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Space Power Technology 21; Photovoltaics

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Abstract

This paper will discuss the Space Power needs for the 21st Century and the program in photovoltaics needed to achieve it. Workshops were conducted in eight different power disciplines involving industry and other government agencies.The Photovoltaics Workshop was conducted at Aerospace Corporation in June 1987. The major findings and recommended program from this workshop are discussed below.

The major finding is that a survivable solar power capability is needed in photovoltaics for critical Department of Defense missions including Air Force and Strategic Defense Initiative. The tasks needed to realize this capability are described in technical, not financial, terms similar to what was presented in the SPT 21 briefing to industry. The paper will also include what efforts are currently being funded and what still needs to be done.

The second finding is the need for lightweight, moderately survivable planar solar arrays especially for SPO future block buys on existing missions where satellite functional requirements are increasing and minimum changes to the basic vehicle structure are desired. High efficiency thin III-V solar cells can meet some of these requirements.

Higher efficiency, longer life solar cells are needed for application to both future planar and concentrator arrays with usable life up to 10 years. Increasing threats are also anticipated and means for avoiding prolonged exposure, retraction, maneuvering and autonomous operation will also be discussed

In conclusion the potential for nearly doubling the specific power in terms of array weight and area and increasing survivability through higher temperature resistance appear real and highly desirable. Funding is slowly becoming available to make these technical goals achievable.

Description

The objective of the SPT 21 study conducted by the Aerospace Power Division of AFWAL and the Technology Group of the Air Force Space Technology Center was to develop a comprehensive space power research and development program to meet the needs of the Air Force and Department of Defense for the next 10 to 15 years. The schedule for this study is shown in Figure 1. This plan enlisted the best talent in the United States to help us in seven workshops looking at all the disciplines needed to provide power to defense satellite vehicles. Even though projections for power requirements were considerably higher in some cases it was felt that nearly all defense requirements would be met with survivable power in the 10 to 100 kilowatts continuous range. This power range was accordingly made the focus of the study.

The workshops were cochaired by Aerospace Power Division experts plus ones chosen by AF-STC in the following disciplines: Photovoltaics, Energy Storage, Power Conversion and Control, Thermal Management, Solar Dynamic Generation, Nuclear Power, and Advanced Concepts/System Demonstration. Each one of these disciplines conducted a workshop involving potential users, other government agencies and industry expert participation. These workshops were to assess the state of the art and technology readiness of key technology and identify basic research, exploratory development, and advanced development programs needed by the 21st century. The technology readiness levels are shown in Table I. The results of this prioritizing were then presented to industry and governnent leaders in a symposium at AFSTC Sept 1987. The results will also be published in a technical report to be released soon.

The Photovoltaic Workshop findings and the prioritized program recommended for funding from the SPT 21 study are presented below. The Photovoltaic Workshop was conducted at Aerospace Corporation by the Cochairmen, Joseph Wise of the Aerospace Power Division and Dr. W. Pat Rahilly and Dr. Robert Francis of Aerospace. The latter also graciously made all arrangements for the meeting and supplies. It was attended by 20-25 government and industry representatives. The major findings of this workshop were that developments are needed in high efficiency cells, survivability of solar arrays-planar and concentrator, and increase lifetime and reduce weight and cost to the extent possible within the constraints of survivability. The top priority program in Photovoltaics is outlined in Figure 2. Supporting technology in energy storage, power regulation and control and thermal management accompany the top priority program. The key technology development is the Survivable Concentrating Photovoltaic Array program being pursued by two contractors. Augmentation of these contracts was recommended in more weapon effects testing, development of higher temperature cells, investigating higher g loading, and producibility of the resultant hardware concepts. In addition several high efficiency solar cell programs are recommended to increase specific power of these survivable systems. Basic research is recommended in cell materials and configurations as well as areas incidental to the cells such as passivating and antireflecting coatings and stable high temperature metallization. Advanced survivability is also required since the work on survivability to date has only addressed passive measures and at relatively high levels. Active measures are required as well as a range of levels for those missions where weight or area may be most important and lower levels of weapon threat are a part of the operating scenario. Flexibility in design technology is one of the keys for continued utilization of photovoltaics for Department of Defense space applications. The rationale of recommending survivable photovoltaic systems as the top priority is briefly summarized in Table II. This technology and its admirable heritage make it a prime candidate for future long life high power systems if we can solve the problems of survivability, reliability, lower cost and increased specific power- watts/kg, watts/sq. meter.

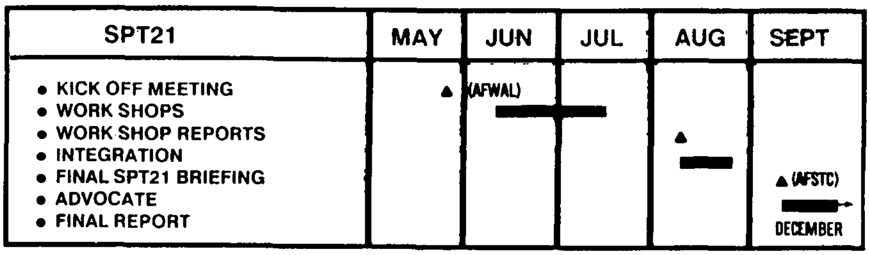
The priorities for development of solar dynamic, nuclear and lightweight planar technology were considered by the SPT 21 as approximately equal. These three technologies are being pursued also. The program for lightweight, hardened technology is shown in Figure 3. The technology begins with the development of thin, high efficiency solar cells. The principal candidate at present is the 150 micrometer thick GaAs on Ge solar cell. Since this study was completed more than six months ago this cell has shown dramatic additional improvements and has the potential of better than 20% efficiency in production. This is especially true when we understand and fully exploit the interface between the GaAs and Ge and preserve the apparent boost in efficiency and voltage from the Ge substrate layer. Evaluation of proposals for developing manufacturing technology for this cell is currently underway. Other technology needed to fully utilize photovoltaics for military missions is to minimize the effects of natural particulate radiation. To this end some work is under way in our laboratory investigating annealing effects on GaAs solar cells. This is also where the indium phosphide solar cell appears promising. Understanding of the dynamics of large array subsystems and their coupling into the vehicle and its attitude control system is vitally important in the application of photovoltaics to mission vehicles which have stringent pointing requirements themselves such as surveillance mission vehicles. The movement of the solar array remains a severe challenge in the development of solar array technology especially in the application of oriented solar arrays.

Program Implementation

How successful have we been in implementing this program? The contracts underway at the time of the study such as SCOPA and thin GaAs solar cells and multibandgap cell development are continuing. The Strategic Defense Initiative Office also recognized late in FY87 the need for nonnuclear baseload power especially for Phase I systems and has provided support for this program. It is indeed fortunate that the planning was conducted so thoroughly that we were able to present a mature plan to SDIO. Much of this program is being supported as illustrated in Figure 4. This includes augmentation of existing programs in photovoltaics and energy storage and the initiation of new efforts both in-house and through PRDAS in multibandgap concentrator cells and advanced hardened solar power technology. Although the latter is open to other than photovoltaic technology, promising photovoltaic proposals are expected to be supported. Similarly the SUPER program, currently on RFP, is to develop power system technology and demonstrate it in flight. Phase I is expected to include photovoltaic technology for power generation among other candidate solar energy conversion concepts. After Phase I there will be a down selection and only the best one or two systems will be continued into Phase II and flight demonstration.

Concluding Remarks

Photovoltaic power technology continues to be the primary candidate for supplying power for military satellites in earth orbit for a variety of missions. The highest priority in the Air Force and SDIO sponsored program is survivability–looking at both active and passive techniques of both avoiding damage and minimizing its effects. Development of higher efficiency and higher temperature solar cells is urgently needed to increase the watts/kg and improve survivability and life. To assist in the development and utilization of photovoltaic technology new facilities are needed to produce the improved hardware and test it from space operation and weapons effects. One recommendation is to develop weapon effects testing capabilities along with the development of the weapons such as lasers, neutral particle beams, pellets and nuclear weapon effects simulation. Basic research is needed to better understand new candidate and existing semiconductors and device concepts, stable high temperature metallization and coatings for passivation and control of absorption and emission from both natural and weapon effects simulation. Modeling is needed both in cell design and performance and solar array dynamics and interactions with vehicle/attitude control systems. Hardened planary array technology is needed in the near term to upgrade the survivability of future versions of existing systems. Ultra lightweight array technology is still enabling technology for very high altitude satellites because of weight limitations and the need for future improved mission capabilities. While higher efficiency solar cells will help somewhat in increasing the watts/kg, development of lightweight solar array blankets and structures are also needed. The photovoltaic industry has a continuing critical role to play in the future US military space missions. I wish to thank all those industry, government and academic experts who assisted in the SPT 21 Workshop on Photovoltaics.



STUDY SCHEDULE
FIG 1

UNCLASSIFIED

(U) TECHNOLOGY MATURITY LEVELS

LEVEL 7	ENGINEERING MODEL TESTED IN SPACE
LEVEL 6	PROTOTYPE/ENGINEERING MODEL TESTED IN RELEVANT ENVIRONMENT
LEVEL 5	COMPONENT/BREADBOARD TESTED IN RELEVANT ENVIRONMENT
LEVEL 4	CRITICAL FUNCTION/CHARACTERISTIC DEMONSTRATION
LEVEL 3	CONCEPTUAL DESIGN TESTED ANALYTICALLY OR EXPERIMENTALLY
LEVEL 2	CONCEPTUAL DESIGN FORMULATED
LEVEL 1	BASIC PRINCIPLES OBSERVED AND REPORTED

UNCLASSIFIED

TABLE I

PHOTOVOLTAIC SURVIVABLE ARRAYS

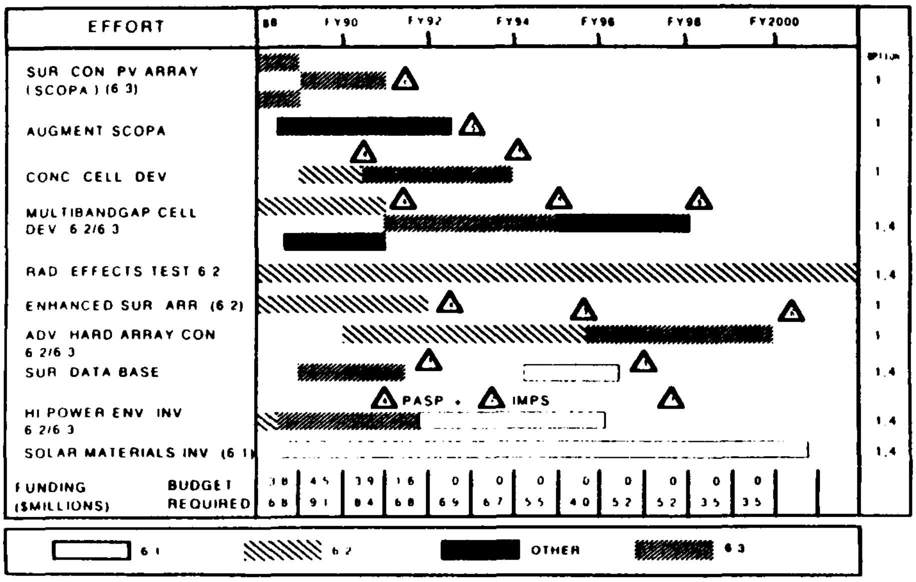


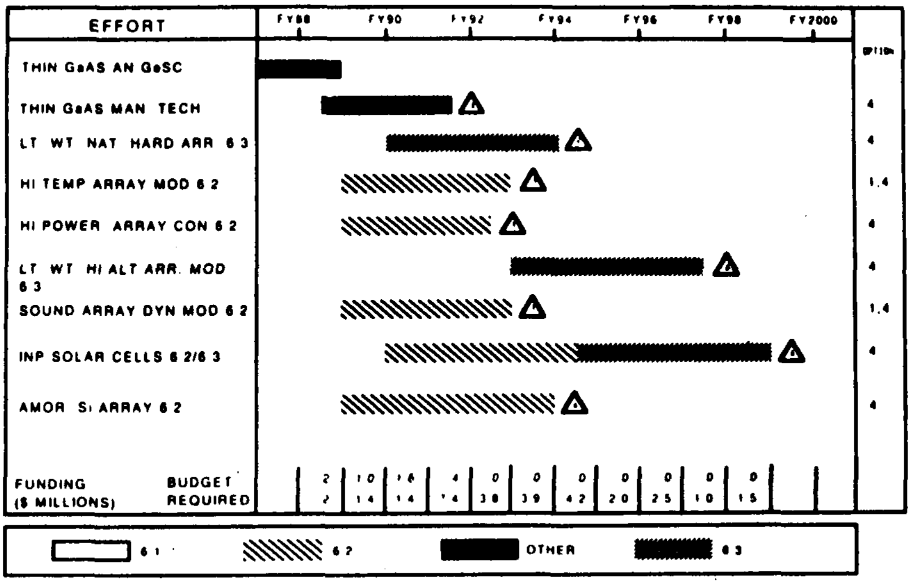
FIG 2

WHY PHOTOVOLTAICS?

- DEMONSTRATED SPACE RECORD FOR 30 YEARS
- HIGH RELIABILITY (STATIC)
- SCALEABILITY/MODULARITY/INHERENT REDUNDANCY
- COMPACT STOWAGE
- POTENTIAL FOR SURVIVABILITY, AUTONOMOUS CONTROL/ RECONFIGURATION
- POTENTIALLY LIGHTWEIGHT
- CAN BE MANEUVERED/RETRACTED/ROTATED/ORIENTED
- MINIMUM SINGLE POINT FAILURE POINTS
- PREDICTABLE WEAR OUT MECHANISMS RADIATION DEGRADATION, THERMAL FATIGUE

TABLE II

PHOTOVOLTAIC LIGHTWEIGHT ARRAYS



LIGHTWEIGHT
FIG 3

FIG 4
SDI SUPPORTED PV PROGRAMS