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FUTURE AIR FORCE SPACE POWER NEEDS

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This paper outlines those space power capabilities needed to meet future Department of Defense needs. The most immediate need is for survivable power systems up to 50 kilowatts. This implies capabilities need to be developed in the areas of increased size, higher reliability, hardening to weapon effects, and autonomy - to be independent of ground stations for satellite control.

Future power systems, as in the past, will need to be able to function in all earth orbits with different requirements for the various orbits. For low and medium altitude orbits the primary considerations are environmental effects and ground based threats. For the high orbits such as geosychronous, the primary considerations are system weight and lifetimes up to ten years. Also as the mission hardware becomes more critical, techniques for array control and pointing must be developed which minimize disturbances to the rest of the satellite vehicle.

Higher power requirements demand high voltage systems. This in turn introduces new considerations such as more interactions with the space environment, higher stress on electronic power control components, and more shielding due to enhanced conditions for arcing and corona. Some progress is underway in these areas. Now some communications satellites are generating voltages over 100 volts directly to provide power to traveling wave tubes. There are also several groups investigating the interactions of the space environments with satellite subsystems including plans for flight experiments (VOLT, IMPS/SPAS). Several high power system studies have been done for the Air Force and NASA which have also studied autonomy and AC vs DC systems. At what power level do the AC systems become attractive and at how high a frequency can we operate these systems? These issues and questions will need to be addressed in the next few years.

INTRODUCTION

The requirements for future power as outlined for various AF satellite mission vehicles in the Military Space System Technology Plan, Volume II, fall into two categories. The first category is in the 1 to 50 kW range for mission of a continuous nature such as communication, navigation, surveillance, data relay and meteorology. The second category is in the multi-megawatt range for either continuous or burst power durations and are for other than solar power sources. Requirements for longer life and survivability in varying degrees are there for all-systems. While the power levels do not appear difficult to achieve in view of the large array developments pursued by NASA Space Station technology, the other military requirements are very challenging and continue to be system drivers. The development of solar cell arrays should be in conjunction with other power supply technologies such as regulation and control components and energy storage subsystems. The needs of future power systems are shown in Table 1.

SURVIVABILITY

The primary new requirement for future AF solar power systems is survivability. This requirement is different for each satellite vehicle and mission and can be approached from several different directions. Table 2 provides a brief history of these directions. In some cases the threat is directly on the satellites. For a direct threat hardening to withstand exposure to the weapons environment is contemplated through the use of concentrator technology . For higher altitude orbits wherein weight is important the hardening may be at a lower level in lightweight solar array concepts.

Active approaches to survivability imply at least two: (1) evasive maneuvering and (2) recovery after exposure. Both of these require autonomy of operation independent of ground stations. Autonomy is also needed if the ground stations themselves are vulnerable and mission survival depends on the satellite being capable of operation without their intervention. To achieve autonomy for the power system we need to develop the functions shown in Table 3.

To survive via redundancy or the use of decoys implies the flight of satellites that can look like active vehicles but can be low in cost and realistic in signature. Paramount considerations here would be low cost solar cell arrays.

SOLAR CELL TECHNOLOGY

The solar cells needed for the concentrator type solar cell arrays are those that can operate efficiently at temperatures of 100°C (or greater). The candidate cells to date for this are GaAs. Efficiency under concentration can be 20% or greater at operating temperatures. Future concentrating systems imply the use of small multi-bandgap solar cells with efficiency in the 25 to 30% range. Solar cells for lightweight minimum hardening high orbit application are thin GaAs solar cells to achieve solar cell blanket performance of 100 to 150 watts per pound. These cells need also be able to withstand temperature excursions and the effects of charge build up and arcing as they emerge from the dark to sunlit portions of the orbits. The multi-bandgap cells could also be of benefit here if they can be made efficient without high cost.

The potential use of decoys challenges us to search for low cost, high lifetime solar cells. Some of the cell types under development by the Department of Energy should be considered once reasonable efficiency is achieved.

Candidates in this case are amorphous silicon or polycrystaline cells wherein the satellite decoy is to have the same observable signature as the mission vehicle without the mission power requirements. Low cost fabrication and assembly are also needed.

HIGH POWER CONSIDERATIONS

Satellite power requirements increase for several reasons such as more functions in the same vehicle, more sensitivity in such missions as surveillance, or higher power signal to avoid jamming or power to communicate with mobile systems in the air or on the earth's surface. Table 4 identifies considerations for High Power

The mission hardware on these satellites may therefore require larger solid angles of observation or greater accuracy to lock on and dwell on target. The solar cell arrays must minimize the blockage or disturbance of this mission hardware. The demand therefore is to minimize solar array size thus dictating high solar cell efficiency. Also, pointing of the array at the sun should be decoupled from the mission vehicle or other means must be used to minimize disturbances.

As these power requirements increase we need to develop building blocks for array standardization. Such modular subarrays should be in the 5 kW power range and be for easy build up into complete solar arrays. This approach should provide economy of fabrication using automated production equipment and could be the first step toward in-orbit assembly and replacements. As the Space Station and Shuttle utility matures, more Extra Vehicular Activity (EVA) is likely to assemble and service or refurbish satellite vehicles. Modular, easily replaced solar cell array packages should be a part of these activities.

The issues involved in interactions with the space environment become more critical as the size and voltage of the solar cell array increase. These effects were briefly discussed in last year's space power systems conference[1] and are presented in Table 5. These issues are being addressed in the Interactions Measurements Platform for Shuttle (IMPS) programs through analysis and ground tests as well as flight tests as will be discussed later in this conference.

CONCLUSIONS

Military requirements for solar power will continue to increase at a moderate rate up to 50 to 100 kW. Future emphasis for all Department of Defense hardware will be on survivability. We must continue to search for and develop technology to react to the various threat and survival scenarios in reliable, light weight and cost effective ways. The bottom line for new technology is reliability and end of life efficiency.

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1. Space Power, NASA Conference Publication 2352, April 10 - 12, P286, L. G. Childester & J. F. Wise.

TABLE 1. - FUTURE AIR FORCE POWER REQUIREMENTS

0 Survivability	Laser nuclear weapons effects
0 Power level	1 - 100 kW (1990 - 2000)
0 Power level peak	1:10 ratio
0 Orbits	All earth orbits Low, mid, high, elliptical
0 Lifetime	5 - 10 years
0 Reduce	Area, weight and cost

TABLE 2. - SURVIVABILITY OPTIONS/METHODOLOGY

Passive	Harden to exposure levels of weapon species
Active	0 Evasive maneuvering 0 Autonomy, sense/reconfigure
Detection/disguise	0 Silent spares 0 Decoys 0 Dummy vehicles

TABLE 3. - ACTIVE SURVIVABILITY TECHNOLOGY

0 Autonomy of power system

0 Sense damage and malfunction

0 Adjust and reconfigure to minimize degradation

0 Become independent of vulnerable ground stations

0 Load management to meet needs and prolong life

0 Monitor and assess system health

0 Maintain system i.e. solar cell annealing, battery reconditioning

TABLE 4. HIGH POWER CONSIDERATIONS MISSION CONTSTRAINTS

0 Look Angles, Disturbance

0 Modularity - Size
Activity

0 Environmental interactions

0 Orientation and power transfer

0 Autonomous functions - Switching

TABLE 5. - ENVIRONMENTAL EFFECTS

0 Radiation Damage

0 Arcing/Discharge at High Voltage

0 Atomic Oxygen Erosion

0 Thermal Cycling

0 Atmospheric Drag

0 Corona in Enclosed Volumes

0 Combined Effects of the Above