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SPACECAST 2020 was a Chief of Staff of the Air Force (CSAF)-directed space study, challenged to identify and conceptually develop high-leverage space technologies and systems that will best support the warfighter in the twenty-first century. This is the first of four monographs: Executive Summary, the SPACECAST 2020 Process, The World of 2020 and Alternative Futures, and Operational Analysis. The SPACECAST 2020 study produced many new ideas and reinforced some old ones. Air University sought to envision the possibilities, capabilities, and technologies the United States will require to exploit the space high ground in pursuit of national security objectives.

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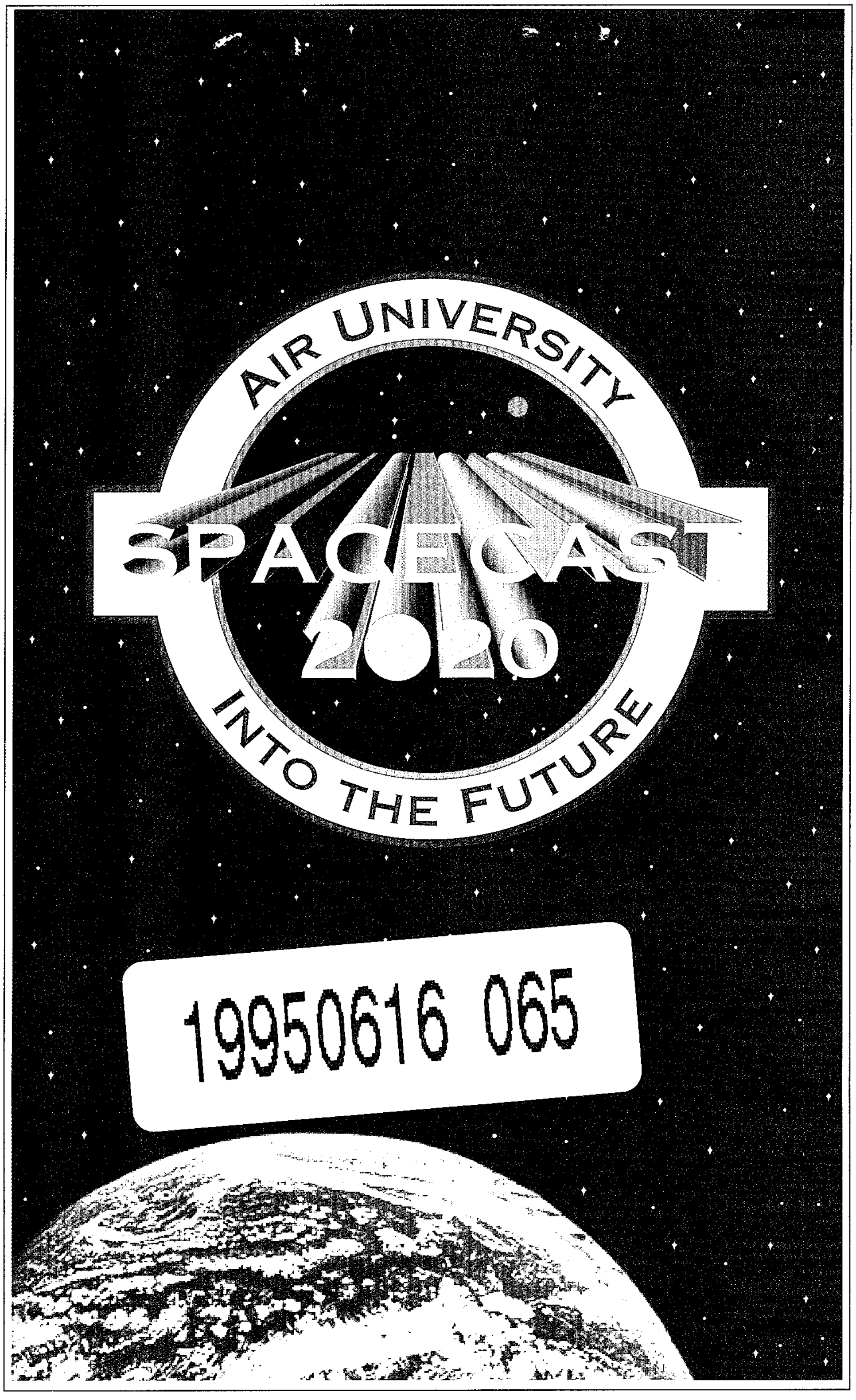
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DISCLAIMER

A study done in compliance with a directive from the CSAF to examine the capabilities and technologies for 2020 and beyond to preserve the security of the US. Presented on 22 June 1994, this report was produced in the Department of Defense school environment in the interest of academic freedom and the advancement of national defense-related concepts. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

Foreword

Perhaps the oldest military maxim concerns the advantages of holding and using the high ground. The high ground has always provided tremendous advantages in vision and extraordinary leverage in force employment. When mankind soared into the air, the concept of holding and using the high ground took on an entirely new dimension, and air power revolutionized the conduct of warfare.

Now, in the latter years of the twentieth century, mankind is making its way beyond the limitations of the atmosphere and into the ultimate high ground of space. It follows that the ability to operate in and through space has the potential to revolutionize yet again the conduct of warfare. But, this potential will only be realized with imaginative forward thinking that breaks the ties binding our minds to the concepts of the present.

The United States Air Force Chief of Staff, General Merrill A. McPeak, challenged the faculty and students of Air University to break the bonds of the present and envision the possibilities, capabilities, and technologies the United States will require to exploit the space high ground in pursuit of national security objectives. SPACECAST 2020 is the result of that challenge.

SPACECAST 2020 makes clear the two paramount military advantages of space—unparalleled perspective and very rapid access to the Earth's surface. Exploitation of these advantages could have a major impact on intelligence, communications, command and control, navigation, force application and many other critical aspects of military operations. Further, the ability to "see over the next hill," as the Duke of Wellington might have put it, can significantly reduce uncertainty and insecurity and thus promote stability.

SPACECAST 2020 also makes clear that to fully exploit the advantages of the ultimate high ground, the United States must pursue a significant number of high-leverage technological capabilities. They range from capabilities that are already needed, such as reusable lift, to those capabilities that are only on the mental horizons of the most ardent futurists, such as defense of the planet earth against asteroids in earth-intersecting orbits.

The hundreds of participants in SPACECAST 2020 rose to General McPeak's challenge. They produced a document of imagination and foresight. They identified many of the capabilities we will need and many of the technologies we must pursue. I believe their final report is well worth reading. An executive summary of the report follows.

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SPACECAST 2020

Introduction

The investigation of emerging technologies for space in the year 2020 and beyond is of paramount importance to the United States. Lead times for advanced terrestrial and atmospheric weapons systems can take as long as 20 years from the initial requirement to operational capability. For projects involving complex technologies, new concepts and materials, or unfamiliar environments, a quarter century seems a minimum planning horizon. In the competitive world in which we live, the failure to investigate such issues in 1994 could imperil national security in 2020.

In May 1993, the chief of staff of the United States Air Force directed Air University to undertake a study to identify capabilities for the period of 2020 and beyond and the technologies to enable them which will best support preserving the security of the United States. The study team considered the full vertical dimension, including the important region of the transatmosphere that both separates and integrates air and space. This 10-month long effort became known as SPACECAST 2020. The study methodology was distinctive in several respects. It

1) involved faculty and class members at the Air Command and Staff College and the Air War College at Air University, Maxwell AFB, AL;
2) depended on the scientists and technologists at the Air Force Institute of Technology, Wright-Patterson AFB, OH, to solicit, provide, and evaluate emerging technologies and creative applications;
3) was not limited to experts in one field or specialty. Instead, personnel with vastly different career backgrounds and educational specialties participated in the study, the majority of whom were from the operational line forces of all the services;

4) included the assistance of members of numerous other government agencies, universities, laboratories, think tanks, and inputs from a worldwide data call;

5) utilized high technology means to collect, analyze, synthesize, and deploy information through video conferencing, computer data bases, and specially devised software;

6) was consistently validated internally through a two-team system of Creative Activity Teams (CAT) and a Realistic Assessment Team (RAT), and externally by an Expanded Realistic Assessment Team (ExRAT) of scientists and technologists, an Executive Board, and a Senior Advisory Group, each of which reviewed each step of the process as it was being accomplished and validated all the major findings;

7) supported the value of "Global Presence" and envisioned the idea of global view through "users"—not scientists;

8) created a large, network of scholars, analysts, creative thinkers, and operators who became partners in the study;

9) produced over 100 officers with an expanded awareness of the national security challenges of the far future and the ways space presence and space operations can contribute to meeting these challenges.

Quite simply, the SPACECAST 2020 study "stirred the pot" and produced some new ideas.

As the product of a creative but disciplined process executed by operators, the findings present a range of possibilities designed to stimulate the thinking of experts. Some findings fail the test of expert validation. The implementation of others will be constrained by resources or the need to invest in urgent, near term requirements. Still other ideas will prove to be constrained by treaty or agreement. SPACECAST's goal was to energize thinking and imagination to produce a set of possibilities refined and integrated so that senior leadership could adopt all, some, or none of its major ideas. They could select any of these ideas with reasonable confidence that they are important issues that the US must address if it is to play a dominant role in space in the twenty-first century.

SPACECAST 2020 was done at marginal cost, with virtually free analytic and creative effort from over 350 people who represented both the operational communities from all the armed services and some of the best scientific and conceptual talent available. It was unconstrained, the only major injunction being to remain detached from the roles and missions debate. It produced a series of white papers which have been assembled into clusters of concern for future space capabilities. Of all the findings of SPACECAST 2020, none is more compelling than the observation that global presence through robust space operations is critical to the security of our nation.

More Than A Place

Space has been called many things by many people—the ultimate high ground, the last dimension of warfare, the high frontier, and the final frontier. **Space is all these and more.** Its most fundamental characteristic from a military perspective is that it possesses unprecedented vantage or view. It answers the age-old wish of military commanders to be able to see the other side of the hill. Variously defined in the past as both a place and a mission, space is also a laboratory of the unknown; a potential area for commercial exploitation; a medium in which surveillance, communication, navigation, and transit are now routine; and an arena of increasing cooperation, competition, and potential conflict.

We are in space regularly. Space has been used for military purposes for nearly four decades. A highly public, technological space race with the Soviet Union characterized a dozen years of the cold war from the launching of Sputnik in 1957 to the landing of Americans on the moon in 1969. During the cold war a source of pride to the citizens of the United States was that we had walked on the moon while others had ventured only a few hundred miles beyond the surface of our planet. The cold war is over, but competition and conflict are not. New relationships are developing and new patterns of both competition and cooperation are emerging. Space offers opportunities for friendships and partnerships to grow.

Even so, national presence and accomplishments in space are and will remain a barometer of international status and prestige, technological prowess and military capability, whether we like it or not. Countries as diverse as Israel and China, Brazil and Pakistan, Japan and Argentina all have interests and assets in space. If the United States seeks to continue to be a great power, let alone the world's only superpower, it must maintain a dominant presence and capability in space. Not to do so may appear to be an abdication of power in the eyes of countries whose capabilities in space are growing. There are things we may do unilaterally in space that have global benefit such as navigation, weather and communication.

Maintaining a space presence and capability is difficult, expensive, and fraught with risk. Our country must invest its limited resources wisely. Selecting the most promising technologies is critical to this venture. Only those states who have the capacity to have an impact on *why* and *how* space is utilized will play a role in shaping the environment of space. **If we want to maintain or increase our presence in space, we must pay the price to do so.** If not, we could cease to enjoy our current status, deference, and power. This study assumes that we will continue a conscious commitment to being a major actor in space.

Why does the US need to be a space-faring nation? What is it that can be done in space that can't be done elsewhere? **The single most important reason to be in space is to have the Global Presence required to maintain global view.** Transformations of technology, the geo-political environment, military dispositions, and capabilities of other states and nonstate actors are all critical information if the US is to maintain its own security and that of many other states dependent on this knowledge. Presence in space to collect, analyze, synthesize, and disseminate information rapidly is vital if we hope to continue to be able to attempt to shape the international environment and preserve not only national but international security. Presence in space is, of necessity, Global Presence.

Before one can respond to changes, one has to know that things have changed. Knowing, raw knowledge, is inherently worthy. The knowledge that can be gained from the vantage of space about the globe enables us to increase the quantity, quality and speed with which information can be utilized. The variety of knowledge and rapidity with which it can be disseminated and utilized makes space critical to successful competition, both public and private, in the twenty-first century.

Global Presence and global view are the enablers for Global Reach, Global Power. There are several reasons for this. (1) Presence is a prerequisite for global view and global view is a prerequisite for global awareness and knowledge. (2) *Knowing* what is transpiring in near-real time is a tremendous advantage for effectively maintaining security—a prerequisite for anything else. (3) More importantly, having others know that we can know what is occurring creates a powerful deterrent for hostile action. Such *deterrent capability* adds to the value of the knowledge itself. (4) Space-based sensors create *presence* which can in many cases, but not all, substitute for forward deployments of military forces. This can diminish the logistical problems of transportation and sustainment and the risk of human lives. (5) Should conflict become a reality, the capacity to combat adversary forces by using our superior knowledge and information derived from space-based presence and communicated by space systems enables *new methods for the warfighter* to use to engage opponents. (6) The quantity and quality of information that can be gained from space presence *enhances the power of existing terrestrial forces,* both conventional and unconventional, by providing more and better information more rapidly. Space presence allows you to see the other side of *all* hills. It is the only real way to come to grips with dispersed threats, distributed capabilities, and disparate data points. There are today and there must always be effective terrestrial means for creating global reach and global power. **Space is the only vantage point from which to attain global view and global view requires Global Presence.**

Technology and the Pace of Change

SPACECAST 2020 does not pretend to provide *the* vision of the future. The world in which we live is chaotic, filled with constantly changing, unknown and unknowable challenges and opportunities. The planet's political, economic, and social instability is a general condition, not always or even necessarily a threat. Attempting to predict with certainty exactly how events and capabilities will unfold in an unstable world is a fool's errand. We cannot know in detail what the future holds. We can, however, speculate in an informed fashion on the technologies that would be of most value and which are not beyond plausibility. We can also assess the relative merits and demerits of certain capabilities, consider the trade-offs among various investments and their returns, and identify the show-stoppers, the items without which we simply cannot progress further. Technological progress is one whose history has proven to be uneven, nonlinear and irregular and promises to be even more so in the future given the pace of change.

There are essentially three different types of technologies. The first type is rapidly emerging, fast-track technology, characteristic of industry and the private sector, evident in areas such as commercial electronics, communications, and computers. The second type of technology has had great investment in the past, but this interest is slowing appreciably or stalled because of the end of the cold war. These were hybrid, public and private ventures, supporting such items as secure and survivable communications, sensors and some basic research useful to the private sector largely because of large government investment and the possibility of commercial spin-offs. The third type is so complex, expensive, and slow in development that only governments who have sufficient need and resources can invest in them. This type generally has no immediate visible civilian applications. Large-scale weapons systems and space lift are examples.

The process of transforming technology into national security capability requires awareness of the three categories of technology emerging in the post-cold war world. To assimilate technology into systems providing national security capability, three separate approaches need to be integrated. First, the armed forces need to remain aware of the rapid advances occurring in computers, communications and electronics and "spin-on" to those developments that can expand national security capabilities. Second, the armed forces need to expand partnerships and contribute to basic research and technology development in all those areas essential to future national security capability. This is the most challenging area because it demands a clear vision of long-range goals and an understanding of future needs never before required. Third, and finally, there is a category of technology where we simply must accept that we are obliged to take the lead. The development of weapons, and affordable space transportation, falls in this category.

Implementing Global Presence and the concept of global view as a reality depends on three things: an integrated, on-demand information system; increased and improved sensing capabilities, and, relatively inexpensive space lift. Having a capacity to utilize an integrated, on-demand information structure in space would reap the greatest benefits. The US has considerable sensing capability, but nothing like what is likely to emerge in the next 30 years. Such a system would empower global vision more fully. None of this is routinely feasible, though possible, without improved lift. Specifically, we must attain a capacity for responsive, flexible, resilient, and most importantly, relatively inexpensive lift. Lift is the basic enabling capability for what is built on top of it. The lack of inexpensive lift will severely limit our abilities.

There are many factors that can affect how we proceed in the future. These factors include the availability of financial resources, the overall state of the economy over decade-long spans of time, the differential rates of technological advancement, political leadership, and decisions on relative priorities on the national agenda. These factors make predictions about the unfolding of future technologies and their interaction difficult. Still, there are some certainties. Consumer technologies will achieve rapid and continuous progress because of the commercial incentives for their advancement. Other joint use technologies that are stalled at the moment may or may not progress. Massive, publicly funded technologies for weapons systems and space lift may be impossible absent a truly significant threat or awareness of clear benefit to the public. First among these in importance is an information architecture that can function on-demand to provide access to information for us and provide it or deny it to others.

"Demand" information systems differ from "command" systems. Command systems evolved to support strictly hierarchical military organizational structures in an era when the cost of bandwidth was high, when data processing required large, fixed mainframes, and when the principal threat to our national security largely was restricted to a single geographical area. Command is top down. Demand is bottom up. The field commander should be able to "pull down" the information desired instead of only being provided information "pushed down" via the command of others. The cost of bandwidth is now lower, even becoming inexpensive, the computational capacity of small, portable computers continues to increase, and military forces are reorganizing to cope with a world of distributed dangers and unexpected, rapidly arising threat possibilities.

These developments allow, and SPACECAST believes require, the creation of a demand information architecture. The architecture for such a system is the novelty; the technology will emerge largely from the private sector because this technology has commercial incentive and application. Global cellular communications and exponential improvements in computing will become realities without government financial participation because of commercial demand and profitability. Without such continued progress, the notion of global view will not happen. The communications and computer technologies required are ones which we have reasonable confidence will be extant by 2020, if not well before. The types of technologies and capabilities made possible by them in an integrated on-demand information architecture are the essence of the requirement for global view.

Acquisition of the type of sophisticated, integrated, multispectral sensors which may make the knowledge possibilities inherent in global view a reality are more costly, more difficult, and less predictable. They may or may not evolve smoothly and they will be the product of public and private co-sponsorship and joint development. While characterized by opportunities for dual civilian and military use, these sensors are costly and depend on certain breakthroughs to become an operational reality. They will require large amounts of funding from both sectors and will have spin-offs, spin-ons, and future opportunities for both partners in the development and application of such technologies. The sensors are the input mechanisms by which the information architecture functions and are hence the enabling technologies required to realize this vision.

All of this depends on space lift and space lift depends on the government. Innovation in space lift—the introduction of a less expensive or reusable vehicle—requires government leadership and public funding, long-term commitments to extensive research and development, continued refinement through different generations of capabilities and high priority support. Unless or until we solve the problem of expensive space lift, we can operate in space using other technologies, but only in a halting and incomplete manner. Inexpensive space lift is the enabling element which makes the other aspects a reality. Without it, we can continue to function with the existing alternatives. However, acquiring inexpensive or reusable lift would greatly enhance the opportunities and capabilities in space. Though not a prerequisite because there are alternative launch vehicles in the inventory for the next dozen years, a low-cost and responsive space lift would reap untold benefits. **Without government support on a large scale, it is not likely that less expensive, resilient, reliable, and flexible space lift will become a reality. Without assured access to space, Global Presence is exceedingly difficult.**

Overview

The following is a set of creative concepts, emerging technologies, and potential capabilities which can enable the US to become a space-faring nation in the twenty-first century. They are not engineering studies, requests for proposals, or fully articulated designs for new systems. They are first cuts at giving substance to the concepts generated from assessing alternative solutions to difficult problems in a complex future world. They are informed conjectures about how we might best plan for our future in space. Taken collectively, they offer suggestions for an investment in the protection of US interests and assets in space in the far future. Some are possible to pursue right now after validation by experts. Others may prove to be impossible. Taken individually, they offer an array of choices, large and small, for investing in a significant arena of global interaction in the twenty-first century.

These concepts are divided into several different categories. The categories represent clusters of functional areas of space activities. If the US is to become a viable actor in shaping the arena of space as the larger adjunct to global security interests, it must develop competence in these areas. These areas or categories of activity are

- ***GLOBAL PRESENCE***
- ***GLOBAL REACH***
- ***GLOBAL POWER***

Taken collectively, these provide the capabilities for accomplishing what we believe will be the military mission. Technological advancements exist today with varying degrees of future promise which make possible a new kind of national and international security in the twenty-first century. The United States must not only be able to be in space, it must be able to act from space and to protect space-based assets. How?

Global Presence

Taking advantage of the opportunities provided by the vantage of space is first and is best done by Global Presence aimed at observing what is happening both on earth and in space from space. The observation and orientation capability afforded by space presence gives us global view. Knowing the disposition of forces is a requisite for any military commander and space based assets give unprecedented capability to do this. The need to know about our adversaries, our allies, and ourselves is greatly enhanced, as is the response time in which we can make decisions in both war and peace, by space operations aimed at monitoring and reporting. **Having friend and foe alike know that we know what is happening is a deterrent capability of immense proportions.** The ability to have access, influence, and control over information is a significant capability enhanced by space presence.

Similarly, **an inability** to have presence to exploit the vantage of space for acquiring information would introduce significant uncertainties and seriously hamper our capability to compete both in space and on the earth. The consequences of our *not* knowing critical information and an adversary possessing such a capability could deter the United States from action or winning a contest of arms. The capabilities listed here under Global Presence, while passive in a sense, are the essence of the successful use of space at the moment. They include such elements as surveillance, reconnaissance, exploration, environmental sensing, information collection, research, intelligence, navigation, command and control, and communication. The near-real-time capability in all these areas offered by the proper utilization of space and the opportunities it presents make this area of concern critical both to presence and to the successful exploitation and control of space.

By 2020 there will be so much information to collect, analyze, assess, synthesize, and disseminate that the quantity will present a challenge of such magnitude as to be almost incomprehensible. There will be a virtual explosion of information, an exponential growth so dense and constantly expanding that we must envision an information sphere which surrounds us in space as the atmosphere does on the earth. Constructing an information architecture to selectively capture, process, and use information is a critical priority. The fusion of relevant data will require a major expenditure of time, money, and effort, but is mandatory to cope with both the problems and the opportunities we will encounter in 2020 and beyond. Command systems are inadequate to cope with the demands for information that combatant forces and other users levy. To be truly effective, information should be provided when requested by the user, not merely when offered by the provider. Demand systems are required.

In the "infosphere" of 2020, knowing the adversary and knowing yourself will unquestionably be essential for success, but may not ensure it. The temporal dimension of a decision cycle will be as important as the information that feeds it. The one that knows and can act on information first will be the side that has a distinct advantage. Space presence offers great advantages in both timeliness and availability of information for decision-making. Such fundamental characteristics of space as vantage point and speed that make it useful today must be further exploited to provide users of 2020 the ability to sense greater portions of the earth more rapidly, communicate more effectively, and decide more quickly what action to take. This section of the SPACECAST study proposes an integrated demand architecture for global view and examines the areas of surveillance and reconnaissance, navigation, space traffic control, and weather that can capitalize on the characteristics of space to support the needs of national security in 2020.

The following provides a brief synopsis of the papers in the full report:

The paper titled **Global View: An Information Demand System for the Joint Warfighter of Tomorrow** presents a proposal for a design and a phased approach for building a demand information system on present capabilities to satisfy the needs for on demand near-real-time global access to all available information relevant to the mission. This information would consist of both raw and processed data and be available to battlestaffs, weapons systems personnel, and forces all the way down to the soldier at the platoon level. The architecture envisions interactive mass data base storage, on-board and on-line interactive distributed processing, and queuing and query capabilities to enable both selective command dissemination and on-demand access to time-sensitive information directly by the user. It is the blueprint for combining separate systems and architectures into an integrated and interactive architecture. This paper outlines an evolutionary transition to achieve revolutionary capabilities.

Leveraging the Infosphere: Surveillance and Reconnaissance in 2020 proposes concepts that use ground and space-based systems incorporating hyperspectral and other imaging and sensing technologies to detect and provide real-time, fused information of all types to the user. This concept combines conventional sensing techniques (by 2020, routine sensing techniques) such as imagery, signals, laser, radar, and so forth with new advances in high-resolution, remote surveillance and hyperspectral sensing in acoustic, seismic, olfactory, and gustatory areas. Data from all sensory inputs are used to identify objects by comparing their structural sensory signature with existing data bases. These "omnispectral" and "omnisensorial" capabilities, diligently pursued and implemented, will be essential to "knowing" in the twenty-first century. Knowing is as essential to finding the lost child or the leaking fuel line as it is to prosecuting military operations economically and effectively. The wealth of ideas outlined, including opportunities for breakthroughs in signature detection and identification, show how the vantage of space can be used.

Navigation and Data Fusion for the 21st Century examines the concept of a Super Global Positioning System (S-GPS) providing three-dimensional navigation capabilities, and shows how it can be fully integrated into real-time battle management and dissemination to all levels of authorized users. Super-GPS increases current GPS capability, refines its accuracy, and effectively fuses it with other sensor information including navigation, geographic spectral imaging, and weather. The system uses on-board processing and fusion to provide near-real-time information availability on demand. It explores the concept of "pay-per-view" type algorithms, codes, and keys to control civilian users' access as well as resolve information distribution challenges in dynamic environments. It asserts that the tremendous advantages already provided by a space-based navigation constellation can be made even more robust, secure, precise and widely available by 2020.

Just as we had to develop "airways" for an expanded number of planes flying in the atmosphere, we will need a means to track and control transatmospheric and space flight as the use of space increases. As the boundaries between space and atmospheric travel become less distinct and as the environment of space becomes increasingly crowded, there will be a growing need for tracking and traffic control of space objects and vehicles. **Space Traffic Control: The Culmination of Improved Space Operations** describes a system employing space-based sensors to provide continuous, in-flight deconfliction of orbital space systems without operator manipulation. Under this concept, space operators in the future would have a system into which they could enter a space or transatmospheric flight plan and automatically receive preliminary deconfliction clearance on a "spaceway." A key theme in the design of this system will be increased satellite autonomy to include navigation and housekeeping functions, as well as new techniques for tracking and controlling the activities of systems in space or transiting space. The belief that space power will evolve along lines similar to air power is unremarkable in itself. The vision that asserts concrete ways to build and control spaceways is remarkable and a prerequisite for safely expanding the routine transit of space in the far future.

Weather conditions will continue to have a significant impact on many aspects of life on our planet, including military mission accomplishment. Timely knowledge of potential weather impacts can enhance decision-making capabilities at all levels. Warfighters will need near instantaneous, worldwide access to current and forecast weather conditions for a given point or area in time and space. **21st Century Weather Support Architecture** examines options in accessing integrated weather information in 2020 and an architecture to provide tailored weather data and forecast products directly to the military *and* civilian end users via the information superhighway. Until humankind is able to exert more control over the natural environment, the ability to know that environment is the dominant task. By the twenty-first century, knowing the weather on earth must be augmented by knowing the weather in space.

Space operations are in constant jeopardy of mission degradation or failure because of space weather. Capability to provide space weather forecasts and hazard alert warnings will become increasingly important as space use increases. **Space-Based Solar Monitoring and Alert Satellite System** proposes a satellite monitoring and alert system in deep space that will continuously observe the solar atmosphere and monitor solar plasma emissions, or solar wind. The system consists of multispectral sensors with on-board analysis capability to provide near-real-time space radiation hazard warnings and forecasts of radiation impact to an operations center on earth or in space for protection of satellite resources and space operations. Commercial users need this service, and this paper argues that it is a government's obligation to help provide it.

Communication and interconnectivity of other monitoring and reporting assets will be critical to sustaining the infosphere of the national security forces of 2020. Ionospheric variability, an attribute of space weather caused by solar radiation, significantly impacts ground and space-based communications. **Space Weather Support for Communications** reviews enhanced ionospheric sensing capabilities to predict and provide warning of potential communications, radar, and navigation disruption or blackout. The concept envisions deploying ionospheric sensing devices on present and future GPS and follow-on commercial satellite constellations to obtain daily, worldwide mapping of the ionosphere.

Each of these concepts can make major contributions to meeting the broad range of information needs of combatants and national decision makers in achieving national security objectives in 2020. They fuse relevant information in the continuous cycle of observation-orientation-decision making-action to create near-real-time capabilities to observe, orient, decide, and act in important areas of activity. These concepts leverage innovative application of technology developments forecast for 2020 with the inherent vantage and speed afforded by space to meet these needs. Failure to develop, deploy, and utilize such opportunities would likely cripple the United States' ability to successfully deter future conflicts or meet our objectives efficiently and effectively in those cases where conflict cannot be prevented.

Global Reach

This section addresses those things it takes to reach into space: the lift, support, and education and training aspects of space in 2020. The papers address the ability to access space and, once in space, the capability to maintain a ready, national security presence. The implications that technological advancement and enhanced space presence will have on our education and training processes are also examined. All are aspects of truly Global Reach.

The United States must have assured access to space to deter adversaries and protect the US, its allies, and intergovernmental organizations promoting regional and global security. This means placing payloads into earth orbits with high reliability, quickly and responsively, affordably, and with great resiliency (or the ability to recover rapidly from a launch or mission payload failure) even if these systems come under attack. Our current space lift capability is certainly inadequate against these criteria. National imperatives dictate developing a lift capability that will enhance our interests while allowing profit-motivated commercial exploitation and a near seamless integration of space with air.

There are few papers in the Global Reach section. Of the 15 SPACECAST teams organized to generate and refine concepts for new capabilities, only one was dedicated to spacelift. The other 14 were told to presume that inexpensive lift was available by 2020. An authoritative and high level launch modernization study was underway at the time and it was the responsibility of that study to respond to the near and mid-term the challenges of launch. But just in case that effort was unable to do so, the one SPACECAST team was directed to be as creative as possible while also emphasizing our present strengths. The SPACECAST effort developed the operational concept for an air refuelable transatmospheric vehicle originated in the Air Force's Phillips Laboratory.

Spacelift: Suborbital, Earth to Orbit, and On Orbit presents a vision of a composite aerospace wing which includes a squadron of rocket-powered transatmospheric vehicles (TAV). As envisioned, these fighter-sized airframes would be capable of placing approximately 5,000 pounds in any low earth orbit *or* delivering an equivalent payload to a suborbital trajectory to any point in the world. The concept would entail aerial noncryogenic propellant transfer from modified KC-135Q aircraft and maintenance, logistics, and ground operations compatibility with the rest of the aircraft wing. Although an experimental prototype, an X-program vehicle (nicknamed *"Question Mark 2"* in honor of the first air-refueled aircraft), may be available well before 2020, test and development is urged now. Proof of concept before the turn of the century would allow TAVs to be available in significant numbers by the year 2020. Transatmospheric vehicles, developed in partnership with commercial aviation, shrink the planet and integrate air and space.

Unconventional Spacelift grew from a mandate to AFIT to explore creative solutions and far future opportunities for unconventional approaches to space lift. How would we get into space using means that did *not* rely on traditional rocket propellants? The question triggered nearly 80 responses. Narrowing the field from 80 proposals to a handful, the paper asserts the need to explore low earth orbiting tethers, geostationary tethers and "space elevators," metastable fuels, nuclear propulsion and even anti-matter systems. Visionary today, one or more of these may provide the breakthrough that makes space access truly routine and commonplace tomorrow. We found, however, no "silver bullet" solutions.

Rapid Space Force Reconstitution is an essential element for military space operations. A change in the way we think about satellite design and launch could lead to more responsive systems and more rapid reconstitution in a crisis. Small satellite and boosters designed for responsiveness could offer the best opportunity to access space in an emergency. It is the traditional obligation of the military to be prepared to succeed, even in emergencies. Some compelling criteria for lift systems and satellite design postulated in the paper are that they be able to reconstitute lost space capabilities rapidly and with the highest reliability. Arguments for this approach to lift system and satellite design are discussed in this paper, an earlier version of which was selected by the commander in chief of the United States Space Command as the winning military space strategy essay of 1994. Its precepts and arguments can, and should be challenged, but some of the concepts it outlines deserve closer scrutiny than they may have received to date.

Global Presence requires a capability to sustain operations in a timely and effective manner. Many of today's satellites are large, complex, redundant, expensive, and cannot be upgraded or repaired except at extraordinary cost and under special circumstances. **Space Modular Systems** and common satellite interfaces complement the TAV lift concept of ready space access with smaller payloads. In this concept, a large satellite will serve as a motherboard to space modules by providing inclusive support of power, communications, and housekeeping. The modules will be small with each having distinct missions or functional capabilities ranging from imagery to communications and will be lifted individually to the motherboard. The modules and motherboard will be mated via common satellite interfaces. These modular payloads will be less complex, upgradable, and will provide national security decision makers and forces a responsive space capability. Physical connectivity to the motherboard is a beginning, replaced eventually by proliferated and distributed modules that are "virtually" or electronically connected as technology allows. The idea of small, distributed and proliferated systems is central to most of the SPACECAST papers.

An on-orbit space depot could provide the logistical support for the motherboards and their modules. In addition to depot functions the station would provide satellite refueling and debris removal. Servicing would be accomplished either through satellite retrieval or on-location servicing of satellites distant from the depot. These functions would be accomplished with orbit transfer vehicles (OTV) and orbital maneuvering vehicles (OMV). If a permanent human presence becomes a goal, provisions could also be made for a manned orbiting industrial park. Beginning as a "bare base" with the organic essentials of gravity, power, water, air, food, and fuel, such a facility could grow to allow industrial processes to synergize with the benefits of the space environment and permit spin-offs into other areas. Even so, and except for routine transit of space by humans flying TAVs, an unexpected finding of SPACECAST is that the *need* for humans in space will be marginal even until the middle of the next century. Advances in high performance computing, robotics and end-effectors, and micro-mechanical devices are envisioned as substitutes that satisfy the need for human presence. This is not an assertion that human presence in space should not increase. It is merely a description of the operating environment of 2020 as SPACECAST participants envisioned it.

Understanding is a prerequisite to doing. Hence, future space education, training, and technological enhancement of educational approaches is mandatory. As our nation extends beyond its terrestrial borders, our personnel must be educated and trained in space concepts. **Professional Military Education (PME) in 2020** provides this vision. It argues that information technology now provides the opportunity and means to change the education and training paradigm for military personnel. Compared with an ambitious view of what may be possible, today's professional military education system is episodic, requires the physical presence and movement of people to and from the site of the university, and cannot offer greatly expanded opportunities for performance-enhancing enrollment. By 2020, or well before, information technology will allow for the creation of a learning environment that is continuous, less costly, made available to the entire force, and characterized by personal networking. The model for a new approach to professional military education could be used by universities and technical training schools, both public and private, and be modified for both resident and distance learning environments.

Global Reach, broadly defined, will eventually grow to the degree that it requires a larger presence in space to be done effectively and efficiently. The military may well become less reliant on its own organic capabilities for training, research, development, and sustainment. Knowing that, commercial enterprises can become involved earlier and begin offering their services sooner. If they do, by 2020, ours truly will be a space faring nation on a basis that seems almost unimaginable today. Doing so will not be easy but it will provide vastly increased opportunities. Both the public and private sectors can gain from the vantage offered by space presence.

Global Power

Counterforce operations are those space or transatmospheric activities aimed at opposing or defending against threatening force anywhere on the planet or in space. This threatening force may arise intentionally as the product of hostile human will or it may exist naturally. By 2020, space operations could be aimed at countering both kinds of threatening force in order to truly achieve Global Power. Our understanding of space power, and with it our lexicon, must grow to embrace powerful new ideas. Just as a Global Presence and global view are essential to a Global Reach, authentic Global Power requires both vision and reach.

The United States must have the capability to protect what it values. Global power helps to provide the required protection. We may also deter marginal powers and some space faring adversaries from hostile acts both in space and on the earth's surface. This paper examines various applications of Global Power beginning with the traditional areas of defensive counterspace operations, offensive counterspace operations, and force application. In addition, the contributions that information power and microscale weather control can make are also examined. Lastly, there is an analysis of the issue of detecting and protecting the earth against asteroids that could intersect the earth's orbit.

Space forces have contributed to national security for nearly four decades. **The tremendous costs of these systems are often offset by their even greater value.** In the future, space systems can evolve to further complement and potentially replace many of the traditional elements of terrestrial forces. Indeed, the rapid development and assimilation of the capabilities proposed could fundamentally transform the character of military forces and the nature of military operations. The line-of-sight and energy advantages of space continue to offer tremendous opportunities for national security.

During Operation Desert Storm, American and Allied forces relied heavily on space presence for navigation, weather information, secure communications, and surveillance support. These and other space systems played a key role in the successful prosecution of the Gulf War. As a result of the reliance on these and the associated success, our reliance on them will only increase. Therefore, these systems will present attractive targets for the enemy and their protection will be a critical consideration in the future.

The **Defensive Counterspace** section examines a force protection platform concept as a creative potential solution to this problem of system survivability. The concept involves the development of a series of satellites designed primarily to protect high-value orbital systems. These satellites could escort the high-value orbital systems and provide protection to inhibit an adversary's ability to detect, identify, track, or destroy our space assets. They thus provide a range of active and passive countermeasures to protect US space assets.

Potential adversaries increasingly will depend on space-based assets to be their eyes and ears on the battlefield for the reception and delivery of information. Presently, the United States has the ability to negate access to some of this information only through diplomacy or earth-bound application of force. We do not have the ability to control adversarial space-based assets. **This could cost many American lives in future conflicts.** To make the adversary blind and deaf on the battlefield and allow our forces to operate inside the decision cycle of the opposition, we must take the initiative to develop the capability to control an adversary's space assets or eliminate them when and where necessary.

The **Offensive Counterspace: Achieving Space Supremacy** section describes a future space-based system that could provide timely control and exploitation of an enemy's space-based assets. This proposed system would incorporate a variety of technologies to influence enemy satellite capability. The section also describes creative methods of reducing the system's visibility to hostile sensors and maximizing its rapid deployment against any adversary's on-orbit assets. The ability to deny useful information from space-based assets to an enemy will be a key to meeting our objectives in any future conflict.

The **Force Application** section proposes various concepts to provide an increased capability to engage terrestrial and atmospheric targets with minimum risk and minimum collateral damage. These systems use global presence and global view to provide global reach and power without the accompanying increase in terrestrial presence required by other forces. Similarly, a space-based weapon's ability to attack numerous aim points precisely and in a short time introduces a strong psychological aspect to deterrence and offense. However, space-based weapons have the disadvantages of lift requirements, maintainability, as well as exploitation by the enemy. This section examines issues and proposes creative counter-countermeasures. Concepts considered in this section include hypervelocity kinetic energy, directed energy, and conventional weapons, as well as unique architectural considerations for effective weapons integration and deployment.

Knowledge is power and it should be fully utilized. In 332 BC, Alexander the Great established Alexandria as the capital of Egypt and its great library symbolized and contained all the knowledge in the civilized world. Over time, invading Romans, Christians, and Muslims controlled, burned, or pillaged the library, waging what might be described today as a form of information war. The fundamental principle of the "Alexandria Concept" is that information is power and that attacking information at its source can help bring its owner to heel. By 2020, the ability to use space to influence someone else's information, both in peace and in war, to further strategic and operational objectives is both realistic and worthy of development. **Projecting Information Power For Peace and War** proposes ways towards the effective use of information to promote stability and enhance the vitality and security interests of the United States and our partners.

The United States ought to strive for superiority in information technology to help maintain its dominant national security posture. Controlling any future enemy's access to and use of the information sphere will comprise a significant portion of the total information warfare concept. Any information warfare capability could be used in a variety of situations, from counter-information acts against recognized adversaries to the continuous benign shaping of the nascent global information sphere. Exploitation of the information sphere through the use of holographic images projected from space in support of unconventional warfare or psychological operations, such as concealment and deception, could add to the future war fighter's "toolbox." This section identifies some projected space-related technologies which could expand a commander's information utilization options, help achieve information superiority or supremacy, and thus improve the security of the nation in the coming decades.

This section also examines a **Counterforce Weather Control** system for force enhancement and identifies the necessary prerequisites for such a system. Atmospheric scientists have pursued terrestrial weather modification in earnest since the 1940s, but have made little progress because of scientific, legal, and social concerns, as well as certain controls at various governmental levels. Using environmental modification techniques to destroy, damage, or injure another state are prohibited. However, space presents us with a new arena, technology provides new opportunities, and our conception of future capabilities compels a reexamination of this sensitive and potentially risky topic.

This conceptual weather control system is developed through a three-stage predictive analysis process: conceptualize a desired end state, hypothesize the preconditions, and develop measures of effectiveness. The desired end state is limited only by imagination. For example, the capability to "bore a hole" through a cloud to allow unrestricted surveillance of an enemy target may be possible.

The difficulty, costs, and risks of developing a weather control system for military applications are extremely high. However, the potential benefits for national security could be even higher. Enemy weather modification weapons are possibilities which, like it or not, may be possible and must be considered.

Recent years have witnessed an expansion of research and discovery of objects from space that potentially may strike the Earth. New and more refined observation techniques shed additional data on the size, nature, and orbit of these objects. These objects vary in size from 10 feet to 6 to 12 miles. It is postulated that 65 million years ago the age of dinosaurs was brought to an end by the impact of an asteroid that measured upwards of 12 miles in diameter. Collisions with objects larger than a few hundred meters in diameter could threaten global civilization and as such the means to mitigate them are worth considering. To have the vision and ability to prepare to defend the planet from natural danger and not do so may be viewed as irresponsible by our own citizens.

Preparing for Planetary Defense: Detection and Interception of Asteroids on Collision Course With Earth develops its theme by initially defining the threat and discussing the surveillance of potential impactors and their orbits. It then examines ways to counter the threat through various mitigation techniques. Finally, it discusses the benefits of a Department of Defense (DoD) role in an international effort and provides some specific recommendations. Although not a traditional "enemy," asteroids are nonetheless a threat that the DoD should evaluate and prepare to defend against. The role of the military has traditionally been to operate in and expand the frontier of space. This role will remain constant as humankind stretches to new frontiers. Provisions for defense of the planet, as far away from the planet as possible, need to begin.

Operational Analysis

In this vision of space and the far future, there are constellations of opportunities. The objective of **Operational Analysis** was to provide insight into which of the SPACE-

CAST 2020 system concepts provide the highest leverage and, of these high leverage systems and their embedded technologies, which ought to be pursued first. Since an analytic model for assessing the contribution that different space systems make to the present objective of controlling and exploiting space did not exist, SPACECAST 2020 had to create one. The Air Force Institute of Technology partnered with the operators participating in the SPACECAST 2020 study to build a weighted decision-making aid. The overall goal of operational analysis was to rank SPACECAST systems and their enabling technologies in a way that was traceable and reflected the value SPACECAST participants attributed to them. As "operators" from the line units of the Army, Navy, Air Force, and Marine Corps who were culminating 10 months of intensive thinking about space and the future, the values operators expressed are consistent with what one would expect combatants to value. Even so, each SPACECAST participant is well aware of the complexity of national security decision making in a democracy and in a world of increasingly complex interactions. Thus the model presented is an aid to senior decision makers. Accepting that humans make decisions based on more factors than military utility or operational effectiveness, the rankings presented should be thought of as "raw scores" within the universe of SPACECAST systems. Seasoning the list to change rankings is not only possible, but expected. Public opinion and support, international agreements, and the global political environment should and will influence decision makers as much as considerations of technical risk, cost, and schedule. The definitions and terms used in the draft JCS PUB 3-14, *Joint Doctrine; Tactics, Techniques, and Procedures (TTP) for Space Operations*, provided the baseline for defining the force qualities contributing to the tasks encompassing military space operations.

High-leverage SPACECAST systems and critical supporting technologies clearly emerged from the model. The highest value SPACECAST 2020 systems for development are

- Creation of an integrated demand information architecture to capitalize on Global Presence and provide the kinds of information demanded by combatants and staffs for global view.

- Development of a transatmospheric vehicle for space lift and Global Reach.
- Development of a multifunctional space-based laser system for surveillance and counterforce operations for Global Power.

The critical technologies embedded in these systems that must be developed to support assimilation of those systems are

- High performance computing. Exploitation of this technology is currently being led by the private sector.
- Micro-mechanical devices. Because of the utility of systems employing this technology, it is a class of technology being pursued by both the government and the private sector. Opportunities for increased partnership may be high.
- Materials technology is another category of technology useful both to the government and the private sector. It includes classes of metals, ceramics, and carbon and ceramic composites. Although the military's needs for this technology are different in many areas than the needs of industry, it too provides opportunities for partnership in the areas of aviation, space and transportation.

Conclusion

The SPACECAST 2020 study produced many new ideas and reinforced some old ones. Its creative and critical approach to future space operations yielded new ideas. These ideas are preserved in appendices which accompany the white papers. Taken together, these offerings are infused with the awareness that by thinking about the future and preparing for it, we are better able to shape the future we desire. *It will take decades to fully exploit some of the ideas offered. By starting now, those decades are available.* Should we fail, for whatever reason, to capitalize on the opportunities the vantage of space allows, it will not be because vision was lacking. To remain a great power in the twenty-first century, our country must choose to do so. This report offers many choices on how this may be done.

SPACECAST 2020, like space itself, has provided the vantage and opportunities to make those choices wisely and well. It is founded on the concept of Global Presence and global view, building on, complementing, and significantly enhancing Global Reach and Global Power. Many of the concepts in the following pages will come to pass. The important questions are who will acquire these capabilities, how will they be utilized, and for what purpose. The United States is in a position to help shape the outcomes and the nature of the planet in the year 2020 and beyond. The vantage and opportunities offered by space are the means to do so. We seek **to operate in the transatmosphere and space to promote stability and to enhance the vitality and security interests of the United States and our partners.** The investment, intellectual as well as financial, in the ideas which address the issues confronting the exploitation and control of air and space and the technologies to make them a reality should begin now. SPACECAST 2020 provides the beginning for doing so.