes place. This migration would involve both collateral use of systems primarily supporting other missions (such as the Space-Based Infrared System [SBIRS]) and, eventually, more dedicated systems to assure options for control of the ultimate "high ground" of space.
- Determination of the best operational role for optical space surveillance assets.
- Active imaging technology programs and their testbeds to investigate the full range of target performance and scalability issues that will follow initial test results.
- An evaluation and selection process for system options for defensive and potential offensive operations, followed by a process to transition technology development activities to system acquisition programs.

Ground Stations

* Department of Defense Directive 3100.10, July 1999.

Mission Area Objectives

Space Surveillance	Protection	Prevention	Negation
• Precise detection, tracking and identification of space objects of interest • Ability to characterize objects as threats or non-threats • Detection and assessment when a threat payload performs a maneuver or separates	• Detection and reporting of space system malfunctions • Characterization of an attack and location of its source • Withstanding and defense against threats or attacks • Restoration of mission capability	• Prevent adversarial use of U.S., allied or third-party capabilities	• Precision negation of adversarial use of space • Strike assessment or BDA against target sets

Supporting Capabilities

Ground- and space-based high-resolution imaging

RF and optical space-based sensor systems

Fusion and registration of data from heterogeneous sensors

Netted, encrypted laser communication links   Automatic cross-cueing

On-orbit maneuvering, servicing, and maintenance
On orbit diagnostics, processing, and mission management

On-board detection of space environment hazards
Advanced laser detection and protection systems

Fusion and dissemination of hazard- and threat-related information

Space-based detection and location of surface and airborne RF jamming

Capabilities to neutralize threats
Techniques for interference or "soft kill"
Home-on-jam (HOJ) weapons
Ground- and space-based high-power lasers

Current Technology Initiatives *(Highlights of Current FYDP)*

Current projects address space surveillance, protection, prevention and negation tasks. As a basis:

- An optics-upgraded Maui Space Surveillance Site (MSSS) telescope will produce high-resolution images for the Space Surveillance Network (SSN) in FY01. Further upgrades will include post-processing algorithms to improve image quality, additional sensors to provide multi-wavelength capabilities, and potentially a laser guidestar capability to improve performance against dim targets
- Also in FY01, the Intelligence Data Analysis for Satellite Systems (IDASS) workstation will provide improved processing and analysis of optical imagery to identify space objects and assess mission payloads
- Integration of a ladar to the MSSS telescope will provide a 30-db signal-to-noise gain for space object engagements, followed by evaluation for range-Doppler imaging and space debris tracking applications. The system may also be used as a contributing sensor to the SSN
- The Geo Light Imaging National Testbed (GLINT) program will demonstrate a satellite active imaging capability out to geosynchronous altitudes

Protection/prevention capabilities will be sought via:

- Satellite threat warning/attack reporting technology development and space-based demonstrations for both the Miniature Satellite Threat Reporting System (MSTRS) and the Advanced Laser Sensor Development (ALSD). Further development of protection technologies will emphasize laser/electro-optic protection materials, with a space demonstration planned for the FY04-05 time period

We will continue additional defensive and offensive concept analysis and advanced technology development to support a Space-Based Laser (SBL) for the FY12-13 time frame both to perform space surveillance and to neutralize ballistic missile targets.

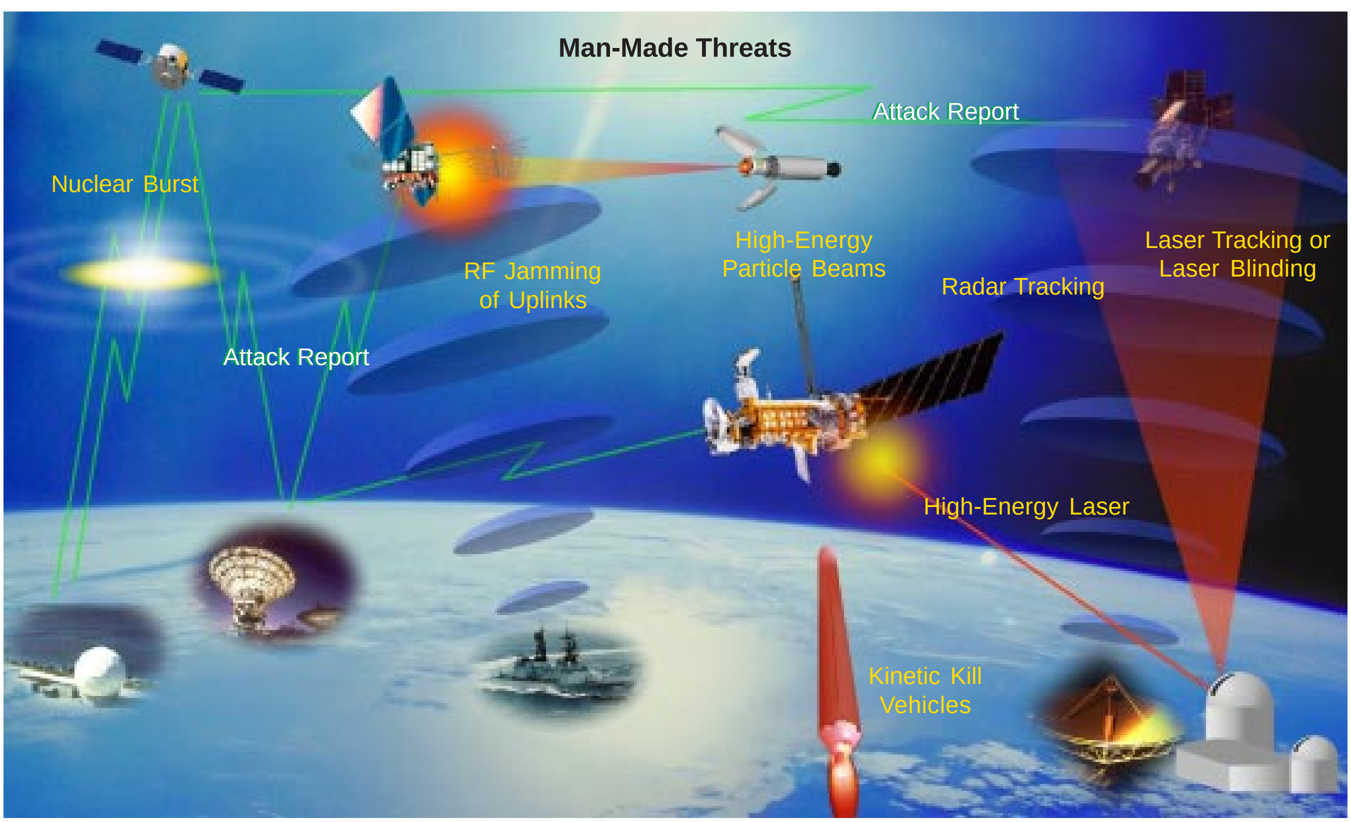
Selected additional project detail is tabulated in "Projected Applications," below.

Enabling Technologies *(Unconstrained)*

- Autonomous, adaptive, self-training, real-time resource planning algorithms for tasking, mission planning/management, processing, exploitation, and dissemination
- Automated cross-cueing, dynamic database fusion, synergy of imagery, spectral and signal processing functions, phenomena and information technologies
- Artificial Intelligence (AI) for data fusion
- Neural networks
- Automatic control, fuzzy logic
- Increased satellite on-board data processing and storage for timely data delivery
  - Non-volatile random access memory
- On-orbit maneuvering, diagnostics, processing and mission management technologies
- Fusion processing software algorithms
- Miniaturized, scalable, power-efficient electronic components and mechanisms
  - E.g., fiber optics, optoelectronics, photonics, microelectromechanical systems (MEMS)
  - E.g., superconducting electronics to eliminate need for sensor cryocooling
- Large, lightweight support structures and materials
- Shape memory techniques and alloy materials
- Active and passive electromagnetic spectrum devices to direct, disseminate, focus and transmit — as well as to detect, extract, sense and receive — energy:
  - Heat (infrared [IR])
  - Visible light
  - Radio frequency (RF)
- Ground-based high-resolution optical/radar/multi-spectral imaging technologies (active or passive)
- Increased sensor range and sensitivity technologies
  - Atmospheric and radiant background characterization, modeling, and processing
  - Improved atmospheric compensation and target classification algorithms for multi-spectral/hyperspectral image processing
- Multiple RF and optical sensors, processors, links, and host spacecraft integration technologies
- Exploitation technologies for bistatic phenomenology of targets and clutter characteristics
  - Bistatic space-time adaptive processing algorithm validation
- Multistatic time and frequency correlation, signal processing, and data fusion
- Advanced target detection technologies
  - E.g., acousto-optical detection and spectral signature exploitation (to see through clouds)
- Non-intrusive inspection technology
- Advanced electro-optical (EO) technology
- Hyperspectral sensing: improved low-power high-capacity on-board processors
- Hyper- to ultra-spectral imagery (HSI-USI) sensors (100s to 1000s of bands)
- Advanced IR technologies

  - Quantum cascade and interband semiconductor IR laser sources
- Multispectral/hyperspectral and very short wavelength infrared (VSWIR) sensors/imagers
  - Multi- to ultra-spectral detector materials, processes, and manufacturing
- Large focal plane array (FPA) detector materials science and manufacturing
  - E.g., staring FPAs for multispectral detection, read-out integrated circuits (ROICs), quantum well IR photodetectors (QWIPs)
- Advanced small, high-capacity, space-qualified cryocoolers
  - More efficient on-orbit storage of cryogenic hydrogen
  - More efficient infrared applications
  - Advanced regenerator/phase-change materials
- Low/high-power laser atmospheric compensation and beam control
  - Optical phase conjugation
  - Adaptive laser optics
  - On-orbit dimensional control
  - Jitter and vibration management
- Advanced acquisition, pointing and tracking techniques
- Space-based high-resolution optical/radar/multispectral imaging technologies (active or passive)
- High-energy laser technologies for:
  - Ground-based high-power laser
  - Space-based high-power laser
- Space-based mirrors for high-power laser relay
  - Large-aperture, lightweight, modular, deployable membrane mirrors/optics, and support structure materials
- Durable thin-film substrate/membrane/coating materials, processing, and manufacturing
- Nonlinear optical materials for specialized sensors
- Optically efficient and variable-emittance mirror coatings
- On-orbit servicing of mirror coatings
- Advanced RF technology
  - Photonics for phase-shifting and beam-forming
  - Spectral analyzers and algorithms
  - Digital RF memory (DRFM)
- Advanced HOJ technology
- Advanced synthetic aperture radar (SAR)
- Advanced automatic target recognition (ATR), moving target indication (MTI), and orbital dynamics processing algorithms
- Large affordable, lightweight RF reflectors and antenna designs
  - E.g., inflatables, deployable array-fed reflectors
  - E.g., solid state phased array electronically steerable antennas
  - Higher strength-to-weight and composite materials and designs
- Radar components with higher frequency and power output
  - High-temperature semiconductor materials for RF/radar components
- Advanced, lower-cost, higher-frequency/bandwidth transmit/receive (T/R) components
- Improved front-end noise rejection for RF systems
- Advanced mixers and analog-to-digital (A/D) converters
- Advanced signal excision techniques
- Laser/optical communications and associated acquisition/tracking/pointing for space-space, space-air, and space-ground applications
- Non-volatile memory optical computing/communications
- Advanced laser and microwave communications technologies for space-space, space-air, space-ground links
  - Advanced netting and encryption technologies
- Reprogrammable radios and other electronics system components
  - Field programmable gate array (FPGA) technologies

- Autonomous, longer-life, higher-energy/power-to-weight on-orbit power generation, conditioning, distribution, and storage
- More efficient solar cells, batteries (chemically or thermally generated electricity, such as thermionic power generation and thermo-electric conversion)
  - E.g., lithium ion/polymer hybrid batteries
  - Affordable solar cell materials and manufacturing
- Integrated/active thermal control
  - Electronics cooling
- Radiation hardening and shielding of components
  - Radiation-resistant composites and associated materials
  - High-temperature and radiation-resistant electronic materials
  - Flash radiation-hardened digital memory (e.g., SiC)
- On-board detection and technologies for space environment hazards
  - Advanced laser detection and protection technologies
  - Detection and location of surface and airborne RF jamming
- Satellite laser and RF interference/vulnerability mitigation
  - Bi-/multistatic techniques
  - Synthetic/virtual apertures
- Advanced filters and limiters for satellite survivability against directed-energy weapon (DEW) threats
  - Laser-hardened materials and concepts for sensors
- Isothermality technologies
- High heat-dissipating thermal doubler/plane materials
- Advanced effects phenomenology
  - Techniques for interference or "soft kill"
- Human-system interfaces for information exploitation and decision-making
- Control center technologies
  - Write once read many (WORM) storage
  - Archival mass storage
- Advanced team training technologies.



Projected Applications

Activities	Status	Agencies
Space Surveillance (ground-based) • ***Full-Scale Adaptive Optics*** – Integration with Maui Space Surveillance Site's (MSSS's) 3.7m telescope • ***Hi-Class Ladar*** – Integration with Maui's 3.7m telescope; 30-db gain for space object engagements – Space surveillance capability; range-doppler imaging and space debris tracking options • ***Imagery exploitation tool*** – Intelligence Data Analysis for Satellite Systems (IDASS), ground-based software to enhance the processing and analysis of Maui's high-resolution imaging products • ***Active Imaging Testbed experiments*** – Active imaging evaluation (of experiments completed in FY00) – Results transitioned to Geo Light Imaging National Testbed (GLINT) to demonstrate optical imaging of GEO space objects – Later GLINT upgrade to provide residual operational capability	 Technology insertion Technology development Technology development Technology experiments	 Air Force Air Force Air Force Air Force
Space Environmental and Threat Reporting • ***Compact Environmental Anomaly Sensor II (CEASE II)*** – To monitor harmful elements of the space environment and provide real-time alerts to the host spacecraft • ***Space Threat Warning and Reporting (STW/AR)*** – To support defensive counterspace capabilities – ***Miniature Satellite Threat Reporting System (MSTRS)*** — To support the RF portion of STW/AR – ***Advanced Laser Sensor Development (ALSD)*** — To support the laser portion of STW/AR	 ACTD Technology demonstrations	 Air Force Air Force
Space-Based Laser Integrated Flight Experiment (SBL IFX) – On-orbit demonstration of integrated performance (planned for FY10-12 time frame) – Parallel programs to enable development of an operational SBL – Concept refinements via the SBL Affordability and Architecture Study – Continuing space optics and laser technology studies	Technology program	Air Force BMDO
Space Maneuver Vehicle – Maneuverable satellite bus with interchangeable payload capability – Launchable on demand, maneuverable to desired locations – Able to rendezvous and co-orbit with LEO/MEO satellites, fly by GEO satellites – Would be able to carry or dispense any type of payload	System concept	Air Force

ACTD Advanced Concept Technology Demonstration

Opportunities for Partnering

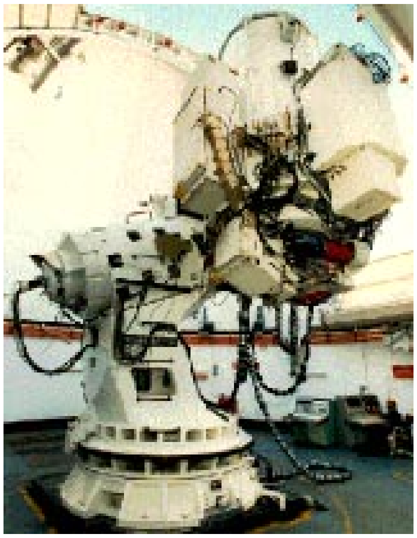
The DoD is pursuing partnerships in space control activities among the Armed Services, Defense Agencies, and interagency national security organizations, as well as work with commercial and foreign entities. Commercial systems and technologies are being leveraged and exploited where feasible. Current examples include:

- The Air Force-BMDO SBL IFX, which will demonstrate on-orbit operation and lethality of a high-energy laser system against a missile in boost phase
- Air Force-NSF use of the Maui Space Surveillance Site's new 3.7-meter telescope and associated adaptive optics system for astronomy, which will combine operational and scientific work
- Air Force plans to partner with BMDO, NASA and NOAA for its multi-link lasercom development initiatives.

Maui Space Surveillance Site (MSSS)

The 3.7m telescope's dome and facility

The 3.7m Advanced Electro-Optical System Telescope



The 1.6m Telescope