THE PHOTOVOLTAIC ARRAY SPACE POWER PLUS DIAGNOSTICS (PASP PLUS) FLIGHT EXPERIMENT

by

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PASP PLUS FLIGHT EXPERIMENT

OUTLINE

- EXPERIMENT DESCRIPTION
- OBJECTIVES
- SOLAR ARRAY MODULES
- CONTROL & DIAGNOSTIC EQUIPMENT
- ILLUMINATED THERMAL-VAC TESTING
- SUMMARY
PASP PLUS FLIGHT EXPERIMENT

PASP PLUS: **PHOTOVOLTAIC ARRAY SPACE POWER PLUS DIAGNOSTICS**

- **PRIMARY EXPERIMENT ON THE USAF APEX (ADVANCED PHOTOVOLTAIC AND ELECTRONICS EXPERIMENTS) MISSION**
- **PURPOSE IS TO TEST A VARIETY OF PHOTOVOLTAIC CELL AND ARRAY TECHNOLOGIES UNDER VARIOUS SPACE ENVIRONMENTAL EFFECTS**

PASP PLUS EXPERIMENT MANAGED BY GEOPHYSICS DIRECTORATE, U.S. AIR FORCE PHILLIPS LAB

- **NASA LEWIS HAS PRIMARY ROLE IN ASSISTING THE U.S. AIR FORCE IN THE INTEGRATION, TESTING & DATA INTERPRETATION OF THE INDIVIDUAL SOLAR ARRAY EXPERIMENTS**
- **POWER & THERMAL MGMT. DIVISION, PHILLIPS LAB HAS THE PRIMARY ROLE IN PV MODULE EXPERIMENT SELECTION AND EXPERIMENTOR INTERFACE (RESPONSIBILITY TRANSFERRED FROM WRIGHT LAB)**
MISSION OVERVIEW

• MISSION: SSD/CLP MISSION P90-6, ADVANCED PHOTOVOLTAIC AND ELECTRONICS EXPERIMENT, APEX

• LAUNCH: PEGASUS, 2Q FY93

• ORBIT: Perigee: 190 nmi (350 km)
  Apogee: 1054 nmi (1950 km)
  Inclination: 70°
  Orientation: Sun Pointing ± 0.5°

• DURATION: One Year Minimum; Three Year Goal
INTEGRATED SYSTEM OF ADVANCED SOLAR ARRAYS AND DIAGNOSTIC INSTRUMENTATION

Arrays: Many Different Materials and Configurations Represented in 12 Arrays Divided into 16 Separate Modules

Subsystems: Experiment Controller/High Voltage Generator Electron Emitter (Vehicle Potential Control)

Diagnostics: Transient Pulse Monitor (Arc Parameters)
Langmuir Probe (Plasma Density & Temp.)
Electrostatic Analyzer (Auroral Passage)
Proton/Electron Dosimeter (Flux & Dose)
QCMs and Calorimeters (Contamination)
Sun Sensor (Concentrator Sun Pointing)
ADVANCED PHOTOVOLTAIC AND ELECTRONICS
EXPERIMENTS (APEX) SATELLITE

MSN#
(SSD/CLPM P90-6)
OBJECTIVES

1. DETERMINE HIGH-VOLTAGE OPERATION LIMITATIONS
   - Measure Plasma Leakage Current for Positive Biasing
   - Characterize Array Arcing for Negative Biasing

2. QUANTIFY DEGRADATION CAUSED BY SPACE RADIATION
   - Performance Shown by I-V Curves
   - Dosimeter with Low-Energy Proton Capability
   - Contamination Monitors To Separate Effects

3. PROVIDE FOR "SPACE QUALIFYING" NEW P/V TECHNOLOGIES

4. ESTABLISH CAUSE-AND-EFFECT RELATIONSHIPS
   - Envir. Sensors To Indicate Space Conditions
   - Analyses, Modeling, Code Development
ON-ORBIT OPERATIONS

• EARLY OPERATIONS (FIRST EIGHT MONTHS)
  □ Bias Selected Arrays to Specified Voltage Levels
    (up to -500 V and +500 V)
  □ For Negative Biasing, Measure Arcing Parameters with TPM
  □ For Positive Biasing, Measure Leakage Current with Electrometer
    (For some 100s of hours, electron emitter turned to control vehicle potential.)
  □ Monitor Diagnostics To Characterize Plasma Environment
  □ Monitor I–V Characteristics of All Arrays

• LONG-TERM OPERATIONS (UP TO THREE YEARS)
  □ Monitor I–V Characteristics of All Arrays
  □ Monitor Diagnostics To Determine Cumulative Radiation Dosage
    and Contamination Build-Up
EXPECTED RESULTS

- HIGH-VOLTAGE OPERATION (SIMULATED BY BIASING)
  - Arc Pulse Parameters for Negatively Biased Arrays
    (pulse rate; amplitude, derivative, integral of largest pulse)
  - Leakage Current Parameters for Positively Biased Arrays
    (electron current below/above "snapover", with emitter off and on)
  - Over Flight Ranges of the Space-Environment Parameters
    (plasma density, velocity-vector orientation, auroral passage)

- RADIATION-INDUCED ARRAY POWER DEGRADATION
  - Continuing I - V Curves for All Array Segments
  - Continuous Radiation Dose and Flux Measurements
    (electrons and protons separately; emphasis on 5-10 MeV protons)
  - Over Three-Year Lifetime of Mission
    (possibly including a major solar proton event)
PASP PLUS FLIGHT EXPERIMENT

PASP PLUS CONSISTS OF 12 DIFFERENT EXPERIMENTAL MODULES (OBTAINED FROM VARIOUS DOD, NASA & INDUSTRY SOURCES) ALONG WITH A VARIETY OF ENVIRONMENTAL AND DIAGNOSTIC SENSORS

<table>
<thead>
<tr>
<th>SOLAR CELL MATERIALS</th>
<th>ARRAY DESIGNS/CONFIGURATIONS</th>
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<tbody>
<tr>
<td>SILICON (Si)</td>
<td>STANDARD Si &amp; GaAs CELL CONFIG.</td>
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<tr>
<td>GALLIUM ARSENIDE (GaAs)</td>
<td>GaAs WRAP-THROUGH CONTACTS</td>
</tr>
<tr>
<td>INDIUM PHOSPHIDE</td>
<td>SPACE STATION FREEDOM DESIGN</td>
</tr>
<tr>
<td>AMORPHOUS SILICON</td>
<td>ADVANCED PHOTOVOLTAIC SOLAR ARRAY (APSA) DESIGN</td>
</tr>
<tr>
<td>GaAs/CIS TANDEM CELLS</td>
<td>MINI-CASSEGRAINIAN CONCENTRATOR</td>
</tr>
<tr>
<td>GaAs/GaSb TANDEM CELLS</td>
<td>MINI-DOME FRESNEL LENS CONC.</td>
</tr>
<tr>
<td>AlGaAs/GaAs MONOLITHIC CELLS</td>
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PASP PLUS FLIGHT HARDWARE

Payload Shelf

Deployed Panel
PASP PLUS FLIGHT EXPERIMENT

(Experiments relating to NASA-sponsored technology)
PASP PLUS FLIGHT EXPERIMENT

(Experiments relating to NASA-sponsored technology)

Mini-Dome Fresnel Lens
Photovoltaic Concentrator

Advanced Photovoltaic
Solar Array (APSA)
EXPERIMENT-CONTROL INSTRUMENTATION

• MULTI-STEP HIGH-VOLTAGE GENERATOR
  – Four All-Positive or All-Negative Steps
  – Each Step about 26 sec Long
  – Bias-Value Range: 50 to 500 Volts
  – Minimum Step-Value Separation: 10 Volts

• ELECTRON EMITTER
  – Generate and Accelerate Outgoing Electrons
  – Help Balance Excess Incoming Electrons
  – Reduce Negative Vehicle-Frame Potential
PASP PLUS DIAGNOSTIC SENSORS

• LANGMUIR PROBE
  Measure Plasma Density and Temperature

• ELECTROSTATIC ANALYZER
  Detect Passage through Auroral Region

• ELECTRON/PROTON RADIATION DOSIMETER
  Outputs: Dose (Energy Deposited) and Flux
  Energy Ranges: Four for Electrons, Eight for Protons

• CONTAMINATION MONITORS
  QCMs and Calorimeters

• SUN INCIDENCE-ANGLE SENSOR
  Assure Concentrator Arrays Are Aligned
INTERACTIONS MEASURING INSTRUMENTATION

• TRANSIENT PULSE MONITOR (Negative Biasing)
  - Measure Electrical Characteristics of Arc Pulses
    Amplitude, derivative, integral, number per time interval
  - E-Field Sensors on Upper Deck and Deployed Panel
  - Current-Loop Sensor on High-Voltage Line

• LEAKAGE-CURRENT ELECTROMETER (Positive Biasing)
  - Electron Current, 1 µA to 20 mA

• CURRENT – VOLTAGE MEASUREMENTS
  - All 16 Array Modules (Biased or Not)
  - 64 Resistance Values from $R_\infty$ to $R = 0$
    corres. to open-circuit voltage $V_{OC}$ and short-circuit current $I_{SC}$
PASP PLUS FLIGHT EXPERIMENT
ILLUMINATED THERMAL-VAC TESTING

TESTING CONDUCTED AT BOEING FACILITIES - JUNE 1992

- DEPLOYED PANEL, PAYLOAD SHELF & ELECTRONIC CONTROLLER

- THREE INDIVIDUAL RUNS NEEDED TO COMPLETE TESTING

WHY WAS TESTING DONE?

- SIMULATE TEMPERATURE RANGE OF PANEL & ARRAYS UNDER FLIGHT CONDITIONS

- OBTAIN MODULE I-V CURVES AT VARIOUS TEMPERATURES

- NEED FOR END-TO-END TEST
PASP PLUS FLIGHT EXPERIMENT
ILLUMINATED THERMAL-VAC TESTING

PV MODULE TEMPERATURE PROFILE (Array #0,1,2)
PASP PLUS FLIGHT EXPERIMENT
ILLUMINATED THERMAL-VAC TESTING

PV MODULE TEMPERATURE PROFILE (Array #3)

Elapsed Time (Min)
PASP PLUS FLIGHT EXPERIMENT
ILLUMINATED THERMAL-VAC TESTING

I-V MEASUREMENTS (Array #15)
PASP PLUS FLIGHT EXPERIMENT
SUMMARY

PROGRAM STATUS

• PHOTOVOLTAIC MODULES INTEGRATED TO FLIGHT PLATES

• ILLUMINATED THERMAL-VAC TESTING COMPLETED

• PASP PLUS EXPERIMENT DELIVERED TO ORBITAL SCIENCES CORP. FOR INTEGRATION TO APEX SATELLITE

• PEGASUS LAUNCH - MAY 27, 1993