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POTENTIAL USES OF SMALLER SATELLITES FOR MILITARY SPACE OPERATIONS

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ABSTRACT

This paper describes potentially attractive uses of smaller satellites for complementing current Air Force space systems. By mission area, the applications of smaller satellites as enhancements to current systems are shown for three operational scenarios: (1) to provide dedicated support to tactical war-fighting users, (2) to provide a quick-response surge to augment current systems in a crisis, and (3) in the case of the failure or loss of a satellite, to provide responsive back-up systems for use until new primary systems can be deployed. Preliminary results show that in every space mission area, smaller satellites can potentially provide a useful enhancement to the current systems. The enhancements in most cases are improvements in coverage, capacity, and data timelines which are required from time to time by certain user segments. Enhancements in some cases simultaneously improve the robustness and resiliency of the space mission area. The smaller satellites probably cannot realistically replace current systems, which have evolved to their current configuration through years of optimization of cost, mission capability, and survivability. The results show that using current technolgy and design practices, the 500-1000 pound weight class of satellite is what is being referred to as smaller, but useful.

INTRODUCTION

The potential use of smaller satellites for military operations has become a subject of great interest. Presented here are the results of work at Air Force Systems Command Space Division to understand what, if any, potential mission enhancements smaller satellites may provide. The term "smaller" refers to spacecraft which are less capable than many of the large steady-state systems we have, but not microsatellites which could use very high technology to miniaturize subsystems.

A considerable amount of previous work has been done on the similar topics of responsive launch, reconstitutable space systems, and survivable launch systems [1], [2], [3], [4]. The past studies primarily focused on communications, missile warning, and weather missions.

Of the numerous potential applications of smaller satellites, three operational scenarios are being investigated: (1) to provide dedicated support to tactical war-fighting users, (2) to provide a quick-response surge to augment the coverage, data quality, or data timelines of current systems in a crisis, and (3) in the case of the failure or loss of a satellite, to provide responsive back-up systems for use until new primary systems can be deployed.

In the first scenario, smaller satellites are used on a steady-state basis to improve support to certain users, in certain areas, who are not getting what they need now but cannot afford to by their own copy of existing large systems. Often this comes from their low user priority rating. The smaller satellites do not necessarily need to be responsive.

The second scenario refers to the surge capability provided by responsive satellites to be quickly deployed to improve service to certain users in a crisis scenario, e.g. the Falklands conflict, Grenada operation, Desert One operation, etc. The users' needs in peacetime are supported by current systems. As a crisis develops, their needs greatly increase, but the current systems cannot quickly adjust. The surge satellites can best be used in this mode by optimizing their performance for the user in need and his area of interest only. After the crisis subsides in a few months, the user no longer needs this additional support.

The third scenario refers to providing a minimum essential interim capability in the event of loss or attack on a large current system. Current systems usually take from 3 to 6 months to launch and check-out on orbit. To re-design them for rapid launch and check-out is not affordable, but a smaller system that can be made affordable could have great utility for this mode of operation. Following is a description, by mission area, of some potentially interesting uses for smaller satellites and some preliminary concepts.

Dedicated Steady-state Communications

The current communications architecture, comprised of the Defense Satellite Communication System (DSCS), Fleet Satellite Commaunication System (FLTSATCOM), and soon MILSTAR systems, is very effective in supporting users' needs for inter-theater communications, but lacks the capacity to also support all intra-theater communications needs of tactical warfighting users (theater commanders and their tactical forces). Because war-fighters have a lower priority for communications usage than strategic, intelligence, and National Command Authority users, they perceive that they will not have essential communications service available for their use in time of crisis. Most users have already purchased terminals, but are unable to use them even in peacetime for combat exercises scheduled far in advance. For example, UHF terminals exceed the available bandwidth capacity by a factor of 10. A review of the Joint Chiefs of Staff-validated communications requirements reveals that 60 percent of the unsatisfied requirements are for intra-theater voice communication.

Smaller satellites may be able to be efficiently used to supplement the current communications architecture and fill the intra-theater need. In order to make the communications affordable, the satellites should offer a smaller, but useful, increment of communications capacity than our current systems. Sizing this useful increment of capability is difficult and requires a number of iterations between the user community and system designers. A preliminary estimate based on MILSTAR's planned capability in a very stressed environment shows that roughly 36 voice channels are a potentially useful capability.

Since continuous coverage is mandatory for the war-fighting users involved in a crisis, geostationary orbits seem to fit this concept best. This allows one satellite to cover an entire theater, thereby reducing complexity for the satellite controller. Other deployment strategies also offer full coverage, but more satellites are required. For example, three satellites in three planes are required for continous theater coverage using semi-synchronous elliptical high inclination orbits. The lowest cost constellation will be eventually decided by launch vehicle capability and cost.

To reduce total cost to the user, a dedicated communications satellite should be compatible with the user's existing or planned terminals, i.e. if the user has an SHF terminal, the satellite should "look" like a DSCS.

To reinforce the theater commander's perception of ownership of the satellite, command and control will not be done in the conventional way. Spacecraft housekeeping (ephemeris uplinking, telemetry read-out) could be performed by AFSPACECOM, but the payload (e.g. antenna, spot beam location) controlled by the theater commander. The theater commander should have total authority to allocate his communications capacity as he sees fit.

Survivability (both against jamming and ASAT attack) is a key driver of cost and size of the current communications systems. Since dedicated satellites would not be relied upon for inter-theater communications, the system survivability could be tailored to meet the threat of tactical scenarios. Threats in tactical scenarios are usually much smaller than in strategic scanarios; hence if affordability is a major goal for theater user-dedicated satellites, it may make sense to tailor survivability measures.

Finally, since tactical forces need to practice and become comfortable with a resource in peacetime before they will rely on it in battle, a user-dedicated communications satellite must operate as a steady-state resource. This could help to alleviate peacetime needs also. The satellite should be equipped with appropriate redundant back-up systems to ensure it has long lifetime.

Keeping this baseline concept of what could constitute an affordable and useful tactical-user-dedicated communications satellite in mind, concepts which operate at SHF and EHF frequencies were developed. These concepts may not be optimized in performance or size, but they are models for first-order feasability analysis. The payload concept at SHF is basically a down-sized DSCS III. A satellite can be built around the two 40 watt transponders of a DSCS III and provide two-thirds the power of a DSCS III with only one-third the bandwidth. A schematic of this payload concept is shown in Figure 1. The payload is ideal for tactical applications since smaller tactical terminals require more satellite power than the larger strategic and wideband communications terminals for which DSCS was designed. This smaller satellite could dedicate more power to each user terminal and provide better service to the tactical user. It is still capable of servicing the wideband users of the SHF spectrum such as the Ground Mobile Forces. Reducing a DSCS to this smaller version would still supply multiple increments of the communications capability determined to be potentially useful to theater commanders (36 voice channels).

A payload concept at EHF is the FLTSATCOM EHF Package (FEP), which is a small secondary payload on some FLTSATCOM satellites. Figure 2 is a layout of the FEP package. The FEP could be the payload on a smaller satellite and meet the required useful increment of intra-theater communications capacity, while providing the anti-jam performance of MILSTAR due to the exotic waveform and EHF spectrum used. This concept would only support narrowband users.

Another concept at EHF is to remove the MILSTAR signal processing equipment from the satellite and instead place it in a mobile ground processing station. The satellite would be a dual relay package. A station would transmit its signal to the satellite which would then downlink the information to the processing station. There the information would be processed and uplinked back to the satellite which would relay the information to the intended receive station of the transmission. To the operator, he still thinks he is talking to a MILSTAR-like satellite.

Responsive Communications Surge

The smaller tactical user-dedicated communications satellite concept previously discussed was designed for theater users who require that the system supporting them is available during noncrisis periods for routine use and training. But needs for communication systems which can be deployed responsively to support particular users in particular areas of interest also exist. Special operations forces, conducting training and exercises somewhere in the continental United States, could be able to obtain communications satellite links on theater-dedicated satellites (just described) to support their training. Hence they would have the chance to become familiar with the communications system during training. Consequently, they would rely on the satellites during a real mission. Should these units quickly deploy to support a developing crisis, they would need responsively deployed communications satellites, with links identical to the ones used for training, to support the units in the area of interest. This holds true for any quick reaction scenario.

Weather Sensing

Several potential uses of smaller satellites to support the weather mission exist. Cloud imagery is by far the most important data received by both strategic and tactical Defense Meteorological Satellite System (DMSS) users. Cloud image data is the only information transmitted directly from the satellites to the tactical earth terminals (ship-board and Mark IVa). The terminals also can receive the cloud imagery downlink data from the National Oceanographic and Atmospheric Administration (NOAA) polar orbiting weather satellites. Many tactical users carry small terminals which receive foreign weather satellite signals.

During unstressed periods, the DMSS refresh rate (of six hours) may be acceptable to tactical users, but during a crisis, the users involved need much more rapid weather updates. To provide this refresh rate on a continuous basis to all parts of the world with DMSP is not realistic or affordable; but for limited periods of time (during conflicts), users in the area of conflict highly value timely cloud imagery. A small satellite, containing only the cloud imaging payload that can be responsively launched and flown in an orbit which optimizes coverage over the crisis area of interest could have utility.

One deployment concept would use two satellites, flown 180 degrees out of phase, in 8 hour period orbits, in one orbit plane inclined at 90 degrees. This constellation provides continuous coverage to all of the northern hemisphere above 34 degrees latitude, if the orbit apogees are positioned over the northern pole. This coverage pattern is stable for about 30 days, after which time the oblateness of the earth causes the line of apsides to rotate, degrading coverage to the region. Two 1000 lb satellites can be launched on a single Delta 6925 booster into this orbit.

Payload options for the cloud imaging satellite include the Optical Linescan System (OLS), which is the primary imagery sensor on DMSP, and the Advanced Very High Radiation Radiometer (AVHRR), which is the primary sensor on NOAA. The total weight of a spacecraft carrying the OLS is in the neighborhood of 700-1000 lb, and in 350-600 lb range for the AVHRR (spacecraft weight can be decreased if higher technology and minimal redundancy are used).

Another use of the same small cloud imaging satellite is as a responsive back-up capability for failed or attacked DMSP satellites which could be used until a new DMSP is deployed. The smaller satellite, in this case, would be deployed in the same sun-synchronous orbit as the failed DMSP, with the same ascending node phasing.

Oceanographic Sensing

The AVHRR also provides three infrared spectral bands which users of the OLS do not receive. Taken together, the IR bands allow one to see the sea surface temperature profiles off of the Atlantic and Pacific coasts. The 3.8 micron band of the AVHRR allows detection of all surface ships because the exhaust steam particles interact with the atmosphere at this wavelength and can be seen as streaks behind ships [5]. Tactical users sometimes rely on AVHRR imagery, but NOAA satellites have an un-encrypted downlink, so the Soviets use the information too. In time of crisis, NOAA may have to be turned off to deny this information to the Soviets; hence a responsive smaller satellite carrying the AVHRR with an encrypted downlink may be needed to replace this capability in such a scenario.

Space Environmental Monitoring

Ionospheric warning and space environmental monitoring is another mission area where small satellites potentially can improve user support from space. Many HF,VHF, and low-frequency UHF terrestrial communicators increase their communication range by bouncing signals off of the ionosphere. A need exists to be able to accurately predict ionospheric disturbances which arise from solar flares and disrupt communications. A smaller satellite carrying a space environmental monitoring instrumentation payload flown in a circular polar orbit can provide greatly improved space environmental data. The optimal altitude for in-situ measurements is 300 km (DMSS altitude is 833 km). The payload could be similar to the 200 lb payload on the NOAA satellite could be flown on a small satellite weighing less than 1000 lb.

Tactical Targeting

Tactical users need to get more timely information of the regions far beyond their battle line, or so-called FLOT (Forward Line of Troops). Responsive launch of smaller satellites into orbits which focus coverage on a crisis area of interest could have potential for supporting this need.

To achieve high resolution imagery, satellites need to be flown in very low orbits (300 km and below). An infrared sensor which provided 1 meter resolution during the day and in clear weather would require a 2000 lb total weight spacecraft. Resolution directly affects weight because it mandates the size of sensor optics. Relaxing the resolution by a factor of 2 to 2 meters, would result in an approximately 1200 lb spacecraft. Another option is a synthetic aperture radar payload.

Infrared Backgrounds and Mapping Surveillance

The capability to provide a timely infrared map of a given area of interest, showing how the infrared background radiation compares to target infrared radiation levels, is needed to support IR guided munitions (heat seeking) deployment. A satellite with an infrared mapping payload which could be responsively launched to support a given area of interest could be useful. Depending on the resolution required, a down-sized version of the Landsat sensor payload (weight of 500 lb, 10 meter resolution in 7 IR spectral bands) could be flown on a satellite with total weight well under 1000 lb. Good coverage requires that a high-inclination, relatively low altitude circular orbit be used.

Wide Area Surveillance

Smaller infrared sensing satellites show potential for augmenting a space-based radar wide area surveillance and tracking system either to provide a steady-state support or support for shortduration crises. Being a passive surveillance system, infrared can be used to provide steady-state surveillance while not alerting the adversary and can cue the pulsing of the active radar system to provide the very exact target information needed just prior to strike. Radar consumes large amounts of power, allowing continuous operation for only a few hours at a time. Continuous radar surveillance also gives away the location of the radar emitter, increasing the threat of ASAT attack. A major limitation of infrared is its inability to penetrate clouds, but infrared phenomenology can complement radar signature phenomenology to allow more precise detection and identification of objects. Deployment of the infrared satellites would have to be in high-inclination circular orbits near the radar platforms. Depending on the resolution required (10 meter resolution should be sufficient to identify large bombers and ships), the smaller infrared satellite could be kept under 1000 lb total weight.

A smaller satellite could be used either as a space-based bistatic radar emmitter which flies over an area of interest, illuminating the region so receivers on the ground can detect objects in the sky or it can be used as a receiver to a large space-based radar illuminator by flying over the region of interest at much lower altitude than the emitter, reducing the emitter power required, since the reflected signal does not travel as far.

Satellite Control Network Augmentation

A small communications relay satellite could be used to replace lost connectivity in a Satellite Control Network which results from loss of an overseas remote tracking station (RTS). By deploying the smaller satellite in a low altitude orbit, a simple SGLS-to-SGLS relay payloads could store telemetry data downlinked from a stranded satellite and then downlink the stranded satellite's telemetry data to another RTS. Commands from the ground could be uplinked in the same way. The weight of such a satellite would be on the order of 500-800 lb. Alternatively, a more complex and heavier SGLS-to-DSCS transponder could be used on the small relay satellite and transmit the stranded satellite's telemetry and uplinked command data in real time.

Navigation

A smaller satellite carrying a navigation (GPS) payload could be used to augment the coverage and availability of navigation satellites over an area of interest in the event that part of the GPS constellation were destroyed by ASAT attack. GPS is a very robust, gracefully degrading constellation which has on-orbit sparing. Useful navigation capability is achieved with as few as half of the constellation operating. But over a period of time, it is possible to draw down the constellation using a co-orbital laser ASAT. In this event, smaller navigation satellites could be flown in high inclination elliptical orbits and improve navigation accuracy over the area of interest.

Space Surveillance

Smaller responsive satellites carrying visible-light sensor payloads (total satellite weight of 1000 pounds) could be used to augment our currently ground-based space surveillance system, improving satellite attack warning for valuable geosynchronous satellites. Depending on the warning time required, one or two visible light payloads flown in elliptical, 16 hour period, equatorial orbits are sufficient. They do not have to be deployed as a continuous augmentation of the space surveillance system but can be deployed prior to escalation of a potential world or theater conflict. They could also be used to increase our space surveillance coverage in the southern hemisphere to detect deployment of payloads from the Soviet space shuttle.

Spacecraft Inspection

High resolution imagery of spacecraft could be acquired using a 1000 pound satellite deployed in an orbit which intersects the orbits of unknown satellites. Resolution of 4 inches at 40 km, which is sufficient resolution to discern the general function of an unkown satellite can be obtained in this satellite weight range.

CONCLUSION

Smaller satellites have potential uses in almost every space mission area as a means for complementing current systems to provide dedicated continuous support to theater tactical users, to provide quick response capabilities which support users in a crisis, and to provide a responsive interim back-up capability for lost systems.

The 1000 lb class of satellites, using conventional technology and design practices for redundancy, seems to be the general limit on size of smaller satellites which still perform useful military missions.

Future work at the Plans and Advanced Programs Office of Air Force Systems Command Space Division will focus on refining and understanding the needs and uses of smaller satellites and developing conceptual designs of smaller satellite systems which are compatible with current user terminals and practices.

It is hoped that mission application studies such as this will be considered when goals for smaller satellite technology development programs, such as the DARPA ASTP, are established.

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