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Lift-Off for Space Weapons?

Implications of the Department of Defense's 2004 Budget Request for Space Weaponization

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INTRODUCTION

This document is the second of two papers that consider current plans by the United States to expand military activities in outer space. The first paper addressed the international reaction to such deployments, in particular the objections by the Chinese Mission to the Conference on Disarmament in Geneva. This paper describes and documents the allocation of funds in the FY04 budget request to three areas:

- Force projection and space control ("Enhancing Space Operations"),
- Space-based elements of the Anti-Ballistic Missile (ABM) System, and
- Space-based command, control, and intelligence ("Integrated Focused Surveillance").

These three areas, identified by the Chinese and other states as drivers toward "weaponization," also (and not coincidentally) underpin the anticipated modernization of U.S. strategic forces as outlined in the recent Nuclear Posture Review (NPR). The NPR endorsed "a New Triad, composed of offensive strike systems (both nuclear and non-nuclear), defenses (both active and passive), and a revitalized defense infrastructure . . . bound together by enhanced command and control (C2) and intelligence systems."[1]

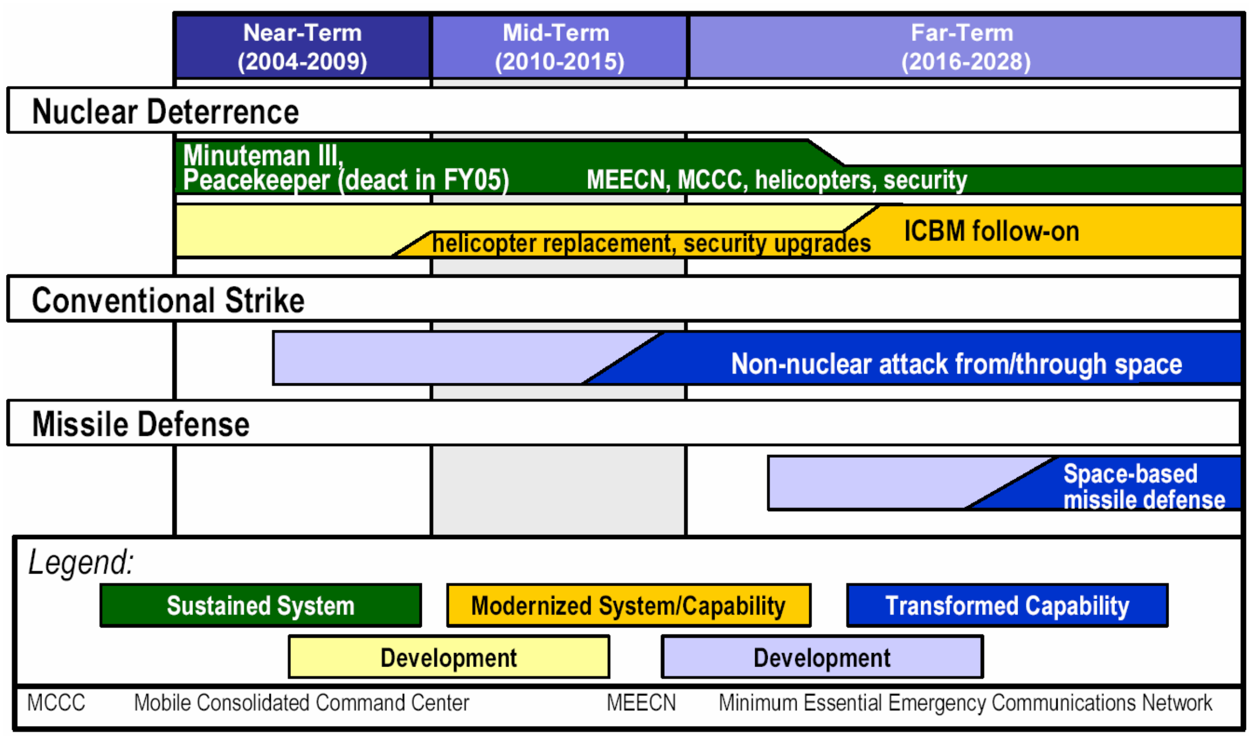
It is reasonable to conclude that the modernization of U.S. strategic forces and the expansion of U.S. military activities in outer space are linked—the transformational elements of the NPR's New Triad are likely to be based in space. The Air Force Space Command *Strategic Master Plan* supports this conclusion, stating that "Conventional, non-nuclear prompt global strikes from and through space and space-based T&E for missile defense will *transform*" U.S. strategic forces (Table 1: Space Force Application Roadmap).[2] The *Strategic Master Plan* concludes:

> The latest nuclear posture review (NPR) speaks of the need to maintain enough capabilities to provide both a credible and adaptable deterrence posture. . . . Thus, our deterrence capabilities should be responsive to and adaptable in a dynamic security environment. Therefore, we remain committed to ensuring our ICBM arsenal is modernized to maintain an effective force and deterrent posture while pursuing a new generation of responsive prompt global strike capabilities.[3]

The Command of United Strategic Command (STRATCOM), James O. Ellis, testified before Congress that the new space-based force application capabilities alluded to in the *Strategic Master Plan* will allow U.S. policy-makers to employ strategic forces in a much wider array of contingencies:

> Space capabilities will dramatically enhance US Strategic Command's newly assigned global strike mission, which extends our long-standing and globally focused deterrent capabilities to the broader spectrum of conflict. The incorporation of advanced conventional, nonkinetic, and special operations capabilities into a full-spectrum contingency arsenal will enable the command to deliberately and adaptively plan for and deliver rapid, limited-duration, extended-range combat power anywhere in the world.[4]

Table 1: Space Force Application Roadmap



U.S. Air Force Space Command *Strategic Master Plan, FY '04 and Beyond* (2002) pp.13-14.

The NPR and the *Strategic Master Plan* followed several studies produced by the United States Space Command (SPACECOM) and the United States Air Force that articulated a strong role for space-based capabilities in strategic forces modernization.[5] Some observers, particularly those in foreign governments and military establishments, expressed concern that the publication of the NPR and its companion documents—particularly the 2002 *Joint Doctrine for Space Operations*, the U.S. Air Force Space Command's 2000 and 2002 *Strategic Master Plans,* and the 1998 SPACECOM *Long Range Plan*—signaled that the United States was pursuing an open-ended strategic modernization, indicating U.S. ambitions that were equally open-ended and, perhaps, revisionist.

Indeed, the development of space-based capabilities *does* mark a substantial departure for United States foreign and military policy. Many of these systems are widely recognized as "space weapons." The earliest of the documents to outline the role of space-based capabilities, the 1998 *Long Range Plan*, accepted this reality, noting an obstacle to its proposed use of space-systems for strategic force modernization: "At present, the notion of weapons in space is not consistent with U.S. national policy. Planning for the possibility is a purpose of this plan should our civilian leadership decide that the application of force from space is in our national interest." The 2002 *Strategic Master Plan*, however, is more demure, noting merely that "To fully develop and exploit potential Counterspace and space-based Space Force Application capabilities, some U.S. policies and international treaties may need to be reviewed and modified."[6]

More importantly, however, the transformation envisioned by the Nuclear Posture Review represents a turn from the principle of mutual vulnerability—accepted during the Cold War—and a shift toward warfighting operations. This shift coincides with a national security strategy that envisions the application of strategic warfighting capabilities across the spectrum of conflict and anticipates coercive and/or preventive force. Although hailed by the Bush Administration as a strategy to reduce U.S. reliance on nuclear weapons, NPR has done so largely by dramatically expanding the range of situations in which the United States would contemplate preventive interference. This shift is consistent with a broader trend in the Bush Administration toward prevention and is rooted in the nuclear strategy backgrounds of important advisors like Keith Payne, principle author of the NPR and co-author of a 1981 article: "Victory is Possible."[7]

Objectors have long derided a strategic posture based on preventive warfare as needlessly provocative in light of the technological futility of the task. Warfighting proponents view space systems as a solution to these objections. Consider a recent article by Simon Worden, then at SPACECOM, and Martin France, at the Joint Staff, concerning the use of space-based capabilities in deterrent operations:

> The alternative deterrent strategy and the one that actually drove military developments throughout most of the Cold War was a "nuclear war fighting" deterrent. In this case, nuclear weapons were valued not so much because they had terrible consequences, but because they were the most potent weapons available. Both sides believed they could have an effective deterrent if they could raise the specter in the adversary's mind that aggression would be met with a military response that would effectively defeat or seriously damage the aggressor's military power. . . . Space systems, particularly weapons in space, were not very appealing to the nuclear warfighter, as they could not be directed against fielded forces of much value—at least at that time.[8]

Worden, now at STRATCOM, and France conclude that "the foundation of any deterrence strategy [remains] rooted in the belief of the potential aggressor—be he near–peer state, lesser power, or non–state actor—that the U.S. has the forces necessary to cause irreparable harm to his economic and political power bases, and that the U.S. is willing to employ those tools to halt his aggression. The effective control of outer space and cyberspace and the ability to use those media to deliver devastating and precise strikes against an enemy's critical assets and fielded forces can provide just that effect."[9]

The *Strategic Master Plan* mirrors this language as it commits the Air Force Space Command to "emphasize four major areas to meet tomorrow's challenges:

> First, AFSPC will continue to provide a formidable, modern nuclear deterrent capability . . . one that is robust and adaptable to meet the threats of a dynamic security environment. AFSPC will also work to develop and expand its prompt global strike capabilities. Leveraging the technologies of our modern deterrence forces, we will develop other responsive space strike capabilities that, with strong defenses and highly responsive infrastructure, will afford the Nation a range of options to address any current or future threat."[10] [ellipses in original]

Despite the enthusiasm displayed by Worden, France, and the *Strategic Master Plan*, the deployment of weapons in space may prove technologically and economically challenging. After examining the current budget request status of the three aforementioned capabilities (in essence, the core of the modernization effort outlined in the Nuclear Posture Review and the

Strategic Master Plan), this paper finds that the United States appears to be a few years away from the first systems that would be considered space weapons. This conclusion is based on the announced levels of budgetary support and projected acquisition schedules described throughout the following pages.

"A few years" is a deceptively short time-frame. If the large levels of funding programmed into the FY04 Budget Request are sustained, the funding will generate momentum toward deployment. This holds particularly true because space weapons are embedded within a national security strategy and force modernization plan that emphasizes what the Rumsfeld Space Commission called "power projection in, from, and through space."[11]

Moreover, the Pentagon is designing many systems of virtually no functionality to be deployed in initial test blocks as part of the "spiral development" acquisition process—a process designed to speed the introduction of new technologies into fielded military forces. Dormant ASAT programs and the inherent anti-satellite capabilities of current ABM systems would also allow the Administration to conduct a space weapons test for political purposes on relatively short notice. Although not fully operational, these systems do have the potential to be highly provocative as symbols of the long-term path for U.S. strategic forces modernization, as well as symbols of U.S. intentions.

SECTION ONE: ENHANCING SPACE OPERATIONS

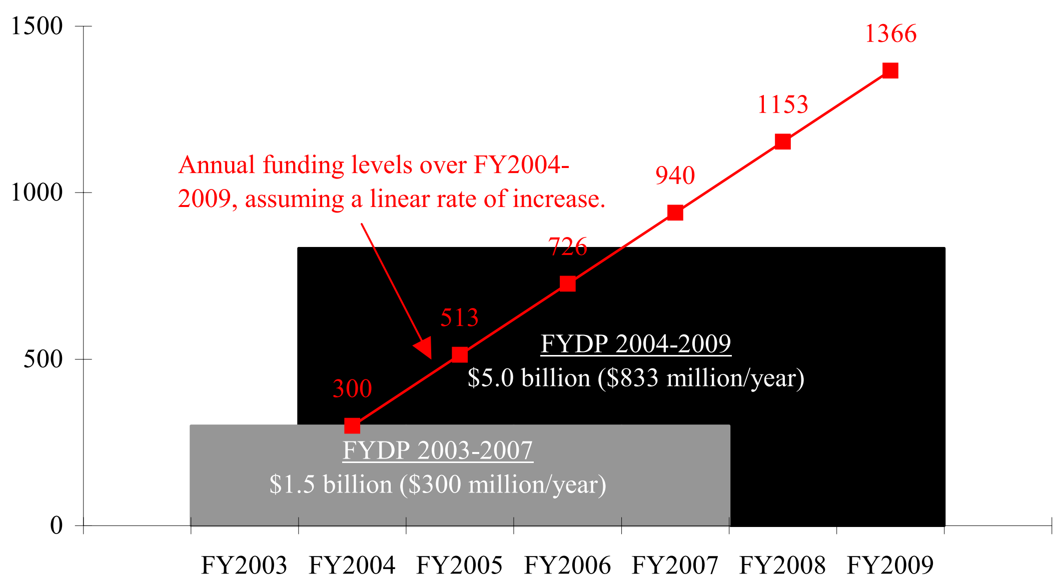
"Enhancing Space Operations" is one of six DOD force transformation goals.[12] "Enhancing Space Operations" refers to "investment," i.e. research development testing and evalutation (RDT&E), and procurement spending on three types of programs: the Common Aerospace Vehicle, space control technologies, and directed energy technologies.[13]

The FY04 budget request for "enhancing space operations" starts at $300 million in FY04[14] then "ramps up quite sharply throughout the six-year future year defense program," reaching a total of $5 billion over FY04-09.[15]

The FY04 request, with an average of $833 million in annual spending, is a dramatic (277%) increase over the President's FY03 request of roughly $300 million in anticipated annual spending.[16] The difference is impressive considering that the 2003 request was a 145% increase over *its* predecessor. Additionally, even given a conservative estimate of a linear growth rate, to spend $5 billion over six years from today's starting point of $300 million would mean spending $1.4 billion in 2009 alone. (Table 2: Spending on Enhancing Space Operations the FY03/04 budget requests).

A significant portion (approximately $2 billion) of spending in this transformation area, especially in the out years, remains classified. DOD Comptroller Zakheim said "[enhancing] space operations . . . is a lot of the space control systems and other elements—many of which are classified. These two [elements] you can see—[*space control technology* and *counterspace technologies*]—this is the thin edge of the wedge. By the time you … aggregate the six-year plan

Table 2: Spending on "Enhancing Space Operations" in the FY03/04 Budget Requests



Sources: Congressional testimony and author estimates.

Table 3: Program Elements Comprising "Enhancing Space Operations"									
Program	PE No.	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Common Aero Vehicle (CAV)	0604856F	0	0	12.2	21.7	27.3	32.6	31.5	39.5
Space Control Technology	0603438F	29.0	13.6	14.7	15.8	14.2	23.0	30.6	40.3
Counterspace Technologies	0604421F	0	39.5	82.6	76.1	27.8	32.8	28.9	77.0
Multi Disc. Space Tec.*	0602500F	0	1.2	5.1	5.1	5.4	5.4	5.4	4.7
Multi-Disc. Adv. Dev. Space Tec.*	0603500F	0	14.6	19.6	23.8	26.5	31.4	33.9	35.8
TOTAL		**29.0**	**68.9**	**134.2**	**142.5**	**101.2**	**125.2**	**130.3**	**197.3**

*Non-directed energy programs in this PE omitted

you're talking about considerable dollars there, but these are really cutting edge programs."[17]

Although small as a portion of the overall request, the unclassified portion of spending on "enhancing space operations" is rather robust: $134.2 million in FY04 and $928.6 million over FY04-09 (Table 3: Program Elements Comprising "Enhancing Space Operations.)

The remainder of Section One considers in detail each of the program elements, and related programs comprising "Enhancing Space Operations."

Common Aero (or Aerospace) Vehicle (CAV)

The Common Aero Vehicle (CAV) is a hypersonic glide vehicle, designed to carry a payload 3,000 nautical miles (5,500 km) downrange, with re-entry speeds of approximately 4,000 feet per second (1200 m/s) and an accuracy (circular probable error) of 3 meters. The CAV is designed to deliver a variety of 1000 pound (450 kg) submunition packages including

- 1 Rigid Penetrator for hard and deeply buried targets
- 6 Wide Area Autonomous Search Munitions (WAASM)
- 4 Small Smart Bomb Systems for facility destruction
- 6 Unmanned Aerial Vehicles (UAV) for intelligence gathering

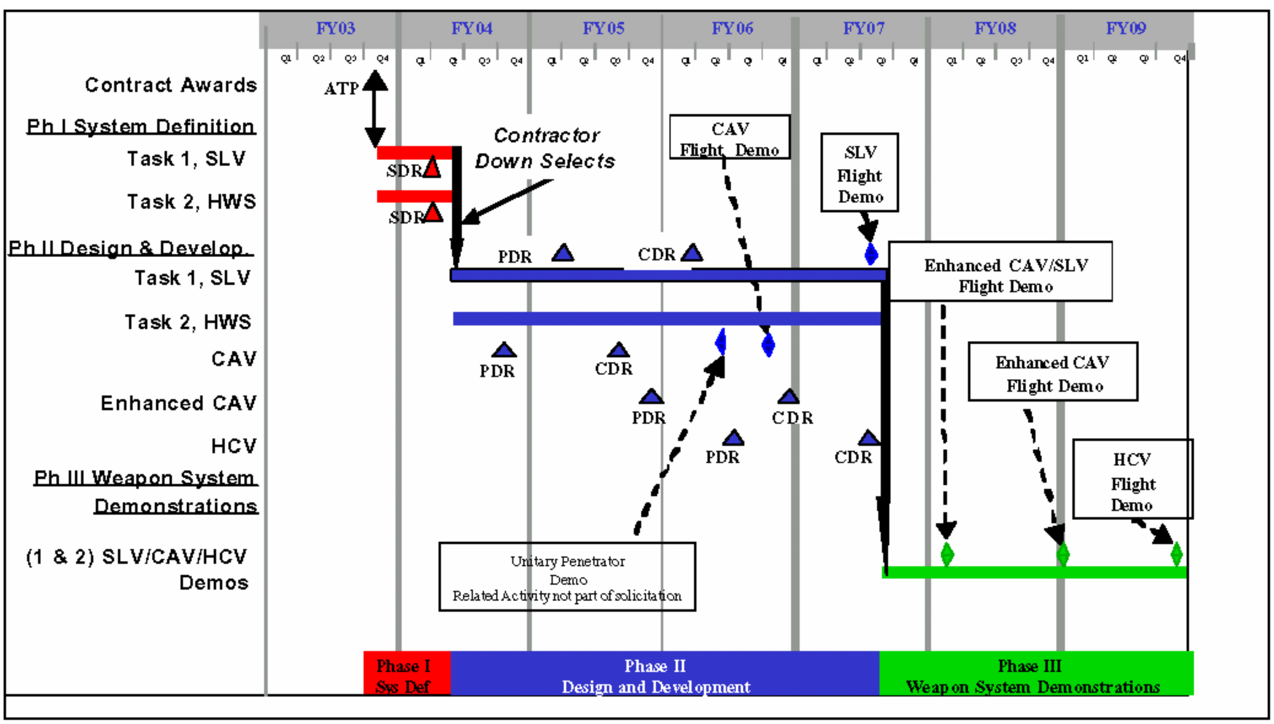
In the near-term, the CAV will be delivered by a ballistic missile or a space launch vehicle, but the DOD is considering a number of other delivery vehicles including a hypersonic vehicle (using technology from DARPA's RASCAL and Hypersoar program), a space operations vehicle, or a space-based platform.[18] Although the CAV is not a space weapon, per se, the program is a product of the DOD force modernization mission requirement that envisions warfighting from space. DOD explicitly intends the CAV program as an evolutionary capability toward two high-speed aerospace system concepts "that provide guidance for integration and technology assessment studies": a hypersonic weapons system and a military space plane. These are, without question, space weapons.

Table 4: CAV and Hypersoar Funding								
Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
0604856F Common Aero Vehicle (CAV)			12.2	21.7	27.3	32.6	31.5	39.5
0603285E Advanced Aerospace Systems (HyperSoar)*		7.5	21.5	25.0	40.0	50.0	50.0	50.0
*Other programs in PE 0603285E omitted								

The Hypersonic Weapons System—pursued under DARPA's Project FALCON (Force Application and Launch from CONUS Technology Demonstration)—is a DOD effort to address a long-standing mission requirement for "conventional global, prompt response" with a total response time of "hours."[19] In December 2002 the Deputy Secretary of Defense directed the Air Force and DARPA to establish a joint program office to accelerate the Common Aero Vehicle (CAV) effort to meet this requirement. As a consequence, the CAV is funded as a "new start" in the FY04 budget at $12.2 million (Table 4: CAV and Hypersoar Funding). The House Armed Services Committee recommended increasing funding of the CAV to $24.2 million.[20]

The CAV was expected to achieve initial operating capability (IOC) from a ballistic missile in 2010, although recent DARPA documents suggest that flight demonstrations may continue through 2009 (Table 5: Notional Timeline for Project FALCON). These estimates are purely notional—DARPA documents state that "this is only a baseline plan and better ideas are solicited based on specific contractor technology development plans."[21]

Table 5: Notional Timeline for Project FALCON



Defense Advanced Research Projects Agency, *FALCON: Force Application and Launch from CONUS Technology Demonstration PHASE I SOLICITATION 03-XX* (June 17, 2003) p.7.

Table 6: Military Space Plane (MSP) Concept of Operations

First Stage

Space Operations Vehicle (SOV)
Reusable first stage capable of lifting a 12,000 lb upper stage to with 2,000-4,000 lb payload to low earth orbit.

Second Stage

Modular insertion stage (MIS)
Low cost expandable upper stage

Space Maneuver Vehicle (SMV)
Reusable satellite bus

Common Aero Vehicle (CAV)
Maneuvering re-entry vehicle

Adapted from: Simon Worden, "Building a New U.S. Strategic Command" (August 7, 2002).

The CAV is expected to be followed by an enhance performance CAV (enhanced CAV) that would have a greater range (9,000 nmi/16,700 km downrange) and improved maneuverability (3,000 nmi/5,500 km cross-range). The enhanced performance CAV would be delivered by a Small Launch Vehicle, which would also be capable of placing a 1,000 kg satellite in a 450 km, 79° inclination sun-synchronous orbit. DARPA anticipates that CAV technologies could eventually support the development of a Hypersonic Cruise Vehicle by 2025 that would carry 12,000 lbs (5,400 kg)—up to six CAVs—9,000 nmi (16,700 km) in two hours.

Unclassified funding levels remain considerably below unofficial Air Force estimates that developing and procuring 70-100 CAVs would cost between $800 million- $1.3 billion. At this time, program work remains focused on concept design; requirements analysis; and various design studies, systems engineering, and program assessments—all activities intended to lead to the selection of a final design. Additional funding may come from the efforts of the House Armed Services and Appropriations Committees to add $100 million to the FY04 Budget Request "to begin research and development work on a new deep strike bomber …[to] help address basing problems highlighted during Operation Iraqi Freedom."[22]

The CAV is also one of three programs designed to operate together as the second stage of the "Military Space Plane," a distinct (but complementary) integrating concept to the Hypersonic Weapons System. The other second stage programs are the Space Maneuver Vehicle and a Modular Insertion Stage (MIS) for the purpose of boosting payloads into geosynchronous orbit (Table 6: Military Space Plane Concept of Operations). The CAV, SMV, and MIS would be delivered to low earth orbit by the system's first stage, a hypersonic Space Operations Vehicle (SOV).[23]

Table 7: NASA Spending on the Space Launch Initiative			
Cost (U.S.$ in millions)	FY02	FY03	FY04
2nd Generation Reusable Launch Vehicle	465.4	0	0
Space Transfer & Launch Technology	69.7	0	0
Orbital Space Plane (OSP) Program	0	295.7	550.2
Design & Integration	0	75.4	324.2
Technology & Demonstrations	0	220.3	226.0
X-37 Approach and Landing Test Vehicle (ALTV)	0	177.6	178.0
Demonstration of Autonomous Rendezvous Technology (DART)	0	19.7	18.0
Pad Abort Demonstrator (PAD)	0	23.0	30.0
X-37 Orbital Vehicle	-	-	-
Next Generation Launch Technology (NGLT) Program	0	583.7	514.5
Total: Space Launch Initiative (Technology)	**535.1**	**879.4**	**1,064.7**

Source: National Aeronautics and Space Administration.

The future of the military space plane concept, particularly the SMV and SOV, depends greatly on the development of technology within NASA's Space Launch Initiative, particularly the X-37 and Next Generation Launch Technologies (NGLT) (Table 7: NASA Spending on the Space Launch Initiative). The Space Maneuver Vehicle is expected to draw heavily on concepts tested by the X-37 Orbital Vehicle, a technology demonstrator, rather than a prototype spacecraft. NASA anticipates a Critical Design Review (CDR) for the X-37 Orbital Vehicle in early 2005, followed by an orbital flight test in CY06.

The U.S. Air Force declined a 2001 request from NASA and Air Force Space Command to take a greater role in the X-37 Orbital Vehicle, citing concerns that the test vehicle would not demonstrate technologies relevant for military systems (The Air Force also declined to fund two other NASA programs—X-33 and X-34—that were subsequently canceled).[24] It should be noted that the X-37 Orbital Vehicle is a separate program from the X-37 Approach and Landing Test Vehicle, which will validate system performance of the approach, landing, and turnaround operations for the Orbital Space Plane.

The Space Operations Vehicle is also expected to rely heavily on technologies generated by (NGLT). The NGLT program was created as part of a November 2002 restructuring of NASA efforts to develop a Second Generation Reusable Launch Vehicle. After cost estimates for developing a new reusable launch vehicle (RLV) by 2010 suggested that the program might cost two or four times the original program goal of $10 billion, NASA developed a new "Integrated Space Transportation Plan (ISTP)" as part of the 2003 budget amendment process. Under the new ISTP, NASA will now invest $2.4 billion over 2003-2007 for Next Generation Launch Technologies, deferring a full-scale development decision on an RLV until 2009 and an initial flight to 2015.[25]

Table 8: Selected "National Aerospace Initiative" Programs in the FY04 Budget										
Program	Service	PE No.	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
National Aerospace Initiative*	USAF	0603211F 5099	0	0	42.3					
Advanced Aerospace Propulsion	USAF	0603216F 5098	0	0	38.9	0	0	0	0	0
NAI Applied Research	Army	0602303A/G02	0	0	11.9	14.7	11.8	11.8	7.9	0
NAI Advanced Technology	Army	0603313A/G03	0	0	2.9	0	0	2.9	6.9	14.7

*"Outyear funding … will be addressed in the FY05 President's Budget Development."
Source: Air Force and Army RDT&E Descriptive Summaries.

Both efforts rely heavily on investments in hypersonic technology for flight and space access. The Department of Defense (along with NASA) is now pursuing an initiative under the Director of Defense Research and Engineering (DDRE) called the National Aerospace Initiative (NAI). A technology initiative, the NAI coordinates research and development in high speed/hypersonics, space access, and space technology.[26] The NAI will not be funded by a single service or agency, but will define common goals and coordinate activities across NASA and the military services.

Although the FY04 Budget Request contains some budget lines specifically for NAI activities within the Army (PE 0602303A/G02 and PE0603313A/G03) and the Air Force (0603211F 5099 and 0603216F 5098), the initiative is too new to have substantially affected the request (Table 8: Selected "National Aerospace Initiative" Programs in the FY04 Budget). Outyear funding for the Air Force's hypersonics program, for example, will not be addressed until the President's budget development for FY05.

In the meantime, many relevant Air Force research efforts in hypersonic technologies remain decentralized in other programs. Despite the lack of representation in the FY04 request, the new focus on hypersonics did, according to Ronald Sega, Director of Defense Research and Engineering, affect budget decisions. According to Sega's testimony, "In the FY04 budget request, the Department focused the increased investment into hypersonic technology, investing over $150M additional funds in hypersonics."[27]

The Senate Appropriations Committee, citing concerns that the Administration's budget request lacked "concise, unified submission that links all these projects together for a clearly defined, clearly stated goal that addresses the overall initiative"— refused to provide the Air Force Program with the $81.2 million it had sought for two hypersonics initiatives (National Aerospace Initiative and Advanced Aerospace Propulsion).[28]

The Senate Appropriations Committee also cut $50 million from other NAI efforts scattered throughout the budget (see Table 9: Other Senate Appropriations Committee Reductions to the National Aerospace Initiative). Although the Senate Appropriations Committee noted that the remaining funding was still an increase over funding levels for previous years, the Senate's decision to cut more than $130 million in hypersonics funding

Table 9: Other Senate Appropriations Committee Reductions to the National Aerospace Initiative			
Program Element (number and name)		Senate Appropriations Committee Reference	Reduction
0601102F	Defense Research Sciences	Hypersonics funding [NAI]	2.0
		Space Access [NAI	0.2
0602102F	Materials	Materials for Structures, Propulsion, and Subsystems	0.2
0602114N	Power Projection Applied Research	Hypersonics funding [NAI]—excludes HyFly	1.9
		Space Access [NAI]—excludes HyFly	2.5
0602201F	Aerospace Vehicle Technologies	Structures [NAI]	0.7
		Aerospace Vehicle Technology [NAI]	4.1
0602203F	Aerospace Propulsion	Hypersonics funding [NAI]	14.0
		Rocket Propulsion Technology [NAI	1.0
0602303A	Missile Technology	NAI Applied Research	1.9
0602500F	Multi-Disciplinary Space Technology	High Speed Airbreathing Propulsion Technology [NAI]	0.7
		Multi-Disciplinary Space Technology [NAI]	4.2
0602601F	Space Technology	Space Craft Vehicle Technology [NAI]	1.9
0603112F	Advanced Materials for Weapons Systems	National Aerospace Initiative	1.6
		Space and Missile Rocket Propulsion [NAI]	0.9
0603114N	Power Projection Advanced Technology	Hypersonics funding [NAI]—excludes HyFly	4.7
		Space Access [NAI]—excludes HyFly	0.2
0603285E	Advanced Aerospace Systems	Hypersonics funding [NAI]	2.8
		Space Access [NAI	1.7
0603313A	Missile and Rocket Advanced Technology	NAI Advanced Technology	0.5
0603401F	Advanced Spacecraft Technology	Ballistic Missile Technology [NAI]	0.5
0603500F	Multi-Disciplinary Adv. Dev. Space Technology	Rocket Propulsion Demonstration [NAI	1.6
Total			**49.8**

Senate Report 108-87.

stands in contrast to efforts in the House to add $100 million for next-generation strike platforms.

In addition to concerns about program management and political support, the National Aerospace Initiative may also be hampered by disputes between NASA and DOD. One potential area of conflict is NASA's focus on more technically straightforward hydrocarbon-fueled first-stage designs for the future Reusable Launch Vehicle (RLV).[29] The Air Force Scientific Advisory Board concluded in 2000 that a hydrogen-fueled first stage would better meet military needs because air-breathing jets can use the fuel to power a return to the launch site. NASA is focused on more accessible hydrocarbon fuels and has cut funding for research on hydrogen engines.

Space Control and Counterspace Technologies

Space control comprises three mission areas: space situational awareness (SSA), defensive counterspace (DCS), and offensive counterspace (OCS). The latter category includes anti-satellite (ASAT) weapons. The FY04 budget contains $134.8 million ($1.5 billion over the FYDP) for enhancing space situational awareness and $91.4 million ($635 million over the FYDP) for defensive and offensive counterspace.[30]

The Space Control Technology program element is an Air Force program that focuses on technology planning, development, demonstrations, and prototyping as well as modeling, simulations, and exercises (Table 10: PE 0603438F Space Control Technology). The most visible program within this element is the "Space Range." The Space Range is a "virtual" test range that the Air Force intends to base at Nellis Air Force Base in Nevada in order to conduct "exercises, training, and tactics development for Space Control systems."[31]

The Space Control Technology PE is also home to the Kinetic Energy Anti-Satellite (KE ASAT) interceptor, which was transferred from the Army to the Air Force as part of Secretary Rumsfeld's designation of the Air Force as "Executive Agent" for space. Advocates for the KE ASAT had long wanted control wrested from the Army, a branch some Congressional proponents considered lacking in enthusiasm for the endeavor.[32] Although the Pentagon did not request any funding for the KE ASAT, the Senate Armed Services Committee authorized $4 million for the program. As a result, the final budget authorization will have to be worked out in committee (Table 11: Congressional Changes to PE 0603438F Space Control Technology Authorization).[33]

Table 10: PE 0603438F Space Control Technology

Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Technology Insertion Planning and Analysis	29.0	13.6	9.4	9.4	9.5	12.6	15.7	20.6
Space Range	0	0	5.3	6.4	4.7	10.5	14.8	19.6
Total	**29.0**	**13.6**	**14.7**	**15.8**	**14.2**	**23.0**	**30.6**	**40.3**

USAF RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/

Table 11: Congressional Changes to PE 0603438F Space Control Technology Authorization			
Request	House	Senate	Conference
14.7	14.7	18.7	???
House and Senate Armed Services Committee Reports.			

Despite the indifference of senior military officers to the KE ASAT (one Air Force official called the KE ASAT an "iffy fly swatter in the sky"), the Senate has provided appropriations—some of which have been quite large (Table 12: Congressional Appropriations for Kinetic Energy Anti-satellite Program 1996-2004).[34] The Senate Appropriations Committee has proposed appropriations Kinetic Energy Anti-Satellite.[35] Although the KE ASAT's Senatorial patron, Robert Smith (R-NH), was defeated in a re-election bid, recent increases in authorization and appropriations suggest that support for the program has survived his departure. The programmatic effect of this sort of budgeting is unclear. GAO released a December 2000 report that found the program "in a state of disarray;"[36] nevertheless, the Pentagon regards the program as completed, and program officers believe they could conduct an on orbit demonstration for about $60 million (an amount that would cover two flight test vehicles and one spare).[37]

The second principle investment account for space control is Air Force *counterspace systems* (See: Table 13: PE 0604421F Counterspace Systems). This PE funds three programs:

- Counter Satellite Communications System
- Counter Surveillance Reconnaissance System
- Rapid Attack Identification Detection and Reporting System (RAIDRS)

Together, these programs are often called "promising space control initiatives" and were, until 2003, funded out of PE: 0603438F as demonstration and validation efforts. The shift in budget categories indicates that the programs have moved into the engineering and manufacturing development stage.

The Counter Satellite Communications System (CSCS) is a ground-based, mobile system "intended to disrupt satellite-based communications used by an enemy for military C3." The Counter Surveillance Reconnaissance System (CSRS), currently in the initial design phase, is also ground-based and designed to impair reconnaissance satellites with "reversible, non-damaging effects." These two systems, which are *offensive counterspace* systems, are expected

Table 12: Congressional Appropriations for Kinetic Energy Anti-satellite (KE ASAT) Program 1996-2004

	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04
Requested by DOD	0	0	0	0	0	0	0	0	0
Senate Markup	30.0	75.0	80.0	0	41.0	20.0	0	0	7.5
Appropriated by Congress	30.0	50.0	37.5	0	10.0	3.0	0	0	?

Derived from annual committee reports on annual national defense appropriations requests.

Table 13: PE 0604421F Counterspace Systems								
Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Counter Satellite Communications System	0.0	9.1	9.6	6.3	6.4	6.5	6.7	6.8
Counter Surveillance Reconnaissance System	0.0	23.5	66.4	53.4	5.0	14.2	9.8	3.7
Other procurement, Air Force	0.0	0.0	0.0	9.9	47.5	38.1	31.2	35.3
Rapid Identification Detection and Reporting System	0.0	6.9	6.6	16.4	16.5	12.1	12.4	66.5
Other procurement, Air Force	0.0	0.0	0.0	0.0	0.0	25.7	26.9	23.6
Total	**0.0**	**39.5**	**82.6**	**85.9**	**75.4**	**96.7**	**87.0**	**136.0**
USAF RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/								

to reach initial operating capability in 2004 and 2007, respectively. The Rapid Attack, Identification, Detection, and Reporting System (RAIDRS) is a *defensive counterspace* system designed to aid the detection, reporting, identification, location, and classification of attacks against valuable space assets. RAIDRS is planned to achieve initial operational capability in FY08.

The third space control investment account is the Air Force's SPACETRAK program element, which comprises most funding for the Space Surveillance Network and other space situational awareness efforts (Table 14: PE 0305910F SPACETRACK).

In addition to the ground-based sensors in the Space Surveillance Network (SSN)—such as the HAVE STARE X-band radar, the GEODSS network and the Navy Space Surveillance Fence—DOD is developing a space-based surveillance system called the Space-Based Space Surveillance (SBSS) satellite program. SBSS, which builds on the Mid-Course Space Experiment (MSX) designed by Lincoln Laboratory, seeks to improve the accuracy and timeliness of satellite tracking data.[38]

Table 14: PE 0305910F SPACETRACK									
Cost (U.S. $ in Millions)		FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Have Stare Radar	4279	8.5	0	0	0	0	0	0	0
GEODSS Sustainment	4791	3.1	0	0	0	0	0	0	0
Space Based Space Surveillance	4930	2.0	9.8	79.0	109.5	84.7	115.6	196.2	204.9
Space Situational Awareness Initiatives	5011	8.3	11.7	15.5	12.1	16.3	10.9	9.3	7.6
Sensor Service Life Extension Programs	A008	0	0	19.9	31.8	25.5	30.0	9.7	0.0
Orbital Deep Space Imager (ODSI)	A009	0	0	3.9	8.9	24.8	57.5	187.4	217.3
Total Program Element (PE) Cost		**21.9**	**21.5**	**118.2**	**162.3**	**151.3**	**214.3**	**402.3**	**429.3**
USAF RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/									

Table 15: Spending in Program Elements Containing Military Microsatellites										
Cost ($ in millions)			FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
PE 0602601F	Project 8809	"MightySat"	33.6	36.7	27.6	30.4	31.4	36.2	43.6	46.6
PE 0603401F	Project 2181	"TechSat 21"	16.0	14.9	20.0	16.1	16.2	18.5	35.2	35.3
	Project 3834	"XSS"	22.8	14.9	20.5	18.6	25.1	27.5	26.5	26.7
Total			**72.4**	**66.5**	**68.1**	**65.1**	**72.7**	**82.2**	**105.3**	**108.6**
PE 0605864F Space Test Program, Project 2617			46.8	49.1	42.9	44.6	45.2	46.2	57.4	58.1
Air Force RDT&E Descriptive Summaries.										

Microsatellites

Although the projects that constitute the Counterspace Systems program element appear to be exclusively ground-based systems, the *Strategic Master Plan* commits the Air Force to "*transform* its Counterspace capabilities by fielding revolutionary space-based capabilities through the mid- and far-term."

Air Force documents suggest that on-orbit counterspace systems will be deployed on microsatellite platforms—small satellites weighing less than 100 kg. A 1999 Air Force Microsatellite Technology and Requirements Study concluded that the idea of using such satellites "deserves high priority and offers a low-cost, low-risk method of achieving an SOI [space object identification] and Counterspace capability."[39] The 2000 edition of the *Strategic Master Plan* anticipated two notional counterspace microsatellites: the "Microsat Payload Imager" and the "Orbit Flexible Counterspace Microsat."

The FY04 budget request contains about $70 million for three microsatellite programs that are Air Force Research Laboratory technology demonstrators: Mighty Sat, TechSat 21, and the Experimental Satellite System (See Table 15: Spending in Program Elements Containing Military Microsatellites).

Although the mission tasks for the various microsatellite efforts in Air Force budget documents do not identify the project being funded, one can map AFRL project names to program elements by following Congressional plus-ups in recent years.[40] All three programs also likely receive some financial support for spaceflight services out of the Space Test Program (PE 0605864F). The Space Test Program does not, however, provide funds to construct experimental instruments or analyze the returned data.[41]

These systems are test beds for future microsatellite efforts. Dr. Donald C. Daniel, Deputy Assistant Secretary of the Air Force, testified before Congress that these three programs will "provide the technology base for 10-100 kilogram microsatellites that will offer new options in many areas of space applications. Applications previously considered not cost-effective due to size and weight limitations, such as satellite servicing or launch on demand, become possible."[42]

Table 16: Characteristics of Selected Air Force Microsatellites						
System	Launch Date	Orbit (km, °)	Dimensions (m×m×m)	Mass (kg)	Contractor	Type
MightySat I	1998	400, 52	0.5×0.5×0.5	60	Orbital	Technology Demonstration
MightySat II.1	2000	600, 98	0.7×0.9×0.9	120	Spectrum Astro	Technology Demonstration
MightySat II.2	TBD				Spectrum Astro	Technology Demonstration
TechSat 21*	2006	600, 35	0.8×1.1×1.1	150	Microsat Systems	Sparse Aperture Radar
XSS-10	2003	800, 40	0.5×0.5×0.9	30	Boeing	Autonomous Operations
XSS-11	2004	800, 65-97	0.6×0.6×1.0	125	Lockheed Martin	Autonomous Operations

Sources: See footnotes 39-50;
*The TechSat 21 project will comprise a cluster of three satellites on-orbit operating within 1000 meters; the dimensions given do not include two 2.3×3.0 m solar arrays deployed on-orbit.

Recent and anticipated AFRL microsatellites range from 30-150 kg. All three programs are designed to serve as test beds. The MightySat program is most explicitly intended in this manner, while the TechSat and XSS programs focus on particular missions—such as space-based radar and imaging—that demonstrate technical challenges such as flying in formation and operating autonomously (see Table 16: Characteristics of Selected Air Force Microsatellites). Short descriptions of these three programs follow.

The MightySat program is the "primary space demonstration" platform for the Air Force.[43] According to the Defense Technology Area Plan, each MightySat "functions as an experimental test bed exploring such objectives as demonstrating concept feasibility, developing a critical knowledge base to exploit new capabilities, identifying system risks under space environmental conditions, and providing flight heritage for critical components scheduled for deployment on future DoD space systems."[44]

MightySat I was launched in December 1998 with five advanced technology demonstrations regarding the structure, power, and avionics for microsatellites. That launch was followed by a larger satellite, MightySat II, which was anticipated to be the first of 5 such satellites launched 18-24 months apart.[45] The FY04 budget request for the MightySat program contains $14 million in Spacecraft Vehicle Technologies (Project 8809) to develop "innovative microsatellite architectures and advanced satellite bus technologies that could enable applications such as space protection, counterspace capabilities, sparse aperture sensing, on-orbit formation flying, inter-satellite communications, distributed processing, and responsive payloads."

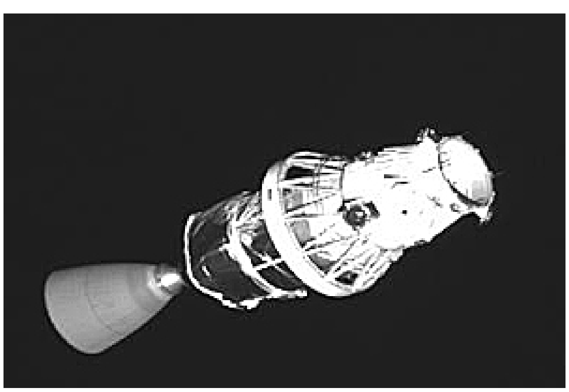
Unlike the MightySat, which is designed to validate a wide range of technologies for microsatellites, the remaining two programs—the TechSat 21 and XSS series—have more specific missions.

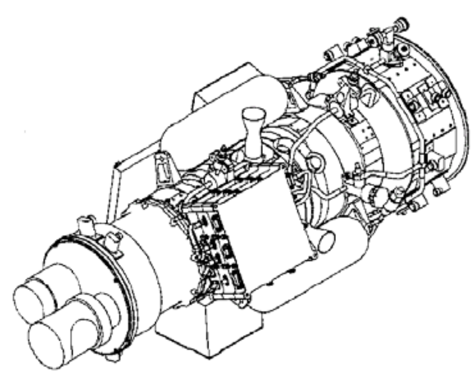
Radar resolution is a function of the size of its aperture—a problem, given the expense and technical difficulty of launching large objects into space. The TechSat 21 (Technology Satellite of the 21st Century) experiment poses a solution: a three-microsatellite constellation that will fly in close (100-500 m) formation to demonstrate so-called distributed or sparse aperture radar. This cluster formation offers a number of advantages, including the ability to reconfigure and modernize satellite components.

The FY04 budget request contains $20 million for programs, including $2.8 million to "Complete and deliver microsatellite cluster management software and integrate into the distributed architecture test bed in preparation for a flight demonstration of collaborating three microsatellite constellation." The Air Force anticipates a 2006 launch date. The demonstration of a satellite constellation that can fly in close formation may also benefit mission concepts beyond radar, including "on-orbit satellite inspection, advanced sensing, and aircraft missile launch of microsatellites."[46]

The Experimental Satellite System (XSS) series is designed as "a building block" for a future platform that can identify space objects and intercept satellites.[47] Just as the TechSat21 demonstrates cluster management through a sparse aperture radar mission, the XSS series also demonstrates autonomous on-orbit operations by performing imaging missions. The first XSS satellite, the XSS-10, was launched from the space shuttle in 2003 and conducted a 24-hour imaging mission (See Table 17: XSS-10).[48] James Engle, Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering, testified that the XSS-10 "demonstrated semi-autonomous operations and visual inspection in close proximity of an object in space—in this case a Delta II upper stage."[49]

Table 17: XSS-10





This image (left) of an expended Delta II launch vehicle was taken from approximately 100 meters by the XSS-10 (illustration, right) on January 30, 2003

Source: Air Force Research Laboratory

Table 18: PE 0603308A Army Missile Defense Systems Integration (Dem/Val)								
Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
978 Space Control	1.0	1.0	1.0	1.0	1.0	1.0	4.9	4.9
990 Space And Missile Defense Integration	40.7	50.8	8.6	8.7	8.5	8.4	7.9	6.3
Total	41.7	51.8	9.6	9.6	9.4	9.4	12.8	11.2

(Other projects in PE 0603308A omitted). U.S. Army RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

The Air Force is now preparing a Fall 2004 launch of the XSS-11, a larger microsatellite designed to remain in orbit for an entire year. The XSS-11 experiment is envisioned as a pathfinder for the Microsat Payload imager and could also support offensive counterspace missions. In fact, "[t]he single strongest recommendation" of the Air Force Microsatellite Study "is the deployment, as rapidly as possible, of XSS-10-based satellites able to intercept, image, and, if needed, take action against a target satellite."[50] The FY04 budget contains $14.4 million to "design, develop, integrate, and test autonomous microsatellites to demonstrate integrated technology concepts for operations around a non-cooperative resident space object" as part of the funding for the XSS series in the Integrated Space Technology Demonstration subelement (3834) of Air Force PE 0603401F, Advanced Spacecraft Technology.

In addition to these three programs, Air Force PE 0601102F, Defense Research Sciences contains $8.5 million in Electronics (Project 2305) to "research the scientific barriers to miniaturization of components" with a goal of reducing "satellite cost, weight, and size each by a factor of ten." The Air Force also spends on propulsion technology development for microsatellites. PE 0603500F, Multi-Disciplinary Advanced Development Space Technology, contains $6.5 million to "prepare for delivery of the advanced small satellite propulsion demonstration unit for a microsatellite formation flying demonstration supporting improved capability for Air Force imaging requirements." PE 0602500F, Multi-Disciplinary Space Technology, contains $5.2 million in Project 5026, Rocket Propulsion Component Technology to—among other tasks—continue "development of microsatellites (<25 kg) propulsion systems (e.g., plasma thrusters) for advanced imaging missions." AFRL and DARPA also fund ten university research centers.

Even with the overwhelming amount of programming for space control under the control of the Air Force, the Army maintains a space control PE under its missile defense systems integration efforts (Table 18: PE 0603308A Army Missile Defense Systems Integration). This PE was home to the KE ASAT before it was transferred to the control of the Air Force.

Table 19: DOD Directed Energy Programs									
Cost (U.S.$ in millions)		FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
High Energy Laser Research Initiatives	*0601108F*								
High Energy Laser Research Init.	5097	0.0	0.0	12.1	12.4	12.5	12.7	12.9	13.1
Multi Disciplinary Space Tec.[1]	*0602500F*								
Laser & Imaging Space Tec.[2]	5023	0	1.2	5.1	5.1	5.4	5.4	5.4	4.7
High Energy Laser Research	*0602890F*								
High Energy Laser Research	5096	0.0	0.0	41.9	45.5	48.4	51.8	52.2	53.0
Directed Energy Technology	0602605F								
Lasers & Imaging Tec.	4866	18.8	21.8	20.6	20.9	23.9	27.2	26.5	26.3
Adv. Weapons & Survivability Tec.	4867	14.7	15.8	14.7	15.4	15.7	18.0	17.3	17.3
Multi-Disciplinary Adv Dev Space Tec[1]	*0603500F*								
Adv. Optics & Laser Space Tec.[2]	5031	0	14.6	19.6	23.8	26.5	31.4	33.9	35.8
Advanced Weapons Technology	*0603605F*								
Advanced Optics Tec.	3150	0	21.5	23.8	0	0	0	0	0
High Power Solid State Laser Tec.	3151	5.0	8.6	14.2	15.1	15.6	15.9	16.2	16.4
High Power Microwave Tec.	3152	7.5	12.7	8.4	11.5	11.6	13.7	11.9	12.1
High Energy Laser Tec.	3647	26.7	8.3	4.4	3.6	2.0	2.1	2.2	2.2
High Energy Laser Adv. Tec. Program	0603924F								
High Energy Laser Adv. Tec.	5095	0	0	10.9	8.6	6.2	3.8	3.9	4.0
DOD High Energy Laser Test Facility	*0605605A*								
DOD HELSTF	E97	22.4	16.7	17.8	18.0	18.2	18.6	19.0	19.5
Total		**95.1**	**121.2**	**193.5**	**179.8**	**186**	**200.6**	**201.2**	**204.2**

1. Other programs in this PE omitted.

2. Space Unique Directed Energy Programs.

Directed Energy Programs

DOD has myriad directed energy programs, many of which are not "space-unique," i.e. not intended solely for missions involving space systems (Table 19: DOD Directed Energy Programs).[51]

From the perspective of DOD, two such programs are the most important:

- Multi Disciplinary Space Technology
- Multi-Disciplinary Advanced Development Space Technology

The Space-based Laser (SBL) program is funded out of the Missile Defense Agency Budget and will be addressed in a separate section of this paper.

The *Multi-Disciplinary Space Technology* PE reflects the Space Commission's recommendation to consolidate all "space-unique" programs; and the large jump in funding reflects transfer of civilian salaries. This PE is a "Budget Activity 2: Applied Research" program and is designed to enhance the technology base by focusing on questions about the technical feasibility of space-oriented lasers and imaging technologies for military applications.

The *Multi-Disciplinary Advanced Development Space Technology* PE, which falls under "Budget Activity 3: Advanced Technology Development," houses all the space-unique directed energy programs that demonstrate technologies for military applications. For example, the FY04 budget line has $5.3 million to conduct "atmospheric compensation/beam control experiments for applications including antisatellite weapons, relay mirror systems, satellite tests and diagnostics, and high-resolution satellite imaging."

These two efforts—*Multi Disciplinary Space Technology* and *Multi-Disciplinary Advanced Development Space Technology*—are new program elements created in the FY04 budget request by consolidating the space unique tasks in PE 0602605F *Directed Energy Technology* and PE 0603605F *Advanced Weapons Technology.* This action was recommended by the Rumsfeld Space Commission. Space-unique efforts in PE 0602605F *Directed Energy Technology*, Project 4866 were transferred to Project 5023 in *Multi Disciplinary Space Technology* PE, while space-unique efforts in PE 0603605F *Advanced Weapons Technology* Projects 3150 and 3647 were transferred to Project 5031 in *Multi-Disciplinary Advanced Development Space Technology*.

In addition to these four directed energy programs, the Department of Defense operates a High Energy Laser (HEL) Joint Technology Office (JTO) and a High Energy Laser test facility. The JTO is designed to fund technology efforts that might impact multiple HEL systems and multiple service missions. It was created in response to a March 2000 report by the Defense High Energy Laser Review Panel which called for the creation of a joint office "tasked with the development and day-to-day management of a joint program for revitalizing HEL S&T and serving as a clearinghouse for new S&T initiatives proposed by DoD components."[52] In fulfillment of these directives HEL/JTO operates three programs:

- *High Energy Research Initiatives* is a "Budget Activity 1: Basic Research" program that funds theoretical, computational, and experimental investigations, principally at universities.
- *High Energy Research* is a "Budget Activity 2: Applied Research" program that funds research aimed "at translating fundamental scientific knowledge into proof-of-concept solutions."

- *High Energy Laser Advanced Technology Program* is a "Budget Activity 3: Advanced Technology Development" program to translate "technology solutions for broadly defined military problems into demonstrated pay-offs such as increased capabilities, increased supportability, or increased affordability."

The *DOD High Energy Laser Test Facility* is home to the Mid Infra Red Chemical Laser (MIRACL) that conducted a 1997 test firing against a U.S. MSTI-3 imagery satellite in low-earth orbit to gather data on the vulnerability of U.S. military satellites to anti-satellite weapons.[53] The Army is transitioning the facility into a multi-service test bed to share operating costs. The FY04 funding request is largely allocated to carry out operations, maintenance, and support, as well as conduct some testing for the Navy's directed energy project office.

Other "Enhancing Space Operations" Programs

In addition to funding these three categories of programs—CAV, space control and directed energy—to enhance space operations systems, DARPA is funding several technology programs that warrant attention (Table 20: DARPA Space Programs and Technology ASP-02).

Among the most important of these programs is "Orbital Express Space Operations Architecture," a demonstration program designed to validate the technical feasibility of satellite constellations capable of conducting robotic, autonomous on-orbit refueling and reconfiguration. By enabling satellites to refuel and reconfigure (thus dramatically lengthening their service lives and simultaneously increasing the rate at which new technology can be deployed), such technology would dramatically alter the architecture of U.S. space systems.[54]

Table 20: DARPA Space Programs and Technology ASP-02

Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Orbital Express Space Operations Architecture	0.0	39.6	55.1	45.1	Detailed budget estimates not available for FY06-FY09			
Space Surveillance Telescope	0.0	4.0	9.0	17.0				
Innovative Space-Based Radar Antenna Technology (ISAT)	0.0	14.9	39.8	48.0				
Deep View	0.0	4.2	9.5	10.2				
Responsive Access, Small Cargo, Affordable Launch (RASCAL)	0.0	24.3	38.5	33.4				
Low Cost Tactical Imager	0.0	3.5	12.2	15.0				
HyperSoar	0.0	7.5	17.5	25.0				
Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST)	0.0	10.2	15.0	15.0				
High Frequency Active Auroral Research Project (HAARP)	0.0	10.2	15.0	15.0				
Suborbital Space Launch Operations		2.4						
Space Assembly and Manufacture			7.7	13.0				
Total	**0.0**	**110.5**	**209.4**	**230.7**	**248.6**	**321.8**	**346.9**	**381.0**

DARPA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

A partial list other DOD space-unique technology programs is provided in Table 21: Other Space Programs. A number of these efforts received substantial increases in the Senate Armed Services Committee Report that may survive conference, including:

- $14.5 million in PE 62601F for novel materials and computing for space technologies
- $7 million in PE 63401F for continued development of thin film multi-junction amorphous silicon arrays on flexible substrates for space applications
- $6.8 million in PE 63401F to continue research and development on hardening technologies for satellite protection[55]

Table 21: Other Space Programs									
Cost (U.S.$ in millions)		FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Multi-Disciplinary Space Technology	*0602500F*								
Laser & Imaging Space Technology	5023	0.0	1.2	5.1	5.1	5.4	5.4	5.4	4.7
Human Centered Applied Space Tec.	5024	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Space Materials Development	5025	0.0	18.2	19.6	23.4	21.6	27.4	37.2	36.7
Rocket Propulsion Component Tec.	5026	0.0	23.1	40.7	43.7	45.6	47.9	49.0	50.0
High Speed Airbreathing Prop. Tec.	5027	0.0	4.1	4.6	4.9	5.0	5.1	5.2	5.3
Space Sensors Photonics & RF Proc.	5028	0.0	43.5	1.7	2.2	2.0	4.2	4.3	4.3
Space Sensor & CM Technology	5029	0.0	6.9	12.7	5.6	1.7	5.2	7.3	6.3
Applied Space Access Vehicle Tec.	5030	0.0	1.3	0.0	0.0	0.0	3.9	8.2	7.3
Space Antennas Technology	5081	0.0	0.0	1.1	1.2	1.3	1.4	5.0	5.0
Optical Networking Technology	5082	0.0	0.0	5.1	5.2	5.1	5.1	5.1	5.1
Space Technology	*0602601F*								
Space Survivability & Surveillance	1010	31.3	23.8	36.3	38.2	38.5	41.2	39.8	40.4
Spacecraft Payload Technology	4846	14.5	11.4	15.3	19.3	20.2	20.9	36.1	40.1
Spacecraft Protection Technology	5018	0.0	4.3	4.0	2.8	2.7	2.5	2.6	2.6
Spacecraft Vehicle Technologies	8809	33.6	36.7	27.6	30.4	31.4	36.2	43.6	46.6
Advanced Spacecraft Technology	*0603401F*								
Spacecraft Payloads	2181	16.0	14.9	20.0	16.1	16.2	18.5	35.2	35.3
Integrated Space Tec. Dem.	3834	22.8	14.9	20.5	18.6	25.1	27.5	26.5	26.7
Space Systems Protection	4400	5.7	2.7	6.0	3.5	3.5	3.6	3.6	3.7
Space Developmental Planning	4938	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Space Systems Survivability	5021	0.0	3.9	4.2	4.8	4.9	5.0	5.1	5.1
Ballistic Missiles Technology	5083	0.0	0.0	6.9	6.9	5.8	4.1	4.1	4.2
Spacecraft Vehicles	682J	8.0	18.3	14.6	10.4	10.5	13.6	13.7	15.8
Multi-Disciplinary Adv. Dev. Space Tec.	*0603500F*								
Advanced Optics & Laser Space Tec.	5031	0.0	14.5	19.6	23.8	26.5	31.4	33.9	35.8
Advanced Space Materials	5032	0.0	6.7	11.7	0.0	0.0	5.8	5.3	3.9
Rocket Propulsion Dem.	5033	0.0	25.7	22.2	22.5	28.2	30.8	32.7	33.2
Adv. Space Sensors	5034	0.0	4.8	6.1	9.5	8.7	11.6	16.1	7.6
Adv. Structures for Space Vehicles	5062	0.0	2.5	3.0	0.0	0.0	2.9	0.9	0.5
Total		**136.8**	**281.7**	**305.5**	**298.1**	**309.8**	**358.4**	**425.1**	**425.8**

Projects and 5023 and 5031 also appear in Table 1: Program Elements Comprising “Enhanced Space Operations”; Project 3834 also appears in Table 14: PE 0603401F Advanced Spacecraft Technology.

SECTION TWO: ANTI-BALLISTIC MISSILE (ABM) SYSTEMS

In a December 2002 announcement, George W. Bush indicated that the United States would continue the "development and testing of space-based defenses, specifically space-based kinetic energy (hit to kill) interceptors and advanced target tracking satellites."[56] Accordingly, in the FY03 budget request, space-based elements formed a substantial portion of MDA spending, reaching almost 20% by 2007. This figure actually tops 25% a year if one includes the SBIRS-High (now SBIRS) program funded by the Air Force (Table 22: Space-based Elements in the FY03 Budget Request). By 2007, MDA was expecting to spend 6% of their budget on space-based kinetic kill interceptors and space-based lasers.

Table 22: Space-based Elements (% of MDA Spending) in the FY03 Budget Request

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Interceptors/Lasers	1%	1%	3%	4%	5%	6%		
Sensors	4%	6%	7%	14%	11%	12%		
Total	5%	7%	10%	18%	17%	18%		

President's FY03 Budget Request, Does not include SBIRS.

This section considers space-based interceptors and sensors, which form a substantial portion of the Administration's FY04 budget request for spending on anti-ballistic missile efforts (Table 23: Space-based Elements in the FY04 Budget Request). Although the Missile Agency no longer counts space-based boost-phase interceptors as a distinct program, based on extrapolations from the FY04-05 spending levels, the FY04 budget request appears to moderately accelerate the shift toward space-based missile defense interceptors.

Table 23: Space-based Elements (% of MDA Spending) in the FY04 Budget Request

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Interceptors/Lasers	1%	1%	3%	3%	5%	7%	8%	10%
Sensors	5%	5%	6%	6%	9%	12%	13%	14%
Total	6%	7%	8%	10%	14%	19%	22%	25%

Source: Author estimates based on President's FY04 Budget Request; Does not include SBIRS.

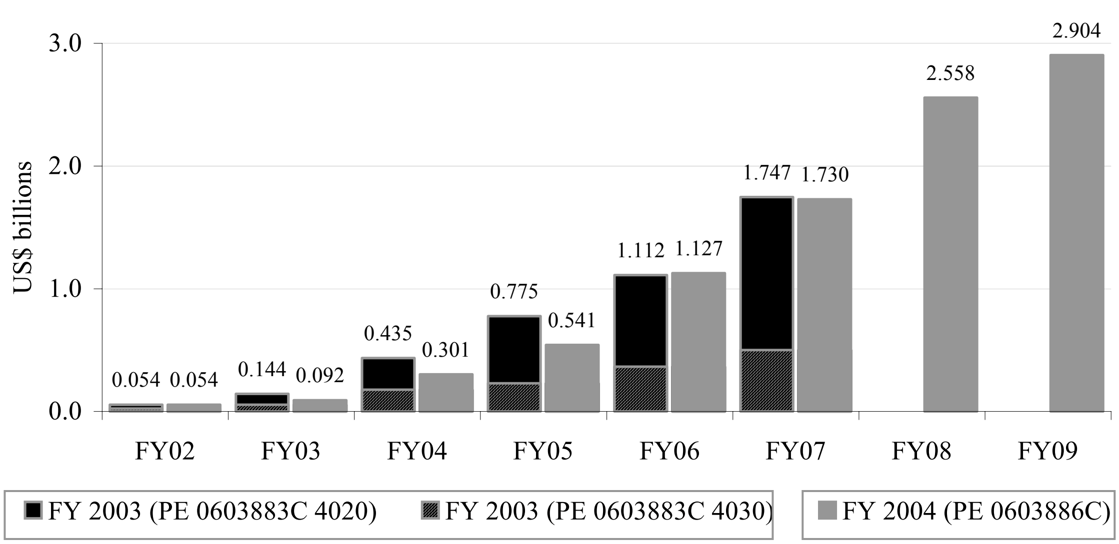
Table 24: PE 0603886C Ballistic Missile Defense System Interceptors								
Cost (U.S.$ in millions)	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09
0913 Ballistic Missile Defense Interceptors Block 2008	0	0	295.5	528.8	1,013.4	1,562.5	1,938.7	1,889.9
0013 Ballistic Missile Defense Interceptors Block 2010	0	0	0	0	97.3	146.4	585.1	974.2
0602 Program Operations	0	0	5.5	12.4	16.4	20.7	34.5	40.0
Total PE Cost	**0**	**0**	**301.1**	**541.2**	**1,127.2**	**1,729.6**	**2,558.3**	**2,904.1**

MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Space-based Kinetic Energy Interceptors

The space-based boost phase kinetic energy interceptor was initially funded as a distinct sub-element within the *Boost Phase Missile Defense Segment.* The Bush Administration has moved toward an open-ended, evolutionary architecture for its ABM efforts, however, combining the space- and sea-based kinetic kill, boost phase efforts in a single program: *Ballistic Missile Defense System Interceptors* (Table 24: PE 0603886C Ballistic Missile Defense System Interceptors). The funding profile for the combined program over the FYDP remains essentially the same as that for the two programs that were funded separately in the FY03 budget request (Table 25: Spending on Boost Phase Kinetic Kill in FY03 and FY04 budget requests).

Table 25: Spending on Boost Phase Kinetic Kill in FY03 and FY04 Budget Requests



MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Table 26: Project 0913 Ballistic Missile Defense Interceptors Block 2008		
COST (U.S.$ in Thousands)	FY 04	FY 05
Ground Based	184.9	341.7
Space Based Test Bed	14.0	119.5
Experimentation & Test	81.6	52.9
Program Management & Engineering	15.0	14.7
Total	**295.5**	**528.8**
MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.		

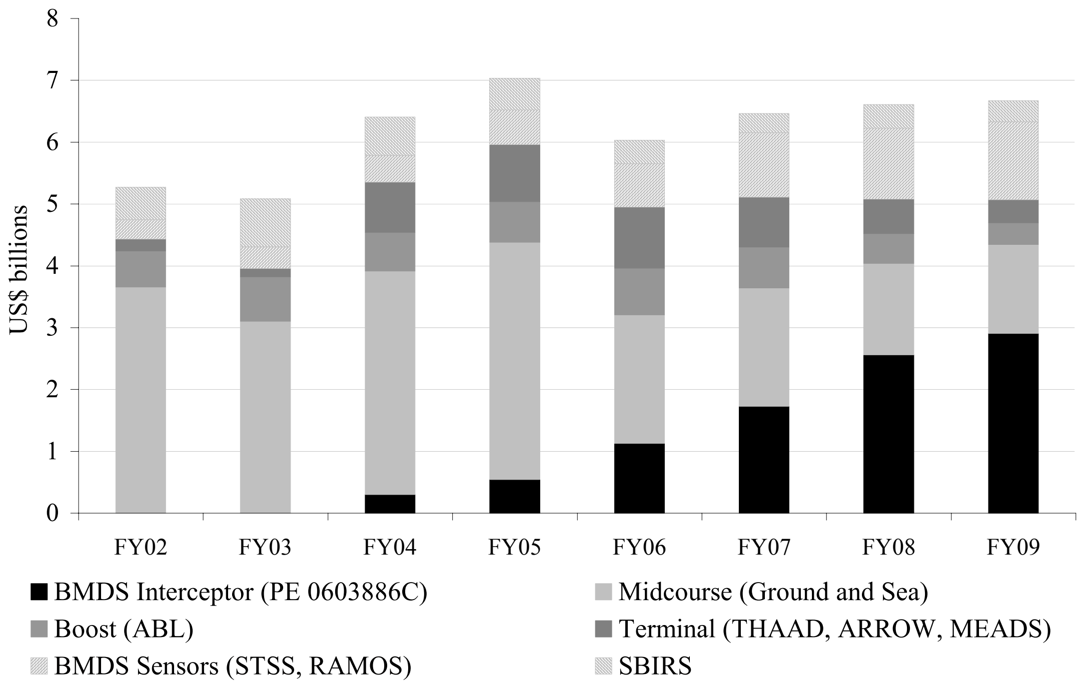
The ratio of spending within the PE for Ballistic Missile Defense System Interceptors also remains about the same as in the FY03 request, with more than half of the funds allocated to ground-based boost phase interceptors (Table 26: Project 0913 Ballistic Missile Defense Interceptors Block 2008). This reflects a programmatic decision to mature ground-based technologies before tackling more difficult challenges involved with sea- and space-basing.

Of the remaining funding, $81.6 million is allocated for "testing and evaluation." This money is allocated for the Near Field InfraRed Experiment (NFIRE) satellite.[57] According to one MDA official, "The objective of the Near Field InfraRed Experiment is to get a close-up view of a burning ICBM at conditions that are truly real world."[58] NFIRE will track two dedicated target launches, as well as other targets of opportunity. The payload may also include the Generation 2 Kill Vehicle (KV) to "execute KV engagement with dedicated target" in 2005.

Over the FYDP, the annual funding level for the BMDS interceptor program (which includes sea- as well as space-based efforts) will quickly exceed historical levels of funding for Brilliant Pebbles in the early 1990s (Table 27: Brilliant Pebbles, Then and Now). Overall, the Bush Administration anticipates spending $13.6 billion—a figure comparable to 1992 and 1996 CBO estimates—between FY03-04 on the BMDS interceptor program for the development costs of a constellation of space-based interceptors. This program will be by far the largest program for the Missile Defense Agency by the end of the FYDP (Table 28: Spending on Selected BMDS Programs).

Table 27: Brilliant Pebbles, Then and Now									
Cost (2004 U.S.$ in billions)	1993	1994	1995	1996	1997			**93-97**	
Brilliant Pebbles (2003)	0.7	0.7	0.7	0.7	0.7			**3.6**	
As a percentage of BMDO	11%	8%	7%	8%	8%			**8%**	
	2003	2004	2005	2006	2007	2008	2009	**03-07**	**03-09**
BMDS Interceptors (2004)	0.0	0.3	0.5	1.2	1.8	2.7	3.2	**3.8**	**13.6**
As a percentage of MDA	0%	4%	6%	15%	21%	30%	33%	**10%**	**14%**
1993 Estimates from Ray Hall and David Mosher, *Cost of Alternative Approaches to SDI*, Congressional Budget Office, May 1992, p.15									

Table 28: Spending on Selected BMDS Programs



MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

In addition to generous funding, MDA has articulated an ambitious schedule for the deployment of its space-based test bed comprising several prototype interceptors. The FY04 budget request includes $14 million for the space-based interceptor test bed that will fund multiple contractor awards, to be followed by a $120 million downselect in 2005 (Table 29: Space Based Test Bed Schedule). Under this plan, MDA plans to begin on-orbit testing "with three to five satellites in Block 2008."[59]

There is little documentation available in support of the optimism expressed by the Missile Defense Agency. The Congressional Budget Office reported that in response to a request for detailed cost-estimates of proposed space-based interceptor architectures,

> The most recent information CBO was able to obtain about that system was a 1992 cost analysis requirements description (CARD). DoD has not done a significant amount of additional work on space-based interceptors since the program was canceled early in the Clinton Administration. Thus, CBO has no basis for revising its previous estimate, which may no longer be applicable. In particular, it is unclear what the relationship might be between the 1992 CARD for Brilliant Pebbles and whatever space-based interceptor system might emerge from the research program that the Bush Administration is beginning..[60]

The lack of detailed information reflects a decision by MDA officials to delay the preparation of detailed life-cycle cost estimates until systems are transferred from the test bed to the services, a practice GAO strongly criticized in a 2003 report.[61]

Table 29: Space-Based Test Bed Schedule								
Space-Based Test Bed	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09
a. Block 08 Multiple Contractor Award			4Q					
b. Block 08 Contract Downselect				3Q				
c. Design Review 1					3Q			
d. Design Review 2						3Q		
e. First Satellite Launch							4Q	
f. First Flight Test								1Q
g. Additional Satellite Launches								1Q-4Q
h. Additional Flight Tests								1Q-4Q
MDA Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.								

The four-year estimate to deploy simple space-based boost phase interceptors in a test bed configuration appears to be based on some of the most optimistic assessments advanced by proponents of Brilliant Pebbles. Gregory Canvan, a physicist at Los Alamos National Laboratory, recently estimated that the Brilliant Pebbles constellation could be deployed within four years for a development cost of about $13 billion ($10 billion in 1990 dollars). It is worth noting that the last defense budget to contain substantial funding for space-based interceptors—the FY1993 Request submitted by the outgoing Bush Administration—did not anticipate deployment of space-based interceptors until "a few years after 2000."

Despite the large levels of funding anticipated by the FY04 Budget request, MDA appears to have cooled on plans to begin testing space-based interceptor components by the second quarter of 2005. Citing a "combination of lagging technology and pressure from Capitol Hill," MDA is now planning to continue basic research on the interceptor through 2008.[62]

This decision follows substantial Congressional reductions in funding for the program element in the FY04 budget request.[63] The reductions follow an expressed concern by the House and Senate Armed Services Committees that the program lacks a clear plan to cope with the technical challenges posed by boost-phase intercepts, particularly in sea- and space-based modes (Table 30: Appropriations for PE 0603886C Ballistic Missile Defense System Interceptor). The House and Senate Appropriations Committees cut $150 million and $210 million, respectively, from the FY04 Request for the BMDS Interceptor. [64]

Table 30: Appropriations for PE 0603886C Ballistic Missile Defense System Interceptors			
Request	House	Senate	Conference
301.1	151.1	91.1	???
Senate Report 108-87, p.169 and *House Report 108-187*, p.211.			

The Senate also adopted an amendment to the authorization bill offered by Senator Bingaman (D-NM) that prohibits the expenditure of funds to "to design, develop, or deploy hit-to-kill interceptors or other weapons for placement in space unless specifically authorized by Congress" and states that only "$14,000,000 is available for research and concept definition for the space based test bed." Although the technical challenges of boost-phase intercept may prevent the effective use of the system in an anti-ballistic missile mode, the monetary allocation for research and concept definition recognizes the inherent capability of these systems as anti-satellite interceptors.[65]

Space-based Laser Technologies

MDA has a much smaller space-based laser program (Table 30: PE 0603175C Ballistic Missile Defense Technology) that has received episodic support. Funding for the Space-based Laser (a cylindrical, hydrogen-fluoride chemical laser designed to intercept a ballistic missile in its boost phase) is well below what would be necessary to deploy such a system in the near-term.

The Congressional Budget Office has estimated that developing a constellation of space-based lasers would cost-between $14-20 billion (Table 31: Costs Of A Space-based Laser National Missile Defense System). The CBO based the estimate on existing MDA plans to conduct an Integrated Flight Experiment in 2012, using a single high-energy laser in orbit. CBO estimated that pursuing a space-based laser in this manner would cost $3-5 billion for the IFE, followed by annual costs for development, production, and deployment of an operational system that would vary from $1-7 billion over FY13-25 (Table 32: Projected Annual Costs For A Space-Based Laser, Fiscal Years 2002-2025). For purposes of the estimate, CBO assumed a constellation of 24 satellites.[66]

Last year, MDA closed its Space-based Laser (SBL) program office and canceled the anticipated 2012 test of the system. MDA's decision followed a $120 million Congressional cut to the program in FY02 and a decision by MDA not to seek substantial funding in FY03.[67] MDA Director Ronald Kadish told reporters that MDA would no longer focus on "putting an experiment in space in the near term . . . . Space basing of this capability can be looked at as a later improvement as opposed to a near-term imperative."[68]

Despite the closure of the program office and transfer of assets, the level of funding for space-based laser technologies in the FY04 budget request is virtually identical to that in the FY03 request (Table 33: Comparison of FY03 and FY04 Requests for the Space-based Laser). This may reflect a decision to continue funding the program at minimal levels until a political decision is made to resuscitate the program.

Table 31: PE 0603175C Ballistic Missile Defense Technology

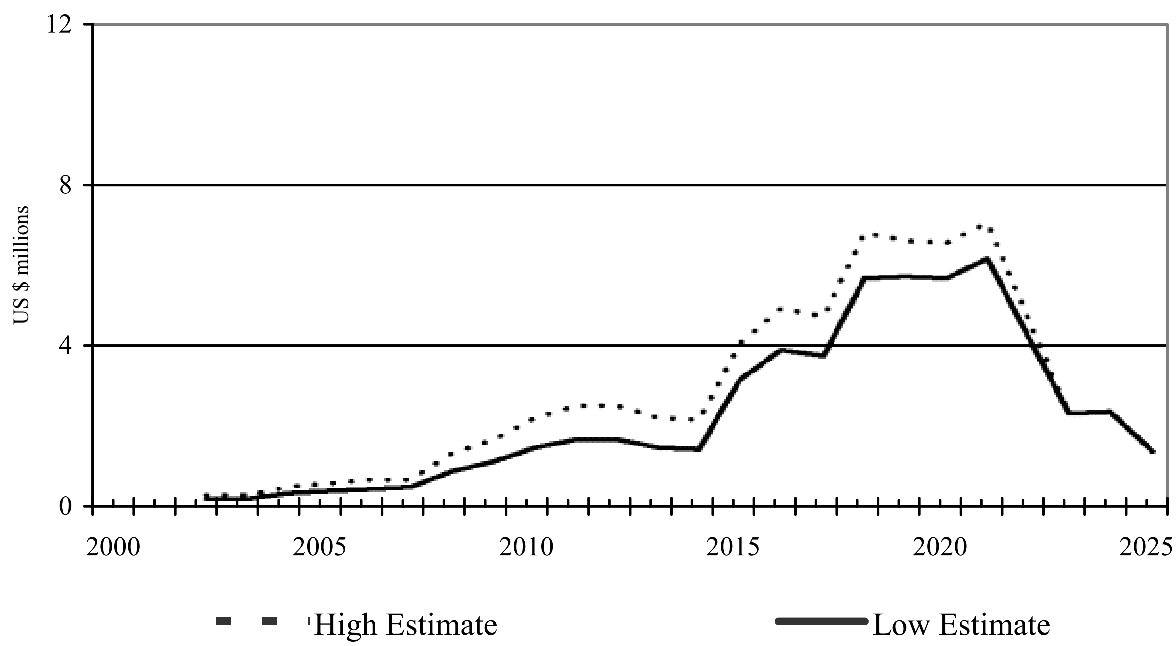
Cost (U.S.$ in millions)		FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
0503	Laser Technology	0	0	47.1	47.0	48.9	48.8	49.7	50.7

MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Table 32: Costs Of A Space-Based Laser National Missile Defense System, Fiscal Years 2002-2025				
(In billions of constant 2001 U.S dollars)	Low	High	Low	High
Research and Development			14	20
IFX laser	3	5		
Operational laser	7	11		
Launch vehicle	3	5		
Production			40	46
Operational laser	27	33		
Launch Vehicle	13	13		
Total Acquisitions Costs			**54**	**67**
Operations Through 2025			2	2
Total Costs Through 2025			**56**	**68**

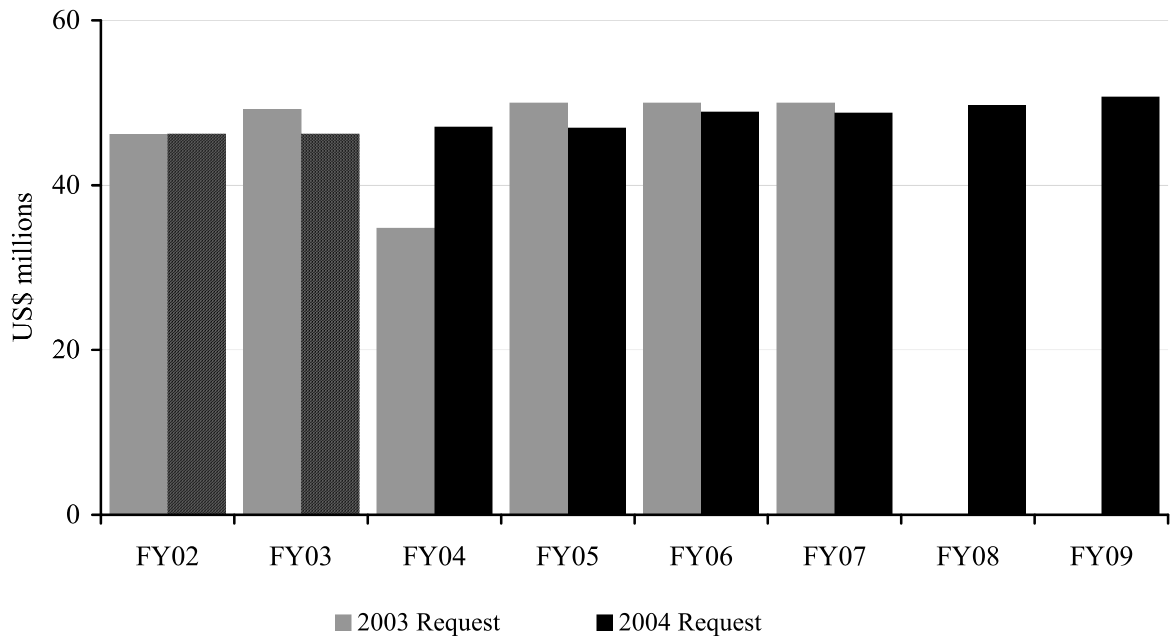
Adapted from CBO, Estimated Costs and Technical Characteristics of Selected National Missile Defense Systems, January 2002

Table 33: Projected Annual Costs For A Space-Based Laser, Fiscal Years 2002-2025



CBO estimates. Total costs through 2025 are $56-68 billion.

Table 34: Comparison of FY03 and FY04 Requests for the Space-Based laser



Striped bars are actual spending; all other bars are estimated spending; MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Space-based Sensors

Satellite-based sensors are the largest space-based element in the anticipated ballistic missile defense system architecture. Basing sensors in space offers numerous advantages, as one missile defense proponent noted:

> Space-based sensors can enhance the effectiveness of ground-based radar by cueing them as to the direction of the threat. They can also provide a highly effective countermeasure against simple decoys. Hence, the ability to deploy freely and employ sensors is critical to the role of missile defenses as both deterrent and defense.[69]

Missile Defense Agency funding for sensor programs has been overwhelmingly dedicated to space-based systems (Table 34: FY04 BMDS Sensor Segment).

One space-based sensor, the *Space Tracking and Surveillance System* is the successor to the former Space Based Infrared System (SBIRS)-Low. STSS is a passive, low earth orbit surveillance system that would provide global coverage of ballistic missile trajectories in all phases of flight (Table 35: PE 63884C Space Tracking and Surveillance System).

Table 34: FY04 BMDS Sensor Segment								
Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
SBIRS/STSS	234.1	286.3	300.2	329.0	517.5	851.0	1002.5	1188.5
RAMOS	50.9	49.0	29.6	77.4	39.1	35.1	24.4	24.4
BMDS Radars	0.0	0.0	101.0	144.9	133.9	136.1	102.5	22.2
Testing and Evaluation	13.8	4.9	0.0	0.0	0.0	0.0	0.0	0.0
Program Operations	14.2	10.2	7.4	11.4	16.1	21.2	23.4	26.8
Subtotal	*313.0*	*350.4*	*438.2*	*562.8*	*706.5*	*1043.5*	*1152.7*	*1261.9*
SBIRS High	524.5	775.4	617.2	508.9	375.6	311.9	381.9	342.0
Total	**837.4**	**1125.8**	**1055.5**	**1071.7**	**1082.2**	**1355.4**	**1534.7**	**1604.0**
USAF and MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.								

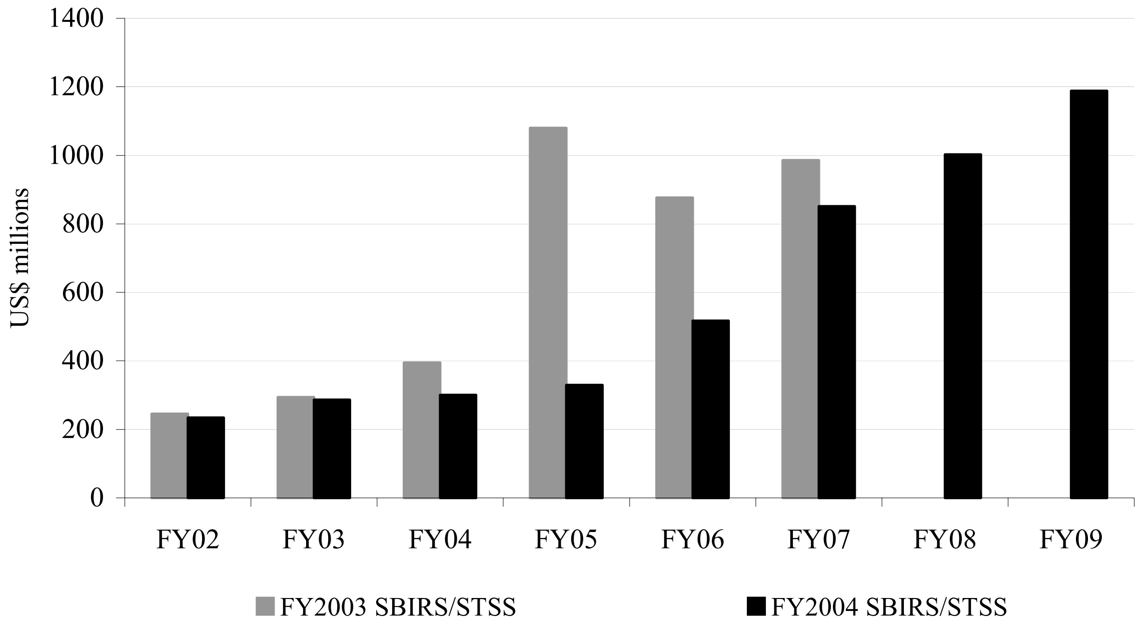
After a February 2001 GAO report warned that SBIRS-Low program was "at high risk of not delivering the system on time or at cost or with the expected performance," Congress removed the SBIRS Low program from the acquisition track. Congress instead appropriated $250 million for “Satellite Sensor Technology” to be used by the Secretary of Defense “to reduce risk and mature technologies for future space sensor applications for missile defense.”[70] In early 2002, MDA restructured SBIRS-Low and renamed the program the Space Tracking and Surveillance System. Rumsfeld explained in testimony:

> Just last session, the Chairman and other members of this Committee raised questions about SBIRS-low. You expressed concern that the time schedule for the program was too aggressive, and the technology was not aggressive enough, suggesting we slow the program down and take a look at some newer technologies. We listened to your concerns, and agreed. And we have restructured the program—slipping it back two years and introducing newer technology.[71]

The restructured program abandoned the planned 2006 launch date in favor of the modest goal of launching two demonstration satellites in 2007, followed by a second generation of satellites in 2011.[72] These satellites may be deployed in one of three different constellations: Basic Coverage (9-12 satellites), Increased Coverage of key threat regions (18-20 satellites), or Worldwide Coverage (25-30 satellites).

Table 35: PE 63884C Space Tracking and Surveillance System								
Cost (U.S.$ in thousands)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
5041 SBIRS Low/STSS	234.1	286.3	0.0	0.0	0.0	0.0	0.0	0.0
0812 STSS Block 2006	0.0	0.0	275.9	285.0	285.4	204.0	75.1	35.1
0912 STSS Block 2008	0.0	0.0	0.0	0.0	0.0	82.0	177.5	88.7
0012 STSS Block 2010	0.0	0.0	24.3	44.1	232.1	565.1	749.9	1064.8
Total	**234.1**	**286.3**	**300.2**	**329.1**	**517.5**	**851.1**	**1,002.5**	**1188.6**
MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.								

Table 36: SBIRS Low/STSS in FY03 and FY04 Budget Requests



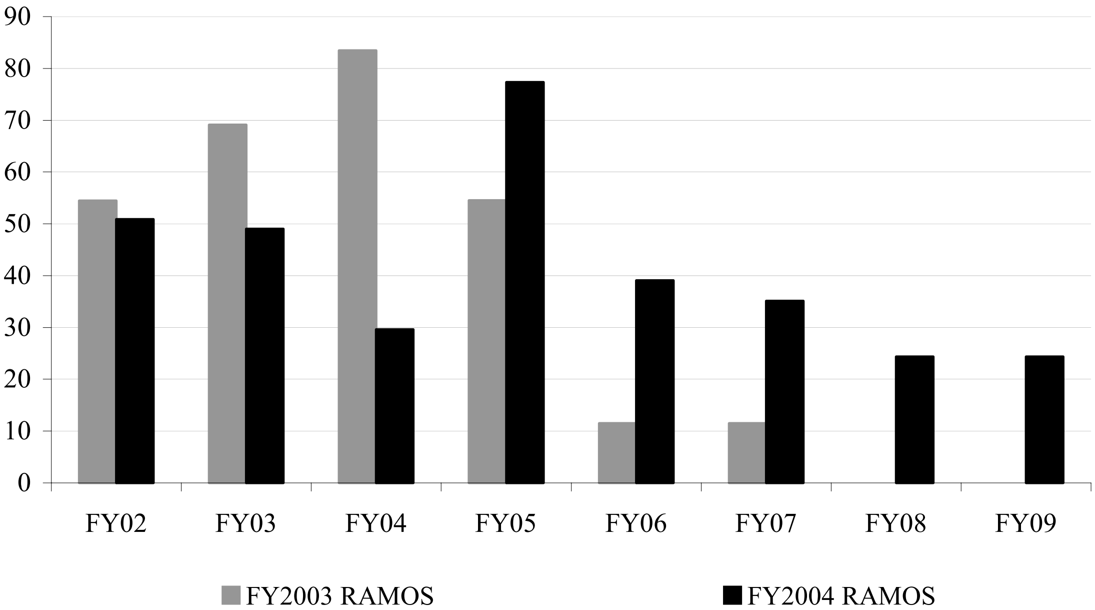
MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Even after the restructuring, a May 2003 GAO report warns that "DOD is at risk of repeating past mistakes because it has made decisions that are largely focused on meeting its 2007 launch date. . . ."[73] The cause for such concern is rooted in a GAO finding that MDA has made significant sacrifices in competition and risk reduction efforts in order to stay on schedule to meet the 2007 launch target. Accordingly, the Senate Armed Services Committee asked for a cut of $15.5 million, citing an "unjustified growth in program management cost since fiscal year 2003" (Table 36: SBIRS Low/STSS in FY03 and FY04 Budget Requests).[74]

Another space-based system, the *Russian-American Observation Satellite* (RAMOS) is a joint U.S.-Russian program to design, build, launch, and operate two satellites that will provide stereoscopic observations of the earth's atmosphere and ballistic missile launches. The satellites are scheduled for launch in FY07-08 with a nominal two-year on-orbit life expectancy and goal to extend the mission an additional five years. RAMOS, along with the proposed Joint Data Exchange Center, was envisioned as a way to back-stop Russian early warning capabilities and build confidence in U.S. intentions.[75]

Both programs remain moribund over administrative issues.[76] The RAMOS program has been tied up in a dispute over a DOD plan to restructure the division of labor within the program The plan proposes that Russia will provide the launch capability, satellite platforms, ultraviolet sensors, and visible cameras, and ground processing and control equipment, while the U.S. will provide the infrared sensors and visible pushbroom cameras. MDA maintains that a new government-to-government agreement between Washington and Moscow is required to release funding to the Russian firm Rosoboronexport and its Russian subcontractors.[77]

Table 37: RAMOS in FY03 and FY04 Budget Requests



MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

In anticipation of a new government-to-government memorandum, Congress has continued to fund a restructured RAMOS program (Table 37: RAMOS in 2003 and 2004 Budget Requests). Additionally, the Senate Armed Services Committee proposed language in the defense authorization bill directing that "no more than $24.6 million [of the $29.6 million] may be available for obligation or expenditure until a government-to-government agreement on the RAMOS program is concluded. The committee intends this restriction to provide an appropriate incentive to the Russian Federation to reach an agreement."[78] The MDA planned to spend about $11 million this year to contract with Russian partner Rosoboronexport, who will subcontract "the development of visible and ultraviolet cameras; satellite platforms; development and operation of the Moscow ground station; and launch services" to Russian firms.[79]

A third space-based sensor program, *Space-based Infra Red System-High*, falls under Air Force budgetary control. SBIRS High will consist of a constellation of four satellites plus one spare in geosynchronous orbit, two sensors on a non-SBIRS satellite in highly elliptical orbit,

Table 38: Space-based Infra Red System (SBIRS)-High

Cost (U.S.$ in thousands)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
3616 SBIRS High Element EMD	524.5	775.4	617.2	508.9	375.6	311.9	381.9	342.0

MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

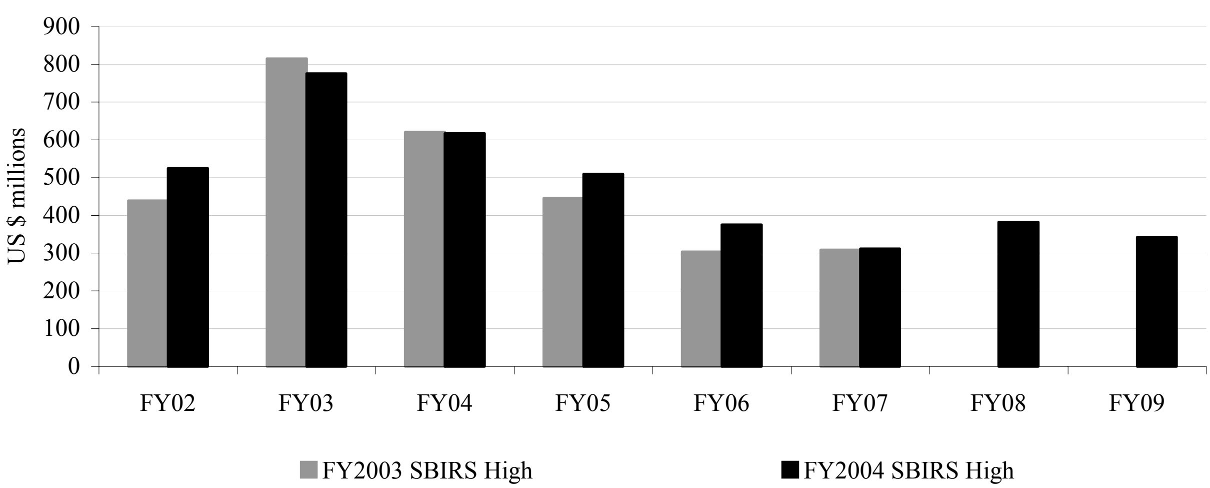
Table 39: SBIRS High Cost Growth			
Cost (U.S.$ in billions)	Approved (March 1998)	Latest (June 2002)	Percent Change
Research & development cost	$3.4	$6.0	79.9 %
Procurement cost	$0.6	$1.4	154.0 %
Total program cost	$4.1	$8.2	99.7 %
Program unit cost	$0.8	$1.6	99.7 %
Total quantities	5	5	-

GAO, *Defense Acquisitions: Assessments of Major Weapon Programs* (May 2003) pp.57-58.

and associated ground stations (Table 38: Space-based Infra Red System-High). The first launch of SBIRS High is scheduled for 2006. SBIRS High has experienced large cost over-runs. The program was originally projected to cost $4.1 billion (in 2003 dollars), but current program estimates are now double that figure. In December 2001, DOD notified Congress that the program unit cost growth for the SBIRS-High program exceeded 25% in a single year (Table 39: SBIRS-High Cost Growth).[80]

To avoid cancellation of the program, the Secretary of the Air Force was required by law to certify that the program was "essential for national security" and undertake restructuring, which was completed in January 2003.[81] This restructuring program has caused concern in Congress, where the Senate Armed Services Committee noted that the latest restructure "will delay the acquisition of the third, fourth, and fifth geosynchronous satellites by two years and leave a three-year gap between the launch of the second and third of these satellites" (Table 40: SBIRS-High in FY03 and FY04 Budget Requests). The committee proposed language directing the Secretary of the Air Force "to develop a plan to reduce the production gap in the SBIRS program from two to one year."[82]

Table 40: SBIRS High in FY03 and FY04 Budget Requests



MDA RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/

SECTION THREE: INTEGRATED FOCUSED SURVEILLANCE

The final category is what the 1998 Space Command Long-Range Plan called “integrated focused surveillance” or command, control and intelligence (C2I). The *Nuclear Posture Review* asserts that its “New Triad is bound together by enhanced command and control (C2) and intelligence systems.”[83]

This section covers two “very innovative, creative, technology-pushing initiatives underway” to improve capabilities: Transformational Communications Architecture (TCA) and Space-Based Radar (SBR).[84]

Transformational Communications Architecture

There are three types of military satellite communications: wide-band, protected, and narrow-band. Wide-band offers large capacity for transmission of relatively routine communications, while protected sacrifices capacity for security. Narrow-band systems—not addressed in this paper—are principally tactical in orientation.[85]

The Transformational Communications Architecture (TCA) refers to two satellite legacy programs—AEHF and Wideband Gapfiller—and the third, transformational program: the Advanced Wideband System (also known as the “Transformational Satellite” or TSAT). The Pentagon envisions these three programs as part of a common architecture that will “increase available bandwidth from 10 to 100 times existing capacity.”[86]

The Air Force recently created a Transformational Communications Office to integrate the legacy satellite communications systems with Advanced Wideband.[87] Although the FY04 Budget Request is the beginning of that process, the final architecture remains contested. For example, the House and Senate have proposed reducing the funding available to the Advanced Wideband System, shifting money into the near-term priorities like the Advanced EHF system. The three elements of the Transformational Communications Office (two legacy programs and the transformational element) are described in the following paragraphs.

The *Advanced Extremely High Frequency (EHF) Satellite* is a high frequency communications satellite constellation. The Advanced EHF provides follow-on capability to the high frequency protected communications of the current MILSTAR satellite program.[88] The Advanced EHF satellite has a requirement to channel data at a rate of six to eight million bits of data per second, a requirement that may prove optimistic.[89]

The program has experienced substantial cost growth since the Air Force proposed a constellation of five satellites (four satellites and one spare) in a low-inclined geosynchronous orbit. Initially estimated at a total cost of $4,071 million (2002 dollars), the program experienced a 36% cost increase to $5,561 million.[90] Shortly thereafter, the Air Force slipped the first launch of the program from June 2006 to December 2006 and announced it would procure only three satellites, funding the first two with RDT&E funds and the third with procurement funds (Table 41: Advanced EHF Program Cost Growth).[91] The future of the remaining two satellites is

Table 41: Advanced EHF Program Cost Growth			
Cost (FY03 US$ in billions)	October 2001	December 2002	Change
Research & development cost	4.4	4.6	6.2
Procurement cost	1.3	5.1	-60.4
Total program cost	5.6	5.1	-9.0
Program unit cost	1.1	1.7	51.6
Total quantities	5	3	-40.0
Acquisition cycle time (months)	111	118	6.3

GAO, Defense Acquisitions: Assessments of Major Weapon Programs (May 2003) pp.57-58. Available at: http://www.gao.gov/new.items/d03476.pdf

uncertain: The Air Force has announced that it will, by December 2004, select between competing options of a five-satellite Advanced EHF constellation or a three-satellite constellation augmented with Advanced Wideband Satellites.[92]

The FY04 budget request includes $778 million for Advanced EHF, but has again pushed back the initial launch to the third quarter of 2007 and delayed a request for $95 million in procurement for the third satellite until FY05 (Table 42: PE 0603430F Advanced EHF MILSATCOM). Both the Senate and House Armed Services Committees recommended an additional $60 million for AEHF.[93] One representative said the increase reflected a shift in funding toward "near-term priorities."[94]

The Senate warned that the Air Force's decision to shift $95 million in procurement funding from FY04 to FY05 would "result in a significant production gap that will require a costly requalification of suppliers, a significant increase in technical risks, and a possible delay in the AEHF schedule" and directed the Air Force to complete a study of the options to restore the FY03 program schedule by February 1, 2004.[95]

The *Wideband Gapfiller*—or Wideband MILSATCOM—is precisely what its name suggests: a short-term solution to bridge the gap between current systems, such as the Defense Satellite Communications System, that handle the large volume of routine defense department communications and transformational programs like Advanced Wideband.

Table 42: PE 0603430F Advanced EHF MILSATCOM								
Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Advanced EHF MILSATCOM	459.6	822.5	778.1	573.7	402.4	317.4	189.6	130.9
Procurement				95.0	377.1		11.8	15.1

USAF RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Table 43: Comparison of Selected MILSATCOM systems			
Satellite	Communications Capacity (million bits per second)	Cost Per Satellite (US$ in millions)	Expected Lifetime (years)
MILSTAR I	0.5	800	10
MILSTAR II	40	800	10
Advanced EHF	375	1,000	TBD
DSCS III	100	200	10
DSCS SLEP	200	200	10
Wideband MILSATCOM	3,600	184	15

Estimates from: Roy Axford, *Advanced Wideband System (AWS) Analysis of Alternatives for Wideband Military Satellite Communications in the 2008+ Timeframe*, CNS Workshop (1-3 May 2001). Estimates for Advanced EHF vary slightly from estimates provided by GAO.

Wideband MILSATCOM is expected to satisfy current wideband communications requirements at a reasonable cost by employing two commercial technologies—a digital signal processor and a phased array antenna—with some military frequency modifications. Each satellite is capable of transmitting about 3,600 million bits per second—a dramatic improvement over the predecessor DSCS (Table 43: Comparison of Selected MILSATCOM systems).

The first launch of a WGS is scheduled for June 2004, followed by two additional launches no later than October 2005.[96] Air Force procurement of an additional pair of satellites will round out the original design of a three-satellite constellation in geosynchronous orbit to help fulfill AEHF requirements in advance of TSAT launches (Table 44: PE 0603854F Wideband MILSATCOM).

Table 44: PE 0603854F Wideband MILSATCOM (Wideband Gapfiller)								
Cost (U.S.$ in millions)	FY02	FY03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09
4811 Wideband Gapfiller	79.9	2.0	0	53.3	7.7	2.3	0.0	0.0
4870 Command & Control System	16.5	11.8	36.7	20.4	8.3	7.0	5.7	6.3
Total RDT&E	**96.4**	**13.8**	**36.7**	**73.7**	**16.0**	**9.3**	**5.7**	**6.3**
Advance Procurement	13.5	0.0	0.0	0.0	51.0	53.0	31.0	0.0
Procurement	347.8	188.2	34.6	21.5	9.4	214.7	139.5	43.7
Total Procurement	**361.3**	**188.2**	**34.6**	**21.5**	**60.4**	**267.7**	**170.5**	**43.7**
No. of satellites	2	1	0	0	0	1	1	0

Air Force RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

Table 45: PE 0603845F Advanced Wideband System (AWS)							
	FY03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09
4944 Advanced Wideband System	118.0	439.3	877.5	1183.2	1327.3	1531.0	736.9
Air Force RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.							

The *Advanced Wideband System* or Transformational Satellite (TSAT) will replace the Wideband MILSATCOM and supplement the Advanced EHF system. The TSAT is expected to integrate a number of technologies, including laser communications, that would dramatically improve the rate of data transmission in much the same way that fiber optic cables have improved ground-based data transmission.[97] The Air Force is still conducting an analysis of alternatives to determine the final architecture of the system. The FY04 Request includes $439 million for Advanced Wideband, a total of $12.5 billion across the FYDP (Table 45: PE 0603845F Advanced Wideband System). Undersecretary Teets testified that the first launch is targeted for 2009-2010.[98]

This schedule appears optimistic. The Government Accounting Office found that "Of the five AWS/TSAT key space segment technologies, one is mature while the other four are scheduled to reach maturity by January 2006, more than 2 years after development starts."[99] Moreover, the House and Senate Committees cut $50 and $80 million, respectively, from the FY04 request citing the same concerns that GAO identified.[100] The Senate Armed Services committee expressed concern that "key AWS/TCA technologies, including multiple access laser communications terminals and information assurance, are immature. . . ."[101]

The Senate and House Appropriations Committee cut $90 million and $150 million from the FY04 request, citing the same report.[102] The House Appropriations Committee, which proposed restricting funding to technology maturation and risk reduction activities, noted that "Incredibly, DoD is pushing to acquire AWS on a pace that even exceeds the AEHF development schedule (known for its aggressive schedule) despite the significantly greater technical challenges associated with AWS."[103]

Space-based Radar (SBR)

The most promising program for space-based ISR is the space-based radar (SBR) program. SBR is "designed to transform surveillance by providing persistent, all-weather detection, tracking, and imagery of time-critical targets." The FY04 budget contains $299 million for the SBR, which is the first space program conceived after the Air Force was designated as Executive Agent for space. SBR has been designated by OSD as "as a key Transformational Space program inextricably linked" to its ISR requirement for transformational forces (Table 436 Spending on Space Based Radar). Eventually, the Air Force estimates that annual funding for the SBR could reach $700-800 million by 2010, the expected launch date of the first satellite.[104]

Table 46: Spending on Space Based Radar

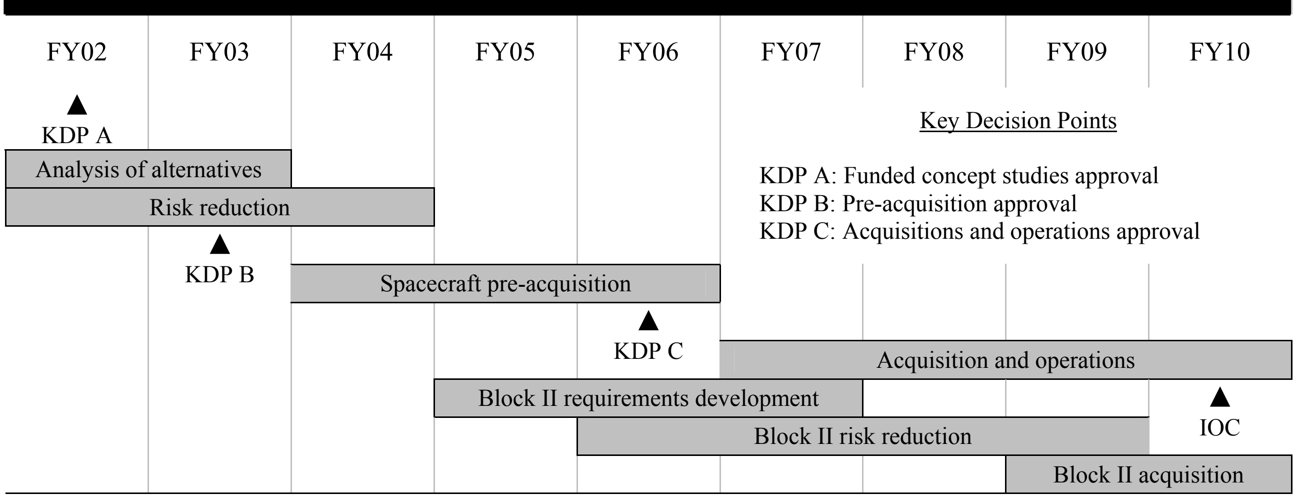
PE	Cost (U.S.$ in millions)	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
0604251F	SBR EMD	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0602500F	Multi-Disciplinary Space Technology		42.5	0.0	0.0	0.0	0.0	0.0	0.0
0603858F	SBR Dem/Val		47.2	274.1	358.7	467.5	503.8	1178.2	1547.5
Total		**23.1**	**89.7**	**274.1**	**358.7**	**467.5**	**503.8**	**1178.2**	**1547.5**

USAF RDT&E Descriptive Summaries. Available at: http://www.dtic.mil/descriptivesum/.

The Air Force is considering different radar constellation architectures in low- and medium-earth orbits (MEO), including a mixed constellation with satellites in both. Although radar operating from MEO requires a dramatically larger antennae than necessary to achieve the same resolution from LEO, there are benefits to the mixed constellation. As a DARPA official from the Innovative Space-Based Radar Antenna Technology (ISAT) Program explained: the "primary reasons for even considering MEO . . . are the significantly reduced number of satellites required to achieve persistent 24/7 coverage and steeper razing angles, alleviating terrain obscuration."[105]

According to a Raytheon official, the anticipated LEO constellation of 9-12 SBR satellites would leave coverage gaps that could last up to five minutes.[106] The Senate Armed Services committee proposed language in the FY04 report directing the Secretary of the Air Force to submit a report on the various options for the SBR architecture and spiral developments (Table 47: Space-based Radar Acquisition Strategy).[107] Similarly, the Senate and House Appropriations Committees, noting that cost estimates for the program had grown by 50 percent from the FY03 request, recommended $75 and $100 million reductions, respectively.[108]

Table 47: Space-based Radar Acquisition Strategy



Shofner, *Space-based Radar Industry Day Introduction and Current Status* (May 30, 2003).

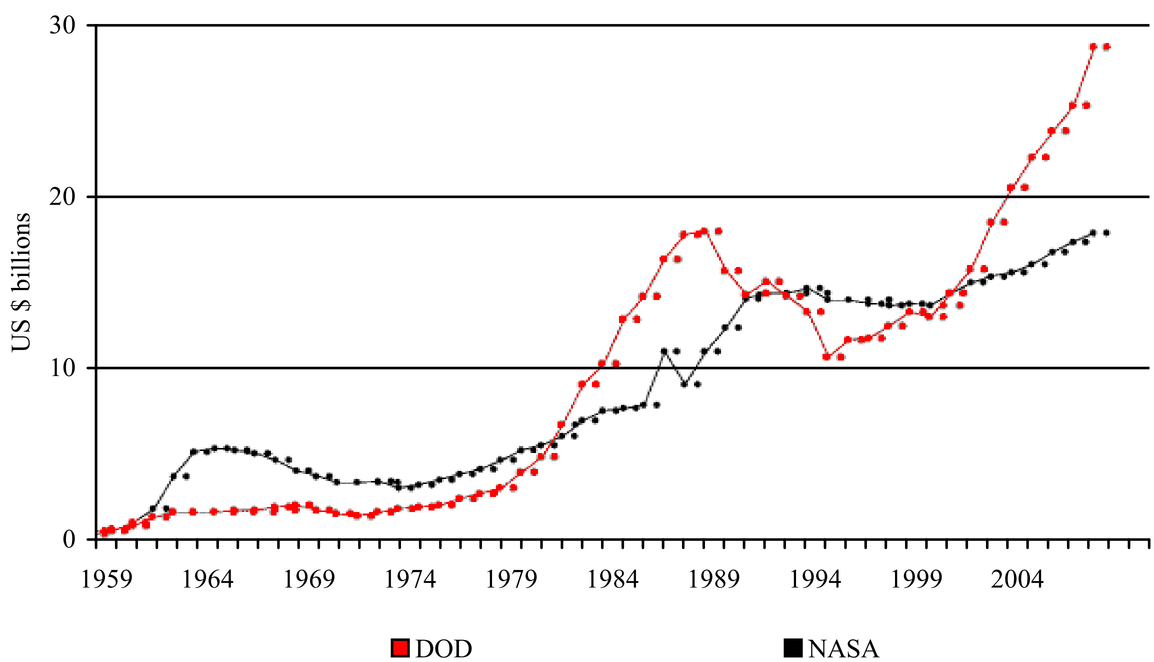
CONCLUSION

The programs detailed here represent a significant, but not comprehensive, portion of overall DOD spending on space-related programs. Although DOD has improved its ability to track spending on space programs, the Congressional Research Service concluded that "tracking the DOD space budget is extremely difficult since . . . DOD sometimes releases only partial information (omitting funding for classified programs) or will suddenly release without explanation new figures for prior years that are quite different from what was previously reported."[109]

The overall level of effort, however, is large and diverse. The Congressional Research Service estimates DOD's total classified and unclassified space budget—including many programs that are demonstrably not space weapons—has grown from $15.7 billion in FY02 to $20.4 billion in FY04, and is projected to reach $28.6 billion in FY08 (Table 48: DOD and NASA Space Spending).[110]

Although many of these programs face technical challenges that suggest the current acquisition schedules are too optimistic, the large amount of funding allocated to so many programs in so many areas strongly indicates that the Administration is serious about transforming the United States military, particularly strategic forces, though the introduction of new space systems. Substantial levels of funding can create momentum in advance of deployments. Moreover, the administration could deploy provocative capabilities in R&D blocks or conduct tests of existing ASAT systems for political purposes.

Table 48: DOD and NASA Space Spending (in then year dollars)



Marcia S. Smith, U.S. Space Programs: Civilian, Military and Commercial (Congressional Research Service, April 22, 2003) p.9. Available at: http://www.fas.org/spp/civil/crs/IB92011.pdf

The move toward deploying the capabilities outlined in this paper—as part of a general effort to use space to support a warfighting posture—is consistent with the organizational decisions made by the Administration to reorganize DOD Space Activities. Since January 2001, the Bush Administration has dramatically reorganized the way that DOD manages its space efforts. Major changes include

- Creating a "virtual" major force program to increase visibility of resources allocated for space activities.
- Designating the Air Force as "Executive Agent" for space within DOD
- Merging U.S. Strategic and Space Commands to capitalize on the "synergy" between space and strategic forces
- Creating a "National Aerospace Initiative" to coordinate research on hypersonic flight, space access, and space systems

Most of these changes, along with many others, reflect the reorganization of national security space management as outlined by the Rumsfeld Space Commission (Table 49: Space Commission Recommendations: Implementation as of January 2003).[111]

A more difficult task than identifying key organizational changes is identifying key thresholds for "weaponization." Currently, the most provocative systems remain a few years away from testing and deployment. For instance, the Missile Defense Agency intends to commence orbital testing of space-based kinetic kill interceptors in 2008, but has canceled the anticipated 2012 test for its space-based laser. The Air Force's Common Aero Vehicle is perhaps a decade away from testing, while the unclassified space control systems are focused principally on temporary, non-destructive interference. And, the military space plane concept remains, at best, a long-term aspiration for the Air Force.

Moreover, most of the programs considered in this paper are experiencing large cost-overruns and delays. Congressional skepticism concerning the technological maturity of a number of programs could further delay many programs as funds are shifted toward more feasible, near-term priorities.

Opponents of expanding military activities in outer space should feel a sense of urgency, rather than complacency, for three reasons: First, these systems are the foundation of current modernization plans. The central role that these capabilities are expected to play, combined with heavy investment, will create a strong momentum toward their testing and deployment. In the absence of arms control agreements, there will be a strong presumption in favor of seeing these systems through to completion.

Table 49: Space Commission Recommendations: Implementation as of January 2003			
Space Commission Recommendation	No action intended	In progress	Complete
The Secretary of Defense and the Director of Central Intelligence should meet regularly to address national security space policy, objectives, and issues.			✓
Secretary of Defense should establish an under secretary of defense for space, intelligence, and information	✓		
Secretary of Air Force should assign responsibility for the command of Air Force Space Command to a four-star officer other than the commander, U.S. Space Command and NORAD.			✓
Secretary of Defense should end the practice of assigning only Air Force flight-rated officers to position of commander, U.S. Space Command and NORAD.			✓
Air Force should realign headquarters and field commands to more effectively organize, train, and equip for prompt and sustained space operations.			✓
Air Force Space Command should be assigned responsibility for providing resources to execute space research, development, acquisition, and operations.			n/a
Amend title 10 USC. to assign the Air Force responsibility to organize, train, and equip for air and space operations.	✓		
Secretary of Defense should designate the Air Force as DOD's executive agent for space.		✓	
Assign the Under Secretary of the Air Force as the Director of the National Reconnaissance Office.			✓
Designate the Under Secretary of the Air Force as the Air Force acquisition executive for space.			✓
Secretary of Defense and Director of Central Intelligence should create a research, development, and demonstration organization to focus on innovative space research and development.	✓		
Secretary of Defense should direct the Defense Advanced Research Products Agency and service laboratories to undertake development and demonstration of innovative space technologies.			✓
Secretary of Defense should establish a Major Force Program for Space.			✓

GAO, "Defense Space Activities: Organizational Changes Initiated, But Further Management Actions Needed." Available at: http://www.gao.gov/new.items/d03379.pdf

Second, DOD is likely to deploy early R&D blocks of these systems well before the programs reach technological maturity. Although these systems may have very limited functionality, other states that feel threatened by weaponization are likely to assume the worst about the systems—both as threats in themselves and as harbingers of future provocations.

Third, the United States retains a considerable residual capability to quickly cross thresholds as part of a political strategy. Just as the Administration appears to have pulled out of the ABM Treaty for political reasons, and well in advance of encountering technical constraints imposed by the Treaty, they could decide to pursue the near-term testing or deployment of symbolic capabilities (particularly anti-satellite weapons) as part of a strategy to break the consensus for non-weaponization. The KE ASAT program is particularly worrisome in this regard, because the DOD could test the KE ASAT within a year of a decision to do so and for a few tens of millions of dollars.

The conclusion of this paper is that the FY04 budget request contains a substantial level of investment projected across a diverse range of space-programs designed to support an increasingly preventive national security strategy. One should not be surprised at the conclusion of the companion paper, which documents growing Chinese concerns about the evolving U.S. military capabilities and, by extension, intentions. The U.S. is pursuing advanced military capabilities without simultaneously providing diplomatic assurances to our allies and potential adversaries that these capabilities are fundamentally defensive of the current international environment. Perhaps most worrisome, the cost-overruns and schedule slippages suggest that many of these potentially provocative systems may be expensive, technological fantasies.

A more prudent approach might be a renewed diplomatic effort at multinational consultations regarding "rules of the road" for military activities in space, a focus on a smaller number of technologically mature systems to provide defensive protection for U.S. space systems, and cooperative efforts to maintain space situational awareness. This will be the topic of a future CISSM paper.

ENDNOTES

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[1] Department of Defense, *Nuclear Posture Review* (January 8, 2002).

Excerpts available at: http://www.defenselink.mil/news/Jan2002/d20020109npr.pdf

[2] U.S. Air Force Space Command, *Strategic Master Plan, FY '04 and Beyond* (November 5, 2002), pp.13-14.

Available at http://www.peterson.af.mil/hqafspc/library/AFSPCPAOffice/Final%2004%20SMP--Signed!.pdf

See also: U.S. Air Force Space Command, *Strategic Master Plan, FY '02 and Beyond* (February 9, 2000).

[3] *Strategic Master Plan, FY '04 and Beyond*, pp.20-21.

[4] Ellis, Admiral James O., USN Commander United States Strategic Command, *Remarks before The Senate Armed Services Committee Strategic Subcommittee on Command Posture And Space Issues* (March 12, 2003).

Available at http://www.senate.gov/~armed_services/statemnt/2003/March/Ellis.pdf

[5] *Joint Doctrine for Space Operations* (August 9, 2002), pp.IV-10.

Available at http://www.dtic.mil/doctrine/jel/new_pubs/jp3_14.pdf

See also: U.S. Space Command, *Long Range Plan: Implementing Air Force Vision 2020* (1998).

[6] *Strategic Master Plan, FY '04 and Beyond*, p.20.

[7] Gray, Colin S. and Keith Payne, "Victory Is Possible," *Foreign Policy* 39 (Summer 1980).

[8] Worden, Simon and Martin France, "Towards an Evolving Deterrence Strategy: Space and Information Dominance," *Comparative Strategy* 20:5 (December 2001), pp.459-460.

[9] Worden and France, p. 454.

[10] *Strategic Master Plan, FY '04 and Beyond*, p.7.

[11] *Final Report of the Commission to Assess United States National Security Space Management and Organization* (January 11, 2001), p.33.

Available at http://www.space.gov/docs/fullreport.pdf

[12] U.S. Department of Defense, *Quadrennial Defense Review Report* (September 30, 2001), p.30.

The six transformation goals are: protecting critical bases of operations, assuring information systems, projecting and sustaining U.S. forces, denying enemies sanctuary, enhancing the capability and survivability of space systems, and leveraging information technology and innovative concepts.

Available at http://www.dod.gov/pubs/qdr2001.pdf

[13] *Department of Defense Instructions* "Transformation Program Detail."

Available at https://snap.pae.osd.mil/PPI/PB2004/TransformationDetailPB04.pdf

[14] Rumsfeld, Donald H., U.S. Secretary of Defense, *Remarks as Prepared for Delivery to the U.S. House Armed Services Committee, Washington DC* (February 5, 2003).

Available at http://www.washingtonfile.net/2003/Feb/Feb06/EUR405.HTM

For the 2004 request, Secretary Rumsfeld testified, "For programs to enhance U.S. space capabilities—such as Space Control Systems—we are requesting $300 million in 2004 and $5 billion over the FYDP."

[15] Zakheim, Dov, U.S. Comptroller *Briefs On the 2004 Defense Budget* (February 3, 2003).

Comptroller Dov Zakheim said, "Conducting effective information operations and space operations. Both do not consume much in the way of resources now, but as you can see [from the slides], it ramps up quite sharply throughout the six-year future year defense program."

Availalbe at http://www.defenselink.mil/news/Feb2003/t02032003_t0203budget.html.

Briefing slides available at http://www.defenselink.mil/news/Feb2003/030203-D-9085M-013.jpg.

[16] Rumsfeld, Donald H., U.S. Secretary of Defense, *Remarks as Prepared for Delivery to the U.S. Senate Armed Services Committee, Washington DC* (February 5, 2003).

Secretary Rumsfeld testified, "The 2003 budget requests about $200 million to strengthen space capabilities—$1.5 billion over the five year FYDP (2003-7)—an increase of 145 percent."

Available at http://www.defenselink.mil/speeches/2002/s20020205-secdef4.html

[17] *Background Briefing on the Fiscal 2004 Budget Submission* (January 31, 2003).

Available at http://www.defenselink.mil/news/Feb2003/t02032003_t0131bud.html

[18] *Air Force RDT&E Descriptive Summaries*.

Available at http://www.dtic.mil/descriptivesum/.

[19] Department of the Air Force, *Air Force Strategic Plan Volume 3: Long-Range Planning* Guidance (April 1999), pp.12, 23-24.

Available at https://www.sab.hq.af.mil/links/afsp-v3.pdf

[20] *National Defense Authorization Act for Fiscal Year 2004—House Report 108-106* (May 16, 2003) p.214.

Available at http://www.gpo.gov/congress/house/pdf/108hrg/hr106.pdf

[21] Defense Advanced Research Projects Agency, FALCON: *F*orce *A*pplication and *L*aunch from *CON*US Technology Demonstration PHASE I SOLICITATION 03-XX (June 17, 2003) p.7. Available at:

[22] House Report, 108-. p.12

[23] Worden, Simon, "Building a New U.S. Strategic Command," (August 7, 2002).

Available at: http://64.177.219.27/BFI02/GenWordenLunchBrief.ppt

[24] Brian Berger, "U.S. Air Force Will Not Fund X-33, X-34 Vehicles," *Space News* (September 5, 2001) np.

Available at: http://www.space.com/news/military_space_010905.html

[25] Smith, Marcia S., *Space Launch Vehicles: Government Activities, Commercial Competition, and Satellite Exports* IB93062 (February 3, 2003), pp.5-8.

Available at http://fpc.state.gov/documents/organization/17353.pdf

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Available at http://www.dod.mil/ddre/nai/nai_brief93002.pdf

[27] Sega, Ron. *Statement Before the U.S. House Armed Services Subcommittee on Terrorism, Unconventional Threats and Capabilities* (March 27, 2003).

Available at http://armedservices.house.gov/openingstatementsandpressreleases/108thcongress/03-03-27saga.html

[28] The Senate Appropriations Committee cut funding for PE 0603211F, project 5099 and PE 0603216F, project 3035—the latter appears to be an error. Within PE 0603216F, the $39 million for the National Aerospace Initiative is located in Project 5098. Project 3035 is an unrelated effort. Senate Report, 108-87, p.165-166

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Available at: http://www.aviationnow.com/content/publication/awst/20020401/aw28.htm

See also: Frank Morring, "NASA Shifts SLI Funds To Kerosene Engines," *Aviation Week & Space Technology* (September 30, 2002).

Available at: http://www.aviationnow.com/content/publication/awst/20020930/aw34.htm

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Available at http://www.fas.org/irp/congress/2003_hr/031203teets.html

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Available at: http://www.dtic.mil/descriptivesum/.

See also: "Air Force Seeking New Approaches, Technologies For Space Control," *Defense Daily* (December 5, 2002).

[32] See *Hearing Of The Senate Armed Services Committee to Consider Defense Department Nominations* (May 10, 2001). Available from Lexis-Nexis Congressional Universe.

[33] *National Defense Authorization Act for Fiscal Year 2004—Report to Accompany S. 1050 (S. Rpt. 108-46)* (May 13, 2003), p.204.

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Aldinger, Charles, "General Warns: High-Tech Warfare Could Litter Space with Debris," *Reuters* (March 28, 2001).

Available at http://www.space.com/news/spaceagencies/space_war_debris_010328_wg.html

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Available at http://www.gao.gov/new.items/d01228r.pdf

[37] Gildea, Kerry, "Possible Funding Boost In FY '04 Budget Could Lead To KE-ASAT Flight Test," *Defense Daily* 216:52 (December 17, 2002), np.

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Available at http://www.ll.mit.edu/ST/sbv/sbv.pdf

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[40] After Congress added funding for the XSS-10 in 2003 to PE 0602602F Conventional Munitions, the Air Force moved the funds to "Program Element 0603401F, Advanced Spacecraft Technology" noting that PE 0603401F "was the more appropriate Program Element for this effort." Similarly, when Congress added 3.0 million in FY2003 for TechSat 21, the Air Force mentioned the increase in PE 0603401F. Based on the mission tasks, the paper concludes that Project 2181 Spacecraft Payloads funds work on the TechSat21, while Project 3834 Integrated Space Technology Demonstrations contains funding for the XSS series of satellites. Based on FY2003 RDT&E descriptive summaries, PE 0602601F Space Technology funds the MightySat program.

[41] For a review of the kind of services that the Space Test Program provides, see: Frank Giovane, *Space Test Program (STP) As A Potential Test Bed For Interstellar Dust Measurement Systems* (January 2002).

Available at: http://www.mpi-hd.mpg.de/galileo/~gruen/DUNE/Giovane_DOD_STP.pdf

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[50] *Military Microsatellites: Matching Requirements and Technology*, p. 9.

[51] This omits a number of other directed energy programs such as the Navy PE 0602114N Power Projection Applied Research and the Army PE 0603305A TR3 Mobile Tactical High Energy Laser or MTHEL.

[52] *Report of the High Energy Laser Executive Review Panel, Department of Defense Laser Master Plan, DoD/S&T/00-001/March 24, 2000* (March 24, 2000), p.iii.

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See also: Office of the Press Secretary, The White House, *National Policy on Ballistic Missile Defense Fact Sheet* (May 20, 2003)

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[63] *Senate Report 108-46,* p.236 and *House Report 108-106*, p.237.

[64] *Senate Report 108-87*, p.169 and *House Report 108-187*, p.211.

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[67] "Space-Based Laser Put on Hold," *Arms Control Today*, (December 2002), np.

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Available at: http://www.csis.org/burke/hd/reports/chartingmd.pdf

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