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Strategy in Space Flight Experiments

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The Workshop consisted of approximately 40 people, representing universities, government contractors, and DOE and DOD agencies. The main topics of the workshop were evaluation of both the need for flight testing of solar array hardware and the opportunities for such testing.

Motivation for Flight Testing

The effect of the space environment on silicon solar cells is reasonably well established. Extensive compilations of radiation degradation are contained in the JPL Solar Cell Radiation Handbook. The accuracy of these ground test data have been verified by flight tests and data from operational systems over the past 30 years. However, the data are more sparse for gallium arsenide and indium phosphide, and almost non-existent for advanced cell materials, such as copper indium diselenide, aluminum gallium arsenide, and indium gallium arsenide. In addition, there has been little flight testing of multijunction cells. There will be more ground radiation testing of devices using these materials as development proceeds, and confirmation of the observed behavior by flight testing is needed. One workshop attendee expressed the opinion that "the flight test is not so much to verify the effects that were identified on the ground, but rather to discover the effects that were not identified".

At the array level discussion centered on the issues of spacecraft charging effects and array dynamics. As new array structures such as light weight or concentrating systems are developed, space testing is needed in these areas. The complex geometry of concentrating photovoltaic arrays makes prediction of plasma interaction very difficult. Flight experiments such as PASP-Plus are essential for assessing array behavior. The design used in many light weight arrays generates new paths for plasma interaction that must be evaluated under realistic conditions. The dynamics of array deployment and response to maneuvers cannot be reproduced in general testing in the one g environment. It was concluded that large area, light weight array designs would benefit from flight tests. The SAFE array test on the shuttle is an example of the beneficial information obtained.

From the customer's point of view, flight heritage hardware is always desirable. The NASA technology maturity scale requires flight-proven performance at level 7 and beyond. The Air Force position is not as formalized, but acceptance of advanced technology by System Program Offices is always facilitated by the presence of encouraging flight data. The acceptance of radically new photovoltaic technology has not been a major issue over the past 20 years because of the success of silicon technology in meeting program needs. However, it promises to take on a higher profile in the next ten years as system requirements exceed the capability of silicon solar cells and competing technologies are closely scrutinized.

Bus Options

The relationship of the flight experiment to the spacecraft as a whole determines the cost of the experiment. At the low cost limit a test panel mounted on an existing vehicle might fly for only the integration expense plus the panel fabrication cost. As discussed below in the Planning section, there are many opportunities for this type of experiment that can be exploited. The major issues are finding a ride to an appropriate orbit and a spacecraft which can support the experiment power, temperature, weight and telemetry requirements.

A more expensive option is a piggy-back flight such as the Living Plume Shield (LIPS) experiments. The cost here is higher because the experiment must be self supporting. However, it offers tailored support to the experiment, reduced spacecraft interface problems, and a paid-for launch vehicle. Since cost of the launch operations far exceeds the cost of all but the largest experiments, this is still an important advantage.

The most costly option is the dedicated flight experiment such as The Combined Radiation Release Experimental Satellite (CRRES) and the Long Duration Exposure Facility (LDEF). In return for paying the entire cost of launch, vehicle procurement, and payload development, the experimenter can select the mission profile that best suits the goals of the program.

Planning

The methods of flight test planning generated the most discussion of any topic in the Workshop. It was clear that better communications between hardware builders (both cell and array level) and those who are aware of flight opportunities would be beneficial. Planning and prioritizing of flight tests for all three military services are handled by the Air Force Space Test Program. However, this process can accommodate only a very small number of programs each year. There is an office at NASA/HQ which tracks scheduled launches many years in advance and disseminates this information to potential users. Many attendees at the Workshop were unaware of this information.

The consensus of the group was that a listing of appropriate NASA and DOD spacecraft which might accommodate flight test hardware should be made available to government contractors. This information is already tracked by NASA/HQ and STP, and the opportunities would be better utilized if the information were disseminated. It would then be up to the individuals involved to discuss the feasibility of an experiment. After some discussion it was clear that many spacecraft have extra area on the solar array (in the case of TDRSS, 50 ft^2 !) which could accommodate an appropriate experiment.

An additional conclusion was that a National effort to insure regular flight opportunities should be made. This could take the form of an LDEF-scale spacecraft launch every 2-3 years. Such a capability would be suitable for either a number of small experiments, or a larger panel or array level test. The British government has such a capability in their Space Technology Research Vehicle (STRV) run by The Royal Aircraft Establishment–Farnborough. STRV-1 is to be launched in 1991 but is still accepting proposals. STRV-2 is scheduled for 1993-4, and STRV-3 is under discussion for the 1993-5 time frame. For the near term it was pointed out that the US Commerce Dept. encourages scientific collaboration with NATO partners, and a number of opportunities exist.

A workshop at last year's SPRAT on Space Environmental Effects concluded that "space flight tests will be needed in the future as far as can be imagined, because of the inadequacy of simulating the complex combined environment of space". This workshop concludes that this need will be best accommodated by a deliberate, improved communication between the civilian and military agencies who fund spacecraft programs and the community of researchers who are developing advanced technologies for those spacecraft.

CONCLUSIONS OF FLIGHT EXPERIMENT WORKSHOP

FLIGHT EXPERIMENTS ARE IMPORTANT:

0 NASA LEVEL 9 MATURITY DEMANDS FLIGHT-PROVEN PERFORMANCE.

0 MILITARY PROGRAMS GENERALLY INSIST ON FLIGHT HERITAGE.

0 SOME PROPERTIES CANNOT BE GROUND TESTED--ARRAY DEPLOY/REDEPLOY MECHANISMS, ARRAY CHARGING/DISCHARGING EFFECTS.

CAVEATS:

0 ORBIT MUST BE REPRESENTATIVE (E.G., ECLIPSE CYCLE, RADIATION DOSE). NEGATIVE RESULTS ARE NOT HELPFUL.

0 HARDWARE MUST BE FULLY DEVELOPED: CAN'T MODIFY AFTER FLIGHT, CAN'T FLY POOR SAMPLES.

0 POOR PERFORMANCE IN TEST CAN BE MAJOR SETBACK FOR A TECHNOLOGY. (GAAS ON LIPS 2)

0 DELAY BETWEEN HARDWARE FREEZE AND RECEIPT OF DATA CAN MAKE RESULTS PASSE'.

CONCLUSIONS OF FLIGHT EXPERIMENT WORKSHOP (CONTINUED)

FLIGHT EXPERIMENT COORDINATION:

- 0 MANY NASA SATELLITES AND CERTAIN DARPA, USAF, AND EUROPEAN PROGRAMS OPEN TO DISCUSSION OF FLIGHT TEST CO-PAYLOADS.
- 0 SOME FLIGHTS PAID FOR BY AF/STP.

PRIMARY CONCLUSION:

- 0 AN OFFICE WITH A NATIONAL PERSPECTIVE ON FLIGHT TEST OF ADVANCED TECHNOLOGIES IS SORELY NEEDED TO COORDINATE OPPORTUNITIES.
- 0 MANY SATELLITES HAVE ROOM FOR SMALL AUXILIARY PAYLOADS, BUT THEY ARE NOT ACTIVELY ADVERTISED.
- 0 MEDIUM SCALE TESTS, E.G., PANELS, ENVIRONMENT DIAGNOSTICS MUST BE PLANNED WELL IN ADVANCED. MAKE USE OF KNOWLEDGE THAT REGULAR LAUNCHES OF CERTAIN SPACECRAFT OCCUR.
- 0 LARGE-SCALE, DEDICATED SPACECRAFT, E.G., LDEF SHOULD BE PLANNED EVERY 2-3 YEARS. NEEDED FOR ARRAY AND MECHANISM TESTING.

Non-Solar Direct Conversion

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TPV
Concepts and Applications

- Solar heated (orbital missions)
- Solar heated with thermal storage (orbital missions)
  - may double subsystem specific power for some missions
- Isotope heated--interplanetary/surface probes/modular microsatellites
  - decreased fuel requirement from RTG
  - increased radiator size
- Nuclear heated--large power supplies (surface or orbital)
  - efficiency may require line emitter
  - low temperture radiator

Key Performance Limiters

- PV cell
  - Low band gap
  - IR reflective
  - High near bandgap response

    GaSb

    InGaAs

    Ge
- Thermal emitter
  - Line emitter desirable

    Most are vacuum incompatible

    Require hermetic sealed system
- Radiator size
  - Sheet radiator beneficial

Recommended Future Work

- PV cell optimization
- Selective emitter development
- Performance demonstration
- Radiator development

Betavoltaics (Particle Voltaics)

Concepts and Applications

- Micropower (5-10 Watts may be practical limit)
- Point power sources
- Miniature satellites
- Surface probes

Key Performance Limiters

- Source self absorption
  - Solution:
    Increase area & stack
    Alpha emitter doped into semiconductor
- Radiation damage
  - Solution:
    Heavy atom compounds
    Thermal annealing
- External/background radiation environment

Recommended Future Work

- Investigate high bandgap/high-Z cells
  - SiC
  - Diamond
  - ZnSe
  - ZnS
- Explore sources vs. new semiconductor candidates
- Explore doping isotopes directly into lattice

Pyroelectric

Concepts/Applications

- Huge spinning sheet (extended structure)
- Compact recuperated system
  - Large (>10 kW) low-cost/light weight
  - Low drag orbits
  - Surface power/thermal sources (bottoming cycles)

Key Performance Limiters

- Low upper temperature limits

  Solution: efficient radiator to lower bottom temperature

- Radiation (?)

- Mechanical pumps and sophisticated PMAD

Recommended Future Work

- Small scale working demo
- Explore advanced materials
- Space systems trade studies