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SPARTA Corp.
Wayne Winton

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQ AFSPC/XPX
ATTN: Lt Col Brandy Johnson
150 Vandenberg St Ste 1105
Peterson AFB CO 80914-4610

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This document summarizes the results of a pilot study that addressed how the Air Force should integrate space capabilities in the future. We considered several recent and ongoing activities, including *New World Vistas*, the Mission Area Planning and Long Range Planning Processes, and Frontier Arena, and tried to take them all into account in pointing out a path to increased military value from space capabilities.

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Space Capabilities Integration

Pilot Study

12 July 1996

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This briefing summarizes the results of a pilot study that addressed how the Air Force should integrate space capabilities in the future. We considered several recent and ongoing activities, including *New World Vistas*, the Mission Area Planning and Long Range Planning Processes, and Frontier Arena, and tried to take them all into account in pointing out a path to increased military value from space capabilities.

Briefing Outline

- **Study Objectives, Scope, Process**
- **Military Exploitation of Commercial Space Systems**
  - Communications
  - Imaging
  - Recommendations
- **Planning & Prioritizing Future AF Space Programs**
  - Process and Criteria
  - Models & Simulation Needs
  - Frontier Arena
  - Recommendations

Challenges in AF Space Planning

- **Linking space capabilities to the warfighter**
- **Integrating the needs of the services**
- **Transitioning from warfighting appliqué to intrinsic warfighting function**
- **Integrating across stovepipes within individual Services**
- **Effective exploitation of future commercial space capabilities**
- **Integration of black and white space capabilities for maximum aggregate benefit**
- **Budget limits, uncertainty, fluctuations**

Overarching issue for the military space program: achieving quantum step in space exploitation with fewer $

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This chart summarizes several of the key objectives and issues in planning for future space programs, representing underlying considerations for the Space Capability Integration Pilot Study effort. The driving factor for planning is annual budget, with the likelihood that Federal budget pressures will result in reduced future annual funding available, in real dollars, at least for Air Force white space programs.

Study Objectives

- **Define and demonstrate a process for planning and integration of Space capabilities**
  - considering current and planned military, National, and commercial space systems/elements, emerging technologies, and current/future (~20 yrs) applications/missions/needs

- **Define how Frontier Arena should evolve and be applied for supporting the Space systems definition/design/evaluation process and programmatic decisions**

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The primary objectives of the Space Capability Integration Pilot Study (SCIPS) were as listed in this chart. Relative to the first objective, the key issue is integration and associated trade-offs of capabilities across separate military space systems and across military, National, and commercial space systems.

We wound up focusing on integration of military and commercial space systems capabilities because we came to the conclusion, early in the study effort, that exploitation of commercial space capabilities for military space functions offers a major opportunity within the next decade. Exploitation of this opportunity will require significant changes to the Air Force space planning process. We chose not to address integration of white and black (National) space systems, in part because of classification and in part because that issue is being addressed in depth by the Space Architect and the DUSD(Space).

The second objective was to recommend how Frontier Arena, the Air Force's planned environment for integration and demonstration of space capabilities, could be best employed.

Summary of Recommendations

- **Increase emphasis on planning for integration of commercial space systems capabilities**
  - Establish joint AFSPC/AFSMC office dedicated to exploitation of commercial space systems
  - Publish policy on use of commercial space, to assure external/internal audiences of commitment
- **Shift from requirement-driven planning/programming toward value-based planning**
  - Priorities driven by military value over time/unit investment, associated with broad objectives for capability
  - Use military worth as primary measure of merit
- **Drive M&S activity to provide tools capable of measuring military worth; address commercial exploitation in models and demos**
  - Pool resources with AFIWC, SWC, NRO, DARO; jointly decide on MW measures/M&S plan with products migrating to JWARS & NSAM/JSIM
  - Separate Frontier Arena into planning/programming & wargaming/training objectives and put separate leaders in charge

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The few examples of commercial space exploitation that we recounted in this briefing are representative of a larger number that make it clear commercial space will be exploited by the US and others. The Air Force already has efforts ongoing to search for opportunities to exploit commercial space capabilities. However, we believe that opportunities to achieve militarily-useful capabilities from near-term commercial space systems at low cost warrant and, to be successful, will require a dedicated staff devoted to this purpose. We recommend that AFSPC and AFSMC establish a joint office to work with commercial space system developers to determine how best to impact the commercial systems design and operation to achieve military space objectives. We also believe it important to convince, perhaps by an Air Force policy statement, both the commercial space world and the AF internal staff that commercial exploitation is a serious intent of the Air Force.

The second recommendation has to do with the planning process. The combination of future budget constraints and opportunities arising from commercial exploitation motivate, and probably dictate, a shift in that process toward what we call value-based planning. One aspect of that process is to measure candidate new space programs (including commercial opportunities) in terms of military worth. However, current campaign models do not provide this capability.

We recommend that several elements of the Air Force and other organizations with a vested interest in information jointly undertake to guide and fund the modification of certain models to provide this capability. We believe Frontier Arena is a good idea but too broadly scoped. We recommend a re-start that describes a few specific roles, proposes what its products are, and puts someone in charge. It should also be a means to demonstrate how commercial space capabilities can be integrated into warfare and what military worth they may bring.

Study Participants

- **Sponsors**
  - Col. Hal Hagemeier (AFSPC)
  - Col. Chris Waln (AFSMC)
- **AF Observers**
  - LtCol Brandy Johnson (AFSPC)
  - Maj Walt Fink (AFSMC)
  - Maj Randy Correll (AFSPC)
- **Core Team**
  - Wayne Winton (Chair)
  - Gen Pete Piotrowski
  - MGen John Corder
  - Bill Nicholau
  - Bill Grenard
- **Red Team**
  - Pete Aldridge
  - Don Cromer
  - Duane Andrews
  - Don Hard

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Colonels Hagemeier and Waln jointly sponsored the study, conducted as a task under the AFSMC EAD contract. The Air Force "observers" provided study support (arranging input briefings and documents) and, as well, participated in the working sessions with the core team. Pete Aldridge and LtGen (ret) Don Cromer each spent several hours with the study team in review of our preliminary results and conclusions. Their observations and suggestions were very useful, and we have reflected those in the briefing material. Later, Duane Andrews and Don Hard reviewed the draft final briefing, providing additional suggestions which we have incorporated in this final version of the report.

Study Process

- **10 days of meetings (March-June, 1996)**
  - Review of inputs
  - Working sessions
  - Preparation of output
  - Ad hoc reviews by Red Team members
- **Input Briefings/Reports**
  - Seven Strategies for Space
  - AF MAP process, AF LRP activity
  - New World Vistas
  - Commercial space programs (Iridium, Teledesic, ...)
  - Frontier Arena, AF M&S
  - . . . . . .

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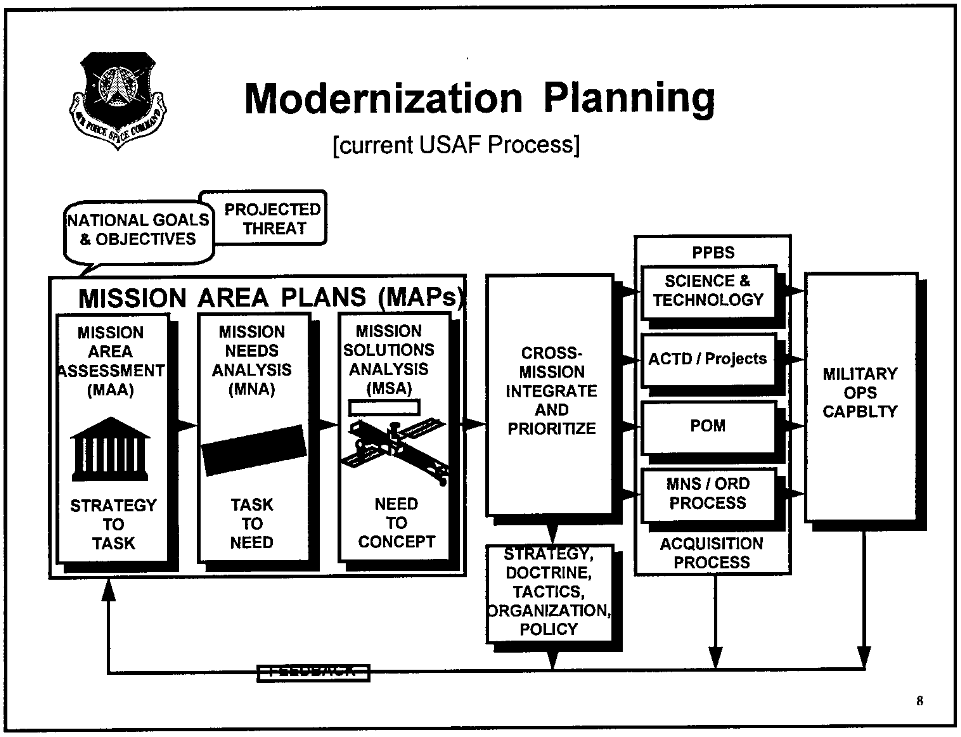
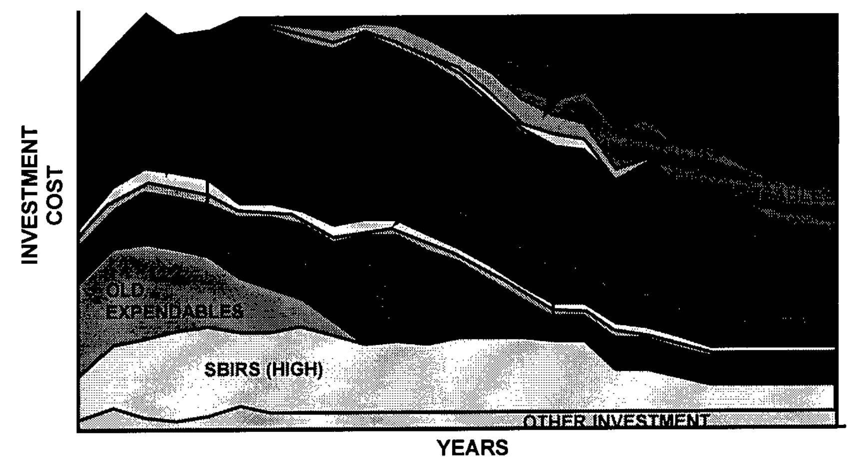
The purpose of this chart is to note that this was a limited effort, essentially a "greybeards" review of recent relevant studies, briefings, and ongoing planning efforts.



This is an Air Force chart from an AFSPC briefing, describing the Mission Area Planning process. We were asked specifically to address the "cross-mission integrate and prioritize" box in the middle (called the "miracle" box), and to suggest for this a process for trade-offs between candidate future space programs, especially between programs crossing space missions. We concluded that trade-offs between commercial space exploitation opportunities and Air Force owned and operated systems also impact the process for deriving the mission area plans (the 3 boxes at the left of the chart), and dictate a tighter "feedback" loop between solutions and trade-offs and definition of needs and requirements, particularly with respect to definition of performance requirements.

Total Investment Picture: Adjusted - No Growth

[example from Space MAP]



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This is another chart from the Air Force briefing on the planning process, illustrating the key output of planning and the diversity of space initiatives across which trade-offs are required.

Ingoing Premises

- **Constrained or declining Space budgets coupled with aging AF Space fleet**
  - Thus, cost of replacement of MILSATCOM, Navigation, TW, mapping fleet likely to crowd out new technology development
- **Domination of space elements population within next decade by commercial space systems for communications and imaging**
- **Even 3rd World entities will have access to militarily-useful space services, almost as capable as those available to US military**

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This chart identifies three primary considerations or observations that drove us to focus on commercial space exploitation. The first notes that much of the current Air Force white space fleet will be reaching the end of its useful life within the next few years, and that the costs of replacing that fleet would very likely limit funds available for new technology unless ways can be found to accomplish some of these space functions much more economically.

The second observation, resulting from a cataloguing of near-term commercial space programs, notes that the Air Force will soon become a minor player in space -- that space will cease (and already has ceased) to be "of the Air Force, by the Air Force, and for the Air Force".

The third observation is a matter of concern -- that future capabilities available at relatively low cost from commercial space systems will be militarily-useful to even third world countries.

Specific Questions and Issues

- **For planning / programming of future AF space system & technology development, how to trade between options associated with separate space missions and/or separate military objectives?**
  - Decision criteria?
  - MOMW, MOE, MOP?
  - Analytic process?
  - Tools?
- **How can and should Frontier Arena best be applied for supporting space planning, and how should it evolve to accomplish this?**

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This chart defines more explicitly specific questions we were asked to address in the study.

Topics

- **Exploitation of commercial space capabilities**
  - Seeing "space capabilities" as information
  - limits and downsides
  - opportunities
- **Improving program prioritization process**
- **Getting the Right Tools**
  - measures
  - models and simulations
- **Refining and reinvigorating Frontier Arena**
  - focusing on fewer objectives
  - addressing exploitation

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Seeing Space Capabilities as Information

- For three decades, the Air Force has developed the space technologies & systems to deliver info (weather, imagery, nav support, comm, etc.)
- Based on where the dollars are spent, future technologies will more often emerge from the commercial world
- Now, the Air Force needs to concentrate on supplying information, getting the best value in warfighting capabilities
- Question: how much can we exploit commercial space?

Need to focus on the cargo of 0's and 1's rather than the "C-130s" carrying them

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The many satellite-borne capabilities developed over the years by the Air Force have paid large dividends to the commercial world and ultimately to private consumers of information. Current military development and acquisition budgets are limited, but large sums are being spent in the private sector (and more and more by foreign governments) to deploy commercial capabilities. We made no attempt to compile the aggregate amount being spent on the development of these systems. However, we identified nearly sixty communication and imaging systems, many of them reported to be capitalized at more than one billion dollars.

It seems reasonable to expect that in the future, new spacebased capabilities and technologies may spring from commercial system development. This presents a new opportunity -- a "defense dividend"-- if we can figure out how to tap this new source.

The preponderance of what Space brings and can bring to the warfighter is information. The Global Positioning System, directly available to every element of our Joint fighting forces except deep-submerged submarines, is a model for future linkages of communications, imaging, surveillance and reconnaissance, and weather. The challenge is to get the best aggregate set of capabilities to the warfighter for the money.

This led us to a central question we addressed in this study: how can we exploit commercial space capabilities to increase the value of space to future warfighters?

One of the reviewers of the study put it well -- we have to think about the zeros and ones, not the truck that hauls them.

What the Commercial World Won't Supply

(What the AF Will Have to Develop/Deploy/Operate)

- **Ballistic & cruise missile warning / tracking**
- **Intel-quality surveillance/reconnaissance for S&T purposes**
  - Hyperspectral
  - SAR
  - Signals intelligence
- **Force Application**
- **Strategic Command & Control**

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Some military space tasks have no analog in the commercial world, so the government will have to continue to develop and provide the capability to perform them. The most obvious example is missile tracking and warning, since there is no foreseeable commercial market.

Although, as we will show, there will be significant commercial imaging capabilities, the fine-resolution images needed for intelligence analysis across the spectrum won't be provided by commercial systems.

Obviously, the military won't be able to turn to the commercial world for weapons in space.

The surety and security needs for Strategic command and control will keep it in the military system realm. However, it may be a candidate in the future for piggybacking on a commercial system.

In many cases, however, commercially available space capabilities closely match what is needed by the warfighter. The following charts review the possibilities for their exploitation.

Looking to the Future: Military Use of Commercial Space Capabilities

Opportunities

- **Rapid emergence of commercial capabilities**
  - communications
  - remote sensing
- **Ways to achieve capability faster, cheaper**
  - subscribe
  - piggyback
  - partner

Challenges

- **Cultural change**
  - requirements and planning
  - acquisition process, including legislation
- **Assuring access, control, and operability during conflicts**
- **Keeping US dominant when others have access**

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For three decades, new space capabilities have been brought on line with Defense dollars. Now, billions of dollars are being invested worldwide in commercial systems to provide substantial capabilities, particularly communications and remote sensing or imaging.

For the first time, the US has the opportunity of shopping the commercial market for military values. Value may be derived by simply subscribing to data or service, or by piggybacking military payloads on commercial systems, by partnering with commercial developers to get augmented capability, or a number of other ways which are described later in the briefing.

If the opportunities are to be taken, they come with some challenges, not the least of which is the cultural change to the way the military does business.

The biggest challenge in the mind of the warfighter is to make sure that the commercial capabilities can be reliably accessed and controlled, especially during conflict. Many of the commercial systems are being provided by multinational companies or consortiums, which heightens the concern in this area.

As already mentioned, whether or not the US makes significant use of commercial space capabilities, other entities around the world surely will. Our challenge is to maintain superiority or dominance.

Near-term Array of Commercial Systems is Substantial

- **About thirty new commercial comm systems**
  - GEOs and large-constellation LEOs
- **About thirty new imagers**
  - electro-optical, synthetic aperture radar
  - in some cases, direct access by subscribers
- **Private TT&C, user equipment**
- **Already playing a military role**
  - GBS system
  - Spot images downloaded in Bosnia
  - Iridium® bus proposed for one SMTS concept

Effective military exploitation will require understanding/influencing commercial systems design

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We found about sixty current and near term satellite systems, about equally divided between communications and imaging. In many cases, these systems use private tracking, telemetry and communication systems and user equipment. (In other words, many of these systems will continue to operate even if the entire US satellite and control network goes down.)

We found several current cases where commercial systems are already being used to support the warfighter. The Global Broadcast System demonstration in Bosnia is discussed later in the briefing, as is the use of Spot images in Bosnia. Also, an alternative approach to the Space and Missile Tracking System (SMTS) has proposed the use of the Iridium satellite instead of development of a new one.

Although the potential opportunities are many, exploitation will require that the Air Force more fully understand and influence commercial system design in the early stages of development.

Commercial Space Downsides

- **Some needed military capabilities may have no commercial market (e.g., ballistic missile warning)**
- **Opportunities with biggest $ payoff don't necessarily meet essential warfighting needs**
  - guaranteed access, esp. during conflict
  - surety & security
    - exclusive control of links when needed
    - encryption, control of keys
  - operability in hostile environment
    - infowar
    - jamming
    - signal intercept
    - nuclear radiation
    - antisatellite attack

Downsides must be resolved to fully exploit the potential

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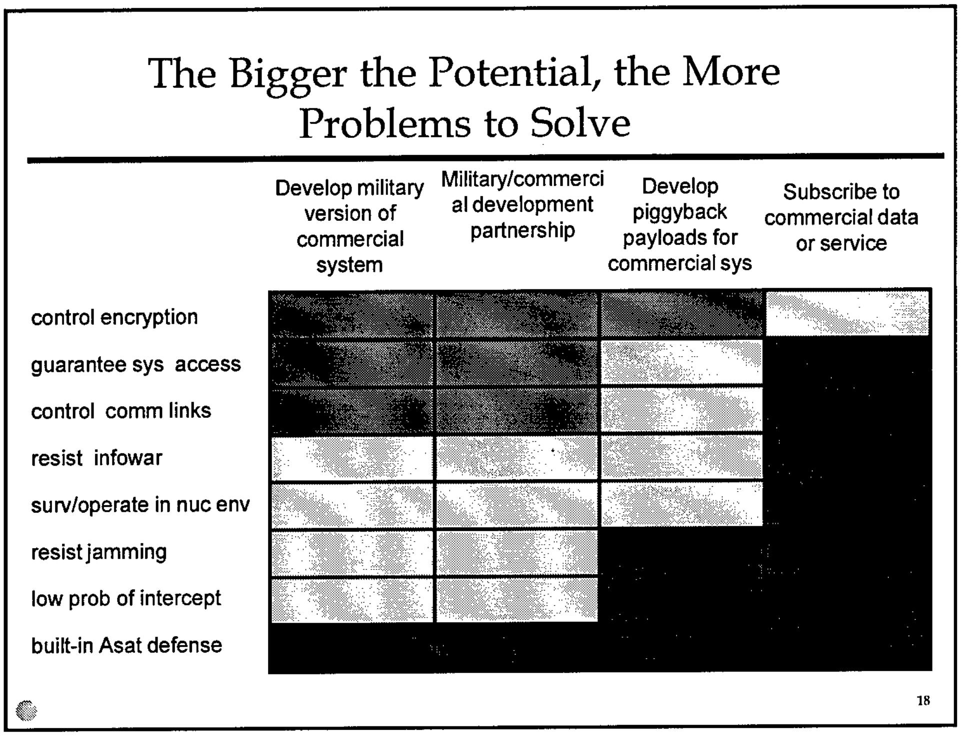
Not every military information need can be provided or augmented with commercial space capability. No commercial market exists for ballistic missile warning and assessment, for an obvious example. The US will have to continue to develop, deploy and operate such systems. Over a broad range of requirements, however, commercial capabilities can be brought to bear.

In warfare, however, a capability, no matter how inexpensive, is of no value if it doesn't exist when it's needed. Two kinds of access problems have to be solved. The first is that the supplier has to agree and assure that the capability will be provided when required. The second is that the capability may have to operate in environments beyond those designed for in the commercial environment (e.g., nuclear radiation effects). Equally important for systems that supply or transport information, we have to be sure that the enemy is not accessing information we don't want him to have, and not decoding, adding, altering or deleting information in our systems. Finally, if commercial systems don't provide for antisatellite attacks, then we may have to provide that capability in some way.

To fully exploit the potential benefits that can be provided by commercial systems, solutions to these downsides have to be implemented.



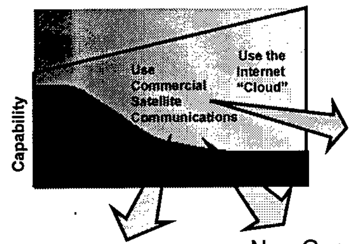
This chart is meant to give a general idea of the range of possibilities and problems with exploitation of commercial space capabilities. Across the top of the matrix is a range of exploitation techniques, from developing a military version of a commercial system, on the left, to simply subscribing to data or services, on the right. In general , the potential savings in cost would be higher as one shifts to the right.

Down the left side of the matrix is a list of desired features that must be provided for systems to be judged useful to support warfighting. One would expect that these features can more easily be provided for a capability provided by a military owned and operated system based on a commercial system, and are likely not to be provided in the subscription option. The ease of providing the features is indicated by the green, yellow, and red boxes.

The basic message of the matrix is that a trade exists, since lower inherent cost for capabilities carries higher cost to implement additional features.

Note: dark areas = red
light areas = yellow
medium areas = green

Potential Commercial Communications Systems



Geostationary Fixed Systems

Astrolink	Orion F7-F9
AT&T VoiceSpan	Spaceway
EchoStar	Morning Star
GE*Star	NetSat 28
KaStar	PanAmSat
LAHI CyberStar	VisionStar
Millennium	

Non-Geo Fixed

Teledesic

Non-Geo Mobile

Iridium
GlobalStar
Odyssey
E-SAT
FAISat
GE-LEO
GEMnet-CTA
Leo One USA
Orbcomm
VITA
Starsys

- Global coverage
- Plenty of bandwidth
- Compatible with encryption
- Some inherent anti-jam, LPI
- Capabilities evolving at fast pace

- **Opportunity to exploit $billions being invested in commercial systems**
- **Pay for added capability (nuclear hardness, extra antijam, LPI)**
- **Resolve operational issues: guaranteed access, access denial to adversaries, etc.**

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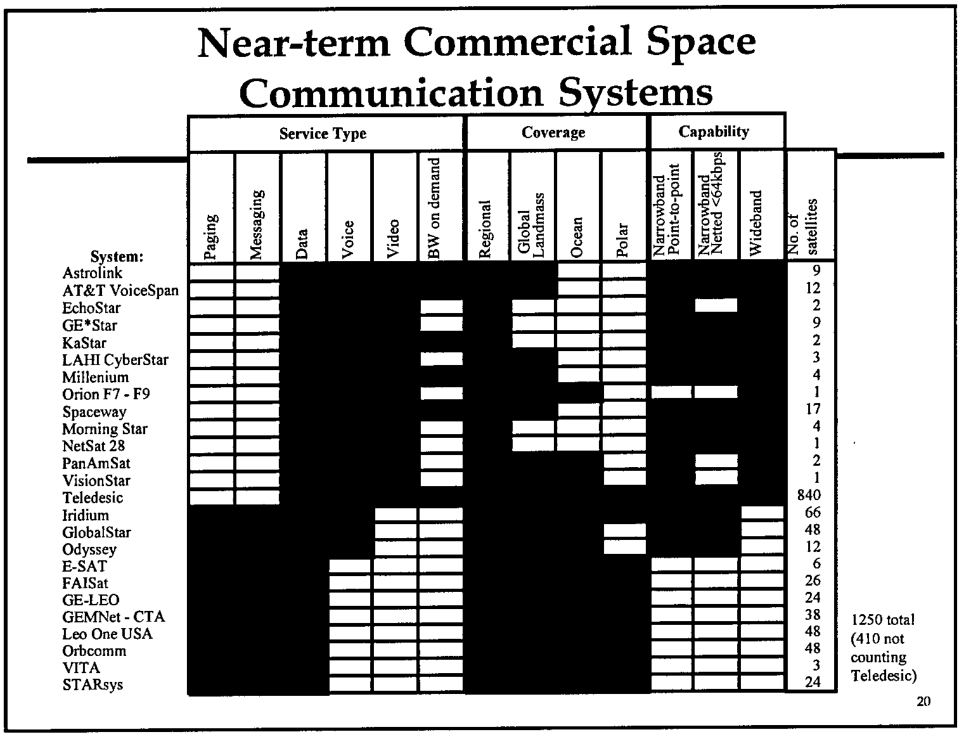
The commercial satellite communication business is an emerging industry, investing billions of dollars for development and production, with significant implications for the Department of Defense. Listed are systems either in operation or with filings with the International Telecommunications Union, providing fixed and mobile satellite services (FSS & MSS) from both geostationary (GS) and non-geostationary orbits (NGSO). Bandwidths range from less than 9.6 kbps to 1.2 gbps. Not all these systems will be developed, but the consensus is that sufficient numbers will be available to provide service for a large portion of the DoD communication needs.

These commercial SATCOM services mean less developmental costs on the part of the DoD, relatively flat budget requirements from year to year for purchased services, and with the number of commercial systems being developed a competitive environment that will assure the DoD the best value per dollar spent.

With most of the DoD communications being satisfied by subscription, DoD can concentrate on the unique facets unavailable in the commercial world, i.e. nuclear hardened systems. These needs can be satisfied by adding payloads to commercial systems (piggyback), decreasing the vulnerability of commercial systems by adding requirements (partnerships), or by developing unique satellites for specific or unique needs (smaller and less costly than today's larger spacecraft).

The graphic notionally indicates the trends we see for communications for the warfighter -- now predominantly military systems with some access and use of commercial links, but transitioning to substantially greater reliance on commercial systems within the next decade or so, which ultimately will become transparent to the user -- a "virtual" communications cloud of connectivity, or the "global grid."



Over 25 commercial SATCOM systems with FCC licenses or in the filing process represent over 1200 satellites. The range of services covers paging and messaging, data, voice and video. In addition, virtually unlimited service and type of service could be satisfied by systems like Teledesic with its bandwidth on demand (up to 1.2 Gbps links), point-to-point connectivity and worldwide coverage. Coverage, in general, is determined by the business niche of the particular system and the degree of technology incorporated (i.e. cross links, etc.).

Taken in its total, the commercial capability could well support the DoD requirements except for a very narrow segment, nuclear hardening. This requirement could be incorporated into any number of these systems through partnering between the Government and the commercial entity.

Example of What's Already Happened: Global Broadcast Demo System

- **Information Dominance for Joint Endeavor (IDJE)**
- **Focused on the warfighter: get secure info down to lower-echelon troops in Balkans as quickly as possible**
  - intel
  - video (incl. from Predator UAV)
  - imagery
  - other information
- **Different way of doing business**
  - leasing transponders on commercial satellites
  - using existing fiber optics
  - employing new management and contracting procedures

Quantum leap in capability --
bypassed the planning and acquisition process

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It's interesting to note the kind of exploitation that's happening now. In Bosnia, search and rescue of the two French pilots downed last year was hampered by a communications bottleneck, even though at the time, US Predator UAVs were able to groundlink imagery of the crash site. Sent through military communications channels, the imagery arrived too late for the rescue teams, and its quality was degraded by data compression.

The Defense Science Board suggested implementing a wide bandwidth comm system using commercial links and technology. By leasing transponders on commercial satellites and using existing fiber optic links, defense forces were able to broadcast encrypted data to nodes of a "secure tactical Internet." Data and imagery can be accessed from the net's "websites" in Bosnia, other European installations, and Washington.

Implementation of an operational system is proceeding based on a demonstration performed in April. The current system can relay 30 frame-per-second video, which can be viewed at web sites in the US with only about a 1-second delay.

Significantly, this quantum improvement was achieved outside normal planning and acquisition channels.

What Commercial SpaceCom Won't Provide Without Business Incentive

- **Nuclear hardened payloads**
- **More than inherent anti-jam, LPI**
- **Positive control of comm links**
  - guaranteed access
  - denial of access by adversaries during conflict
  - multi-level security
- **Assured resilience against information warfare**

Need to address a range of solutions: formal agreements, add-on military requirements, piggyback payloads, military ownership of commercial versions.

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Our study team looked for military communication needs and features that commercial space comm won't provide.

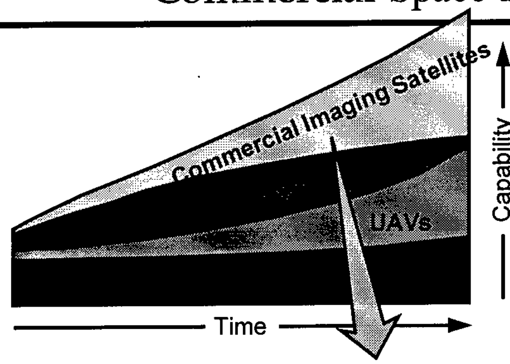
Post-attack communications to our strategic nuclear forces require link survivability in a nuclear radiation environment, a level of survivability not necessary for commercial systems. The military will have to continue to develop and provide this capability. Commercial systems may still play a role, by giving a ride to hardened self-contained piggyback comm packages.

Although commercial systems have inherent features to prevent RF interference, these may not be enough to counter enemy attempts to jam or intercept messages. For these cases, the government may have to pay to have additional capabilities added.

The biggest problem facing the military user of commercial systems is the need for some level of guaranteed access to the capabilities when they are most needed. Beyond that, the military may need a means to deny communication access to adversaries once the shooting starts, and may need to implement multi-level security, which is not required in the commercial world.

Solutions to these deficiencies of commercial communications systems need to be addressed. Possible solutions include formal agreements (like the embargo of Spot images to Iraq during Desert Storm), incorporation of military unique requirements into the commercial satellite systems, piggyback payloads, or military owned and operated version of the commercial systems

Commercial Space Imaging



- Potential to greatly augment information for the warfighter
- 29 near-term commercial Spaceborne Imaging sensors on orbit or in work
  - electro-optical and synthetic aperture radar (SAR)
- Global coverage, some accessible directly in theater
- Commercial impetus for resolution improvement
- Compatible with encryption

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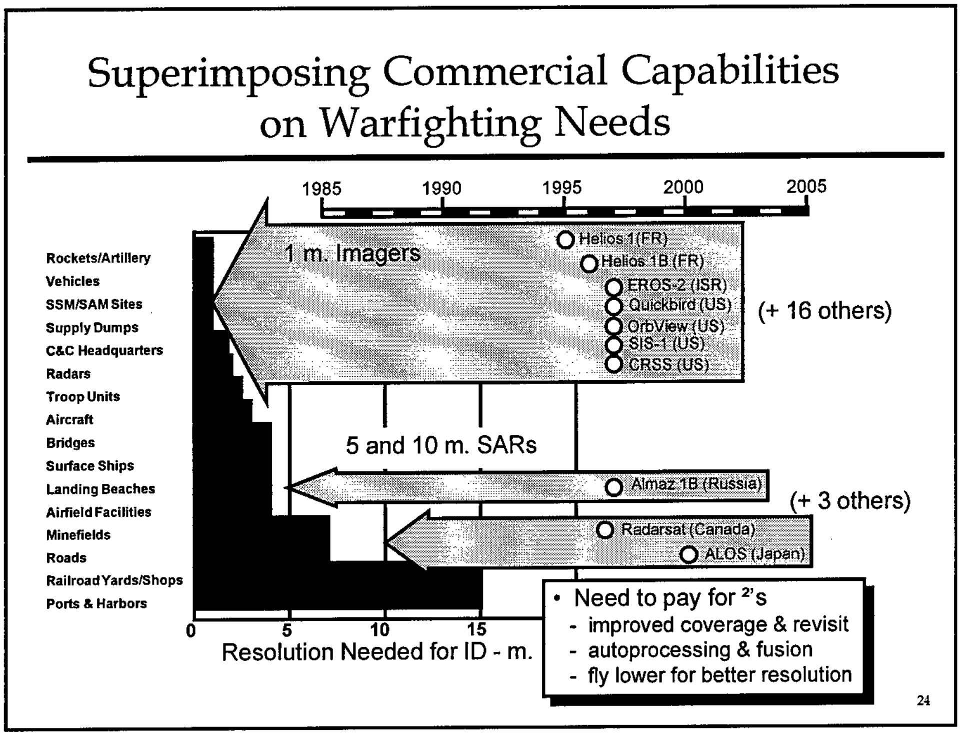
The role of commercial space capabilities in providing images for the warfighter differs from the role for commercial space communications. In addition to the use of National means for imaging, the warfighter now has at his disposal manned airborne platforms such as the U-2 and the JointSTARS, and UAVs such as the Predator, now being used in the Bosnia theater, and the near term Tier 2 platform.

There are at least twenty-nine existing and near-term planned commercial satellite systems that have the potential, especially in the aggregate, of augmenting military imaging systems with electro-optic and synthetic aperture radar images. (One of these, discussed later, has already been used in-theater, in Bosnia.)

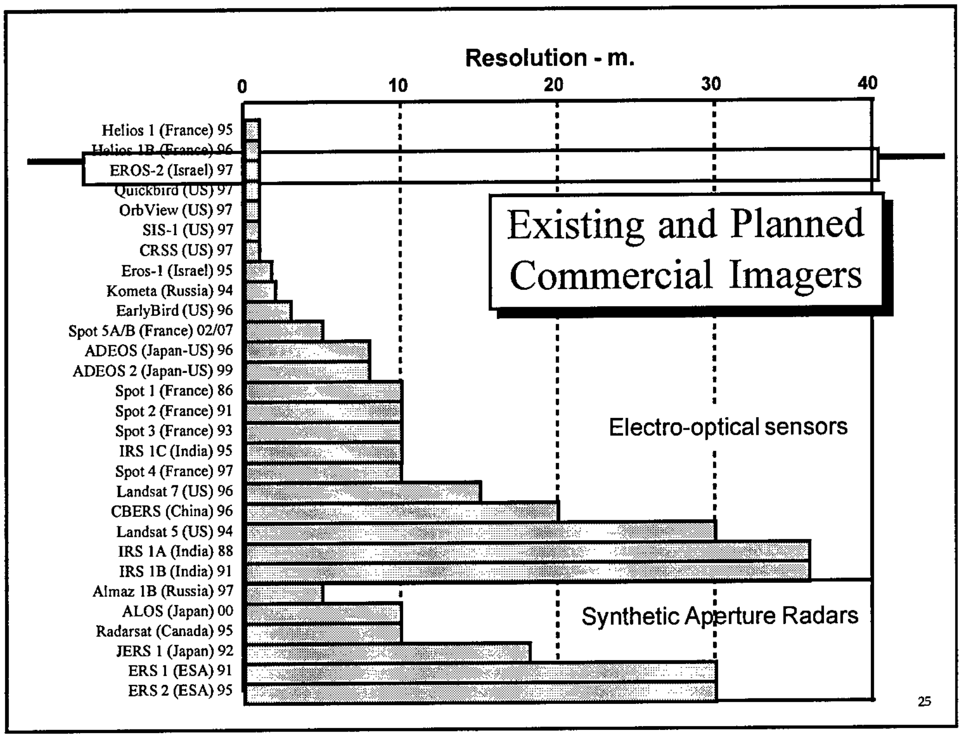
The capabilities of the commercial imaging systems vary, but all can provide images valuable to warfighting.



Commercial imaging systems are just beginning to appear, with a flood of systems forecast to come on line in the 1997 timeframe. Of significant importance is the speed by which the world's business is changing based on the access to this type of imagery. Industry is creating an entirely new market and businesses and Governments are starting to base decisions on visual access.

This chart superimposes near term commercial imagers, the time they will become available, and the resolution they will provide, relating it to a bar chart that shows what kind of resolution is required for identification of various types of targets. It is clear from a resolution standpoint that commercial images may have great value, given access to them. Typical revisit time for these systems (all planned for sun-synchronous orbits) is 3 days or more. In aggregate, revisit time can be reduced to considerably less than 24 hours. However, images produced for a given battlefield area will be "clumped" in time. To get very frequent revisits more distributed in time, the military will have to pay for additional satellites, perhaps not directly but through guaranteed subscription to the additional information that is furnished by the added satellites.

As mentioned earlier, this information must be assumed available to the enemy, which implies that the US may need to re-examine where our "edge" is in a conflict. The edge may be in the utilization (capture, automatic processing, fusion and dissemination) of the imagery rather than the imagery itself.

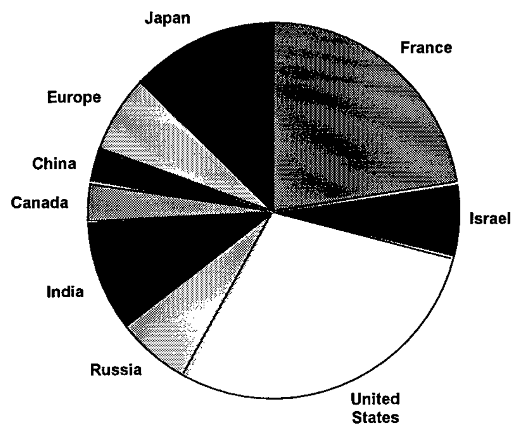


This is the list we compiled of existing and near-term commercial imaging systems. The chart shows the name, primary country of origin, first launch date, and ground resolution capability for each system.

Many technical factors need to be analyzed. How much area can be covered per pass? How quickly can the sensor be steered to different target areas? How directly can a field commander task the satellite? How quickly, over what link, and with what ground equipment can the field commander receive the images? These, and questions of frequency of revisit, spectrum, and ability to automatically process all have to be considered in coming to a decision of whether and how to use the capabilities.

As shown on the next chart, the national origin of these capabilities poses some political questions.

Origin of Near-term Commercial Imaging Satellite Systems



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This pie chart breaks down the data from the previous chart by country of origin. "Europe" stands for the European Space Agency.

The use of the word "commercial" in the title of this chart deserves some comment. The US has in the past had the luxury of being rich enough to carefully partition private commercial, civilian government, military, and intelligence systems. The rest of the world has not had this luxury. Instead, foreign imaging systems have been developed with significant foreign government funding and involvement. So, "commercial" simply means that the images from these systems can be purchased on the commercial market.

Moreover, many of the systems have multinational involvement. For instance, Brazil is a partner with China in their CBERS venture. Even systems listed as US have foreign involvement in some cases.

This aspect must be factored into decisions to use the systems -- i.e., if and under what circumstances will the system owner deny imagery? The problem is to figure out how to augment our warfighting capabilities with these systems and have the means to assure we'll have the capabilities when we need them.

Example of What's Already Happened: Fusion of SPOT Images in the Balkans

- **Fusion of Spot 10 m. imagery with hi-res digital terrain data of Bosnia**
  - 3D imagery used by USAF pilots to practice flyovers
  - Cartographically precise
- **Spot imagery downlinked directly to US forces in Bosnia via USAF Eaglevision terminals**

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Commercially-available imagery has already been put to use in a very innovative fashion to aid US pilots to conduct real-time simulated "flyovers" in Bosnia.

To do this, the pilots "fly" simulators that display three-dimensional images of the Bosnia theater. These are created from the fusion of 10-meter resolution Spot satellite images with precision digitized terrain maps of the area. The images are electronically "draped" over the digitized terrain to create realistic 3-D views of the areas to be overflown.

The Spot imagery was downloaded directly to in-theater EagleVision consoles, and the draped images were used in training NATO pilots for bombing missions last September. The images have been credited with playing a part in the Dayton peace accord.

Making Commercial Imagers a Useful Augmentation to Military Capability

- **Imagery of the battlefield has target and synoptic requirements**
  - commercial systems can provide useful augmentation to military imaging capabilities
  - add-ons needed for frequent revisit, time-distributed images
    - subscribe to multiple systems
    - buy additional spacecraft
- **Concentrate development $ on capabilities that provide US an edge:**
  - autoprocessing, fusion and dissemination
  - piggyback payloads for unique requirements - e.g., MTI

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As was stated earlier, the utilization of imagery for users will become more important than the quality and quantity of the imagery. The glut of commercial systems, offering almost any type of imagery (IR, literal, SAR, and multi-spectral) will almost assure our adversary has access. The real question is what can he do with the data?

The requirements for imagery in support of a conflict fall into two basic categories: one, a battlefield synoptic view and two, point targets. Synoptic views require large area coverage, which may take a number of passes by various systems. Great quantities of data will be produced and require processing and exploiting. The same can be said of target data...a lot of pixels.

The US with existing capabilities (i.e. IDEX*) and planned augmentation and proliferation of imagery exploitation capabilities can capitalize on imagery utilization over any foreign source. Today, even the developed nations (our allies) are less capable in this arena...if we are to have an "edge" and keep it, we must continue to convert the imagery better than our foe.

* Lockheed's Image Digital Exploitation software

Planning Options for Exploiting Commercial Space Systems

Cost and Military Utility

Increasing

• Subscriber	Pay fees for comm or image services as an ordinary subscriber
• "Anchor Tenant" Subscriber	Major subscriber with priority in return for long-term commitment
• CRAF-Analog Subscriber	Option for very high usage in emergency
• Piggybacking	Military instruments carried as fly-along tenant on commercial spacecraft
• Production Subscriber	Buy more satellites/launches from commercial line for military coverage/capacity
• Partnering	Commercial/Government joint venture development/production/sales to meet combined military & commercial needs
• Military Version	Development of military system version as spin-off of commercial development (the reverse of 707 via KC-135)

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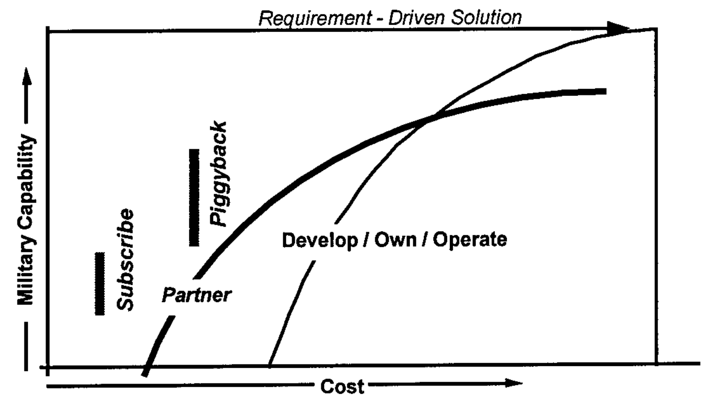
There are several ways the Government can take advantage of the billions of dollars being pumped into commercial space systems. Many of our military requirements in both communication and imagery could be satisfied by the emerging capabilities of commercial space systems. Options to tap into these capabilities range from a purchased service (be a subscriber) to creating a military owned and operated version of a commercial space system.

The options available are only constrained by the ability of Government and Industry to meet on common grounds that support the business requirements of Industry and the procurement laws of Government. It is not clear that laws need to be changed, but rather cultural thinking. The need for the government not to be involved in each step of the development process, but accept an end product, the need to make long-term commitments to the use of a product, and to agree to an end capability rather than the interim requirements specifications may be difficult changes...but must be considered. The cultural change can lead to new partnerships and increased capability for the Warfighter at a reduced cost.

Commercial Options May Provide More Value/Cost Than Military Development



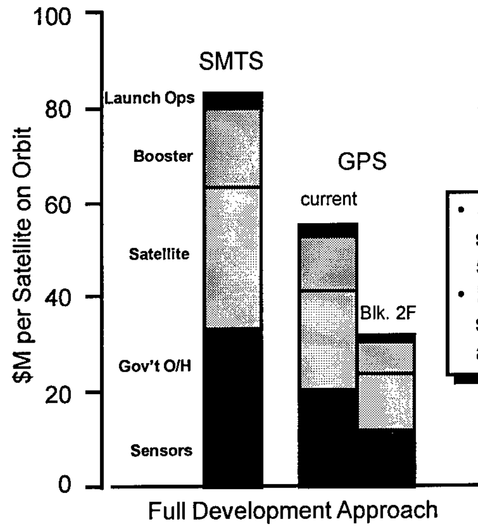
- Commercial options create step functions in capability/cost
  - early low-cost interim capabilities while awaiting robust solutions
- For some comm functions, commercial systems may provide 100% of desired capability

30

This chart attempts to capture the difference between traditional military space system development and the options becoming available from the commercial world. The "Develop/Own/Operate" curve requires the expenditure of large amounts of money (and time, of course) for development before any capability can be placed on orbit. During this time period, technology can leap forward, and Congress can question and cut budgets. Then, more money has to be spent to deploy a system that is designed to reach a predetermined "requirement." The question is, can militarily useful capability be obtained at lower cost by exploiting commercial space capabilities?

As we have indicated, commercial space capabilities more than ever before promise potential utility to the warfighter. Shown notionally on the chart are three ways that capabilities can be acquired at lower cost -- in other words, better values, given that they can support the warfighter. The vertical bar on the left indicates cases where information or services can be subscribed to. The military capability may or may not reach the overall requirement, but may provide useful capability at very low cost. Another bar illustrates that capability may be achieved through piggybacking military payloads on commercial satellites. This may cost more than subscription, but less than full development. The shaded curve, which is in the same form as the full development profile, represents the case where the military has gone into partnership on a new commercial development, paying for additional capability, but benefiting with cost sharing and perhaps a shorter development cycle time.

Potential for Piggybacking on Commercial Spacecraft



- Sensors/instruments on military space systems typically represent 5 - 20% of total system cost
- Piggybacking opportunities for small sensor payloads (~100 lb) appear likely

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The instrument or sensor typically is a small fraction of the cost of a deployed space system, as shown by the examples for SMTS and GPS. Of course the remainder of the costs must be borne by someone, but in some cases, leftover payload capability could be available at very low cost -- commercial outfits want to fill up their satellites with paying customers just like the airlines do, even if the ticket to ride is offered at a much reduced price.

Thus, "piggybacking", in which the military supplies its own payload to occupy excess space and payload capability on commercial satellites, may offer an opportunity to substantially reduce costs for some applications. One of the commercial satellites that has filed for a frequency slot, the Leo One system, will launch a constellation of 48 satellites, and has announced that it has 100 pounds of available payload space, supported by prime power and thermal control for a piggyback user. The relatively low weight of the GPS instruments make future generations of GPS a particularly good candidate for piggybacking in the future.

Recommendations for Commercial Space Exploitation

- **Plan to leverage commercial communications capabilities to reduce future MILSATCOM investment costs**
  - Military-peculiar needs: own/operate, pay delta, or piggyback
- **Explore piggybacking of future generations of GPS**
- **Exploit aggregate capability of commercial Imagers to augment military systems**
  - Commercial resolution capability useful now, will improve
  - Pay for enhancements (revisit, coverage, special payloads)
  - AF development priority should be auto-processing, true fusion
- **Take a hard look at delivery-on-orbit, or joint venture dev. of future launch vehicles required for military payloads**
- **Establish AFSPC/SMC office for Commercial Space Exploitation**
  - Plan appropriate transitions to commercial use
  - Get in the commercial development loop to influence future designs

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The emerging commercial global space communications capabilities will soon provide capacity far exceeding that of the military space systems. We recommend that the Air Force plan for a transition, to significantly increase reliance on the future commercial systems to support military communications needs. During our review, we were told that the next block of GPS satellites have excess payload that the Air Force could make available to commercial customers. It seemed to our panel that the idea of piggybacking GPS payloads on commercial satellite constellations has the potential for larger cost savings.

The aggregate capability of commercial imagers has potential to significantly augment the flow of valuable information to the warfighter. The overall capability of the commercial imagery systems will continue to improve. We recommend that the Air Force figure out how best to get those commercial capabilities, and perhaps pay for additions to the aggregate constellation of commercial imagers. Our development budget should be focused on how to use the aggregate imaging data effectively, which means the processing, exploiting, fusion and dissemination of the information extracted from the imagery. We may have to augment the commercial system with specialized systems that provide the increase in capacity or uniqueness of coverage we need for our strategy of war.

While we did not spend much time reviewing space launch issues, it did appear that contracting for delivery-on-orbit may be a way of getting to an integrated satellite and launcher solution not requiring new military launcher development.

The Air Force needs to get into the lead for this transition. Our primary recommendation is the creation of an office to develop the interface between the commercial business needs and the Warfighter requirements. The US needs to take advantage of the industry development dollars being pumped into space capabilities by either using them as they exist, or influencing future commercial developments to make them more valuable to the warfighter

Office for Commercial Space Exploitation

- **Understand how best to work with commercial world**
  - what do they prefer to sell (data, service, hardware)?
  - what kind of contracts (terms & conditions) will they sign?
  - will they let AF pay them to add capabilities?
- **Determine how to get the most value for the money**
  - subscribe, anchor tenant, CRAF-analog, piggyback, etc.
- **Figure out how to guarantee adequate access & control**
- **Match available and extrapolated capabilities to needs**
  - from industry: what can they provide at what cost?
  - from warfighters: what do they have, what do they think they need?
  - from field unit equippers, how to achieve seamless integration?
- **Select, plan and program**
  - XP inputs to POM, identify agreements to be signed, changes to policy, practices, process
  - each program assigned to appropriate SPO (a la GBS)
- **Clout, access assured if Office reports to AFSPC/CC**

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The implementation of new space communications and imaging capabilities in Bosnia should raise a warning flag that the exploitation of commercial space capabilities is happening piecemeal, outside the Air Force's planning and acquisition process. If AFSPC and SMC are to play a lead role in the transition, the recommended Office for Commercial Space Exploitation must have the responsibility, authority, and budget to accomplish these objectives.

First, and key to this effort, is to understand how the commercial space business operates -- what do they sell, what kind of contracts will they sign, how much and in what manner will they let the military influence their products and what incentives or costs are involved.*

With that basis of understanding, determine for each kind of capability, what kind of acquisition gives the warfighter the most value for the money.

A different objective, but equally important, is to figure out how to assure military access and control of commercial capabilities to support warfighting. Commercial capabilities need to be factored into the planning process - how can commercial space capabilities meet Joint warfighting needs?

Finally, the Office should support the POM process by integrating commercial exploitation into the programming process.

Placement of the office is important if it is to impact planning and programming for future military space systems. Our recommendation is that it report directly to the Commander.

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* For example, Boeing recently proposed to the Air Force to re-engine the B-52 fleet with commercial engines furnished under long-term lease, and maintained by a partner ship of Boeing, Rolls-Royce, Allison, and American Airlines.

Major Concern: Enemy Use of Commercial Space

- **Lesser adversaries who can't afford to develop and deploy space systems may have access to space capabilities for**
  - communications
  - tracking and control of their (dispersed) forces
  - target area imagery
  - precision navigation support
  - weather
  - remote sensing using distributed ground and airborne sensors

- **Must identify capabilities that we can develop and they cannot; e.g.,**
  - autoprocessing and fusion (synoptic view of the battlefield)
  - understanding, exploiting, controlling use of the future "cloud" of communication links

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In the future, third world adversaries will have the ability, by subscribing to services provided by commercial space systems, to gather remote imagery and other data from satellites, aircraft and ground sensors. They will be able to disperse their own forces while tracking precisely and communicating with each unit. Their communications will be hard to intercept, and if intercepted will be encrypted. Much of this capability will be purchased as a subscriber, supported by commercial off-the-shelf PCs and displays.

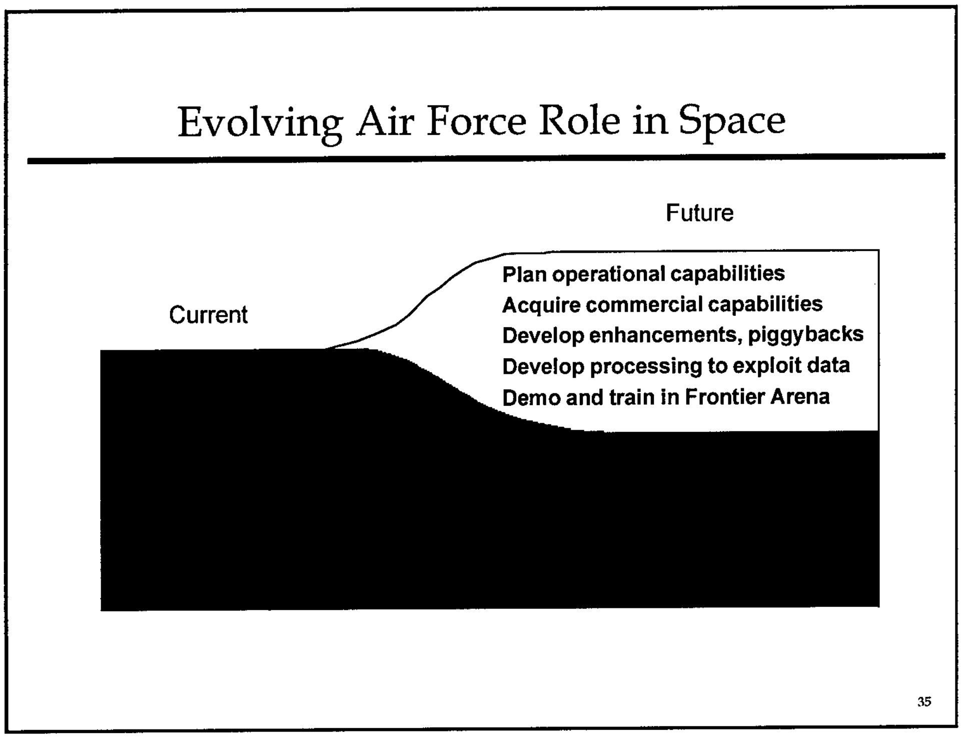
Our recommendation is that we ought to focus our development activity on things that will give us a warfighting edge over such opponents. In essence, we need to continue to be able to operate inside the adversary's response loop.

Some examples:

Provide a continuous synoptic view of the battlefield. This will require substantial capability to automatically process digital imagery and reduce it to an understandable picture for the commander.

Gain a complete understanding and synoptic view of the future communications "cloud." This information is not easily assembled, but if it is, we'll get insights into what links the military may have to add to assure access, what actions can be taken to deny access to adversaries, or add spoofing data.

Then, of course, getting accurate, understandable information rapidly to the warfighting units, completes the "O-O-D-A" loop.



It became clear to us that the traditional role of the Air Force in Space is inexorably changing. The role of developing and deploying satellite systems will continue, but only in niches where there is not commercial market, such as missile launch detection. (Even in that category, Rockwell has announced an alternative approach for the Space and Missile Tracking System (SMTS) that would carry a SMTS sensor suite aboard the satellite currently in production for Iridium®.)

The dark section of the chart shows the traditional Air Force role of developing and operating military space systems. With future exploitation of commercial space systems, that traditional role will diminish but not disappear. The items in the white section of the chart represent a change in the focus of future Air force space activities, concentrating on the acquisition and employments of space *capabilities* rather than space *systems*.

Topics

- **Seeing "space capabilities" as information**
- **Exploitation of commercial space capabilities**
  - limits and downsides
  - opportunities
- **Improving program prioritization process**
- **Getting the Right Tools**
  - measures
  - models and simulations
- **Refining and reinvigorating Frontier Arena**
  - focusing on fewer objectives
  - addressing exploitation

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Space Program Planning/Prioritizing Responsibility

- **Responsibility for Space Program Prioritization (military worth assessment)**
  - DUSD (Space)?
  - Space Architect?
  - AFSPC?
  - SWC?
  -

implied in the charter for each

- **We gave up on the question of who -- addressed only how and what**

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After some consideration we gave up on understanding who has ultimate responsibility for the Air Force Space planning and prioritization activity, and concentrated our effort on the how and what of the planning and prioritization process.

Prioritizing Across Missions

Information Dominance
- space-derived info/comm
Force Application
- missiles, space weapons

Space Support
- launch, operations
Space Control
- surveillance/control, BMD

USAF Space Missions cut across separate National objectives:
nuclear deterrence, defense of allies/ peacekeeping

Dilemmas in Planning/Programming (largely investment policy issues):

- Stretched parallel programs vs accelerated sequential programs
- Long-term high payoff initiatives vs near-term needs
- Programs related to separate National objectives
  - relative priorities for supporting nuclear deterrence vs theater warfighting
- Investment in space support/control vs improving space systems performance
- Opportunity costs in fixed/uncertain budget profiles

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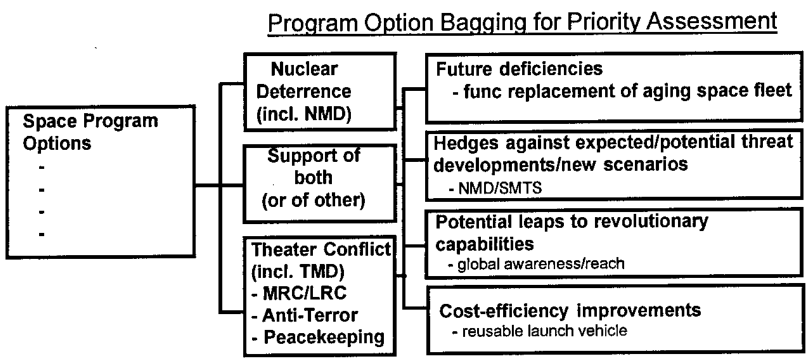
Current AF space investment planning and budgeting efforts are focused in the four space mission areas shown at the top of this chart, with a major issue being how to prioritize programs across these missions. Part of the difficulty for this prioritization is the fact that these missions cut across fundamentally different warfighting missions and national objectives. Further, listed at the bottom of the chart are a set of investment strategy "policy" issues, not particularly amenable to analytic trades, that drive the prioritization process.

A different way to think about the problem is needed to permit prioritization and trades across these missions. The next chart will suggest such a new way.

Space Program "Bagging" for Prioritizing

- Current 4 AFSPC Mission Areas:
  - Useful for characterizing program type
  - Not useful for comparing program options

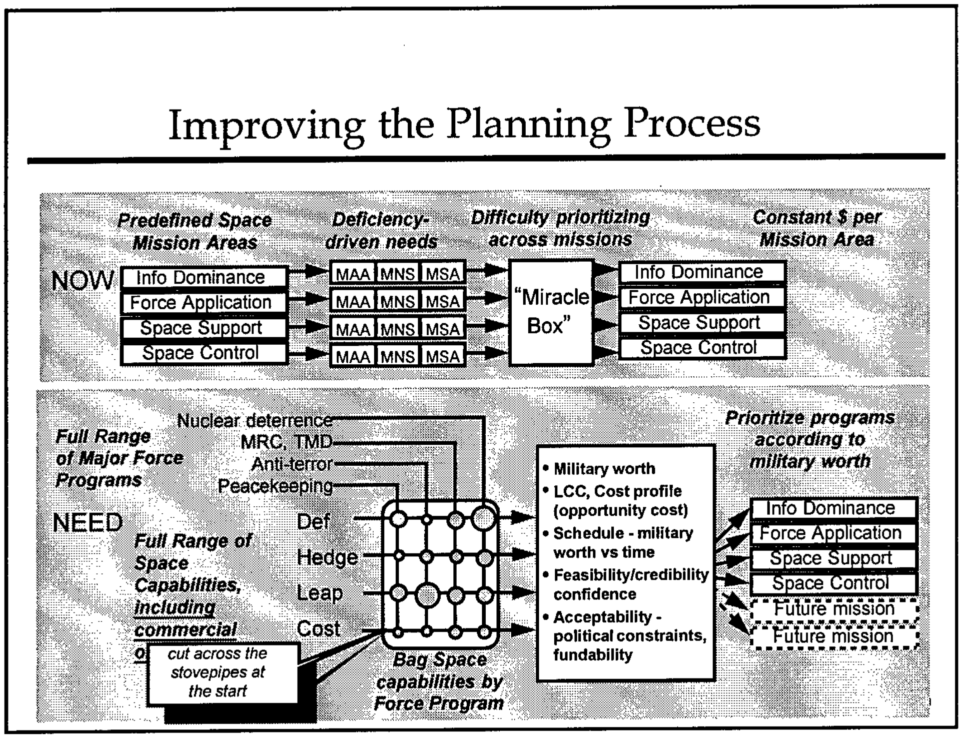


39

The current process starts with the four Space Mission Areas. The Mission Areas are as good a way as any to characterize the type of each program and assign responsibility for it. We found that they were not useful in comparing program options.

Perhaps another way to think about prioritization of Space program options is to consider the spectrum of wars our country might have to face. As shown in the center set of boxes this could run from nuclear deterrence to the entire spectrum of conventional war (Operations Other Than War through Major Regional Conflict), recognizing that some program options may apply for both. Such "bagging" would allow common measures of military value to be used to compare all program options applying to a given warfighting mission.

The current process of justifying every space program option in terms of a "solution to a deficiency" obscures insight into relative urgency for a new or improved space capability. Instead, we believe it would be helpful to categorize program options associated with given warfighting missions in terms of the nature of the problem they are intended solving, e.g. true future deficiencies against current requirements, hedges against threat growth or countermeasures, major leaps in capability, and cost-efficiency improvements. Examples for each of these categories are listed.



The top part of this slide shows how AF space planning and investment prioritization is done today. The problem is, no one knows how to deal with the "Miracle Box" (make trades across the Space missions), with the result being a tendency to allocate roughly constant annual $ per space mission area, prioritizing program options within the individual mission areas.

US Space forces carry or supply information that is used pervasively by Joint Forces to conduct warfare or operations other than war (OOTW). What the planner needs to address head-on is, what is the military value of the information available from alternative space program options for each major warfighting mission?

By rebagging space capabilities or options against the spectrum of war as shown in the bottom part of the slide, it now becomes possible to deal analytically with the various alternatives identified. After each set of alternatives is analyzed, decisions can be made with the benefit of insights into the relative military worth of the alternatives. The resulting prioritized programs can be mapped or rebagged back to the four current space mission areas or other missions that might appear in the future.

Obviously, a very important aspect of a revised planning "front end" is the inclusion of commercial capabilities among the candidate programs.

Planning/Prioritization Observations

- **"Requirement-driven" planning must transition to "value-based" planning in environment of constrained/austere budgets**
  - uncertain future/uncertain threat ⇨ uncertain requirements:
    - which of the uncertain requirements do we program to satisfy and when, if budget precludes satisfying all?
  - budget, not just requirement, becomes an independent variable
  - this leaves time as the dependent variable
- **"Value-based" planning**
  - maximum military worth vs time, within budget constraint, considering other primary criteria
  - accepts interim solutions < threshold requirements (e.g. commercial options), to enable nearer-term capabilities in lieu of waiting until requirement-satisfying solution affordable

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In the future, requirements-based planning will have to give way to value-based planning.

In times past, the requirement was the primary independent variable, and cost, while important was basically looked at as a dependent variable. With the demise of the cold war, the budget situation has become more stressful and cost now must be treated along with the requirement as an independent variable. Consequently, time to achieve the requirement becomes the dependent variable in planning, with the likelihood that that time could become very long for some new requirements, in an era of limited budgets.

"Value-based planning" is what we call a planning approach that recognizes the existence of the mutually-contradictory independent variables, requirements and annual budgets. The objective in value-based planning to derive a plan of aggregate programs that deliver maximum aggregate military value vs. time within a given budget profile. In this approach, interim capabilities short of requirements are accepted, especially when such interim capabilities can be provided economically, in lieu of waiting until the budget enables procurement of a new space system capable of meeting 100% of a requirement. The existence of extensive future commercial space capabilities is likely to provide opportunities to provide such interim capabilities at costs affordable within likely future budgets.

Improving the Planning and Prioritization Process

- **View Space as Information**
- **Don't start with predefined "Space Mission Areas;" instead, apply information capabilities to a range of future warfighting needs**
- **Consider range of military & commercial candidates**
  - solutions of deficiencies
  - hedges against possible future threats
  - leaps in capabilities
  - cost savings
- **Base priorities on the military worth of candidates, then assign them to mission areas**

If priorities are to be based on military worth, we need tools to help assess military worth

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This chart summarizes our recommendations for improving the planning and prioritization process.

First of all, think of space capabilities in terms of information for the warfighter. (Of course, we recognize that a few programs involve space-based weapons, another category of capability.)

Then, apply the range of candidate space capabilities over a range of future warfighting needs.

Bag the candidates by what kind of National objective is involved (nuclear deterrence, protection of allies, other) and categorize the candidates by type.

Then, perform the analysis to determine the military worth of the candidates, and plan and program based on the sensed aggregate value of programs. The programs can then be assigned to the logical Space Mission Area based on type of program.

Of course, to prioritize base on military worth assessment, we have to be able to estimate, or at least gain insight into military worth.

Topics

- **Seeing "space capabilities" as information**
- **Exploitation of commercial space capabilities**
  - limits and downsides
  - opportunities
- **Improving program prioritization process**
- **Getting the Right Tools**
  - measures
  - models and simulations
- **Refining and reinvigorating Frontier Arena**
  - focusing on fewer objectives
  - addressing exploitation

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Tools for Assessment of Military Worth

- No campaign models currently exist to assess military worth of space capabilities/information quality
- Planning/ programming in 1996/97 will have to rely on top-down models + Delphi assessment
- AFSPC/SMC needs to acquire tools to provide higher confidence assessment of military worth of space capabilities
  - enable combined analysis by:

sorting/screening, parametric evaluation		**selected case verification**		**military judgment**		**demonstration**
⇩		⇩		⇩		⇩
Top-down models	**+**	**Detailed (bottom-up) campaign models**	**+**	**Delphi**	**+**	**Warfighting exercises**

- JSIMS/NASM/JWARS unlikely to fill needs for several years
  (accreditation is a multi-year process)

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The bottom line is that there are currently no campaign level models that can be used to assess the military worth of space/information. For the next couple of years, the community interested in the military worth of information will have to rely on top level or top-down highly aggregated models and military judgment of experts (Delphi).

What is really needed is a combination of models and judgments to arrive at the best decisions. The third bullet on this chart shows points out that, even when campaign models capable of assessing the military worth of information become available, planning/programming requires the employment of these models in conjunction with other tools/processes for evaluation. Campaign models help to add confidence about military outcomes, but they are not useful for addressing the wide variety of scenarios, threats, force structures, system capabilities, and other variables necessary to fully illuminate the value of any given future space capability (information). Thus, top-level models are necessary, with "confirmation" of the results of those models with the much more detailed campaign models. Further confirmation is provided by Delphi "analyses" and exercises or demonstrations. All have a necessary function in helping to define programs that best support maximizing military value over time.

JSIMS/NASM is the USAF C4ISR training model of the future. JWARS is the joint analytical model for the future. Both will take several years (at least 3-5) to be completed and then to gain acceptance in the community. It is important that the development of these models be structured to be sure they will address and can illuminate the military worth of information.

The next series of charts will suggest a way to modify existing campaign models to address the military worth of information in the several year interim before the JWARS/JSIMS/NASM series become available and accepted.

M&S Spectrum

- **Engineering level**
  - Component vs. component physics
  - Measures of performance (meet the spec)
  - Cost not modeled, considered off-line
- **Engagement / Mission level**
  - System vs. system (one vs. one or few vs. few)
  - Measures of effectiveness (how well it works)
  - Same scenario many times
  - Cost not modeled, considered off-line
- **Campaign level**
  - System vs. system (many vs. many)
  - Measures of military worth (determination of relative value)
  - Interactive 10-30 day war
  - Cost / resources integral to model/process

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This chart shows the hierarchy of models which eventually lead to a fine-grained, well-rooted, bottom-up campaign model. It should be noted the top-down campaign model usually bypasses the engineering and the engagement and mission level work and deals in a highly aggregated manner with the campaign from the top down.

The point of this chart is that a good campaign model builds on the engineering and engagement and mission level models.

Military Worth

- **Cost / benefit for understanding / gaining insights**
  - Alternative concepts / architectures
  - Program trades
  - Program advocacy / justification
- **Base case vs. alternative - determine relative change**
- **Measures of military worth**
  - Outcomes (e.g., war length)
  - War cost / resources

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We have talked a lot about military worth. This chart begins to get at a specific understanding concerning what it is. It is a way to judge or gain insights into the cost and benefit of an option. It usually involves running a base case and then a second case with the option under consideration included. The difference is expressed in measures of military worth which have dimensions of campaign outcomes and effectiveness in conjunction with associated cost or resources expended.

The need to be able to measure military worth is especially important if we are to judge the value of commercial capabilities that may or may not meet specific military requirements. Unfortunately, most existing models and simulations are aimed at demonstrating that systems meet various types and levels of requirements.

The next chart provides some examples of measures of military worth.

Measures of Military Worth

- **Outcomes**
  - Reduction in length of war
  - Days to halt enemy
  - Delay in enemy rate of advance
  - Recovery rate of lost territory
  - Days to restore border
  - Deepest enemy penetration
- **Effectiveness**
  - Time to accomplish mission
    - Air superiority
    - Interdiction, CAS, etc.
  - Reduction in sorties to accomplish mission
  - Reduction of blue attrition
  - Increase of red attrition
  - Future value of aircraft not lost
- **Associated cost or resources**
  - Base case
  - Alternative architecture / concept or program

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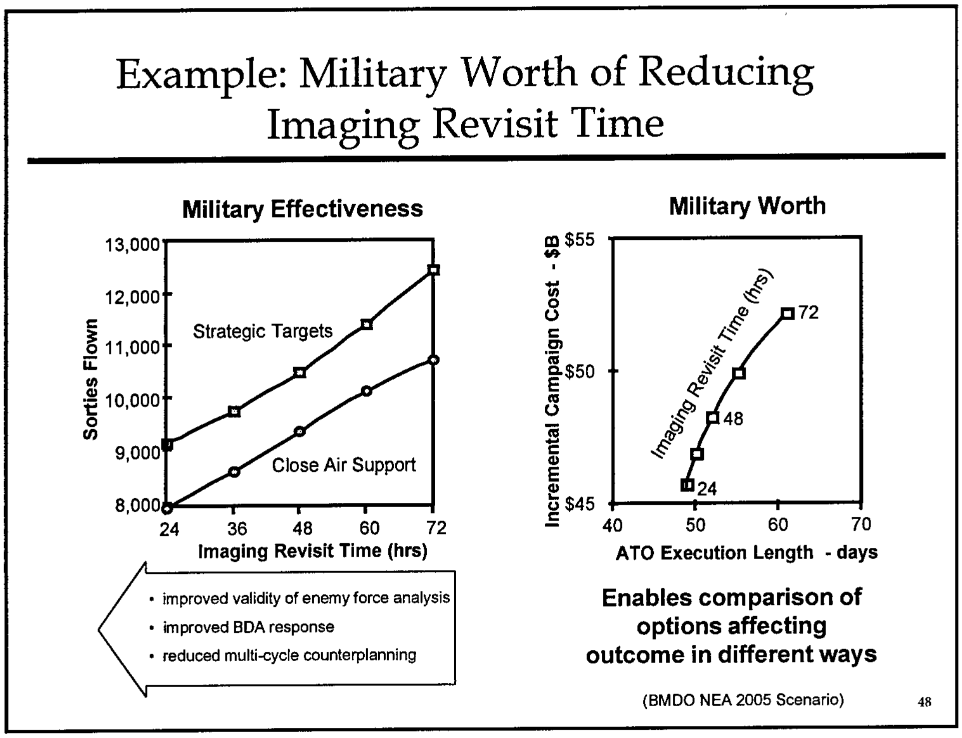
This chart shows examples, for theater conflict, of measures of military worth in contrast to examples of measures of effectiveness. Measures of effectiveness tend to be specific in terms of how a given program option (capability) affects a military campaign, e.g. one program option might affect the air superiority mission while another affects the number of sorties required to complete an ATO (Air Tasking Order). But measuring military value in that way makes it difficult to compare the relative value of these program options. A good measure of military worth will allow comparing program options that impact in different ways a military campaign, e.g. for this example, both effectiveness outcomes affect war length (the duration required to achieve our objectives for the conflict) -- if the military value is expressed in terms of impact on war length, then a common basis can be used for comparison and prioritization.

At this time, there is no consensus in the community on choosing a common measure of military worth (nor is there debate -- no one has really thought about the virtue of having a common measure). We believe the Air Force should decide the measures to be used for judging military worth (recognizing that different measures will be necessary for different types of conflict, e.g. a different measure will be needed for nuclear deterrence than for theater conflict). Then drive the development or modification of tools (M&S) to provide outputs in that form.



This chart shows an example of the output of a top-down campaign level military worth model for an air campaign in a Northeast Asia conflict. It can be seen in the graph on the left that as revisit time for imagery is reduced, the number of sorties to attack strategic targets and provide close air support are reduced. If these sorties are used to attack real targets resulting from a faster revisit time, then the length of the war and the resulting cost of the war can both be significantly reduced as shown in the graph on the right. The advantage of using the higher level measures of war cost and war length is that one can compare the worth of a program (a space capability) that reduces sorties to that of another program that would have some effect other that reduction of sorties.

For confidence in the results of top-down models, we must be able to verify selected results by running more detailed campaign models, supported by engineering simulations, and capable of properly treating the effects of information on warfare.

However, current detailed campaign models do not have the capability of directly treating space system capabilities or the utility of space-derived information.

M&S Recommendations

- **Decisions need to be based on military worth of space capabilities compared to other alternatives**
- **Few tools exist now ("top-down" models, Delphi)**
- **Detailed models don't model the effects of information on warfighting very well, lack common, high-level measures military worth**
- **Others (AWC, AFWIC, SWC, NRO, DARO) have same vested interest, same problem**

> AFSPC/SMC needs to join forces with other info organizations, aggregate funds, produce a toolset that measure worth of information to the warfighter

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We can't get much insight into the value of space capabilities to the warfighter unless we can measure the potential worth of these capabilities. Currently, we have to rely on top-down models, and the judgment of experts (the Delphi method). To add confidence to our assessments, we need to substantiate those higher-level assessments with accepted detailed campaign models, but those models need to produce measures of worth that allow comparison of a wide range of warfighting elements, and to better portray the effects of information on the warfighter. Our recommendations are:

1) Influence the development of JWARS and NASM/JSIMS to ensure that they provide the capability to assess the military worth of space information. If some or all of Thunder may migrate to JWARS, make sure Thunder is modified to accommodate information (space and manned and unmanned airborne). Since Thunder may not be viewed by the other services as a valid instrument for assessing military worth of information from space to their military units, other campaign models not uniquely tied to the Air Force may make more sense. But again, be sure that these models treat information from space systems adequately, and provide output that will support the estimation of the military worth of space capabilities. Also important is making sure that the models include provisions for assessment of commercial space capabilities.

The suggested undertaking will probably take 1-2 years. In the interim, top-down highly aggregated models for the military worth of information, and military judgment and advice from panels of experts (Delphi), are all we will have and must be employed as best we can.

2) Since several other organizations have a vested interest in assessing the value of information to the warfighter, explore the possibility of getting high-level commitment from them to pool resources and produce a toolset that can be used by each participant.

Specific M&S Recommendations

- **AFSPC/CV direct an audit of all SPACECOM M&S activity**
- **AFSPC/M&S Board compare audited activity to need for Space Campaign M&S effort**
- **AFSPC/CC initiate action to unite AFIWC, DARO, NRO, AWC, and SAF/AQ to acquire Information Campaign level M&S capability**
  - community consensus
  - Joint "CC" message to CSAF
  - pool money to get critical mass
- **Decide on MOMW needed by the united group**
- **Select campaign models to modify to encompass multi-services**
- **Turn over MOMW & resources to AF/XOM for execution**
- **Monitor/work with AF/XOM closely (steering group)**

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Start with a rigorous audit of all Space Command and SMC models and simulations. Next, compare what exists or is ongoing to what is needed to assess military worth of space information. Then, derive a plan to satisfy the needs.

The Commanders of Space Command and SMC should initiate action to join up with other Air Force Commands and other organizations, to see if it is possible to pool efforts to get a critical mass.

If it can be decided to pool resources and work together, then develop an agreed upon list of measures of military worth.

Work with AF/XOM and support a selection process to determine the campaign level model(s) to be modified. (Add Information military worth; make sure they migrate to JWARS.)

Pool resources and along with agreed upon measures of military worth, turn all over to AF/XOM to make it happen.

Form an appropriate steering group and monitor and work with AF/XOM closely.

In conclusion, without intervention at the top, the current piecemeal, struggling, non-critical mass situation will continue on autopilot and no serious motion toward the kind of needed model for military worth of information will occur.

Topics

- **Seeing "space capabilities" as information**
- **Exploitation of commercial space capabilities**
  - limits and downsides
  - opportunities
- **Improving program prioritization process**
- **Getting the Right Tools**
  - measures
  - models and simulations
- **Refining and reinvigorating Frontier Arena**
  - focusing on fewer objectives
  - addressing exploitation

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Frontier Arena

- **"Frontier Arena should be an evolutionary, dynamic, distributed, and interactive space environment for technology development, system development/acquisition evaluation, CONOPS and contingency planning & rehearsal"***
  - ". . . communicate, exploit, and validate military value of Space"
  - " . . . coalescing MS&A capabilities with existing simulations, creating an environment for assessing battlefield utility of current and future system concepts"
- **Essentially all M&S activities now described under the mantle of Frontier Arena**
- **All-encompassing description/charter appears to have paralyzed commitment to a plan, funding, authority for Frontier Arena**
- **AF might be better off focusing on one objective for FA -- e.g., injecting Space (incl commercial space) into ACTDs, ATDs as an element of concept development & assessment**

* All quotes taken from *Frontier Arena: Supporting the Synthetic Battlespace of the Future* 52

The quotes at the top are from a recent paper describing Frontier Arena. As can be seen, Frontier Arena is described as having a very wide range of attributes and objectives. We liked the idea of validating the military value of space. However, this and other briefings and discussions led us to the conclusion that, having been unsuccessful in getting funded, Frontier Arena now is being used as "top cover" by essentially all modeling and simulation activities.

Those who decide on funding may have been paralyzed by the all-encompassing charter.

The Air Force might be better off focusing on narrower, more specific objectives for Frontier Arena, i.e. it may be easier to get commitment and funding for Frontier Arena if its objectives are more bounded. From the viewpoint of this pilot study, one objective should surely be to play a role in the transition to wider use of commercial capabilities.

Frontier Arena Now

- **Attractive Code Word generally perceived to relate to wargaming with geographically-distributed elements**
- **Minimal funding, no boss (cart without a horse or driver)**
- **Products to date are better networking, improved capability to participate in wargames -- accomplished by cooperative efforts of a few people in several elements of AFSMC & AFSPC**
- **Original intent was broader than wargaming; current intent unclear**

- **We looked at a couple of options:**
  - planning/programming support
  - wargaming/training

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Our group was briefed on Frontier Arena. We held discussions with personnel at Space Command, SMC, and Phillips Lab. We read a recent paper describing Frontier Arena, and went back and reviewed briefings describing the original plan for Frontier Arena.

The early documentation described it as an implementation of a "Virtual Battlefield" for Space systems, an environment in which existing and new capabilities could be integrated and demonstrated, ultimately in concert with "Blue Flag" war games. In the intervening months, Frontier was unable to get funding, and has now become "top cover" for a broad range of modeling and networking efforts.

In order to reach conclusions on where the Air Force should go with Frontier Arena, we examined the modeling and simulation needs for tow objectives: support of planning and programming, and support of wargaming and training.

Frontier Arena Roles

- Planning/programming
  - analytical rigor
  - ease of data input
  - quick - lots of trades, lots of future options
  - much faster than real time
  - community acceptance, warfighter/user "validation"

- Training/ACTDs
  - real time, realism to the participant
  - integration of distributed elements
  - models, real HW/SW of current & near-term systems
  - Space Flag

Distinctly different implementations required

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We found that many of the possible purposes for Frontier Arena had merit, but that distinctly different implementations may be required to accomplish different objectives. This chart summarizes the attributes of two kinds of implementation -- one to support planning and programming, the other to support Advanced Concept Technology Demonstrations, or exercises. In the latter case, integration with distributed simulation nodes is a requisite, in the former it is not. If Frontier Arena is to accomplish both objectives, it needs a separate approach for each.

Recommendations for Frontier Arena

- **Narrow the focus and clearly identify roles and products**
- **Separately identify what exists, what's needed for each:**
  a) planning/programming, migrating to JWARS
  b) training/ACTDS, migrating to NASM/JSIMS
- **Identify common elements**
- **Lay out plan, migration path, and budget to get the job done, taking advantage of commonalities**
- **Put a strong leader (two?) in charge**
- **Get commitment and authority to execute**
- **Show some dramatic results from the exploitation of commercial space**

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Our recommendations are these. First of all, focus in on one or two areas, and clearly define the roles and products of each. Having a compelling story on what Frontier Arena will produce, rather than what tools it will use, may help in getting funding.

After the case is made for what products will result and what their benefit will be, then identify, for each role, what new or upgraded tools are needed, keeping in mind that tools for planning and programming may migrate to the JWARS model, and that those for training and ACTDs may migrate to NASM or JSIMS. Since there are bound to be common elements, identify them.

Then lay out a plan and budget that takes into account the commonalities and migration paths.

Put someone in charge, with the authority and commitment to execute the plan. Because the two objectives (support of planning and programming, and support of wargaming and training) are distinct and have separate modeling and simulation needs, there probably should be separate leaders for the two objectives.

It made a telling point on our group that commercial space exploitation demonstrations like those in Bosnia had taken place without any involvement of Frontier Arena. An important aspect of Frontier Arena planning could be to describe and schedule some near-term demonstrations of how commercial space capabilities can pay off.

Reinvigorating Frontier Arena

- **Currently no funding, no one in charge**
- **Several possible hurdles in way of funding**
  - paralyzing effect of too broad a scope
  - emphasis on tools and exercises rather than results and their worth
- **Get back to original purpose: demonstrate the military worth of space (information) capabilities to the Joint Warfighters**
- **Take on an additional task of removing the downsides of use of commercial capabilities**

Include products beyond implementing software and networks and participating in wargames

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This summarizes our thoughts on Frontier Arena. It needs to be adequately funded. Prior attempts to get funding may have suffered from trying to paint too broad a scope, and perhaps by an emphasis on the tools and exercises, rather than the results of using the tools and performing the exercises.

Frontier Arena should return to the essence of the original purpose -- demonstrating the military worth of the information space systems can provide to the warfighter.

The potential use of commercial space capabilities also poses a new challenge for Frontier Arena. It should provide the environment and testbed to demonstrate that the downsides of commercial exploitation can be overcome.

Finally, when making the case of Frontier funding, more emphasis should be placed on defining some specific results from the use of the Frontier Arena tools.

Other Recommendations

- **Look for new concepts for use of space capabilities**
  - global collection from ground, airborne remote sensors
  - cooperative engagements
  - tracking and control of our own dispersed forces
  - etc.
- **Understand what lesser powers will be able to accomplish when they exploit commercial capabilities**
- **Consider bypassing the "process" and M&S when it appears that commercial capability can be integrated effectively and cheaply**

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One activity that needs encouragement is the development of new concepts for using space in warfighting. Some of this is being done already (we heard briefings on concepts for moving Aircraft Warning and Control, and Target Acquisition and Tracking from Airborne Platforms to Space).

What might be seen as a "poor man's remote sensing system" is one that makes use of a very large number of groundbased or airborne sensor packages, each of which knowing exactly where it's at (via GPS), having one or more of a wide range of instruments or sensors, sending its information to a remote control center over commercial telephone systems.

Another is the use of overhead capabilities (military or commercial) to provide targeting updates to very long range cruise and ballistic missiles.

Another is to use Space comm and navigation capabilities to put our own forces under more positive control, and enable better dispersion of forces. (Of course, such a system cannot allow the adversary to make use of it to find our forces). The Yellow Cab company in Denver is just implementing a sophisticated system for tracking and control of its dispersed resources -- there may be a way for the warfighter to do the same.

Finally, the Bosnia examples discussed earlier illustrate that in some cases, it may be best to bypass the planning process and computer simulations and just try something.

Issues

- **In portraying commercial capabilities as having military potential, we've challenged widely-held assertions**
  - can't depend on access and control
  - commercial won't build in the availability, reliability, protection we need
- **There are indications from the theater that commercial space capabilities can augment, and in some cases outperform military systems**

1. **How can we best avoid the downsides and take advantage of the best capabilities, incl commercial?**
2. **How will we maintain warfighting dominance when the rest of the world has access to commercial space?**
3. **Will AFSPC/SMC have a role in this?**

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The central theme of this study turned out to be the exploitation of commercial space capabilities. The idea that we can do more than we presently do challenges some widely-made assertions about the lack of dependability and assured access. We have explored a range of commercial options. Some of them offer the potential of providing militarily-useful capabilities at low cost but with issues of assured access and resilience to countermeasures; other options cost more but come closer to meeting overall military requirements (or are more amenable to enhancements to meet those requirements). Here and there, commercial capabilities are already being implemented in-theater, indicating in those cases the acceptability of commercial systems to the warfighter, for certain functions.

The main issues are first, how do we best overcome the downsides to get the best information from space to the warfighter; second, what can we do to maintain military dominance when the third world will have commercial access to information from space; and finally, what role should Air Force Space Command and SMC play?

Summary of Recommendations

- **Increase emphasis on planning for integration of commercial space systems capabilities**
  - Establish joint AFSPC/AFSMC office dedicated to exploitation of commercial space systems
  - Publish policy on use of commercial space, to assure external/internal audiences of commitment
- **Shift from requirement-driven planning/programming toward value-based planning**
  - Priorities driven by military value over time/unit investment, associated with broad objectives for capability
  - Use military worth as primary measure of merit
- **Drive M&S activity to provide tools capable of measuring military worth; address commercial exploitation in models and demos**
  - Pool resources with AFIWC, SWC, NRO, DARO; jointly decide on MW measures/M&S plan with products migrating to JWARS & NSAM/JSIM
  - Separate Frontier Arena into planning/programming & wargaming/training objectives and put separate leaders in charge

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The few examples of commercial space exploitation that we recounted in this briefing are representative of a larger number that make it clear that commercial space will be exploited by the US and others. The Air Force already has efforts ongoing to search for opportunities to exploit commercial space capabilities. However, we believe that opportunities to achieve militarily-useful capabilities from near-term commercial space systems at low cost warrant and, to be successful, will require a dedicated staff devoted to this purpose. We recommend that AFSPC and AFSMC establish a joint office to work with commercial space system developers to determine how best to impact the commercial systems design and operation to achieve military space objectives. We also believe it important to convince, perhaps by an Air Force policy statement, both the commercial space world and the Air Force internal staff that commercial exploitation is a serious intent of the Air Force.

The second recommendation has to do with the planning process. The combination of future budget constraints and opportunities arising from commercial exploitation motivate, and probably dictate, a shift in that process toward what we call value-based planning. One aspect of that process is to measure candidate new space programs (including commercial opportunities) in terms of military worth. However, current campaign models do not provide this capability.

We recommend that several elements of the Air Force and other organizations with a vested interest in information jointly undertake to guide and fund the modification of certain models to provide this capability. We believe Frontier Arena is a good idea but too broadly scoped. We recommend a re-start that describes a few specific roles, proposes what its products are, and puts someone in charge. It should also be a means to demonstrate how commercial space capabilities can be integrated into warfare and what military worth they may bring.

Organize and Implement the Changes

- **Establish AFSPC/SMC office for exploitation of commercial space capabilities**
- **Fill the missing link:**

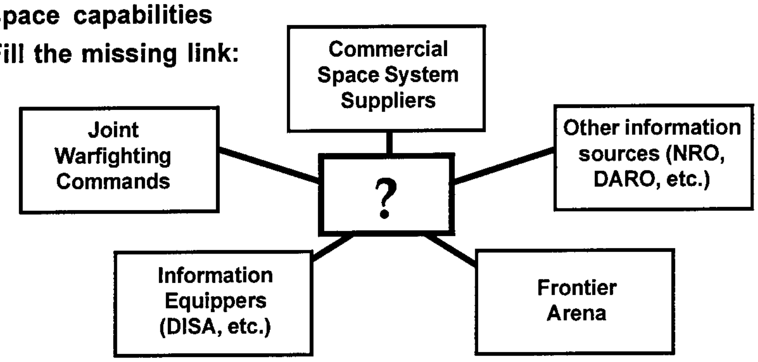

Figure out how to remove the downsides, impact commercial system design during concept formulation, exploit the benefits of commercial space capabilities

Emerging new commercial space capabilities have the potential for providing or augmenting information for the warfighter. To succeed in exploiting them, we have to figure out how best to bring the capabilities to bear, and how to make sure they are robust and secure when we need them (i.e. how best to influence commercial space developers to accommodate military needs).

The trend toward exploitation of commercial capabilities seems inexorable. A lot of players will be involved, as indicated on this chart, if we are to get the best aggregate capability from space. The Air Force has the opportunity to fill what is now a void, provide leadership, and lay out an intelligent path to the future.