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AIR FORCE AND DOD SOLAR POWER REQUIREMENTS

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The Air Force and other members of the Department of Defense have been operating in space since our space program began in 1957. Power requirements have grown to meet the needs of critical missions and in concert with launch vehicle capabilities. The performance parameters which have made photovoltaic solar cell arrays the principal power supplier for these satellite missions are long life, reliability, minimum vehicle disturbance, low weight and reasonable cost. These parameters will continue to make photovoltaics the primary choice for space power systems provided we develop the component and system technology needed for future, higher power, survivable systems.

Two major activities are guiding and determing future space missions and their power requirements - the Strategic Defense Initiative (SDI) and Project Forecast 2 (PF2). The SDI power requirements range from 10's to 100's of kilowatts steady-state power to many megawatts of burst or pulse power. (1) In addition, these systems are to be survivable, long life, affordable, and able to function under a variety of launch, operation and emergency conditions. The missions outlined under PF2 project new requirements for the traditional missions as well as new missions. These new requirements include survivability from not only direct attack, but also such electronic threats requiring antijamming, secure data and communication links, and operation without ground station support. These emerging requirements are driving the power needs up to the 50 to 100 kilowatt range for certain critical missions, but the bulk of the satellite power needs will be below 25 kW in the next 15 years.

There are several critical technologies that need to be developed to enable these new or expanded missions to be accomplished. These include survivability which includes weapon threats, environmental interactions, hardening and autonomy, longer life, higher power density and efficiency, and minimum vehicle disturbance. The specific technologies needed are shown in Table I.

Future system power requirements beyond 1995 will grow to the hundreds of kilowatts. This in turn requires on-orbit assembly and servicing, modularity, and standardization of interfaces. With a well supported photovoltaics program, I feel we can meet the needs of future systems with the most versatile, light weight, long life, and economical technology.

FUTURE SPACE POWER REQUIREMENTS

Studies relative to Air Force and Department of Defense missions for the future indicate requirements for increased capabilities and survivability of the standard missions as well as new missions in the areas of transportation and defense. Mission expansion requirements include improved surveillance both

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infrared detection and radar, more secure data links to resist the effects of scrambling or signal upset, jamming, and functioning with fewer ground stations should some Earth geological areas be denied to us. These expanded capabilities push near-term requirements to the 50 kW power level for survivable system technology although many vehicle power requirements will still be below 25 kW. Figure 1 shows the trend in future power requirements. New missions such as Orbital Transfer Vehicle and Strategic Defense systems project not only higher power levels but newer requirements for radiation resistance and annealability, maneuverability and possibly on-orbit assembly, servicing and maintenance. These new missions may also require very large pulse or burst power as shown in Figure 2. The photovoltaic/battery supply would not supply all the power needed - specifically the burst power may utilize a chemical source - but the technology to handle the base load and the alert mode should be developed. These vehicle missions represent a large investment and need to operate 10 years or more.

TECHNOLOGY REQUIRED

The primary future power need is for survivable systems up to 50 KW. The concentrator concept being developed under the Air Force Survivable Concentrator Photovoltaic Array (SCOPA) program is our first attempt to meet this need from a hardening to laser and nuclear weapons standpoint. This concentrator is also a prime candidate for operation in high radiation environments because of the inherent shielding afforded to the solar cells by the metallic reflector optics. This is thus enabling technology for "Belt Fliers" in mid altitude orbits which traverse the Van Allen belts. Other aspects of survivability are being investigated in the Aero Propulsion Laboratory's program, Enhanced Survivability Array. This includes both increased hardening of array components as well as developing the technology for autonomous operation and control of solar cell arrays. Table II (2) presents a summary of what controls are needed to provide autonomy. Similar functions are needed for the other power subsystems such as Energy Storage, Power Conditioning and Switching, and Electrical Power System Management. One possible approach to achieving this is the use of artificial intelligence in the power system subsystem microprocessor controllers and to develop the algorithms for all operational, malfunction, or damage conditions. The third technology needed to be developed is thin light weight solar cell arrays. A paper by John Scott-Monck in 1984 (3) demonstrated that the potential for better than 200 watts/kg of the solar array was achievable utilizing thin silicon solar cells of 16% efficiency. This kind of technology is under development by the Jet Propulsion Laboratory except for the 16% efficient thin silicon cell. A new thin GaAs solar cell technology is emerging and will be reported on in this conference consisting of GaAs on thin germanium substrates with a potential efficiency of 18 to 20% with a solar array performance potential of 100 watts/lb or better. The fourth capability needed for future growth is development of solar cell concepts up to 30% efficiency. These cells also need to withstand high radiation doses and relatively high temperatures (600C) to be utilized in planar and contractor solar arrays. A 30% efficient solar cell will permit us to achieve 300 to 350 watts/kg (150 watts/lb) in a solar array and with improvements in power conditioning and battery technology up to 25 watts/lb can be achieved in a complete power system (4). The fifth technology development needed is how to design, develop, deploy, and operate high power survivable solar power systems. Several workshops and studies have been conducted to define the problems and the technologies needed in this area including the High Voltage High

Power Solar Power System Study for the Air Force by LMSC, the High Voltage Design Guide for the Air Force by Boeing (5), the Study of Multimegawatt Technology Needs for Photovoltaic Space Power Systems by General Dynamics (6) and the Space Power Workshop held by NASA LeRC in 1984 (7). These all identify new problems as shown in Table III from environmental interactions with high voltage solar arrays from the space plasma arcing and/or leakage, effects of natural and vehicle generated debris, radiation effects, and the synergistic effects of several of these species interacting simultaneously. Problems with high voltage will exist with all high power systems-terrestrial, aircraft, or space - and we need to develop the analytical and experimental tools to solve them. Flight experiments such as the Voltage Operating Limit Test (VOLT) series planned by NASA and the Interactions Measurement Payload for Shuttle (IMPS) series planned and under construction by the Air Force are needed to acquire quantitative data in space to validate the models and the plasma chamber experiments being conducted by NASA and the Air Force. The Photovoltaic Array Space Power (PASP) flight experiment, shown in Figure 4, is part of the IMPS/SPAS mission experiment and is to determine the performance and environmental interactions of the polar and equitorial environments with oriented, illuminated, voltage biased, advanced solar array modules. Both concentrator and planar arrays and silicon and gallium arsenide solar cell modules will be tested with bias voltages to +- 500 volts applied to simulate high voltage high power solar cell arrays. Other technology needed besides understanding environmental interactions is how to fabricate, launch, deploy or construct large power systems in space. On-orbit construction and servicing will make new demands on ruggedness, modularity and standardization of interfaces so that solar array modules can be exchanged or replaced to improve system performance.

SUMMARY

Future power requirements are increasing for some expanded and new missions within the Air Force and Department of Defense. New requirements are needed in terms of lifetime, survivability, power level, and performance. The photovoltaic arrays have a demonstrated record of reliable performance, life, affordable cost, and utility; and they can be a prime contender for these future high power missions. We need to push for the R & D resources needed to develop the technology base for these future power system needs.

List of References

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3. John Scott-Monck, et. al., Recent Developments in High Performance Planar Solar Array Technology. 19th IECEC, San Francisco, CA. 1984 Vol 1

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5. W. G. Dunbar, High Voltage Design Guide: Spacecraft. AFWAL TR 82-2057 January 1983

6. D. M. Peterson, et. al., Study of Multimegawatt Technology Needed for Photovoltaic Space Power Systems. Contract NAS3-21951 Final Report Vol I II, May 1981

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Table I Needed Technology For Future Space Power Systems

Concentrator Solar Arrays

Autonomous Operation

Lightweight Thin Array Technology

High Efficiency Solar Cells for Planar and Concentrator Application

High Power System Capability, High Voltage, Min. Environ. Interaction

Table II Solar Cell Array Autonomy Needs

Maintain Sun Orientation

Provide Power Management - On-Array Switching

Sense Malfunction and Damage - Reconfigure

Provide for Survivability and Graceful Degradation

Minimize Thermal Management Load - On-Array Switching

Annealing Radiation Damage to Array Segments

Monitor and Report Solar Array Status

Table III High Power System Concerns and Interactions

Survivability:	Direct Threats
	Loss of Ground Station Links
High Voltage:	Arcing, Leakage
	Corona
	Beads of Pearls
Structure/Array:	Stowage
	Deployment
	Vehicle Interfaces
Environmental Effects:	Plasma
	Debris
	Radiation
	Thermal
	Electrostatic
	Solar Storms

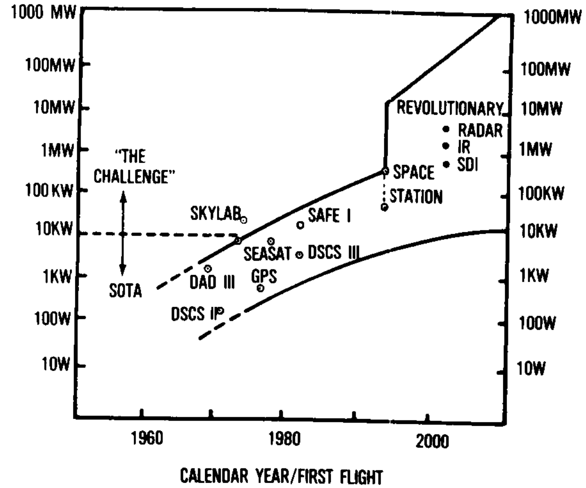

FIGURE 1. SPACECRAFT ELECTRICAL POWER TRENDS

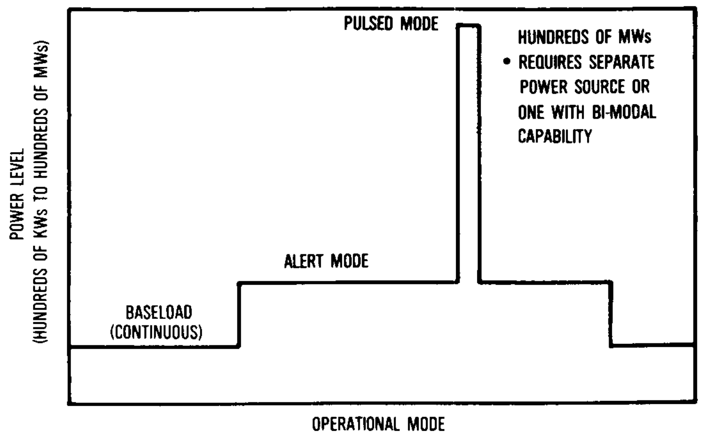

FIGURE 2. HYPOTHETICAL MISSION LOAD PROFILE

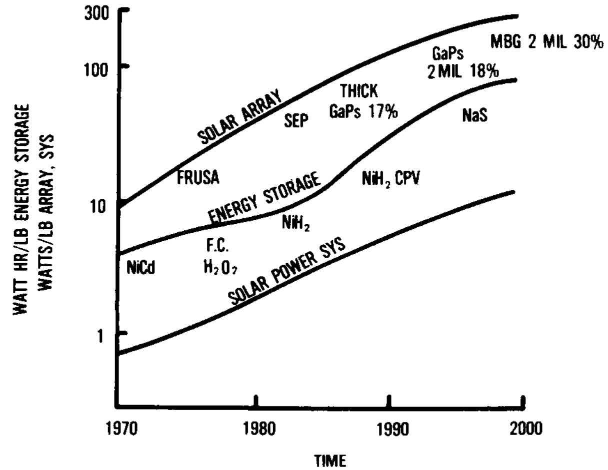

FIGURE 3. SOLAR CELL ARRAY CAPABILITIES

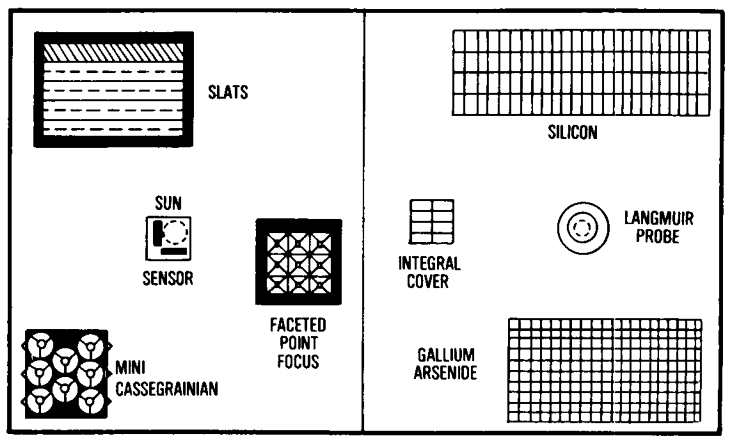

FIGURE 4. IMPS/PASP PANEL