Appendix F

Contributed White Papers

(Arranged Alphabetically by Organization)

National Media Laboratory
Dr. William Mularie

- The Coming Flood: The Challenge of Information Management in the DoD

SAIC
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Future Military Space Systems and the Principles of War

SAIC
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- Possibilities for the Use of Current and Emerging Technologies to Enhance Future Warfighting Capabilities Using Space Systems

The Coming Flood:
The Challenge of Information Management in the DoD

Dr. William Mularie

Introduction

New technologies are traditionally viewed only in terms of what they will *do* and not in terms of what they will *undo*.(1) Dr. Edward Teller at a recent SAB meeting at Maxwell AFB, asked the questions (paraphrased), *"With a thousand-fold increase of data and information to the command structure-Who makes the decisions? How are they made?"* The current explosion in information technologies, driven by the power and ubiquity of computer & communications architectures, will severely stress the DoD command and control structures unless the nature and scope of the problems that it will generate are recognized and addressed.

I. Who is in Charge?

Bureaucratic structures have traditionally held their power by their ability to control and manage information. The downward flow of processed information to each level of the organization was only that subset necessary for decisions and control to be exercised at that level. The disruptive impact of the information revolution upon traditional government and corporate structures is now being played out. For example, world governments and central bankers now recognize that the monetary structures that they envisaged to control the boom and bust cycles of global economies, for example the Bretton Woods agreement of 1948, are now dysfunctional. The relative value of world currencies are now controlled by market traders who employ mathematicians and physicists to build computer-driven mathematical models and communications channels to move $$ Trillions daily. These models, for illustration, instantaneously relate the movement of futures oil contracts on the Singapore exchange to, say, the value of the Spanish peseta options(2) The current realization is that attempts at bureaucratic control of information in is now essentially futile. The "flattening" of business organizations and the "empowerment" of employees throughout the business structures is largely the result of the ubiquity of information flowing throughout all levels of the corporation through computer information channels(3). The conundrum that traditional corporations face is that, in the new world of equal access to information throughout organizational levels, the traditional hierarchical, information-based, decision-making tree, is no longer relevant. Thus, the source of power and control in current corporate structures is principally budgetary.

The DoD is replicating the commercial drive to build the high bandwidth communications channels((from T1(1.5 Mbps) to Sonet OC-12(622Mbps)) to allow extraordinary data flow throughout the command structure. What is the form and function of the future of the DoD command and control structure, when information in a massively parallel manner is available instantaneously at all levels of the command structure? For example, what is the effect of the direct downlinking of imagery and other sensor data to the field commander (increasingly from commercial providers outside the control of the DoD), and the ability of the warfighter to communicate globally outside the DISN channels, with low cost, personal PCS devices via Iridium, Spaceways and other high bandwidth commercial channels? In this new world, who in the command and control structure has the best, most timely information? Who makes the decisions? Is the concept of "empowerment" consistent with military practices? Further, even if we can satisfactorily develop a construct which deals with the new information access realities in the command and control structures for current amounts of information, consider the impact of the coming flood of 1000x in the received data and information in the next decade.

II. Information: The “Garbage” of our New Age:

Neil Postman[1] argues in his book, *Technopoly: The Surrender of Culture to Technology* that: “there are very few political, social or personal problems that arise because of insufficient information,” and, “information now appears indiscriminately directed at no one on particular, in enormous volume--disconnected from theory, meaning or purpose.” Man, in this information technology age, becomes merely an information processor, relieved of making decisions based upon the traditional process of using his experience, intuition and insight. We are like the residents of the garbage dumps of Manila, picking around in increasing mounds of refuse trying to glean those tiny bits of material that will sustain us. On the Internet we employ surrogate agents to search the overburden for us with the unlikely names of “Vernonica” and “Yahoo”--the latter probably reflecting the sheer joy of finding any useful information. One is also struck by dulling effect of the enormous traffic burdening the network, limiting access to the needed information.

III. The Conundrum: Man and Machine:

The fear is that the gridlock that we have created in the civilian world will be replicated in the DoD structure because the seeds of the problem lie within us:

- Our importance scales in a monotonic way with the amount of information to which we access, collect or process
- We hoard, revere and give information expensive places to dwell—whether the libraries of the Medici or the magneto-optical, holographic or magnetic storage devices populating our systems
- We never question the current or future value of our information hoard (consider what valueless, expired information lies on our hard drives or in our file cabinets), and
- What we *need* to access is effectively hidden by the overburden of what we will *never need*

Computer technology and networks are the insidious enablers of our destructive tendencies. Our current experience allows us to project the following scaling laws for future DoD computer networks:

- The available storage capacity and bandwidth will be oversubscribed, independent of the network capacity and bandwidth
- “Requirements” and technology will develop bandwidth-intensive applications that will bring any network to it’s knees. Excess bandwidth is an anathema to users and applications developers (the parallel of “nature abhors a vacuum”), and
- Non-critical (unimportant, time-insensitive) requests will represent 99% of traffic on network (e.g, downloading video clips or TIFF images of the Playmate of the Month)

IV. Rethinking our Information Systems:

Admiral William Studeman, former Deputy Director of the CIA, described the three levels of activity as organizations attempt to deal with new realities:

- **Relabeling -** continue on present course under a different banner
- **Restructuring -** continue on present course with a new, politically correct organization chart, and
- **Rethinking -** the most difficult but most necessary exercise to deal with new realities-questioning current doctrine and creating new structures and cultures to deal with new problems

In **rethinking**, some areas to be addressed include:

1. Information Control

2. Bitway Architecture Control, and

3. Things We Don't Control (but must utilize)

The latter recognizes the commercial capabilities, such as Direct Broadcast Satellite (DBS), available in the electromagnetic "ether" that surrounds the DoD structures from the JCS to the shooter. These commercial *technologies* are currently being tested and integrated into the DoD planning process for communications architectures. Less visible is the attempt is invest in and *use commercial platforms to carry the bits*. Replication of commercial systems for the sole use of the DoD addresses only 1/2 the commercial benefit—that of obtaining state of the art technologies. It does not mitigate the huge DoD investments required to emulate commercial performance, nor does it satisfy the investment rationale: the provision for "assured access, security and robustness." The massive parallelism of global commercial broadband communications systems yields a robustness that exceeds that of defense systems, where single point of failures are inherent in the designs. Network security using simple public key encryption schemes provide data integrity even in unbounded networks. But let us focus on the former two areas:

1. Information Control:

According to Postman[1], there are three interrelated methods by which society controls the flow of information:

- **Bureaucracy -** which he describes as a "coordinated series of techniques for reducing the amount of information that needs processing"
- **Expertise -** the expert concentrates on one field of knowledge and determines what information to use in solving a problem and what to ignore, and
- **Technical Machinery** - reduce the types and quantity of information admitted into a system

Within these methods of information control we recognize some general principles that should be adopted to prevent the replication of the current civilian chaos to the emerging DoD information systems. DoD information systems design must be designed to keep the experts and expert systems in the information channel to:

• Provide value-added insight (expertise), and

• To provide ”natural” compression (data to knowledge)

Expert exploitation (the process of converting data and information into knowledge) of, for example, specialized sensor data, is critical. For example, the task of rapidly and accurately deciding whether signals from diverse sensors signals, such as those looking for an enemy missile launch, can only be done by imbedding experts in the data stream , using their experience and total knowledge of the system. Having access to the same signal data in a tactical field situation does not yield the same result and could have catastrophic international consequences.

Data compression is viewed as applying mathematical transforms to allow stuffing more data bits through a communications channel. Man, in the information channel, has a much more powerful influence in assimilating and reducing large, disparate data sets into higher level languages (e.g., “yes”, “no”,...)

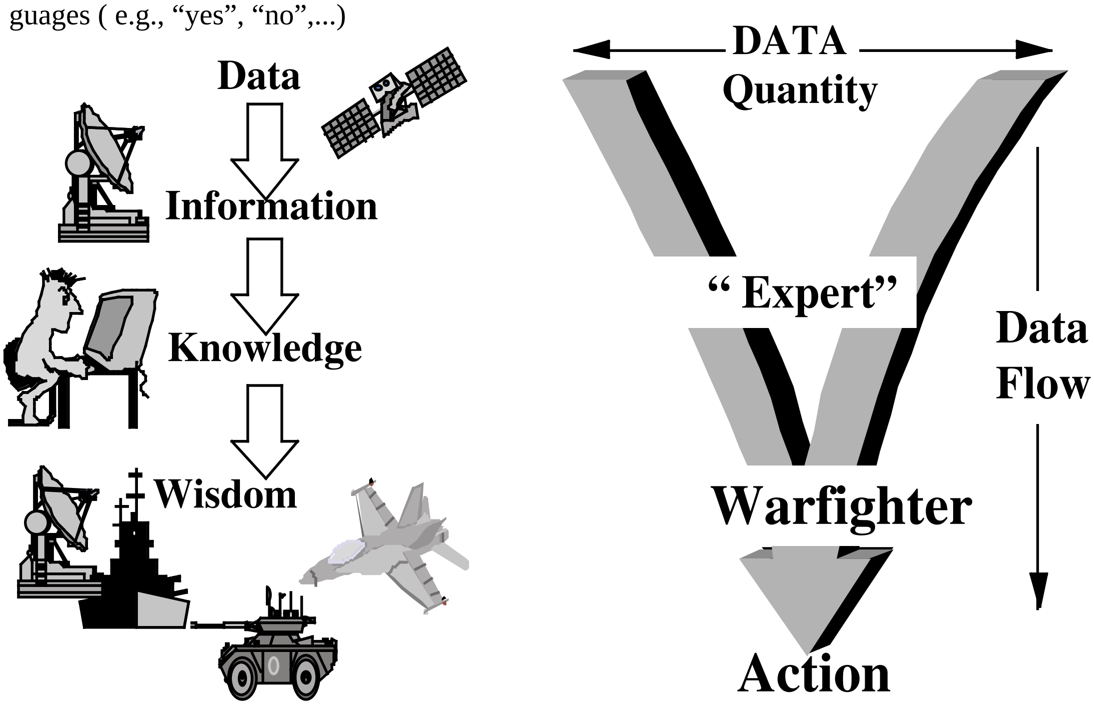

Figure F-1. ***The Dark Side of the Current Communications Push: The Concern***

Technology evolution in the DoD and commercial markets has given the DoD the ability to transmit to the field those sensor data (imagery, signals intelligence) and processing tools which were once the domain of the experts. Instantaneous, parallel delivery of sensor data to all levels of the military structure, as illustrated in Figure F- 2, raises the concern voiced by Dr. Teller: “Where are the decisions made?, Who has the best information ? Additionally, if one overlays this picture with a 1000x increase raw data bits, the problem becomes untractable.”

However, the *reasons* for circumventing these expert nodes in the information chain should be carefully examined in light of the above consequences of information chaos.

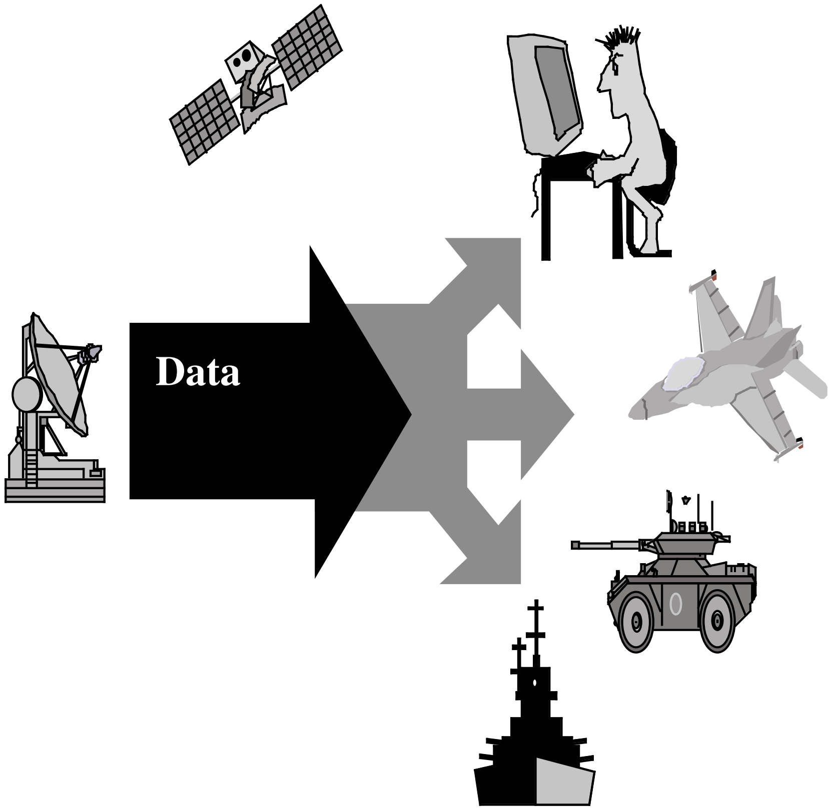

Figure F-2. The Coming Age: Every " Bit" to Everyone

2. "Bitway" Architecture Control:

Communications architectures must be designed from the *user needs upward*, rather than from the content providers (Imagery, Mapping,...) or engineering offices downward. This statement appears obvious, but I would point out the commercial failure of Video-on-Demand (VOD) where ostensibly market and technology-wise corporations wasted hundreds of $millions. They had assumed, through engineering studies and "customer" surveys, that the technology and consumer demand was present to deliver video into the home in a instantaneous fashion, keeping the ability to keep the VHS tricks (stop, start, rewind...). They were wrong on both counts, at great cost.

Lastly, information management requires that DoD architects optimally parse information types among the available DoD and commercial "bitways". Information varies in criticality, timeliness, security, file size, origin and destination, to fixed or mobile commands, etc. "Bitways" vary in their capacity, availability, robustness, geographic reach, interface requirements. This is an "m x nî, where the variables are time dependent. This problem that requires knowledge and close cooperation with US commercial entities to ensure the access, capacity, security and robustness to carry the DoD in this new information age.

Conclusion:

Organizations, in the rush to incorporate new technology, must consider and reconcile the negative as well as the positive impacts of technology insertion. Critical to the planning process is the need to negotiate the role of the human in the new technology paradigm. This paper argues specifically that the DoD, in the design of its information architecture (meaning hardware and systems), must also construct a user architecture((meaning, determining the appropriate(what, where, when) information needed by the decision makers in the system)) to allow military operations to flow quickly and accurately from raw sensor data to force application.

Bibliography:

1. Postman, Neil, Technopoly: The Surrender of Culture to Technology, Institute for Information Studies, Book Summary, 1992. Neil Postman is a critic and communications theorist, and chair of the Dept. of Communications Arts at New York University. *Note: This is provocative reading for left-brained physicists and technocrats-WMM.*

2. Millman, G. The Vandals Crown, Simon & Shuster, Jan,.1995

3. Treece, James B. “Breaking the Chains of Command”, Business Week/The Information Revolution, 1994 p.112.

Future Military Space Systems and The Principles of War

Robert Rosenberg

Introduction

The world is a rapidly changing place--a place with continuously disruptive impact on even the best military planners' approaches to the architecture of our military forces. Without well founded underpinnings for our military force architecture, force structure and training, we often are accused of preparing for the next war by designing to refight the last one. For this reason it is instructive to return to first principles when we examine the needs for our space architecture of the future. As the race of technology unquestionably establishes space as a future theater of war, it is important that we build an architectural foundation for space which draws on the principles of war. These principles have been stable over the ages, changing only in their implementation through technology rather than their fundamental thrust.

Regardless of the future, what is certain is change. Independent of what changes occur, we must guarantee the right of free passage of U.S. and friendly flag carriers in and through space as well as deny that ability to space capabilities that threaten our national security interests in time of war. We must guarantee that free right of passage because, as we will see through the examination of the principles of war, space systems can make valuable contributions to our land, naval, air and space war-fighting forces, whether in day-to-day, peace time operations or as we employ whatever force is required to meet our national security objectives.

A Return to First Principles

For years the military has considered space in the context of mission areas (i.e., communications, navigation, etc.) or tasks (i.e., space control, force enhancement, etc.). Unfortunately, much of the way we currently view space systems is channeled by these convenient, but often over-simplified definitional areas to which the role of satellites has been assigned. Today's thinking overwhelmingly assigns satellites to a support role, assisting terrestrial warfighting. Modern day thought about satellites stands where our thinking about the airplane stood at the early stages of World War I - as scouts or messengers. Most contemporary thought about the contribution of space systems to the military has started from today's requirements, and most of it, while making valuable contributions to current thought, has concentrated only on pointing out current shortfalls and describing how to make only small incremental advances to today's state of the art. Those advances have been aimed at satisfying near-term requirements. None has gone back to "first principles", attempting to tie this new warfighting medium with its remarkably new, often counter-intuitive operating environment into a set of fundamental warfighting principles. This is the new ground that we shall break here.

We will set aside the conventional approach to gain new insight into future space systems by returning to the often-discussed Principles of War. We shall explore how space systems can contribute to the successful execution of future warfare using those time-tested warfare Principles as a starting point.

Principles of War - Definitions and Impact of Space Systems

We have considered three types of contributions that space systems can make to future warfare: (1) as support to all terrestrial warfighting, (2) as support to land, naval and air components, and (3) as a separate, unique warfighting arena. We list each Principle, define it, and then summarize our conclusions about the impact that space systems can have on future warfighting.

Objective - *Direct every military operation toward a clearly defined, decisive, and attainable objective.*

Space provides the means for precise coordination of beyond-the-horizon land, sea, air and space operations, and will contribute to the outcome of conflicts either as weapons or as critical parts of the military decision cycle. They will assist in the direction of fire and the targeting of weapons, especially as space systems become critical parts of weapons loops. Increasingly, the objective of space control will be a prerequisite for effective land, sea and air control.

Defensive - *Resist attack or aggression through appropriate operations, positions, or attitudes.*

Detection satellites will provide warning to terrestrial forces, giving the time needed to defend against attack and gain offensive initiatives. Against the proliferation of tactical ballistic missiles they will be critical in determining where an attack came from and how to respond. Information gathering provides indications of enemy actions and intentions, to optimize defensive positions. The proliferation and omnipresence of space assets will make defense of terrestrial assets much more difficult. Multiple space assets, cueing with terrestrial assets, will make defensive concealment more difficult. Satellites will assist in narrowing the number of defense corridors to be defended. Combinations of active and passive satellite defenses will enhance each other and will strengthen the defensive posture. While physical attacks from earth to space will be discouraged by the large amounts of energy and expense required, physical and other defensive anti-satellite measures such as directed energy weapons will still be required to gain space control and to degrade or deny enemy use of space. Physical attacks from earth can be discouraged by “keep-out” or self-defense zones, with the zones depending not only on distance from the defended satellite but also on time and energy considerations that are required to approach a defended satellite. The attack potential from space will stimulate the development of defensive weapons and countermeasures such as lasers, directed energy, and kinetic energy weapons. Defenses such as antijam, maneuver, and mobile TT&C, will be required for space system defense, and improved ground-based satellite position, identification and warning systems will be required to provide an adequate defense.

Offensive - *Seize, retain, and exploit the initiative. Act rather than react.*

Proliferated satellites will provide timely information to globally dispersed users, assisting coordinated offensive operations among multiple forces. Communications satellites will provide military connectivity for coordinated operations; environmental satellites will optimize the efficient routing of forces; and navigation satellites will provide for positioning, timing and coordination of forces. For tactical operations, navigation satellites will provide the common reference frame necessary to assure strike force connectivity. Long range terrestrial offensive weapons supported by space will increasingly threaten all fixed and moving targets. Offensive operations against satellites will first include physical attacks from the ground and inevitably later from space, directed energy attacks from the ground and space, and the use of jamming and other forms of electronic warfare. Farther in the future weapons in space are inevitable. The ability to strike targets directly from space will revolutionize warfare. Any nation that can target terrestrial forces with a space-based weapon can produce a substantial global threat. Such a capability will provide a strong incentive for the development of precisely targeted weapons from space to ground or space to space.

Security - ***Act to assure that the enemy will not acquire an unexpected advantage. Take continuous positive measures to prevent surprise and preserve freedom of action. Use both active and passive defense.***

Physical security of forces will be enhanced by satellite-derived knowledge of enemy space order of battle and knowledge of enemy concentrations. Satellite security will be enhanced by decoys, autonomy measures, shielding, hardening, maneuvering, proliferation, concealment, shoot-back, and other forms of physical defense. Space system security will be enhanced by redundancy and on-board data processing. Secure communications will be provided by encrypted communications, use of signal relays, spot beams, frequency hopping, and electronic counter countermeasures. Cross links will tend to eliminate the need for secure ground station relay points. Software security will assure successful operations under stress, and care and attention will be needed to avoid “Trojan horses”, system take-over, and software sabotage.

Surprise - ***Strike the enemy at a time, place, and manner for which the enemy is neither prepared nor expecting an attack.***

The high dependency of the military on satellites will make space a good candidate for initiation of hostilities. Moreover, an attack on space assets is less likely to provoke escalation than a terrestrial attack. Surprise strikes will result from satellite collection, and synchronization of those strikes involving separate force components will be aided by satellites. Covert deployment of spacecraft capabilities, the activation of satellites assumed dead or dormant, and unconventional use of satellite capabilities will enhance surprise. Strikes conducted directly from space will give a new surprise dimension to warfare. Surprise concerning future enemy weapons capability can be minimized through the use of technical intelligence, aided by satellite collection. Satellites can also provide early warning of attack, acting as a “trip wire” to reduce surprise.

Mass and Concentration - ***Concentrate or focus combat power at the decisive point in space and time.***

Rapid deployment and dispersal of forces will be aided by satellites, both to support normal operations for forces on the attack and to avoid attack. Using space systems precision target interdiction effectiveness will be considerably improved. Navigation satellites will provide a uniform position and time grid permitting massing, rendezvousing and refueling, close-in surgical strikes, and concentration of forces to take place with increased precision. Moreover, navigation satellites will reduce the possibility of troops becoming lost or disoriented in battle. Forces will take advantage of satellites that are operated synchronously with each other, performing such missions as focusing information collection, relay and point-to-point communications. Space manifestations of the principle of mass include satellite asset apportionment, concentration of satellite coverage capability, the concentration of energy to perform time-dependent missions, and the capability to surge. Mass concentration of satellites can be provided by more assets of the same kind on orbit, and the affinity of satellites to operate in key clustering locations (e.g., low earth orbit, geosynchronous and sun synchronous orbits, the Lagrangian points, etc.). Larger numbers of satellites in orbit will degrade more gracefully, provide better timeliness, provide more rapid collection, drive more rapid dissemination, provide better system endurability, complicate enemy targeting solutions, and complicate an enemy's ability to determine satellite system missions and functions.

Concealment and Deception - ***Hide forces from observation. Cover, mask and disguise them. Mislead, delude, beguile, and divert the enemy by all possible means.***

Space systems can be used to assist in the detection and identification of concealed forces. Locations of military forces can be denied to space systems only by effective deception. Because of the multiplicity of space systems, deception against detection must be effective against many systems, and the high probability against simultaneous deception will be a major driver of the need for antisatellite weapons. Collection and dissemination of false data by satellite will deceive an enemy, while properly executed satellite deceptions will draw an enemy to vulnerable locations. Space system mission areas can be concealed by design and other techniques because missions and functions of hostile satellites are difficult to assess. Effective use of these designs will contribute to surprise and survivability. Maneuvers can be employed deceptively. The natural cycle of "first conceal, then deceive, then engage" is applicable to space as well as to other forms of combat.

Economy of Force - ***Allocate minimum-essential combat power to secondary efforts. Execute attacks with appropriate mass at the critical time and place without wasting resources on secondary objectives.***

Space systems increase the effectiveness of terrestrial combat systems and proper use of those same ground-based systems will enhance the effectiveness of assets in space. Satellites will optimize target sets for strikes by a spectrum of weapons systems, and will reduce the need for organic assets. Space systems will allow a better determination of optimum attack/defense force ratios. In general, the transfer of good information between ground and space-based assets will optimize the use of all weapons systems, assuring economy of action.

Maneuver, Timing, Speed and Tempo - ***Place the enemy in a position of disadvantage through the flexible application of combat power. Maneuver your strength selectively against an enemy's weakness while avoiding engagements with forces of superior strength. Involves flexibility in thought, plans, and operations. Execute military operations at a point in time and at a rate which optimizes the use of friendly forces and which inhibits or denies the effectiveness of enemy forces. Dominate the action, remain unpredictable, and create uncertainty in the mind of the enemy.***

The keys to effective use of satellites in wartime are rapid tasking, timely data collection and fast delivery of targeting information to the shooter. Such a process will operate in an environment of near real-time, near-continuous coverage of force movements by space systems. More accurate position determinations from satellites, combined with accurate timing of maneuvers, will lead to better coordination of strikes and maneuvers, tighter operational timing, higher speed maneuvers, and more effective use of smart munitions. Better satellite-derived positions will permit forces to fight battles at more advantageous times and places. Position-location will permit advance routes to be preprogrammed for low echelon use, increasing the effectiveness of vehicular and other platform maneuvers and force coordination.

Deployment - *Rearrange forces for the attack or spread them out to minimize effects of enemy attack.*

Space systems will provide very precise timing and position information for force deployments and the optimum, timely execution of those deployments will be improved. Vectoring of forces onto strategic and tactical targets will be more effective through the use of precise navigation information. The global communications provided by satellites will optimize deployment of forces; space will continue to be a major player in strategic deployment. A rapid on-orbit replenishment, replacement, or deployment capability for satellites will be required under most wartime military scenarios. Satellite deployment will consist of launches on schedule, surge on demand, or the activation of satellites stored on orbit.

Simplicity - *Prepare clear, uncomplicated plans and clear, concise orders to ensure thorough understanding. Give quick, clear, and concise guidance. Provide clear, simple, and unencumbered command structures, strategies, plans, tactics, and procedures to permit ease of execution.*

Communications are simplified through the simultaneous coordination of land, sea, air and space units. Common navigation techniques provides a common grid used by many different fighting platforms to simplify both offensive and defensive operations. In the smaller satellites of the future, standard satellite buses and standard launch vehicles will simplify operations. There will be a concerted effort for ground station controls not to require highly-skilled and trained personnel for routine activities. Space system design will be done with user-friendliness as a principle of paramount importance, from the design details to preparations for launch, to spacecraft TT&C, through spacecraft tasking, to the delivery of mission data to the overall systems operation.

Battlefield Friction, The Fog of War - *Varying levels of confusion will exist during combat engagements which will confuse the m.*

Denial of information will tend to blind operating terrestrial forces, reducing their effectiveness and slowing them down, and the disruption of satellite communications will be a major contributor to battlefield confusion. Whether the source of failure of a satellite is a “soft” attack or a mechanical failure will be a primary source of confusion in future conflict. Disruption of relay satellites will be a force multiplier in the fog of war, for many links to decisionmakers will take place simultaneously for many operating satellites through relay satellites.

Doctrine and Training - *Prepare, qualify, and educate personnel to fully understand their role in the conflict, the capabilities and limitations of all weapons systems that will aid or threaten them in battle, the methods of employment of those weapons, and their principles of operation.*

All terrestrial users of space system products must know their capabilities and limitations and this will require extensive training. Good training in space matters will be an important part of space doctrine. All forces will be taught how to avoid enemy space reconnaissance and all forces will be taught how to use friendly space assets to their advantage. Exercises, simulations, operations research, and war gaming are important components of doctrine and training. Because of the features of space that make it unusual and distinct from the features of terrestrial operations, space warfare will be different from terrestrial warfare. The operating environment of space is different than those in which other forces operate, necessitating a different approach to the military use of space. The potential for space assets to aid or hurt an airland operation must be taught. As the enemy begins to cue his space assets more effectively, the tactics of land, air and sea warfare will require change. Many of those changes can be identified through exercises, simulations, operations research and war gaming. In future major wars, space will no longer be a sanctuary; conduct of future operations there will be important to war's outcome. That importance must be taught, and good, supporting doctrine must be formulated and continually tested. War plans will include consideration of friendly and hostile space systems, and they will address the impact of space system degradation on terrestrial operations. Space doctrine, training and war plans will incorporate the use of commercial and foreign satellite systems in wartime, as appropriate. Exercises will continually probe the minimum required level of wartime communications.

These features of doctrine and training are necessary because the orbitology of the movements of space assets obey an altogether different set of principles than do those of more familiar terrestrial force platforms. Unmanned military assets operating in an often hostile, frictionless vacuum for months at a time requires non-traditional, often counter-intuitive approaches and thinking. Its effective use requires good training. Space is not merely an extension of air warfare; it is another warfighting medium. The effective use of space in warfare will require retraining, rethinking, and paying concerted attention to operations research, exercises, simulations and war gaming.

Summary

Time-tested Principles of War have given us new insights about the use of space systems in future warfare. These principles are still adequate to accommodate this new arena of warfighting. In fact, a review of the functional areas and the principles lead us to several key drivers that need to be stressed in any future space architecture. These drivers are (1) viable R&D programs for developing promising satellite concepts like we now have for developing new ships, tanks and aircraft; (2) centralized command and control, coordination of doctrine, training and operational concepts for the use of satellites; (3) decentralized mission execution (tasking and dissemination of information); (4) effective interoperability across functional areas; (5) ability to plan and coordinate employment of space systems with forces to be supported; (6) assured mission capability; (7) cohesiveness of space systems where each system complements the other; (8) timeliness of tasking, data collection and dissemination; (9) user-friendliness; and (10) simplicity of the data flow.

Possibilities for the Use of Current and Emerging Technologies to Enhance Future Warfighting Capabilities Using Space Systems

Robert Rosenberg

Joint Warfighting

Future warfighting will be joint. From the US perspective it will be high-tech, regardless of whether it will be directed against a high tech or a low tech enemy. The cutting edge we achieve in future conflict will depend on the types of capabilities in which we now invest. Against a high tech enemy, our advantage will depend on the extent to which our new capabilities exceed those of the enemy. Against a low tech enemy, who may use a myriad of novel, low tech, unconventional, guerrilla, terrorist, high tech/low cost, subversive, or fifth-column tactics against us, our advantage will depend on how efficiently our high tech arsenal can be used against those threats and how effectively we can address them.

The Requirements Process Favors "Stand-Alone" Systems

Partly because of the way the military uses the requirements process and partly because the acquisition process tends to encourage "stovepipe" weapons systems, we have become accustomed to designing systems that "stand alone," that serve a relatively small set of warfighters, or that lack what is being referred to as "horizontal integration." During times of budget plenty we could get by with this view of systems development, but in times of budgetary drought we must approach systems development differently.

Our current requirements process tends to develop an approach to systems by forcing any new system to satisfy a rather rigidly proscribed set of requirements. If a proposed system gives an 80 per cent capability at 40 per cent of the cost, it tends to be rejected because it does not meet enough of the requirement. The fact that it may be a relative bargain with a high "bang for the buck" ratio, that it may fit nicely into an vacant "niche" among our spectrum of weapons, or that it makes a significant contribution to a current capability shortfall goes unrecognized during a process in which we often find that the 100 per cent solution is unaffordable, especially for space-related activities.

Recognition of this situation is of vital importance because many aspects of our technology development process are tending to develop capabilities that best match small scale, low cost additions to what we are already doing or that take advantage of systems that are already in place or are being used for other purposes. We have tended to neglect add-on capabilities from space, low cost solutions that meet only a fraction of the requirements, or solutions that require both land and space nodes to be successful.

The Need for Synergy Between Space and Other Weapons Systems

Our military approach to space has tended to ignore much of the potential that space systems could afford to the warfighter, largely because they are expensive, stand alone "stovepipes." In the mid-1980s, Navy space advocates wanted to orbit a system known as NROSS (Navy Remote Ocean Sensor System). This proposed satellite had a number of sensors aboard that operated in concert to do remote sensing of ocean conditions from space. It had a stand-alone capability. No attention had been paid to collections that might have been routinely be made by buoys at sea, collected by satellite and forwarded to some central manned collection point, although that possibility could have led to a much cheaper total collection system. This stand-alone approach to space must be abandoned, and with that abandonment must come the recognition that space systems should be designed into our collection systems of the future.

Sensor-to-Shooter Operations

We have experienced the remarkable contribution that GPS technologies have made to military operations in the Gulf War. Aside from contributing personnel, the only investment that the military had to make to achieve that extraordinary success was the purchase of small, inexpensive, hand-held GPS receivers. The rest of the satellite infrastructure was contributed by others.

Technical advances that have increased the sensitivity and sophistication and decreased the size, weight, and cost of some types of sensors have brought the evolution of these sensors to the point where military investment in their use could lead to the same marked advances to warfighting that we have experienced with our GPS receivers. We are at the point where we can tie sensors to fusion points or directly to shooters in real time and deliver weapons rapidly on target.

Generically, we can locate our sensors on aircraft, UAVS, or on the ground and provide them connectivity to the shooter through either space or airborne assets. Just as GPS receiver investments promise to change the way the military conducts its operations, investment in other types of sensors that can be placed on the battlefield by aircraft or special forces, could also revolutionize the way we operate. Our investment would not be in high-cost space assets, but rather in more affordable ground or air-based sensors that communicate information in real time to our shooters through a space or an airborne communications link, many of which already exist.

It is conceivable that strikes, triggered by these sensors, can be made within seconds of receipt of sensor information that can reveal where and what to shoot.

Candidates for sensors types and technology/system development include, but are not limited to, those appearing in Table F - 1.

Table F - 1. Sensor Type

Acoustic detectors with or without interferometry	Mass Transport Sensors (air mass, H_2O mass, flow indicators)
EM/ELINT collectors	Weather/Meteorological collectors
Optical/IR/UV/Thermal/Temperature detectors	Gravity measuring sensors
Multispectral/hyperspectral detectors	IR Tripwires
Particulate/Fog detectors	Radar Detectors
Pressure Sensors	Laser Detectors
Chemical/Molecular/Exhaust, etc. detectors	LADAR
Motion detectors	LIDAR measurers
Siesmic detectors	GPS Reciever components in other collectors
Interferometers of various types	Attitude Sensors-Pitch sensors
Wiretapper collectors	Status Sensors
Spoofers	Triangulation/Interactive arrays
Nuclear detectors	Using GPS techniques to track
Magnetic/Electro-detectors	Human/Spy reporting
Acceleometers	Imaging Radars
Ground Moisture Sensors	Railroad Track Counters
Cutouts and relay systems	

The lesson to be learned from our experience with GPS in the Gulf War is that we should be taking more advantage of ground-based service investments, which, when in place, have some type of link or connection to space or aircraft assets.

Small Satellites and Aircraft Collection

Since the inception of the ill-fated ARPA Lightsat program, a number of small military satellites to satisfy military collection requirements using platforms that were less costly, more plentiful (hence more timely), and less stringent in their collection requirements when such issues as resolution were considered. The ARPA MACSAT, a store-and-forward communications satellite, was effectively used by the Marine Corps in the Gulf War for logistics purposes. That satellite cost less than $10M and filled a “niche”. The Navy has flown special purpose satellites for ocean research.

InfoSoldier - An Example of Sensor-to-User Application

InfoSoldier originated in the Army but has a wide joint application to warfighting. At a projected cost of less than $65 million, InfoSoldier takes the name and the location of every company-level headquarters in theater, combines it with simple company unit status information, and sends it through space-oriented communications links to all headquarters levels in theater from battalion to the theater commander, keeping CONUS informed -- all within 2 minutes of transmission. It promises to revolutionize situational awareness and reduce fratricide. InfoSoldier involves CECOM and the Battle Command Battle Lab, and uses an ASPO experiment, Grenadier BRAT, as a precursor to a full-up capability. The Navy has a similar concept, called SABER, that could be effectively merged with InfoSoldier. InfoSoldier has joint operational capability.

Broadening *InfoSoldier* to a Joint Forces Air Force Leadership Concept

As we move into the 21st century, the missions the military forces are being challenged with are changing. Important implications of these changes include better command and control of forces, increased situation awareness, and information dominance. General mission needs include requirements for timely battlefield intelligence to support targeting and battle assessment, implying integrated imagery and intelligence, better assured communications, and better and more current weather. Concomitant needs include capability to train as we fight, and to incorporate space into exercises, including use of simulated or virtual capability, as well as objective capability.

The following will address two of these specific requirements: 1) Capability to provide full knowledge of friendly forces status in the theater in a three-dimensional view, providing situation awareness to address integrated operations and that they can project a battle into, and 2) Ensuring availability of sufficient communications to support the ballooning information requirements, providing bandwidth on demand.

1.0 Two concepts are described in this paper which address the specific required capabilities. They are:

1) *Provide situation awareness to support integrated operations.* As concepts for digitization of the battlefield evolve, it will become more necessary to have a complete and continuous picture of the deployment and status of all friendly force units, and to minimize the amount of interceptable communications required to facilitate this big picture. The concept to address this need employs the capability to broadcast LPI signals which include GPS positions/velocity and other status about the transmitting forces, and relaying the information to ground for use in force planning and assessment. This use will include fusion with other data, providing local area scenes with current position of all friendly forces, as well as the situation of the forces, e.g., munitions remaining, mission status, etc. Primary system components include LPI transmitters, satellites with appropriate signal reception and data recovery capability, ground fusion and tactical comm.

2) *Better assured communications, providing bandwidth on demand.* To support theater operations in the 21st century, there will be a need to significantly increase area communications and communications capacity to CONUS. One general concept provides communications

as tactical augmentation, in highly elliptical orbits tailored to contingency areas, to augment "fixed" MILSATCOM and CRAF'd sources, affording secure "bandwidth on demand" to the theater with cross links to provide coverage to CONUS as well. Canisterized rounds would be ground maintained until needed, with capability to recover/refurbish the satellites for subsequent use. These satellites would be designed for relatively short life times, and the resulting radiation hardness levels would be reduced.

2.0 The following develops the concepts summarized above, providing operations concepts, sub-system concepts, and summary of enabling technologies and associated status.

2.1 LPI Force Reporting System Concept

As stated earlier, the purpose of this concept is to provide total battle space awareness via communications of theater wide status of forces. For this system, each theater force entity (e.g., maneuver squad, SOF group, aircraft or aircraft flight, etc.) would embody a transmitter which would aperiodically transmit a low power, spread spectrum pulse that would contain position and velocity information and status of mission and stores. Transmissions would be collected by satellites equipped to detect, acquire, and process the transmissions. Downlink data structures containing all such data will be created for broadcast into the theater. Ground reception and processing stations would be capable of recognizing and extracting those receptions in their sphere of influence, and of incorporating the resulting data into their situation assessment and associated force planning. In the event specific access to a force entity is required, the potential would exist to interrogate that entity using narrow bandwidth, low data rate communications (similar to pager operations) to request status.

- *Situation Assessment Concept* - This system augments other information by providing periodic updates on all friendly forces in the theater(s). As a GPS based information source, it will provide accurate positioning for battle arena entities that will reduce the possibility of fratricide. As a down-linked set of information, it is available to multiple planners simultaneously within the theater, and can be readily made available to pilots' heads-up displays to augment existing knowledge of friendly forces location and status.

2.1.1 Improvement to AF Capabilities/Operations.

This LPI Force Reporting System concept will provide theater command and control with full knowledge of the location, configuration and mission status of the friendly forces while minimizing the probability of enemy detection of the friendly forces, since their transmission will be LPI. This capability should enable better and more timely force engagement planning, better tracking of the covert forces, etc. This data transmission concept also provides a good vehicle for covert data transmissions, enabling more timely knowledge of mission status and location of the covert forces.

2.2 Tactical Deployment of HEO Communications

The burgeoning requirements for supporting all levels of deployment, in parallel, with more timely imagery, intelligence and video data to support the planning, execution and assessment of missions will create a tremendous demand for supporting communications bandwidth.

This concept addresses providing the world-wide availability of sufficient bandwidth to support joint force operations.

2.2.1 Description of System Elements

This set of satellites would be stored at ground locations, prepared (canisterized) for launch on as-needed basis, maintained in orbit for a period of time required to support contingent operations, then de-orbited and recovered, refurbished and readied for next use. An initial concept for the satellites would be combined UHF and EHF, providing signal communications compatible with other communication systems in use, including commercial satellites. However, to provide relatively high bandwidth capability, use of alternative communications structures, e.g., direct broadcast satellites with multiple T1 channels, should be considered. Orbits would be HEO, tailored to provide high-throughput theater-level communications. Satellites would be provided with cross-links to facilitate around the world communications. Satellite design would accommodate requirements for thermal and shock conditions at re-entry and to achieve a soft-landing.

- *Launch Concept* - The launch vehicles would be designed for minimum maintenance and handling. Processing would be highly automated, requiring a very minimum launch support personnel contingent. Launch time and orbit requirements would be determined to specifically support the contingency conditions, and launch parameters automatically entered into the launch vehicle flight computer and verified.
- *Ground Equipment Concept* - There is little change in existing and planned ground equipment for the operations within the theater. If the resulting concept is DBS based, small DBS antennas would be placed at theater command and control nodes to enable the receipt and filtering of the broadcast data to minimize the impact on the deployed operations. Secondary broadcast of the appropriate data to requesting units would be done from the theater C2 nodes. The ground equipment associated with minimum hands-on management and launch of canisterized launch vehicles at Western range will require significant planning and development. However, the Russians have been conducting launch operations in this fashion for years, so the technology is available, and not driving.

2.2.3 Improvement to AF Capabilities/Operations.

This concept for tactically deployable communications provides for rapid augmentation of communications to accommodate rapid growth in communications requirements to manage increasing growth in multi-spectral imagery and situation assessment information. In addition, the concept provides for rapid reconstitution of C2 capability in case of loss of communications.

ACCU-Strike Weapons Use of Differential GPS for a Pin-Point Strike Weapon

These concepts will allow our military to deliver high explosives onto preplanned, stationary targets with accuracies of some tens of inches. Differential GPS is the key to the concept since GPS alone offers accuracies of only 20 meters (60 feet) or worse. GPS accuracy, while quite good, is usually larger than the radius of the target, so even higher accuracies are desirable differential. GPS offers accuracies of inches, so that weapons can potentially be delivered within inches of the center of even a small target. This means that it is possible with this delivery concept to use only one sensor system from shooter to target and thus avoid the additional expense of two or more sensor pass-offs that are often characteristic of other weapons systems. It also means that more accurate targeting can be done at lower cost.

In the concepts described above, the target is stationary and the accuracy of weapons delivery onto the target is of the same order as our ability to measure the position of the target in the first place. The differential GPS technique is so accurate that the uncertainties in the position of the target will probably dominate the targeting solution.

This class of weapons would have a high element of surprise. These weapons concepts would be relatively inexpensive and relatively hard to counter.

Satellite Station-Keeping and Offensive Operations at the Geostationary Orbit Using Very Long Baseline Interferometry (VLBI) Techniques

Satellite Station Keeping: Sets of three, 1-5 foot diameter antennas located about 1 km apart at any latitude between the equator and about 45 degrees latitude and linked with a fiber optic line to a central computer could be used to provide station keeping for satellites located along the geostationary arc. Normal emissions from the satellites or friendly beacon frequencies located on the satellites would be simultaneously observed by the three antennas and fed into a central processor which would then use Very Long Baseline Interferometry (VLBI) techniques to determine their relative positions along the geostationary arc.

VLBI techniques have been used by radio astronomers since the mid 1960s. With those techniques, they can determine the positions of antennas located at intercontinental distances to a precision of less than 10 centimeters. This technique can be used to monitor satellite positions with a precision that is of the order of less than a spacecraft diameter. Current orbit keeping is restrained to keep-off distances of the order of 1 km or more. The ability to "pack" the geostationary orbit in this way will enable thousands more geostationary satellites to operate simultaneously along the arc. While this will place stringent conditions on the use of radio frequencies since the satellites would operate quite near each other, the ability to accurately station keep will be worth many millions or even billions of dollars as the geostationary arc becomes more and more crowded and the ability to accurately station keep to this precision allows more satellites to operate very close to one another.

Offensive Operations at the Geostationary Orbit: When a friendly satellite is nearing the end of its useful life in geostationary orbit, it is moved outward into an orbit that goes around the earth a few times per year. If the near-dead satellite were to have a beacon aboard that could be turned on and off over very short intervals of time, the position of the near-dead satellite could be determined to an accuracy within its own diameter using VLBI techniques. In the above paragraph we saw that it was possible to determine a target satellite's position using its own emissions by tuning a ground based receiver to the frequency of the emitting satellite. Thus, if we can determine both the target and the near-dead satellite positions to high precision, and if there is still a small amount of station keeping ability left in the near-dead satellite, it should be possible to slowly steer the near-dead satellite into the active target satellite, hitting it and putting it out of commission. When this activity is applied to several pairs of satellites at once, there is the possibility of putting several target satellites out of commission within a relatively short interval of time. If done surreptitiously, the enemy would not know what was happening. Targeting solutions could be run at frequent intervals, with the best combinations quickly chosen when needed.

Use of Direct Broadcast Satellites for Warfighting Support

The commercial market is planning to use direct broadcast satellites (DBS). They will have worldwide coverage. While the use of these commercial satellites by the military often presents problems, they can be used for selected purposes in defensive postures. We should include the use of these satellites use as part of our satellite support structure. Routine use of DBS satellites would be preferable because it would continue to add to our experience base. Barring that, arrangements can be made to use bandwidth in certain situations, similar to the arrangements made for the use of commercial aircraft.

There are many uses to which DBS availability could be put. They include the real-time transfer of information of all kinds in theater, the contents of which are needed by many echelons of command simultaneously. DBS satellites can do tailored multicasting in theater. Point-to-point transfer of information at high data rates could take place worldwide. Processed information, including unit ID, location and unit status of forces in the vicinity, derived from initiatives like InfoSoldier, could be automatically tailored and transferred to many units on the battlefield, including the lowest ones, at low data rates.

Use of Beepers for Warfighting Support

Military planners would revise many of their warfighting procedures if there were the capability to do simple paging on the battlefield. At the moment, such paging is available commercially within CONUS, but it will rapidly become available worldwide. At present, the least sophisticated paging capacities consist only of simple information transfer such as an alert signal. More sophisticated devices contain a string of alphanumeric information as well, permitting the transfer of more information, perhaps in coded form.

The ability to page on the battlefield has many potential uses, among which are:

- Transmitting an alert to perform a particular action (e.g., attack, perform a function, achieve simultaneity, look at an information update, etc.)
- Transmitting a short message to confirm an action
- Other types of short messaging

A two-way beeper system, with an uplink as well as a downlink, would offer a very powerful combination of capability on the battlefield, because its line of sight access would permit simple connectivity to all units in theater. The improvement in the timelines of situational awareness of battle units would be remarkable if the system were properly planned

A Library Database in Orbit

While the use of direct broadcast satellites and battlefield beepers would aid military operations, the presence of an instantly accessible database of information would be useful to a commander. The database could consist of: (1) long-term information which might be changed infrequently by means of command updates from the ground, and (2) short-term information which might be changed on time scales of less than a day. The information content in those databases might include the following types of information:

Long term information

Weapons system information - friendly and enemy

Platform information, including capabilities

Procedural instructions

Short term information

Order of battle and status of units

Satellite ephemerides

Enemy battle frequency and signals information

Hidden messaging

Use of Bi-Static Radar Space Illuminators

Orbiting satellites emit radiation that falls on wide areas of the earth's surface at a variety of frequencies. These emissions vary in intensity, but they might be used to provide a bi-static radar capability in conjunction with aircraft collectors operating near the ground to catch the reflections and make use of them.

Emissions from transmitters, if strong enough, can be used by collectors, if large enough, that are strategically placed in order to provide a trigger for detecting and tracking objects such as aircraft or incoming missiles that pass through and disturb the field produced by the radar. Scanning algorithms can be developed to search in space and time and to increase the effective integration time, hence provide a good signal-to-noise ratio, to detect and track the threat as it passes through the radiation field. Candidate satellites range from commercial communication satellites, TV DBS satellites, down to the constellation of GPS satellites.

Emerging Technologies that are Ripe for Exploitation

Examples of key technologies in the recent past are: the global positioning system which has permitted our military to perform coordinated maneuvers as never before; lasers which can designate targets so that munitions can strike with high precision; radars which can detect and track moving targets; and night vision devices that give our troops a decided competitive edge in night warfare.

While our future vision is not 20/20, we can venture an intelligent guess at some key enabling technologies of the future, including:

- Fiber optics and laser communications that permit information databases to become rapidly synchronized around the world through ground and space communications, respectively
- Aided target recognition techniques that take the output of aircraft and space sensors and analyze them to recognize the presence of targets more quickly
- The incorporation of differential global positioning techniques to permit targeting to fractions of a meter
- The use of hyperspectral collection techniques from the air to spot enemy threatening targets and from space, combining spectral and subpixel recognition techniques
- Bi-static radar techniques that use emissions emanating from spacecraft to assist in target detection on and nearer the ground, and
- The emergence of new methods to store energy so that our spacecraft and our warfighters can operate more independently for longer periods of time, assisted by long-lived, battery-powered, high-tech equipment

This list only scratches the surface of what may lie in store for us.

If we now focus on additional critical technologies that are space-related, we can derive the following list of enabling technologies that deserve attention:

- A*dvanced materials*

Advanced alloys, ceramics, composites, and polymers

- Directed energy

Directed energy systems that include lasers and radio-frequency devices. Breakthroughs in optics, improved device efficiency or propagation through the atmosphere could lead to a revolutionary space-related weapon.

- Guidance and navigation

These technologies are needed for better precision guided munitions that can be coupled closely to space systems

- *Information management technology*

Advances in information systems and sensors generate large volumes of data which must be efficiently managed and exploited for military operations. Relevant technologies support the management of exceptionally large databases and the products of real-time, large-scale information retrieval systems. These databases are often physically distributed among many sites separated by great distances, like the Internet. Battlefield surveillance data must be fused from multiple sources in near real-time, requiring high data rates.

- *Information warfare*

Uses high-power microwave, electromagnetic pulse, and radio frequency technologies that are capable of jamming, upsetting, or damaging spacecraft electronics from the ground.

- *Microelectronics*

Further emphasis is needed to gain increases in performance in higher temperature semiconductors and opto-electronics, to enhance on-board processing systems, and to improve both guidance and control, and command, control, and communications abilities.

- Power storage and conversion

High energy density and low mass power supplies, pulse power supplies, and high power solid state switches support the development of more effective weapons-delivery and reconnaissance vehicles, and of radars, jammers, other electronic warfare systems, and directed energy weapons.

- *Propulsion*

Propulsion technologies, such as advanced rocket propellants and exotic fuels, support the development of better aerospace platforms and permit heavier payloads.

- *Sensors*

Advanced sensors support intelligence collection, strategic warning, treaty monitoring, and weapons targeting. Advances in sensor technology enable increased performance in all-weather detection, identification, and military targeting. Sensor needs include better space-based radars, wider field optics, and more efficient infrared detectors. Fusion of all types of data collection and the integration of processing and communications capabilities need attention and improvement.

- *Signal processing*

Signal processing technologies support more efficient extraction of information derived from signals received from sensors. As signal processing technologies advance, more decision-making processes can be automated (see *User-friendly system development*, below). Signal processing technologies include software correlation techniques, neural networks, algorithm development, and artificial intelligence.

- *Software engineering*

Software engineering includes software development and maintenance technologies as well as signal processing software. Applications include the control of large digital switches for telecommunications, battlefield surveillance systems, air defense systems, and ballistic missile defense.

- *Space warfare modeling and simulation*

There is a need for a well-equipped joint space warfare center, not related to missile defense issues (which would tend to divert attention away from critical space issues). In that center, space-related studies and analyses should be undertaken by operators and doctrine developers working together, to understand and use more effectively the space systems that are available, including national space systems and the interface between space and aircraft collection. The center should be oriented toward the development of concepts of operation and modes of employment of all types of existing and proposed space systems, the refinement of requirements, and the submission of substantive input to the design of future military and intelligence spacecraft of all kinds. It should test the efficacy of using commercially available space launch and space collection capabilities and the worth of their products. No single service or organization should do this alone. Human decisionmaking should not -- and cannot -- be modeled, but the human use of spacecraft products can.

• *Survivability*

Survivability technologies involve those materials and techniques designed to enable a space system to operate in a hostile environment that requires hardening against natural radiation, man made jamming and all types of systems upset.

• *User-friendly system development*

As automatic systems and massive information flows become more prevalent, the human in the loop will increasingly become a bottleneck to the speedy execution of tasks. There is a need to help human intervention and human decisionmaking in the form of filtering, information control, and data digestion to improve all aspects of the machine-human interface.