# NEW WORLD VISTAS
## AIR AND SPACE POWER FOR THE 21ST CENTURY

SPACE APPLICATION VOLUME

*This report is a forecast of a potential future for the Air Force. This forecast does not necessarily imply future officially sanctioned programs, planning or policy.*

# Executive Summary

## Military Foundations of Space Application

Space is the ultimate high ground. It is substantially different from air, land and sea because operations in space are truly global by nature. Space is fundamental to achieving global presence, global reach, and global force. The challenge in this new age is how to efficiently manage our space assets consistent with rapid commercial technology evolution and limited defense budgets.

Modern day thought about the utilization of space stands where our thinking about the airplane stood at the early stages of World War I - as scouts or messengers. We must go back to first principles, to tie this new warfighting medium with its remarkably new, often counter intuitive operating environment into a set of fundamental warfighting principles. The need for information dominance of the battlefield and the critical nature of winning at information warfare leave us no choice.

As world population and economic pressures grow, political and market boundaries blur, the information explosion accelerates, capability growth and technological advances in commercial space abound, and supra-national entities take on a growing role on the geopolitical scene, the United States freedom of action to operate in space will be severely constrained. Future military space planning must recognize that access to space will be widespread and adversaries will also use it for their purposes. Extremely capable space systems and their products, until recently protected by strict security and trade restrictions, will be available to all buyers on the commercial market. The producers, owners and operators of these systems will include domestic and foreign governments and corporations as well as alliances and multinational consortia.

We are witnessing a revolution in military affairs. It is the recognition that information dominance of the battle space and winning at information warfare are key to the success of joint and coalition warfare. In fact, information warfare may be more effective in collapsing an enemy than traditional military force. Space systems enable maintaining a high tempo of combat operations day/night and in all-weather. The product of information dominance is an integrated and synchronized force with decisive combat power which can be applied at the desired time and place, rapidly overwhelming the enemy with minimal friendly losses or collateral damage. Critical to making this happen is space systems support to the warfighter, which produces a significant force multiplier effect.

The need for the integration of all space assets to provide the force multiplier requires a paradigm shift from the old way of thinking about space. For years the military has considered space in the context of tasks like communications and navigation, or mission areas such as space control and force enhancement. This view of space utilization is channeled by these oversimplified but convenient definitions. We need a “system of systems” approach, rather than the stove pipe single mission approach of the past. This overarching system must include future dedicated military space capabilities and civil, commercial, national and international assets in a complementary way.

The time tested principles of war give us new insights about the use of space systems in future warfare. These principles are still applicable, and their implementation is enhanced by the new dimension of space and its impact on terrestrial warfighting forces. In fact, a review of the functional areas and the principles leads us to several key drivers that need to be stressed in any future space architecture:

Changing of current technology push to user pull focus

Conversion from independent missions to missions integrated with terrestrial forces

Evolution of military doctrine based on appreciation of the contributions of space

Understanding the utility of space by the land, sea and air combat elements

Operation of space systems that can be maintained with minimum manpower

Dramatic reduction in cost through more effective cost control.

## Future Vision of Space Application

The contribution of space systems to information-based warfare has become central to military operations. Space based sources and transmissions are crucial for the "information" in information-based warfare, so that U. S. forces can respond to changing operating environments and evolving threats. A huge mass of data is available from sensor systems, and many different sources, and this data needs to be processed into information useful to the warfighter. He needs just the right information at just the right time, day/night and all-weather, to provide situation awareness, threat assessment, targeting, and battle damage assessment. This means information fusion for true global presence. Total awareness of the operational environment will become a necessity for global presence and with it the knowledge of who and where the enemy is and where the friendly forces are. The end goal will be the omnipresent view of the battle field in real time in all weather. It will require continual world wide coverage of any location at militarily useful fidelity, in addition to exquisite fidelity of special areas for technical intelligence.

The U. S. needs to be prepared to fight wars in an environment in which the enemy has access to a high level and quality of battlefield navigation, weather, and situation awareness data. In this new environment dominance of information-based warfare requires control of space. We must develop and field the capabilities to protect U. S. and allied interests in space and to deny our adversaries similar useful support through investment in capabilities to deceive, manipulate and destroy. Passive and active protection measures must be taken for friendly space assets.

With continued proliferation of missile technology and weapons of mass destruction throughout the world there will be a growing threat not only to U. S. forces overseas and our allies, but also to the territory of the United States. This threat could be from ballistic missiles or cruise missiles launched by large or small powers who may not be deterred by traditional means. Surveillance and warning of these events and battle management can be effectively accomplished with space based sensors, and defense against these threats may be effected by space based weapons.

For the U. S. to sustain its superpower status it will become necessary not only to show global awareness through space based information, but also to be able to project power from space directly to the earth's surface or to airborne targets with kinetic or directed energy weapons.

Thus the application of space in future military operations will facilitate global presence, knowledge on demand, space control and power projection. This is possible with the continued improvement of space systems operations with reduced manpower at lower cost, design of spacecraft with modern low cost techniques, adaptation of innovative architectures incorporating small distributed satellite systems and above all the development of affordable access to space.

## Conclusions and Recommendations

A general assessment of the future world environment and technological developments leads to conclusions and related recommendations for action by the United States Air Force. The recommendations are provided in the context and on the assumption that the Air Force will be the executive agent for DoD space matters and that the Air Force is prepared to assume the responsibility of supporting all military customers and national needs as required by the National Command Authority.

The overarching conclusions are:

- Successful integration of space with our information based warfare capabilities will be critical to maintaining information dominance of the battle space and winning at information warfare
- The proliferation of commercial space systems gives our adversaries unprecedented access to militarily significant capabilities that will reduce the information advantage our forces presently enjoy
- The Air Force must welcome and capitalize on capability growth and technological advances in commercial space in the fielding of militarily useful systems
- The need to disrupt, deny and influence the enemy's perception of the battle space while assuring our use for information based warfare is essential, and thus space control takes on new significance in this environment
- In the long term space systems will be well suited to project force from space to targets anywhere on earth
- Some near term program activities could limit efficient implementation of the future options envisioned in this report, and the Air Force should establish roadmaps to correct this situation

The Space Application Panel arrived at the following specific conclusions and recommendations:

## Information Warfare

**With the proliferation of commercial information sources the management of information and influence of the enemy's perception of the battle space through information warfare will be the dominant factor in deterring and winning future wars. Collection, fusion, analysis, disruption, disablement, denial and tactical and strategic deception of battlefield awareness are warfighter functions that must be integrated into our joint warfare operations to attain and maintain information dominance.**

Recommendations

1. The Air Force should support integrated but dispersed processing and fusing of intelligence and battlefield awareness data to provide our forces the advantage of faster and more expert use of available information.

2. The Air Force should advocate the creation of a joint warfare information function to be in charge of all information that influences the outcome of the battle.

3. The Air Force should take the lead to define the space system requirements to support offensive and defensive information warfare.

## Commercialization

**Capability growth and technological advances in commercial space, especially communications, positioning, environmental monitoring and reconnaissance will far outpace government efforts in many areas. Customers, including individuals, corporations and nations, will have unprecedented access to militarily significant data that will reduce the "information advantage" our forces enjoy presently. These systems will be comparatively robust, secure and accessible as unique military systems.**

Recommendations

1. The Air Force should develop specific road maps for the exploitation of commercial communications, positioning, environmental and reconnaissance systems that assure availability of these assets from day to day peacetime operations through major regional conflicts.

2. The DoD must develop, document and implement an approach to positively incentivize commercial providers of space-based goods and services to do business with the government and to add military-unique functionality to their commercial systems to give the DoD incremental advantage at lowest costs. The key is to establish relationships with commercial providers early in their development cycle.

3. The Air Force representing DoD should establish an integrated product team to: a) maintain a continuous assessment capability of commercial space systems and their supporting communications and ground infrastructures which may be potentially useful or threatening to the United Sates; b) act, or enable a clear path to higher authority to recommend action, as a result of these assessments; and c) infuse commercial technology/operational capability awareness throughout the relevant planning, acquisition and operational elements of the USAF.

4. The Air Force, representing the DoD, should establish much more effective mechanisms to promote regular dialog, alliances, and investment to interact/participate with US commercial

space enterprises in the areas of: a) standards definition, b) bandwidth/frequency allocation, c) joint specifications definition, d) joint development, especially for low-demand but cutting-edge technologies important to the US government, and e) operational control/access/privileges during times of declared national emergency.

## Distributed Satellite Systems

**Advances in computers, sensors, and materials permit establishment of large constellations of interlinked satellites, whose integrated output will give global, real-time coverage. Reducing range to target and constellation altitude reduces satellite size and cost of coverage. The advantages of such systems have already been embraced by the commercial space industry as the way ahead.**

Recommendations

1. The Air Force should create a road map which recognizes the twin realities of inexpensive, single-sensor, small satellites and distributed processing and communications enables a significant advance in reconnaissance, surveillance and battle awareness.

2. The Air Force should begin development of a suite of small satellites to complement the evolving national sensors for timely battle field reconnaissance.

3. The Air Force should focus, where appropriate, on hybridized, distributed architectures, employing on-board processing, storage and cross-linking now being incorporated in commercial distributed space system designs.

## Communications

**Future multimedia communications systems will provide broadband communications to any person and to any point on the globe. These universal capabilities, whose transmission media and routing will be transparent to the users, will be available commercially and will provide reliability, flexibility, capacity, security and quality of service that will be difficult to match with government owned systems. Connections to other elements of the information systems may be more limiting than the communications systems themselves. Rapid expansion of use of available bandwidth due to advances in processing and antenna technology will significantly improve communications available to mobile users.**

Recommendations

1. The Air Force should develop and implement a global terrestrial and satellite communications architecture whose infrastructure would be built upon both DoD and commercial capabilities.

2. Published standards should be established for future communications architectures to be distributed, flexible, scaleable, fault-tolerant, reconfigurable, and transparent to the users.

3. The Air Force should advocate the practice that DoD users who can reside on fiber optic arteries should be required to do so, and the warfighters given priority for satellite communications for mobile and tactical users.

4. Truly unique military survivable and enduring satellite communications requirements should be identified and implemented through a combination of unique military space systems, complemented with appropriate non-military systems and technologies.

## Global Positioning, Time Transfer And Mapping

**The current Global Positioning System (GPS) using the P(Y) code meets the present basic requirements of the military for precise position location and time transfer. The GPS employs the Defense Mapping Agency WGS 84 world wide grid permitting maps and data, such as derived from reconnaissance, to be expressed in a common position language for use as needed by the warfighter. The GPS user receivers when properly designed and integrated with Inertial Measurement Units provide highly accurate navigation in three dimensions to fast moving vehicles. Such military receivers are resistant to jamming especially when equipped with self-nulling antennas. The C/A code is available to all GPS user receivers. It thus can be used by potential enemies unless jammed in the battle area. The use of the Selective Availability concept has reduced international acceptance of the GPS for such civilian uses as commercial air navigation and proliferation of differential GPS has diminished its usefulness.**

Recommendations

1. The use by the DoD of selective availability (S/A) to reduce the accuracy of the C/A code position location should be discontinued.

2. Methods and systems should be developed to assure U. S. and allied forces positioning information over limited battle areas while denying similar quality support to the enemy forces without seriously affecting essential out of area civil and commercial operations.

3. In the long term the Air Force should aggressively support advanced technology using space systems leading to consistent positioning and mapping accuracies on the order of 30 centimeters. Such space systems should support relative position accuracies in the centimeter range.

4. Time transfer to accuracies of a nanosecond or less should be an integral part of any global positioning system to provide synchronization in future communications and information systems. The highly accurate temporal and spatial information should be assigned eventually to all information and serve as the basis for the storage and retrieval of this information.

## Observation And Battlefield Awareness

**The information that can be obtained from space-based sensors integrated with airborne systems and geopositioning capabilities offer the potential for revolutionary changes in the combat environment and employment of forces. Future U. S. commanders must have near real-time, all weather information on the location and status of friendly and hostile forces; locations of moving ground, sea and airborne vehicles, and space objects; current and future projections on terrain and weather; nearly instantaneous threat warnings; and the ability to share this information with all levels of command.**

Recommendations

1. In order to exploit fully the available technology to the warfighter's advantage, the Air Force should be a full participant in planning, developing, acquiring, launching, and operating of U. S. military and intelligence space reconnaissance assets.

2. Aggressive investment should be continued on methods and technologies to extract information from data at all points of the process. The focus should be on rapid, smart systems to reduce the dependency on humans wherever appropriate.

3. A user-needs driven attitude should prevail within the information acquisition community and a seamless interface should be established with the intelligence community to ensure sharing of data bases, and commonality of objectives. System, and architecture definition and implementation with full warfighter input, recognizing the need for balance among all users, technology and attendant costs should be pursued.

## Space Control

**Because of the general recognition of the importance of space systems to successful combat, we must assume our space systems will be threatened and it will be necessary to limit an adversary's access to space capabilities. Survivability requirements and techniques, against both hostile and natural threats, are as important for space system acquisition and operations as for terrestrial systems. A spectrum of offensive capabilities ranging from temporary disruption of hostile ground operations to satellite negation should be available to our forces. Local control of an enemy's environment, through disruption of his communications and information infrastructure, without global disruption will be an important tactic.**

Recommendations

1. The Air Force must ensure that its most valuable space assets are safe against attack by third world nations, rogue groups and major powers.

2. The Air Force must develop and field a capability to deny, degrade, disrupt, exploit and, if necessary, destroy the use of space assets by others, globally or in a local region.

3. The Air Force should continue to study the potential threat posed by space debris and the necessary techniques for its surveillance, mitigation and removal, if necessary.

## Force Projection

**Future space systems will be well suited to project force against air, land and sea-based targets anywhere on earth. Precise delivery of munitions, directed energy or electronic warfare on virtually any target, heavily defended or not, within minutes or hours of tasking and with minimal risk to U. S. forces could have a decisive impact at all levels of conflict.**

Recommendations

1. The Air Force should broaden the use of space to include direct force projection against surface, airborne, and space targets.

2. The Air Force should define and develop microwave and laser space-based weapons for tactical and strategic applications

3. The Air Force should develop space munitions capable of precision strikes against surface and airborne targets.

## Access To Space

**A number of commercial projects are underway to develop small and medium launch vehicles and there is strong competition from the international providers of large vehicles. Full integration of space capabilities into routine military operations will only be realized when launch is no longer a significant operational constraint. Although expendable vehicles may continue to provide limited, unique services, over time, dramatic improvements in cost and capability will come through an operational reusable system for all orbital regimes. The same technologies and operational concepts needed for reusable space launch will support transatmospheric systems that could provide presence anywhere on the globe in under two hours. Military human roles in space may evolve in time for on-orbit support of complex systems.**

Recommendations

1. Continue to support the NASA reusable space launch technology efforts within the Air Force laboratories including the X-33 technology efforts but emphasize operability and reliability.

2. Continue to support a hypersonic technology development program with the objective of readying the technology base to support the development of future transatmospheric vehicles.

3. In conjunction with NASA continue to investigate the utility of humans in space for military operations.

4. Place emphasis on developing high specific impulse, high thrust propulsion technology to support development of future launch and orbital transfer vehicles.

## Modeling, Simulation, And Analysis

**Modern and future tools for connecting widely distributed centers of MS&A excellence and the explosive growth of virtual reality concepts and technologies will make it possible to conceive ideas and test them with technology, hardware and humans in the loop and then smoothly transition these experiments, demonstrations, and exercises into operations with unprecedented speed at heretofore unrealizably low costs. This is particularly true for the utilization of space systems. The Air Force should exploit these opportunities and the substantial investments in the National Test Bed to underwrite the development of doctrine, lower the costs of modernization, and train the joint warfighter.**

Recommendations

1. The Air Force should quickly press ahead with a joint implementation of a DoD “virtual test bed” for space technical concepts and warfighting conops.

2. The DoD must eliminate the boundaries between MS&A for modernization support and MS&A for operations support. A seamless process which includes the joint warfighter in acquisition MS&A and the acquirer in operations support MS&A will be essential for rapid and cost effective reconfiguration of systems of space systems.

3. The Air Force, in conjunction with the Army, Navy, Marines, and others, should exploit virtual reality implementations to make space support more readily understandable to the political decision maker and the warfighter by allowing individuals to immerse themselves in the space-terrestrial operations continuum.

## Space Applications to Warfighting and Related Issues

We must view our total force posture as an integrated warfighting machine of various space systems, aircraft, UAVs, ships, submarines, vehicles, ground stations and communications links. To reach this goal, the physical hardware and software must be defined, designed, built, tested and deployed. Thus it is necessary to examine the impact of the postulated future vision on individual elements and systems. The missions considered are: missile warning and space surveillance; global reconnaissance; communications; global positioning; time transfer and mapping; space control; and force projection. Each of these missions has a heritage from the past and their systems represent a substantial investment of funds, talent, infrastructure and operational experience. Current reality, projections for the future and the necessary changes to improve effectiveness and affordability generate a number of issues that deserve special examination. They are: space launch in the 21st century, use of commercial capability, international space developments, survivability of space systems, distributed space systems, and human role in military space applications. All of these mission and cross cutting issues are addressed by individual papers written by the various members of the Space Application Panel.

# Abstracts of Issue Papers

Printed in Chapters 4 and 5

## Imagery Reconnaissance and Battle Field Awareness

The USAF will be aggressive in working out an appropriate role in the U. S. dominance of the high ground of space not only for combat, but also for crisis surveillance of potential battlefields. The USAF should adopt a charter and vision which at least incorporates the following:

- A system-of-systems to collect, analyze, archive and disseminate information of importance to the warfighter. This should include at least weather, maps, imagery of possible battlegrounds, condition of roads, lines of communication, weapons types, precise location of friendly and hostile forces during combat, and numbers, readiness and organization structure of the probable adversary.
- An array of collectors, including manned aircraft, remotely piloted vehicles with loiter capability , with all-weather sensing capability, and either a permanent high orbit long-dwell capability, a constellation of single-function small satellites, or a launch-on-demand tactical satellite system with all-weather imaging capability to supplement and enhance the coverage of current systems.
- An open architecture to permit easy incorporation of technology advances in collectors, data storage and transmission, including all-source fusion methodologies, algorithms, techniques, and automatic and/or analyst-aided exploitation decision support systems as they become available, proven and affordable.
- An inherent ability to deploy the forward elements of the system to any part of the world on short notice and to be ready within minutes to pass desired information from all current and archival data bases to the deploying troops, systems and smart weapons.
- A strong and well-funded team to design, develop, acquire and operate the system with suitable assignment of responsibilities among the warfighters, the developers, and the global communications infrastructure.
- A policy of cooperation with commercial developers of systems and subsystems to ensure conformance with standards and availability of data throughout the development cycle, importantly including USAF understanding and potential denial of commercial imaging data to enemies or their probable allies.
- A seamless interface with the intelligence community to ensure sharing of databases, commonality of objectives, and straightforward cooperation during any transition from peace to crisis to conflict.

The Air Force must develop and learn to use effectively the triad of manned aircraft, UAVs and satellites for synergistic as well as complementary intelligence. The Air Force must move military user-level processing, fusion and exploitation down the chain from the centralized exploitation resource of a few ground stations and a few exploitation centers to the maximum dispersal and availability of archival information consonant with advances in computer distributed storage, processing and exploitation support and with the users' needs, including direct downlink to the battle area as appropriate. The USAF must commit to provide this information in the form desired by the user and in time for him to benefit from it.

## Missile Warning and Space Surveillance

We now have a missile warning system based on radars and satellite short wave infra red (SWIR) sensors. The Defense Support Program (DSP) satellite missile warning system is the primary element but is based on decades-old technology using largely single band SWIR detection. It uses linear arrays of detectors scanning at a relative low speed with large pixels designed to produce adequate signal to noise ratio against large strategic missiles. Their main weakness is the scanning delay between revisits, which cause the system to miss transient events and take tens of seconds to establish tracks. Offsetting this is the Talon Shield ability to integrate the outputs of several satellites for stereo track reconstruction and the use of lower thresholding, which makes these satellites effective against order of magnitude smaller theater missile signatures and provides more accurate and timely tracks.

The Strategic Defense Initiative (SDI) with its initial objective of countering massive ICBM raids resulted in IR satellite designs using large focal plane arrays either scanning or staring with massive on board signal processing and computation. Attempts to use this approach for a DSP follow on has not met with acceptance. The present plan is a Space Based IR System (SBIRS) that contains a high altitude component in GEO and HEO orbits, a LEO flight demonstration system, and, assuming a year 2000 decision to deploy is made, a low element in LEO. The low altitude element will have sensors that could search below the horizon for missile launches as well as visible and MWIR sensors to track reentry vehicles and other space objects above the horizon. There is the nagging question of the need in the long term for both GEO and LEO systems since it appears both the missile warning and the midcourse tracking requirements of BMD could be done from LEO. The principal stumbling block with the LEO system is demonstrating the MWIR and LWIR capability to track RVs and space objects and the control of a relatively large number of satellites with an efficient satellite control system using minimal manpower.

The present space surveillance system is comprised of a number of ground sensors including radars and optical devices, some of which are in the United States and others are at foreign bases throughout the world. The optical devices include imaging, photo/polarimetric and conventional telescopes using electronic image tubes. The data from these devices are fed into Cheyenne mountain in Colorado Springs where orbital parameters are calculated for each of the cataloged items and sensor tasking is prepared and sent out to allow update of the space catalog.

The radars were generally built for other purposes and have inadequate calibration for this task. The optical sensors have marginal intrinsic resolution and dated focal plane technologies. Both are supported by dynamic models based on inadequate physics that have been ported from earlier computers and advantage is not taken of modern computer architectures or hardware. The result is an expensive and inaccurate surveillance system that is in need of change. In the long term, a space surveillance capability will be needed to search for objects that are more numerous, maneuvering, stealthy, and potentially hostile.

## Communications

The communications capabilities of the future will include global person to person connectivity, high speed digital data, voice and multimedia, direct access to vast reservoirs of information, and enable virtual reality, computer simulation, rehearsal and event execution. These universal capabilities, whose transmission medium and routing will be transparent to the customers, will be available commercially and will provide reliability, flexibility, capacity, security and quality of service. The rate of technology changes will make it difficult to match these capabilities with any government-owned systems. There will be an explosion in data transmission capacity, made possible by major advances in fiber optics, microprocessor and antenna technologies, that will have a profound effect on doctrine, planning, tactics, organizations and where various functions are performed and by whom.

Major changes must be made in space communication assignments with respect to the current Milsatcom channel allocations. Those users that can reside on fiber optic arteries must be required to do so, freeing the capacity on orbit for use by the mobile, tactical users. There is a pressing need for a DoD global terrestrial and satellite communications architecture whose infrastructure could be built upon both existing and planned DoD and commercial capabilities. This architecture should embody the essential features of any architecture, i.e. seamless, open operating environment, "user-pull", multimedia, scaleable and multi-level security/trusted systems and be distributed, flexible, and reconfigurable. The infrastructure for this architecture will include commercial and DoD communication satellites in different orbits, in different frequency bands that are interconnected by cross links.

Massive on board signal processing should be a major factor in the design of future communications satellites to improve the signal to noise ratio and effectively increase the power output and ameliorate the power aperture problem for the mobile, tactical users with small antennas. This leap in processing capability will enable communications 30 to 40 dB and possibly greater, below the noise level, permitting users to operate on top of each other without interference.

There will be an ever increasing demand and competition for frequency spectrum, that will require wide use of frequency-reuse technologies and procedures, i.e. large numbers of simultaneous spot beams with extraordinarily small footprints, usage of higher frequencies (millimeter, infrared, and optical wavelength), etc. Soon one will be able to communicate via polyglot computers that will translate and provide language error correction for duplex communications with most nationalities in the world.

## Global Positioning, Time Transfer and Mapping

The horizontal accuracy of the current Global Positioning System (GPS) was specified as 16 m and the time transfer accuracy as 100 ns. Actual performance in military user equipment has exceeded the specified performance by a factor of about two. Special civilian applications have developed higher relative accuracies. In real time relative position accuracy using ground reference receivers (differential GPS) can provide accuracy of better than 1 m. Post processing for surveying purposes yields accuracies of relative locations to 1 mm for each 10 km.

The GPS currently broadcasts two sets of signals - the C/A acquisition code and the P/Y encrypted military precision code. The C/A code is available to all users, military, civilian and commercial. The GPS with the C/A code is revolutionizing the movement of goods and people through out the world as well as improving world-wide digital communications, etc. By the same token, unless steps are taken to deny its availability to an enemy in combat areas, it can be used against the U. S. and allied forces in time of war.

An attempt was made by the Air Force to reduce the accuracy of the C/A code by deliberately introducing errors, a condition called Selective Availability (S/A). Differential GPS developments and wide area augmentation programs have essentially nullified the utility of S/A. In addition, S/A has reduced international support for the adoption of the GPS by the ICAO for world-wide aircraft navigation.

The anti-jam capabilities of the current GPS receivers depend on many factors, such as the signal strength at the receiver, the receiver design, the use of the C/A code, and antenna design. The use of the P/Y code and self nulling antennas provide a more robust system for the military. The P/Y code is broadcast on both the L1 and L2 frequencies, while the C/A code uses only L1. Since only the C/A code is generally available because it is not encrypted, the denial of the GPS to an enemy by jamming the L1 frequency use in the battle area is feasible. Such jamming may affect civilian use of GPS in peripheral areas requiring use of back-up navigation systems in the affected regions.

In the future many technical opportunities exist to improve the accuracy of information to the receiver. The signal strength at the receiver supporting the P/Y user should be increased substantially to further improve resistance to jamming. Cryptographic security can be improved by electronic key distribution. In the long run, overall system accuracy should approach 30 cm in three dimensional position, system time and time transfer accuracy will be 1 ns. The net result is mapping and target coordinates with highly improved accuracies allowing operations such as passive weapon system precision delivery against fixed targets with no requirement for terminal homing, more accurate reconnaissance and surveillance, Category III aircraft landing in unprepared fields, air-to-air refueling under all visibility conditions, and improved coordination of joint and combined operations.

Technological opportunities for improvement in future satellite navigation systems are available through: satellite and constellation design; receiver and antenna designs; as well as by improved integration into user systems. System designs which easily allow technology insertion will lower evolutionary costs and provide more robust capabilities.

## Space Control

The totality of US spacecraft in orbit twenty to thirty years from now, military and commercial, together with their ground-based control nodes and launch sites will form a high value element of the national military capability. As such, it is likely to provide a tempting target set in the times of crisis, as well as a target of opportunity for rogue nations or terrorist groups intending to maximize the political and publicity benefit of tweaking the tail of a superpower. During the time period of interest, there will also be constellations of spacecraft operated by other nations and international consortia. Adding to the complexity of the situation expected to exist 20-30 years from now, is the likely presence of several, if not many, larger, manned space stations and space power stations. It may be in the national interest of the US to develop and deploy capabilities to disrupt, degrade or even destroy the space assets of adversaries with great precision and discrimination while also having the capability to protect U. S. national security and commercial assets by passive and active means.

The issue of space control—the sum of defensive operations to protect US military and commercial assets and offensive operation against adversaries, will require continuing attention to the survivability of space systems (and other space nodes) on the one hand and the capability for discriminate attack, electromagnetic or physical, on hostile space assets.

Total protection of space assets against a determined and technologically sophisticated adversary is difficult. However, a whole host of technological solutions currently exists which can, at least in part, protect space systems against cheap shots. The challenge is not to allow these technologies to atrophy or be forgotten during this post-cold war era, so that, at all times the nation's most valuable space assets are appropriately protected against physical and electromagnetic threats.

Commercial systems, current and particularly future systems such as Iridium, Odyssey and Teledesic, have inherent survivability of the space segment because of the numbers of spacecraft involved, excepting attack on the ground control nodes or nuclear detonations in space. A modest effort in selected survivability enhancement may be warranted for these systems as well.

Physical, electromagnetic, and laser attack as well as jamming of hostile space assets is currently technologically feasible and will become increasingly so as technology is developed. Space interceptor technology is well developed now and is likely to become increasingly affordable. Space surveillance capabilities and integration of several weapons system to provide the nation with an integrated capability for negation of spacecraft while avoiding collateral effects is likely to be the principal challenge.

The saturation of orbital positions at synchronous orbit, for example, is almost upon us. The physical and electromagnetic interference problems affecting space systems will become an issue, unless care is taken through international agreements to establish "rules of the road," zones of avoidance/exclusion, etc.

The launch rates and staging events to create the constellations of the future will likely drive up the debris population to the point that the probability of physical collision may exceed the probability of a mechanical or electronic failure on a spacecraft. This will require the rigid control of debris production and also the development of debris clearing procedures.

## Force Projection from Space

In the next two decades, new technologies will allow the fielding of space-based weapons of devastating effectiveness to be used to deliver energy and mass as force projection in tactical and strategic conflict. This can be done rapidly, continuously, and with surgical precision, minimizing exposure of friendly forces. The technologies exist or can be developed in this time period. The resulting capabilities would include denial of air supremacy at will, defense against ballistic missiles, and ECM/ICM on demand, and could radically increase the cost-effectiveness of the US forces in future conflicts.

A first option for force projection from space would capitalize on advances in large, lightweight antenna technologies. These would result in antennas many hundreds of meters across, which will enable space-based electro-magnetic weapons with very high effective radiated power. These weapons would project very narrow beams with extremely high power density on airborne, surface, or space targets. A single spacecraft in GEO would suffice to continuously cover an entire theater with one beam, or form a number of beams to localize its effect within many footprints of only a few miles diameter each.

The energy density in these beams would greatly overpower and incapacitate sensors, receivers, and unprotected electronic equipment for extended periods, or burn them out. In addition it could provide surgically precise and overwhelming jamming or spoofing on demand, as well as introduce network saturation, disruption, and computer interference.

A second option is space based high energy laser weapons, which will become much more attractive in the future as a result of new technologies, such as 20 meter thin film mirrors used in conjunction with phase conjugation correctors, and lowered cost of access to space. These advances will enable lasers with reasonable mass and cost to effect very many kills compared to current concepts, and therefore they could be utilized against a large number of high value surface, airborne, and space targets. These laser weapons would be highly effective against strategic or theater ballistic missiles, and have a much more favorable cost-exchange ratio than previously considered concepts.

The commercial sector, responding to market forces demanding clean and inexhaustible energy, may develop megawatt-to-gigawatt level microwave beam power transmission systems in orbit, with several lower-power developmental systems. These could be adapted to beam large amounts of RF or laser energy to the space-based force projection weapons. Alternatively, dedicated power beaming systems could be built by the Air Force on the ground or in space. A power beaming capability would provide virtually unlimited power to space weapons, as well as greatly increase their delivered energy and useful life.

A third option for force projection from space can be created by recently introduced technologies that would permit extremely accurate delivery of long rods from space rapidly to anywhere on earth on command. These munitions would be precision guided and arrive at hypersonic speeds, penetrating hundreds of feet deep to destroy hardened bunkers. Alternatively they could home in on surface armor, aircraft such as AWACS, and other high value targets, also with complete surprise and devastating effectiveness.

## Launch in the 21st Century

Today’s expendable launch vehicles are derived from the ballistic missiles of the 1950s. All these vehicles require substantial on-pad time to check out the vehicle, ranging from 50 days for the Atlas to 110 days for the Titan IV and call up time to assemble and check out the vehicle at the launch base ranging from 98 days for the Delta to 180 days for the Titan IV. The Air Force would like the on pad time to be no more than 3 days and have the payloads shipped ready to launch as encapsulated payloads that conform to standard interfaces. These are all achievable objectives of a redesigned expendable launch vehicle with today’s technology.

The Air Force is currently pursuing the Evolutionary Expendable Launch Vehicle (EELV) program. The concept is to replace the existing ELV fleet with a single family of expendable launch vehicles with common subsystems, and to achieve high reliability, low cost and improved operability. If the EELV program is continued to completion, it undoubtedly will be the expendable launch vehicle of the next twenty to thirty years.

Besides the long preparation times, these vehicles are expensive to procure and to operate. Typically the cost per pound for US launch vehicles is on the order of 4500 $/lb to LEO, and 10,000 $/lb to GTO, and 14,000 $/lb to GEO. The high cost of access to space has slowed the development of both commercial and military space. While the EELV has the goal of reducing the cost, order of magnitude cost reduction is only possible through reusability.

NASA contracted studies call for developing a full-scale conceptual design as well as developing a subscale Single Stage To Orbit (SSTO) reusable vehicle that can demonstrate the feasibility of the concept. In parallel critical technologies are being developed. The key issue is whether the technology can support true reusability, that is, refly with the minimum of servicing and not require recertification in the manner the Space Shuttle does. If this can be achieved a major part of the military space program, namely the medium class payloads, will probably be launched by the SSTO.

A key item that will have to be developed to support the future operations is the orbital transfer stage in that most military satellites are in orbits higher than LEO. If this stage is expendable it will add appreciably to the cost of operations. On the other hand if this stage returns to the SSTO and is recovered and returned to earth it may provide for lower cost operations if the infrastructure to support the recovery is not too costly of an investment.

Transatmospheric vehicles will ultimately come of age and be capable of carrying surveillance and strike missions anywhere on the globe in times measured in a few hours or less. These vehicles will be expensive and few in number, but their capabilities will make them a vital part of the future Air Force global capability.

The future of the transatmospheric vehicle lies with the enabling technologies which span material sciences and new propulsion systems, advanced passive and active thermal systems and high speed computational capabilities needed to control and configure the vehicle. Considering the scope and the needed progression of these technologies, a practical and operational useful transatmospheric vehicle is probably beyond the time frame of this New World Vistas Study.

## Use of Commercial Capability

The current explosive growth of commercial digital systems for broadband communications, information and entertainment signals a rapidly increasing gap between these commercial systems capabilities and that of our military and intelligence communications and information systems. The development of these systems in the context of a business and consumer-driven market( high volume/ low unit price) ensures widespread global access and use to these capabilities.

In parallel to this remarkable revolution in information technologies , space missions are also becoming more financially appealing to the commercial sector. There has been a resultant increase in the amount of high resolution imagery, worldwide "cellular-type" communications, and commercial space-lift capabilities that are granting access to space for more and more nations. "Commercial Space" is simultaneously coming of age with "Information Warfare.

In the near term, it is clear that the relative benefits of this revolution will fall disproportionately upon our enemies in that access to worldwide advanced communications, computer processing and information and surveillance systems, previously denied due to the barriers of high entry costs or infrastructure deficiencies, will be assured. By the end of this decade, consumer broadband communications channels, desktop supercomputing power, processing software and widespread information sources, such as imagery and positioning, will be ubiquitous. Computing power in teraflops will be available on the desktops. Worldwide broadband communications will use direct broadcast satellites and new communications satellite constellations, such as Iridium. Proliferated positioning systems, such as commercial applications of GPS and GNSS, commercial imaging satellites, such as Eyeglass, wireless communications (28Ghz), and fiber optic communications networks are examples of the near future reality.

The US military can benefit from the commercial industry's profit-driven thrusts to reduce costs and streamline development costs for their space systems. This will be reflected in lowering DoD R&D costs, access to greater systems capabilities at lower costs and increased overall system robustness through efficient parsing of requirements between commercial and military-specific systems.

In order to reach this new world, the DoD must change the way it does business with commercial developers. New relationships must be built around greater interaction of DoD and industry partners early in the development cycle.

## International Space Developments

The increasing worldwide availability of space technology and services applicable to military space systems portends a future in which military access to space is affordable, broad, and brokered through many global institutions. The development of appropriate and effective US space policy and the associated national security space system architecture must accommodate the internationalization of space as it significantly affects US military advantage from space. One of the more striking observations is the growing influence and probable dominance of the international commercial sector. Most of the international decisions affecting space development, including that of US military space, will be governed to a large extent by economic and business considerations.

The future of international space will be affected by, among other things, technology proliferation, the increasing influence and military utility of commercial space, increasing opportunities to access space to support foreign national security, and growing utility of space by foreign militaries. This is likely to lead to the enhancement of conventional foreign military forces, increased threats to US and allied space forces and a reduction in the global market influence of the US space industry.

The diffusion of space technology and related applications worldwide will continue unabated between friends and foes alike. This has fostered a more pervasive global understanding and exploitation of the commercial and military utility of space. Facilitating this process is a maturing international commercial sector that provides services via space and which has the ability to respond more quickly to changes in market demand and profitability than traditional military space programs. In addition, there are new players and their relationships to US sovereign interests may not be singular and stable over current planning horizons. The traditional roster of nation-state players must be reconsidered to reflect the geographically dispersed international commercial consortia, multinational corporations, allied coalitions and international criminal organizations. These new entrants will form complex technical and institutional interrelationships affecting the economics and utilization of international space.

More foreign militaries are incorporating space into their military doctrine and operations and are doing so more rapidly without having to re-trace the development steps of the US and Russia. There are increasing opportunities for foreign warfighters to obtain support from the international commercial space services sector as well as from new, dedicated foreign military space capabilities. In addition, the rest of the world has recognized the growing US reliance on space to support its warfighters thereby inherently increasing the vulnerability of US and allied space assets to foreign compromise. The potential is increasing for all international space systems to become targets as reliance on space services increases and enabling technology for counter space activities becomes more widely available.

The development of future us space policy and architectures must seek to exploit international opportunities to influence space support to warfighters, foreign and domestic. This might be accomplished through cooperative ventures with the commercial sector, linking technology export control and national space program objectives, and exerting positive control over technology proliferation. In addition, the global development and utilization of space must be constantly monitored by us space planners to ensure consistent and appropriate courses of action. This includes understanding the ramifications and threats posed by a growing reliance on complex international and domestic relationships providing critical national security space services.

## Survivability of Space Systems

Erosion of previous inhibitions and diffusion of technologies will make survivability an increasing concern. Missile defense initiatives in the U. S. and the former Soviet Union developed and made public interceptor and laser technology. In the future, efficient rockets and kill packages suitable to attack satellites will be widely available. Interceptors can be cued by commercial optical systems. Signature reduction is possible, but difficult for satellites that can be observed over long periods of time from many angles. Visible or infrared search or occultation could suffice for detection and track. Such systems might be mounted for $30-50M. They could be manned by third world personnel. The availability of components, cost, and integration are not likely to be a significant hurdle to their development.

Large satellites can not out-maneuver interceptors. Decoys increase the number of targets interceptors face and force them to include more sophisticated discrimination sensors. But decoys take mass. Fragment warheads reduce the benefits of satellite maneuver. A 100 kg kill package could spread centimeter pellets over 100 m. If the attacker could reduce the satellite's maneuver distance to a kilometer, the penalty for survival through maneuver would increase to about the satellite's mass. Attrition attacks can exhaust satellite fuel and decoys over time, defeating its mission. Space mines are small, simple payloads which rest of the world countries might be able to put into space soon after they gain launch capability or access.

Lasers were previously large, expensive devices, whose beams were spread by atmospheric turbulence. Recent developments have removed these constraints. Lasers can now be scaled to lethal levels for a few million dollars with technologies that are compact and could be hard to find. Active systems can sense phase errors and correct them with active optics. The technology required is modest. It is being provided to U.S. and foreign astronomers for scientific projects. The astronomical community has adopted and improved them and shared them internationally.

Lasers track targets at the speed of light, negating the effectiveness of maneuver, and their beams enter space without penalty, which gives them a significant mass and cost advantage. Continuous lasers deposit heat and kill by melting structural members. Pulsed lasers vaporize material, produce impulse by recoil, penetrate surfaces, and break structural elements. Even if it were possible to block bulk damage, it would still be necessary to prevent sensor kill. Short pulses of even a few kilojoules could damage a significant fraction of an unprotected detector array.

Distributed systems promote survivability. Their degradation would be reduced only in proportion to the number of satellites lost. Flexible interconnection of the rest could make the overall system intrinsically survivable. The loss of one satellite would not even be felt for several days, and lost elements could be replaced quickly on demand with modest launchers.

## Distributed Space Systems

Advances in computers, sensors, and materials permit large constellations of satellites with good sensors and communication, whose integration will give global, real-time coverage. Reducing range to target and constellation altitude reduces the size and cost of passive sensor and systems. The distribution of active sensors such as lidars, radars, and SARs over large constellations offers reduced, but significant, advantages. Staring sensors and space-based kinetic energy systems, which must cover the surface of the Earth at all times, benefit less, although distributing them minimizes response time.

Defenses benefit from the high spatial and temporal resolutions of distributed systems. Missile warning from distributed systems with advanced detector arrays and active sensors would be better, cheaper, and more survivable than current systems—and would have growth potential for aircraft and cruise missile detection. Global surveillance requires very high temporal resolution. Tens of satellites can produce resolutions of meters and revisit times of minutes. They offer an inexpensive way to fill the current gap in wide-area surveillance with quality information.

Distributed sensors and on board processing can perform instantaneous damage assessment, moving target detection, and missile launcher detection and track. All would be enhanced by distributed lasers, radars, and SARs, which can also detect chemical and biological weapons as well as current cloud distribution, composition, and winds at all altitudes. Distributed communication could make thousands of voice-quality circuits available in theaters, solving the "last mile" distribution dilemma. Distributed constellations have the potential of forming a coherent high gain communication arrays for electronic intelligence, jamming, communication to besieged or covert groups, or precision positioning. High capacity cross links can provide real-time, high-quality information and discrimination support, effectively projecting man into the battlefield.

The current sensor state of the art is represented by the visible and infrared cameras and lasers developed for missile defense. Current systems use megapixel arrays in cameras weighing a few kilograms, consume a few watts of power, and produce images with meter to tens of meter resolution. Laser capabilities have increased to hundreds of watts within tens of kilograms. They provide spatially and temporally resolved measurements of water vapor and temperature constituents. Adding to commercial communications systems offers synergisms and opportunities for cost savings. There is a sound technical basis for DoD/civil/commercial cooperation. The key enabling technologies are the ability to affordably build, launch, and control small spacecraft, whose key elements are the application of industrial methods for producing and operating spacecraft. Continued progress in computers, megapixel visible and infrared arrays, lasers, SARs, microwave sounders, lightweight apertures, and kinetic energy will lead to important new capabilities.

## Human Role in Military Space Applications

Global presence beyond the 2020 time period may well require direct participation of the Air Force personnel operating in space rather than relying entirely on remotely controlled systems as is now the case. The unique Air Force interests in supporting DoD space assets can not be abdicated to other agencies, countries, or commercial ventures. The Air Force must be prepared, when appropriate, to directly utilize manned space capabilities to support the DoD overall space mission.

In the mid 1960's the Air Force initiated the development of a Manned Orbital Laboratory (MOL) which was to have operated in low earth orbit for classified missions. The program was canceled before MOL became operational for various reasons, including budgetary, political, but primarily because of parallel development of similar unmanned capabilities that required substantially less supporting infrastructure. In the years since the MOL was canceled considerable experience has been gained in manned systems including the Apollo missions, the very successful Skylab and the Space Shuttle missions which have included the Spacelab missions and various special purpose missions such as the repair of the Hubble Space Telescope.

As we look forward into the future we can envision a mix of military satellites including small distributed systems and large platforms that may require assembly in space to accommodate launch by the then existing space lift capability. In order to achieve affordable and cost effective operation we may need to view these platforms as we view aircraft today. That is, the platform (airframe) may have a life of 10 or 20 years or more and in order to keep it up to date with the latest technology we will need to upgrade the subsystems as we do with aircraft. This may require that the Air Force have a manned space capability to assemble, maintain, and to change out modules and subsystems on future space platforms. This defines two broad areas that need attention, the man peculiar techniques and equipment for servicing and the design approach to the platforms and subsystems to assure future space platforms can be efficiently and timely serviced.

A key component in the supporting infrastructure will be the orbit transfer vehicle to move crews and equipment from the space lifter vehicle to the platform to be serviced. It is assumed that in the time frame of interest, NASA and commercial interests will have developed solutions to this problem, but the Air Force will need to adopt what ever capabilities that exist to the DoD mission and purpose.

In the immediate future the Air Force needs to maintain close liaison with NASA on the space station design and operation and develop guide lines and doctrine as how they might utilize and support future space platforms and missions. As part of this activity technology objectives can be identified so that future technology investment can advance the Air Force's mission in this area.

## Modeling, Simulation and Analysis

Modeling, Simulation and Analysis (MS&A) of space capabilities and the integration of those capabilities into terrestrial operations and the overall force structure is extremely partitioned. This situation is antithetical to advancing the application of space capabilities to joint warfighting. The SDIO, through its National Test Bed, spearheaded the concept of interlinked MS&A which could be used to demonstrate technical and operational concepts well before substantial hardware investments were necessary. The concept remains valid.

The concept was extended by the Air Force to include—military, intelligence, civil, and commercial space stakeholders. The concept was expanded to support decision making through experiments, demonstrations, and exercises with technology, hardware, and humans in the loop. The AF concept was named Frontier Arena and focused on exercise support in the early phases and then to provide support to DoD level modernization decision-making by enabling warfighter in the loop alternative assessments.

Ultimately, Frontier Arena may be used to evaluate tactics, operations, and strategies involving the integration of space and terrestrial capabilities. By linking space and terrestrial MS&A capabilities in a shared environment where each stakeholder can take advantage of the whole. Frontier Arena or something like it is essential to maturing our thinking about space and space related terrestrial issues.

Beyond Frontier Arena, virtual reality implementations offer the opportunity for political leaders and warfighters to visualize the interaction of all force elements—lethal and otherwise. Within the horizon of New World Vistas it will be possible for military officers and their civilian leaders to stand in the middle of a virtual theater and conduct digital sand-table maneuvers in multiple dimensions—space, time, and consequences. Commanders will be able to design their operations, test them, deploy the orders to the forces, and evaluate the results and required changes in one continuous intuitively visualized environment. Such a concept will put us inside our adversaries political, military, and economic turning circles for decades to come.

The Air Force plan for the joint implementation of Frontier Arena is fundamentally sound. It represents the first step on a path to command situation awareness previously only in the province of the futurist or science fiction writer. The Air Force is particularly well suited to lead such an enterprise and should commit to do so on behalf of the DoD.

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