Appendix A

Congressional Direction

TITLE XVI—NATIONAL SECURITY SPACE MATTERS

Subtitle A—Space Technology Guide; Reports

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Subtitle A—Space Technology Guide; Reports

SEC. 1601. SPACE TECHNOLOGY GUIDE.

(a) REQUIREMENT.—The Secretary of Defense shall develop a detailed guide for investment in space science and technology, demonstrations of space technology, and planning and development for space technology systems. In the development of the guide, the goal shall be to identify the technologies and technology demonstrations needed for the United States to take full advantage of use of space for national security purposes.

(b) RELATIONSHIP TO FUTURE-YEARS DEFENSE PROGRAM.—The space technology guide shall include two alternative technology paths. One shall be consistent with the applicable funding limitations associated with the future-years defense program. The other shall reflect the assumption that it is not constrained by funding limitations.

(c) RELATIONSHIP TO ACTIVITIES OUTSIDE THE DEPARTMENT OF DEFENSE.—The Secretary shall include in the guide a discussion of the potential for cooperative investment and technology development with other departments and agencies of the United States and with private sector entities.

(d) MICRO-SATELLITE TECHNOLOGY DEVELOPMENT PLAN.—The Secretary shall include in the guide a micro-satellite technology development plan to guide investment decisions in micro-satellite technology and to establish priorities for technology demonstration activities.

(e) USE OF PREVIOUS STUDIES AND REPORTS.—In the development of the guide, the Secretary shall take into consideration previously completed studies and reports that may be relevant to the development of the guide, including the following:

(1) The Space Control Technology Plan of 1999 of the Department of Defense.

(2) The Long Range Plan of March 1998 of the United States Space Command.

(3) The Strategic Master Plan of December 1997 of the Air Force Space Command.

Deadline.

(f) REPORT.—Not later than April 15, 2000, the Secretary shall submit a report on the space technology guide to the congressional defense committees.

Appendix B

Research and Technology

Technological superiority continues to be the cornerstone of our national military strategy. Maintaining our technological edge becomes even more important as U.S. force sizes decrease and as higher-technology weapons become more readily available on the world market. In this environment, it is all the more necessary that U.S. forces possess technological superiority to achieve and maintain dominance across the full spectrum of crises and military operations. Just as the technological advantage we enjoy today is a legacy of decades of investment in science and technology (S&T), so will our future national security and warfighting capabilities be substantially determined by our S&T investments today and in the years to come.

S&T Strategy

- Today's dangers include proliferation of weapons of mass destruction, regional conflict, and ethnic violence.
- Our strategy rests on three lines of defense:
  - Prevent threats from emerging;
  - Deter threats that do emerge; and, if necessary —
  - Defeat threats by military force.
- Executing this strategy requires strong, ready military forces equipped with a well-integrated, flexible mix of the most advanced technologies.
- The challenge for DoD's S&T program is to put the best available technology into the hands of the warfighter in a way that is timely and cost-effective both tomorrow and far into the future.

- **Budget Activity 1** and **Research Category 6.1, Basic Research.** This activity includes all efforts of scientific study and experimentation directed toward increasing knowledge and understanding in those fields of physical, engineering, environmental and life sciences related to long-term national security needs. It provides farsighted, high-payoff research, including critical enabling technologies that provide the basis for technological progress. It forms part of the base for (a) subsequent applied research (exploratory development) and advanced technology developments in defense-related technologies, and (b) new and improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, and personnel support.
- **Budget Activity 2** and **Research Category 6.2, Applied Research** (formerly Exploratory Development). This activity translates promising basic research into solutions for broadly defined military needs, short of major development projects. This type of effort may vary from fairly fundamental applied research to sophisticated bread-board hardware, study, programming and planning efforts that establish the initial feasibility and practicality of proposed solutions to technological challenges. It includes studies, investigations, and non-system-specific development efforts. The dominant characteristic of this category is that it be pointed toward specific military needs with a view toward developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters. Applied Research (Exploratory Development) precedes the system specific research.
- **Budget Activity 3** and **Research Category 6.3A, Advanced Technology Development** (formerly Advanced Development). This activity includes all efforts that have moved into the development and integration of hardware for field experiments and tests. The results of this type of effort are proof of technological feasibility and assessment of operability and producibility rather than the development of hardware for Service use. Projects in this category have a direct relevance to identified military needs. The activity is system-specific and includes advanced technology development that is used to demonstrate the general military utility or cost-reduction potential of technology when applied to different types of military equipment or techniques. Advanced Technology Development also includes evaluation and synthetic environment and proof-of-principal demonstrations in field exercises to evaluate system upgrades or provide new operational capabilities.

Strategic planning for defense S&T is managed by the Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T)) via the *Defense Science and Technology Strategy*. Four generic considerations apply to technology decisions: affordability, dual use potential, speed of technology transition, and strengthening of the technology base. The S&T strategy is articulated in three documents:

- The *Basic Research Plan* (BRP; 1999 issue used), which presents the DoD objectives and investment strategy for the Program 6.1 technical disciplines and their research projects. It is updated biennially.
- The *Defense Technology Area Plan* (DTAP; 1999 issue used), which presents the DoD objectives and investment strategy for Program 6.2 and 6.3 activities and sponsors Advanced Technology Demonstrations (ATDs). It is updated biennially.
- The *Joint Warfighting Science and Technology Plan* (JWSTP; 2000 issue used), which in effect examines DTAP S&T activities from a warfighter's point of view. The JWSTP also sponsors Advanced Concept Technology Demonstrations (ACTDs). It is updated annually.

Taken together, the BRP, DTAP, and JWSTP provide programming guidance for the DoD S&T community and ensure that near-, mid- and far-term operational needs are properly balanced and included in the DoD's S&T planning, programming, budgeting and assessment processes.

S&T investment is focused and guided through Defense Technology Objectives (DTOs), which are updated annually. Each DTO identifies a specific technology advancement that will be developed or demonstrated, the anticipated date of technology availability, the specific benefits resulting from the technology advance, and the funding planned to achieve the new capability. This process, also known as Defense S&T Reliance, is accomplished and coordinated through the Defense Science and Technology Advisory Group (DSTAG), whose Steering Committee membership is shown below:

DSTAG Steering Committee	
• Deputy Under Secretary of Defense (Science and Technology), Chair	(DDR&E)
• Deputy Assistant Secretary of the Army (Research and Technology)	(Army)
• Chief of Naval Research	(Navy)
• Deputy Assistant Secretary of the Air Force (Science, Technology, and Engineering)	(Air Force)
• Deputy Director, Defense Advanced Research Project Agency	(DARPA)
• Assistant Deputy Director for Technology, Ballistic Missile Defense Organization	(BMDO)
• Deputy Director, Defense Threat Reduction Agency	(DTRA)

The Defense S&T Reliance process helps to eliminate unnecessary duplication and seeks out opportunities for synergy, integrating the various DoD Component programs into a corporate S&T program. Reliance enables the DoD S&T community to work together to enhance S&T's role in supporting the Department's acquisition programs and their prospective users.

Basic Research Plan *(Program 6.1 Technologies)*

Current Defense-wide basic research efforts with potential space applications may be found across almost all of the BRP's twelve technical disciplines. *

* These twelve technical disciplines are coordinated by ten Strategic Planning Groups (SPG): two pairs of closely connected disciplines are handled by one SPG each, namely, Mathematics and Computer Sciences, and Terrestrial and Ocean Sciences.

Physics	Chemistry	Mathematics	Computer Sciences	Electronics	Materials Science
Mechanics	Terrestrial Sciences	Ocean Sciences	Atmospheric and Space Sciences	[Biological Sciences]	Cognitive and Neural Science

It should be kept in mind that basic research is conducted with no assurance of "success" — but with no assured limits to its eventual utility either. Typically, major new technologies may require years of basic and applied research to yield a first demonstration and more years for an initial military application. After that "proof," applications may proliferate and performance improve exponentially for decades to come. [#]

To provide more specific focus on warfighting and peacekeeping, in 1995 six Strategic Research Objectives were established; since 1999, they have been known as Strategic Research Areas (SRAs):

SRA	Research Objectives
Biomimetics	New synthetic materials, processes and sensors via exploitation of design principles found in nature
Nanoscience	Major enhancements in the properties and performance of structures, materials and devices with controllable features on the nanometer scale (tens of angstroms)
Smart Structures	Advances in modeling, predicting, controlling and optimizing the dynamic response of complex, multi-element, deformable structures used in terrestrial and aerospace vehicles and systems
Mobile Wireless Communications	Rapid and secure transmission of large amounts of multimedia information (speech, data, images, video) whether point to point or broadcast or multicast over distributed networks of heterogeneous C4ISR systems
Intelligent Systems	Advanced systems that can sense, analyze, learn, adapt and function well in uncertain, changing and hostile environments
Compact Power Sources	Power source performance improvements well beyond current technologies

In basic Physics and Atmospheric and Space Sciences research, one area key to ISR involves trying to understand the scientific underpinnings of object and/or signal recognition through obscuring media or against background clutter or noise. Scientific and engineering advances in the propagation and detection of radiated energy across the infrared, visible and RF portions of the electromagnetic (EM) spectrum have historically offered both the promise and the challenge of breakthroughs, witness radar and laser technologies during the second half of the 20th century.

In Chemistry and with Materials Science, Mechanics and Electronics in particular, basic research has produced breakthroughs in understanding the relationships between the microstructure and properties of new elemental combinations and the relative equilibrium of their phases. Electro-optical and infrared sensor materials are among the most significant examples to date. Molecular-level understanding is key to design and synthesis of new materials (metals, oxides, polymers, ceramics, composites, semi- and superconductors) and applications in structures, electronics, optics, magnets, coatings, fuels, lubricants, and others.

In Mathematics and with Computer and Cognitive and Neural Science applications in particular, basic research in extremely high-speed logic, data processing and filtering is vital to future advances in non-linear real-time C4ISR problem solving. The now-famous Kalman filter, a computation-efficient algorithm originally used in fire control systems, is now widely used in guidance and navigation systems and serves as a classic example of how pervasive the applications of such research can be.

[#] An obvious example is the airplane, whose concept was researched during the second half of the 19th century, culminating in the Wright Brothers' initial flight in 1903, followed by military deployments during World War I. In the decades since, aircraft have exceeded Mach 3, reached high into the stratosphere, carried hundreds of people, fought each other and launched all sorts of armaments in battle, and continue to evolve as helicopters, unmanned aerial vehicles, aerospace platforms (like the Space Shuttle), common commercial carriers, and private transportation (from business jets to "ultralights").

The BRP presents the DoD's objectives and investment strategy for DoD-sponsored Basic Research (6.1) performed by universities, industry, and Service laboratories. In addition, it presents the planned investment in each of the Basic Research Program's ten technical disciplines.

The coupling of the BRP with the DTAP and JWSTP is carried out through several interactive processes. For example, during the planning stage of the BRP's individual research areas, Service laboratory and warfighter representatives review requirements and sometimes participate in the basic research activities' planning. Such representatives also take part in the activity evaluation process via Service S&T program reviews and the DUSD(S&T) Technology Area Reviews and Assessments (TARAs).

The BRP's space-related technology activities are summarized by S&T discipline in Appendix C.

Defense Technology Area Plan *(Program 6.2 and 6.3 Technologies)*

The DTAP presents the DoD's S&T objectives and the Applied Research (6.2) and Advanced Technology Development (6.3) investment strategy for technologies critical to DoD acquisition plans, service warfighter capabilities, and the JWSTP. It also takes a joint, horizontal perspective across the Services' and Defense Agencies' activities, thereby charting the DoD investment for a given technology. Although not all-inclusive, the DTAP documents the focus, content, and principal objectives of the overall DoD S&T program. This plan provides a sound technology basis for acquisition decisions and is structured to respond to the need for rapid transition of technology to the operational forces.

Twelve technology area panels provide the technology planning content of the DTAP. Their products are drawn from Service/Defense Agency S&T plans and operational concept documents. Those with technology activities most directly supporting national security space are referenced in the Space Platforms chapter, while the Sensors and Electronics and Battlespace Environments Panels also have a significant space component.

DTAP Technology Area Panels		
Air Platforms	Chemical/Biological Defense	Information Systems Technology
Ground & Sea Vehicles	Materials/Processes	Biomedical
Sensors and Electronics	**Battlespace Environments**	**Space Platforms**
Human Systems	Weapons	Nuclear Technology

As noted, the DoD's S&T investment is focused and guided through Defense Technology Objectives (DTOs), which are updated annually. Each DTO identifies a specific technology advancement that will be developed or demonstrated, the technology's anticipated date of availability, the specific benefits resulting from the technology advance, and funding required to achieve the new capability. These benefits not only include increased military operational capabilities but also address other important areas, including affordability and dual-use applications, that have received special emphasis in the Defense S&T Strategy.

The DTAP's space-related technology activities and DTOs are summarized in Appendix D.

Joint Warfighting Science and Technology Plan *(Program 6.2 and 6.3 Technologies)*

Over the past year the Office of the Secretary of Defense (OSD), Joint Staff, Military Services, Defense Agencies and operational Commanders-in-Chief (CINCs) have worked together to develop the Joint Warfighting S&T Plan (JWSTP). This plan takes a joint perspective across the Program 6.2 and 6.3 plans of the Services and Defense Agencies to ensure that the technologies and advanced concepts required for joint and coalition warfighting are supported. It identifies twelve Joint Warfighting Capability Objectives (JWCOs), which have been validated by the Joint Requirements Oversight Council (JROC) as critical for warfighting advantage. In turn, the JWCOs guide the Joint Warfighting Capability Assessment (JWCA) process that supports the four Joint Vision 2010/2020 operational concepts of dominant maneuver, precision engagement, full-dimension protection, and focused logistics.

Twelve JWCO panels provide the technology planning content of the JWSTP. Those with technology activities most directly supporting national security space are referenced in the Protection of Space Assets chapter, while the Information Superiority and Joint Theater Missile Defense chapters also address specific space systems and capabilities. As with the DTAP, the JWCO activities are not all-inclusive. Other important joint and Service-unique warfighting and operations-other-than-war capabilities need strong S&T support; nevertheless, the JWCOs provide an important operational focus for the S&T program.

Joint Warfighting Capability Objectives		
Information Superiority	Precision Fires	Combat Identification
Joint Theater Missile Defense	Military Operations in Urbanized Terrain (MOUT)	
Joint Readiness & Logistics, and Sustainment of Strategic Systems	Force Projection/Dominant Maneuver	
Electronic Warfare	Chemical/Biological Warfare Defense & Protection, and Counter Weapons of Mass Destruction	
Combating Terrorism	**Protection of Space Assets**	Hard and Deeply Buried Target Defeat

The JWSTP is issued annually as defense guidance. Advanced concepts and technologies identified as enhancing high-priority joint warfighting capabilities, along with prerequisite research, will receive funding priority in the President's Budget and accompanying Future Years Defense Plan (FYDP).

The JWSTP's space-related technology activities and DTOs are summarized in Appendix E.

Defense Technology Objectives for Space

DTOs are not only featured in both the DTAP and JWSTP but are also aggregated in a separate document: the *Defense Technology Objectives of the Joint Warfighting Science and Technology Plan and the Defense Technology Area Plan.* Both the DTAP and JWSTP identify sets of DTOs that are clearly associated with their key space panels. In addition, they cross-reference DTOs from other panels that support their technological and operational focus on space, respectively.

The letter-coding for the nearly 350 DTAP and JWSTP DTOs is shown in the two tables below. The letters precede the numerical identifiers for the specific activities.

The DTAP's principal space-oriented panel is Space Platforms (SP), though the current Sensors and Electronics and Battlespace Environment panels also oversee space technology activity. With the increasing utility of space products and services in all types of national security activity, the Space Platforms panel's interests extend to many other panels' technologies to a varying degree. Accordingly, the DTAP identifies the DTOs supporting Space Platforms directly and also lists key space-relevant DTOs from other panels in the Space Platforms chapter. The DTAP's summary of space DTOs is shown in Appendix D.

1999 DTAP Panels	DTO Letters
Air Platforms	**AP**
Chemical/Biological Defense	**CB**
Information Systems Technology	**IS**
Ground and Sea Vehicles	**GV**
Materials/Processes	**MP**
Biomedical	**MD**
Sensors, Electronics, and **Battlespace Environment***	**SE, BE**
Space Platforms	**SP**
Human Systems	**HS**
Weapons	**WE**
Nuclear Technology	**NT**

• Subsequently divided into two panels (see DTAP for 2001)

2000 JWCO Panels	DTO Letter(s)
Information Superiority	**A**
Precision Fires	**B**
Combat Identification	**C**
Joint Theater Missile Defense	**D**
Military Operations in Urbanized Terrain	**E**
Joint Readiness and Logistics and Sustainment of Strategic Systems	**F** **K**
Force Projection/ Dominant Maneuver	**G** **M**
Electronic Warfare	**H**
Chem/Bio Warfare Defense and Protection and Counter Weapons of Mass Destruction	**I** **J**
Combating Terrorism	**L**
Protection of Space Assets	**A, N, NT, SE, SP (Others)**
Hard and Deeply Buried Target Defeat#	(None Yet)

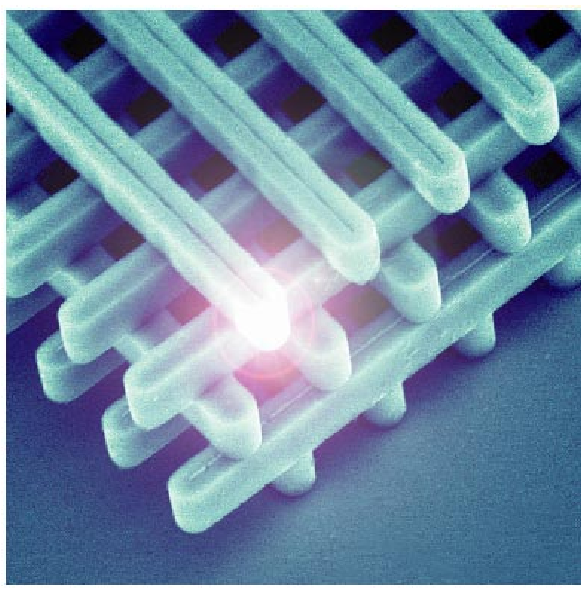
New JWCO for 2000 (see 2001 JWSTP for DTOs)

The JWCO's principal space-oriented panel is Protection of Space Assets. This focus recognizes the joint interest of all operational communities in assuring the continuous availability of space products and services. Thus, as with the DTAP, the JWSTP treats its space-related DTOs relatively broadly. Further, instead of one or two panel-unique letter identifiers, it both incorporates space functions from the other panels and relies heavily on DTAP technologies to address its operational concerns. Finally, recognizing that Protection is just one of five key objectives under the USSPACECOM Control of Space concept, the JWSTP also identifies those DTOs that provide key support to the other Space Control objectives: Assured Access, Surveillance of Space, Prevention, and Negation. The JWSTP's summary of space DTOs is shown in Appendix E.

The panel structures supporting both the DTAP and the JWCO processes remain subject to change to meet evolving policy as well as operational needs and technological perspectives. It should also be noted that the nearly 350 DTAP and JWSTP DTOs really represent the "tip" of the S&T "iceberg." Many other technology activities, from 6.1 through 6.3 projects, constitute a broad range of S&T from which future DTO-level projects may emerge.

Optoelectronics

Light wave of the future



According to Sandia Laboratory, light may soon replace electrons as the "engine" that drives many of our technologies. The photonic lattice, a Lincoln log-like device, is revolutionizing what engineers can do with light. Developed at Sandia in partnership with DOE's Ames Laboratory, this invention belongs to a category of light-driven microtechnologies called *photonics*. The photonic lattice acts like a crystal in guiding light by virtue of its tiny, regularly placed silicon "logs," which are 1.2 microns wide.

Additional National Security Space References

1. Technologies for USSPACECOM's *Long Range Plan*

In its 1998 *Long Range Plan: Implementing USSPACECOM Vision for 2020* (LRP), the joint operational defense space community projected the concepts, capabilities, potential systems and candidate technologies it considers necessary to meet the strategies and objectives of the future. These concepts and the potential means to implement them were provided:

- As guidance for USSPACECOM's component commands: Army Space Command (ARSPACE), Naval Space Command (NAVSPACE), and Air Force Space Command (AFSPC)

- To encourage interactions and partnerships with other national security agencies and with the private sector.

The LRP's concepts and candidate system technologies are tabulated in Appendix F. AFSPC has implemented LRP concepts in the *Air Force Space Master Plan* of 2000. (Meanwhile, USSPACECOM is updating its Vision and LRP to assure conformance with the new 2000 issue of *Joint Vision 2020.)*

2. Other Space R&D Activities and Stakeholders

- Space technology demonstrations and Space Test Program activities are tabulated in Appendix G
- The national security space technology programs of NASA and the DOE, as DoD partners in many activities, are addressed more comprehensively in Appendix H
- A space industry view of selected space technology and funding needs and a limited survey of commercial initiatives are contained in Appendix I.

Summary of National Security Space S&T Activity

The multiple interactions among and applications of the DoD's and other Federal agencies' comprehensive S&T programs have underlain the U.S.'s military prowess for a century. Our current preeminence in space derives from technologies first researched decades ago. We have seen how the synergistic effects of multiple technologies have yielded revolutionary capabilities for operational systems in the second half of the 20th century. Meanwhile, today's technology projects are yielding the capabilities that will set our course for the 21st century. The DoD's current task is to continue to identify those key enabling technologies that must be pursued in a timely fashion to preserve our national security space preeminence through the 21st century also.

Appendix C

Basic Research Planning (Space)

Among the BRP's twelve technical disciplines, those whose project areas have the most direct potential space applications during the STG's 20-year planning window are indicated in the tables below.

BRP Scientific Discipline/Areas	**Service Focus** (Potential Space Applications) **Army (A)**	**Navy (N)**	**Air Force (AF)**
PHYSICS			
• RADIATION - Sources - Propagation - Detection	Uncooled detectors Sub-MMW research Tunable IR lasers	X-ray sources Blue-green lasers Quantum noise	Optical compensation Microwave sources
	Ultra-fast EO, Novel lasers, Nonlinear optics, Optics diagnostics and testing, Coherent free-electron radiation sources **(all)** Optical image processing **(A, AF)**		
• MATTER AND MATERIALS - Optical - Atomic - Molecular - Plasma	Atomic-scale systems Low observables	Physical acoustics Energetic and nonlinear IR materials	Visible lasers Semiconductor lasers
	Nanostructures, Atom optics and atom traps, Computational physics, Nonlinear control **(all)** Ferro-electrics **(A, N)** High-Tc superconductors **(N, AF)** Surfaces and interfaces **(A, AF)**		
• ENERGETIC PROCESSES - High Voltage - Plasmas - Power Generation	Mobile power sources	Compact accelerators Pulsed power Ultra-high fields Beam plasma dynamics	Nonneutral plasma effects
		Nonneutral plasma, Collective phenomena **(N, AF)**	
• TARGET ACQUISITION - Atmospheric	Integrated sensory science Imaging science Unconventional optics		Atmospheric discharges
	Nonlinear dynamics/chaos **(all)** Ionospheric modification and propagation **(N, AF)**		

BRP Scientific Discipline/Areas	**Service Focus** (Potential Space Applications) **Army (A)**	**Navy (N)**	**Air Force (AF)**
CHEMISTRY			
• MATERIALS CHEMISTRY - Theory - Molecular design - Synthesis and properties of compounds		Nanoelectronic materials Inorganic semiconductors Minimally adhesive surfaces Complex oxides Nanotubes/organic composites	Inorganic-based protective coatings and space materials Polymeric high-temperature materials
	Nanostructures, Power sources, Functional polymers, Lubricants **(all)** Energetic materials **(A, AF)** Lubricants **(N, AF)**		
• CHEMICAL PROCESSES - Atomic and molecular energy transfer - Transport phenomena - Reactions - Changes of state	Organized assemblies Diffusion/transport in polymers Energetic ignition/detection	Combustion/conflagration in fuels Surface / interface processes Self-assembled mesostructures Ion/charge transport Adhesion	Chemical lasers Atmospheric and space signatures and backgrounds Processing (ceramics, polymers, sol gels) Thin-film growth
	Chemistry dynamics, Tribochemistry, Sensors, Chemistry of corrosion and degradation, Power sources **(all)**		

BRP Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
MATHEMATICS			
• MODELING AND MATHEMATICAL ANALYSIS - Physical Modeling and Analysis	Mathematics of materials science Reactive flows		Control and guidance Nonlinear optics
	Multiscale phenomena, Nonlinear dynamics **(all)** Inverse problems **(N, AF)**		
• COMPUTATIONAL MATHEMATICS - Numerical Analysis - Discrete Mathematics	Computational mechanics Data representation Discrete mathematics	Computational acoustics Computational statistics and logic	Computational control Compressible and hypersonic flow
	Adaptive methods **(all)** Computational electromagnetics **(N, AF)**		
• STOCHASTIC ANALYSIS AND OPERATIONS RESEARCH - Statistical Methods - Applied Probability Optimization	Statistical modeling Simulation methodology	Random fields Nonlinear filtering	Intelligent search Discrete event systems
	Mathematical programming, Network and graph theory **(all)** Stochastic image analysis, Stochastic partial differential equations (PDEs) **(A, N)**		

BRP Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
COMPUTER SCIENCES			
• INTELLIGENT SYSTEMS - Control - Learning - Natural language processing (NLP) - Motion planning - Virtual Environments - Languages	Intelligent control NLP Machine intelligence	Case-based reasoning Machine learning Motion planning	Intelligent real-time problem solving Intelligent tutoring Intelligent accents
	Machine vision, Novel computing paradigms **(all)** Virtual environments **(A, N)** Data fusion **(A, AF)**		
• SOFTWARE - Software Engineering - Software Environments - Languages	Formal languages Automation of software development	Hard real-time computing Structural complexity Programming logic	Information Warfare high-performance knowledge bases
	Software environments, Programming languages **(all)** Formal design and verification **(N, AF)**		
• ARCHITECTURE AND SYSTEMS - Compilers - Operating Systems	Hybrid system architectures	Ultradependable multicomputing systems Secure computing	Distributed computing for C3
	Operating systems **(all)** Compiler optimization, Man-machine interface **(A, N)**		

BRP Scientific Discipline/Areas	**Service Focus** (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
ELECTRONICS			
• SOLID-STATE AND OPTICAL ELECTRONICS - Detectors - Superconductors - Nonlinear Circuits	IR and UV detectors Power switches Terahertz electronics Low-power and low-voltage analog electronics	Wide-gap semiconductors Magnetic thin films All-digital RF electronics Magneto-electronics 6.1-angstrom materials	Radiation-hard electronics Nonlinear optical materials High-temperature electronics
	Nano- and mesoscale electronics, Heterostructures, Multifunctional devices and micro-optics **(all)** Lithography, Quantum transport **(A, N)** Device reliability, Superconductors **(N, AF)**		
• INFORMATION ELECTRONICS - Modeling - Simulation	Mobile, wireless multimedia distributed communications IR target recognition and image analysis	Sensor array processing Distributed networks Soft/fuzzy-logic/neural networks Reliable, fault-tolerant VLSI	(None)
	Sensor fusion, Digital signal processing, adaptive arrays, array processing **(all)** Modeling/simulation of circuits, devices, and networks **(A, N)** Target acquisition **(N, AF)**		
• ELECTROMAGNETICS - Antennas - Transient Sensing - Tubes	Wireless and radar propagation Advanced MMW circuit and antenna integration Mobile tactical wireless and printed antennas	Dispersion-free beam-steering	Transient electromagnetics Secure propagation Distributed-aperture radar
	Integrated transmission lines, EM numerical techniques, Discontinuities in circuits, Optical control of array antennas, Power-efficient RF components **(all)** EM scattering, Vacuum electronics **(N, AF)**		

BRP Scientific Discipline/Areas	**Service Focus** (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
MATERIALS SCIENCE			
• STRUCTURAL MATERIALS - Synthesis - Processing - Theory - Properties - Characterization - Modeling	Manufacturing science	Layered designed materials	High-temperature fatigue and fracture Functionally graded materials Space plane, spacecraft, and launch vehicle materials Material properties integration
	Advanced composites, Tribology, Ceramics **(all)** Adhesion/joining **(A, N)** Intermetallics **(N, AF)**		
• FUNCTIONAL MATERIALS - Synthesis - Processing - Theory - Properties - Characterization - Modeling	Defect engineering Optical components IR detector materials Smart materials	Ferrite films Ferroelectrics Diamond Acoustics/active materials Superconductivity	*(Topics addressed under Chemistry, Electronics, Physics and Mechanics basic research areas)*
	Optoelectronics, Magnetic materials **(A, N)**		

BRP Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army (A)	Navy (N)	Air Force (AF)
MECHANICS			
• Solid and Structural Mechanics - Structural Dynamics - Composites	Finite deformation, impact, and penetration	Structural acoustics Micromechanics of electronic devices and solids	Hypersonic aeroelasticity Mechanics of high-temperature materials Particulate mechanics
	Structural dynamics and control, Damage and failure mechanics/quantitative nondestructive evaluation, Smart structures **(all)**		
• Fluid Dynamics - Aerodynamics - Turbulence - Unsteady Flow			Hypersonic aerothermo-dynamics
	Unsteady separated flow **(all)** Turbulence **(N, AF)**		
• Propulsion and Energy Conversion			Spacecraft and orbit propulsion
	Turbulent flows **(all)** Spray combustion **(A, AF)** High-energy materials combustion/hazards **(N, AF)**		

Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army	Navy	Air Force
TERRESTRIAL AND OCEAN SCIENCES			
• Terrain Properties and Characterization	Terrain generation and analysis Properties of natural materials Site characterization	Continental terraces	(None)
• Terrestrial Processes and Landscape Dynamics	Surface processes and geomorphology Hydrometeorology and hydrology Coastal erosion and engineering Ground water flow and mass transport	Near-shore sediment processes	(None)
• Terrestrial System Modeling and Model Integration	Tactical mobility and Logistics Over the Shore (LOTS) Sustainable testing and training lands Contaminant remediation	(None)	(None)
• Oceanography	(None)	Physical, chemical, biological and optical modeling and prediction	(None)
• Ocean Acoustics	(None)	Shallow water acoustics High-frequency acoustics Long-range propagations	(None)
• Ocean Geophysics	LOTS Coastal engineering Coastal erosion	Continental terraces Sediment processes	(None)

BRP Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
ATMOSPHERIC AND SPACE SCIENCES			
• Meteorology	Continental boundary layer Small-scale meteorology Transport, diffusion, obscuration Chemical-biological defense	Marine boundary layer Maritime and coastal meteorology Heterogeneous flows Major storms worldwide Synoptic to mesoscale modeling Aerosol models	(None)
	Aerosol effects, Coherent structures, Subgrid scale parameterization, Large eddy simulation, Atmospheric transmission, Radiative energy transfer, Nested models of all scales, Surface energy balance, Cloud formation and processes, Contrast transmission, Data assimilation **(A, N)**		
• Remote Sensing	Fine resolution of wind, temperature and humidity fields within boundary layer Chemical/biological detection	Marine refractivity profiles	(None)
	Atmospheric profiles of temperature, humidity, winds and aerosol concentration **(all)**		
• Space Science	(None)	Precision time Space-based solar observation Wave-particle interactions Astrometry	Ground-based solar observations Energetic solar events Ionospheric structure and transport Optical characterization
		Neural density, Ionospheric C3I impacts, Celestial background, Geomagnetic activity **(N, AF)**	

BRP Scientific Discipline/Areas	Service Focus (Potential Space Applications)		
	Army (A)	**Navy (N)**	**Air Force (AF)**
COGNITIVE AND NEURAL SCIENCE			
• Reverse Engineering - Machine Vision - Autonomous Vehicles - Automatic Target Recognition (ATR) - Telerobotics	(None)	Neural computation plasticity	Infrared biosensors
		Machine vision **(N, AF)**	

ATR	Automatic Target Recognition
C3	Command, Control, and Communications
C3I	Command, Control, Communications, and Intelligence
EO	Electro-Optical
EM	Electromagnetic
IR	Infrared
LOTS	Logistics Over the Shore
MMW	Millimeter-Wave
NLP	Natural Language Processing
PDE	Partial Differential Equation
RF	Radio Frequency
UV	Ultraviolet

Appendix D

Defense Technology Area Planning (Space)

Space planning within the DoD S&T community now involves both military and other Federal agencies with common interests in S&T planning.

In 1997, the Space Technology Alliance (STA) was created to "coordinate the development of affordable, effective space technologies for the greatest return on government funds." The STA's:

- Member organizations include the Air Force, Army, Navy, the NRO, NASA, BMDO, DARPA, and the DOE.
- Principal representatives are executive-level technical directors from: the AFRL (Chair); NRO; NASA; BMDO; Naval Research Laboratory (NRL); the Army's Space and Missile Defense Technical Center (SMDTC); DARPA; and DOE.
- Ex officio members include representatives from: the Office of the Secretary of Defense (DUSD(S&T) and ODASD(C3ISR&SS)); the National Security Space Architect's office (NSSA); NIMA; and the Air Force (SAF/AQR, AF/ST, SMC, A2CISRC, and AFSPC).

The STA both coordinates government S&T investment in space and categorizes space technologies via its Space Technology Inventory (STI),* shown in the table at right. The STI does not currently cover all Federal space-related S&T,# but it does cover all areas where DoD agencies currently have interests.

The STI information contained in this document is located in the DTAP's Space Platforms panel chapter, but it is cross-referenced to the space technologies

TECHNOLOGY AREA	DTAP Panel
Integrated Spacecraft Systems Technology	
Systems Analysis and Design Methods	Space Platforms
Advanced Concept Definition	Space Platforms
Standardization	Space Platforms
Advanced Integration and Test Methodology	Space Platforms
Demonstrations (Space and Ground)	Space Platforms
Autonomy	
On-Board Autonomy	Space Platforms
Mission Operations	Space Platforms
Advanced Methods	Space Platforms
Space Vehicles Technology (Spacecraft)	
Structures:	
Structural Controls and Dynamics	Space Platforms
Multifunctional Structures	Space Platforms
Materials	Materials/Processes (a)
Thermal Management:	
Controls and Materials	Space Platforms
Conventional Cooling	Space Platforms
Cryogenic Cooling	Space Platforms
Heaters	Space Platforms
Command and Control:	
Guidance, Navigation, and Control	Space Platforms
Astrodynamics and Geodesy	Space Platforms
Attitude Determination and Control	Space Platforms
Radio Navigation	Space Platforms
Command and Data Handling	Space Platforms
Telemetry, Tracking, and Control	Space Platforms
Ground Stations	Space Platforms
Satellite Software Architecture	Space Platforms (b)
Multisatellite Communications	Electronic Warfare
Electronics:	
Flight Computers and Components	Electronic Warfare
Microelectronics	Electronic Warfare
Photonics	Electronic Warfare
Radiation-Hard Technologies	Electronic Warfare
Survivability and Vulnerability:	
Threat Warning and Attack Reporting	Space Platforms
Protective Technologies	Space Platforms
Self-Protective Modes	Space Platforms
Man-Made Radiation	Chem-Bio Defense (c)
Aerothermodynamics	Chem-Bio Defense (c)
Onboard Propulsion:	
Chemical	Space Platforms
Electrical	Space Platforms
Space Power:	
Energy Production	Space Platforms
Energy Storage	Space Platforms
Distribution and Conditioning	Space Platforms

* The STI tabulated at right reflects a methodology in progress and is subject to change.

\# E.g., it does not include S&T for human space activities.

being pursued by other panels of both the DTAP and JWCO processes. These other DTAP panels are:

- Information Systems Technology;
- Materials/Processes;
- Sensors, Electronics, and Battlespace Environment;
- Weapons; and
- Sustainment of Strategic Systems.

The government laboratories conducting space projects tabulated in the DTAP are:

- U.S. Army Materiel Command;
- AFRL Directorates of:
  - Space Vehicles
  - Directed Energy
  - Information, and
  - Sensors;
- Air Force Space Battle Lab;
- DARPA;
- DOE's:
  - Lawrence Livermore National Laboratory (LLNL)
  - Los Alamos National Laboratory (LANL), and
  - Sandia National Laboratory (SNL);
- NRL;
- U.S. Army Space and Missile Defense Command; and
- U.S. Army Topographic and Engineering Center.

The regular coordination by all the above agencies and STA participants represents an expanded partnering approach to S&T across the national security technology spectrum. Moreover, the rapidly increasing roles and utility of space technologies have resulted in broad treatment of national security space technologies and the planning and investments required they require.

* Addition and changes from Basic Research Panel (pending issuance of DTAP update for 2001).

TECHNOLOGY AREA (Cont'd)	**DTAP Panel**
Sensors	
Detection:	
Microwave/Millimeter Wave	Sensors
Radar	Sensors
Lidar	Sensors
Infrared	Sensors
Ultraviolet/Visible	Sensors
Multi- and Hyperspectral	Sensors
Optics:	
Adaptive	Sensors
Segmented	Sensors
Arrays	Sensors
Instrument Systems	Sensors
Communications	
Radio Frequency:	
Sources	Electronic Warfare
Electronic: MMICs, LNAS	Electronic Warfare
Antennas: Adaptive, Arrays, Multibeam	Electronic Warfare (d)
Laser:	
Sources	Electronic Warfare (d)
Optics	Electronic Warfare (d)
Detectors	Electronic Warfare (d)
Architecture and Networks:	
Network Management	Electronic Warfare
Protocols/Interoperability	Electronic Warfare
Link Hardening	Electronic Warfare (d)
Space Environment	
Solar	Sensors *
Deep Space	Basic Research
Debris and Micrometeorites	Space Platforms
Upper Atmosphere:	
Neutral Species Density	Sensors *
Ionospheric Characterization	Sensors *
Total Electron Content	Sensors *
Electronic Profiles	Sensors *
Local Plasma Effects	Sensors *
Radiation Belts *	Sensors *
Contamination (i.e., outgassing)	Space Platforms
Special Ground Simulation Facilities	(e)
Optical Backgrounds	Sensors
Information Systems Technology	
Intelligent Systems and Networks	Info Systems Tech
Human-Computer Interfaces	Human Systems
Advanced Computing Concepts Mission Data	Info Systems Tech
Processing and Exploitation:	
Onboard Processing	(e)
Ground Processing and Exploitation	(e)
Image Processing	(e)
Signal Processing	(e)
Data Fusion	(e)

(a) Generic development by Materials/ Processes, adapted for space use by Space Platforms

(b) New techniques by Information Systems Technology, adapted for space use by Space Platforms

(c) Generic development by Chem/Bio, adapted for space use by Space Platforms

(d) Generic development by Electronics, adapted to space environment by Space Platforms

(e) Developed by each DTAP panel, as required.

TECHNOLOGY AREA (Cont'd)	**DTAP Panel**
Launch and Transfer	
Propulsion:	
Chemical	Space Platforms
Electric	Space Platforms
Nuclear	(**NASA/DOE** responsibility)
Advanced concepts	Space Platforms
Vehicles:	
Structures and Materials	Space Platforms
Aerothermal	Space Platforms
Guidance and Control	Space Platforms
Systems (batteries, actuators, etc.)	Space Platforms

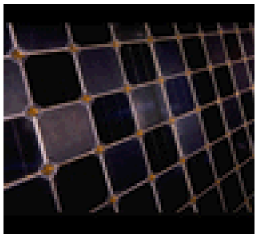
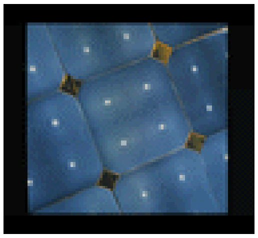
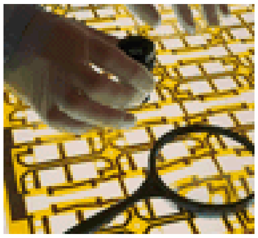
Primary source: DTAP, 1999

The DTAP's summary of defense space needs is drawn from USSPACECOM's *Long Range Plan:*

As the nation and DoD move into the 21st century, space forces will continue to provide support from space and conduct space operations in support of the other warfighters. The emerging synergistic relationship of space with land, sea, and air will enable the United States to achieve full spectrum dominance on the battlegrounds of the future. USCINCSPACE will need the following capabilities to dominate space and integrate space power throughout military operations:

- Real-time surveillance of space
- Timely and responsive spacelift
- Enhanced protection for military and commercial systems
- Flexible negation and prevention systems
- Nonintrusive surveillance of Earth from space
- National missile defense
- Enhanced command and control (C^2)
- Enhanced sensor-to-shooter capabilities
- Battle manager—the ability to have common protocols, communications standards, and fused databases
- Precise modeling and simulation of space systems
- Capability to rapidly share space-based information within a comprehensive space systems architecture
- Ability to influence space systems design.

Examples of Solar Cell Technology


The DTAP's key space-related DTOs associated with its and the JWSTP's different panels are:

DTO #	DTO Title	STI Area/Technology	Cognizant Panel
SP.01 [SP.02] * SP.03 SP.05 SP.08 SP.22	Cryogenic Technologies [Thermal Management Technology] Space Structures and Control Large, Precise Structures Space Power System Technologies Advanced Cyrogenic Technologies	Space Vehicles/Thermal [Space Vehicles/Thermal] Space Vehicles/Structures Space Vehicles/Structures Space Vehicles/Power Space Vehicles/Thermal	Space Platforms Panel *Space Vehicles and Launch Vehicles Subpanel* (DTAP)
SP.10 SP.11 SP.20	Liquid Boost Propulsion/IHPRPT Phase I Orbit Transfer Propulsion Spacecraft Propulsion/IHPRPT Phase I	Launch & Transfer/Propulsion Launch & Transfer/Propulsion Space Vehicles/Onboard Prop	Space Platforms Panel *Propulsion Subpanel* (DTAP)
A.06 A.07 [A.09] * A.11 A.13	Rapid Terrain Visualization ACTD Battlefield Awareness and Data Dissemination ACTD [Semiautomated Imagery Processing ACTD] Counter-Camouflage Concealment and Deception ACTD Satellite C3I/Navigation Signals Propagation Technology	Info Systems Tech/Processing Info Systems Tech/Processing [Info Systems Tech/Processing] Sensors/Detection (Radar) Space Environment/Upper Atmosphere	Information Superiority Panel (JWCO)
D.03 D.05 D.08	Discriminating Interceptor Technology Program Advanced Space Surveillance Atmospheric Interceptor Technology Space	Info Systems Tech/Processing Sensors/Detection Vehicles/Thermal	Joint Theater Missile Defense Panel (JWCO)
G.12	Lightweight Airborne Multispectral Countermine Detection System ATD	Sensors Detection (Multispectral)	Force Proj/Dom Maneuver Panel (JWCO)
K.01 K.02 K.06	Post-Boost Control System Technology Missile Flight Science Missile Propulsion Technology	Launch & Transfer/Aerotherm V. Launch & Transfer/Chem Prop Launch & Transfer/Chem Prop	Sustainment of Strategic Systems Panel (JWCO)
NT.01 NT.02 NT.05 NT.06	Nuclear Operability and Survivability Testing Technologies Electronic System Radiation Hardening Balanced Electromagnetic Hardening Technology Survivability Assessments Technology	Space Vehicles/Survivability Space Vehicles/Survivability Space Vehicles/Survivability Space Vehicles/Survivability	Nuclear Technology Panel (DTAP)
IS.23 [IS.24] * IS.38	Digital Warfighting Communications [Multimode, Multiband Information System] Antenna Technologies	Communications/RF [Communications/RF] Communications/RF	Information Systems Technology Panel (DTAP)
MP.29.01	Materials and Processes for IHPRPT	Launch & Transfer/ Chemical Propulsion	Materials/Processes Panel (DTAP)
[SE.28] * SE.37 SE.38 SE.55 BE-06	[Low-Power RF Electronics] High-Density, Radiation-Resistant Micro-electronics Microelectromechanical Systems Space Radiation Mitigation for Satellite Operations Satellite Infrared Surveillance Systems Backgrounds [formerly BE-56]	[Space Vehicles/Electronics] Space Vehicles/Survivability Space Vehicles/Electronics Space Vehicles/Survivability Space Environment/ Backgrounds	Sensors, Electronics & Battlespace Environment Panel# (DTAP) # Now two panels: Sensors and Electronics, and Battlespace Environment
WE.21 WE.41	Fiber-Optic, Gyro-Based NavigationSystems Multimission Space-Based Laser	Space Vehicles/C2	Weapons Panel (DTAP)

Primary source: DTAP, 1999. Updates per DTOs for DTAP, 2000. * Completed or delisted (per DTOs for DTAP, 2000)

As an integrating body for federal collaboration and for government-industry-academia coordination, the STA is:

- Developing a common database, to facilitate communication and investment tracking among organizations*
- Developing joint strategic technology roadmaps, which are reviewed by industry#
- Developing leveraged collaborative programs
- Sponsoring forums to increase communication (i.e., beyond government to the private sector).

The STA has developed five working groups so far to address specific technology areas of common interest to its principals. Each working group seeks to assure a sound return on government investment via increased collaboration and coordination among space technology stakeholders. Their activities are shown below.

Working Group	Completed/Current Actions	Next Steps
Space Power	• Roadmapped investments made by member organizations • Surveyed industry on investment strategies, specific development programs, and their views on the role of government in the space power technology development process • Developed a comprehensive roadmap of government-funded R&D for the next 10 years • Coordinated roadmaps with industry (1998-99) and briefed industry on results (April 2000)	• Develop a comprehensive survey of government needs over the next 20 years • Complete matching investment strategy with resources
Hyperspectral Imaging	• Exploring the current mission/science requirements and how air and space demonstration results will drive technology needs • Established two subgroups (Sensors and Integration, and Exploitation and Data Fusion), which developed technology roadmaps • Identified key investment areas as: improved optics, improved FPAs, autonomous calibration, and exploitation tools • Briefed findings and roadmaps to industry (October 1999)	• Meet with individual companies to flesh out the roadmaps and form partnerships for future imaging systems
Micro-Satellites	• Focusing on multiple micro-satellite uses: – Satellite servicing (including adjunct satellites) – Launch-on-demand satellite capability – Planetary services (Earth and other planetary bodies) – Space-based sensing – Atmospheric and space phenomenology – Distributed satellite systems – Concepts such as low-cost test beds and space debris removal • Sponsored information exchange workshops (1998, 1999) and prepared a micro-satellite development roadmap	• Continue to advance relevant technologies for ultra-capable micro-satellites • Complete roadmap coordination
Large Optics	• Air Force, NASA and NRO jointly funding Advanced Mirror System Demonstrator (AMSD) program to push the state-of-the-art in very large lightweight aperture technology • Via workshops and meetings (1998-99), identified unfunded technology needs • Drafted an AFRL-NRO roadmap for large, lightweight optics; adding NASA and other agency inputs	• Via AMSD, develop prototype mirror segments to meet common technical requirements for NASA's Next Generation Space Telescope (NGST) and DoD's Space-Based Laser (SBL) and space surveillance missions
Advanced Communications	• Developing a community roadmap of government technology investment and projects	• Establish a process like the Space Power Working Group's

* It is hosted on the Research and Development in CONUS [Continental United States] Labs (RaDiCL) database, managed by the NRO.

\# STA working groups coordinate with industry to provide both sectors with insights and feedback, and to enable adjustments to plans and programs.

Appendix E

Joint Warfighting S&T Planning (Space)

Within the Joint Warfighting Science and Technology Plan (JWSTP), each of the twelve Joint Warfighting Capability Objectives (JWCOs) has the potential to make use of space systems and capabilities. The JWCOs are:

Joint Warfighting Capability Objectives		
Information Superiority	Precision Fires	Combat Identification
Joint Theater Missile Defense	Military Operations in Urbanized Terrain (MOUT)	
Joint Readiness & Logistics, and Sustainment of Strategic Systems	Force Projection/Dominant Maneuver	
Electronic Warfare	Chemical/Biological Warfare Defense & Protection, and Counter Weapons of Mass Destruction	
Combating Terrorism	Protection of Space Assets	Hard and Deeply Buried Target Defeat

Thus, any of the technologies that support space system operations can be applicable to these objectives; specific space-relevant technologies may be identified by cross-referencing the JWSTP document. A key example is Protection of Space Assets. While Protection is just one of several objectives in USSPACECOM's Space Control concept, it is considered a crucial national objective because space products and services are integral to joint warfighting capability and are becoming an increasingly important part of our national politics, economics, and culture.

Protection includes both active and passive defensive measures to minimize threats (natural and manmade) to space systems, including space platforms, links, launch assets, and ground segments. Five goals or operational capability elements (OCEs) are associated with the Protection of Space Assets objective, which are enabled by eleven functional capabilities, as illustrated below. These capabilities in turn provide focus for the technologies and S&T program efforts contained in the JWSTP as expressions of operational community priorities.

PROTECTION OF SPACE ASSETS

Enabling Functional Capabilities	Operational Capability Elements: Detect and Report Threats/Attacks	ID, Locate and Classify Threats	Withstand and Defend	Reconstitute and Repair	Assess Mission Impact
1. Hardening/Shielding of System Components	○	○	●	○	○
2. Developing Robust Battle Management	●	●	●	●	●
3. Improving System Maneuverability	○	●	●	●	○
4. Attaining Adequate Force Protection	●	●	●	○	○
5. Developing Adequate Defensive Information Operations	○	○	●	○	○
6. Threat Warning and Assessment Reporting	●	●	○		○
7. Space Weather Sensor Systems	●	●			○
8. Mobile Mission Processors			○	●	
9. Diagnostics and Repair Technology				●	●
10. Quick Launch Recovery			○	●	
11. Modeling and Simulation		○	○	○	●

Source: JWSTP, 2000

● Strong Support ○ Moderate Support

A growing recognition of the need for broader space control capabilities is adding impetus to the DoD's technology programs. Further, an increasing reliance on civil, commercial and international space systems will lead to the development of partnerships, laws and agreements to protect these assets against both natural and man-made hazards.

The DTOs and their demonstrations associated with the Protection of Assets objective are tabulated below. Their support for the associated OCEs, or goals, is shown in the accompanying matrix.

DEMONSTRATION SUPPORT for PROTECTION OF SPACE ASSETS

DTO	Demonstration	Operational Capability Elements: Detect and Report Threats/Attacks	ID, Locate and Classify Threats	Withstand and Defend	Reconstitute and Repair	Assess Mission Impact	Svc/ Agency	Type
N.01	Space Radiation Mitigation for Satellite Operations			●	●		AF	
N.02	Compact Environmental Anomaly Sensor II ACTD	●	●	○	●		AF	ACTD
N.03	Space Environments and Hazards	●	○				DTRA	
N.04	Satellite Passive Protection		○	●		○	AF	
NT.01	Nuclear Operability & Survivability Testing Technologies			●	●		Joint	
NT.02	Electronic System Radiation Hardening			●	○		Joint	
NT.05	Balanced Electromagnetic Hardening Technology			●	●		Joint	
NT.06	Survivability Assessments Technology			●	○	●	Joint	
NT.09	Nuclear Phenomenology	○	○	●	●		Joint	
SE.37	High-Density, Radiation-Resistant Microelectronics			●	○		AF	
SP.20	Spacecraft Propulsion/IHPRPT Phase I	○	○	●			AF	

DTRA Defense Threat Reduction Agency

IHPRPT Integrated High-Payoff Rocket Propulsion Technology

Source: JWSTP, 2000

● Strong Support ○ Moderate Support

The JWSTP associates DTOs with a full range of objectives under USSPACECOM's Space Control concept.

SPACE PROTECTION			
DTO	Title	DTO	Title
N.01	Space Radiation Mitigation for Satellite Operations	N.03	Space Environments and Hazards
N.02	Compact Environmental Anomaly Sensor II ACTD	N.04	Satellite Passive Protection

SPACE PROTECTION-RELATED			
DTO	Title	DTO	Title
A.13	Satellite C3I/Nav Signals Propagation Technology	NT.06	Survivability Assessments Technology
NT.01	Nuclear Operability & Survivability Testing Technols	NT.09	Nuclear Phenomenology
NT.02	Electronic System Radiation Hardening	SE.37	High-Density, Radiation-Resistant Microelectronics
NT.05	Balanced Electromagnetic Hardening Technology	SP.20	Spacecraft Propulsion/IHPRPT Phase I

SURVEILLANCE OF SPACE*			
DTO	Title	DTO	Title
D.03	Discriminating Interceptor Technology Program	SE.33	Advanced Focal Plane Array Technology
D.05	Advanced Space Surveillance	SE.38	Microelectromechanical Systems
HS.06	Joint Cognitive Systems for Battlespace Dominance	SE.58	Lookdown Bistatic Technology
HS.13	Human-Centered Automation Testbed	SE.59	Low-Light-Level Imaging Sensors
HS.21	Decision Support Systems for Command and Control	SE.61	Multiphenomenology Sensor Fusion for ATR and Tracking
HS.23	Immersive Interfaces and Visualization Techniques for Controlling Unmanned Vehicles	SE.65	Long-Wavelength and Multispectral, Large-Area, Staring Focal Plane Arrays
HS.28	Distributed Mission Warfighting Training Techniques and Technologies	SE.67	Hyperspectral Applications Technology

* See also A.28, Space-Based Space Surveillance Operations (SBSSO) ACTD, under JWSTP IV, Information Operations (described in Appendix G, p. G-3).

PREVENTION			
DTO	Title	DTO	Title
IS.38	Antenna Technologies	IS.50	Advanced Intelligence, Surveillance, and Reconnaissance Management

NEGATION			
DTO	Title	DTO	Title
WE.22	High-Power Microwave C2W/IW Technology	WE.43	Advanced Multiband Infrared Countermeasures Laser Source Solution Technology
WE.41	Multimission Space-Based Laser		

ATR Automatic Target Recognition
C2W Command and Control Warfare
IHPRPT Integrated High-Payoff Rocket Propulsion Technology
IW Information Warfare

Appendix F

LRP Roadmaps and Technologies

In its ***Long Range Plan: Implementing USSPACECOM Vision for 2020,*** USSPACECOM provided both broad conceptual statements of future space capabilities and a supporting infrastructure and roadmaps of the systems and underlying technologies needed to get there. The following charts are derived from these operationally driven roadmaps to help survey and analyze the technologies identified in a systems context by the operational community as preeminent in meeting their projected needs.

ASSURED ACCESS				
Key Capabilities	**Candidate Systems 98**	**05**	**12 / 20**	**Candidate Technologies**
Launch to Sustain Required Constellations for Peacetime Operations (100%) On-Demand Satellite Deployment (Days/ Hours) Recoverable Rapid-Response Transport to/through/from Space (2 - 6 Hours) Global Traffic Control (Integrated NRT) On-Demand Satellite Operations Execution (All Required) Integrated SATOPS Mission Planning (Minutes/NRT, Automated)	Atlas, Delta, Titan EELV Commercial Launch Services Range Standardi-zation and Automation Current Ground System Mobile/Trans-portable Systems ARTS Upgrade	AUS SMVs LOD Systems Space-Based Relay	Super Heavylift SOVs Space-Based Range Virtual Satellite Control Network	Reduced-cost launchers AUS: fuels, propulsion, power, avionics RLVs/SOVs, propulsion, fuels, structures, TPS, O&M, power, avionics, M&P LOD: Standard interfaces, M&P, O&M, load-and-launch payloads, shortened on-orbit checkout Improved weather forecasting Advanced antennas Precise on-board navigation Advanced human-computer interfaces Advanced tools for M&S Advanced processing Advanced/improved application software Standard Adaptive Comm'ns I/F

SURVEILLANCE OF SPACE				
Key Capabilities	**Candidate Systems 98**	**05**	**12 / 20**	**Candidate Technologies**
Real-Time Characterization of All HIOs (100%) Detect and Track with Precise Size and Location (LEO / GEO) (Size: 1 cm / 10 cm) (Loc: 10 m / 100 m) Timely Surveillance of HIOs (NRT) Catalog Monitoring (NRT)	FBXB Radar HAVE STARE FBXB Radar	SBEON RIDSN CoS BM S-Band Fence SBIRS-Low RIDSN	USSPACECOM BM GDIN	Spectral SAR ATR Processing Cross-Cueing MTI MSX Fusion Processing

PROTECTION				
Key Capabilities	**Candidate Systems**			**Candidate Technologies**
	98	**05 12**	**20**	
Detect and Report Threats (National Interest) Withstand and Defend (100%) Reconstitute and Repair (Hours/Days) Assess and Disseminate Mission Impact (Seconds) ID, Locate and Classify Source (Seconds)	Mobile Mission Processors N/UWSS	TW/AR N/UWSS Space-Based Relay CoS BM TW/AR RIDSN	On-board Protection Suites GDIN USSPACECOM BM SBR	AI Radiation Hardening and Shielding On-board Maneuvering On-board Diagnostics Cross-Cueing On-board Processing (See ***Surveillance of Space***)

PREVENTION				
Key Capabilities	**Candidate Systems**			**Candidate Technologies**
	98	**05 12**	**20**	
Detect and ID Unauthorized Use or Exploitation of U.S. and Third Party Space Capabilities (100%) (Detect/ID all systems with military utility) Assessing Mission Impact (100% in Minutes) (On all National and International systems) Timely, Flexible Denial (NRT, in Seconds)	N/UWSS LPI Encryption	CoS BM	USSPACECOM BM GDIN	On-board Detection LPI Encryption On-board Software Cross-Cueing

NEGATION				
Key Capabilities	**Candidate Systems**			**Candidate Technologies**
	98	**05 12**	**20**	
Flexible Effects (60% of total capabilities must offer reversible effects) Precision Attack (Negate 100% of adversarial space systems or services in all orbits) Employ on Demand (Minutes) (When required) Combat Assessment (100%, NRT)	Conventional Forces Relocatable RF Jammers Relocatable Lasers NMD GBIs GBL TOS NMD GBI	Small RF Kill Vehicle SBEON RIDSN S-Band Fence CoS BM	SBJ SBP SOV Space-Based Laser (SBL) GDIN USSPACECOM BM	Big Crow MIRACL KE ASAT HPM Technology Fusion Processing

INTEGRATED FOCUSED SURVEILLANCE

Key Capabilities	Candidate Systems 98 05 12 20			Candidate Technologies
Real-Time Target ID and Characterization (100% of Target Set) Ballistic and Cruise Missile Warning (Global) Locating Ballistic Missile Launch Point and Impact Point Prediction (Sub-Meter) Target Set Detection/ Surveillance/ Monitoring/ Tracking (Real-Time) Battle Management (NRT)	EWR DSP Theater Systems National Systems FBXB Radar Lower Tier Upper Tier THAAD SBIRS-High	SBIRS-Low GE BM	SBR, GDIN USSPACECOM BM	Auto Cross-Cueing Fusion Auto Recognition HSI USI Advanced EO MTI

MISSILE DEFENSE

Key Capabilities	Candidate Systems 98 05 12 20			Candidate Technologies
BMC3 (100%) On-Demand Missile Defense (Global, Minutes) Full-Spectrum Engagement (All Phases) Combat Assessment (100%, Real-Time)	PAC-3 Aegis Lower Tier GBI GBL	GE BM Upper Tier THAAD ABL	GDIN USSPACECOM BM SBL GDIN SOV HPM SBP	Auto Cross-Cueing Fusion Auto Recognition HSI USI Advanced EO MTI Ballistic Missile Replacement HPM

FORCE APPLICATION

Key Capabilities	Candidate Systems 98 05 12 20			Candidate Technologies
BMC3 (NRT) On-Demand Force Application (Minutes) Flexible Force Application (100% of Limited, Varied Target Set) Flexible Effects (30% Non-Lethal) Combat Assessment (100%, Real-Time)	CBM ACTD CBM (3 Assets) CBM with CAV	GE BM GBL w/ Mirrors	GDIN USSPACECOM BM SBL SBR	Auto Cross-Cueing Fusion Auto Recognition HSI USI Advanced EO MTI Ballistic Missile Replacement HPM Ordnance Technology Advanced Fusing and Guidance Systems

ABL	Airborne Laser
ACTD	Advanced Concept Technology Demonstration
AI	Artificial Intelligence
ARTS	Automated Remote Tracking System
ASAT	Anti-Satellite
ATR	Automatic Target Recognition
AUS	Advanced Upper Stage
BM	Battle Manager
BMC3	Ballistic Missile Command, Control and Communications
CAV	Common Aero Vehicle
CBM	Conventional Ballistic Missile
CoS	Control of Space
DSP	Defense Support Program
EELV	Evolved Expendable Launch Vehicle
EO	Electro-Optical
EWR	Early Warning Radar
FBXB	Forward-Based X-Band
GBI	Ground-Based Interceptor
GBL	Ground-Based Laser
GDIN	Global Defense Information Network
GE	Global Engagement
GEO	Geosynchronous Earth Orbit
HIO	High-Interest Object
HPM	High-Power Microwave
HSI	Hyper-Spectral Imagery
ID	Identification/Identify
I/F	Interface Facility
KE	Kinetic Energy
LEO	Low Earth Orbit
LOD	Launch on Demand
LPI	Low Probability of Intercept
LRP	Long Range Plan
M&P	Manufacturing and Processing
M&S	Modeling and Simulation
MIRACL	Mid-Infrared Advanced Chemical Laser
MSX	Midcourse Space Experiment
MTI	Moving Target Indicator
NMD	National Missile Defense
NRT	Near-Real-Time
N/UWSS	NORAD/USSPACECOM Warfighting Support System
O&M	Operations and Maintenance
PAC-3	PATRIOT Advanced Capability – Three
RF	Radio Frequency
RIDSN	Radar Imaging and Deep Space Network
RLV	Reusable Launch Vehicle
SAR	Synthetic Aperture Radar
SBEON	Space-Based Electro-Optical Network
SBIRS	Space-Based Infrared System
SBJ	Space-Based Jammer
SBP	Space-Based Platform
SMV	Space Maneuver Vehicle
SOV	Space Operations Vehicle
ST	Space Transport
THAAD	Theater High-Altitude Area Defense
TOS	Transportable Optical System
TPS	Thermal Protection System
TW/AR	Threat Warning/Attack Reporting
USI	Ultra-Spectral Imagery

Integrated Space Operations of the Future

Appendix G

Space Technology Demonstrations

The DoD conducts and participates in several series of technology demonstration programs. These demonstrations are normally competitively awarded to industry, and are designed to validate new technologies and approaches to meet military and other user requirements and new concepts of operation.

Integrated High-Payoff Rocket Propulsion Technology (IHPRPT) Demonstration Programs

Under the national DoD/NASA/U.S. industry IHPRPT program, the Air Force is teamed with NASA, the Army, the Navy and the major U.S. propulsion contractors in joint, goal-oriented planning and development of new technologies. These investments provide the foundation for new space propulsion capabilities and resolution of current propulsion-related problems. Eight programs are described below.

Boost and Orbit Transfer Propulsion

Demonstration	Objective	Descriptive Summary
Cryogenic Booster Engine	Demonstrate technologies critical for a low life-cycle cost (LCC), highly reusable rocket engine with a mean time between overhauls (MTBO) of >100 missions (current MTBO is <5)	These propulsion technologies will be demonstrated in a brassboard integrated engine configuration on a static test stand Reusable military orbital/suborbital vehicle concepts are generally believed to have the greatest potential for low cost. In addition, a truly on-demand vehicle could provide revolutionary military capability to address time-critical military missions. The limiting factor for reusability of these systems is their rocket propulsion. The life-limiting factors of the Space Shuttle Main Engine (SSME) have been identified and are being addressed to increase its margin of life
Cryogenic Upper Stage Engine	Demonstrate (in an engine configuration) high-energy upper stage propulsion with more than twice the thrust in the same volume and similar mass as the RL-10 Centaur engine	As the last stage of a multi-stage vehicle, upper stage propulsion has significant payoff leverage through mass reductions and performance increases. The technologies being developed allow a single engine to replace two engines (current Centaur), cutting the engine costs in half while increasing payload capability by up to 22%. For military launches this could save the military >$20 million per year
Solid Boost Motor	Demonstrate increased reliability, reduced cost and increased performance motor technologies in full-scale motor static tests Provide risk reduction for Strategic Sustainment	Historically, expendable and reusable space launch vehicles use high-thrust solid rocket motors to escape the Earth's gravity at low altitudes. Increased performance solid rocket boosters allow greater payload for the same launch vehicle or can allow launch vehicle step-down. Either of these results significantly reduces the cost per pound of payload to orbit. Increased performance, improved reliability and reduced hardware cost motor technologies are being developed to this end. In addition this technology can directly support variants of reusable systems that use relatively low-cost expendable solid stages being developed
Aging and Surveillance	Double our ability to predict the service life of a particular strategic missile motor from 5 to 10 years with 90% confidence, and halve the nondestructive evaluation (NDE) data processing time and cost	By decreasing uncertainty about (1) material properties measured *in situ,* (2) how they change with time, and (3) factors used in predicting motor service life, doubling of the "look-ahead window" is possible. Doubling this window will increase system availability and significantly reduce LCC. With a 10-year look-ahead, sufficient time exists to avoid premature and expensive motor remanufacture or replacement. Automating this improved understanding via NDE tools will enable ≥50% decrease in data reduction time and costs

Demonstration	Objective	Descriptive Summary
Post-Boost Control System (PBCS)	Identify and demonstrate low-cost and sustainable PBCS propulsion system technologies to replace expensive and/or unavailable technologies Reduce system cost by 25%	Existing solid propulsion uses expensive materials and processes for valves, propellant, and solid rocket motor cases. Titanium, HMX, TZM and niobium will be replaced with cost-effective and commercially available materials. In addition, improved valve response increases system efficiency and reduces the number of gas generator subassemblies
Missile Propulsion	Demonstrate solid rocket motor technologies applicable to the sustainment of strategic missile capability to improve existing systems or provide technology for the next generation of strategic missiles	Long life sustainable solid rocket motor technologies are critical to maintaining affordable intercontinental and sea-launched (ICBM and SLBM) strategic capability. This effort, along with Aging and Surveillance and PBCS, represent the current boost propulsion-related strategic sustainment technology efforts

Spacecraft On-Orbit Propulsion

Demonstration	Objective	Descriptive Summary
High-Performance Hall Thruster	Demonstrate highly efficient spacecraft propulsion for increased satellite maneuvering (up to 5x), increased on-orbit life (up to 4x) Perform combined station-keeping and orbit raising, thereby increasing payload capability	Decreasing the need to replace on-orbit assets could drastically reduce operational costs by eliminating some launches. Critical system availability would be improved. The new Hall thruster system may improve this capability significantly
Solar Thermal	Demonstrate the feasibility of a new type of propulsion system with payoffs in niche missions like highly elliptical orbits and a revolutionary space tug capability	Demonstration of this propulsion system includes ground testing for performance and mass properties. Pointing and control accuracy will be demonstrated on-orbit This new type of propulsion uses concentrated sunlight to heat propellants and expand the resulting gases through a nozzle to provide thrust. Much higher propulsion efficiency can be attained than via conventional chemical or electric propulsion systems

HMX Cyclotetramethylene Tetranitramine (an oxidizer)

TZM Titanium-Zirconium-Molybdenum (a molybdenum alloy)

Highly Reusable Propulsion System Development

Among DoD-owned space technology demonstration programs, some are designated as Advanced Concept Technology Demonstrations (ACTDs), others as Advanced Technology Demonstrations (ATDs). The ATDs focus on the hardware-software functions in a system-development environment, while the ACTDs also include operator participation, concept of operations (CONOPS) considerations, and questions of military utility. Notable examples sponsored by Defense Agencies and the Military Services are summarized below.

DARPA Space Technology Demonstration Programs

Demonstration	Objective	Descriptive Summary
Discoverer II **(Tech Demo)**	Addressed the feasibility of moving target detection using an affordable space-based radar. Program intended to lead to a space-based reconnaissance and surveillance system in the 2010 time frame	Joint DARPA, Air Force, NRO and Army activity Goals: theater-wide, day/night, all-weather, near-continuous high-resolution radar (HRR)-GMTI search and track; very-high-resolution SAR imagery; and DTED generation. Planned to include on-demand, theater-tasked intel collection, along with direct, near-real-time downlink to theater to address tactical user objectives Program also intended to explore satellite constellation control concepts (to include payload control for other missions), space-based radar (SBR) feasibility, and SBR with GMTI and SAR imaging to test space-based sensor support to operations Elevation of radar air and ground surveillance to space wanted to enable continuous global coverage of larger areas/volumes while increasing system survivability Terminated for FY01
Orbital Express **(ATD)**	Demonstrate concepts for autonomous satellite servicing to enable a broader range of satellite operations, longer satellite life, and more maneuver-able satellites (due to fuel replenishment) Standardize and modular-ize spacecraft designs for ease of interface on orbit	DARPA program for research, development and on-orbit demonstration of robotic techniques for on-orbit refueling and reconfiguration of satellites, and for preplanned satellite electronics upgrade. The servicing spacecraft will be an on-orbit micro-shuttle designated Autonomous Space Transporter and Robotic Orbiter (ASTRO), which will be able to access satellites at all orbital altitudes and in different planes. New fuel options will be analyzed Potential support for a broad range of future U.S. national security and commercial space programs Reprovisioning capabilities on orbit could make space operations "routine" Design competition in FY00 Launch planned for FY04

NRO Space Technology Demonstration Program

Demo	Objective	Descriptive Summary
Space Technology Experiment **(STEX)** **(ATD)**	Demonstrate state-of-the-art, very-low-cost space-craft designed to support operational requirements while testing and maturing enabling technologies for next-generation space intel collection systems	NRO's first unclassified satellite. Demonstrated a streamlined approach to acquisition and management that incorporated performance-based specifications and leveraged contractor best practices. Tested more than two dozen advanced technology subsystems for satellites. Ops terminated early June 1999 for a solar array failure. Valuable lessons learned for streamlined acquisition management

BMDO Space Technology Demonstration Programs

Demonstration	Objective	Descriptive Summary
Midcourse Space Experiment (MSX)	Observe and characterize shuttle plumes from MSX satellite	Early warning/surveillance project to explore space-based sensor capabilities to see and characterize missile-type targets in midcourse phase. (See Air Force's SBSSO) Launched Apr 96
Space Technology Research Vehicle series (STRV)	STRV 1c/1d: Test structure, radiation effects, space environment	BMDO-UK Ministry of Defence (MoD UK) NASA, Air Force, European Space Agency (ESA) collaboration to test multiple advanced space technologies on two 100-kg microsats: multifunctional structure, radiation susceptibility, advanced common communications protocol, space environmental effects measurements Launch planned for late-2000
	STRV-2: Test space-ground laser communications	BMDO-MoD UK communications/navigation and future satellite technology/architectures project. Aircraft detection by thermal contrast Launch in 2000

Space Technology Research Vehicle (STRV) 1c/1d

STRV supports risk-reduction flight tests of improved satellite technologies designed to enhance future capabilities of communication, navigation and surveillance space systems

Air Force Space Technology Demonstrations

Demo	Objective	Descriptive Summary
Space-Based Space Surveillance Operations (SBSSO) (ACTD)	Conduct space surveillance operations in space to advance technologies needed for SBIRS-Low and support the Space Surveillance Network (SSN)	Midcourse Space Experiment (MSX). BMDO-sponsored early warning/surveillance project that successfuly demonstrated sensor functionality from space by collecting midcourse target and background data. Observed and characterized shuttle plumes from MSX satellite. Used a long-wavelength infrared (LWIR) sensor whose cryogen cooling has since been exhausted. MSX/Space-Based Visible (SBV) Sensor. Using the MSX/SBV sensor as an on-orbit testbed for space surveillance. The SBV instrument is demonstrating above-the-horizon (ATH) surveillance of missiles, RSOs and backgrounds using a non-cooled visible-to-very-near-IR band sensor. Assets are currently operating as an AFSPC-controlled contributing sensor to USSPACECOM's SSN, with BMDO pursuing its MSX objectives on a non-interference basis.

Demonstration	Objective	Descriptive Summary
Compact Environmental Anomaly Sensor II **(CEASE II)** **(ACTD)**	Monitor elements of the space environment known to produce harmful effects on space systems and provide real-time alerts to the host spacecraft.	USSPACECOM-Air Force-NRL-supported ACTD. Small, low-power, low-mass instrument resident on host spacecraft. Two-year period on orbit to show ability of CEASE II to reduce anomaly resolution time and increase situational awareness. Benefits could include reduced satellite downtime and user impact from satellite malfunctions, and improved ability to rule out hostile actions. CEASE II to be on DSP-21 for launch in 2000.
MightySat II **(ATD)**	Demonstrate high-payoff space system technologies in on-orbit "labs" to ensure readiness for operational missions.	MightySat II involves a series of AFRL-designed multi-mission 300-lb spacecraft. The two MightySat II payload classes are: • *Experimental Bus Components,* to include: Solar Array Concentrator (SAC); NRL's miniature Space Ground Link System Transponder (NSX); and Multi-Functional Composite Bus Structure (MFCBS). • *Stand-Alone Experiments,* to include: Fourier Transform Hyperspectral Imager (FTHSI); Quad-C40 processor (QC40); Shaped-Memory Alloy Thermal Tailoring Experiment (SMATTE); and Solar Array Flexible Interconnect (SAFI). MightySat II.1 launched 19 Jul 00
Integrated Space Technology Demonstration **(ISTD)** **(ATD)**	Demonstrate advanced technologies and assess them for operational use. Determine cost/benefits of leveraging DoD, civil and commercial spacecraft.	A series of ATDs to address AFSPC mission needs by testing emerging technologies from AFRL, other Government labs and industry in system-level operational demonstrations for the user community. These technologies will be demonstrated in three-year cycles to assess: • Their state-of-the-art capabilities; • Their applicability to specific operational needs; and • Cost reductions achievable by leveraging non-dedicated spacecraft. These demos aboard DoD, civil and commercial spacecraft will both reduce direct costs and show how to provide operational capabilities at a fraction of the cost of dedicated military systems. First launch (in March 1994) was the Technology for Autonomous Operational Survivability (TAOS) satellite, which remains on orbit following experiment completion in Aug 00. Second launch, Warfighter I, planned for early-2001

MightySats will provide orbital testbeds for advanced satellite technologies, such as multifunctional structures and miniaturized avionics.

MightySat II.1 is already demonstrating a new on-board processing technique for HSI imaging data

Demonstration	Objective	Descriptive Summary
XSS-10 **(ATD)**	Fly an integrated microsatellite system to demonstrate and assess space-servicing technologies via such smaller satellites.	The XSS-10 is a microsatellite demonstration program to support AFSPC requirements for space support/servicing. Once on orbit, the 30-kg microsatellite will conduct autonomous operations around the Delta II second stage, to include a six-point inspection of the second stage and tracking a resident space object (RSO; e.g., an active payload, rocket body, upper stage, or space debris). Launch planned for late-2001
Comm/Nav Outage Forecasting System **(C/NOFS)** **(ACTD)**	Demonstrate capability to warn of outages to GPS navigation and satellite communications links due to the near-Earth space environment events.	Instrument resident on GPS spacecraft. C/NOFS will specify and forecast equatorial scintillation in the ionosphere to allow preemptive selection of backup systems and alternate links, aid anomaly resolution, and facilitate operational planning. Anticipate reduced GPS link outages from ionospheric scintillation events. AFSPC-sponsored FY00 ACTD. Launch planned for 2003
TechSat 21 **(ATD)**	Demonstrate utility of small groups of microsatellites flying in close proximity to perform missions otherwise performed by larger, monolithic satellites.	TechSat 21 is a formation of three satellites to create a "virtual satellite," using crosslinks for distributed operations and processing (like a PC network). They will have precise differential GPS positioning, intersatellite ranging and communication, micro-propulsion, and X-band antennas to perform sparse aperture sensing, geolocation, and communications. Expectations include: • Low-cost mass manufacturing; • Reduced launch costs; • Increased total sensor aperture and resolution; • Reconfigurability to perform several missions; and • Multi-satellite robustness. TechSat 21 will also be proof-of-concept for mass production of identical satellites with far less total weight than an equivalent large satellite. Fully funded in the Air Force S&T budget. Launch planned for 2003.

Comm/Nav Outage Forecasting System (C/NOFS)

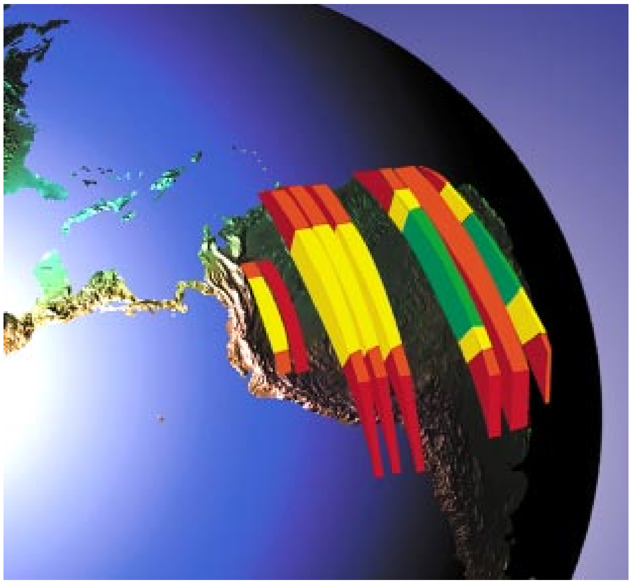


Illustration of C/NOFS predictions of communication/navigation system outages in equatorial latitudes.
C/NOFS is the Air Force's top-ranked Advanced Concept Technology Demonstration (ACTD)

Demonstration	Objective	Descriptive Summary
Space-Based Laser Integrated Flight Experiment **(SBL IFX)** **(ATD)**	Demonstrate operation and effectiveness of a high-energy laser system vs. a boosting missile target	IFX to progressively test and demonstrate high-energy laser capabilities against theater and national missile targets in boost phase, to include SBL operations and lethality SBL IFX jointly funded by Air Force S&T funds and BMDO. Supporting work will include follow-on acquisition processes and operational concepts. Full-scale integrated system ground test planned for FY07; and spacecraft launch projected for 2012.
Adaptive Sensor Fusion (ASF) **(ATD)**	Build an open, standards-based architecture for information fusion.	The fusion architecture includes an adaptive fusion manager to optimize the performance of the selected group of fusion engines to provide effective and complete use of the available sensor data. The ASF system is planned to have standard data and application interfaces to maximize interoperability among different fusion systems. It will be designed to optimize fusion algorithms, parameters, models and configurations according to specified user needs, situational changes, and available fusion engines. Four "spiral" ASF software development models should lead to a hardened system for operational use.
Moving Target Indicator (MTI) Exploitation Tools Program **(ATD)**	Develop automated tools to exploit MTI data from current and future sensor systems to enable them to locate, identify and track high-value moving targets.	This ATD expands the DARPA-AFRL Moving Target Exploitation (MTE) program. To help C2 and weapons operators, it will develop algorithms in four technology areas: • Ground moving target tracking; • Motion pattern analysis; • Behavioral pattern analysis; and • Resource allocation and scheduling. The first three will comprise an operators' tool set to exploit MTI data for a more comprehensive battlespace picture. The fourth will help detect, track and exploit moving targets (ground and air).
Hyperspectral Information Fusion **(ATD)**	Develop software tools to enable DoD image analysts to fuse HSI information with other intelligence sources to consolidate the exploitation report.	The Battlespace Analyst needs to correlate products of various sensors and intelligence sources (INTs) to extract objects of interest (OOIs). A suite of tools will be developed to fuse HSI sets with data from various INTs and both EO and radar sensors. A stand-alone HSI viewer will access hyperspectral databases and select appropriate scenes. An exploitation toolkit will enhance mission-specific OOIs relative to their background and also locate other potential OOIs.
Collaborative Virtual Environment for Space Systems and Missions **(ATD)**	Develop information, visualization, human-computer interface (HCI) and simulation technologies for Collaborative Engineering that permit joint teams to design and evaluate advanced concepts for missions, systems, subsystems, and sensors.	This ATD will demonstrate a virtual environment for both simulations and operations that provides the flexible interface needed for space system control and operations. Its Virtual Collaborative Environment will comprise: • A domain-independent framework for information exchange across multiple disciplines; and • A set of domain and mission-dependent tools. The framework unites the physical assets, processes and personnel needed to accomplish an enterprise task. Distributed collaborative environments will allow the entire enterprise team to solve problems simultaneously via a common set of models, simulations, databases, and tools.

Navy Space Technology Demonstration Programs

Demonstration*	Objective	Descriptive Summary
Microelectronics and Photonics Testbed (MPTB)	Test commercial off-the-shelf (COTS) devices in the space radiation environment and determine their optimal orbits	Future satellite technology/architecture experiment to test performance, reliability and survivability of new microelectronic and photonic devices and subsystems in a high-radiation orbit. With radiation-hardened components in short supply, COTS devices will be needed to achieve order-of-magnitude performance improvements for future space subsystems. Launched Nov 97
Polar Ozone and Aerosol Measurement III (POAM III)	Measure ozone and aerosol at polar latitudes	Weather/space environment project Launched Mar 98
Unconventional Stellar Aspect (USA)	Autonomous navigation using X-ray sources	Communications/navigation project Launched Feb 99
High Temperature Super-conducting Space Experiment II (HTSSE II)	Space testbed for high temperature superconducting devices	Future satellite technology/architectures project to demonstrate feasibility of incorporating high-temperature superconductor (HTS) components into communications and signal processing subsystems. HTSSE II will also demonstrate an advanced mechanical cryocooler option for FPAs and cooled semiconductors. Launched Feb 99
High Resolution Airglow/Aurora Spectroscopy (HIRAAS)	Flight test Special Sensor Ultraviolet Limb Imager (SSULI) sensor for DMSP	Weather/space environment project Launched Feb 99
WindSat	Use polarimetry to measure sea-surface wind vectors from space	Navy-DOC weather/space environment project to demonstrate the ability of a polarimetric microwave radiometer to measure wind speed and direction for use by operational Navy units and to reduce risk for NPOESS's Conical Microwave Imager Sounder (CMIS). WindSat is the primary payload on the DoD Space Test Program (STP)'s Coriolis mission. Launch planned for 2001
CloudSat	Measure altitude of cloud tops and bottoms	Weather/space environment project Launch planned for 2003
Modulating Retro-Array in Space (MODRAS)	Test space-space and ground-space laser communications with miniature sensor	Communications/navigation project to demonstrate a simple, compact, lightweight means of optical data transfer in free space by eliminating the need to fly a laser and gimbaled telescope. Long-term goal of data rates > 1 MB/sec in the near-IR band (0.8 – 1.06 µm). Launch planned for end-FY03
Indian Ocean METOC Imager (IOMI)	Demonstrate revolutionary hyperspectral atmospheric characterization	Navy/NASA project to validate advanced technologies for civil and military weather observation and forecasting. Using NASA's Geostationary Imaging Fourier Transform Spectrometer (GIFTS) instrument, IOMI will make altitude-resolved "water vapor" winds measurements from GEO and downlink real-time data to the fleet. Launch planned for early FY05
Full-Sky Astrometric Mapping Explorer (FAME)	Update star catalog for Navy navigation, precise time-keeping, and surveillance	Navy-NASA communications/navigation project to provide observations over a 2.5 – 5-year period to catalog the positions, proper motions and parallaxes of 40 million stars. This will be the first space-based test of technology for optical interferometry. Launch TBD

* All ATDs.

Demonstration*	Objective	Descriptive Summary
Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC)	Test microsat constellation for global weather prediction	Navy-NASA-NSF-NOAA weather/space environment project Launch TBD
Remote Atmospheric and Ionospheric Detection System (RAIDS)	Full characterization for improvement of DMSP instrument database	Weather/space environment project Launch TBD

CloudSat

CloudSat will provide the first global survey of cloud profiles and their physical and optical properties, which will serve to improve predictions of weather and climate. On-board instruments will include an optical imager, a near-IR spectrometer, and a millimeter-wave radar

* All ATDs.

Army Space Technology Demonstration Programs

Demonstration	Objective	Descriptive Summary
Laser Communication	Provide secure, wide-bandwidth, line-of-sight laser communications	Development of wide-bandwidth, secure, space-to-ground two-way communications; integrates into the Army's point-to-point tactical communications ATD
Battlefield Ordnance Awareness (BOA)	Provide real-time location and ID of ground explosive ordnance events	Development of infrared air/space sensor technical requirements for systems to support information dominance and deep strike capability
Overhead Sensor (OHS) Technology for Battlefield Characterization	Provide real time multi-/hyperspectral battlefield intelligence	Development of infrared multi-/hyperspectral space sensor technical requirements for systems to support force protection and Intelligence Preparation of the Battlefield (IPB)
Space Surveillance	Provide capability to determine in-theater satellite operational status	Development of tactical radar capability to determine satellite sensor field of regard and operational status
On-the-Move Tactical SATCOM Technology	Provide an on-the-move SATCOM ground terminal capability	Development of ground terminal software protocols and techniques applicable to all communications satellite constellations for rapid signal recovery from terrestrial object blockages
Battlespace Tactical Navigation (BTN)	Improve robustness of navigation systems and minimize registration errors	Development of pseudolites, anti-jam technology, and back-up navigation capabilities for GPS
Tactical ISR	Provide an integrated Red and Blue Force picture	Project to provide communications, networking, software and sensor integration for the Brigade Commander
Point-Hit Multiple Launch Rocket System (MLRS)	Provide precision guidance package and ways to transmit GPS corrections to tactical missiles	Development of jam-resistant GPS guidance package for MLRS and equipment/techniques for corrected GPS signals to missiles
Handheld C2 Wireless Communications (HC2WC)	Provide capability to pass mission-critical information between commanders and forward-deployed forces	Army Space Exploitation and Demonstration Program (ASEDP) project to develop a lightweight, satellite enabled communications system that provides two-way, over-the-horizon communications with Blue-Force tracking, targeting/intelligence data for dismounted troops
Enroute Mission Planning and Rehearsal System (EMPRS)	Provide enroute planning and rehearsal support to a deploying commander	ASEDP project to develop the capability to provide enroute planning and mission rehearsal using emerging communications technology and software
Tactical Weather Integrated Meteorological System (IMETS)	Provide a weather support architecture that enhances the Army's IMETS	ASEDP project to develop capabilities to provide mission-focused forecasts, real-time weather imagery, weather effects assessments, and digital overlays
Precision SIGINT Targeting System (PSTS)	Provide precision targeting data with reduced sensor-to-shooter timelines	ASEDP project to develop the capability to provide precision targeting data with reduced sensor-to-shooter timelines by exploiting existing tactical communications architectures and leveraging black/white air/space sensor integration
Eagle Vision II (EV II)	Provide in-theater near-real-time satellite optical and radar imagery	ASEDP project to develop an in-theater near-real time direct downlink capability for commercial optical and radar satellite imagery

Space Test Program

Background

In 1966, the DoD established the interagency Space Test Program (STP) to evaluate space experiments and facilitate access to space for those selected. It conducts space missions to demonstrate advanced technologies in operational space environments to help reduce risks. With the Air Force as executive agent, the STP has supported spaceflight for the Army, Navy and Air Force, the NRO, NASA, NOAA, BMDO, DOE, and other sponsored agencies and stakeholders.

The multi-agency Space Experiments Review Board (SERB) meets annually to review and rank candidate space experiments from the various government agencies. The STP process then seeks out the most cost-effective means of spaceflight for the maximum number of experiments, consistent with available funding, experiment priority, and launch opportunity. Depending on each experiment's requirements, the STP can provide launch services, a host spacecraft and up to a year of on-orbit operations. Launch opportunities include a medium launch vehicle every four years, a small launch vehicle biennially, inclusion as a secondary payload on other expendable launch vehicles, or access to Space Shuttle launches and the future International Space Station (ISS). Sponsoring agencies are responsible for funding all other costs of their experiment.

Current Technology Initiatives

At present, the STP is supporting 33 experiments in six categories, as tabulated below.

Category	Experiments	Sponsors	Objective	Launch
Communications/ Navigation	• Comm/Nav Outage Forecast System (C/NOFS)	Air Force	- Characterize and predict outages in equatorial latitudes (4 – 6-hr forecasts)	Feb 03
	• Full-Sky Astrometric Mapping Explorer (FAME)	Navy NASA	- Update star catalog for navigation and time-keeping	TBD
	• Modulating Retro-Array in Space (MODRAS)	Navy	- Test space-space and ground-space laser communications with miniature sensor	Sep 03, STS-128
	• Space Technology Research Vehicle (STRV) series: - STRV 1c/1d - STRV 2	BMDO (et al) BMDO MoD UK	- STRV 1c/1d: Communication protocol, aircraft detection, contamination - STRV 2: Test space-ground laser communications	Late-00 Ariane 5 Jun 00, TSX-5/ Pegasus XL
	• Unconventional Stellar Aspect (USA)	Navy	- Autonomous navigation using X-ray sources	Feb 99, ARGOS/ Delta II
Early Warning/ Surveillance	• Active Cleaning Experiment for SBIRS Low (ACSBIRS)	Air Force	- Demonstrate ability to actively clean SBIRS optics in space	Dec 00, STS-107
	• Critical Ionization Velocity (CIV)	Air Force	- Help identify plume and wake signatures of space and launch vehicles	Feb 99, ARGOS/ Delta II
	• MightySat II.1	Air Force	- Demonstrate multi-functional structures and hyperspectral imaging using Fourier transform processing	19 Jul 00, OSC Minotaur
	• Midcourse Space Experiment (MSX)	Air Force (now)	- Observe and characterize shuttle plumes from MSX satellite	Jul 99, STS-93
	• Satellite Threat Warning and Attack Reporting (STW/AR)	Air Force	- Identify and report hostile attack against satellites	Dec 00, STS-107

Category	Experiments	Sponsors	Objective	Launch
Future Satellite Technologies/ Architectures	• High Temperature Super-conducting Space Experiment II (HTSSE II)	Navy	- Space testbed for high temperature superconducting devices	Feb 99, ARGOS/ Delta II
	• Lightweight Flexible Solar Array Hinge (LFSAH)	Air Force	- Test lightweight flexible solar array hinge	Jul 99, STS-93
	• Microelectromechanical Systems for Space Applications 1 (MEMS 1)	Air Force	- Space testbed for microelectro-mechanical devices	Jul 99, STS-93
	• Microelectronics and Photonics Testbed (MPTB)	Navy	- Space testbed for opto-electronic components	Nov 97
	• Mid-deck Active Controls Experiment II (MACE II)	Air Force	- Artificial intelligence algorithms to control attitude and pointing	Jul 00, STS-100
	• MightySat I	Air Force	- Test high-efficiency solar cells	Dec 98, STS-89
	• STRV 1c/1d • STRV 2	BMDO (et al) BMDO MoD UK	- Multifunctional structures, radiation susceptibility of advanced electronics - Test active vibration damping	Late FY00 Ariane 5 Jun 00, TSX-5/ Pegasus XL
	• Nanosat Constellation	Air Force NASA	- Test formation flying and microthruster propulsion	TBD
	• Materials on the International Space Station Experiment (MISSE)	Air Force NASA Industry	- Investigate space environment effects on various materials for future spacecraft and space vehicles	Jun 01
	• TechSat 21	Air Force	- Space-Based Radar mission using microsat constellation	2003

Tri-Service Space Experiment (TSX) Missions

TSX missions will flight test a variety of space technologies, to include laser communications and active vibration damping for space-based optics. TSX Mission 5 is also demonstrating an ability to alert spacecraft of disruptive radiation and electrostatic conditions

Category	Experiments	Sponsors	Objective	Launch
Low-Cost Launch	• EELV Secondary Payload Adapter (ESPA)	Air Force	- Allows inexpensive launch of up to six small satellites using excess margin (in development)	TBD
	• Electric Propulsion Space Experiment (ESEX)	Air Force	- Electric arcjet for high-efficiency station keeping and reduced launch cost	Feb 99, ARGOS/ Delta II
	• Space Maneuver Vehicle (SMV)	Air Force NASA Boeing	- Test support for captive, atmospheric and orbital flight tests of NASA's X-37 air and/or space test vehicles	Aug 98
Nuclear Treaty Verification	• Array of Low Energy X-ray Imaging Sensors satellite (ALEXIS)	DOE	- Test and demonstrate capability for monitoring space-based nuclear detonations	Apr 93, Pegasus
	• Fast On-Orbit Recording of Transient Events (FORTE)	DOE	- Enhanced signal detection for weak nuclear bursts	Aug 97, Pegasus XL
	• Multispectral Thermal Imager (MTI)	DOE	- Precision radiometric imaging and thermometry	Mar 00, Taurus
	• Space Atmospheric Burst Reporting System Space Validation Experiment (SAVE)	Air Force	- Report on atmospheric or space nuclear bursts	FY03, DSP-23/ Titan IV
Weather/Space Environment	• CloudSat	Navy NASA	- Measure altitude of cloud tops and bottoms	2003
	• Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC)	Navy NASA NSF NOAA	- Test microsat constellation for global weather prediction	TBD
	• STRV 1c/1d	BMDO (et al)	- Fluctuation of Van Allen Belt	Late FY00 Ariane 5
	• Hard X-Ray Spectrometer (HXRS)	NOAA	- Predict high-energy flares and proton storms	Feb 00, MTI/Taurus
	• High Resolution Airglow/ Aurora Spectroscopy (HIRAAS)	Navy	- Flight test Special Sensor Ultraviolet Limb Imager (SSULI) sensor for DMSP	Feb 99, ARGOS/ Delta II
	• Polar Ozone and Aerosol Measurement III (POAM III)	Navy	- Measure ozone and aerosol at polar latitudes	Mar 98, SPOT IV/ Ariane IV
	• Remote Atmospheric and Ionospheric Detection System (RAIDS)	Navy	- Full characterization for improvement of DMSP instrument database	TBD, STRIPE
	• WindSat	Navy DOC	- Flight test microwave polarimeter for measuring sea-surface winds, risk reduction for NPOESS instrument	Dec 01, Coriolis/ Titan II
	• Solar Mass Ejection Imager (SMEI)	Air Force	- Provide 2-3 day warning of geomag-netic storms	Dec 01, Coriolis/ Titan II

Contributions to National Security Space

As shown above, the multi-agency STP has supported DoD and several other agencies' space demonstrations in pursuit of common and compatible goals. During its 34-year history, the program has flown 147 missions carrying 407 experiments into space with a greater than 90% success rate. A few key accomplishments:

- In the 1970s, the STP flight-tested prototype rubidium and cesium atomic clocks, which evolved into today's GPS system.
- In the 1980s, STP tests of auroral and ionospheric remote sensing demonstrated UV sensor monitoring, which was later implemented on DMSP.
- During the 1990s, STP support for DARPA and Orbital Sciences helped to develop the Pegasus and Taurus launch vehicles, which are the premier small launch vehicles in the world today.
- STP partnership with NASA's Goddard Space Flight Center resulted in a public "Access to Space" data base, which lists space flight opportunities for DoD, Civil, University and Corporate space experimenters.
- Using Foreign Comparative Technology funding, the STP collaborated with Surrey Satellite Technology, Ltd., of the UK to build the 65-kg PicoSat satellite.
- In cooperation with NASA, the STP provided launch for the first-ever South African (Sunsat) and Danish (Orsted) satellites on the ARGOS/Delta II launch in Feb 99.
- The STP supported BMDO and its other national and international partners by manifesting experiments on the Space Technology Research Vehicles (STRV) 1c and 1d, launched on an Ariane 5 in 4Q FY00.
- The program has a long history of collaboration with the NRO.

Space technologies currently under STP-supported test will provide risk reduction:

- Over the next 5 years to DMSP, GPS, SBIRS, EELV, and NPOESS. For example, the STP-managed Coriolis mission provides spaceflight for the Navy's Windsat instrument. This mission is the #1 near-term risk mitigation effort for the DOC/DoD/NASA-sponsored NPOESS program; and
- During the next 5 to 10-year span, to mid-term programs like the SBL, SBR, Military Space Plane, and a Space-Based Hyperspectral Imaging System.

Finally, STP missions are demonstrating emerging space technologies such as MEM devices, distributed microsatellite systems, and multifunctional structures that will enable new, as yet undefined, space systems for the U.S. Government in the next 10-20 years. Thus, the STP is postured to continue its historical role as the premier DoD process for on-orbit testing of the most promising technologies in support of the nation's future defense space systems.

Appendix H

Other Federal Agencies

The primary non-DoD agencies developing technologies that also support national security space objectives are NASA and the DOE. Both agencies pursue a wide variety of space-related or potentially -related technologies, many of them as lead-agencies in proprietary or niche areas under a national security space umbrella, even as they pursue their own national responsibilities.

Summaries of their activities, many of them in partnership with DoD, are tabulated below.

NASA

Agency Approach

NASA has changed its approach from "technology driven by missions" (i.e., the desirability of scientific objectives and opportunities), to "missions enabled by technologies" — where "technology investments for generic classes of . . . missions are made in advance, [but] specific missions are not approved . . . until the enabling technologies have matured."[*]

NASA's Technology Strategy

To counter the shorter-term focus exercised by "mission pull," NASA has identified "technology-push" areas deemed strategically important to achieving ambitious future NASA missions. Six are identified as **Strategic Technology Areas:**[#]

• Advanced miniaturization	• Self-sustaining human support
• Intelligent systems	• Deep space systems
• Compact sensors and instruments	• Intelligent synthesis environments

Five are of immediate and continuing relevance to national security space objectives, and even the sixth, human support, will be of interest if or when human forces need to be deployed in space.

Four additional areas aligned with the commercial space industry and designated **Space Industry Sectors**, also have relevance to DoD areas of focus:

• Space transportation	• Remote sensing
• Communications	• In-space processing

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* *NASA Technology Plan*, Section 1.2, 3d paragraph.

\# Idem, Section 2.3, 2d paragraph.

Space Enabling Technologies for NASA's Strategic Technology Areas

NASA identifies the enabling technologies associated with its Strategic Technology Areas as tabulated below.

Strategy Technology Area	Enabling Technologies	
Advanced Miniaturization (Key Enabling Technologies)	• Micro- and Nano- Devices: – Micro and nano electronics – Photonics – Superconductivity – Micromagnetics – Quantum wells – Detector devices – Device physics and modeling – Advanced materials – Material & device fabrication and characterization • Computation, Avionics, and Communications: – Revolutionary computing — Biological/DNA, quantum, single electron, superconducting – Neural networks – Optical processing – Scalable, fault tolerant, flight computer – Avionics sensors – Low-power electronics – Radiation resistant materials and architectures – Innovative radiation shielding – Wireless sensors & systems – Monolithic Microwave Integrated Circuits (MMIC)	• Microelectromechanical Systems (MEMS): – Micromachining techniques – MEMS sensors — Physical, chemical, biological – MEMS actuators – Micro-optics and optoelectronics – Radio frequency components – LIGA (Lithographie Galvanoformung Abformung) – Integration and packaging – Space environmental compatibility — Radiation, temperature, shock,failure mechanisms, reliability • Microsystems: – System on a chip – mixed signal systems – Smart sensors – Architecture & systems analysis – Hybrid bonding & packaging – Reliability modeling – Systems simulation & test – Distributed networked microsystems – Microspacecraft – Microprobes – Nanorovers/nanorobots – Constellations, microprobe networks – Vehicle health monitoring system
Intelligent Systems (Pacing Technical Issues)	• Automated Reasoning Research • Human-Centered Computing	• Intelligent Systems for Data Understanding
Compact Sensors and Instruments (Pacing Technical Issues)	• Receivers/Detector Systems • Compact Instrument Architectures	• Active Sensor systems • Integrated Payloads
Self-Sustaining Human Support (Goals for Advanced Power Technologies)	• Advanced Power Technology: – Fuel Cells – Photovoltaics – Energy Conversion – Power Management – Reactors	• Goals: – 20,000-hr life – >400 Whr/kg – 30% efficiency – 300 W/kg – Large deployable structures – >25% Brayton – >15% static conversion – >2000V (DC/AC) distribution and control – >25 W/kg (system level)

NASA's X-33 Reusable Launch Vehicle (RLV) Prototype

<table>
<tr><th>Strategy Technology Area</th><th colspan="2">Enabling Technologies</th></tr>
<tr><td>Deep Space Systems
(Key Enabling Technologies)

Featuring:
Computing
Autonomy
Small, inexpensive launch vehicles
Small, sophisticated robotic spacecraft
Lightweight highly efficient propulsion
Extremely long-range communications
that will pace military systems</td><td>• <u>Electric Power</u>:
– Power generation (solar energy conversion, on-board nuclear power sources if beyond solar energy exploitation)
– Energy storage (for primary power or when cyclical power is inadequate)
– Power and thermal management technologies
• <u>Propulsion</u>:
– Propulsion systems whose mass decreases faster than their spacecraft's, while increasing in propulsive efficiency (e.g., electric and ion propulsion systems
• <u>Robotics</u>:
– Technologies to support planetary landers/ rovers, to include subsurface explorers and chemical analysis capabilities
• <u>Other Selected Technologies</u>:
– Aerocapture and aeromaneuvering
– Thin-film materials for large membranes
– Autonomous operation of remote spacecraft constellations or fleets; formation control</td><td>• <u>Communications</u> – major advances needed in:
– Ka-band and optical frequency equipment
– Spacecraft antennas (larger and lighter)
– Thermally stable lightweight optics
– Data compression techniques to 100x, with negligible image distortion
– Error correction coding for both RF and optical channels pushed to channel limits
– Low noise temperature, large aperture receiving systems (ground-based or on orbit, radio and optical)
– Ultrastable frequency sources (space and ground)
– Lightweight "plumbing" to keep pace with size and weight reduction of avionics
– Low mass/power acquisition and tracking systems using uplink optical beacons for beam pointing
– Efficient short-range communications at 400 MHz to 2.4 GHz
– Effective integration of all deep-space communications components</td></tr>
<tr><td>Intelligent Synthesis Environments</td><td colspan="2">These will provide:
• "NASA's future engineering and science design and development environment, which links leading-edge technologies to establish a widely distributed, integrated collaborative virtual environment for designing, testing and prototyping aerospace systems and for synthesizing missions"
• The technologies needed for collaborating diverse teams, especially engineering and science teams, the advanced intelligent agents required for human-centered computing, the rapid tools for near real-time simulation and design trade studies, and an implementation strategy" for a national program</td></tr>
</table>

Space Enabling Technologies for NASA's Enterprise Missions

NASA's key capability areas and enabling technologies required for its four Enterprise Missions are listed below:

Enterprise	Key Capability Areas	Key Enabling Technologies
Space Science (Key Capabilities)	• Advanced Structures Deployment and Control	– Ultra-precise deployment of lightweight structures; Control of structural shape and vibration in space; Precise pointing of large structures
	• Communications	– High-data-rate telecommunications technologies, including radio and optical transmitters and receivers; Lightweight, low-power, robust electronics systems; Lightweight antenna materials
	• Design Tools and Spacecraft Operability	– Advanced spacecraft design environment and rapid prototyping; Integrated modeling of spacecraft and optical systems; Ground information systems for low-cost spacecraft operations, data visualization, and analysis
	• Lightweight Optics	– Advanced segmented optical systems with high-precision controls; Large lightweight mirrors
	• Metrology	– Extremely precise measurement of orientations of in-space structures using stabilized lasers
	• Power	– High-efficiency solar arrays tolerant of extreme thermal and radiation environments; New radioisotope power sources and conversion systems; lightweight power for small vehicles
	• Sample Acquisition and Return	– Techniques for surface and sub-surface sampling of planetary surfaces and small bodies, including drills, coring devices, scoops, etc.; Sample handling and packaging techniques; sample return capsules
	• Science Instruments	– New sensors and detectors for telescopes, interferometers, and remote and in situ instruments; Highly integrated, lightweight instruments compatible with micro-spacecraft; Coolers and other instrument support systems
	• Spacecraft Systems and Intelligence	– Advanced miniaturization of electronic and mechanical components; New, highly autonomous and survivable spacecraft and computer architectures; Lightweight, multi-functional structures
	• Transportation and Mobility	– Efficient in-space propulsion; Mobility on planetary surfaces and within planetary atmospheres; Information technologies; Lightweight, high-temperature atmospheric entry systems
Earth Science (Research Themes and Areas of Technology Investment)	• Land-Cover/Land-Use Change and Global Productivity Research • Seasonal-to-Interannual Climate Variability and Prediction • Long-Term Climate: Natural Variability and Change Research • Atmospheric Ozone Research • Natural Hazards Research and Applications	1. Advanced instrument and measurement technologies to expand scientific knowledge of the Earth system: – Advanced instrument and measurement technologies; Active sensors for space-based lidar and radar applications; Detector arrays and passive sensing systems; Miniature, self-contained instrument packages for *in situ* and remote-sensing measurements 2. Cutting-edge technologies, process, techniques, and engineering: – Techniques and algorithms for formation flying by small spacecraft; mechanical and electronic innovations that reduce demands on the host spacecraft; increased space/ground system autonomy; Onboard data fusion and data comparison involving multiple space, air and ground capabilities 3. Advanced end-to-end mission information system technologies: – Improved Earth data collection, compression, transmission, processing, distribution and archiving from remote and *in situ* sensors; Linking of multiple data sets with effective information extraction and visualization

Enterprise	Key Capability Areas	Key Enabling Technologies
Human Exploration and Development of Space (Key Activities and Strategic Goals)	• Near-Term: Development and assembly of the International Space Station (ISS) • Mid- and Far Term: Improved Space Shuttle operations (via safety processes and system upgrades)	• Goal #1: Exploring the Role of Gravity in Physical/Chem/Bio Processes: – High-bandwidth communications; Mini-biosensor systems (for animals and humans); AI/expert systems for on-orbit operations; Active/ passive vibration isolation; High-temperature microgravity heat pipe; Portable clinical lab systems (for animals and humans) • Goal #2: Preparing to Conduct Human Missions of Exploration: – Wide range of improved and new system capabilities keyed to robotic, animal and human operations: robotic mission payloads (near term on; near-space/lunar operations (mid-term on); and deep-space/planetary operations (far term on) • Goal #3: Continuing to Open and Develop the Space Frontier: – Similarly wide range of improved and new system capabilities keyed to robotic, autonomous and human operations: space shuttle upgrades (near- to mid-term); ISS upgrades and evolution (mid- to far term); and new launch system and future habitation support (far term on) • Goal #4: Aggressively Seeking Investment from the Private Sector: – Increasing privatization and commercialization of space exploration and development will again require new and advanced capabilities across the space technology spectrum
Aero-Space Technology Pillar #3: Access to Space (Enabling Technology Objectives)	• Enabling Technology Objective #9: Reduce Launch Cost to LEO 100x by 2022 • Enabling Technology Objective #10: Reduce in-Space Transport Cost 10x by 2012	– Reduce payload cost to LEO 10x by 2007 (from $10,000/lb to $1,000/lb) – Reduce payload cost to LEO 10x more by 2022 (from $1,000/lb to $100/lb) – Reduce Earth orbital transportation cost 10x by 2012 – Reduce propulsion system mass and travel time for planetary missions 2x - 3x by 2012 – Enable missions to the edge of the solar system and beyond by 2022, by reducing travel times by 10x - 100x

NASA's Aero-Space Technology Enterprise Pillar No. 3, Access to Space, is clearly of fundamental importance to the overall U.S. national capability to assure that access. NASA is lead-agency for the near-term Reusable Launch Vehicle (RLV) program, which is "structured to respond to the industry's need to reduce or eliminate the technology risk of building a new system."[*] Its centerpiece is a series of "X-vehicle" flight demonstrators to reduce demonstration risk by forcing technologies from the laboratory into real-world operating environments as part of their maturation process. The primary technology challenges for the RLV program are:

- Highly reusable technologies that are mass-fraction scalable to a single-stage-to-orbit rocket launch system, including the primary structure, cryogenic tankage, insulation, and thermal protection system;
- Robust subsystems that will enable vehicles with ≥100-mission life, 20 flights between depot maintenance, and 10x less processing labor hours than the Space Shuttle;
- Durable, lightweight thermal protection systems that will be easy to inspect, maintain, and repair;
- Main propulsion system with ≥80:1 thrust-to-weight with robust subsystems enabling ≥50% reduction in between-flight engine inspections, compared to the Space Shuttle;
- System reliability of ≥0.995 for mission success and ≥0.999 for vehicle/payload recovery; and
- DDT&R costs and production costs <1/3 those of the Space Shuttle.[#]

[*] Idem, Section 3.4, subsection titled "Enabling Technology Objective 9, Near Term Objective."

[#] Ibidem, Table 3.4-11.

For the longer term, NASA's Advanced Space Transportation program is focused on highly reusable vehicle and propulsion systems well beyond the RLV. Joint NASA-DoD-industry planning has focused on advanced vehicle structures, thermal protection systems, propulsion systems and avionics/operations, involving advanced materials, nozzles, and turbomachinery technologies.

Further, space missions are increasingly requiring payloads to be placed into orbits well above LEO: by 2010, over 30% of expendable launches will be to GEO. Significant performance improvements in in-space propulsion could be used either to increase payload capability or to step down to a smaller, less costly launch vehicle. Jointly coordinated technology investments are through the Integrated High Payoff Rocket Propulsion Technology Initiative (IHPRPTI).

Technologies of interest for the next 20+ years (some requiring significant prior advances or breakthroughs) include:

- Solar electrostatic technology (1 to 4 kilowatts) for orbital maintenance;
- 20-kilowatt power levels in combination with chemical propulsion for orbit raising and higher orbit insertion. Here, the development and demonstration of electrostatic (Hall-effect) propulsion is a top priority in both NASA and DoD space transfer technology programs;
- Solar-thermal propulsion (if specific impulses on the order of 1,000 seconds can be obtained in an operational system);
- Electrodynamic tether propulsion or propellantless Earth orbit transfer; and
- The technology for tethers, which is relatively mature and has a flight demonstration planned to validate a small deployer system by deorbiting an upper stage within days instead of the months now required.

In the far term, reusable orbit transfer vehicles, either space-based or returned to ground for turnaround, are key to achieving an order-of-magnitude reduction in orbit transfer costs.

NASA's Aerospike Engine

DOE

Agency Approach and Focus

While its primary mission is to manage, support and oversee the nation's nuclear power infrastructure, and in the process develop and provide nuclear weapons and technologies to the DoD, it is also the primary agency applying its expertise to determine the nuclear programs and capabilities of other powers around the world, by monitoring both nuclear tests and signs of proliferation of weapons of mass destruction (WMD). Thus, in addition to carrying the major responsibility for technology development and operational production of space sensors for the U.S.'s nuclear explosion detection systems, DOE funds system and component R&D that is aimed at producing new ISR capabilities to go after precursive evidence of proliferation, such as reprocessing or enrichment of nuclear energy fuels, and production, test and storage of nuclear, biological and chemical (NBC) WMD. As these are inherently hard to detect, a lot of the requisite technology developments also improve ISR capabilities in other national security areas.

For the past 40 years, DOE's major role in the nation's space program has been primarily in its core competency areas of sensor and computing technologies. The work includes everything from:

- Detailed signatures and source term analysis of actual and likely proliferation problems (so that monitors know what to look for and how hard it will be to detect and quantify);
- Science to understand the propagation and environmental distortion of measurable signals from the target to sensors, including the environmental fate and transport of certain measurable quantities that persist and even accumulate in the environment. (Where existing technology is insufficient, the DOE conducts engineering and development of novel sensor concepts capable of collecting these signals);
- Field tests to validate and demonstrate sensitivity and utility; and
- Exploitation and analysis tools so that regular users of the new technology can get meaningful information from the new (and often complex and voluminous) data collected.

The DOE has more than three dozen laboratories and facilities, generally collocated with university or industrial centers, that pursue S&T across the national security spectrum. However, DOE's national security space-related S&T activities primarily involve its three "defense program" national laboratories at Lawrence Livermore (LLNL), Los Alamos (LANL), and Sandia (SNL). DOE is funding ground-breaking state-of-the-art work in the following areas:

- Spectral systems (multi, hyper, and ultra);
- Synthetic aperture radar (SAR); and
- Others (that are sensitive and beyond the scope of this document).

DoD and NASA both use DOE sensors and microprocessors in space and will continue such use for the foreseeable future. Electronic components largely determine the reliability and life of systems in severe environments like space. Commercial products cannot meet many of the requirements for these devices and without the federal government as customer, there would be no business case (supply/demand/profit economics) for the industrial base needed to provide them.

In all of this work the DOE is tightly coupled with the agencies that will eventually deploy these technologies for operational use. The DOE itself is not a collection agency, although its Intelligence component is a user of the data collected. Its ISR research objective is to develop the technology that will enable better systems in the future. Sometimes that requires testing or demonstrating the technology in a space environment. Often, the most productive developments are accomplished through ground or air experimentation followed by partnerships and collaborations to get the technology into the right hands for space deployment or post-space processing.

Thus, DOE partners with DoD and NASA in the Space Technology Alliance (STA), which serves as a forum both for collaboration and to eliminate unnecessary duplication among their collective efforts.

The STA's RaDiCL (Research and Development in CONUS [Continental U.S.] Laboratories) database is just one of the means used for the cooperative exchange of information and reflects only that fraction of the DOE's R&D efforts that are space-related. DOE is also an active member of the Space Experiments Review Board (SERB), which prioritizes and determines which projects are provided with access to space via NASA's Shuttle or DoD or commercial expendable launch vehicles as part of the Space Test Program (STP).

DOE's Space-Related Technology Highlights

DOE's space enabling technology efforts involve materials science, miniaturization, electric power functions, thermal management, both detected and directed energy, and supercomputing. Within these areas, the DOE's core competencies are tabulated here.

Area	Subareas/Functions
Materials Science	• Molecular structure and properties – Characterization and understanding • Radiation-hardened/-tolerant materials and devices • Semi- and superconducting electronics • High-precision manufacturing: Fabrication and Packaging – Ultra-low-mass close dimensional tolerance structures — Scale: large (macro) and small (micro/nano) — Deformation/vibration-controlled/tolerant/adaptive – Multi-layers, thin films
Miniaturization	• Devices: – Micro/opto-electronic – Microelectromechanical – Optical – Magnetic — Analog and digital — Vacuum and solid-state (E.g., waveguides and focal plane arrays)
Electric Power (Generation, Storage, and Distribution)	• Devices: – Electrochemical – Electrostatic – Photovoltaic – Thermoelectric
Thermal Management (Active and Passive)	• Conduction • Convection • Radiation – Cryogenic cooling – Heat pumps/pipes – Insulation
Detected Energy (Imaging, Mapping, Signatures)	• Heat/thermal, photons/light/electromagnetic particles/waves • Sensors: – IR, EO, RF, Multi/Hyper/Ultra-spectral • Radar: – Real and synthetic aperture radars (SAR)
Directed Energy	• Lasers: – Communications, computing, cooling • Lidar: – Standoff effluent measurement (using lidar and hyperspectral techniques – Lidar imaging
Supercomputing (High Performance: Speed, Memory, and Data Storage)	• Modeling, Simulation • Autonomous/biomorphic/intelligent machines, neural networks, and robotics • Automated recognition of objects, signals /and signatures • Reconfigurable and redeployable computers for onboard processing • Massively parallel supercomputer software and hardware systems

DOE Space-Relevant Activities by National Security Laboratory

The three DOE Defense Program (DP) laboratories work with the DoD, NASA and the Intelligence Community to leverage their capabilities and provide long-term R&D support to meet future national security challenges. Much of this work is intended to stabilize the U.S.'s core nuclear weapons programs. In 1998 they were asked to address *(inter alia)* the challenge of detecting and defeating hard and deeply buried targets; this work continues.

- **Lawrence Livermore National Laboratory (LLNL).** Livermore was founded as a nuclear weapons laboratory and national security remains its defining mission. Its national security programs align directly with the major goal in DOE's Strategic Plan to support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction. LLNL's WMD proliferation detection and counter-proliferation activities support both the DoD and other national security agencies. Other areas of space-relevant technological advances include missile defense, solid-state lasers, conflict simulation modeling, miniaturized sensors, and specialty support for advanced conventional munitions.
- **Los Alamos National Laboratory (LANL).** During the past 40 years, Los Alamos has played a significant role in the nation's space program by uniquely combining national security missions with leading-edge investigations of space science and space technology. Its DoD work focuses on innovative solutions to requirements and a strong, enduring S&T base. Among its core competencies, it includes: complex experimentation and measurement; computing theory, modeling and high performance to deal with vast amounts of information; analysis and assessment to support complex models and systems; Earth and environmental systems that address both the near-Earth space environment and remote sensing of the Earth from space; nuclear and advanced materials such as ceramics and exotic polymers; and nuclear science, plasmas and beams that span the study of high-energy/density systems driven by intense beams.
- **Sandia National Laboratory (SNL).** Sandia also addresses technical issues of critical national importance. Its core research foundations are in the sciences and applications of: materials and process (to include world leadership in MEMS); computation and information (at giga- and teraflop scales); microelectronics and photonics (to include radiation-hardened integrated circuits, integrated microsystems, ultrahigh-efficiency optical devices, and loss-free guided-wave optical systems built in silicon); engineering (to include microcoolers and control actuators); and pulsed power (largely to support the nuclear inventory).

DOE National Labs and Facilities

Sensors, Miniaturization, and Supercomputing Technology

Appendix I

Private Sector Perspectives

Industry Views

The Aerospace Industries Association of America (AIA) provided* collected views of its member companies with respect to key areas of space-related technology. The gist was to identify those areas for which industry believes more investment is needed (industry as well as government), or which the government should underwrite until they are mature enough for commercial markets to absorb. Seven of the nine space technology areas identified are in the Space Transportation category; the other two apply to Space Operations and space missions in general. These areas and amplifying comments are summarized and tabulated below.

Space Transportation

Technology Area	Key National Security Issues	Industry Perspective
Space Maneuvering Vehicle Propulsion Technology Development	The Air Force is planning a future space maneuvering vehicle for missions involving a variety of sorties within space. This vehicle requires reliable and proven propulsion that employs "clean" non-toxic propellants that are storable for long duration in space	Kerosene-Peroxide liquid rocket engines providing variable thrust up to 12,000 – 15,000 lbs may satisfy this requirement, but the technology is immature and needs to be developed and proven in a timely manner to field a prototype system and vehicle by 2007. Recent advances in catalytic technology to enable the use of peroxide above 98% purity may let the propulsion industry meet the Air Force's requirement Additional government R&D funding would enable an early risk mitigation demonstration program to prove this technology
Highly Reusable Boost Stage Cryogenic Propulsion Technology	A key candidate boost stage propulsion system for a next-generation reusable launch vehicle is offered through the possibility of a 250,000-lb thrust cryogenic boost stage engine employing Staged Combustion or the Expander cycle (The Air Force and industry are pursuing technologies for both cycles under the Integrated High Payoff Rocket Propulsion Technology [IHPRPT] Program)	The Stage Combustion cycle provides more thrust in a smaller volume and weight to enable future single-stage-to-orbit (SSTO) boost stage missions where performance and thrust to weight are the prime technology needs The Expander cycle, although larger and heavier than a Staged Combustion cycle engine, has the advantage of operating at lower pressures and temperatures which in turn stress the engine far less, thereby offering robust operating margins required for higher reusability Under the IHPRPT program, a 250,000-lb Thrust Staged Combustion Engine suitable for boost stage operation has already been designed and is currently being fabricated. The Staged Combustion Program is focused on improving operating margins to enhance reusability. The Expander cycle is being developed at a 50,000-lb thrust level and could be scaled up by a factor of four to meet boost stage propulsion needs. The Expander cycle program is focused on generating higher thrust than previously demonstrated for improved thrust to weight. Both engines feature advanced altitude compensating nozzle technology capable of improving performance from sea level to low earth orbit. R&D funding provided by industry over and above that programmed by the DoD would enable this next generation of engine technology as part of the IHPRPT program

* Electronic correspondence to OASD(C3I), dated 4 February 2000

Technology Area	Key National Security Issues	Industry Perspective
High-Performance Electric Propulsion for Satellites/ Spacecraft	Advances in electric propulsion offer the promise of a leap over traditional chemical propulsion systems for affordable, reliable satellite station-keeping, attitude control, orbit raising, and de-orbit	Advances in electric propulsion will enable heavier satellite dry weight, higher power-level operation and/or increased transponder broadband capacity — as well as longer satellite life Air Force IHPRPT support has helped achieve early success. Added IHPRPT support to mature and flight-demonstrate advanced electric propulsion would enable the Air Force and commercial satellite industry to maximize satellite performance and longevity. This would include several thrust levels of Hall Effect Thrusters (HETs) to cover the range of thrust needs for station-keeping and efficient orbit transfer. Also included: the Power Processing Units (PPUs) that control the operation of the various thrusters on board the satellite bus
Propulsion System Technology Improvements	Liquid rocket, scramjet and combined-cycle engine propulsion base technologies and improvements to engine operability are truly enablers for improved launch systems. Without them, such new launch systems will not emerge	Those engine technologies that demonstrate reliability and performance improvements coupled with reusability should be vigorously pursued Technologies for improved engine operability, such as health management systems, fail-safe and redundant components, inspection-friendly/simplified components, modular engine design and maintenance-free engines, also need support to complement basic engine technologies These engine propulsion advances must be demonstrated before significant investment can be made in new systems S&T propulsion technology funding level needs to be increased over current levels and maintained over at least a ten-year period
Advanced Thermal Protection Systems	Emerging requirements for reusable vehicles dictate the need for “aircraft-like” turnaround times and operability. This in turn drives the requirement for robust, low maintenance thermal protection systems (TPSs)	Great strides have already been made in this area with the TPS (metallic and refractory composite) developed for NASA's X-33, but additional work is needed to develop, demonstrate and certify these technologies and to drive down their total production costs. Their key elements are: • Development and commercial availability in foil gauges of low density, high-temperature metals (such as gamma titanium aluminides and oxide dispersion strengthened alloys) • Fully developed refractory composite hot structures for RLV control surfaces (includes appropriate design data with representative environmental exposure, design concepts, manufacturing scale-up, and verification testing) • Advanced, robust seal materials and design concepts • Environmental assessment of TPS material/configuration options (e.g., rain/hail erosion, micrometeorite impact) • Low-cost high-yield manufacturing processes for full-scale metallic and refractory composite structures • Verification of all technologies by flight demonstrations
Non-Toxic Mono-propellant Technology	Hydrazine propellant and the systems that employ it are prevalent in the aerospace industry for such diverse uses as launch vehicle and satellite attitude control, aircraft and spacecraft power generation units, and gas generators. However, hydrazine is a toxic EPA-regulated chemical, which requires strict environ-mental controls. Meeting these controls is costly and time-consuming	The aerospace industry currently is investigating the use of hydroxy-ammonium nitrate (HAN) and glycine derivatives as a possible replacement for hydrazine. These derivatives can be used in the same reaction chambers used by hydrazine systems This new technology shows much promise and indications are that HAN-glycine systems could provide performance equal to or better than the performance of current hydrazine systems. At least one company has already built a functioning thruster using this technology Additional funding for prototype testing, system architecture studies and enabling technologies research could provide benefits to such DoD programs as the Evolved Expendable Launch Vehicle (EELV), defense satellites, and military aircraft programs

Technology Area	Key National Security Issues	Industry Perspective
Composite Cryogenic Tank Technology	The Air Force has supported future Military Space Plane vehicle concept studies which are dependent upon an SSTO launch vehicle Next-generation launch vehicles (including SSTO) require high propellant mass fractions and long life	The single most important technology anticipated to make higher propellant mass fractions possible is composite propellant tankage. For a full-scale SSTO vehicle concept, cryogenic composite tanks would result in a nearly two-fold cost reduction in placing a payload into orbit, while reducing the dry weight by 30-40% Although the Air Force and NASA have sponsored past work in this area (through the National AeroSpace Plane [NASP], DC-X, DC-XA, MSPITT and X-33 programs), the technology is not mature and needs further development to give confidence and provide a low-risk solution to meet future DoD space vehicle system and mission requirements. Additional government investment is needed to develop a prototype composite cryogenic tank to demonstrate long life (reusability) and high mass fraction — key enabling characteristics of an affordable space plane system

Space Operations and General Missions

Technology Area	Key National Security Issues	Industry Perspective
Strategic Radiation-Hardened Electronics	Extreme radiation immunity called for in certain strategic programs	The commercial space market does not require, and cannot afford to use, such rad-hard electronics Not economically feasible for a private company to maintain a specialized foundry to produce rad-hard microcircuits for the small and specialized military customer base DoD investment needed in rad-hard technology research and facility maintenance to meet special requirements
Data Processing and Exploitation	Vast amounts of data collected from National Technical Means is expanding and placing a stress on our ability to process the data in a timely manner	The processing of multi-spectral imagery, radar and more traditional data categories can benefit from advances in a number of areas including: • Advanced algorithm development • Sensor modeling and processing techniques • Architectures that incorporate both tailored applications and commercial off-the-shelf (COTS) tools • A more simplified, straightforward, intuitive Human-Machine Interface (HMI) to reduce operator training, errors and workload, and improve efficiency Advanced sensor modeling will enhance the accuracy of information extracted from the growing number of sensors and will enable better data fusion as well as direct support for tactical warfighters via a full range of geospatial products through precision aimpoints Additional investment should be in intelligent agents and databases, information and intelligence integration, target phenomenology and assisted target recognition, and change detection

Commercial/Industrial Initiatives

In addition to DoD and other federal labs, and to universities, industry and non-profit institutions, private sector entities are pursuing S&T investments and infrastructure initiatives for potential commercial advantage in the world's evolving space-related industries. A DoD solicitation in January 2000 generated a range of responses of varying nature and scope, but which generally addressed the traditional themes reflected in this STG, which themselves summarize national security space interests and investments:

- Economies in motion, both propulsion to orbit and on-orbit;
- Thermal/radiation control/endurance/management/tolerance;
- Economies in producibility of reliable space system components via design and manufacturing innovations;
- Ensuring the integrity and security of information across all media, including space; and
- Commercial space interest/investment/exploitation/incentives, with transition to operational use.

The following provides a sample of commercial focus and initiatives:

Company	Focus / Initiative
AeroAstro, Inc.	• Escort Microsat Fleet. Pursuing the concept of a low-cost "Escort" microspacecraft fleet to provide real-time space-based intelligence by maneuvering up to and around an intelligence target on GEO orbit. Alternatively, an Escort could maneuver to a satellite experiencing anomalous behavior and make diagnostic observations. This system is designed to be launched as a secondary payload on a number of launch vehicles, thereby reducing launch costs and on-orbit costs thereafter. • "SPORT" Vehicle. Developing a detailed design leading to a prototype for a Small Payload Orbit Transfer vehicle, as a low-cost alternative for small payloads to both access space and achieve an orbit transfer capability. While the system concept is new, most of its technologies are well established. Potential micro- and nanosatellite applications include satellite inspection, reconnaissance clusters, and communications systems.
Ball Aerospace & Technologies Corp.	• Cryocooler Producibility. Pursuing more easily producible and reliable (hence cheaper) cryocoolers for IR focal plane and instrument operation aboard SBIRS Low and a variety of other satellites. Improvements to current cryocoolers will protect existing performance while advanced techniques are tested and validated. Producing space-qualified cryocoolers in economic quantities is projected to represent a tenfold improvement in size and weight over current cryogen-storing alternatives.
Boeing	• Two-Stage Light Gas Gun. NASA and several labs have built and tested gas guns. Boeing's design would launch propellant via a 7-step process and 1800-meter gun barrel (with a 0.4-meter internal diameter) inclined 25 – 30° to achieve orbital velocity (24,000 fps). Once on orbit, the fuel could be warehoused and then transferred to fuel or refuel satellites already in LEO. (Smaller launchers could thus be used initially for these near-empty satellites and their on-orbit lives extended by follow-on refuelings.) Company and government studies indicate a reduced satellite cost to orbit of 33% to 50%.
BWX Technologies	• Solar Bi-Modal Rocket Engine. Designed and ground-tested to date, this technology is projected as an upper-stage propulsion and satellite power system; it is the enabling technology of solar upper stage systems, which will either increase payload capacity or permit smaller launchers. Exploring innovative and hybrid concepts for on-orbit motion and propulsion, i.e., beyond conventional, consumable chemical propellants or photovoltaic solar cells, for application as reaction engines and devices (e.g., via direct heat-to-electricity conversion).
E.L. Courtright, et al.	• Producibility Assessment Methodology. Proposes a government program to enable a data-based, orderly producibility analysis of promising new space materials at an early stage, vice successive RDT&E steps that may culminate in a costly or even unsuccessful manufacturing effort. When a new material is proposed for space applications, a preliminary trade study should address both materials and mechanical design. If still promising, a producibility analysis should investigate the manufacturing feasibility, reliability, reproducibility and cost of actual components. This approach could assist both government and industry in their space materials and system decision-making.

Company	Focus / Initiative
Electron Power Systems (EPS)	• Space Propulsion Technology. BMDO funding an EPS-MIT collaborative proof-of-concept effort based on a newly discovered stable plasma (SP) that requires no external magnetic fields for cohesion. Acceleration via magnetic techniques could achieve 600,000 m/s for a specific impulse (ISP) >60,000 sec (compared to ISP of 500 sec for chemical rockets), for a >99% reduction of satellite propulsion system mass and 50% reduction in launch cost to orbit. Based on a simpler and cheaper proprietary SP production method, scale-up to a relatively high level of total thrust is projected with production within ten years.
IntraSec Corporation	• Strategic Approach to InfoSec. Proposes a comprehensive, system-wide approach to information network security. Instead of piecemeal, reactive approaches based on COTS techniques, an integrated network-wide approach is needed that includes proactive monitoring and counteractions to neutralize an attack source, vice only treating attack symptoms. Five concepts apply: identification of normal situations and activity; recognition and alerting of deviant activity; defensive segmentation of own activities; reactive and offensive countermeasures against an attacker; and standardization of efforts.
L'Garde, Inc.	• Space Structures Technology. Key space structures include antennas, solar arrays, booms, platforms, solar concentrators, and solar sails. While such structures may have to be packaged to survive launch forces, once *in* space they experience very low load forces and can operate as stiff but very light structures to resist high levels of radiation and particles. For ISR missions requiring high-resolution large-diameter optics, precision membranous optics may be the most practical solution. Lightweight deployable structures may also be used as decoys to confuse or negate attack.
Lockheed Martin	Company sees more emphasis on short-term technology investment at the expense of the longer term, owing to changes in opportunities and market forces. Following initiatives should be realized by 2005: • Active Phased Array Communications Antennas for Spacecraft. These modular antennas for both military and commercial spacecraft can operate simultaneously at multiple frequencies or solely at any of several frequencies. Electronic steerability both enhances reception and reduces vulnerability. • Electric Power Generation and Storage. Transitioning high-efficiency (≈30%) solar cell technology from Sandia National laboratory to an industrial supplier, augmented by a government-industry agreement to develop Li Ion batteries. Also, extremely small and very high-efficiency electronic power converters are being developed to exploit the increased generation and storage efficiencies. • Very-Large-Diameter Thinned Aperture Optics. Developing hardware and control algorithms to enable optical telescopes with 5 – 10 times the Hubble's aperture size. The combination of increased spatial resolution in smaller telescopes launchable via existing boosters will support both NASA and DoD reconnaissance/surveillance missions. Technology ready to be incorporated into space systems. • Hyperspectral Imaging (HSI). Gathering aircraft HSI data to develop advanced algorithms to increase the information content (e.g., discriminate among material types being imaged. Expect to apply this technology to airborne and space-based systems in the near future. • X-33/RLV/EELV. Significant investment in materials and propulsion for both reusable and expendable launch vehicles. Project X-33 and EELV first launches in 2002; RLV is a 10+ year program.
Mainstream Engineering Corporation	• Low-Lift Heat Pump as Thermal Control. Future high-power spacecraft will need active thermal controls to dissipate their excess heat. A low-lift heat pump thermal control system may save >20% in radiator area and >15% in system mass over single-phase pumped loop systems, and have other advantages over two-phase pumped loop systems. Also, it uses a non-ozone-depleting refrigerant and does not need a lubricant. Company proposes a full development and demonstration effort to measure key parameters as a prelude to flight testing. A range of weapon, surveillance and communications applications are projected for both military and larger commercial satellites.
Mission Research Corporation (MRC)	• Radiation Effects on Focal Plane Arrays (FPAs). Proposing a more complete collection of data sets for steady and transient radiation effects on FPAs, as a comprehensive basis for projecting their on-orbit performance degradation. As visible-light and IR FPAs within space defense imaging sensors (for space-based acquisition, tracking and discrimination of targets) will need to be insensitive to trapped and cosmic radiation, their "noise budgets" must be carefully planned. Prior review of existing data sets and ground lab radiation measurements on existing FPAs need to be augmented by space-based tests and data collected under realistic operational conditions to achieve the requisite radiation-hardness for FPAs aboard such systems as SBIRS sensors and NMD kill vehicles.
Moonspace Corporation	• Proposes creation of a Space Technology Assessment Center and Technical Library to facilitate and control space technology transfer to U.S. military components, government agencies, and approved private sector entities. By extending existing government and public domain technical data and resource material via controlled access to commercial firms and other institutions, space launch costs will be lowered and U.S. commercial competitiveness will be increased.

A Military-Civilian Collaboration

Recently, military assets were used in a new way to launch a collection of private sector demonstrations and experiments with potential utility in a variety of fields. On 26 January 2000, the Air Force's Space and Missile Systems Center's (SMC)'s Orbital/Suborbital Program (OSP) space launch vehicle, the first satellite to be boosted by rocket motors from a deactivated Minuteman II, successfully orbited the five payloads listed in the table below.

Organization	Project	Description
Air Force Academy, Weber State University	Joint Air Force Academy/Weber State Satellite **(JAWSAT)** Multi-Payload Adapter	• "Workhorse" mission payload that (1) held and deployed the other four satellites (following) and (2) conducted its own experiments, which included: – NASA's Plasma Experiment Satellite Test – Weber State's Attitude Control Platform – (Other experiments) • After deploying the other satellites, the JAWSAT team concentrated on "flying" the JAWSAT satellite and collecting data from its own experiments
Air Force Academy (AFA)	**FalconSat**	• Program created to teach AFA cadets the steps necessary for a successful satellite program • The primary experiment on-board FalconSat is the Space Test Program-sponsored Charging Hazards and Wake Studies – Long Duration (CHAWS-LD) • Cadet operators are communicating with the satellite and configuring its payloads to obtain experimental data
Arizona State University (ASU)	Arizona State University Satellite **(ASUSat)**	• Program created to give ASU students access to space and to prove the viability of a 10-lb class satellite • Several days after launch, the ASU team lost contact with ASUSat due to the failure of its battery re-charging system. Despite this setback, the ASU team reported that they had achieved 70-80% of their mission requirements
L'Garde (under AFRL contract)	Optical Calibration Sphere **(OCS)**	• OCS is a large, highly reflective balloon used for instrument calibration by the Starfire Optical Range at Kirtland AFB, NM , expected to provide useful service for over two years (into 2002 and beyond) • Easily visible from the ground, OCS is the least complex of all the JAWSAT payloads, as it has no electronics
Stanford University	Orbiting Picosat Automatic Launcher **(OPAL)**	• Designed and built by faculty and students, OPAL's primary mission was to launch hockey puck-sized picosatellites • Within three weeks of launch, OPAL had deployed six picosatellites designed by The Aerospace Corporation, Amateur Satellite personnel, and Santa Clara University students (with funding from DARPA) • OPAL and all its picosatellites performed successfully

Orbital Sciences Corporation, Chandler, AZ, developed and integrated the launch vehicle as part of the Rocket Systems Launch Program. The vehicle comprised the first two stages of a Minuteman II and the upper two stages of a Pegasus XL rocket. The Air Force's 30th Space Wing supplied range support.

The culmination of over two years of effort by Air Force and contractor personnel, this mission proved the viability of a new launch capability by putting working satellites into orbit. The missile successfully inserted the five payloads into a 400-nm polar orbit, with liftoff occurring at the beginning of the required launch window. While several technical issues were dealt with during the mission, the launch itself was almost flawless, with early post-launch data indicating that nearly all systems performed optimally.

In addition to the satellites, the AFRL's Soft Ride for Small Satellites (SRSS) was flown. Essentially, the SRSS is a set of titanium structures between the launch vehicle and the payload(s) that "tunes" dangerous frequencies away from the sensitive satellites. Designed and built by CSA Engineering, SRSS enabled the satellite manufacturers to design to lower G and shock levels.

Appendix J

References

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Appendix K

Abbreviations and Acronyms

3D	Three-Dimensional
ABL	Airborne Laser
AC2ISRC	Aerospace Command and Control, Intelligence, Surveillance and Reconnaissance Center
ACDA	Arms Control and Disarmament Agency
ACP	Airborne Command Post
ACSBIRS	Active Cleaning Experiment for SBIRS Low
ACTD	Advanced Concept Technology Demonstration
A/D	Analog-to-Digital
AEHF	Advanced Extremely High Frequency (System)
AFA	Air Force Academy
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AF/ST	Air Force Chief Scientist
AI	Artificial Intelligence
AIA	Aerospace Industries Association of America
AIM	Automated ISR Management (program) (DARPA)
ALEXIS	Array of Low Energy X-ray Imaging Sensors
ALSD	Advanced Laser Sensor Development
AMSD	Advanced Mirror System Demonstrator
AMTI	Airborne Moving Target Indication/Indicator
ARGOS	Advanced Research and Global Observation Satellite
ARSPACE	Army Space Command
ARTS	Automated Remote Tracking System
ASAT	Anti-Satellite
ASEDP	Army Space Exploitation and Demonstration Program
ASF	Adaptive Sensor Fusion
AST	Advanced Solar Telescope
ASTRO	Autonomous Space Transporter and Robotic Orbiter
ASU	Arizona State University
ATD	Advanced Technology Demonstration
ATH	Above the Horizon
ATR	Automatic Target Recognition
ATSOG	Automation Technology for Space Operations Group
AUS	Advanced Upper Stage
AWACS	Airborne Warning and Control System
BAA	Broad Area Announcement
BDA	Battle Damage Assessment
BDI	Battle Damage Information
BM	Battle Manager
BMC3	Ballistic Missile Command, Control, and Communications
BMD	Ballistic Missile Defense
BMDO	Ballistic Missile Defense Organization
BOA	Battlefield Ordnance Awareness
BRP	Basic Research Plan
BTN	Battlespace Tactical Navigation
C2	Command and Control
C2W	Command and Control Warfare
C3	Command, Control, and Communications
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance

CACC	Configurable Aerospace Command Center
CAV	Common Aero Vehicle
CBD	Commerce Business Daily
CBM	Conventional Ballistic Missile
CC&D	Camouflage, Concealment, and Deception
CEASE II	Compact Environmental Anomaly Sensor II
CEE	Collaborative Engineering Environment
CHAWS-LD	Charging Hazards and Wake Studies – Long Duration
CINC	Commander-in-Chief
CIV	Critical Ionization Velocity
CME	Coronal Mass Ejections
CMIS	Conical Microwave Imager Sounder (NPOESS)
C/NOFS	Communication/Navigation Outage Forecasting System
CONUS	Continental U.S.
CoS	Control of Space
COTS	Commercial Off-the-Shelf
DARPA	Defense Advanced Research Projects Agency
DC/AC	Direct Current/Alternating Current
DCI	Director of Central Intelligence
DDR&E	Director for Defense Research and Engineering
DE	Directed Energy
Delta V	Rate of Change of Velocity (Acceleration)
DEW	Directed-Energy Weapon(s)
DISN	Defense Information Systems Network
DMSP	Defense Meteorological Satellite Program
DNA	Deoxyribonucleic Acid
DOA	Department of Agriculture
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
DP	Defense Program
DSN	Defense Space Network
DSP	Defense Support Program
DSTAG	Defense Science and Technology Advisory Group
DTAP	Defense Technology Area Plan
DTED	Digital Terrain Elevation Data
DTIC	Defense Technical Information Center
DTO	Defense Technology Objective
DTRA	Defense Threat Reduction Agency
DUSD(S&T)	Deputy Under Secretary of Defense (Science and Technology)
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMPRS	Enroute Mission Planning and Rehearsal System
EO	Electro-Optics/-Optical
EPA	Environmental Protection Agency
ERM	Earth Remote Monitoring
ESA	Electronically Scanned Array
ESA	European Space Agency
ESEX	Electric Propulsion Space Experiment
ESPA	EELV Secondary Payload Adapter
EV II	Eagle Vision II
EW	Electronic Warfare
EWR	Early Warning Radar

FAA	Federal Aviation Administration
FAME	Full-Sky Astrometric Mapping Explorer
FBXB	Forward-Based X-Band (radar)
FCC	Federal Communications Commission
FORTE	Fast On-Orbit Recording of Transient Events
FPA	Focal Plane Array
FTHSI	Fourier Transform Hyperspectral Imager
FYDP	Future Years Defense Program
GAVT	Global Awareness Virtual Testbed
GBI	Ground-Based Interceptor
GBL	Ground-Based Laser
GDIN	Global Defense Information Network
GE	Global Engagement
GEO	Geosynchronous Earth Orbit
GEOSAT	Geodetic/Geophysical Satellite
GFO	GEOSAT Follow-On
GIFTS	Geostationary Imaging Fourier Transform Spectrometer
GIS	Geographic Information System
GLINT	Geo Light Imaging National Testbed
GMTI	Ground Moving Target Indication/Indicator
GN	Ground Network
GPS	Global Positioning System
HAN	Hydroxy-Ammonium Nitrate
HC2WC	Handheld C2 Wireless Communications
HCI	Human-Computer Interface
HDR	High Data Rate
HET	Hall Effect Thruster
HIO	High-Interest Object
HIRAAS	High Resolution Airglow/Aurora Spectroscopy
HLV	Heavy Lift Variant (of EELV)
HMI	Human-Machine Interface
HMX	Cyclotetramethylene Tetranitramine
HOJ	Home on Jam
HRR	High-Resolution Radar
HSI	Hyperspectral Imagery (Imaging)
HTS	High-Temperature Superconductor
HTSSE II	High Temperature Superconducting Space Experiment – Two
HXRS	Hard X-Ray Spectrometer
IC	Intelligence Community
ICBM	Intercontinental Ballistic Missile
ID	Identify, Identification, Identity
IDASS	Intelligence Data Analysis for Satellite Systems
I/F	Interface Facility
IFX	Integrated Flight Experiment
IGEB	Interagency GPS Executive Board
IHPRPT	Integrated High Payoff Rocket Propulsion Technology (Program)
IMETS	Integrated Meteorological System
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
INT	Intelligence (source or discipline)
I/O	Input/Output
IOC	Initial Operational Capability
IOMI	Indian Ocean METOC Imager
IPB	Intelligence Preparation of the Battlefield
IR	Infrared
Isp	Specific Impulse

ISR	Intelligence, Surveillance, and Reconnaissance
ISS	International Space Station
ISTD	Integrated Space Technology Demonstration
ISTP	Integrated Space Transportation Plan
IVHM	Integrated Vehicle Health Monitoring
IW	Information Warfare
JATO	Joint Aerospace Tasking Order
JAWSAT	Joint Air Force Academy/Weber State Satellite (Multi-Payload Adapter)
JBI	Joint Battlespace Infosphere
JCS	Joint Chiefs of Staff
JDUAP	Joint Dual Use Applications Program (DARPA)
JPL	Jet Propulsion Laboratory
JPO	Joint Program Office
JSTARS	Joint Surveillance and Target Attack Radar System (also Joint STARS)
JTT	Joint Targeting Toolbox
JWCA	Joint Warfighting Capability Assessment
JWCO	Joint Warfighting Capability Objective
JWSTP	Joint Warfighting Science and Technology Plan
KE	Kinetic Energy
LADAR	Laser Detection and Ranging
LANL	Los Alamos National Laboratory
LCC	Life-Cycle Cost
LEO	Low Earth Orbit
LFSAH	Lightweight Flexible Solar Array Hinge
LIGA	Lithographie Galvanoformung Abformung
LLNL	Lawrence Livermore National Laboratory
LNAS	Low Noise Amplifier System
LOD	Launch on Demand
LOS	Launch on Schedule
LOTS	Logistics Over the Shore
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LROS	Laser Remote Optical Sensing
LRP	Long Range Plan (USSPACECOM)
LWIR	Long-Wavelength Infrared
MACE	Mid-deck Active Controls Experiment
MASINT	Measurements and Signatures Intelligence
M&P	Manufacturing and Processing
M&S	Modeling and Simulation
MB	Megabyte
MBTO	Mean Time Between Overhauls
MC&G	Mapping, Charting, and Geodesy
MCCAT	Multi-Sensory C2 Advanced Technologies
MEMS	Microelectromechanical Systems
METOC	Meteorology and Oceanography
MFCBS	Multi-Functional Composite Bus Structure
Microsat	Microsatellite
MIRACL	Mid-Infrared Advanced Chemical Laser
MIT	Massachusetts Institute of Technology
MLRS	Multiple Launch Rocket System
MLV	Medium Lift Variant (of EELV)

MMIC	Monolithic Microwave Integrated Circuit
MMINS	Multi-Mission Inertial Navigation System
MOA	Memorandum of Agreement
MoD	Ministry of Defence (UK)
MODRAS	Modulating Retro-Array in Space
MOUT	Military Operations in Urbanized Terrain
MPTE	Microelectronics and Photonics Testbed
MSP	Military Space Plane
MSPITT	Military Spaceplane Integrated Technology Testbed
MSSS	Maui Space Surveillance Site
MSTRS	Miniature Satellite Threat Reporting System
MSX	Midcourse Space Experiment
MTD	Missile Technology Demonstration
MTE	Moving Target Exploitation
MTI	Moving Target Indicator/Indication
MTI	Multispectral Thermal Imager
NASA	National Aeronautics and Space Administration
NASP	National AeroSpace Plane
NAVSOC	Naval Satellite Operations Center
NAVSPACE	Naval Space Command
NBC	Nuclear/Biological/Chemical (weapons)
NCA	National Command Authorities
NDE	Nondestructive Evaluation
NEMO	Naval EarthMap Observer
NextSat	Next-generation Serviceable Satellite
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Standards and Technology (DOC)
NMD	National Missile Defense
NOAA	National Oceanic and Atmospheric Administration (DOC)
NDE	Non-destructive Evaluation
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office
NRT	Near-Real-Time
NSF	National Science Foundation
NSSA	National Security Space Architect
NSSMP	National Security Space Master Plan
NSX	NRL Space Ground Link System Transponder
NUDET	Nuclear Detonation
N/UWSS	NORAD/USSPACECOM Warfighting Support System
O&M	Operations and Maintenance
OCE	Operational Capability Element
OCS	Optical Calibration Sphere
ODASD(C3ISR&SS)	Office of the Deputy Assistant Secretary of Defense (C3ISR and Space Systems)
OE	Orbital Express (program) (DARPA)
OHS	Overhead Sensor
OISL	Optical Intersatellite Link
ONR	Office of Naval Research
OOB	Order of Battle
OOI	Object of Interest
OPAL	Optical Picosat Automatic Launcher
ORU	Orbital Replacement Unit
OSD	Office of the Secretary of Defense
OSP	Orbital/Suborbital Program
OTS	Off-the-Shelf

PAC-3	PATRIOT Advanced Capability – Three
PBCS	Post-Boost Control System
PC	Personal Computer
PDE	Partial Differential Equation
PGM	Precision-Guided Munition
PNT	Positioning, Navigation, and Timing
POAM	Polar Ozone and Aerosol Measurement
POES	Polar-orbiting Operational Environmental Satellite (DOC system)
POM	Program Objective Memorandum
PPU	Power Processing Unit
PSTS	Precision SIGINT Targeting System
QC40	Quad-C40 Processor
QWIP	Quantum Well Infrared Detector
RaDiCL	Research and Development in CONUS Laboratories
RAIDS	Remote Atmospheric and Ionospheric Detection System
R&D	Research and Development
RDDS	Research and Development Descriptive Summary
RF	Radio Frequency
RIDSN	Radar Imaging and Deep Space Network
RLV	Reusable Launch Vehicle
ROIC	Read-out Integrated Circuits
RSO	Resident Space Object
S&T	Scientific and Technical; Science and Technology
SAC	Solar Array Concentrator
SAF/AQR	Deputy Assistant Secretary of the Air Force/Science, Technology, and Engineering
SAFI	Solar Array Flexible Interconnect
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications (network)
SatOps	Satellite Operations
SAVE	Space Atmospheric Burst Reporting System Space Validation Experiment
SBEON	Space-Based Electro-Optical Network
SBIR	Small Business Innovative Research program
SBIRS	Space-Based Infrared System
SBJ	Space-Based Jammer
SBL	Space-Based Laser
SBP	Space-Based Platform
SBR	Space-Based Radar
SBSSO	Space-Based Space Surveillance Operations (ACTD)
SBV	Space-Based Visible (sensor)
SCN	Satellite Control Network
SecDef	Secretary of Defense
SEP	Spherical Error Probable
SERB	Space Experiments Review Board
SIGINT	Signals Intelligence
SLBM	Sea-Launched Ballistic Missile
SMATTE	Shaped-Memory Alloy Thermal Tailoring Experiment
SMC	Space and Missile Systems Center (Air Force)
SMDTC	Space and Missile Defense Technical Center
SMEI	Solar Mass Ejection Imager
SMP	Strategic Master Plan (for FY02 and Beyond) (AFSPC)
SMV	Space Maneuver (Maneuvering) Vehicle

SN	Space Network
SNL	Sandia National Laboratory
SOC	Space Operations Center
SOV	Space Operations Vehicle
SOTV	Spacecraft/Orbit Transfer Vehicle
SP	Stable Plasma
SPO	System Program/Project Office
SRA	Strategic Research Area
SRM	Solid Rocket Motor
SRSS	Soft Ride for Small Satellites
SSME	Space Shuttle Main Engine
SSN	Space Surveillance Network
SSTO	Single Stage to Orbit
SSULI	Special Sensor Ultraviolet Limb Imager
ST	Space Transport
STA	Space Technology Alliance
STG	Space Technology Guide
STI	Space Technology Inventory
STP	Space Test Program
STRV	Space Test Research Vehicle
STW/AR	Satellite Threat Warning and Attack Reporting
TBD	To Be Determined
TBM	Theater (Tactical) Ballistic Missile
THAAD	Theater High-Altitude Area Defense (missile)
TMD	Theater (Tactical) Missile Defense
TOS	Transportable Optical System
TPS	Thermal Protection System
T/R	Transmit-Receive
TT&C	Telemetry, Tracking, and Commanding
TW/AR	Threat Warning/Attack Reporting
TZM	Titanium-Zirconium-Molybdenum (a molybdenum alloy)
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensor
USA	U.S. Army
USA	Unconventional Stellar Aspect
USAF	U.S. Air Force
USCINCSPACE	Commander-in-Chief, U.S. Space Command
USI	Ultra-Spectral Imagery (Imaging)
USIA	U.S. Information Agency
USN	U.S. Navy
USSPACECOM	U.S. Space Command
UV	Ultraviolet
VI	Virtual Intelligence
VSWIR	Very Short Wavelength Infrared
WMD	Weapons of Mass Destruction
WORM	Write Once Read Many

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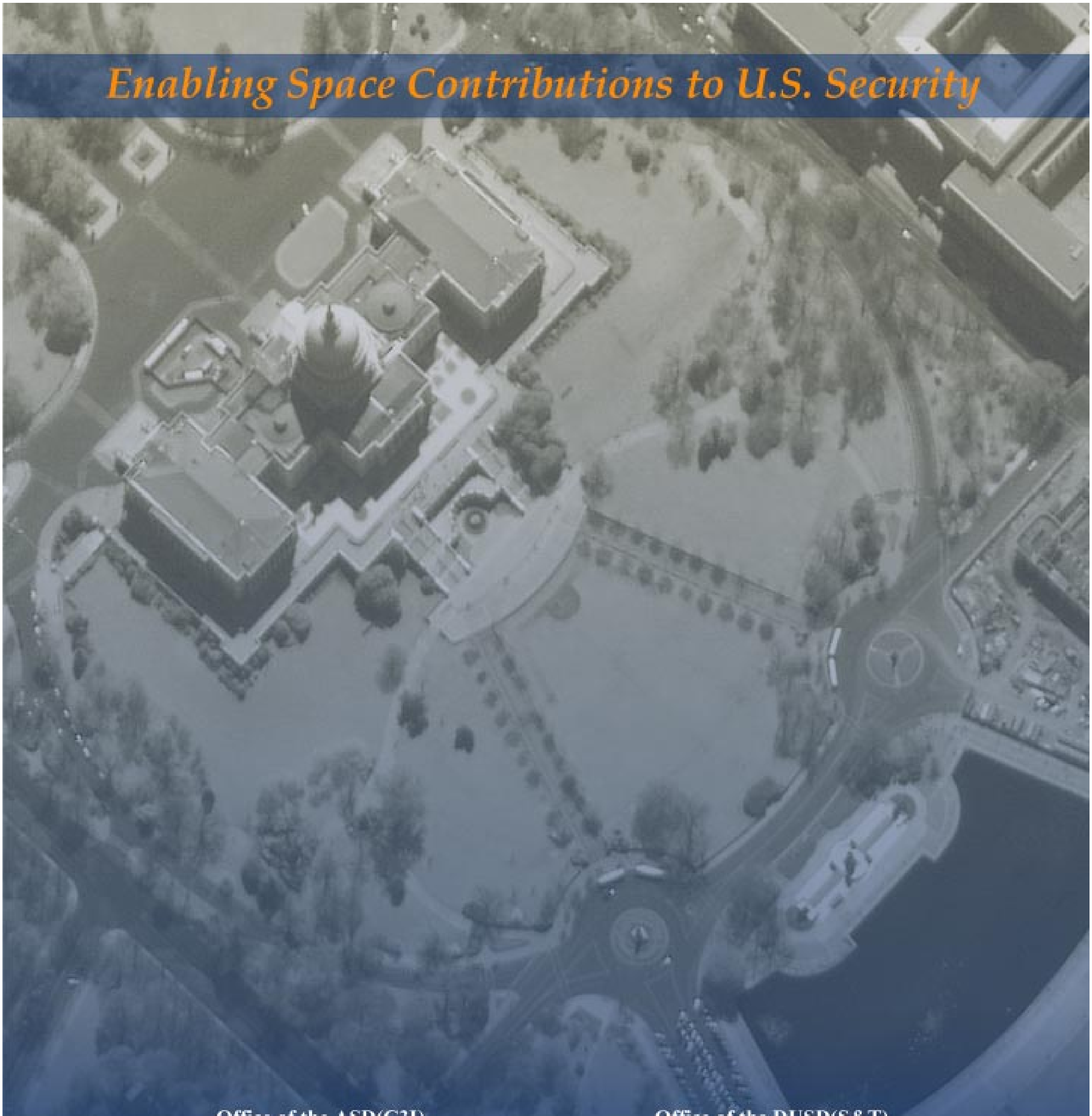
- Moonspace Corporation

Enabling Space Contributions to U.S. Security



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