United States Air Force
Scientific Advisory Board

Report on

A Space Roadmap for the 21st Century Aerospace Force

Volume 1: Summary

SAB-TR-98-01

November 1998

Authorized for Public Release

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)

2. REPORT DATE
November 1998

3. REPORT TYPE AND DATES COVERED
Final, January 1998 - November 1998

4. TITLE AND SUBTITLE
A Space Roadmap for the 21st Century Aerospace Force
Vol. 1: Summary

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
AF/SB
Pentagon
Washington, DC 20330-1180

8. PERFORMING ORGANIZATION REPORT NUMBER
SAB-TR-98-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
SAF/OS
AF/CC
Pentagon
Washington, DC 20330-1670

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution authorized to U.S. Government agencies and their contractors; administrative or operational use; November 1998. Other requests for this document shall be referred to the Department of the Air Force, AF/SB, Washington, DC 20330-1180

12b. DISTRIBUTION CODE

ABSTRACT (Maximum 200 Words)
The Air Force Scientific Advisory Board (SAB) produced this study. The Chief of Staff of the Air Force and Secretary of the Air Force requested and approved the study. It summarizes the Committee-recommended steps the Air Force should take to make the best use of space in accomplishing its assigned operational tasks in a rapidly changing world. While this report stands alone, it builds on the foundation of the Doable Space Quick-Look study led by the Air Force Chief Scientist and it complements the Aerospace Integration Task Force work.

This volume starts with an overview of the study tasking, organization and methodology. The next chapter summarizes the challenge confronting the Air Force. The following chapters present the primary findings and recommendations, the results of an initial analysis of budgets to assess the affordability of various future alternatives, and a number of related matters necessary for a complete treatment of the study topic. The final chapter is a summary of the study team's recommended roadmap and program strategy for the future of the Air Force as it learns to conduct functionally seamless operations across the different physical media of air and space.

14. SUBJECT TERMS
Global Engagement, Joint Vision 2010 (JV2010), Aerospace Force, 21st Century, Aerospace Integration Task Force (AITF), Global Grid, Information Architecture, Space-Based Radar (SBR), Position, Navigation and Timing (PNT), Global Energy Projection, Recognized Space Picture (RSP), Common Operating Picture (COP), Space Assets, Modeling, Simulation and Analysis (MS&A), Aerospace Operations Vehicle (AOV), National Launch Facilities, Commercial Models, Commercial Acquisition

15. NUMBER OF PAGES
102

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

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Foreword

". . . and it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things . . ." Niccolo Machiavelli

"Just DO it!"   Nike slogan

The United States Air Force faces enormous challenges in evolving to an integrated aerospace force that has the capabilities needed to cope with the military challenges of the next century. Between today's air and space forces and the desired end state that is emerging from long-range planning lies a difficult and uncertain path. The Air Force Scientific Advisory Board was asked to help the Air Force map that path, and we have tried to lay the foundation of a roadmap for achieving the envisioned future of aerospace power. While this report stands alone, it builds on the foundation of the Doable Space Quick-Look study led by the Air Force Chief Scientist, and it complements the work of the Aerospace Integration Task Force, which has been chartered to develop an Aerospace Integration Plan.

All of us who worked on this study are grateful for the opportunity to participate in this important effort, and we hope our recommendations will help the Air Force make sound decisions and deal effectively with the contentious issues involved.

Dr. John M. Borky
Study Chairman

November 1998

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Executive Summary

Becoming an Integrated Aerospace Force

The United States Air Force is today an air and space force whose core competencies, as articulated in *Global Engagement*,[1] entail the integrated employment of weapon and support systems across the physical media of air and space. But that force is largely a legacy of the Cold War, it often treats air and space operations as separate activities, and it faces wrenching changes in evolving to deal with the very different world of the 21st century. Among the basic forces that drive decisions from doctrine to system acquisition are:

- Tremendous uncertainty and variability in the situations calling for military action to support national objectives, across the full spectrum of conflict and at any place on the globe
- Continuing withdrawal from forward basing and rapid change to a continental United States–based, globally committed expeditionary force
- A military budget climate characterized by a stringency that has not been seen since before World War II, at a time when significant changes and upgrades in force structure are needed
- Persistent problems with personnel shortages, high operational tempo, aging weapon systems, and archaic information infrastructure, at least some of which are potentially addressable by migrating functions to space
- Levels of growth, diversity and maturity in commercial space enterprises that consistently outpace the most optimistic forecasts and thereby create an entirely new environment for providing important military capabilities
- The loss of Department of Defense (DoD) and Air Force leverage over commercial space operations, both in determining system capabilities and in being seen as a primary customer
- A long-term trend under which a growing fraction of Air Force resources go to provide services to others rather than to the direct warfighting mission

The future relevance and success of the Air Force—indeed, its ability to remain a preferred instrument of national power in this complex and uncertain emerging world—depend critically on becoming an integrated aerospace force which can execute the responsibilities assigned to it under *Joint Vision 2010* (*JV2010*).[2] The essential capabilities of such a force are concisely expressed as Global Knowledge, Global Reach, and Global Power.

Global Knowledge

JV2010 depends on information dominance to enable virtually every aspect of military superiority. The heart of this capability is a system of systems. It starts with intelligence, surveillance, and reconnaissance (ISR), coupled with real-time communications and information processing. The result, from initial collection of data to its timely use by warfighters, is victory through knowing more and knowing it sooner than the enemy.

Today's Capability. Intelligence satellites and airborne platforms provide localized and generally discontinuous sensing, often impeded by weather, terrain, and hostile countermeasures.

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[1] *Global Engagement: A Vision for the 21st Century Air Force*, Secretary of the Air Force S. Widnall and Chief of Staff of the Air Force Gen R. Fogleman.

[2] *Joint Vision 2010*, Gen John M. Shalikashvili, Chairman of the Joint Chiefs of Staff, 1996.

Processing and dissemination of time-sensitive data to warfighters is improving but still falls far short of the true need.

Tomorrow's Promise. The aerospace force can and must deliver precise, global situational awareness to commanders and fighters at all levels, providing the right information at the right place and time, while overcoming countermeasures and denying similar knowledge to the enemy.

Global Reach

The nation requires global presence to influence events and defend American interests, but with much less of the traditional forward basing. The mobility of aerospace forces is the key to rapid response and to the projection of all kinds of military power from U.S. bases to worldwide contingencies.

Today's Capability. Airlifters and tankers allow expeditionary forces to deploy and are engaged every day in missions from humanitarian relief to combat force sustainment. However, lift is limited, deployments take days to weeks, and success often depends on support from countries in the regions of interest—support that cannot be guaranteed in times of crisis.

Tomorrow's Promise. The aerospace force, with the right organization, training, and equipment, could deliver precisely calibrated effects, from taking a picture to dropping a precision munition, anywhere on earth, in less than an hour from the "go" order, with surprise and immunity to most defenses. Larger-scale deployments would be lighter, faster, and more effective, and the need to station forces in foreign theaters would be greatly reduced.

Global Power

America's military forces must be able to prevail in operations anywhere on earth, ranging from disaster relief to hostage rescue to shows of force and, when required, combat.

Today's Capability. Modern fighters and bombers with steadily improving precision targeting and munitions have impressive ability to prosecute targets with economy of force and greatly reduced collateral damage and casualties. However, proliferating air defenses threaten their survivability, and almost any adversary has or can have the ability to use space-based systems, eroding a long-term U.S. advantage.

Tomorrow's Promise. The aerospace force can and must enable the full richness of the "effects-based targeting" concept,[3] using a wide range of lethal and nonlethal means to shape the desired end state of any conflict. At the same time, real space control, including assured access for friendly forces and denial of the same to enemies, can restore the decisive edge in space operations.

The challenge facing the Air Force is summarized in Figure ES-1,[4] which shows the overarching operational and infrastructure tenets of *JV2010*, the Air Force core competencies which address those tenets, and the ultimate vision of Full Spectrum Dominance. A major conclusion of this study is that the Air Force can achieve *genuinely revolutionary capabilities* which make *JV2010* achievable and which offer unprecedented options for achieving national objectives.

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[3] "The Road Less Traveled," Briefing by Lt Gen Gamble, 1998.

[4] "The Air Force After Next … Is Now," Briefing to the National Defense Review, Brig Gen Wald, 1998.

Figure ES-1. *The Challenge Facing Aerospace Forces in the 21st Century Is to Develop and Apply Core Competencies That Effectively Implement National Military Policy*

A Revolution in Aerospace Power

In this study, the U.S. Air Force Scientific Advisory Board (SAB) examined the future capabilities and uses of aerospace forces and the courses of action available to the Air Force to achieve advances which are essential to its continued effectiveness. Two examples illustrate the great potential of integrated aerospace power. Figure ES-2 sketches a scenario for precision strike of a terrorist enclave or other time-critical target. It is based on a system capable of

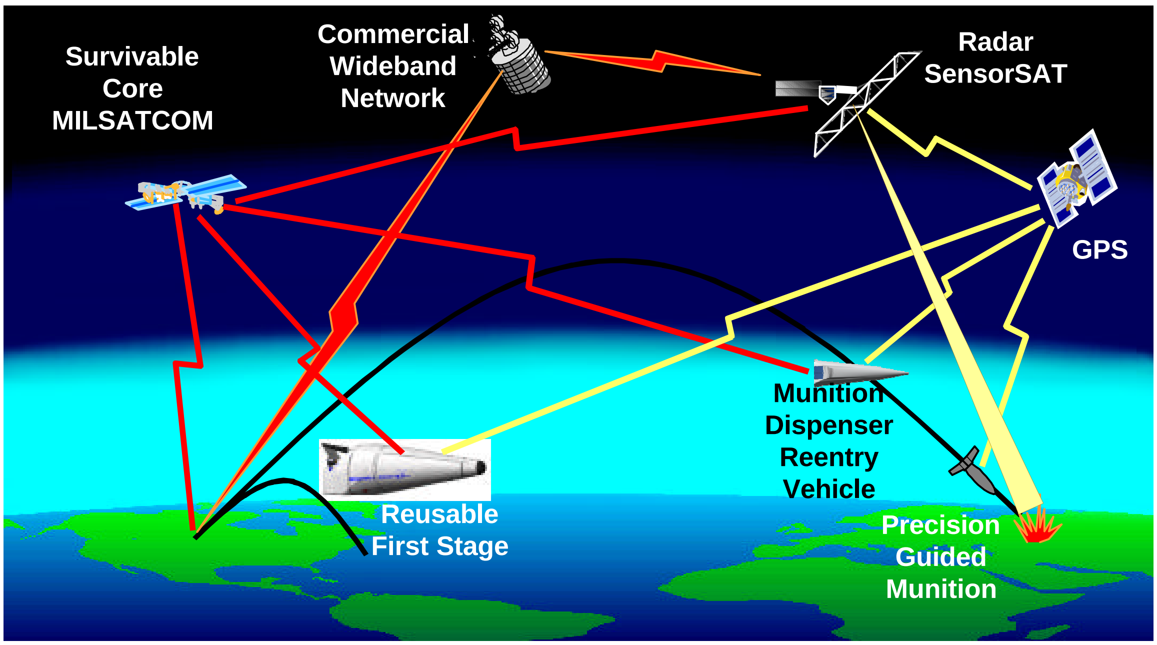

Figure ES-2. *Rapid, Precise, Global Strike Capability Illustrates the Potential of Aerospace Forces to Contribute in New Ways to Achieving National Objectives* delivering precision-guided munitions at orbital speeds, combined with global, all-weather, synoptic, high-resolution sensing; precision navigation and timing; and responsive command and control. Such a system would permit destruction of the target in less than an hour from a National Command Authorities order with complete surprise, immunity to currently fielded active defenses, and a lower prospect of collateral damage. It could equally well conduct a photo reconnaissance mission to produce proof that a prohibited action was in progress. At the other end of the spectrum, Figure ES-3 (borrowed from the Information Management study that was done in parallel with this one[5]) suggests the pervasive role of aerospace forces in a major conflict, including the ability to facilitate cooperation of joint and coalition forces to deliver the maximum total military effect. Here, space systems create information-rich warfighters, negate asymmetric threats like theater missiles, and make the diverse elements of the force interoperable. These examples illustrate capabilities that have not been available in earlier conflicts and that have enormous potential to promote the nation's security and influence.

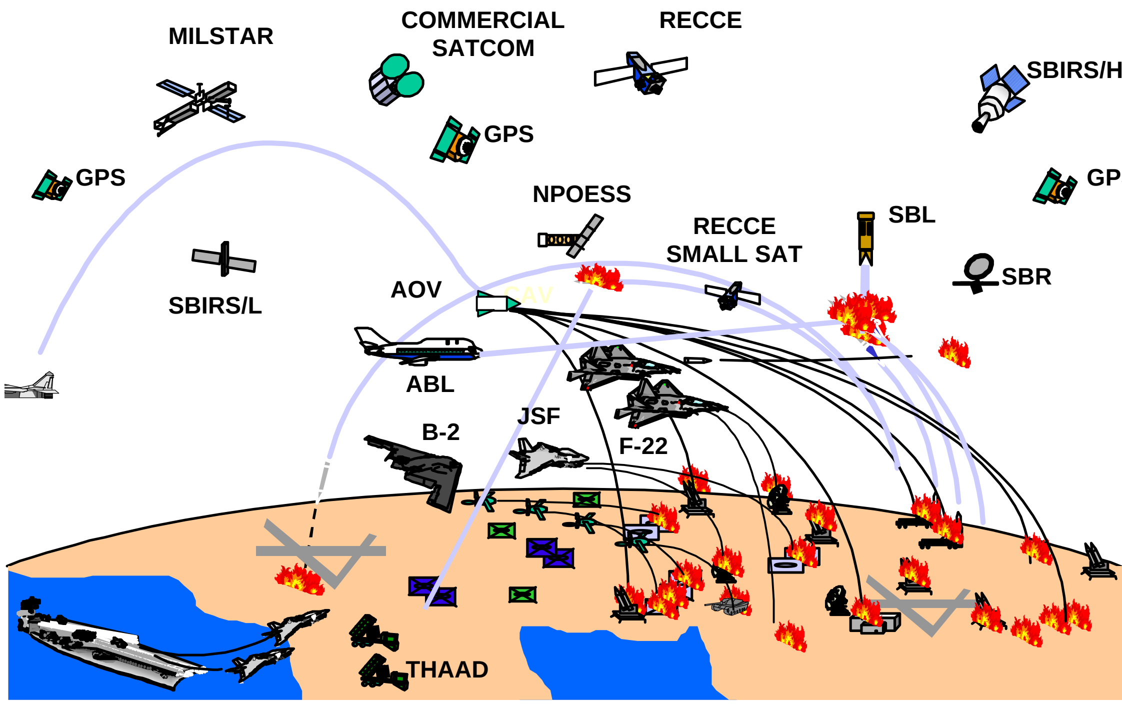

Figure ES-3. *Integrated Aerospace Power Is an Essential Element of Joint and Coalition Warfare*

Paying for Change

However, the other side of this coin is the reality of military budgets and end strengths that are inadequate to satisfy current needs, let alone pay for major new force structure initiatives. In order to fund new and modified systems, the Air Force will have to find ways to save money elsewhere. There are a number of such areas, and all of them involve hard choices. They include:

- Getting out of some mission areas, including things like space launch that have a long history as Air Force "stewardship" missions. The Air Force should limit itself to military-unique functions that fall within its core competencies.

[5] 1998 SAB Study on Information Management.

- Dramatically changing requirements generation, acquisition, and operations to an approach in which buying commercial and applying commercial practices to how the Air Force does business are assumed to be the answer, unless it can be proved otherwise.
- Taking advantage of partnerships, synergism among systems, and carefully scrubbed requirements to pare acquisitions to the minimum that will accomplish the mission. This includes treating airborne and space systems involved in common functions like ISR as an integrated force structure that is optimized as a whole, and thus requires a true system-of-systems architect empowered to enforce such decisions.
- Doing large-scale streamlining of operations, again using commercial models, to eliminate thousands of personnel (whose positions can be used to fill other critical needs) and get rid of expensive and unsupportable facilities and equipment.
- Breaking the mindset that each program area in the Air Force budget has a "fair share" percentage which cannot be changed by other than trivial amounts. Total Obligation Authority (TOA) will probably have to be moved into the space area from other programs, at least in some years of high space activity. Failure to do so will send a clear message to DoD and the world that the Air Force is not serious about taking a leadership role and becoming the aerospace force that the nation needs. However, as discussed in more detail in the body of this report, the available offsets will help a great deal with this problem.

A Vision of the Future Force

In this study, we have started with a vision of 21st century aerospace operations, drawn both from earlier analyses such as New World Vistas and Spacecast 2025 and from the Desired Operational Capabilities and Mission Element Task Lists that describe current Air Force tasking. We have compiled the "baseline" force structure from planning and programming documents (see Table 2-2), and we have evaluated excursions in the form of added or deleted systems and functions. We have assessed the resulting alternatives in terms of four measures of effectiveness:

- Operational Effectiveness—ability of the resulting force structure to address current and projected tasking
- Affordability—ability of the alternative to fit into an executable program within reasonable budget projections
- Technical Risk—availability of the required enabling technologies and products to implement the system or systems under consideration on a given schedule
- Integration—ability of the alternative under consideration to maintain continuity of service to warfighters and to fit into an evolving force structure, including backward compatibility as appropriate

A future aerospace force which can implement this vision, yet be feasible in the likely fiscal circumstances, will be characterized by:

- Effectiveness—in executing the exceptionally diverse taskings that will be laid on it
- Survivability—when exposed to new, ambiguous, asymmetric and rapidly changing threats
- Efficiency—in delivering precise effects with great economy of resources

From our analysis, we have arrived at a number of recommendations which are discussed in more detail in this volume and in the individual reports prepared by each of the panels composing the study team. They fall into three categories. Those which impact combat performance tend to support both effectiveness and survivability; those that deal with infrastructure have their primary payoff in improved efficiency. A third set are concerned with how the Air Force does business today and lays the groundwork for future progress. For each recommendation, we suggest one or more Offices of Primary and Collateral Responsibility (OPRs/OCRs) to work the issues, and we give a reference to the section of the main body of this volume where a fuller description is to be found.

We have taken the Doable Space Quick-Look study[6] as a point of departure, and have concentrated on the "equipping" dimension of evolving the aerospace force. Our study complements the work of the Aerospace Integration Task Force (AITF) and other related efforts. We rely on the AITF to develop the conceptual foundation for aerospace employment in the 21st century and to embody it in an Aerospace Integration Plan (AIP). The AIP will define new theory and doctrine for the future aerospace force and the strategies needed for equipping, resourcing, training, educating, and organizing for integrated application of air and space assets. Our results are also fully coordinated with the parallel SAB study on Information Management and support earlier studies on Unmanned Aerial Vehicles and Aerospace Expeditionary Forces. We have enjoyed extensive participation and support from the National Reconnaissance Office (NRO) and have assiduously sought information from the Army, Navy, Defense Advanced Research Projects Agency (DARPA), National Aeronautics and Space Administration (NASA), and industry. In short, while this is an independent report presenting the objective opinion of the study team, we have worked hard to ensure that all relevant facts, user requirements, joint and coalition warfare concerns, and related programs are properly considered.

Primary Recommendations

Enhanced Effectiveness and Survivability

Move to a Network-Centric, Global Grid Information Architecture. The Air Force should plan and execute the earliest feasible phase-out of noncore military satellite communications (MILSATCOM) operations in favor of commercial services and interoperable user terminals (core MILSATCOM is that capacity which must have levels of assurance and security above what commercial service can provide, presumed to be provided by the Milstar system). Evaluate a maneuverable MILSATCOM system that can be positioned for optimum support to specific theaters as needed. In so doing, the Air Force should maintain backward compatibility to legacy user equipments for a reasonable period of time, but not indefinitely. The Air Force should develop with commercial satellite communications (SATCOM) providers a set of on-orbit gateways to provide robust access for military users. The Air Force should develop and install affordable aircraft SATCOM antennas to provide connectivity between aircraft and the information infrastructure. (See a later recommendation on partnering with industry.) Disparities in military and commercial communications coverage and bandwidth requirements must be resolved before placing primary reliance on commercial services. *Recommended OPR:* HQ USAF/SC. *Recommended OCRs:* SAF/AQ for acquisition, HQ USAF/XO for operational matters, and HQ USAF/XP for long-range planning. *Refer to Section 3.1.*

Develop and Deploy a Global, All-Condition, Intelligence/Surveillance/Reconnaissance Capability. The Air Force should continue current risk-reduction and concept definition efforts, as well as analysis of associated concepts of operations (CONOPS), to define the requirements for a space-based radar system, initially capable of synthetic-aperture radar imaging and ground moving-target indication. The new sensor constellation should complement NRO, civil, and

[6] Doable Space Quick-Look, AF/ST, 1998.

commercial systems in providing the information for global situational awareness, with a target Initial Operational Capability date not later than 2010. The frequency allocation problem needs continuing attention, preferably in partnership with emerging commercial space radar systems for earth observation. *Recommended OPRs:* SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF/XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for initial planning and programming for a follow-on engineering development, manufacturing, and deployment program. *Refer to Section 3.2.*

Provide Robust Position, Navigation, and Timing (PNT). In keeping with national policy arising from the recommendations of the Global Positioning System (GPS) Independent Review Team and a proposed Presidential Directive, the Air Force should retain, on behalf of DoD, ownership and management of GPS. The Air Force should provide the advocacy needed to maintain adequate budget priority for purely military PNT functions, especially robust services to warfighters in hostile environments through system improvements and augmentation as recommended by the Joint Program Office. At the same time, the Air Force should continue to provide civil and commercial services, and should vigorously pursue GPS funding from other, especially civil, agencies. The Air Force should similarly develop and field capabilities to selectively deny these services to adversaries. *Recommended OPR:* SAF/AQ. *Recommended OCRs:* HQ USAF/XO for operational matters, and HQ USAF/XP for long-range planning. *Refer to Section 3.3.*

Prepare for Global Energy Projection. Do not proceed with large-scale, on-orbit high-energy laser demonstrations such as the proposed Space Based Laser Readiness Demonstrator at this time, but pursue aggressively the precursor efforts needed to enable global energy projection at the earliest feasible date. The Air Force should develop a CONOPS for the employment of high-energy laser projection from space, using space-based or terrestrial lasers, and should conduct requirements analysis to identify the most effective and affordable approach to implementing such a system with the capability to deliver tailored effects, both lethal and nonlethal. Alternatives to the usually assumed chemical lasers should be explored, including electrically powered solid-state lasers. No development or deployment decisions should be made until the military worth and optimum approach are established. The Air Force should start now a focused technology development effort in areas supporting high-performance optical systems in space, with emphasis on large, lightweight, low-cost optics. *Recommended OPRs:* SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF/XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for long-range planning. *Refer to Section 3.4.*

Improve Space Surveillance and Develop a Recognized Space Picture (RSP) Construct for the Common Operating Picture (COP). The Air Force should migrate selected space surveillance functions to space. A possible approach is to modify the Space-Based Infrared System (SBIRS) Low constellation to perform both its primary warning mission and tracking of objects in high orbits.[7] The Air Force should implement enhancements to ground sensors, especially a supportability upgrade to the FPS-85 Spacetrack radar,[8] and should evaluate the value of importing and fusing data from Army missile defense radars. The Air Force should lead the development of an RSP corresponding to existing air, ground, and maritime pictures, under the COP. As a key element of the RSP, the Air Force should provide timely attack warning and

[7] *SAB Report on Space Surveillance, Asteroids and Comets, and Space Debris, Vol. 1: Space Surveillance,* SAB-TR-96-04, June 1997, pp. 11-15 and Appendix 1.
[8] Ibid.

reporting for all satellites used by the military. *Recommended OPR:* HQ USAF/XO. *Recommended OCR:* SAF/AQ. *Refer to Section 3.5.*

Protect U.S. Space Assets Against Likely Threats. The Air Force should take a number of steps, including encryption, selective hardening of satellites, use of system and orbital diversity/redundancy, threat location, and physical security for ground sites, to minimize the risk from the most likely future threats. The goal should be maximum mission survivability at minimum cost. *Recommended OPRs:* SAF/AQ for acquisition and HQ USAF/XO for operational matters, respectively. *Recommended OCR:* HQ USAF/XP for long-range planning. *Refer to Section 3.6.*

Develop a Space Test Activity and Adequate Modeling, Simulation, and Analysis Tools. It is urgent that the Air Force be better able to demonstrate the military worth of aerospace. The Air Force should ensure that emerging or updated models at the campaign and mission/engagement levels accurately portray the characteristics and effectiveness of air and space systems; one promising opportunity is the National Air and Space Model at the Electronic Systems Center. The resulting analytical capability should be used to support system requirements definition, operational analysis, integration of air and space, and many other purposes. The Air Force should create a space test activity, exploiting existing systems to keep costs low. This activity will be useful for development and operational testing, training, system effectiveness evaluation, and similar purposes analogous to those performed for aircraft by air test ranges, but allowing such activities to occur in the real space environment. *Recommended OPR:* HQ USAF/XO. *Recommended OCRs:* SAF/AQ for acquisition and HQ USAF/XP for long-range planning. *Refer to Section 3.7.*

Preserve the Option to Develop an Aerospace Operations Vehicle (AOV). The Air Force should continue the current Space Maneuvering Vehicle demonstration and perform analysis of associated CONOPS to develop a system concept and a plan and roadmap for a phased program with clear milestones for continued development in the event the results of these activities warrant a follow-on. A program decision should be made in approximately 2002. The Air Force should provide the minimum level of funding in the area of reusable launch vehicles (RLVs) needed to ensure that the NASA-led effort addresses Air Force lift requirements. *Recommended OPR:* SAF/AQ. *Recommended OCRs:* HQ USAF/XO for CONOPS analysis and system concept definition and HQ USAF/XP for long-range planning. *Refer to Section 3.8.*

Space Control. Classified aspects of the Space Control area are discussed in the Space Control Panel report.

Enhanced Efficiency

Transition National Launch Facilities to Civilian Operations With the Air Force as a Tenant. The Air Force should act in two steps to exit the launch operations field except for essential military missions: Step 1—award an omnibus contract for operation of the Eastern and Western Ranges, with economic provisions for modernization of facilities. Step 2—transfer responsibility to a suitable civil agency (e.g., support creation of a National Space Port Authority) for operations and to the Federal Aviation Administration for safety. Continue direct cost commercial launch pricing for onshore launch through the national program. Provide up-front funding, if required, to make privatization feasible as a business opportunity. Phase-out legacy tracking systems in favor of GPS-derived tracking (a "space-based range"). *Recommended OPR:* SAF/AQ for transition policy. *Recommended OCRs:* HQ USAF/XO for operational matters and HQ USAF/SP for long-range planning. Transfer of responsibility involves multiple organizations and national policy. *Refer to Section 3.10.*

Transition Launch to Primary Reliance on Commercial Services. The Air Force should begin an orderly phase-out of most current organic booster procurement and launch programs and should increase use of commercial launch services, leading to primary reliance on them. Retain minimum essential organic launch capability, possibly in the form of the AOV, for payloads that cannot be commercially launched. The Evolved Expendable Launch Vehicle program should be completed, and the Air Force should maintain close coordination with NASA to support RLV technology. Satellite design, especially weight, should be predicated on compatibility with commercial launchers. *Recommended OPR:* SAF/AQ for transition policy. *Recommended OCR:* HQ USAF/XO for operational analysis and planning. *Refer to Section 3.11.*

Implement Commercial Models and Other Improvements to Satellite Operations and Tracking. The Air Force should streamline satellite operations by transitioning to a commercial model for staffing and system operation; outsourcing noncritical functions; separating payload control from tracking, telemetry, and control to allow optimization in each area; and making selective investments in ground equipment upgrades where justified by manpower savings and other benefits. The Air Force should make better use of Air Force Reserve personnel to raise skill levels and reduce training and turnover in satellite operations. For new systems, developers should be required to apply best commercial practices (e.g., spiral development) and to set and apply performance metrics for human factors. The Air Force should plan and execute an orderly phase-out of legacy tracking assets and replace them with GPS-derived tracking; commercial options for operation and upgrading of tracking systems should be considered. *Recommended OPR:* SAF/AQ. *Recommended OCR:* HQ USAF/XO for manpower and operations planning and reform. *Refer to Section 3.12*.

Enhanced Programs and Practices

Create an Air Staff Concept Development Process and Central Aerospace Architecture Function. The Air Force should create a central focus for dealing with issues associated with (1) an integrated aerospace system-of-systems architecture that balances space, air, and surface capabilities; (2) conducting an ongoing, proactive partnering with the commercial space industry; and (3) aligning the requirements process and acquisition practices with the realities of a space environment that is dominated by commercial enterprises. This includes creation of a concept development process structured around a properly empowered force structure architect and requirements coordinator with the authority to perform trades among force structure segments and coordinate requirements to deliver maximum warfighting capability for the resources available. The aerospace architect is the logical authority to oversee the continuing interaction with industry. No new personnel are required to implement this function, but integration across multiple current Air Staff activities is essential. At the same time, the Air Force should reform the requirements definition process to focus only on key performance/capability parameters and to shorten the requirements approval cycle to be consistent with commercial product lifetimes (which are often 18 months or less). As part of this reform, requirements should be iterated with commercial capabilities to ensure that commercial space is properly accounted for and should replace traditional platform-centric thinking with a capability or mission focus based on employing the best available combination of systems and other assets. *Recommended OPR:* HQ USAF/XP. *Recommended OCRs:* HQ USAF/XO and SAF/AQ. *Refer to Section 5.1.*

Develop and Implement Aerospace Power Doctrine and Strategy. The Air Force should develop the doctrinal basis for integrated aerospace power and should carry it out through strategies that apply that power effectively to satisfy assigned tasks. *Recommended OPR:* HQ USAF/SP. *Recommended OCR:* Air Force Doctrinal Center. *Refer to Section 5.2.*

Improve Acquisition Practices. The Air Force should make both a *revolutionary* change to switch from military to civilian models for system development, procurement, and operations, and an *evolutionary* change based on continuous improvement throughout the program. Elements of this include:

- Adopt a policy that the assumed approach to any procurement is to buy commercial, with alternatives such as government system developments requiring justification for an exception to this rule; maintain high-level emphasis to overcome resistance and inertia in the affected organizations.
- Adopt commercial practices such as business case analysis, streamlined procurement, and spiral development of ground segments; develop an acquisition work force with the skills to effectively execute commercial procurements and cooperative endeavors. Use commercial space wisely to exploit its advantages while protecting military interests and meeting military-unique needs.
- Require a comprehensive acquisition strategy as a fundamental part of a program plan from the outset, restore a high-level program review process analogous to the "summits" of prior years, and develop improved cost/performance models that improve visibility into program status and identify effective initiatives to deal with emerging problems.
- Maintain adequate budget reserves in acquisition programs to minimize reprogramming actions and avoid highly visible program disruptions.
- Require human factors practices and metrics in system development.

Recommended OPR: SAF/AQ. *Refer to Sections 5.1, 5.3, and 5.4.*

Focus the Technology Base on Military-Unique Technologies. The Air Force Research Laboratory (AFRL) has initiated action through the FY 00 Program Objective Memorandum to significantly increase support to space and deserves credit for tackling this difficult but necessary reorientation of the Technology Base program. However, both this initiative and the overall health of the Technology Base are in jeopardy as a result of recent budget cuts. In keeping with the overall move to greater reliance on commercial space, AFRL should structure its program on the basis of (a) funding military-unique technology needs not likely to be met by commercial sources, (b) funding competing concepts to those in commercial development, (c) identifying and pursuing opportunities to insert technologies in both commercial and military applications, and (d) maintaining longer-term high-risk/high-payoff technologies where commercial companies cannot justify investing. In addition, AFRL should focus on the areas identified in this study where critical technology needs exist, e.g., for low-cost, lightweight space optics and reusable launch vehicles. Senior Air Force leadership should strongly support AFRL with Office of the Secretary of Defense and the Congress in obtaining approval of the necessary changes. *Recommended OPR:* SAF/AQ. *Recommended OCR:* AFRL/CC. *Refer to Section 5.5.*

Develop and Execute a Coordinated Program for the Integrated Aerospace Force. The Air Force should pursue a coordinated set of programming and budgeting actions to achieve the integrated aerospace force. Building on and continuing the work of the AITF, an executable program should be constructed through TOA adjustments and through economies and transfers of responsibility that help offset resource increases. A preliminary and high-level budget analysis done as part of this study suggests that a large part of the resources required can be made available from within the current baseline space superiority program area, minimizing the requirement to transfer funds from other program areas. A more detailed budget and program analysis is required to quantify costs and economies and develop a coherent programming strategy, including the possibility of transfers of TOA among program areas. *Recommended OPR:* HQ USAF/XP. *Recommended OCRs:* HQ USAF/XO and SAF/AQ. *Refer to Chapters 4 and 6.*

Summary

In order to meet the obligations likely to be laid on it in the years ahead, the Air Force must complete the transition to a flexible, responsive, integrated aerospace force that is organized, trained, and equipped for a broader range of missions and tasks than ever before. In so doing, it must place unprecedented emphasis on affordability and on shedding activities that do not properly belong in the Air Force program. Commercial space and partnerships with other Government agencies offer important opportunities which must be sought out and pursued. Technology breakthroughs increasingly allow us to deploy markedly improved systems while reducing development and operation costs. However, none of this will happen without new approaches and the leadership to put them into action.

Effecting this transition in an era of flat or declining budgets will be brutally hard, and some cherished Air Force traditions and politically powerful vested interests will suffer in the process. The Air Force faces huge budget problems in space (and almost everywhere else) whether this study's recommendations are acted on or not. There is no way out of this dilemma that does not involve both changing fiscal priorities and divesting large pieces of today's Air Force mission and infrastructure. As one example, thousands of military manpower authorizations that are now dedicated to support activities in space system and launch operations can be replaced with a far smaller workforce, largely contracted out, and moved to fill urgent needs elsewhere. This would be consistent with the development of a corps of aerospace warfighters, skilled in all the dimensions of applying spaceborne and airborne instruments of national power.

We are convinced that the Air Force can and must make the necessary changes within the constraints of budgets and system development timelines. Actions should begin immediately to streamline organizations and operations, to make better use of commercial opportunities, and to better incorporate space capabilities into terrestrial operations. For example, procurement of space and airborne ISR systems should be based on an integrated functionality and should account for the contribution of commercial and other Government systems. The result will be to buy fewer platforms and to avoid wasteful overspecification of any single element in the total force structure. The work of the AITF is especially important here.

Inescapably, to reach the levels of capability which we believe will be increasingly necessary, money will have to be spent on several carefully defined new systems and on upgrades to a number of legacy systems. Restructuring of the budget must start during the current Future Years Defense Program (FYDP), and we project significant investment needs to arise toward the end of the FYDP period. These largely can be offset by savings in many areas. Planning and programming preparations should start immediately, along with decisions on organizational restructuring, outsourcing and privatization, transfers of missions and facilities to other agencies, and other economy measures.

We have tried in this study to outline the kinds of actions the Air Force must take and to establish the basis for a concrete and detailed program roadmap which should now be developed through the program planning and budgeting process. We understand the difficulty of the course we advocate. However, the alternative is for the Air Force to become progressively less capable of doing the jobs that will be assigned and less relevant as an instrument of national power. The time to make the commitment and take the first steps is now.

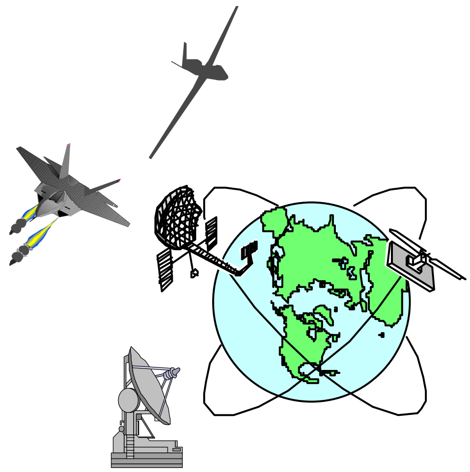

Table of Contents

List of Figures

List of Tables

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List of Acronyms and Abbreviations

ABL	Airborne Laser
AFDD	Air Force Doctrine Document
AFFMA	Air Force Frequency Management Agency
AFMETL	Air Force Minimum Essential Task List
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AIP	Aerospace Integration Plan
AITF	Aerospace Integration Task Force
AOC	Air Operations Center
AOR	Area of Responsibility
AOV	Aerospace Operations Vehicle
ARIA	Advanced Range Instrumentation Aircraft
ASEDP	Army Space Exploitation Demonstration Program
AWACS	Airborne Warning and Control System
BM	Battle Management
BMEWS	Ballistic Missile Early Warning System
CAV	Common Aero Vehicle
CBM	Conventional Ballistic Missile
C^2	Command and Control
C^3	Command, Control, and Communications
C^4I	Command, Control, Communication, Computers, and Intelligence
C^4ISR	Command, Control, Communication, and Computers, Intelligence, Surveillance, and Reconnaissance
CER	Cost Estimating Relationship
COMSAT	Communications Satellite
CONOPS	Concept of Operations
CONUS	Continental United States
COP	Common Operating Picture
COTS	Commercial Off-the-Shelf
CSAF	Chief of Staff of the Air Force
DARPA	Defense Advanced Research Projects Agency
DE	Directed Energy
DISA	Defense Information Services Agency
DISN	Defense Information Systems Network
DMSP	Defense Meteorological Satellite Program
DOC	Desired Operational Capabilities
DoD	Department of Defense
DSCS	Defense Satellite Communications System
DSP	Defense Satellite Program
EELV	Evolved Expendable Launch Vehicle
ELINT	Electronic Intelligence
ELV	Expendable Launch Vehicle
EMD	Engineering and Manufacturing Development
EO	Electro-Optical
ER	Eastern Range
F^2T^2EA	Find/Fix/Track/Target/Engage/Assess
FOC	Full Operational Capability

FYDP	Future Years Defense Program
GBS	Global Broadcast System
GEO	Geosynchronous Earth Orbit
GEODSS	Ground-Based Electro-Optical Deep Space Surveillance
GHz	Gigahertz
GMTI	Ground Moving-Target Indication
GOES	Global Operational Environmental Satellite
GPS	Global Positioning System
HSI	Hyperspectral Imaging
IBS	Integrated Broadcast Service
ICBM	Intercontinental Ballistic Missile
ILS	Instrument Landing System
IOC	Initial Operational Capability
IPB	Intelligence Preparation of the Battlespace
IPT	Integrated Product Team
IRT	Independent Review Team
ISR	Intelligence, Surveillance, and Reconnaissance
JMETL	Joint Mission Element Task List
JointSTARS	Joint Surveillance, Target, and Attack Radar System
JSF	Joint Strike Fighter
JV2010	*Joint Vision 2010*
kW	Kilowatt
lb	Pound
LEO	Low Earth Orbit
MEMS	Micro-Electro Mechanical System
METSAT	Meteorological Satellite
MILSATCOM	Military Satellite Communications
MIS	Modular Insertion Stage
MOE	Measure of Effectiveness
MOOTW	Military Operations Other Than War
MS&A	Modeling, Simulation, and Analysis
MTW	Major Theater Warfare
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Model
NAVAIDs	Navigation Aids
NBC	Nuclear, Biological, and Chemical
NCA	National Command Authority
NFIP	National Foreign Intelligence Program
NMD	National Missile Defense
NOAA	National Oceanic and Atmospheric Administration
NPOES	National Polar-Orbiting Environmental Satellite
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NRO	National Reconnaissance Office
NUDET	Nuclear Detonation
OCR	Offices of Collateral Responsibility
OODA	Observe, Orient, Decide, Act
OPR	Office of Primary Responsibility
OPTEMPO	Operational Tempo
OSD	Office of the Secretary of Defense
PB	President’s Budget

PD	Presidential Directive
PNT	Position, Navigation, and Timing
POES	Polar-Orbiting Environmental Satellite
POM	Program Objective Memorandum
RDT&E	Research, Development, Test, and Evaluation
RLV	Reusable Launch Vehicle
RSP	Recognized Space Picture
SAB	Air Force Scientific Advisory Board
SAR	Synthetic-Aperture Radar
SATCOM	Satellite Communications
SBIRS	Space-Based Infrared System
SBL	Space-Based Laser
SBLRD	Space-Based Laser Readiness Demonstrator
SBR	Space-Based Radar
SensorSAT	Sensor Satellite
SIPRNET	Secret Internet Protocol Router Network
SMV	Space Maneuvering Vehicle
SSTO	Single-Stage-to-Orbit
TENCAP	Tactical Exploitation of National Capabilities Program
THAAD	Theater High-Altitude Area Defense
TOA	Total Obligation Authority
TOR	Terms of Reference
TPED	Transmission, Processing, Exploitation, and Dissemination
TSTO	Two-Stage-to-Orbit
TT&C	Tracking, Telemetry, and Control
UAV	Unmanned Aerial Vehicle
UFO	UHF Follow-On
VORTAC	VHF Omnidirectional Range Station/Tactical Air Navigation
WAAS	Wide-Area Augmentation System
WMD	Weapons of Mass Destruction
WRAP	Warfighters Rapid Acquisition Program
WR	Western Range

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Chapter 1

Introduction

The U.S. Air Force Scientific Advisory Board (SAB) was tasked to examine the steps which the United States Air Force should take in order to posture itself to make the best use of space in accomplishing its assigned operational tasks in a rapidly changing world. The study team was composed of SAB members, a number of *ad hoc* members with expertise in particular areas, and a broad cross section of Government personnel from the Air Staff and several major commands. The present volume presents a summary of the study and its principal findings and recommendations. Each panel has also prepared a detailed report dealing with matters in its assigned area in greater depth. These reports are contained in subsequent volumes.

This Summary Volume starts with an overview of the study tasking, organization, and methodology. The next chapter summarizes the challenge confronting the Air Force in evolving to a fully integrated aerospace force while coping day-to-day with serious problems arising from operational demands, limited resources, and social and political pressures. The following chapters present a concise description of our primary findings and recommendations, the results of an initial analysis of programs and budgets to assess the affordability of various future alternatives, and a number of related matters necessary for a complete treatment of the study topic. Finally, we end with a summary of the study team's recommended roadmap and program strategy for the future of the Air Force as it learns to conduct functionally seamless operations across the very different physical media of air and space.

1.1 Study Tasking

The Terms of Reference (TOR) under which the study was launched are given in Appendix A. Initially, the title chosen was "Going to Space: A Roadmap for Air Force Investment." This reflected the thought, which has been prevalent in recent years, that the U.S. Air Force is migrating from an air and space force to a space and air force, perhaps even ultimately to a space force. Very early in our deliberations, the study leadership realized that this initial focus was inappropriate. The Air Force is *already* an aerospace force; we are not going to space, we are already there. In terms of dollars and people devoted to space missions and of tasks performed for all of the Department of Defense (DoD), the U.S. Air Force is overwhelmingly the leading Service in space. What is really at issue is how the U.S. Air Force should act to steadily improve the integration of air and space assets and activities in performing assigned missions, to properly allocate functions to the air and space media, and to adjust its "portfolio" of assets and functions for greatest effectiveness with constrained resources.

Accordingly, the original title has been changed to "A Space Roadmap for the 21st Century Aerospace Force." This reflects two key themes of the study:

- Primary attention to the space segment of an integrated aerospace force, but with due attention to the implications of decisions about space for the airbreathing and surface elements of that force.
- An examination of programmatic and architectural alternatives in an effort to identify the best choices for investment and disinvestment, along with an estimate of the resulting schedules and resources. From this analysis, we have constructed a top-level roadmap, which we believe will move the Air

Force to its desired end states[9] at the fastest pace compatible with the dollars and manpower likely to be available.

Despite the title change, our tasking has remained substantially as described in the TOR. Under that tasking, we have sought to gather as complete as possible a set of data and opinions on the subject from Government and industry, to understand the likely operational context and tasking which the Air Force will face in the coming decades, to understand the implications of a rapidly expanding commercial space sector, and to anticipate both the needs and the opportunities associated with emerging technologies. We have weighed the operational benefits and expected costs of plausible force structure alternatives to find the key vectors and waypoints of a path to an effective, efficient, and affordable aerospace force. Finally, we have considered a number of related issues in such areas as acquisition strategy and the Air Force Technology Base, and have formulated recommendations aimed at ensuring that a complete framework is put in place for achieving the desired future force.

1.2 Organization and Methodology

The study team was organized into seven panels as summarized in Appendix B. In general, the panel breakout was based on broad areas of technical and operational expertise, but extensive coordination across panels was required on many issues. The Study Chairman and Panel Chairs, together with the Senior Advisor to the Chairman, Senior Air Force Civilian Participant, and General Officer Participants, constituted both the overall study leadership and the Integration Committee for resolving disputes and assembling panel outputs into a coherent whole.

Discussion of future space forces necessarily raises important issues of joint and coalition operations. This, and the vital importance of integrating National Reconnaissance Office (NRO) and other Defense systems, as well as commercial and civil space capabilities, with Air Force systems caused us to seek extensive interaction with the NRO, Army, Navy, National Aeronautics and Space Administration (NASA), Defense Advanced Research Projects Agency (DARPA), and other Government and industry organizations. We have taken the Doable Space Quick-Look study[10] as our point of departure and have coordinated our efforts with those of the Aerospace Integration Task Force (AITF), the parallel study entitled “Prioritizing Army Space Needs” being done by the Army Science Board, and a number of other efforts in the area. We had productive meetings at the NRO and with General Anderson, Commander of the Army Space and Missile Defense Command, and Admiral Moneymaker, then Commander of the Navy Space Command. In short, while this is an independent report presenting the objective opinion of the study team, we have worked hard to ensure that all relevant facts, user requirements, and related programs are properly considered.

The overall plan of attack is summarized in Figure 1-1. Three parallel strands of activity led up to the actual Summer Study: development of the operational context and candidate changes to the baseline force structure, amassing information on technologies and commercial opportunities, and developing a model and methodology for affordability assessment. During the study period, we defined and evaluated options to arrive at a recommended roadmap and developed a set of additional recommendations associated with the effective implementation of that roadmap. The evaluation was based on four measures of effectiveness (MOEs):

- *Operational Effectiveness*—ability of the resulting force structure to address current and projected tasking

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[9] End states are taken to be those articulated in the Air Force Long Range Plan, as well as those implied by emerging aerospace doctrine (e.g., AFDD 2-2 [draft]) and by operational task lists such as Desired Operational Capabilities, the Joint Mission Element Task List, and Air Force Minimum Essential Task List (AFMETL).

[10] Refer to Doable Space.

- *Affordability*—ability of the alternative to fit into an executable program within reasonable budget projections
- *Technical Risk*—availability of the required enabling technologies and products to implement the system or systems under consideration on a given schedule
- *Integration*—ability of the alternative under consideration to maintain continuity of service to warfighters and to fit into an evolving force structure, including backward compatibility as appropriate

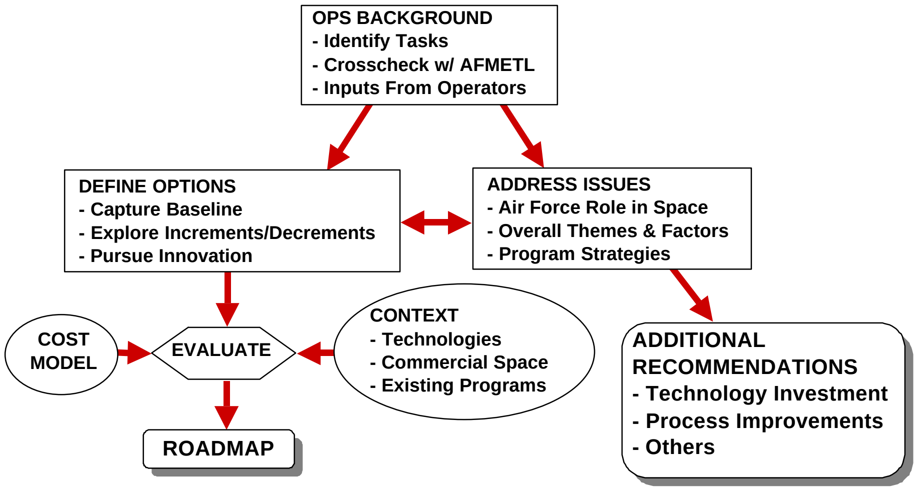

Figure 1-1. *Overall Study Flow*

The outcome of this process is presented in the following chapters, leading to a description of our recommended roadmap in Chapter 6.

1.3 Study Time Frames

It is convenient to define three rough time frames for the actions recommended in this study. We take the near term to be roughly the 5 years of the current Future Years Defense Program (FYDP). In this period, fiscal realities mean that no significant new investments can be planned, but important steps to begin streamlining operations, making better use of commercial space, integrating space into aerial operations, and instituting acquisition program improvements can and should be started. We refer to the period through roughly 2010-2015 as the mid-term. In this period, significant new capabilities can begin to be deployed, and the full program of improvements in organizational efficiencies, acquisition processes, and operational integration can be carried out. Beyond 2015 is the far term, when the benefits of advanced technologies now in development can begin to reach operational reality and the full vision of 21st century aerospace power can be achieved.

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Chapter 2

A Vision of 21st Century Aerospace Power

2.1 The Challenge of *Joint Vision 2010*

Joint Vision 2010 (*JV2010*)[11] spells out national military strategy and provides the "conceptual template for how America's Armed Forces will channel the vitality and innovation of our people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting." Aerospace power is essential to the tenets of *JV2010*. The AITF has described nine complementary characteristics of air and space power, which enable unique contributions to national military power.[12] Table 2-1 gives examples of the ways space systems can contribute to meeting the challenge of making *JV2010* a reality.

Table 2-1. *Examples of Space Contributions to JV2010 Operational Concepts*

Operational Concept	***Aerospace Capability***	***Space System Contributions***
Dominant Maneuver	• Expeditionary Air Power	• Global Situational Awareness • Smaller Deployed Footprint
	• Dispersed/Synchronized Ops	• Communications/Networking • Intelligence Support • Weather/Environment Sensing
Precision Engagement	• Precise Delivery of Tailored Effects	• Space/Time-Referenced Battlespace • Precision Targeting • Precision Navigation
	• Battle Damage Assessment	• Multimode/Fused Sensing
Full Dimensional Protection	• Detection/Defeat of Hostile Actions	• Detect Use of Nuclear/ Chemical/Biological Weapons • Real-Time Intelligence/Warning • Denial of Hostile Use of Space
	• Highly Survivable Services to Warfighters	• Intel Transmission/Processing/ Exploitation/Dissemination • Robust/Survivable Connectivity
Focused Logistics	• Tailored Sustainment	• Reachback Connectivity • Navigation & Communications for Tankers & Transports
	• Effective Space Logistics	• Responsive Launch • Satellite Retrieval/Servicing

An aerospace force that can make these possibilities real must possess unprecedented capabilities in terms of global knowledge, global reach, and global power.

[11] *Joint Vision 2010*, Gen John M. Shalikashvili, Chairman of the Joint Chiefs of Staff, 1996.
[12] *Beyond the Horizon*, Draft Aerospace Integration White Paper, AITF, 14 September 1998; the characteristics are access, energy, flexibility, maneuver, persistence, perspective, precision, range, and speed.

Global Knowledge

JV2010 depends on information dominance to enable virtually every aspect of military superiority. The heart of this capability is a system of systems. It starts with intelligence, surveillance, and reconnaissance (ISR), coupled with real-time communications and information processing. The result, from initial collection of data to its timely use by warfighters, is victory through knowing more and knowing it sooner than the enemy.

Today's Capability. Intelligence satellites and airborne platforms provide localized and generally discontinuous sensing, often impeded by weather, terrain, and hostile countermeasures. Processing and dissemination of time-sensitive data to warfighters is improving but still falls far short of the true need.

Tomorrow's Promise. The aerospace force can and must deliver precise, global situational awareness to commanders and fighters at all levels, providing the right information at the right place and time, while overcoming countermeasures and denying similar knowledge to the enemy.

Global Reach

The nation requires global presence to influence events and defend American interests, but with much less of the traditional forward basing. The mobility of aerospace forces is the key to rapid response and to the projection of all kinds of military power from U.S. bases to worldwide contingencies.

Today's Capability. Airlifters and tankers allow expeditionary forces to deploy and are engaged every day in missions from humanitarian relief to combat force sustainment. However, lift is limited, deployments take days to weeks, and success often depends on support from countries in the regions of interest—support that cannot be guaranteed in times of crisis.

Tomorrow's Promise. The aerospace force, with the right organization, training, and equipment, could deliver precisely calibrated effects, from taking a picture to dropping a precision munition, anywhere on earth, in 90 minutes from the "go" order, with surprise and immunity to most defenses. Larger-scale deployments would be lighter, faster, and more effective, and the need to station forces in foreign theaters would be greatly reduced.

Global Power

America's military forces must be able to prevail in operations anywhere on earth, ranging from disaster relief to hostage rescue to shows of force and, when required, combat.

Today's Capability. Modern fighters and bombers with steadily improving precision targeting and munitions have impressive ability to prosecute targets with economy of force and greatly reduced collateral damage and casualties. However, proliferating air defenses threaten their survivability, and almost any adversary has or can have the ability to use space-based systems, eroding a long-term U.S. advantage.

Tomorrow's Promise. The aerospace force can and must enable the full richness of the "effects-based targeting" concept,[13] using a wide range of lethal and nonlethal means to shape the desired end state of any conflict. At the same time, real space control, including assured access for friendly forces and denial of the same to enemies, can restore the decisive edge in space operations.

In an even broader sense than *JV2010*, U.S. national space policy calls for the ability to execute missions in the areas of

- Space Support—including launch and system operations

[13] "The Road Less Traveled," Briefing by Lt Gen Gamble, 1998.

- Force Enhancement—using space-based assets to improve the effectiveness of terrestrial operations
- Space Control—including assured access to space and denial of space capabilities to an adversary
- Force Application—involving delivery of force to, through, and from space

In addition, the policy calls for the United States to

- Maintain the capability to evolve and support space transportation systems
- Pursue integrated satellite control and continue to enhance the robustness of satellite control capability
- Propose modifications or augmentations to intelligence space systems
- Develop, operate, and maintain space control capabilities
- Pursue a ballistic missile defense program

While the existing force can provide much of the capability suggested by Table 2-1, truly revolutionary improvements are possible. They include far more effective use of limited forces through new approaches to the controlled application of force under emerging concepts such as effects-based targeting, nodal analysis of an adversary's vulnerable points, and asymmetrical strategy.[14] The following examples hint at the kinds of options aerospace forces could offer to the National Command Authorities through advanced technology and full air/space integration:

- Precise, Assured, Global Situational Awareness. The combination of space-based sensors, automated information fusion and processing, high bandwidth connectivity, and rapid delivery of information to warfighters at all levels which this study envisions would enable an entirely new level of knowledge about the battlespace. This would greatly improve intelligence preparation on timelines compatible with the deployment of an expeditionary force, minimize the chances of hostile surprise action, and allow commanders to apply available forces most effectively and survivably. As an intrinsic element of information dominance, such superiority in knowledge is the key to winning by acting faster and more decisively than an opponent (often referred to as "getting inside the enemy's OODA[15] loop.") The leverage on the effectiveness of the entire joint warfighting force will be tremendous.
- Rapid, Global Reconnaissance and Strike. One possible outcome of our roadmap is a highly operable vehicle for both space and atmospheric missions at orbital speeds. With the appropriate payloads, this system would allow a photoreconnaissance mission, delivery of a precision weapon, or other "surgical" effects delivery anywhere on earth in something like 45 minutes from a "go" order. The implications for counterterrorism, hostage rescue, rapid support to a threatened ally, and many other situations likely to dominate the military picture in the next century are unprecedented.

[14] Ibid.
[15] Observe, orient, decide, and act.

Figure 2-1. *An Integrated, Knowledge-Rich Aerospace Force Is a Key Element of Joint Vision 2010*

- Expeditionary Air Power. The 1997 SAB study on Aerospace Expeditionary Forces highlighted the need for improvements in, among other areas, reachback for command and control (C^2) and logistics, rapid intelligence preparation of the battlespace, and precision space/time referencing for navigation, targeting, and weapon delivery. The capabilities our roadmap sees as achievable would help to enable the full power of the expeditionary air concept with major payoffs in enhanced operational capability, reduced operational tempo (OPTEMPO), and improved ability to deploy to unprepared operating locations.
- Crisis Management. In embracing the prompt application of highly responsive combat systems, it is also necessary to embrace new burdens for the quality and quantity of data that must be made available to civilian and military leaders. Without the knowledge to apply the force wisely, including broad and prompt insight into political, humanitarian, economic, legal, and other issues beyond the tactical situation, the national leadership will lack a sound basis for action. Conversely, knowledge loses its value when it cannot be exploited where and when necessary. Force application and knowledge enrichment are inseparable in our vision of the future.

We have not, in this study, attempted a new exercise in predicting future operational requirements and environments. Instead, we have used the results of recent studies such as *New World Vistas*[16] and *Spacecast 2025*,[17] as well as the insights of the many military experts in all Services who have served on or provided inputs to the study team. Together with the vision articulated in *JV2010* and *Global Engagement*,[18] these paint a picture of extremely diverse, ambiguous, unpredictable, and frequently time-critical contingencies in which low levels of conflict are far more likely than major engagements, making flexibility, agility, precision, and superior use of information key attributes of military forces. For example, the growing involvement of U.S. military forces in military operations other than war puts an increasing premium on global information, rapid response, and excellent coordination of diverse organizations and resources. The capabilities of space systems have high value in such scenarios in addition to their role at higher levels of conflict. While no one can foretell the exact times, places, and

[16] *New World Vistas: Air and Space Power for the 21st Century*, SAB, 1995.
[17] *Spacecast 2025*, Air University, 1997.
[18] *Global Engagement: A Vision for the 21st Century Air Force*, Secretary of the Air Force Widnall and Chief of Staff of the Air Force Gen Fogleman.

circumstances in which aerospace power will be employed, we have based our work on a broad body of prior analysis that provides a sound basis for understanding the capabilities likely to be needed.

2.2 Real-World Constraints

The possibilities just sketched are exciting, but the Air Force faces a daunting array of problems, both immediate and longer term, that limit the available courses of action. The following realities form an essential part of the background and context of this study.

Today, and for the foreseeable future, resources and demands are badly out of balance. The FY 99 Defense Appropriation involves the 14th consecutive annual decline in military spending in real dollars; the most optimistic future is one of zero real growth, and further declines are likely. At the same time, peacekeeping and other operations keep up an OPTEMPO that damages morale and retention, accelerates the wearout of weapon systems, and steals money from modernization and quality-of-life needs. ISR platforms like the airborne warning and control system (AWACS), joint surveillance, target, and attack radar system (JointSTARS), U-2, and Rivet Joint have especially serious OPTEMPO problems because of their high value and limited numbers. An aging aircraft fleet, perennial shortfalls in spares and repairs accounts, and endless stretchouts of acquisition programs are just a few symptoms of the overall problem.

On top of materiel concerns, both officers and enlisted personnel in many critical specialties are leaving the Service at rates that are increasingly hard to manage, still further exacerbating the burdens on the force that remains. While the pilot exodus has gotten the most public attention, the loss of midgrade noncommissioned officers is depriving the Air Force both of today's supervisors and of the trainers and experience base for tomorrow's Air Force. "Doing more with less" has passed beyond being an oxymoron to become a cruel and destructive joke.

Another fundamental reality is the rapid transition of the Air Force, not entirely by choice, to a garrison force that conducts expeditionary operations from continental United States (CONUS) bases. This places great emphasis on reducing the deployment footprint through effective planning, reachback, distributed command and control, and improved weapon system reliability and supportability. Going further, an aerospace force with true, responsive global reach might obviate many deployments altogether. It is clear that judicious allocation of functions among space, air, and surface segments can improve both effectiveness and efficiency of the overall force, and that the Air Force must capitalize on all such opportunities. Two obvious ways in which effective use of space may help alleviate the OPTEMPO situation and its consequences are by reducing the demands on airbreathing ISR systems and by enabling CONUS forces to achieve essential early effect on distant events.

2.3 Operations in Space

Today, the United States has sharply limited abilities to conduct operations in space, or to prevent an adversary's operations, in any sense that approximates aerial missions. Although every Administration in recent times has endorsed concepts such as antisatellite capabilities, there is no such deployed and available system. National policy, going well beyond treaty prohibitions on weapons of mass destruction in space, forbids the stationing of any weapons in orbit. Even our ability to track and identify objects in orbit, especially debris, is less than desired. Essentially, we can fly satellites for a variety of support functions such as communications, sensing, and navigation, and replace them, with long lead times, when they fail. We cannot fight, even defensively, in space with the resources we have today.

This situation stands in stark contrast to the rapidly growing dependence of the nation on space for vital economic purposes. Numbers like those in Figure 2-2 support the view that space is becoming, if it is not already, an economic center of gravity, the loss of which would cripple commerce, finance, and numerous other private and public activities. Space systems therefore present an irresistible target to many who wish us harm. History teaches that where such threats to national economic interests arise, military force will be used to defend those interests. A requirement to conduct offensive and defensive operations in space, lethally or nonlethally, will inevitably become a reality, and sooner more likely than later. Given that many potential space targets are commercial, indeed multinational, property, it is likely that such actions will involve information warfare far more often than physical damage or destruction.

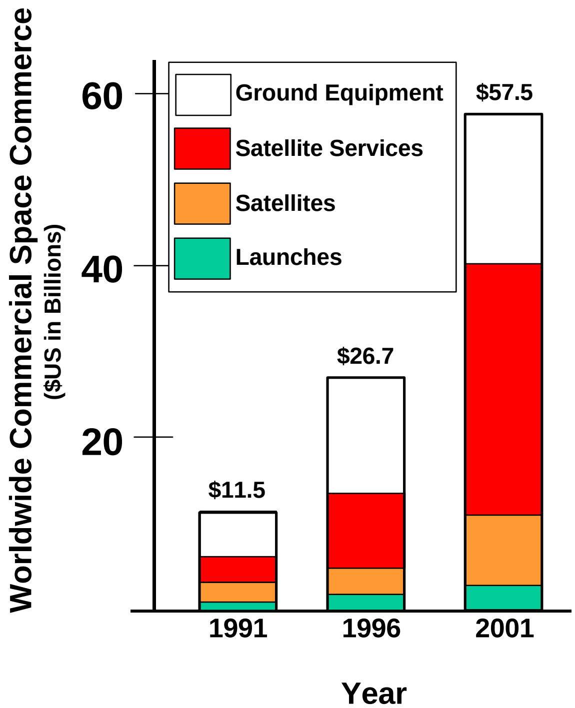

Figure 2-2. *The Rapid Growth of Commercial Space Makes It Increasingly an Economic Center of Gravity*

Transforming operations in space from a risky, infrequent, and expensive proposition into a real capability to respond to military contingencies will require changes in systems, organizations, and tactics. Highly responsive and affordable launch is one prerequisite. Another is possession of systems which can both protect our own satellites and deal with those owned or used by our adversaries across the spectrum of effects (deception, disruption, denial, degradation, and destruction). The overall subject of space control is dealt with in more detail later in this volume and in the Space Control Panel report. For now, it is important to note that as an essential element of developing an aerospace vision, we have found it important to account for the likelihood that operations in space will grow in importance as an Air Force mission.

2.4 Integrating Air and Space

"Integration" has at least two distinct meanings that are important to this study. The first deals with the need to treat terrestrial and space assets as elements of a single force, both in terms of optimally allocating functions to each category in a "system of systems engineering" process, and in terms of making space an integral part of the doctrine, tactics, and procedures of aeronautical operations. It has been said that air and space are simply two flight regimes, one of which ignores Kepler while the other ignores Bernoulli.

The AITF is composed of representatives from across the Air Force and has been tasked to develop the conceptual foundation for aerospace power in the 21st century, to assess force mixes, and to develop an Aerospace Integration Plan. Operational integration is obviously central to their charter, and we have coordinated our work with theirs. Defining the functions best done on orbit and the implications for connectivity, control, responsiveness, etc., in their interaction with terrestrial systems is crucial to establishing a roadmap for evolving to an integrated aerospace force and has thus been a central theme of our study.

The other dimension of integration involves the incorporation of other DoD systems, as well as civil and commercial systems, into a cohesive and affordable structure that provides robust service to warfighters. Important aspects of this include the best use of NRO sensor and communications systems in theater operations, cooperation with other agencies such as the National Oceanic and Atmospheric Administration (NOAA) for weather satellites, coordination with space activities in the Army and Navy, and, especially, finding the best way to use commercial space. This last is a special topic treated more thoroughly in Chapter 5 as an element of acquisition strategy. In crafting our vision and roadmap, we have tried to ensure that the Air Force invests only in those capabilities which are proper to its core competencies and necessary to complement these other participants.

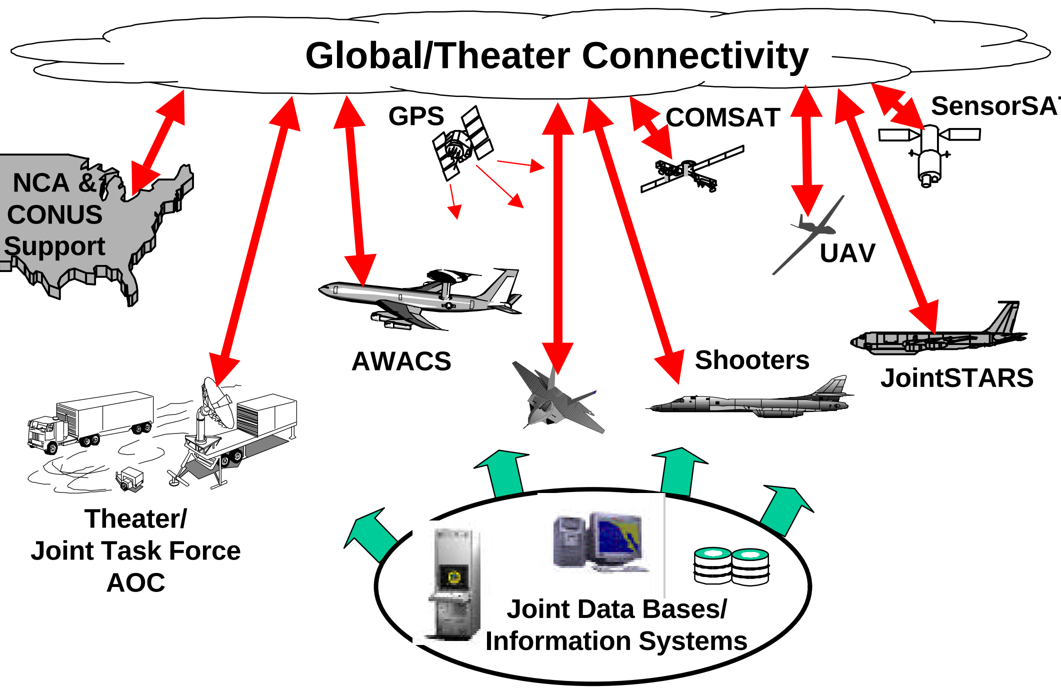

Figure 2-3. *Operational Architecture Addresses the Interactions Among Elements of a Force*

Both aspects of integration highlight the importance of architecture as a framework within which to define functions and systems and their interactions. Although all panels had a part in addressing architecture, it was the primary responsibility of the Architecture Panel and is explored in their report. Using the terminology of the *DoD Joint Technical Architecture*,[19] we have been concerned with both system architecture to define the assets that make up an integrated force structure, and with operational architecture to address how those assets are controlled and used to perform military functions. Figure 2-3 sketches this system-of-systems framework. We have coordinated this work with the parallel SAB *ad hoc* study on Information Management.

[19] *DoD Joint Technical Architecture*, Version 2.0, 26 May 1998.

2.5 Assessing Operational Effectiveness

Inherent in our approach is a way to assess how various options for changing the baseline force structure contribute to achieving our vision. We have examined a range of possible changes to the baseline program, defined as the current Air Force budget and FYDP, and evaluated them against the MOEs described in Chapter 1. This analysis has led to the selection of a recommended option. The baseline and recommended force structures are summarized in Table 2-2, with the systems each includes broken out into the functional areas listed in the first column of the table.

As a way to evaluate the operational effectiveness MOE, we have correlated the baseline and candidate force structure options against the operational tasks of the Air Force. The Joint Mission Element Task List (JMETL) provides a listing of the key tasks which a joint force must be able accomplish to fulfill the requirements of *JV2010*. The specific Desired Operational Capabilities (DOCs) of the JMETL, which currently number 72, are grouped by the *JV2010* operational concepts: Command and Control, Information Superiority, Precision Engagement, Dominant Maneuver, Full-Dimensional Protection, and Focused Logistics. The current DOC list is based on today's air operations and does not reflect the growing importance of space that is at the core of our vision. Accordingly, we have extended the list in two ways. First, we have expanded the definitions of many DOCs to include both space and terrestrial dimensions. For example, "Provide comprehensive battlespace awareness" and "Protect friendly civilian information infrastructure" are readily extended to space, and we have treated them as including capabilities delivered in, to, from or through space. Others, such as "Provide short-notice conventional global attack capability," allow an assessment of the improvement that an enhanced force structure would deliver, in this case through a high-speed weapon delivery system as in Figure ES-2. We have also added a few new notional DOCs in areas we believe will be important, such as "Rapid replenishment of critical space assets," "Continuous protection of friendly space assets," and "Global energy projection through space."

A quantitative comparison of force alternatives against these DOCs would depend on a host of assumptions and subjective judgements about priorities among DOCs and about force effectiveness, supported by an analysis whose scope would go far beyond what is feasible in a summer study. Instead, we have performed a qualitative assessment to identify the kinds of improvements our recommended option would deliver. We have done this by first assigning a *critical*, *important*, *supporting*, or *not related* rating to the degree that each functional area of an option (the first column of Table 2-2) is important in satisfying each DOC. Next we have estimated the ability of the option being evaluated, again by functional areas, to achieve each DOC, paying attention to the ways in which the option under evaluation falls short. Since there are 75 DOCs on our enhanced list and 9 functional areas, 675 assessments of importance and effectiveness are required. Situations where the baseline force is judged to have significant deficiencies while the importance is considered critical or important provide the focus of the search for better alternatives. Table 2-3 summarizes this Operational Effectiveness MOE by listing typical problems we see with the baseline force and typical improvements that our preferred option will deliver.

Table 2-2. *Summary of Baseline and Recommended Force Structures*

Functional Area	***Segment***	***Baseline Program***	***Recommended Option***
Infostructure/C^3	Space	DSCS, Milstar, UFO, GBS/IBS, Gapfiller, NRO Communications, Commercial SATCOM	Core MILSATCOM (Milstar), NRO Communications, Commercial SATCOM, ServerSAT Gateways
	Terrestrial	Troposcatter, DISN/SIPRNET, TENCAP, Commercial Landline	Baseline, Enhanced User SATCOM Gateways, Enhanced Fusion/BM/C^2/TPED Nodes
ISR/Warning	Space	DSP, SBIRS-High, SBIRS-Low, NRO Sensors, NUDET, Commercial Sensors	Baseline, New Sensor Constellation (1)
	Terrestrial	AWACS, JointSTARS, Rivet Joint, U-2, COBRA BALL, Predator, Global Hawk, Dark Star, Other UAVs, Other ISR Aircraft, BMEWS/North Warning, PAVE PAWS, COBRA JUDY, COBRA DANE, Surface ELINT	Baseline, w/ Adjusted Acquisition & Phase-Out Schedules as Allowed by Deployment of New Space System
Space Control	Space	N/A	Space-Based Surveillance, DE Projection (2)
	Terrestrial	GEODSS, FPS-85 Spacetrack, Haystack	Upgraded Sensors, DE Sources (2)
Launchers		Delta, Atlas/Atlas II/Atlas III, Titan II/Titan IV, EELV, Pegasus/Taurus, Other Commercial	Commercial Launch Services, EELV, AOV (3)
Force Application	Space	SBLRD	DE Projection (2)
	Terrestrial	ICBMs, CBMs, ABL, Combat Aircraft, NMD Interceptor	Baseline
Position, Navigation and Timing	Space	GPS/GPS IIF Transit, WAAS	Baseline + GPS Enhancements and Augmentation
	Terrestrial	NAVAIDs (VORTAC, ILS, etc.)	Baseline
Environmental	Space	DMSP, GOES, POES/NPOES, Foreign METSATs	Baseline (4)
	Terrestrial	Surface & Balloon Weather Sensors	Baseline
Infrastructure		Eastern/Western Ranges, AFSCN, ARIA, Commercial Ranges	National Space Ports GPS Space-Based Ranges Modernized Ground Environments
Modeling, Simulation & Analysis		Thunder, TACWAR System & Engineering Models	Upgraded Campaign Models for Space & Air

NOTES TO TABLE 2-2 (see later chapters and p. xxiii for definitions of acronyms and new systems):

(1) Includes space-based radar with synthetic-aperture radar imaging and ground moving-target indication modes; may include additional functions such as Hyperspectral Imaging sensor.

(2) May be terrestrial laser with relay mirror satellites or space-based laser; development contingent on successful technology demonstrations and concept of operations (CONOPS) development. Deployment requires a change in national policy.

(3) Aerospace Operations Vehicle (AOV) development contingent on successful technology demonstrations and CONOPS development.

(4) New space sensor constellation may support chemical/biological agent detection.

Overall observations include the following:

- The recommended force structure option delivers across-the-board improvement in operational capabilities, especially in the changing world of the coming decades, for about the same resources (see resource analysis in Chapter 4).
- ISR/Warning and Infostructure/C^3 are key to all of the operational concepts. The majority of all DOCs are impacted by these recommendations.
- Infrastructure has a small effect on operational effectiveness. Its importance lies mainly in reducing cost.
- Modeling, Simulation and Analysis (MS&A) is a crosscutting recommendation that yields benefits in areas where other recommendations have limited leverage. Examples include "Experience and Judgement" and "Provide Trained, Organized, and Equipped Forces."
- Position, Navigation, and Timing (PNT) is important for virtually every DOC, especially if it can be made truly robust in the face of hostile actions.

Table 2-3. *Examples of Shortfalls of the Baseline Force and Improvements From the Recommended Option vs. JV2010 Operational Concepts*

JV2010 Operational Concept	*Baseline Force Structure*	*Recommended Option*
Command and Control	• Unity of effort limited by connectivity & interoperability • Overall timeliness & responsiveness similarly limited • Many problems with inadequate MS&A	• Improved connectivity, near–real time information collection & dissemination • Significantly improved decision aids, including MS&A tools able to adequately represent aerospace
Information Superiority	• Inadequate situational awareness, esp. in WMD, MOOTW, & low-level conflict • Shortfalls in capacity, assurance, & interoperability • Shortfalls in protection of military & civilian assets	• Significant improvement in all areas of concern with baseline • Remaining deficiencies in affecting adversary information operations
Precision Engagement	• Significant limitations on time-critical targeting • Little or no space control capability • Lack of near–real time force projection	• Significant improvement in time-critical targeting • Range of space control options • Multiple options for global delivery of tailored effects
Dominant Maneuver	• Little capability for short-notice global conventional attack • Inability to deny hostile use of space	• Global delivery of tailored effects at orbital speeds • Range of space control options
Full-Dimensional Protection	• Limitations on intelligence preparation of the battlespace • Limitations on positive ID & data fusion • Little ability to protect space assets	• Significant improvement in all areas of concern with baseline
Focused Logistics	• Problems with logistics information systems & processes • Little ability to sustain or replace space assets	• Significant improvement in all areas of concern with baseline • Problems remain with joint logistics

2.6 Elements of a Vision

From our examination of requirements and opportunities there arises an overarching vision, suggested by Figure 2-4, and described by the following three dimensions.

2.6.1 Optimized, Integrated Use of Space, Air, and Surface Elements

As shown in the preceding section, judicious changes to the existing and currently programmed force structure (the baseline) can significantly improve the ability of the Air Force to meet the coming operational challenge. We look forward to an aerospace force that is more flexible, agile, and responsive in dealing with contingencies across the spectrum of conflict and more efficient in doing so with constrained resources of manpower and materiel. At the same time, we envision a force that better supports joint and coalition operations by providing to both Air Force and other warfighters services that are more robust, available, and affordable than is the case today. The keys to this optimized force are:

- Continuous progress in integrating all elements of the force through the AITF, operational experiments and exercises, and other aspects of the "intellectual underpinning" of future aerospace power.[20]
- Blending of Air Force, NRO, commercial, and civil space systems to achieve required capabilities at minimum cost.
- An information infrastructure that enables the collection, analysis, dissemination, and use of information to create knowledge at every level of the force structure and thus produces the decisions that yield decisive results. The Information Management study mentioned earlier articulates this complementary vision.

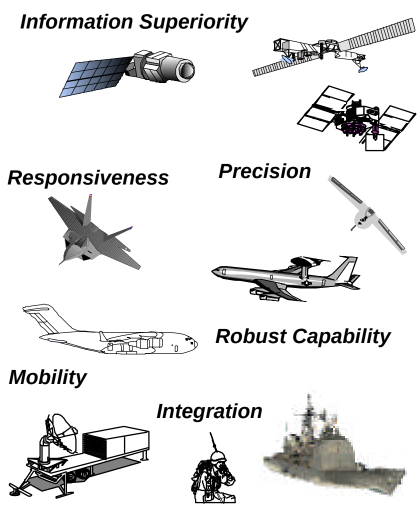

Figure 2-4. *Our Vision Is Based on an Integrated Force Able to Deal Efficiently With the Full Range of Taskings*

2.6.2 Revolutionary Advances in Capability Through Advanced Technologies and System Concepts

We have already given examples of the kinds of enhanced capability which are achievable. The Air Force must remain open to innovation and committed to leadership in the development and fielding of advanced systems. Accordingly, our vision is based on continued investment in high-leverage

[20] Doable Space.

technologies, improved means of exploring future options and demonstrating the military worth of space in joint warfare, and selective acquisition of new and upgraded systems to keep pace with evolving operational requirements.

2.6.3 Living With the Realities of Budgets, National Policy, Treaties and Public Laws, and the Demands of Day-to-Day Operations

Finally, our vision includes an approach to reach the desired end states without calling for unrealistic new or diverted budget dollars, and in a way that implements national policy and maintains compliance with applicable laws and international obligations. Once again, three things are key to success:

- Leverage the opportunities presented by a rapidly expanding and maturing commercial space enterprise, including application of commercial models for system development, acquisition, and operations
- Maintain existing and pursue new partnerships and supporting programs to lessen the burden on Air Force resources
- Vigorously pursue organizational and functional streamlining to shed redundant, inefficient, or inappropriate activities and infrastructure

In summary, we see an achievable aerospace force that makes unprecedented contributions to meeting national objectives. The specific actions needed to implement our recommended force structure option are presented in the next chapter.

Chapter 3

Force Structure Findings and Recommendations

The actions needed to implement our preferred force structure option are described in the following paragraphs along with brief statements of the accompanying rationale. They are in order by our estimate of their leverage on achieving our vision with available resources. Some involve significant expenditure, others little or none. Some deal with specific new or improved systems and others with products or functions. Together, they constitute our recommended changes to the baseline, and all are needed to fully achieve the vision we have conceived.

3.1 Move to a Network-Centric, Global Grid Information Structure

The ability to move information of all types globally and throughout the joint warfighting structure is the essential underpinning of information dominance. It requires a truly seamless ground, air, and space connectivity architecture for both individual communications channels and networks. In operational terms, we must ensure that we know what is necessary to tailor our response to any opponent, anywhere, in a way that shapes our actions and his to achieve our desired outcome.

Providing this connectivity is widely seen as the primary opportunity to use commercial space to provide a military function better and less expensively. It is not a simple subject, and failure to consider all the ramifications, both in performance and in economics, will certainly lead to problems. This is an area where profound changes from current systems and practices are in order. Perhaps nowhere else is the role of the "system-of-systems architect" discussed in Section 5.1 of this report more important.

Two key elements of our concept for dealing with the connectivity challenge are (a) a network-centric communications architecture that incorporates all available systems and channels in a system-of-systems framework and applies network management and optimization, and (b) a "ServerSAT" function on commercial satellites for military users to access the commercial space communications fabric. A ServerSAT is envisioned as a custom payload on a commercial satellite or satellite bus that provides a gateway between military systems and commercial networks, and would include high-speed crosslinks for such functions as connecting a sensor satellite (SensorSAT) to commercial channels. The ServerSAT gateway would have to be complemented by terrestrial gateways to complete the path to military systems or users. Figure 3-1 illustrates the concept.

Findings

Military satellite communications (MILSATCOM) today is a collection of stovepiped systems, each of which provides certain services to certain users. This leads to less effective use of available capacity and less robustness in the face of failures and hostile action than would be the case if all systems were managed as elements of a coordinated network.

Commercial space communications services of various types, including systems now in development or licensed, will have an aggregate capacity early in the next century that is about 1,000 times that of even the most ambitious MILSATCOM structure. Traditional geosynchronous earth orbit (GEO) communications satellites (COMSATs) are increasingly being supplemented by low earth orbit (LEO) constellations, offering orbital diversity as an element of a survivable and redundant service network. However, disparities in coverage and bandwidth between military and commercial systems must be resolved before primary reliance can be placed on commercial services for military needs.

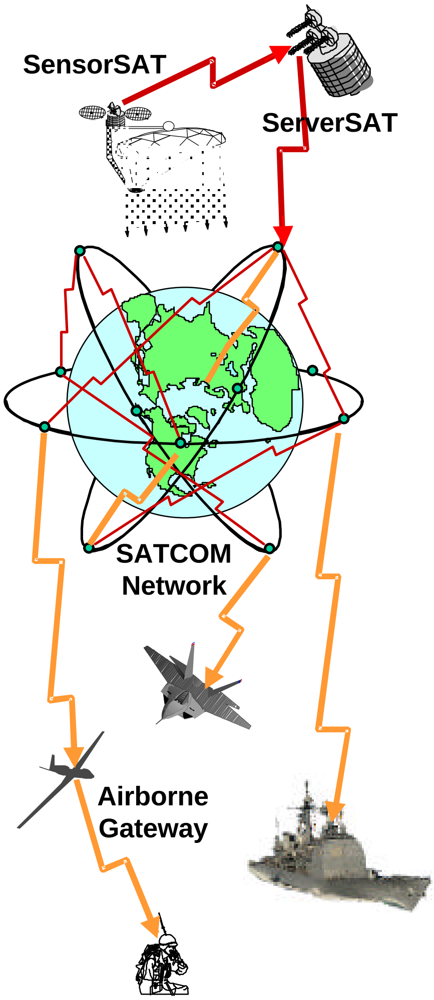

Figure 3-1. *A Diverse, Redundant, High-Capacity Network Provides the Essential Connectivity to the Joint Warfighting Force*

Effective connectivity for warfighters requires that access to military and commercial channels be both dependable and transparent. This implies a gateway function that interfaces user equipment to the network(s) being used and that routes traffic adaptively through the best path in any given circumstances. Such connectivity supports much more than space assets; airborne ISR systems are a prominent example of terrestrial platforms that need the same kind of dependable, high-data-rate communications.

The entire information infrastructure, not just communication channels, is central to achieving information dominance on the battlefield. Achieving the full capability of *JV2010* requires that every warfighting element, certainly every aircraft, be able to operate as a node in the battlespace network. In network engineering terms, this means that every tail number would have an associated network address. A truly optimized system-of-systems architecture and implementation is the essential foundation. Limitations on data links and the lack of satellite communications (SATCOM) transceivers on many aircraft are a serious problem in implementing such an information-enabled force. Dual-use L-band apertures for both Global Positioning System (GPS) and SATCOM are a possible approach to reduce the cost of solving it.

Commercial space can support military-unique services. In many instances, user equipment can provide encryption and other functions to allow military traffic to use commercial channels. Core MILSATCOM capacity can complement commercial systems for traffic whose security and urgency demand absolute assurance. These systems require high levels of protection as described in Section 3.6.

Commercial SATCOM is the leading current example of bulk purchase of a commercial commodity service to meet military needs. However, there is widespread dissatisfaction among operational customers with the way the Defense Information Services Agency (DISA) procures and provides this service.

The Services, and our allies, hold large inventories of terminals and other user equipment for existing MILSATCOM systems. By one account, the Army owns Defense Satellite Communications System (DSCS) terminals whose original aggregate cost was $7 billion. Any plan for migrating to a more effective and affordable connectivity fabric must account for maintaining the usefulness of this legacy equipment for a reasonable lifetime. One way to do this, suggested in Figure 3-1, would be the use of theater gateways such as the Airborne Communications Node on an unmanned aerial vehicle (UAV) or manned aircraft to bridge user equipment into the battlespace network.

The Navy has successfully applied a policy of seeking early partnerships with commercial SATCOM providers. Mutually advantageous business arrangements could include offering an early revenue stream from military usage in exchange for design features that enhance security and robust service. Conversely, the lack of such early dialog may mean that an important commercial system is unusable by DoD; e.g., the Teledesic system now in design is based on a business model with zero Government customers or requirements. This issue is further discussed in Chapter 5.

Assuming that suitable partnerships can be achieved, several commercial SATCOM networks appear to be compatible with a ServerSAT concept in which a gateway function for military traffic is added, either as a function of the primary payload or through some additional hardware. By guaranteeing a stable, early business base, DoD should be able to make it economically attractive to such providers to incorporate this capability. A ServerSAT would have crosslinks to systems such as sensor satellites that need broadband connectivity and would provide routing of such traffic through commercial networks. The ServerSAT function would be operated by the commercial provider and either owned or leased by the Government as appropriate.

An appealing approach to provide core MILSATCOM affordably involves a small number of GEO satellites that can be moved to provide connectivity over an Area of Responsibility (AOR) as needed. Under this concept, MILSATCOM would provide hardened, highly assured connectivity localized to a specific contingency, while purchased commercial services would continue to provide global connectivity for less urgent communications. In combination with launch on demand, from commercial lift services or an Aerospace Operations Vehicle (AOV) system, this concept would minimize the number and cost of MILSATCOM platforms to deliver a given level of guaranteed service to a theater.

An important connectivity issue that has been badly neglected involves the relay of data from the battlespace. Unattended ground sensors, Special Operations Forces radios, survival radios, and other transmitters are examples of the high-priority, time-sensitive message sources that must somehow be plugged into the global communications structure. COMSATs designed to work with small handheld user equipment like cellular phones might have a role here, as might a hybrid system using airborne gateways to pick up weak signals and relay them to space.

Recommendation

Plan and execute the earliest feasible phase-out of noncore MILSATCOM operations in favor of commercial services (core MILSATCOM is that capacity which must have levels of assurance and security above what commercial service can provide, presumed to be provided by the Milstar system). In so doing, the Air Force should maintain backward compatibility to legacy user equipment for a reasonable period of time, say seven years, in coordination with U.S. and allied warfighter organizations. The Air Force should develop with commercial SATCOM providers a set of on-orbit ServerSAT gateways to provide robust access for military users. The Air Force should develop and install affordable aircraft SATCOM antennas to provide connectivity between aircraft and the battlespace information infrastructure. The Air Force should evaluate a follow-on core MILSATCOM system using a small number of maneuverable GEO platforms for hardened, assured connectivity to one or more AORs. The Air Force should ensure that data relay is included in requirements for future communications architectures.

Recommended OPR: HQ USAF/SC. *Recommended OCRs:* SAF/AQ for acquisition, HQ USAF/XO for operational matters, and HQ USAF/XP for long-range planning.

3.2 Develop a Global, All-Condition, Intelligence/Surveillance/Reconnaissance Capability

The one major new system to which we believe the Air Force should commit itself based on information available now is a sensor satellite constellation as sketched in Figure 3-2 to complement other space and airbreathing ISR platforms. The primary payload would be a space-based radar (SBR) with synthetic-aperture radar (SAR) and ground moving-target indication (GMTI) modes, as well as secondary functions such as data relay and signals intelligence. Additional payloads, especially a Hyperspectral Imaging (HSI) sensor, are possible if their operational payoff justifies the greater weight and cost of the satellite. Space, airborne, and surface systems must work together in an integrated architecture to deliver maximum service to warfighters while containing costs.

Findings

Baseline space ISR assets are not adequate to support the kind of global situational awareness and dominant operations required by *JV2010*. An all-weather system that complements other assets, responds directly to the needs of the theater warfighter (direct tasking from and downlink to theater), and provides the required quality and timeliness of information to find/fix/track/target/engage/assess (F^2T^2EA) is essential.

Technology availability for an SBR with SAR and GMTI modes would allow engineering development to begin in about 2004, achieving initial operational capability (IOC) in about 2008 and full operational capability by about 2010-2012. The Discoverer II program, cofunded by the Air Force, the NRO, and DARPA and managed in the current phase by DARPA, is a sound risk-reduction and capability-demonstration effort that will provide much of the data needed to refine system requirements, develop a concept of operations (CONOPS), and establish a baseline for engineering and manufacturing development (EMD). In the longer term, advanced technologies for large space structures, high-power devices, and the like will make an air moving-target indicator mode feasible for a follow-on SBR system.

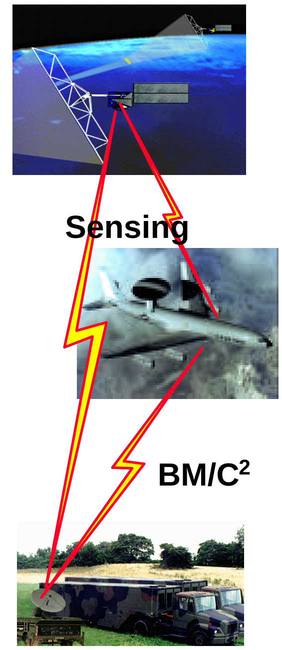

Figure 3-2. *A New SBR Cooperates With ISR Aircraft and Ground C^4I Nodes to Enhance Situational Awareness*

Additional sensors, especially the HSI concept, which is to be demonstrated on the Warfighter I experimental satellite, have great potential for detecting the use of chemical/biological agents; countering camouflage, concealment and deception tactics; and improving target detection. However, any passive electro-optical sensor is defeated by cloud cover, and so cannot be relied on as a primary source of real-time warfighting information. Nevertheless, packages as small as 200 lb or less with useful performance are possible and may warrant inclusion in the system, if they earn their way based on an assessment of risk, cost, and operational benefit. Ongoing programs like Warfighter I will produce important data to address these issues.

Both technology for affordability and synergism with other systems can significantly reduce the cost of such a sensor compared to earlier systems. Technologies include lightweight structures, improved power systems, high-performance onboard computers, and transmit/receive modules with better power, bandwidth, and efficiency, the latter coming from programs such as the Multifunction Integrated Radio Frequency System program that is intended for the Joint Strike Fighter. One opportunity for synergism is to exploit broadband crosslinks and downlinks to simplify onboard processing. Another involves reliance on highly responsive, affordable launchers to minimize the number of satellites permanently stationed on orbit by allowing rapid emplacement of additional platforms in tailored orbits and quick replacement of failed satellites. The overall efficiencies resulting from best commercial practices, described in Chapter 5, apply with particular force to this program because of its similarities to commercial SensorSATs.

The recommended SBR sensor is broadband (on the order of 1 GHz instantaneous bandwidth) and higher in frequency than current airborne platforms doing the same functions (X-band vs. L- or S-band radar). This can be expected to result in a very difficult frequency allocation challenge. However, commercial SBR systems for earth observation are highly likely for all-weather delivery of services from traffic monitoring to mapping. The Air Force Frequency Management Agency (AFFMA) is already engaged in assisting DARPA in formulating a frequency allocation strategy. This is one of several areas where the Air Force should be proactive in partnering with commercial enterprises to achieve common solutions, using the clout of commercial industry in international frequency allocation organizations.

Recommendation

Continue support for Discoverer II, Warfighter I, and other supporting technology developments. Use results of these demonstrations, together with operational analysis, to develop a system requirement and CONOPS. Start preparations now to program for a follow-on EMD program for an IOC in around 2008. Continue emphasis through AFFMA on efforts for a frequency allocation, including seeking commercial partners with similar needs.

Recommended OPRs: SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for initial planning and programming for a follow-on engineering development, manufacturing, and deployment program.

3.3 Provide Robust Position, Navigation, and Timing

Any vision of dominance in future operations includes the ability to precisely reference the battlespace in space and time, presumably to the WGS-84 coordinate datum. Beyond that, the entire world is coming to rely on GPS navigation for everything from land surveys to wilderness hiking. Current U.S. policy calls for providing GPS service as a free public utility to all users. The study team had several members on the GPS Independent Review Team (IRT), which has been developing a recommended course of action to both comply with national policy and meet military requirements. Our recommendations are in harmony with those of the IRT and the proposed Presidential Directive (PD) on GPS.

Findings

Precision PNT is absolutely critical to *JV2010* precision engagement and to the entire F^2T^2EA process. It must therefore be robustly available in the face of the certainty of hostile attempts to exploit it, deny us our use of it, or both. Similarly, there is high leverage in denying it to an adversary.

Upgrades to GPS, notably GPS IIF, have been identified to help ensure service to warfighters. However, firm program plans and budgets are lacking, and the vulnerability of the system to jamming will continue if these enhancements are not fielded. The GPS Joint Program Office has defined and done cost estimates for a series of improvements to the GPS constellation and augmentations which would make the system more robust in the face of hostile actions, and has estimated a fair sharing of the resources between DoD and civil agencies.

Given that GPS is now a national system of vital importance to both military and civilian users, it is appropriate to fund it from a wide range of agencies and programs, not just the Air Force budget. The PD mentioned above calls for the use of sources such as the transportation trust fund.

If the military retains management of the system, there will be greater confidence that military needs will be identified and addressed through design changes to enable or enhance unique capabilities. Civil management may not be as responsive to these specialized requirements. In addition, GPS is not a good candidate for commercialization because, as a public service provided *gratis* by the Federal Government, it offers no obvious business opportunity beyond normal system contracting. User equipment, by contrast, is already a thriving competitive commercial industry.

Recommendation

Retain, on behalf of DoD, ownership and management of GPS and continue to provide civil and commercial services while pursuing implementation of improvements needed to maintain military performance in hostile environments. These include enhancements to the GPS constellation and augmentation through systems such as airborne "pseudolites" to provide a more diverse and jam-resistant signal in the battlespace. Advocate funding from non-DoD sources. Similarly, develop and field capabilities to selectively deny these services to adversaries.

Recommended OPR: SAF/AQ. *Recommended OCRs:* HQ USAF/XO for operational matters; and HQ USAF/XP for long-range planning.

3.4 Prepare for Global Energy Projection

One of the most controversial areas of military space concerns the projection of high-energy laser beams from or through space to attack both space and, potentially, terrestrial targets. The appealing features of such a system include near-instantaneous (literally speed of light) delivery of effects and the ability to modulate the power level to achieve tailored effects ranging from sensing to nondestructive effects to physical damage of a target. Multiple studies, including *New World Vistas*, make the case that directed energy from space, whether generated in space or relayed from the air or ground, will be a major weapon capability in the next millennium. Concepts like the space-based laser (SBL) and ground-based laser trace their origins to the height of the Cold War and the Strategic Defense Initiative. It is common to encounter very strongly held opinions supported by very limited facts and data. In this situation, committing major resources to a particular concept is far more likely to waste the money than to deliver meaningful operational capability. There is a great deal of homework to do first. Moreover, pursuit of any orbital weapons requires modification of existing national policy.

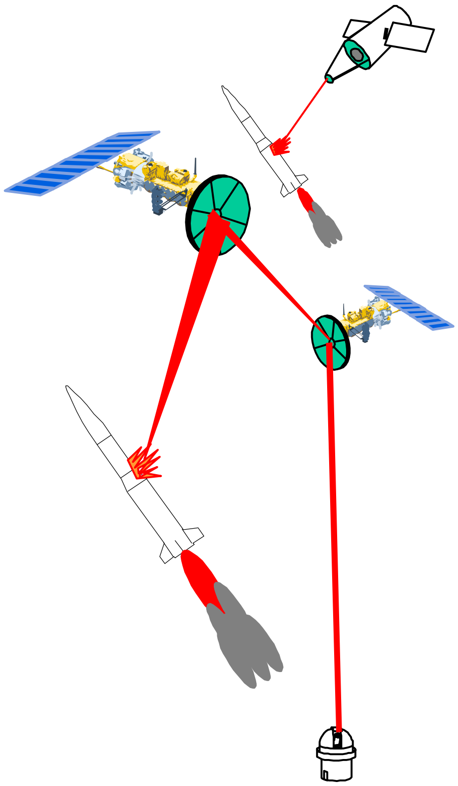

Figure 3-3. *A Number of System Concepts Have Been Proposed for Energy Projection Through Space*

Findings

Multiple scenarios and system concepts have been put forward for "lasers from space," as suggested by Fig. 3-3. The power source may be space-, air- or ground-based, or some combination of these. Many concepts involve relay mirror satellites with bifocal optics to direct beams around the globe and focus them on targets.

The estimated cost and level of risk associated with such an energy projection system depend critically on the CONOPS. A high-energy force projection system could contribute to a wide range of missions, including counterair, space control, and missile defense. It could also deliver a range of effects—from active optical sensing modes to disruption of optical systems—to the earth's surface with exquisite precision. A system whose primary mission is space control requires far fewer lasers and mirrors than one sized to do boost-phase intercept of a large number of simultaneous missile launches as part of a national missile defense. Another major driving factor is whether the system must do the assigned job alone or whether it is integrated with other means (e.g., ground-based interceptors) in a larger force structure. These issues must be settled before even preliminary system engineering, let alone a large-scale demonstration, can be undertaken with any confidence.

SBL advocates tend to assume that ground lasers can be reengineered for the launch environment and acceptable lifetimes on orbit. The fact that such a laser has never been demonstrated, and that high-energy lasers on the ground are notoriously fickle and require a good deal of care and attention, means that any SBL concept is higher in risk. Another problem is the need to refuel a chemical laser after a comparatively small number of shots. On the other hand, a terrestrial source must be a good deal higher in power because its beam typically traverses more mirrors and a longer atmospheric path, increasing losses and pointing errors. The problems of atmospheric compensation have been adequately solved to allow high-quality beam propagation from the ground or air to space and thence to a target, but atmospheric effects such as blooming and turbulence will always mean greater beam losses than in space. SBL concepts have been more thoroughly analyzed than those using terrestrial lasers, and the latter should be subjected to the same level of scrutiny before a program decision is made.

Currently, the technology to support a major near-term demonstration of a space-based laser is the ALPHA-LAMP-LODE chemical laser (hydrogen fluoride) large optics system, designed in the ’70s and now in testing. It is our assessment that this technology is not mature enough to support such a demonstration. Engineering maturation requires a new generation of test hardware that goes beyond mere “fixes” to the current system. More work is also needed in system engineering and integration, beam and fire control, and other areas to reduce the risk to an acceptable level. Moreover, current cost estimates are preliminary and vary widely, but tend to be in the range of $2 billion to $2.5 billion, which is a very large investment to put at risk in our current state of knowledge.

To a remarkable degree, the cost of all competing concepts is driven by “glass on orbit.” The current very high cost and long time associated with fabricating suitably high-quality mirrors that can handle high energy levels, and the launch cost to orbit them, are major, perhaps the largest, elements in a cost buildup. This common factor tends to make cost estimates for various system concepts closer than might be expected. Technology to make large space optics lighter and cheaper, both for weapon applications and for sensor systems that do not deal with high optical fluences, would benefit virtually any such system.

SBL concepts have centered on high-energy chemical lasers, which require lifting large fuel masses to orbit. An alternative approach that looks promising involves a large number of satellites with modestly sized electrically powered solid-state lasers, operating at shorter wavelengths and thus with smaller optics. Simultaneous but noncoherent illumination of a target like a missile in boost phase by many such lasers would be used to achieve a kill. Such a satellite would recharge its electrical energy storage during the nonoperating part of the orbit to allow nearly continuous firing when in sight of the target area. Benefits of this approach include reliability through redundancy, learning curve savings, and elimination of on-orbit refueling. Technology exists for all key elements of the system, including solar electrical or thermal power generation, flywheel energy storage for repeated deep discharges, and solid-state continuous-wave lasers that demonstrated 1 kilowatt (kW) in 1997 and should be scalable to as high as 100 kW while retaining adequate efficiency, even with frequency doubling.

Recommendation

Do not proceed with large scale, on-orbit high-energy laser demonstrations such as the proposed Space-Based Laser Readiness Demonstrator at this time, but pursue aggressively the precursor efforts needed to enable global energy projection at the earliest feasible date. Exploit earlier work on system concepts and technology demonstrators wherever possible. Develop a CONOPS for the employment of high-energy laser projection from space and conduct requirements analysis to identify the most effective and affordable approach to implementing such a capability, including both lethal and nonlethal effects. No development and deployment decisions should be made, and premature and expensive demonstrations should be resisted, until the military worth and optimum approach are established. Start a focused technology development effort in areas supporting high-performance optical systems in space, with emphasis on large, lightweight, low-cost optics. Conduct an adequate ground demonstration program before committing to an orbital test. Work the full range of technical, technology, and operational issues to allow such a decision to be made in the ’03 time frame. Continue development and evaluation of alternatives to chemical lasers, with emphasis on electrically powered solid-state lasers.

Recommended OPRs: SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF/XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for long-range planning.

3.5 Improve Space Surveillance and Develop a Recognized Space Picture Construct for the Common Operating Picture

As space becomes an integral part of the battlespace, the requirement grows to maintain the same kind of detailed, current, and available information about objects and events as is now incorporated in the Common Operating Picture (COP) and the subordinate Recognized Air, Maritime, and Ground Pictures. Such a Recognized Space Picture (RSP) would include friendly and hostile military satellites, as well as commercial and civil systems, debris, parameters of the space environment ("space weather"), and events of interest. It implies both enhanced ability to do surveillance of space and an information construct that feeds the COP and builds the RSP.

Findings

The space dimension of the COP is growing both in importance and in complexity. Information of interest includes (a) the location, status and capabilities of friendly, neutral, and hostile forces, including military, civil, and commercial systems; (b) data about the space environment, including space "weather," debris, threats, and events; and (c) targeting data on hostile space and counterspace forces.

An RSP is a logical and necessary extension of the joint force command, control, communications, computers, intelligence, surveillance, and reconnaissance structure. It would complement the existing recognized pictures in providing situational awareness and supporting joint force intelligence functions.

Building the quality of RSP that is needed requires better surveillance capabilities, especially at higher orbital altitudes. Current space surveillance sensors are ground-based, aging, and intended primarily for detection and tracking of satellite-sized objects in LEO. Moving certain sensing functions to space, especially surveillance of higher orbital altitudes, is an important aspect of achieving the required capability.

Recommendation

Migrate selected space surveillance functions to space. A possible approach is to modify the Space-Based Infrared System (SBIRS) Low constellation to perform both its primary warning mission and tracking of objects in high orbits. This may require changes to the constellation and the SBIRS-Low payload to provide continuous coverage and adequate performance while maintaining the system's primary warning mission.[21] Implement enhancements to ground sensors, especially a supportability upgrade to the FPS-85 Spacetrack radar.[22] Evaluate the opportunity to enhance space surveillance at low cost by importing and fusing data from Army missile defense radars. Lead the development of an RSP corresponding to existing Air, Ground, and Maritime Pictures, under the COP. As a key element of the RSP, provide timely attack warning and reporting for all satellites used by the military.

Recommended OPR: HQ USAF/XO. *Recommended OCR:* SAF/AQ.

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[21] *SAB Report on Space Surveillance, Asteroids and Comets, and Space Debris, Vol. 1: Space Surveillance*, SAB-TR-96-04, June 1997, pp. 11-15 and Appendix 1.

[22] Ibid.

3.6 Protect U.S. Space Assets Against Likely Threats

During the Cold War, military satellites and missiles were routinely hardened against nuclear weapons effects. Today, such hardening is more commonly limited to achieving a specified lifetime in the natural space radiation environment. However, other kinds of threats are becoming more likely. As both military and commercial space assets become vital parts of our military posture, an effective and affordable strategy for survivability becomes ever more important.

Findings

Likely future threats include jamming of space sensors and communications/navigation links, physical attacks on ground stations, and information warfare attacks to intercept or corrupt data and commands.

Although sensors to detect various kinds of attacks, especially by directed-energy weapons, can be miniaturized and placed on every militarily important satellite, it is often the case that main payload sensors can do a better job of recognizing an attack and even locating the source.

The threat that a terrorist group or rogue nation might use a theater missile as a booster to get a small nuclear device into low earth orbit and detonate it is real. By "pumping the Van Allen belts," such a warhead could rapidly induce electronic failure in virtually every low- and medium-orbit satellite not hardened against weapon-level effects. Critical DoD systems, especially in orbits below GEO altitude, will therefore require such hardening for assured survival.

Depending on which data source is considered more credible, the cost to radiation-harden a satellite to "strategic" (i.e., weapon) levels is estimated at 5 to 12 percent of the total system cost. Selective hardening, meaning careful choice of systems and of functions within systems to implement with hardened components, shielding, and other protective measures, is therefore an important affordability consideration. Better ways to achieve radiation hardening at lower cost would be extremely valuable, and might make protection of commercial systems more economically viable.

Recommendation

Take a coordinated set of steps to achieve survivability against likely threats at affordable cost, including

- Counter information warfare attacks by encrypting command and communications links on both Government and commercial satellites used by the military. Retain a minimum essential core MILSATCOM capability, which is very robust against such attacks, under Government control.
- Counter communications jamming by a combination of core MILSATCOM and terrestrial communications capacity and a diverse, redundant set of commercial SATCOM channels (GEO and LEO satellites from multiple suppliers).
- Counter ISR sensor jamming by measuring susceptibility through tests against dedicated orbiting targets and end-of-life satellites, then implementing appropriate hardening (e.g., filters to block laser wavelengths from optical sensors).
- Counter GPS jamming through planned system upgrades.
- Radiation-harden selected systems and subsystems where needed to assure survivability without incurring excessive costs. These include core MILSATCOM and ISR systems, such as SBIRS, that are critical for early warning.
- Counter attacks on ground stations through improved physical security and dispersed backup sites.

- Complete the current warning sensor program and deploy the results on satellites requiring the capability.

Recommended OPRs: SAF/AQ for acquisition and HQ USAF/XO for operational matters, respectively. *Recommended OCR:* HQ USAF/XP for long-range planning.

3.7 Develop a Space Test Activity and Adequate Modeling, Simulation, and Analysis Tools

Recent high-level studies such as the Quadrennial Defense Review have highlighted the lack of models above the most basic engineering/phenomenology level that accurately and realistically represent aerospace systems. As a result, the true military worth of aerospace is repeatedly understated in force structure analyses. This is a long-recognized and largely ignored problem. There is a matching shortfall in our ability to test and exercise systems in space to prove their performance and correct their problems. A means to explore, demonstrate and quantify the operational payoffs of aerospace in joint warfighting and to systematically establish system parameters is essential to achieving the proper role of air and space systems in *JV2010*.

Findings

There is no space analog to the air test ranges at places like Eglin, Tyndall, and Edwards Air Force Bases. Although some work can be done through simulation, this deficiency limits the ability of the Air Force to prove the utility of space systems and build warfighter confidence and insight. It also limits our ability to test and verify space system performance in the real space environment and to find and fix problems early in a system's life. Finally, it creates a gap in our ability to do training and exercises. A space test activity to cure this problem could use assets such as the GPS tracking space range described in Section 3.6 and existing space system ground stations to minimize the cost.

Similarly, there are no MS&A tools that play space (or, for that matter, air) adequately except at the lowest level of the modeling hierarchy, i.e., engineering and science phenomena. In this situation, the effectiveness of aerospace is always distorted and generally grossly underestimated in analyses and war games. The SAB and others have pointed out this problem repeatedly over the years, but in the current competition for resources, it has become critical that it be addressed.

Recommendation

Be proactive in ensuring that emerging or updated models at the campaign and mission/engagement levels accurately portray the characteristics and effectiveness of air and space systems; one promising opportunity is the National Air and Space Model (NASM) at the Electronic Systems Center. Ensure that the analytical capability is created to support system requirements analysis, operational and force structure analysis, experiments in integrating air and space systems, and similar tasks. Create a space test activity for development and operational testing, training, system effectiveness evaluation, and similar purposes analogous to those performed for aircraft by air test ranges, but allowing such activities to occur in the real space environment. Make maximum use of existing assets to minimize the cost of this added capability.

Recommended OPR: HQ USAF/XO. *Recommended OCRs:* SAF/AQ for acquisition and HQ USAF/XP for long-range planning.

3.8 Preserve the Option to Develop an Aerospace Operations Vehicle

A highly responsive and reusable launch system would be able to perform multiple missions to and through space. The AOV concept under discussion involves a two-stage-to-orbit (TSTO) system with a family of upper stages, each compatible with a variety of expendable boosters and with a relatively low-speed reusable first stage. A wide variety of reusable launchers is possible, with the level of technical risk increasing with the performance of the system, ultimately leading to a single-stage-to-orbit (SSTO) capability.

Findings

For several years, the Air Force, in partnership with NASA, has been exploring a Space Operations Vehicle. NASA, under its national charter, is developing reusable boosters. The Air Force has funded analysis and initial prototyping of upper stages: the Space Maneuvering Vehicle (SMV) for operations on orbit, Common Aero Vehicle (CAV) for delivery of payloads in the atmosphere, and the Modular Insertion Stage (MIS) for basic satellite launches. This program is minimally funded in FY 99 and subsequently threatens to delay the date on which a decision about proceeding with a follow-on system can be made.

The AOV concept is involved in a number of the revolutionary capabilities of a future aerospace force described earlier in this report. The system is one way to achieve highly responsive launch (defined in this study as less than 24 hours to integrate, prepare, and launch a vehicle and payload), creating the possibility for the first time of spacecraft operations with a sortie rate analogous to that of heavy aircraft, depending on the requirements placed on the first stage of a two-stage system. The SMV, by allowing significant orbital changes, emplacing or retrieving satellites and other payloads, providing refueling and other servicing on orbit, and providing fast access to the entire LEO volume, would be the basis for tactical operations in space. For example, the ability to rapidly orbit space control assets would greatly reduce the need for politically difficult permanent stationing of such systems in space. The SMV involves low technical risk and could be launched from expendable launch vehicles (ELVs), reusable launch vehicle (RLVs), or large aircraft. The CAV idea underlies the global, precise reconnaissance/strike concept. The MIS would allow the system to function as a basic reusable launch vehicle. Conceivably, the SMV could also participate in these last two missions.

A TSTO system could involve considerably lower risk than an SSTO system depending on the Mach number requirements for the first stage. The TSTO AOV system offers the opportunity to develop the concept in a physically reasonable and affordable way. The first important step would be flight demonstration of the low-risk SMV to demonstrate the utility and explore the CONOPS. The decision on exactly what the first stage should be can be deferred until completion of a careful study of requirements. This would allow maturation of NASA's RLV concept and the development of required technologies.

In order for the cost per launch using an RLV to drop to or below the cost of using an ELV, the RLV must maintain a roughly once-per-week operation rate to spread its higher fixed costs over enough launches. This rate will be hard to attain even if our recommendation that the Air Force move to primary reliance on commercial launch services is adopted. However, if an RLV system like the AOV could maintain a composite launch rate across its various mission categories of perhaps twice a month, we believe the cost differential compared to an ELV would not be prohibitive, while the operational benefits of highly responsive launch would be realized. In addition, the Air Force would thereby retain at least a limited organic launch capability for payloads which, for any reason, cannot or should not be commercially launched.

Air Force Space Command has developed an initial CONOPS, which can serve as a starting point for more thorough operational and system analysis to refine concepts, quantify operational benefits, and establish a sound basis for a possible development program.

Recommendation

Continue the SMV demonstration (estimated at ~$35 million/year for 4 years) to preserve the AOV option. Use the demonstration results and operational analysis to validate a refined CONOPS and an AOV system concept, requirements documents, plan, and development roadmap. The roadmap should define a staged program with milestones at which technical feasibility and operational utility are proved before commitment to future expenditures. If the results of technology demonstration and operational analysis are favorable at a decision milestone in about 2002, start a follow-on program leading to a first demonstration flight in about 2009 and an operational AOV in about 2015. Maintain the existing RLV partnership with NASA, but provide funding only at the level necessary to ensure that the program addresses Air Force needs, including first stages for the AOV. If successful, the NASA X-33 may provide the basis for a variant suitable for the first stage.

Recommended OPR: SAF/AQ. *Recommended OCRs:* HQ USAF/XO for CONOPS analysis and system concept definition and HQ USAF/XP for long-range planning.

3.9 Space Control

Classified aspects of the Space Control area are discussed in the Space Control Panel report.

3.10 Transition National Launch Facilities to Civilian Operations With the Air Force as a Tenant

The rapid growth in commercial space is leading to an increasing number of launches, more and more outpacing Government launches.[23] A major milestone was recently passed: the number of commercial launches exceeded the military total for the first time. Thus, what began as an Air Force–operated military launch capacity with occasional commercial missions is undergoing a basic inversion that prompts a hard look at the proper long-term Air Force role.

Findings

Reliable, timely and affordable launch is indispensable to assured access to space for all purposes. In order to maintain a healthy onshore launch capability in the face of competition from subsidized foreign providers, the Government gives a *de facto* subsidy in the form of Air Force funding, which constitutes roughly 90 percent of total launch costs at the Eastern and Western Ranges (ER/WR). The 1984 Commercial Space Launch Act and 1998 Amendment govern the price the Air Force charges.

Figure 3-4. *Deteriorating Facilities and an Increasingly Commercial Launch Schedule Create a Serious Air Force Burden*

Launch operations like those in Figure 3-4 are costly and becoming increasingly unreliable. In FY 98, the Air Force budget for launch facilities and operations was around $520 million. The rate at which launch opportunities are lost due to range failures has tripled in the past 2 years. ER/WR facilities badly need modernization, but these accounts have been raided for many years to pay more urgent bills. Aging equipment increases operations and maintenance costs, and both launch sites are steadily deteriorating. Their ability to compete effectively for the rapidly growing commercial launch market is ever more

[23] Doable Space.

questionable. Replacement of current range tracking systems with a GPS-derived tracking capability is an attractive alternative (see Section 3.12).

The accelerating dominance of commercial launches puts the Air Force in the position of providing a primarily commercial service at great cost to its military needs in a disastrous overall budget situation.

As part of the process of privatizing the launch facilities, the Air Force and DoD may have to fund some up-front costs to assess the exact condition of the facilities and perform urgent repairs in order to make this a viable business proposition for prospective contractors.

Recommendation

Take action in two steps to exit the launch operations field except for essential military missions: Step 1—award an omnibus contract for operation of the Eastern and Western Test Ranges, with provisions to use committed savings resulting from operational efficiencies for modernization of facilities. Step 2—transfer responsibility to a suitable civil agency (e.g., support creation of a national program office or National Space Port Authority) for operations and to the Federal Aviation Administration for safety. Advocate that launch subsidies which are in the national interest and required to maintain a viable onshore launch industry be provided through the national authority and, if possible, from local government agencies interested in this as an economic development opportunity. Start a program to phase-out legacy tracking networks and move to a space-based range approach using GPS-derived tracking with appropriate packages on launch vehicles and payloads.

Recommended OPR: SAF/AQ for transition policy. *Recommended OCRs:* HQ USAF/XO for operational matters and HQ USAF/SP for long-range planning. Transfer of responsibility involves multiple organizations and national policy.

3.11 Transition Launch to Primary Reliance on Commercial Services

The complement of the growing dominance of commercial over military launch business is that an increasingly competitive and capable launch industry is springing up. This creates the opportunity for the Air Force to both exit the mainstream launch business, per the previous recommendation, and pursue lower launch costs for its own payloads from commercial service providers.

Findings

The Evolved Expendable Launch Vehicle (EELV) program is a high national priority for both military and commercial space. It is the key, in the near term, to assured access to space and cost reduction compared to current boosters.

The exponentially growing commercial space business offers large volume opportunities and competitive sourcing as ways to pursue continued cost reduction in military launches.

In the mid to long term, RLVs will provide substantial reduction in dollars per pound to orbit under two conditions: (a) commercial space business continues to grow so that launch frequencies stay high enough to amortize the nonrecurring and high fixed costs of RLV operations over enough missions, and (b) remaining technology barriers are overcome. In the long term, one or more of the several advanced launch technologies under consideration is likely to make access to space very cheap, perhaps one-tenth to one-hundredth the cost of today’s operations.

NASA has the national charter for RLV technology and system development. Historically, NASA and the Air Force have had very different concepts of and requirements for RLVs. There is a strong possibility that NASA RLV efforts will be of limited value to the types of boosters needed for military purposes unless the Air Force stays closely coupled to NASA and exercises the necessary influence.

If fielded, the AOV system would maintain a limited organic launch capability in the Air Force which might be of value for payloads that, for any reason, cannot or should not be commercially launched.

Recommendation

Begin an orderly phase-out of most current organic booster procurement and launch programs and increase use of commercial launch services, leading to primary reliance on them. Retain minimum essential organic launch capability, possibly in the form of the AOV, for payloads which cannot be launched commercially. Finish the EELV program. To allow purchase of commercial launch with adequate assurance and best pricing, start training acquisition specialists to develop the necessary skills base. Continue close coordination with NASA in the RLV area to get as much technology benefit as possible for future RLVs that meet military needs. Require that satellite designs, especially in the area of weight, be predicated on compatibility with commercial launchers.

Recommended OPR: SAF/AQ for transition policy. *Recommended OCR:* HQ USAF/XO for operational analysis and planning.

3.12 Implement Commercial Models and Other Improvements to Satellite Operations and Tracking

Allowing for the fact that there are no perfectly comparable military and commercial space systems, the study team consistently found that commercial ground operations are far less people-intensive and far more efficient overall than military systems. This is an area with important potential as a source of savings and one where selective modernization can have big payoffs.

Findings

Like the launch range tracking systems discussed in Section 3.4, the Air Force Satellite Control Network (AFSCN) relies on legacy systems that are aging, costly to operate, and increasingly hard to support. They suffer from obsolescent technology that makes replacement parts hard to find and from years of inadequate preventive maintenance and updating that increase the frequency and scale of repairs.

Current satellite operation ground environments are mostly proprietary, closed, single-system designs that are user-unfriendly and hard to upgrade. The result is to increase staffing and training requirements, ensure rapid technological obsolescence, and make updates, both hardware and software, extremely costly when they are possible at all. The ingenuity and frustration of many operators has led them to identify improvements that could be locally made, but funding and system control rules preclude most such actions. The staffing model must accommodate wartime surge, and any civilians must be under a legal obligation as in any direct operational role.

Current military systems are people-intensive compared to modern commercial systems. Again, no exact side-by-side comparison is available, but the staffing numbers we saw suggest that a typical ratio would be on the order of 10 to 20 times more people in a military operation. This potentially amounts to several thousand manpower slots that could be used for other purposes if commercial staffing models could be implemented.

It is unlikely that most legacy systems can be upgraded significantly, given the cost and their remaining lifetimes. However, systems now in development or still in planning could be based on commercial practices with great savings in personnel and in the costs to operate, maintain, and upgrade them. Members of the Air Force Reserve whose civilian jobs are in satellite operations and related fields would be ideal system operators, especially for aging systems, since they would bring high levels of experience and expertise, capitalize on skills developed in civilian employment, and reduce turnover and training burdens. Moreover, this is a field with highly predictable schedules that facilitate planning of Reserve participation.

Space system ground environments provide another sad example of the almost total neglect of human factors engineering that pervades military systems.[24] System developers apply no systematic process to define and measure human factors parameters, and the result has been a set of systems that cost more to own and operate than could have been achieved for the same or less development cost, had competent human factors discipline been applied. This is further discussed in Chapter 5.

Legacy systems generally combine the telemetry, tracking and control (TT&C) and payload management functions in a single work station or complex. TT&C has many similarities across many satellites, while payload management tends to be both more specialized and more highly classified. Separating these functions in the ground environment, even if both use the same command links to interact with the satellites, would allow each to be optimized without compromising the other, and would create the possibility of a more efficient TT&C operation based on use of commercial products.

The Navy is already actively moving to outsource and streamline its satellite ground operations; there may be useful lessons learned in its experience.

Recommendation

For systems now in development or in the future, move to a commercial model for staffing, establish requirements for open systems and other best commercial practices (e.g., spiral development of human-system interfaces), and set performance metrics for human factors. In addition, separate and optimize the requirements for TT&C and payload control functions and plan to contract out noncritical activities. Pursue satellite operations as an Air Force Reserve mission. For legacy systems, evaluate opportunities to make selective investments in commercial off-the-shelf (COTS) software tools and mission software packages to reduce manpower and training requirements. Start a program to replace tracking assets of the AFSCN with GPS-derived tracking in coordination with the space-based range addressed in Section 3.10. Consider commercial options for this implementation.

Recommended OPR: SAF/AQ. *Recommended OCR:* HQ USAF/XO for manpower and operations planning and reform.

3.13 Summary

The recommended actions in this chapter will improve the currently programmed baseline force in specific ways that have high leverage on achieving our vision and accomplishing the tasks required by *JV2010*. Next we must examine how these actions can be fitted into an executable program under the prevailing budget and manpower constraints.

[24] See the 1996 SAB study on UAVs for comparable findings about their operator environments.

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Chapter 4

Affordability Analysis

As shown in Figure 4-1, implementing the changes the Air Force must make to fulfill its role in the emerging military environment is essentially a balancing act. On one hand, there are programs that require additional resources, some small and some very large. On the other, there are multiple opportunities to become more efficient, to terminate less-effective programs, and to transfer to other agencies functions that are not essential parts of the Air Force mission and that sap the Air Force budget. While we could not do financial analysis with the detail and fidelity that will eventually be needed to support Program Objective Memorandum (POM) inputs, we have taken a consistent and integrated high-level view of the budget and have sought to erect a framework within which an executable program can be constructed.

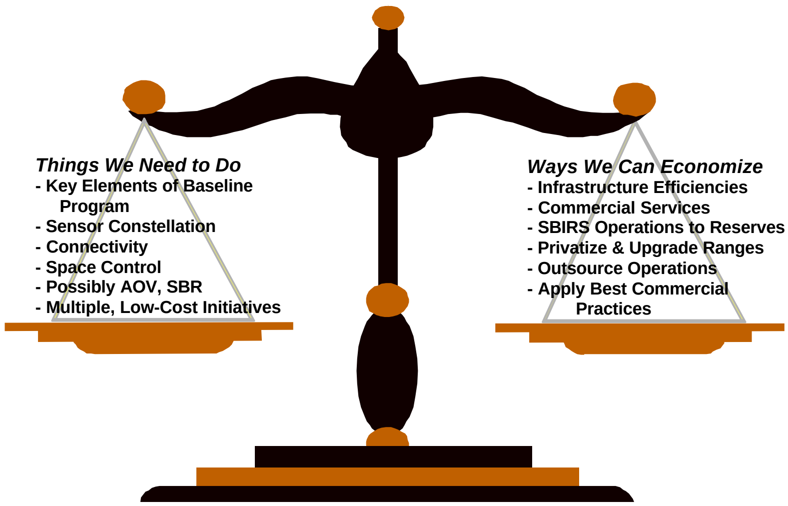

Figure 4-1. *Achieving an Executable Program Requires a Balance Between New Spending and Savings From Ongoing Activities*

4.1 Affordability Analysis Methodology

Affordability is the second of the MOEs used to evaluate force structure alternatives. The Cost Estimation and Acquisition Strategy Panel, with contractor support from Tecolote, undertook the construction of a methodology for assessing and comparing the costs of various program and system options in order to provide a basis for affordability assessment. The existing automated cost-estimating integrated tools cost analysis shell and RI$K model were used for formatted outputs, access to cost databases, and various cost estimating relationships (CERs).

The goals of the methodology development were to achieve completeness and consistency, but not to attempt a level of costing detail or precision that is impractical within the confines of this study. We need an instrument that allows us to compare at an aggregated level the fiscal impact of alternative courses of action and to make a rough check of the extent to which savings and added costs can be brought into balance. It is also important that the methodology account as fully as possible for all cost elements associated with development, acquisition, and operation of the systems in question. Equally important, it must be applied consistently to allow valid comparison of alternatives.

The methodology is described in detail in the panel's report. It includes factors such as the elements of cost in a conceptual system, CERs based on prior experience, and an evaluation of technical risk and its impact on cost. The Cost Panel interacted extensively with the other panels in defining alternatives to the baseline program and in compiling and evaluating data for the affordability assessment.

4.2 A Look at the Budget

Depending on what elements are included, the Air Force space program totals approximately $7 billion annually. The elements of the baseline program that were analyzed in this study total $4.1 billion in FY 99 (see Figure 4-3). Historical budget data and future projections show these amounts to be relatively constant from FY 94 through FY 03. Beyond the current FYDP, the budget assumes only growth to match a standard 2.2 percent inflation escalator, as shown by the line in the figure. This challenging budget situation is the backdrop for our search for a way to convert our recommendations into a feasible roadmap.

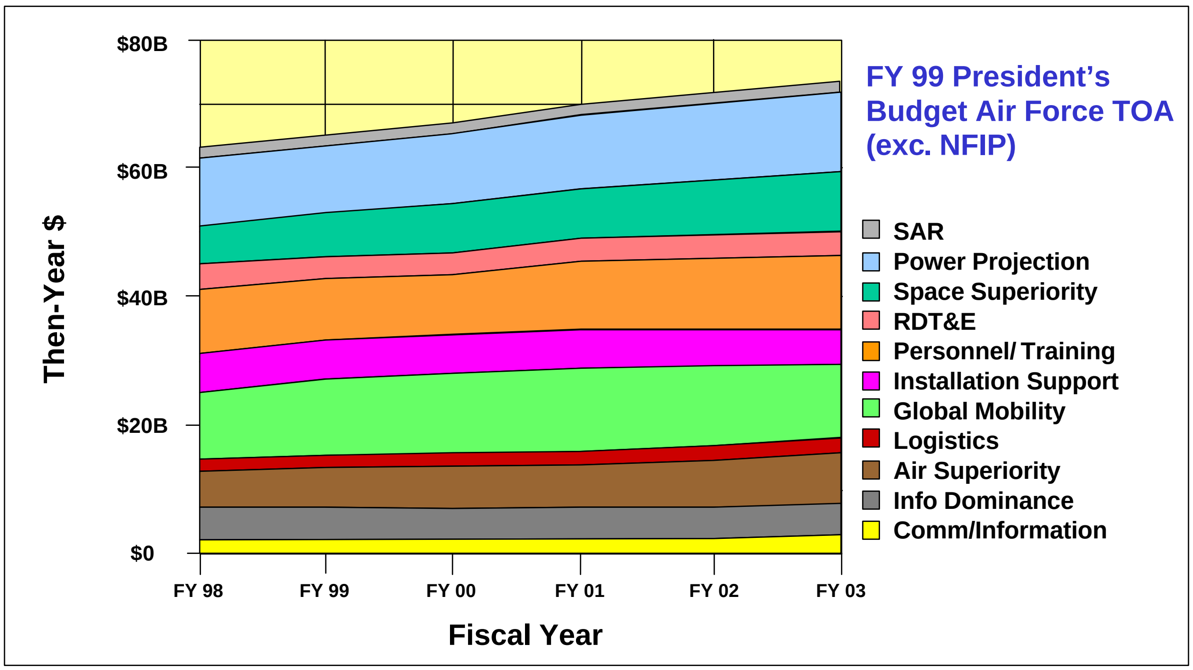

Figure 4-2. *Current Total Air Force Budget Profile*

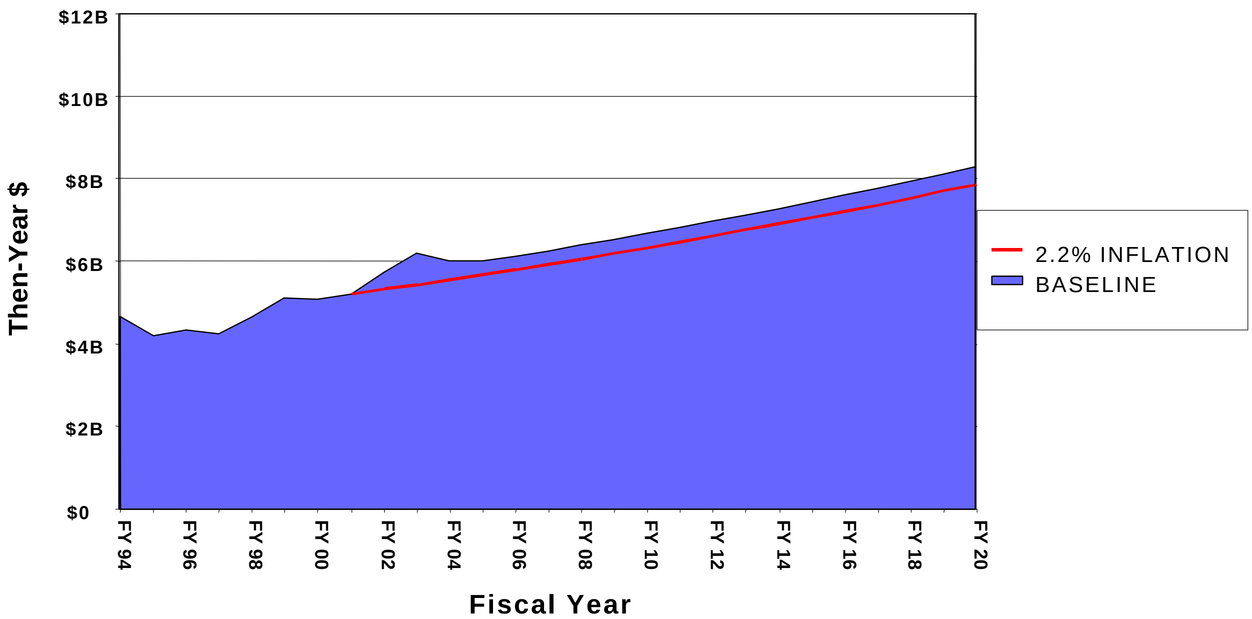

Figure 4-3. *Breakout of the Baseline Space Program by Functional Areas*

We have applied our cost estimation methodology to the various initiatives discussed in Chapter 3, using our best collective judgment about the general characteristics of such systems, e.g., the number and weight of the satellites in a constellation. We have also applied the experience of the program and financial management experts on the team to sketch out typical development timelines and to spread the estimated funding, taking account of both the need for a rational funding profile for a major development effort and the need to smooth the peaks and valleys in the overall budget. Programs such as the sensor constellation, AOV, and energy projection system would involve billions of dollars of development, production, launch, and operating costs. However, we have made reasonable estimates of the savings likely to accrue from improved business practices, synergism among systems in an integrated force structure, application of technologies that improve affordability, and other things that will make future systems less costly than past ones.

We have also attempted to estimate the savings that are available from outsourcing, modernization, use of commercial models, and other strategies discussed in Chapters 3 and 5. In general, we have taken the current budgets for ongoing activities and made (generally conservative) estimates of the percentage reductions that are achievable. We first looked at a specific set of areas where we believe economies can be realized, including the results of our recommendations in the areas of launch and tracking ranges, communications, and satellite operations. The results are identified as "Conservative Savings," and we have high confidence that our recommendations will produce at least this level of cost reduction if implemented. We then did a less specific and more aggressive exercise based on projecting the overall force structure and mission efficiencies that an integrated aerospace force and maximum use of commercial and civil space systems could produce. We emphasize that this latter was intended only to get a feel for the order of magnitude of savings that might be achievable, and should be considered even less accurate than the preliminary program cost estimates described above.

Figure 4-4 shows the baseline program with conservative savings applied, and the decrease from the baseline 2.2 percent escalated profile is obvious. This does not, however, correspond to a meaningful force structure because it does not deliver the capabilities that our vision of 21st century aerospace power demands, as discussed in Section 2.5. In Figure 4-5, we add in the sum of the estimated funding required for all the programs and initiatives described in this study. This can be considered a worst case,

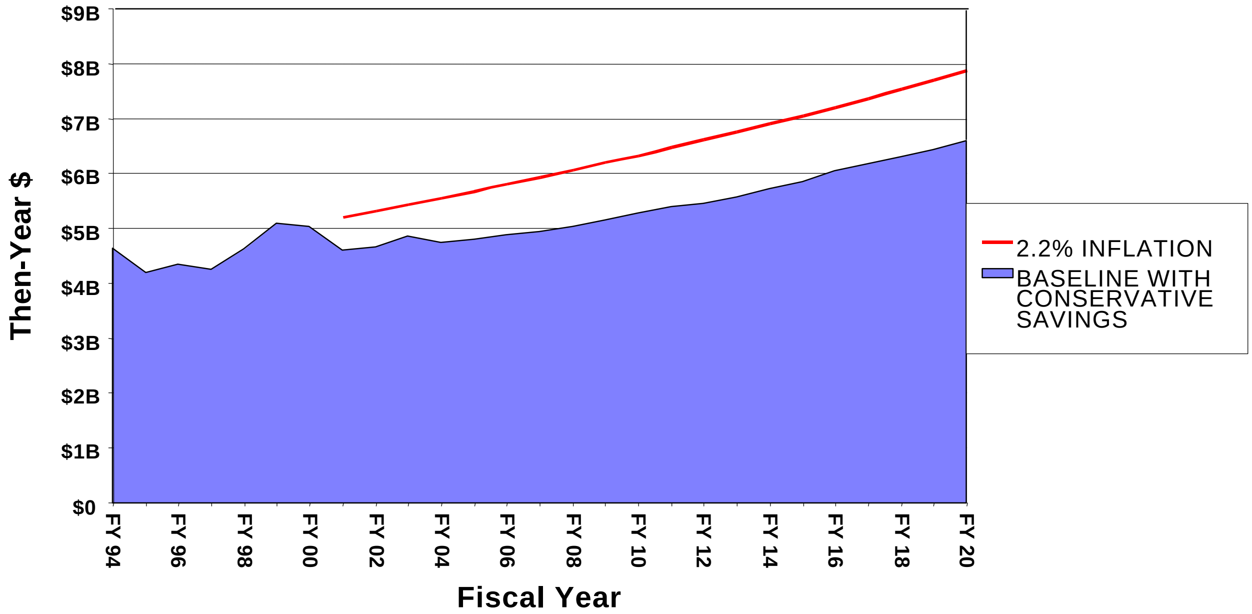

Figure 4-4. *Baseline Less Conservative Savings Estimate*

because it includes systems like the AOV, which we do not recommend pursuing unless and until results of CONOPS analysis and risk-reduction demonstrations warrant proceeding to a full-scale development. Also, we have not broken out the individual program funding profiles, because even these preliminary estimates can be politically sensitive and because our estimates should be refined by more thorough program analysis before being publicly discussed. The increased funding of roughly $2 billion to $3 billion per year takes the top line somewhat above the original baseline, although not catastrophically.

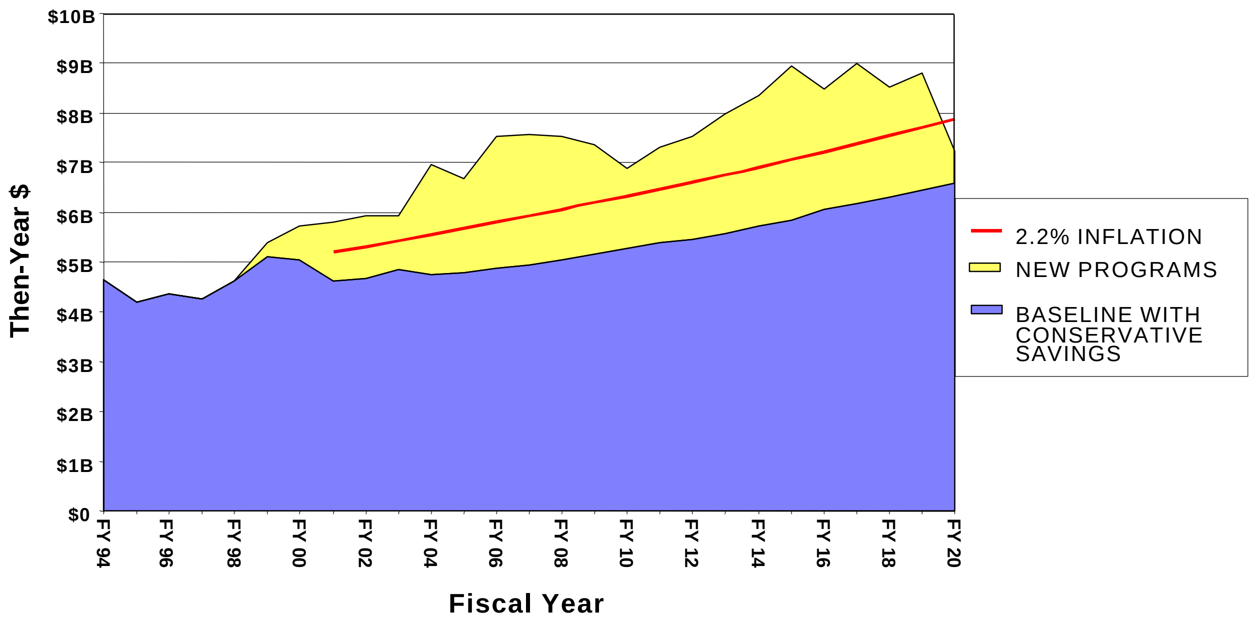

Figure 4-5. *Impact of Worst-Case New Program Funding After Conservative Savings*

Finally, in Figure 4-6, we show the impact of aggressive cost reductions. Even a modest improvement on our conservative savings estimates brings the top line of the space program back into rough balance with the current top line. On the basis of this analysis, we believe that an executable program based on our recommended changes can be defined. A hopeful precedent is the recent transfer of the Defense Meteorological Satellite Program (DMSP) from the Air Force to NOAA, producing an estimated savings to the Government of about $1.3 billion,[25] partly through consolidation of DMSP and Operational Environmental Satellite operations.

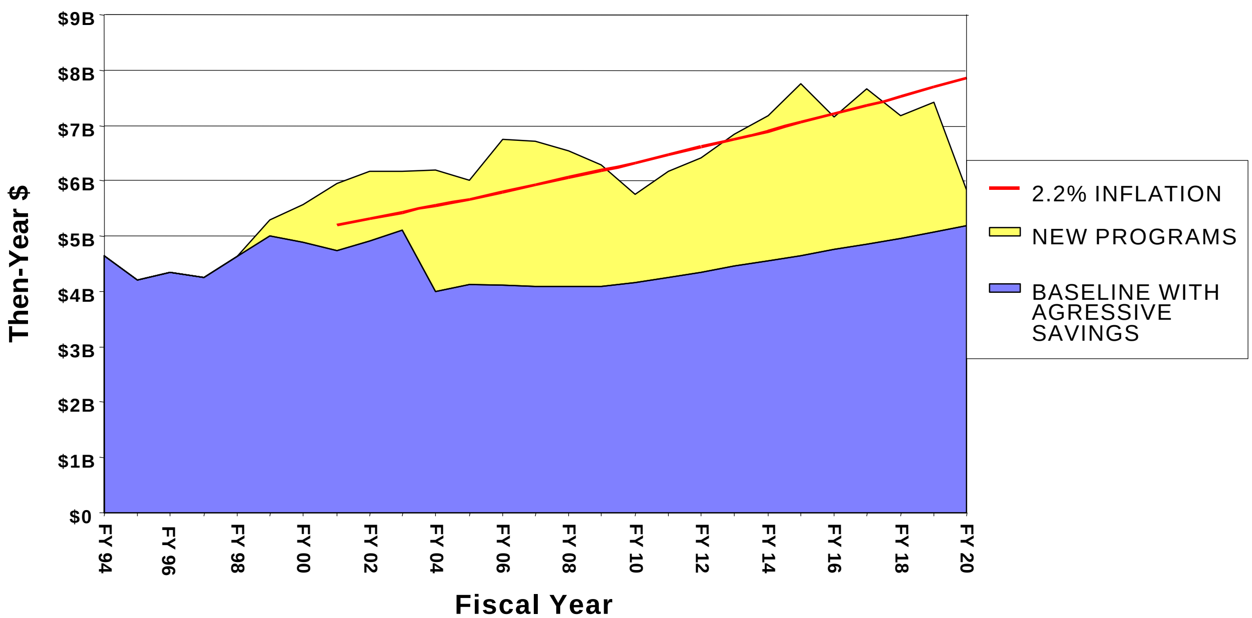

Figure 4-6. *Realizing Our Aggressive Savings Estimates Brings the Enhanced Program Back Into Balance With the Original Baseline*

An example of the factors included in our aggressive savings estimate, which is difficult to quantify but very real, is the effect of synergism among systems that can be exploited once traditional stovepiped thinking is eliminated. One example is the use of commercial and Government systems to provide broadband communications for data downloading from satellite sensors. A new sensor constellation should not incorporate a stand-alone downlink under our recommendation that a set of gateway ServerSATs provide access to diverse and redundant high-speed paths through the rapidly growing ensemble of space-based networks.

Another example involves the impact of highly responsive launch on the required on-orbit assets to deliver a given level of sensor coverage. A combination of launch on need and the ability to maneuver or reposition existing satellites means that a tailored constellation for a given AOR can be provided with many fewer satellites permanently stationed in space. Similarly, there would be less need to launch spares. Satellites designed to be retrieved, perhaps by an AOV, could be designed for shorter mission life and would allow technology upgrading over time. A logical extension would be to develop a satellite family with a mixture of expendable and permanent or reusable models. In combination with technologies for lighter weight, lower cost, greater efficiency and higher reliability, this new way of thinking about providing a space-based capability offers the prospect of significant cost savings compared to earlier systems.

[25] News item, *Aviation Week and Space Technology*, 8 June 1998, p. 18.

4.3 Required Actions

As indicated in the funding profiles, we recognize that major changes over the current FYDP are unlikely. We see both the initial low levels of spending for new initiatives and the first savings from economy measures starting in the 1999–2000 time frame, with a ramp-up to significant levels in the following years. However, decisions need to be made now and preparatory work begun, principally in defining the 2000 POM, to implement the recommended changes. The critical point is that an overall coordinated program strategy under central management and with continuing high-level attention is needed. A set of piecemeal initiatives will almost certainly be defeated one at a time. We recommend that HQ USAF/XP be given overall responsibility to construct and oversee this action, drawing on the work of the AITF, especially the Aerospace Integration Plan as it matures.

The primary decisions, with respect to both new programs and actions to save money, are spelled out in Chapter 3. We recognize that most of the economy measures will have substantial organizational impacts and will meet with resistance. In the aggregate, actions such as outsourcing launch and satellite control operations, winding down a number of MILSATCOM systems, and phasing out legacy tracking systems will affect thousands of manpower positions and large fractions of the current budgets of the affected units. We also understand that a great deal of advocacy and prior coordination with Office of the Secretary of Defense (OSD), Office of Management and Budget, and Congressional staffs will be needed. This will be a hard sell over a number of years, and a gradual transition will be needed in some cases to make it more palatable. However, the alternative to basic change is for the Air Force to stagnate and, as a consequence, continue to lose ground in its ability to meet evolving operational requirements.

A further set of actions involves transitions from legacy systems to new ones. An example is the long-term management of the AWACS and JointSTARS fleets as UAVs and space sensor platforms take an increasing role in meeting the ISR needs of warfighters. The system-of-systems architecture and trade studies advocated in the next chapter have an important role here. Both of these manned aircraft systems will remain in service for many years. However, coordinated planning and budgeting for phase-out/phase-in actions will help ensure that only required expenditures are incurred. At the same time, such planning is essential to ensure continuity of service and to prepare warfighters to use new systems as they come on line.

In performing this preliminary budget analysis, we have confined ourselves to the space segment of the force structure. The question will obviously arise whether TOA should be moved from other program areas, e.g., aircraft, to accelerate enhancements of space capabilities. In the next chapter, we propose the creation of a force structure architect empowered to make trades across the entire Air Force, and this process of optimizing the overall capability of the aerospace force is the logical way to address such resource questions. Consistent with our charter, we have limited our examination to the space program, and we find that much of the TOA needed for new investments can result from economy measures that ought to be taken in any case. We urge the corporate Air Force to examine the question of whether historical “fair shares” of the budget among program areas are the best answer to tomorrow’s challenges.

Chapter 5

Related Findings and Recommendations

The preceding chapters have drawn a vision of future aerospace power, identified the actions necessary to implement it, and suggested a way to fit the program into a realistic budget. Several other actions are required, however, for the strategy to be complete. In this chapter, we make some additional recommendations, largely about processes for executing the recommended program, that are essential to success.

5.1 Create an Air Staff Concept Development Process and Central Aerospace Architecture Function

Achieving an integrated aerospace force requires that many activities which today are fragmented and spread across Air Staff organizations be brought together under a central focal point. In addition, key processes such as concept development, analysis of alternatives and requirements definition are inadequate to the realities of an aerospace integration and the growing dominance in space of commercial enterprises. Examples of the kinds of problems resulting from the present situation are

- Limited ability to balance capabilities and requirements across space, airborne and surface elements, including the absence of an integrated system-of-systems perspective and the means to do objective, meaningful trade-offs among these domains. A traditional military mindset that is platform-centric, i.e., thinks in terms of a specific system doing a specific thing in isolation from other systems, must give way to a mission- or function-centric approach that looks for the best *combination* of assets to accomplish a given task. We believe that a comprehensive aerospace force architecture and the means to enforce it in requirements definition, resource allocation, and acquisition decisions are badly needed.
- Insufficient interaction with industry, especially in the early stages of the development of commercial products and services, to promote the most effective possible use of commercial space to meet military needs.
- Requirements definition and acquisition processes that are fundamentally inconsistent with the commercial marketplace and thus interfere with, or even prevent altogether, the use of commercial space.

The study panel believes changes are both urgently needed and possible without additional manpower. Both organizations and processes must be reformed to deal with the new world of aerospace. As one example among many, the current requirements definition cycle often takes several years from initial identification of a need or deficiency by an operational command to final coordination and approval of a requirements document. One factor driving this long time is that there remains a problem with requirements that go to inappropriate levels of detail rather than succinctly stating key, top-level performance parameters, leading to many cycles of debate and revision and impeding industry's ability to propose innovative, cost-effective solutions. In sharp contrast, many commercial products and services that are attractive for military purposes have market availability windows as short as 18 months. Thus a requirement based on what commercial space offers when it was started is likely to be obsolete and ineffective by the time it is approved.

Another consequence of increasing military use of commercial space is that the Services must engage in a continuous and proactive dialog with industry. This is highlighted by the example of systems like Iridium, where early DoD involvement led to design changes that greatly improved the system's ability to handle secure message traffic. We believe that there will be many such instances in the years ahead where DoD can work with commercial developers in ways that would be impossible once system designs are well along. Conversely, given our recommendation (Section 5.3) that use of commercial space be the presumed answer to obtaining capability, it is imperative that the requirements definition process be linked to trends and plans in the commercial marketplace. It will often be the case that operationally acceptable adjustments to a requirement will allow it to be met most affordably by a commercial provider, whereas purely military considerations might preclude this. Requirements definition must be based on current knowledge of what commercial space offers and plans to offer, and some form of iteration of draft requirements with industry will be valuable in many situations.

Recommendation

The Air Force should create a concept development process structured around an aerospace force structure architect who is sufficiently senior and empowered to

- Lead a continuing concept definition process aimed at finding the most effective and affordable ways to satisfy the requirements and tasking levied on the Air Force, emphasizing the best combination of assets, including commercial products and services, for each need.
- Serve as the focal point for aerospace integration and resolution of issues across space, air, and surface domains, specifically including development and refinement of a system-of-systems architecture and associated trade studies and requirements allocation.
- Manage the Air Staff requirements definition process, coordinate interaction on requirements with operational commands, and pursue needed improvements, especially to remove barriers to use of commercial space.
- Carry out an ongoing dialog with the commercial space industry to track and evaluate planned commercial products and services, incorporate commercial capabilities in the requirements definition process, and capitalize on opportunities to influence emerging commercial systems so as to better meet military needs.

Recommended OPR: HQ USAF/XP. *Recommended OCRs:* HQ USAF/XO and SAF/AQ.

5.2 Develop and Implement Aerospace Power Doctrine and Strategy

An aerospace force needs aerospace doctrine as the bedrock foundation for everything it does. It is certainly essential to realizing the vision of an integrated future force as we have considered it in this study. Among other things, doctrine provides a foundation for decisions about roles and missions, including choices of activities which the Air Force should seek to divest as discussed in Chapter 3. The natural unity lent to aeronautical doctrine by the nature of atmospheric flight loses its power when the different characteristics of air and space vehicles come together in a common frame. The current draft Space Operations Doctrine Document[26] speaks to many of the issues, and this subject is central to the deliberations of the AITF. While we have made no explicit attempt to formulate doctrine, we urge that this be a priority effort, and that it be elaborated in acquisition and operational strategies to make it real.

[26] AFDD 2-2, *Space Operations*, June 1998 (draft).

Recommendation

Create and promulgate space power doctrine and harmonize it with air power doctrine in a coherent and comprehensive doctrine of aerospace power. Carry this forward in the form of a strategy to implement national space policy.

Recommended OPR: HQ USAF/SP. *Recommended OCR:* Air Force Doctrinal Center.

5.3 Improve Acquisition Practices

Both the current acquisition reform climate and the need to make affordability and cost control the highest priorities in system acquisition dictate that traditional military space system program practices be greatly improved. For decades, military space system acquisition focused on maximum performance, great reliability, and a highly bureaucratic management and oversight process. Recent programs such as SBIRS have taken major steps toward program streamlining, emphasis on affordability, and reduced development timelines. Even so, commercial enterprises consistently show the ability to design, manufacture, launch, and operate high-performance spacecraft far faster and more cheaply than the Government.

We advocate a fundamental reorientation of the requirements definition and acquisition processes, based on two elements:

- A revolutionary change involving replacement of military models for development, acquisition, and operations with commercial models. This begins with a firm policy of “buy commercial first,” meaning that any need will be met by purchase of commercial products or services unless a compelling case can be made to do otherwise.
- An evolutionary change consisting of applying the principle of continuous improvement to every program. This has many elements, from use of open system designs to facilitate incremental technology insertion to the use of proven commercial methods for quality assurance.

Since any viable contractor for military space business will be leveraging a line of commercial products and services in order to be competitive, much of the required change amounts simply to being open to the application of design, qualification, integration and testing, documentation, and other practices from the commercial side. A good example is the use of spiral development and rapid prototyping methods in developing ground equipment both to save time and money and to produce better human-machine interfaces. Further discussion of the promises and pitfalls of buying commercial occurs in the next section. In any case, the ultimate goal must be to identify and use the best qualified source and to seek the most advantageous price for achieving a given capability.

A number of other acquisition process improvements are in order. One would be to make acquisition strategy a core element of program planning from the outset. That strategy would evolve as the program moves from concept definition to EMD and on to production and deployment, but its creation would provide both a vehicle for ensuring that the underlying issues have been addressed and a means for considering how commercial practices are or will be incorporated. For example, the strategy could well call for the use of spiral development and rapid prototyping for the human-system interface and a defined approach to identifying and using COTS products in the satellite.

Another practice that was highly useful in the past but has fallen out of use is periodic high-level program scrubs. These reviews were once referred to as “summits,” although that term has since taken on other meanings. They can be very valuable in forcing program managers to surface and deal with issues and in providing an objective, experience-based evaluation of the status, risk, strategy, schedule, and budget. In a related vein, the Cost Estimation and Acquisition Strategy Panel Report contains detailed recommendations for improving the models and other tools for predicting and measuring cost and performance. These improved tools would give better visibility into the true cost drivers in a program, which are often far from obvious and masked by other factors. This, in turn, would facilitate both the definition and justification of initiatives to reduce cost and enhance program performance. Just as with acquisition strategy, we advocate the mandatory application of a structured and comprehensive affordability analysis from day one of every program.

Today's military space program is adversely affected by the inability of program managers to cope with the inevitable problems and changes that arise in developing advanced systems. The Air Force is constantly forced to reprogram money to cover such contingencies. This disrupts both the sourcing and the receiving program, often causes delays, and wastes a great deal of money through the resulting inefficiencies in execution. Adequate budget reserves to allow programs to respond promptly and effectively to at least a high percentage of problems would benefit the entire space program and deliver significantly more capability for the dollars expended.

The Army has had success with accelerated acquisition programs like the Army Space Exploitation Demonstration Program (ASEDP) and the Warfighters Rapid Acquisition Program (WRAP) for rapid prototyping and reduced acquisition program timelines. ASEDP and WRAP exist in addition to more conventional Advanced Concept Technology Demonstration efforts, of which the Army also has several, and are seen by their users as having important advantages, including less bureaucratic oversight. These projects are linked to force experimentation and doctrine development and thus help to ensure that the right systems get demonstrated, developed, and fielded in the shortest possible time. The Air Force might well consider a similar mechanism, especially in areas where the lifetime of commercial technologies and products is shorter than that of the requirements definition and procurement cycle.

As with other recommendations in this study, those affecting the acquisition process will be opposed by individuals and organizations that will be forced to change. Both policy and continued high-level attention will be needed to see these improvements through to completion. This is an important element of realizing the cost savings that are essential to our vision of the future.

Recommendation

Adopt a "buy commercial first" rule within an overall rigorous process of finding and using the best source to satisfy any requirement. Adopt commercial development, procurement, and operating models and practices. Institute mandatory acquisition strategy and affordability review processes and revitalize high-level program reviews. Develop improved cost/performance models and use them to support improved visibility and continuous improvements in programs. Build program budgets with adequate reserves to minimize reprogramming and avoid highly visible disruptions.

Recommended OPR: SAF/AQ.

5.4 Use Commercial Space Wisely

Any strategy for the future of military space must proceed from the recognition that commercial enterprises are rapidly coming to dominate space operations and that this expanding and maturing industry must be used to the fullest to obtain military capabilities at minimum cost. However, "going commercial" means far more than writing purchase orders for commercial products and services. It means adopting the mindset, acquiring the skills, and using the practices of the commercial marketplace. It also means seeking opportunities to partner with commercial space enterprises on anything from common frequency allocations to shared investments in technologies and spacecraft components. This is a logical corollary of the "buy commercial first" philosophy and is part of the proactive industry dialog described in Section 5.1.

To start with, as with any major investment by a commercial firm, the Government must build a valid business case as the basis for selecting the best option for fulfilling a requirement. This begins with defining requirements in a way that allows a range of implementations within which the most cost-effective solution can be sought. This is in sharp contrast to traditional weapon system requirements, which set hard performance thresholds. The Government must be willing to trade performance for cost, and to consider that an "80 percent solution" may be the best in the overall force structure context. Put another way, the view should be to satisfy military needs based on capability delivered rather than meeting *a priori* system requirements.

Table 5-1. *Categories of Purchases*

Category	***Examples***
Commodity Services – *COTS or Civil Equivalent of Military Function*	• Communications Channels • Weather Sensing • Earth Observation (Non–Real Time)
Commodity Products – *COTS Hardware & Software Usable as Is or in Military Systems*	• Satellite Buses & Equipment • Hardware Components • Reusable Software Code & Tools
Unique Products – *No Commercial/Civil Equivalent*	• Force Applications • Signals Intelligence • Real-Time Targeting • Real-Time/High-Resolution Earth Observation • Surveillance of Space

The business case must also consider a market analysis that considers all feasible options, including a Government development program, procurement of a commercial product or service with modifications, and procurement of such a product or service as it is (COTS). Table 5-1 suggests a basic division of purchases into three broad categories. The options are then weighed on the basis of such things as opportunity cost (alternative uses of limited funds), financial measures such as return on investment (or in military terms, cost to perform a function), technical feasibility and risk, and an overall measure of military worth or utility (contribution to task accomplishment). Finally, the selected option must be translated into a business plan that spells out everything from negotiating strategy to fallback positions in the event of failure. The key differences in the commercial mindset, compared to traditional military acquisition practice, include:

- Use of firm-fixed-price contracts in situations where requirements are firm and fully defined and technical risk is manageable.
- Use of financial rather than performance measures as the criteria for selection of a source.
- Low tolerance for risk, leading to a preference for established products and vendors.

A typical issue in such a business case is comparison of the cost of Government ownership of a system with buying service on a commercial system. Some prior analyses have shown that the former is cheaper when the Government is the principal user of a system's capacity. That conclusion might change if factors such as periodic reprocurement to obtain access to the latest technology and to exploit price reductions caused by marketplace fluctuations were taken into account. In any event, this is the kind of issue with which the business case should deal.

Such a commercial procurement environment would be a new world for much of the Government acquisition community. Culture, skills, and processes all will require updating to enable success in both meeting military needs and saving money. Education and training, which might include an exchange program to give Government personnel firsthand knowledge of the commercial world, are obvious requirements. The formal acquisition process, including policies and instructions, should force the kind of evaluation of options and selection of the most advantageous approach described above. Incentives to acquisition personnel based on demonstrated success in using commercial space to advantage would be a powerful aid to creating commercial awareness and changing the culture of the community.

Recommendation

Develop and implement a program of education and training, revise policies and instructions, and adopt commercial processes, such as the use of business cases, to create within the acquisition community the capability to function effectively in a predominantly commercial marketplace. Adopt a policy that military space systems and services will be defined in the context of the commercial space industry. Include the appropriate corresponding tasking in program direction to acquisition organizations.

Recommended OPR: SAF/AQ.

5.5 Focus the Technology Base on Military-Unique Technologies

The Air Force Research Laboratory (AFRL) initiated action through the FY 00 POM to double the percentage of the budget devoted to space. We applaud this initiative and recognize that a great deal of work went into decisions about which areas to increase, which to continue, and which to cut. We are concerned that recent budget cuts threaten this initiative and, indeed, the health of the Technology Base as a whole. We believe that an urgent need is the increased focus of whatever resources are available on a select set of areas with maximum leverage on the future capabilities of our vision.

We recommend the following basic principles in planning the lab program:

- Concentrate on military-unique technologies that commercial sources will not meet.
- Support concepts that are in competition with those in the mainstream of commercial system development in order to support a healthy, diverse space system environment and give the Government choices in meeting its space requirements. Don't duplicate existing system development programs, but focus on upgrades and opportunities to leapfrog the current state of the art.
- Coordinate the content and schedule of AFRL programs with a view to demonstrating solutions to both military and commercial system needs in order to maximize the chances of technology insertion.
- Maintain a healthy basic research and exploratory development program in long-term technologies characterized as high-risk/high-payoff in order to ensure a sound foundation for the next generation of space systems.

Each of the panels prepared, in the course of its work, a list of technologies that are both essential to enable our recommended future force structure and unlikely to be available, at least entirely, from commercial sources. These are summarized in Table 5-2, along with an indication of who is working on each area and a rough assessment of how adequate existing efforts and those which could result from the

POM initiative described above are to meet the technology availability dates of our program roadmap. These risk assessments are somewhat subjective and imprecise, but the picture that emerges is basically valid. Today's program would get an overall Yellow rating, meaning that there is significant risk that enabling technologies will not be mature when needed. The proposed AFRL POM initiative certainly improves things, but does not turn the assessment Green. Furthermore, while the study team could not produce a set of detailed technology program plans, we have indicated whether each item in the table is critical, important, or contributing to our vision by assigning priorities 1, 2, or 3, respectively. Clearly, the nation as a whole is not making the technology investments necessary to enable the kind of integrated aerospace force we believe will be required. Accordingly, this table should provide guidance and food for thought to AFRL and to the Air Force as the laboratory works through the implementation of a greater emphasis on space, with this analysis as one input to resource reallocation decisions.

Table 5-2. *Examples of Areas Where the Air Force Technology Base Should Be Focused*

Functional Areas and Technologies	***Who's Working****	***Risk Level***		***Air Force Tech Base Priority***
		Today	***AFRL POM***	
Infostructure/C³				
Information Fusion, BM/C² Technologies	I, L, U	Y	Y	1
Two-Way Air-to-Space Communications	I, L	R	R	1
Intelligent, Cross-Functional Air/Space Tasking Systems	L	R	Y	1
Technologies for the Global Grid	I, L, U, N	Y	Y	1
Airborne Gateways	I, L	Y	Y	2
Standard High-Bandwidth Space Crosslinks	I, L	Y	Y	2
Human/System Interface Technologies	I, L, U	G	G	3
Positioning, Navigation & Timing				
Survivable Navigation & Selective Denial Technologies	L	Y	G	1
Space Control				
Attack Warning & Assessment Sensors	L	Y	Y	3
Survivability Technologies	L	Y	G	2
Negation Technologies	L	Y	Y	2
Space Surveillance Techniques	L	Y	G	2
ISR/Warning				
Large/Distributed Structures	I, L	Y	Y	1
Space-Based Radar Technologies	I, L, U	Y	G	2
Hyperspectral and Ultraspectral Sensors & Algorithms	I, L, U	G	G	3
Launch				
Health Monitoring	I, L, N	Y	G	1
Propulsion System Technologies	I, L	Y	Y	1
Materials & Other Technologies for Reusable Vehicles†	I, L, N, U	Y	Y	1
Energy Projection				
Very Large, Lightweight, Low-Cost Deployable Optics and Antennas	I, L, N	Y	G	1
High-Power Solid-State Lasers	I, L, N	Y	Y	2
High-Payoff Longer-Term Technologies				
Microsatellites, MEMS, Active EO Sensors, Sparse/Distributed Apertures, Brilliant Sensors, Adaptive Networks, High-Density Energy Storage, Advanced Composites & Atomic Bond Materials, etc.	I, L, U, N	R	R	Continuing Emphasis Required

* Organizations doing work, with Government or their own resources:
I = Industry, L = DoD Labs, U = Universities, N = NASA

† AFRL should provide the minimum level of funding needed to preserve the NASA partnership and ensure that NASA RLV efforts address Air Force needs.

A related issue concerns coordination of AFRL efforts, both across lab directorates and with other agencies and industry. An example that illustrates the concern lies in SBR. Some time ago, AFRL formed an SBR Integrated Product Team (IPT), led by the Space Vehicles Directorate and with participation from the Sensors and Information Directorates. This is exactly the kind of coordinated effort needed to get maximum results from limited resources. However, effective coordination and a clear technology transition path are needed between the IPT and Discoverer II to maximize support for the desired operational system. We emphatically do *not* advocate turning the AFRL budget into a DARPA management reserve, but we believe that our recommendation of a new Air Force sensor constellation based in part on the results of Discoverer II and the significant Air Force funding contribution warrant close coordination to guard against duplication and ensure that available funds go to the most important risk areas. Recent actions to bring the IPT and Discoverer II program management together are highly encouraging and deserve continued management emphasis. Having said all this about focus on technologies for the next generation of systems, we must also stress that "seed corn" funding for longer-term, higher-payoff technologies needs to continue. A few suggestive areas, by no means exhaustive, are listed in the last line of the table. Within a generation, it is quite possible that access to space will become cheap and routine, say 100 times cheaper in dollars per pound to orbit than today. Entirely new kinds of satellites such as clusters of small structures that stationkeep with each other and synthesize enormous apertures may allow far greater performance at a fraction of today's weight and cost. Some of the enabling technology will emerge from commercial developments, but AFRL can play a key role with modest funds in nurturing highly promising concepts, in advancing technologies that the commercial and civil space sectors do not support, and in remaining skilled as a "smart buyer" of advanced technologies and systems.

Recommendation

As part of the ongoing review and planning of the Technology Base program, AFRL should focus available resources on military-unique, high-leverage technologies. AFRL should be proactive in setting up coordination mechanisms to ensure best use of limited resources. In addition, AFRL should preserve "seed corn" investments in areas that have the potential to yield revolutionary advances in aerospace capability, such as large, lightweight, distributed space structures; space-based radar technologies for air targets; and highly efficient and reusable engines.

Recommended OPR: SAF/AQ. *Recommended OCR:* AFRL/CC.

5.6 Improve Human Factors in Space System Development and Operations

As noted in Chapter 3, human factors remains a perennially neglected discipline, with serious long-term consequences. Poorly designed operator stations and other aspects of the human/system interface impact everything from the effectiveness of system operation to training requirements to morale. The root problem is that neither the Government nor contractors treat human factors as a critical aspect of system requirements and a mandatory element of the system engineering process. Two years ago, the SAB study on UAVs highlighted the problems with their ground stations.[27] We found much the same bad design practice in our inspection of satellite operations centers. As long as this problem is ignored, a host of unnecessary costs, many of them hidden, will continue to be paid.

Recommendation

Require system contractors to define and apply mission-specific human performance metrics and require that human factors specialists be involved in system programs from requirements definition through deployment. Require system contractors to apply human-in-the-loop simulations to improve the effectiveness of development, training, exercises, and system operations.

Recommended OPR: SAF/AQ.

[27] SAB-TR-96-01, *UAV Technologies and Combat Operations*, Volume 2, Chapter 6, December 1996.

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Chapter 6

A Space Roadmap and Strategy

6.1 An Integrated Program for the Aerospace Force

Finally, we bring together our recommendations on force structure, missions, processes, and technology to assemble a roadmap for achieving our vision. A consolidated top-level schedule for the major program and facility actions is presented in Figure 6-1. The figure shows areas where the Air Force should phase-out activities, sometimes, as in the case of launch ranges, in favor of another agency. It also shows major milestones for new programs and distinguishes the sensor constellation, which we believe should go forward on the basis of data already in hand, from others, including AOV and global energy projection, whose decisions to proceed await successful technology demonstrations and development of satisfactory CONOPS. It shows growing dependence on commercial SATCOM and launch; other commercial products and services, e.g., imagery, could be added. The timeline suggests that significant progress in reducing costs and integrating operations can be made over the next 5 to 10 years, whereas achieving the full power of our vision of 21st century aerospace power will take at least 20 years.

In addition to operational effectiveness and affordability MOEs, we applied two "sanity check" measures to our roadmap. The first of these is technical feasibility. Our review of commercial and Government programs supports the view that every new activity called out in Figure 6-1 is or can be supported by the required enabling technologies on the schedules shown, given the necessary investment decisions. In some cases, this is due to technology demonstrations like Discoverer II that are already under way. In others, it results from the better focusing of the Technology Base program called for in the preceding chapter. The final MOE is continuity of service to warfighters and other aspects of integrating new and legacy assets into a coherent force structure. Here, the keys are (a) to coordinate the phase-out of old systems with the phase-in of replacements, (b) to proceed in parallel with the greatly improved information infrastructure represented by the Battlespace Infosphere[28] and its implementing systems, and (c) to ensure that aerospace doctrine, strategy, tactics, and procedures evolve to keep pace with the changing force. Again, this is quite feasible, provided the necessary attention is paid to these matters in synchronism with development and acquisition programs.

As noted in Chapter 4, in laying out funding profiles for recommended and potential new efforts, we have applied expert judgment and past experience. However, nothing like the kind of detailed program analysis and planning needed to construct actual budgets was possible or attempted. Accordingly, while the milestones in Figure 6-1 are not unreasonable, they should be taken only as a point of departure. Even so, it is possible to get a sense of the shape of the emerging integrated force. For example, it should be possible to proceed in parallel on multiple fronts with streamlining and other economy measures so that by 2002, the Air Force should be nearing completion in divesting itself of inappropriate functions and in the outsourcing, modernization, and transfers to the reserve components that are the key to cost savings. This is about the point where significant investment funding starts to flow for the new sensor constellation, space-based surveillance, and other enhancements. In as little as a decade, the kind of revolutionary new capabilities that motivate our entire approach to the future of aerospace warfare can begin to reach operational status.

This study has looked at one aspect of the overall complex subject of moving toward an integrated aerospace force. It must be kept in the context of other recent and ongoing efforts that examine other parts of the problem. To begin with, a number of recent SAB efforts, along with this year's Information

[28] SAB 1998 Information Management Study.

Management study, provide background for and expansion of our work. We have taken the Doable Space Quick-Look study as an important initial condition and, with minor exceptions, have validated and enlarged its findings and recommendations. We have coordinated our efforts with those of the AITF. We have evaluated planning and doctrine documents, some still in draft, dealing with space operations, and have sought the views of planners, program managers, and executives in both Government and industry. Collectively, this large body of information and analysis provides a sound basis for decisions about the future of the Air Force.

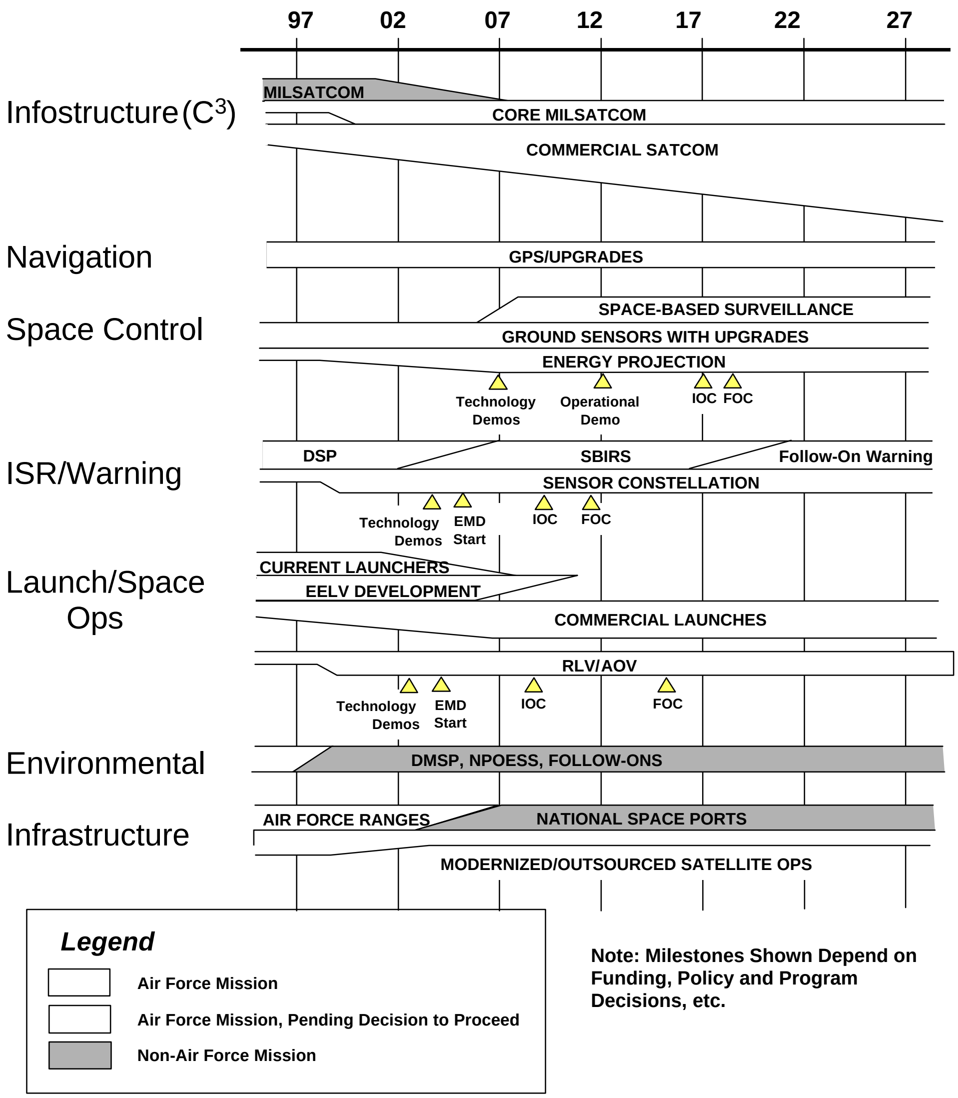

Figure 6-1. *Consolidated Roadmap Based on the Study's Recommendations*

A logical follow-on to this study would be to examine our vision and recommendations in more detail than was possible within the confines of a summer study. For example, the Space and Missile Systems Center Quick Reaction Tool Kit, a set of models for campaign and system analysis, could be used to produce an initial evaluation in perhaps 60 days. The result could be used both as a check on our results and as further data for defining and executing the kind of MS&A upgrades we recommend in Chapter 3. A longer and still more detailed analysis, possibly including early application of the NASM or its derivatives, would presumably be needed to support POM inputs and other actions to lay the groundwork for our recommended actions. We stress again that early planning and programming work is essential to maintain the kind of timeline we anticipate in Figure 6.1.

This study, and the related studies mentioned above, should be used as the basis for a concerted programming action that treats the aerospace force as a whole and convincingly displays the synergism among the actions needed to achieve it. The corporate Air Force should adopt this program as the complement to Global Engagement and should consistently and aggressively pursue it in all applicable channels to bring it to fruition. The AITF has been chartered to build a single, consolidated plan that will provide continued integration of air and space power, along with orderly migration to future capabilities that best exploit the seamless aerospace dimension. This plan will guide future planning and programming actions to develop a fully capable aerospace force. It is to be fiscally sound, technically feasible, and grounded in evolving aerospace operational theory, doctrine and strategy. We believe this study contributes to the formulation of this Aerospace Integration Plan.

6.2 Relationship of the Study to Other Air Force Initiatives

The timeliness of this study's subject is highlighted by its relationship to the AITF and to two other broad initiatives that look at the future of the Air Force. One of these is the ongoing discussion of a set of thrust areas that strike a balance between the broad generalities of the Air Force Core Competency list and the very specific end states of the Long Range Plan. Six thrust areas have been proposed and are now under discussion. The other related activity is the 1998 CSAF Aerospace Future Capabilities Wargame (Future Games 98). Table 6.1 lists the six thrust areas and the 12 Future Games 98 action items now in coordination that resulted from this game. For each, the items that are directly addressed by this study are marked. Our recommendations support all of the thrust areas and seven of Future Games 98 action items.

6.3 Study Summary

In closing, we stress one final time that the Air Force can and must articulate and pursue a future in which the full, exciting potential of aerospace power is realized. Only aerospace forces have the speed, reach, flexibility, precision, and, if need be, overwhelming force called for in a world of global interactions and national interests, ambiguous and asymmetric threats, and sharply curtailed forward presence. In a generation, probably sooner, travel and commerce in and through space will be boringly routine. The incorporation of space in the fabric of daily life will raise the same sort of security issues that use of terrestrial resources involves today. The continued presence of national and non-national groups whose envy, hatred, religious fanaticism, or other motivations cause them to seek to harm the U.S. and its citizens will only grow harder to cope with as they acquire advanced means of probing our affairs and wreaking many kinds of havoc on our citizens and property.

Properly organized, trained, and equipped, the Air Force can bring to the nation a steadily improving and utterly unique capability to deal with this complex new world. Able to monitor events and patterns globally and continually, to apply precisely measured effects in minutes to hours anywhere on earth or in space, and to protect our national infrastructure from the new forms of attack, the integrated aerospace force will be the military instrument of choice in many circumstances. That force cannot be simply, or even mainly, a provider of services to older modes of warfare. It must lead the theory and practice of applying military force to achieve the nation's ends and advance the nation's values. Visionary action is needed now to ensure that such capability will be there when the country needs it.

Table 6-1. *Relevance of This Study to Ongoing Initiatives Addressing the Future of the Air Force*

Proposed Air Force Thrust Areas	***This Study***	***Future Games 98 Action Items***	***This Study***
Develop the Airman of the Future	√	1.1 Develop a concept for future force sustainment that incorporates both logistics and mobility aspects so that they are seamless.	
Conduct Seamless Operations to Control the Aerospace Dimension	√	2.1 Study the most effective way to employ new capabilities while managing unintended consequences.	
Find/Fix/Track/Target/Engage/Assess	√	2.2 Develop a comprehensive CONOPS for standoff warfare.	√
Be an Expeditionary Air Force	√	2.3 Study the best mix of terrestrial, atmospheric and orbital standoff assets.	√
Provide a Capable and Credible Nuclear Deterrent Force	√	2.4 Examine the capabilities of future standoff forces in small-scale contingencies.	
Shape an Infrastructure for the Future Aerospace Force	√	3.1 Evaluate the capability of C^4ISR architectures to support operations at greatly increased speed of war.	√
		3.2 Develop a methodology to allow C^4ISR architecture to be degraded in exercises, training and wargames.	
		4.1 Develop a long-term plan to foster an understanding and awareness of policy and fiscal thresholds for weaponizing space.	√
		5.1 Study the best way to protect military and commercial capabilities in space.	√
		6.1 Study aspects of the theater missile threat.	
		7.1 Evaluate the best methodology for assessment of aerospace power's effectiveness against ground forces in wargames.	√
		8.1 Update the Air Force Vision, including integration of air and space power, weapons in space, stewardship of protecting space assets, and Air Force contributions to offensive and defensive theater operations.	√

There are many paths to such a future. We have sketched one which, if not accurate in every detail, shows the kind of migration that is possible and the kinds of actions and decisions that must be taken. Any successful strategy must involve the coordination of many elements, including the selective acquisition of new things and the divestiture of others, some of which are long and dearly held but no longer affordable in today's harsh fiscal reality. We are convinced that the resources can be balanced and that the difficult task of moving to the future while meeting the demands of the present can be managed. We urge the Air Force to commit itself to this difficult course, to find its vision and its voice, and to act steadfastly over the coming decades to bring that vision to reality.

Appendix A

Terms of Reference

BACKGROUND: The growing importance of space systems in the emerging global security environment makes it imperative that the Air Force, as the executive agent for DoD, deploy and operate effective space and transatmospheric systems and associated infrastructure. However, the current costs to develop, manufacture, orbit, and operate space assets in a climate of severely constrained modernization funding limit Air Force options and demand action both to make space systems more affordable and to craft a carefully optimized investment strategy.

Operation Desert Storm has been called the "first space war" in recognition of the role of space systems in providing information to warfighters. This experience highlighted both the potential of space in other than national missions and the importance of making support from space highly responsive to the dynamic needs of customers from the theater commander to the individual combatant. Moreover, the increasing prospect that adversaries will exploit both dedicated military and commercial space systems against the U.S. means that the role of Air Force space forces in providing services to air and surface operations will be complemented by surveillance and control of space itself.

The international world of space is changing dramatically, with strategic partnerships and commercial projects multiplying rapidly. Moreover, the once dominant position of the DoD and NRO in the space arena is moving toward parity by 1998 and is projected to drop to a distinctly minority position, estimated to be less than 25 percent of satellites launched and resources invested, in the near future. The leading example of this trend is a set of American-led commercial communications consortia that will place more than 100 GEO satellites and over 250 LEO satellites in orbit by 2005 with a collective investment estimated at $53B. This profound change in the space community and business will significantly impact the economics of the marketplace, the infrastructure available to all classes of customers, the rules for control of space assets, and the acquisition strategy through which the Air Force obtains required space capabilities. Two examples are the reality of offshore ownership and control of space services which could be used by adversaries and the possibility that proliferation of communications channels may allow a measure of security by burying military message traffic in a much larger volume of civilian transactions.

At the Fall 1996 CORONA, the Air Force senior leadership set in motion a plan for migrating to space a variety of capabilities currently provided by terrestrial systems. These include collection of imagery and signals intelligence, surveillance and reconnaissance sensing, and communications relay. The realization of this vision requires a change in way space systems are developed and operated, including the elaboration of a strategy for optimizing the use of services provided by allies and commercial operators. The cost, time, and risk associated with deploying and replenishing space assets must all come down substantially.

Major operational aspects of the use of space also need improvement, including the integration of space functions into the overall force structure and control of those functions to deliver the right service to the right customer at the right place and time. Space operations must be as routine and reliable as any other military operation. A robust and affordable national defense demands that the unique attributes of space, airbreathing (including UAV) and surface systems be combined synergistically to deliver the full spectrum of operational capabilities.

The investment strategy for going to space must be based on operational needs, fiscal realities, opportunities presented by technology and investments made by others, and time. Operational imperatives such as the need to accomplish intelligence preparation of the battlespace (IPB) in time to support the deployment of a rapid reaction air expeditionary force may best be met by a combination of space systems (response in minutes), UAVs (response in hours) and manned platforms (response in days). The cost to operate and upgrade current airbreathing platforms to maintain required capabilities, which increases as they age, must be balanced against the costs of various replacement options. As systems like AWACS, Rivet Joint, and the U-2 age out of the force, investment funds for migrating their functions to space could become available.

STUDY PRODUCTS: Briefing to SAF/OS & AF/CC in Oct 1998. Report completion by Dec 1998.

STUDY CHARTER: The charter of this study is to:

(1) Analyze the missions in which space or transatmospheric platforms currently or potentially participate, including space surveillance and control and support to terrestrial operations, to determine the roles such platforms can fulfill and to assess the associated system characteristics.

(2) Identify and evaluate options for migrating the capabilities and functions of existing terrestrial (airborne and surface) systems to combinations of space, airborne, and surface platforms. Stress innovation and affordability in the search for alternatives. Assess the availability or enabling technologies and the associated level of risk. Define timelines for implementing various options and group options in near-term (5 years or less to implement), mid-term (5 to 15 years) and far-term (15 years or greater) categories. Apply the best available cost data and cost estimating methods to quantify the cost of each option.

(3) Prioritize the options found to be feasible on the basis of operational effectiveness, affordability, technical feasibility, and time to implement.

(4) Develop a roadmap showing the time-phased investment from science and technology through production, required risk reduction and feasibility demonstrations, actions to achieve operational status, and interactions of investments with funding for existing systems. Include near term decisions and actions needed to begin implementation of the roadmap, recognizing the lead time from investment decisions to on-orbit capabilities.

It is fundamental to the definition and evaluation of future space options that past approaches to the acquisition and operation of military space systems must give way to faster, lower risk, and less expensive ways of delivering support to warfighters. Major themes of the study include the following:

(1) All panels will stress innovation and affordability, seeking new and fundamentally better ways to attain space and air power.

(2) The study will address both the migration of current functions from terrestrial to space platforms and the new and enhanced functions that may become available by operating in space. The focus will be on meeting the needs of warfighters and creating new options for using space and air power to accomplish missions.

(3) The study will stress the ways in which the Air Force can draw upon commercial space, both in terms of business and engineering practices that enhance affordability and responsiveness and in terms of uses of commercial products and services.

Recognizing the limitations on the level and amount of analysis that can be accomplished in a Summer Study, the committee will carry out preliminary analyses and will seek to identify key areas, define measures of effectiveness (MOEs), and frame more detailed analyses for subsequent efforts.

STUDY ORGANIZATION: This Summer Study is part of an overall Air Force investigation of its future in space. A Doable Space Quick-Look study led by the Air Force Chief Scientist will establish important background. The study will draw on all applicable prior work, including SAB studies such as

New World Vistas, UAV Technologies and Combat Operations, and A Vision for 21st Century Command and Control; Spacecast 2020; and, especially, the work of the Quick Look study group.

The study will require extensive interaction with commercial industry and with other agencies involved in space, including NASA, the Army and Navy, the NRO, and Air Force organizations involved in plans, technology development, acquisition, and operations.

The study will be conducted by a committee composed of the study chairman and 7 panels; panel chairs with broad areas of responsibility may designate subpanels as appropriate. The study chairman and panel chairs will constitute an integration committee for drawing together the products of the panels and resolving interpanel issues.

Operational Requirements and Force Integration. This panel will consider the capabilities required for future space and air power operations, from military operations other than war (MOOTW) through major theater warfare (MTW). It will systematically identify and define force options for satisfying these requirements. It will address both space control and support to terrestrial operations, and will evaluate both migration of current capabilities to space, recognizing that this does not necessarily imply placing equivalent systems in space, and the kinds of new capabilities that space platforms afford. It will formulate system concepts for these new capabilities. A specific topic is the migration of ISR functionality to space. The panel will also consider the feasibility and military utility of force applications in space through such systems as a Space-Based Laser and from space to surface targets. It will also establish the interactions among space, transatmospheric, airbreathing, and surface systems in each option and address issues of control, responsiveness, operational tempos, etc. in meeting warfighter needs. The panel will capture the current and projected capabilities and the operating and projected modification costs of existing systems as the point of departure for innovative future options. It will draw on the large existing body of prior analysis of current systems which are candidates for migration to space in such areas as OPTEMPO and response time to contingencies. Since this panel's work provides an essential framework for the other panels, it will provide periodic interim reports to the other panels and will present initial results in the areas listed not later than the SAB Spring Meeting in April 1998.

Payloads. This panel will address sensors, communications, navigation, onboard processing, and other payloads of interest for satellites, transatmospheric vehicles, and airbreathing platforms to satisfy the requirements identified by the Operational Requirements and Force Integration Panel. It will consider issues of platform autonomy, enabling technology and technical risk, use of commercial and existing products and technologies, operational flight software, and system control and integration. The panel will stress ways to reduce cost and weight by exploiting advanced technology and new design principles. It will explicitly consider tradeoffs between complex (multifunction) and simple (few functions) satellites and among various design lifetimes. The panel will seek to identify and use results of prior trade studies in its area of responsibility. It will identify applicable commercial products and services and perform trade studies between these and dedicated military systems in support of prioritization of options.

Space Control. This panel will perform a study parallel to that of the Payloads Panel in the areas of surveillance of space and of weapons and fire control for employment from satellites and transatmospheric vehicles in order to achieve denial, disruption, damage, or destruction of targets. It will consider both directed energy and projectile weapons and will consider tradeoffs among various means of effecting the spectrum of effects from covert denial of service to asset destruction. It will address the use of such weapons to attack both space and terrestrial targets and will consider the implications of such use for both policy and treaty compliance.

Vehicles and Lift. This panel will address launchers and transatmospheric vehicles, with emphasis on major reductions in the cost per unit weight to orbit, major reductions in the time to generate and launch a satellite or transatmospheric vehicle, and use of commercial or other launch services. It will consider both reusable and expendable launchers, with emphasis on the lift needs of Air Force Systems and their differences from other major space flight activities such as the International Space Station and on lessons learned from earlier RLVs such as the Shuttle. It will also investigate satellite buses and associated power, TT&C, thermal management, and other bus subsystems. The panel will emphasize responsiveness, especially time to replenish a constellation after damage or failure and to launch payloads in response to dynamic world conditions and specific contingencies. The panel will evaluate the feasibility of concepts such as preprocurement of standard buses and rapid integration of tailored payloads. It will examine related programs such as NASA's X-33/34 and will address combinations of dedicated military and commercial launch capacity and infrastructure. A major outcome of this panel's work will be to place lift and space vehicle alternatives in a coherent structure that facilitiates analysis and comparisons.

Terrestrial Segment. This panel will address ground stations and equipment, human-machine interfaces, personnel and training, interfaces between military space ground environments and other military and civilian systems, and related aspects of the terrestrial segment, recognizing that roughly half the life cycle cost of such systems is currently entailed in this area. It will consider options for reducing the cost of acquiring and operating ground stations, especially the need to move away from system-unique and proprietary ground segments and to lower required staffing and operator skill levels. The panel will address the application of standardization, automation, advanced displays, human factors, and other related technologies and disciplines to reduce the costs of acquiring and operating space systems. It will explicitly consider issues associated with seamless integration of terrestrial segments into overall command and control and combat operations, including ways to achieve needed responsiveness to warfighters at all levels of a force and in joint and combined operations.

Architecture and Information Management. This panel will address the information infrastructure associated with integrated space, airbreathing, and ground systems. It will also consider the technical architecture dimension of integrated force structure and will seek to quantify the required connectivity, asset management schemes, network robustness and fault tolerance, and service times to customers based on operational needs and system concepts. It will evaluate the role of terrestrial communications channels such as undersea fiber optics. It will address security issues, including multi-level security, the impact of inappropriate or inconsistent classification on effective use of space capabilities, and secure connectivity into the battle area. It will explicitly evaluate alternative approaches to providing direct service from platforms to warfighters and the allocation of asset control to combatants, commanders at all levels, and national authorities, working closely with the Operational Requirements and Force Integration panel. It will consider the requirements and constraints posed by joint and combined operations.

Cost Estimation and Acquisition Strategy. This panel will be responsible for developing a cost estimation methodology for the study and for applying that methodology to quantify the costs of the options that are developed. The panel will assemble and, as appropriate, expand upon existing cost models and cost estimating relationships (CERs) and will seek to assemble the most complete data base feasible on the current and projected costs of hardware, software, and services. The panel will seek to establish a basis for valid comparisons among alternatives, e.g., placing a given function on an orbiting or airbreathing platform for a given level of service to customers. The panel will consult both Government and industry organizations in attempting to compile this cost estimation basis. The panel will also address alternative acquisition strategies in light of the rapid evolution of the space community and industry, the paramount importance of affordability, the practical aspects of migration and progressive replacement of terrestrial functionality, acquisition reform, and the need to accelerate the cycle of defining, developing, and fielding space capabilities.

Appendix B

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Appendix C

Panel Report Abstracts

This report consists of two Volumes. Volume 1 is the Summary Volume of the report. Volume 2 contains Appendices E-J:

Appendix E: Operational Requirements and Force Integration (not available at this time)

Appendix F: Architecture and Information Management

Appendix G: Payloads

Appendix H: Vehicles and Lift

Appendix I: Terrestrial Segments

Appendix J: Cost Estimation and Acquisition Strategy

A short summary of the contents of each appendix follows.

Architecture and Information Management: Volume 2, Appendix F

The Architecture and Information Management Panel's portion of the Scientific Advisory Board Summer Study evaluated the status, ongoing dynamic changes, and exciting future of the Air Force Information Management Architecture. This appendix will report on the critical aspects leading to aerospace power through information dominance. Global Knowledge, Global Reach, and Global Power are all critically dependent on robust network-centric Global Grid information management architecture. This panel concentrated on two tasks. The first was to establish a baseline architecture to determine the validity of options within the aerospace roadmap. The second was to evaluate the state of Air Force information management activities.

The complexity and extent of the architectures involved in the current and future national security environment dictate the adoption of a consistent framework for the entire study. That framework accepts the premise that, for the foreseeable future, systems cannot be considered in isolation from each other or in isolation from the architecture they comprise. Beyond that, architectures can no longer be considered in isolation from other architectures with which they interface. The architectural framework used in the Summer Study included (a) an "Operational Architecture" that identifies essential nodes in some operationally relevant context with the interconnectivity between each node and (b) a "Systems Architecture" that provides the technical systems with a response to the operational need in terms of physical characteristics and performance parameters. Across the Air Force's aerospace framework, there are multiple systems architectures, each composed of several systems. The evaluation of the Air Force Information Management Architecture led to some major recommendations and findings.

The Air Force needs an information management architecture to realize the full potential of aerospace power capabilities. Information management touches upon a host of important military needs from intelligence, surveillance, and reconnaissance to command and control (C^2) of forces. Each commander will be able to tailor the architecture envisioned in this report to the specific mission for which he or she is responsible. The architecture will integrate information from global and theater assets, both inside and outside the Air Force, and enable seamless C^2 of forces around the globe. In addition, it will exploit commercial technologies in order to be technologically current and affordable. The future information architecture will include elements based in space, in the air, and on the surface of the globe. Many of these systems may be operated by the military Services of the United States, allies, or coalition partners. However, the majority of the systems will be operated by commercial companies, both domestic and international. The information management architecture recommended in this report is intended to modernize Air Force military capabilities and to be a key enabler of new operational concepts for the employment of aerospace power.

Commanders rely on information to depict the battlespace, detect attack, determine adversary intent, define capabilities, and direct the maneuver and positioning of commanded forces. C^2 depends on the exploitation of information. This critical reliance underwrites the *JV 2010* tenet of Strategic Dominance and is the basis for the Air Force's Global Engagement goal of Information Dominance. Achieving Information Dominance requires universal connectivity among deployed forces, CINCs, the National Command Authority, and supporting elements. This demands that the Global Grid system-of-systems provide bandwidth and other communications functions to support the expeditionary Aerospace Force (eAF) mission and Information Dominance. Lean and mean eAF operations will demand that C^2 be distributed and collaborative. Virtual battlestaffs will be the central elements in future C^2. Improved connectivity—through the Global Grid—is the fundamental enabler for the eAF operational concept.

Table C-1. *Overview of Architecture and Information Management*

Section Number	***Title***
1.0	Introduction
2.0	Aerospace Force Structure and Architectural Approach
3.0	Information Management Philosophy
4.0	Current Information Management Structure
5.0	Vision for Air Force Information Management
6.0	Technology Enablers
7.0	Migration Strategy
8.0	Acquisition Strategy
9.0	Recommendations/Implementation

Payloads: Volume 2, Appendix G

The Payloads Panel examined topics of significance to defense missions that either currently have a space segment or might, in the view of the panel, justify a space segment in the future.

Historically, DoD missions have taken advantage of the high ground of space to collect—with passive receivers—electromagnetic energy that passes easily through the earth's atmosphere (visible, infrared, and radio frequency) for electronic intelligence, communications intelligence, imagery intelligence, measurement and signals intelligence, weather forecasting, and warning. The receivers relay radio-frequency communications with relatively low-power spacecraft (10^2 to 10^3 watts) to provide precision passive terrestrial navigation through one-way range measurement based on precision timing distributed from space.

While commercial forces have increased spacecraft total power to approximately 10^4 watts and, through increased demand for commercial launch services, stimulated a significant drive toward lower-cost launches, there is no foreseeable scenario in which payload weight and power consumption are not major constraints on space system design.

In structuring this study of payloads for the future, existing missions with space segments were parsed into their basic elements to allow the generic underlying science, technology, engineering, and art to be dealt with as they might be applied across multiple missions and applications. Thus the current space missions, including communications, intelligence, weather, surveillance/warning, and navigation, are mapped into technology areas. This study is not comprehensive in the sense that not all current space missions were examined in depth to suggest appropriate payloads for future missions. The sections individually focus on major payload investment areas of the near term, system architecture and integration issues, and technologies of interest for the future.

Table C-2. *Overview of Payloads*

Section Number	*Title*
1.0	Introduction
2.0	Space-Based Radar
3.0	Communications
4.0	Navigation, Position, and Timing
5.0	Space-Based Electro-Optical (Visible and Infrared) Systems
6.0	System Architecture and Integration Issues
7.0	Roles for Small Satellites
8.0	RADSAR
9.0	Space-Based Laser Weapons
10.0	Other Promising Technologies
Annex	SATCOM Frequencies Usage

Vehicles and Lift: Volume 2, Appendix H

The Vehicles and Lift appendix addresses current issues and provides recommendations dealing with space launch vehicles, launch infrastructure, space operations vehicles, spacecraft buses, and potential high-leverage technology areas.

Lift vehicles are analyzed from the standpoint of metrics such as cost per unit weight to orbit, turnaround time, robustness, responsiveness, and desired level of commercial involvement. Both reusable and expendable launch vehicles are considered, with emphasis on the lift needs of Air Force systems and their differences from current and projected commercial lift requirements. The launch infrastructure portion, dealing primarily with launch pads and ranges, focuses on the increasing need to modernize the facilities and the organizational structure to support the projected growth in commercial launches. The Aerospace Operations Vehicle is presented based on a military concept of operations. Spacecraft buses are addressed in terms of the adaptation of commercially available buses for unique military requirements to minimize cost and cycle time. Radiation susceptibility of commercial low earth orbit and geostationary earth orbit buses is described. The chapter concludes by describing high-leverage technologies that can revolutionize the approach to spacecraft and launch vehicle structures and propulsion, and satellite power generation.

Table C-3. *Overview of Vehicles and Lift*

Section Number	Title
1.0	Introduction
2.0	Summary Findings and Recommendations
3.0	Expendable Launch Vehicles
4.0	Launch Infrastructure
5.0	Reusable Space Launch Vehicles
6.0	Aerospace Operations Vehicle System
7.0	Spacecraft Buses
8.0	High-Leverage Technologies for Air Force Investment

Terrestrial Segments: Volume 2, Appendix I

The Terrestrial Segment Panel was tasked to consider options for reducing the cost of acquiring and operating military ground systems, recognizing that roughly half the life-cycle cost of military space systems is entailed in this area. The growth of the commercial space industry has yielded products, services, and operational practices that are substantially more cost-effective than current Air Force operations, notably in the area of satellite operations. A comparison sometimes cited is that the Air Force has about 2,000 people operating about 100 satellites, whereas the Iridium constellation has about 200 people operating 60 satellites. Since the Air Force is now in a position to consume and use technology, rather than create it, the Air Force must learn to *use commercial first* in order to leverage these cost benefits.

The panel also considered the issues associated with seamless integration of space systems into overall command and control and combat operations. Military operational effectiveness can be greatly improved by taking a mission-centric (or capability-centric) view across a system-of-systems architecture including air, space, and terrestrial components. This evolutionary migration from a platform-centric view can enable new capabilities and expanded services while maintaining backward compatibility with existing infrastructure and user equipment. Implementation of this vision will require the development of robust connectivity across the battlespace, tying together planning, sensing, processing, and user elements (or nodes) of the air, space, and ground segments of a battlespace network.

To leverage the rapid advances in commercial technology for satellite operations, the Air Force must adopt new acquisition practices. The traditional DoD acquisition process takes a minimum of 5 years for development, while commercial information technology performance improves 100 times every 10 years. The Air Force should make both a revolutionary change—switching from military to civilian models for system development, procurement, and operations—and an evolutionary change based on continuous improvement throughout the program, using the spiral development process as a model.

Human factors remains a perennially neglected discipline, with serious long-term consequences. Poorly designed operator stations and other aspects of the human-system interface affect everything from the effectiveness of system operation to training requirements to morale. The root problem is that neither the Government nor contractors treat human factors as a critical aspect of system requirements and a mandatory element of the system engineering process. As long as the problem is ignored, a host of unnecessary costs, many of them hidden, will continue to be paid. To resolve this problem, we recommend that the Air Force incorporate human factors as an integral part of the acquisition process.

Table C-4. *Overview of Terrestrial Segments*

Section Number	*Title*
1.0	Introduction
2.0	Commercial Practices for Satellite Operations
3.0	Mission-Centric Distributed Architecture
4.0	Connectivity for the Network-Centric Battlespace
5.0	Spiral Development: Moving to Best Commercial Practices
6.0	Human Factors
7.0	Conclusions and Recommendations

Cost Estimation and Acquisition Strategy: Volume 2, Appendix J

The Cost Estimation and Acquisition Strategy report is a forecast of a potential future for the Air Force, but does not necessarily imply future officially sanctioned programs, planning, costs, or policy.

In the 52-year history of the Air Force Scientific Advisory Board, we have made estimates of the future and technology. We understand the uncertainties that accompany any attempt to predict the future; most predictions become increasingly inaccurate after a decade or so. In that respect this study is no different than the others that have preceded it; however, this is the first SAB study to add the dimension and complication of cost estimation.

Today, we assert that affordability must be emphasized as much as technology, for it is the hard-earned dollars of the American taxpayer that pay for our national security. In the Cold War, a monolithic threat and potential scenarios were well known. But in the current and expected environment of constrained budgets, we must train and equip our military forces for a diverse set of situations across the full spectrum of conflict. These constraints require that the cost and performance of competing potential systems be evaluated and compared.

With an environment of limited dollars and competing solutions to ill-defined problems, we must evaluate the rising capabilities of commercial technologies and enterprises as we consider divestiture of support functions. This brings another dimension to the cost-effectiveness of any force options analysis and requires new approaches to meeting Air Force goals.

Lord Rutherford once said, *"We are out of money and thus, we must think."* This study represents that thought process. Other panels addressed the capabilities enabled by the new technologies we envision. Here we delineate the cost methodology and the relative costs of those envisioned force options considered. We also consider alternative means of acquiring necessary capabilities.

Table C-5. *Overview of Cost Estimation and Acquisition Strategy*

Section Number	***Title***
1.0	Introduction
2.0	Cost Estimation Methodology
3.0	Cost Data
4.0	Cost Panel Recommendations
5.0	Acquisition Findings
6.0	Acquisition Recommendations
Annex	Cost and Acquisitions Strategy Panel Charter

Appendix D

Initial Distribution

Headquarters Air Force

SAF/OS	Secretary of the Air Force
AF/CC	Chief of Staff
AF/CV	Vice Chief of Staff
AF/CVA	Assistant Vice Chief of Staff
AF/HO	Historian
AF/ST	Chief Scientist
AF/SC	Communications and Information
AF/SG	Surgeon General
AF/SF	Security Forces
AF/TE	Test and Evaluation

Assistant Secretary of the Air Force

SAF/AQ	Assistant Secretary for Acquisition
SAF/AQ	Military Director, USAF Scientific Advisory Board
SAF/AQI	Information Dominance
SAF/AQL	Special Programs
SAF/AQP	Global Power
SAF/AQQ	Global Reach
SAF/AQR	Science, Technology and Engineering
SAF/AQS	Space and Nuclear Deterrence
SAF/AQX	Management Policy and Program Integration
SAF/SN	Assistant Secretary (Space)
SAF/SX	Deputy Assistant Secretary (Space Plans and Policy)

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AF/XOC	Command and Control
AF/XOI	Intelligence, Surveillance and Reconnaissance
AF/XOJ	Joint Matters
AF/XOO	Operations and Training
AF/XOR	Operational Requirements

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AF/IL	DCS, Installations and Logistics
AF/ILX	Plans and Integration

Deputy Chief of Staff, Plans and Programs

AF/XP	DCS, Plans and Programs
AF/XPI	Information and Systems
AF/XPM	Manpower, Organization and Quality
AF/XPP	Programs
AF/XPX	Strategic Planning
AF/XPY	Analysis

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AF/DP	DCS, Personnel

Office of the Secretary of Defense

USD (A&T)	Under Secretary for Acquisition and Technology
USD (A&T)/DSB	Defense Science Board
DARPA	Defense Advanced Research Projects Agency
DISA	Defense Information Systems Agency
DIA	Defense Intelligence Agency
BMDO	Ballistic Missile Defense Office

Other Air Force Organizations

AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
– ESC	- Electronic Systems Center
– ASC	- Aeronautics Systems Center
– HSC	- Human Systems Center
– AFOSR	- Air Force Office of Scientific Research
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– ASC2A	- Air and Space Command and Control Agency
– 366th Wing	- 366th Wing at Mountain Home Air Force Base
AMC	Air Mobility Command
AFSPC	Air Force Space Command
PACAF	Pacific Air Forces
USAFE	U.S. Air Forces Europe
AETC	Air Education and Training Command
– AU	- Air University
AFOTEC	Air Force Test and Evaluation Center
AFSOC	Air Force Special Operations Command
AIA	Air Intelligence Agency
NAIC	National Air Intelligence Center
USAFA	U.S. Air Force Academy
NGB/CF	National Guard Bureau
AFSAA	Air Force Studies and Analysis Agency

U.S. Army

ASB	Army Science Board

Initial Distribution (continued)

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Other

USSPACECOM	U.S. Space Command
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