

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

by

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AEROSPACE TECHNOLOGY DIRECTORATE

POWER TECHNOLOGY DIVISION



Lewis Research Center

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 $\pm 0.5^\circ$
- **DURATION:** One Year Minimum; Three Year Goal

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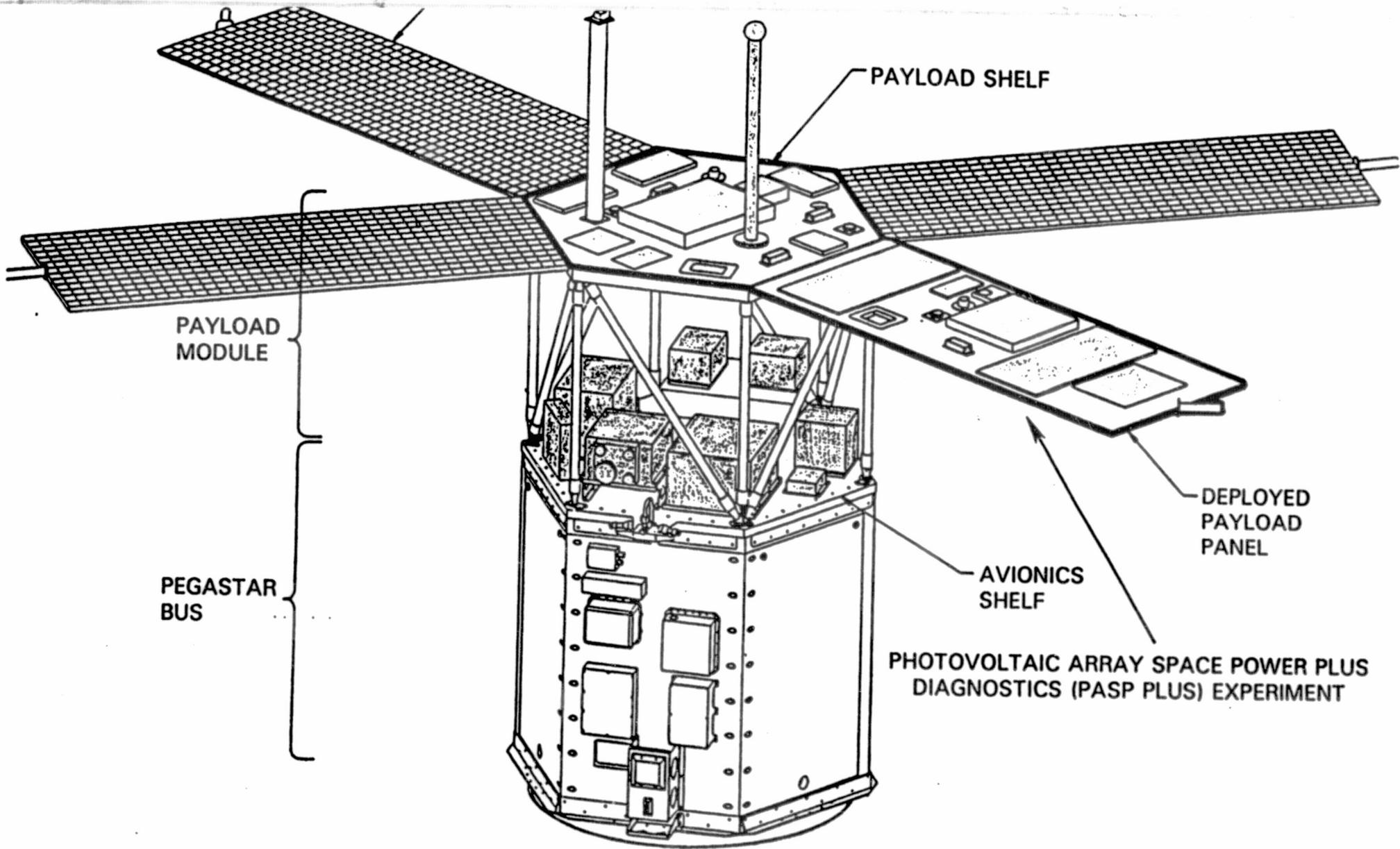
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EXPERIMENT DESCRIPTION

● 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)



PAYLOAD
MODULE

PEGASTAR
BUS

PAYLOAD SHELF

DEPLOYED
PAYLOAD
PANEL

AVIONICS
SHELF

PHOTOVOLTAIC ARRAY SPACE POWER PLUS
DIAGNOSTICS (PASP PLUS) EXPERIMENT

**ADVANCED PHOTOVOLTAIC AND ELECTRONICS
EXPERIMENTS (APEX) SATELLITE**

MSN#
(SSD/CLPM P90-6)



PASP Plus



OBJECTIVES

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

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

- PROVIDE FOR "SPACE QUALIFYING" NEW P/V TECHNOLOGIES

- 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**

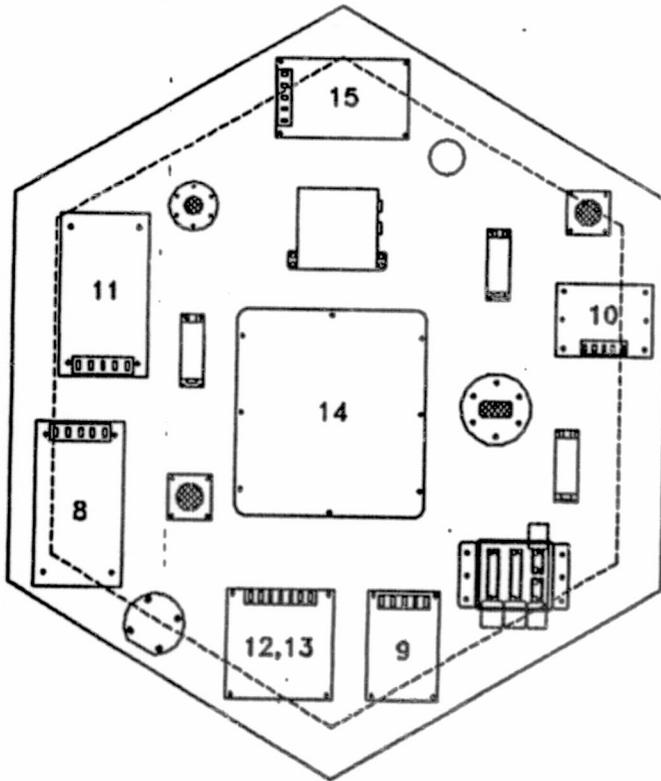
SOLAR CELL MATERIALS

**SILICON (Si)
GALLIUM ARSENIDE (GaAs)
INDIUM PHOSPHIDE
AMORPHOUS SILICON
GaAs/CIS TANDEM CELLS
GaAs/GaSb TANDEM CELLS
AlGaAs/GaAs MONOLITHIC CELLS**

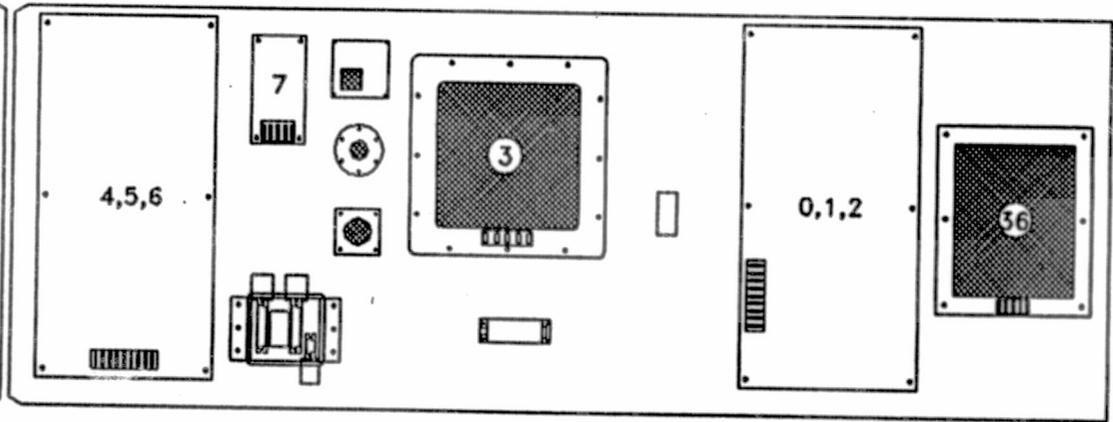
ARRAY DESIGNS/CONFIGURATIONS

**STANDARD Si & GaAs CELL CONFIG.
GaAs WRAP-THROUGH CONTACTS
SPACE STATION FREEDOM DESIGN
ADVANCED PHOTOVOLTAIC SOLAR
ARRAY (APSA) DESIGN
MINI-CASSEGRAINIAN CONCENTRATOR
MINI-DOME FRESNEL LENS CONC.**

PAYLOAD SHELF



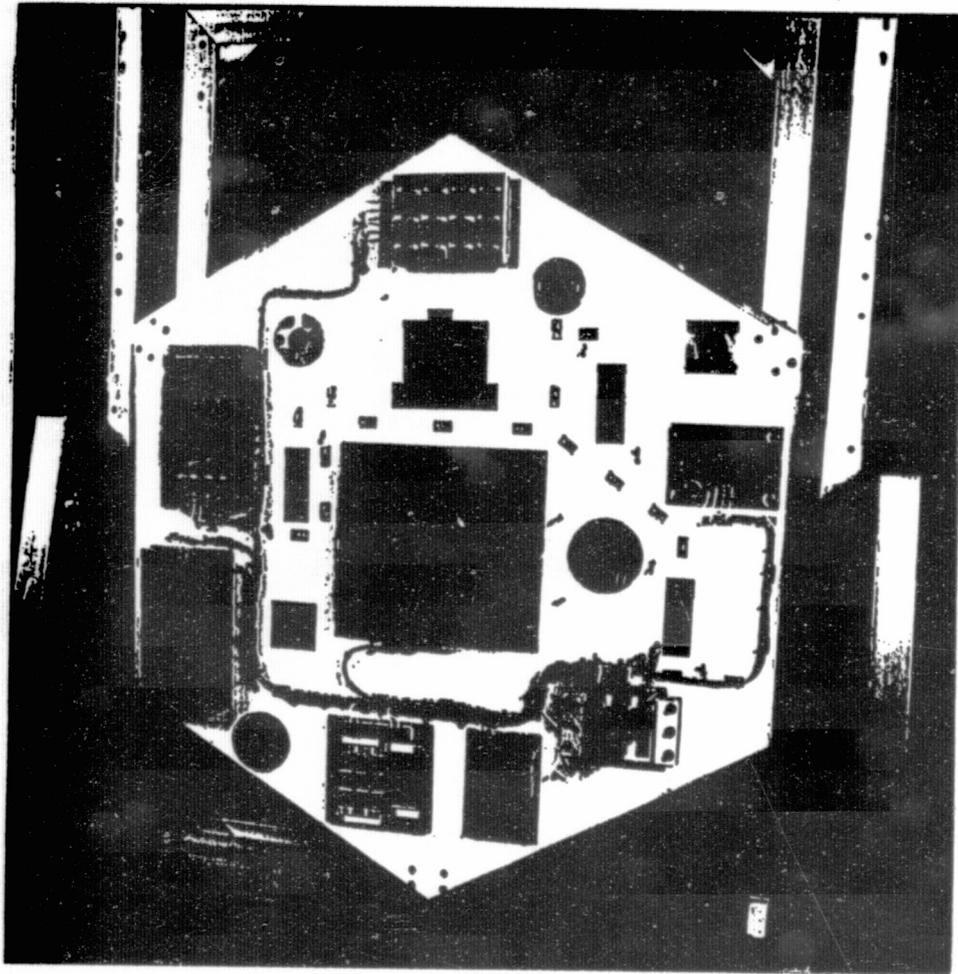
DEPLOYED PANEL



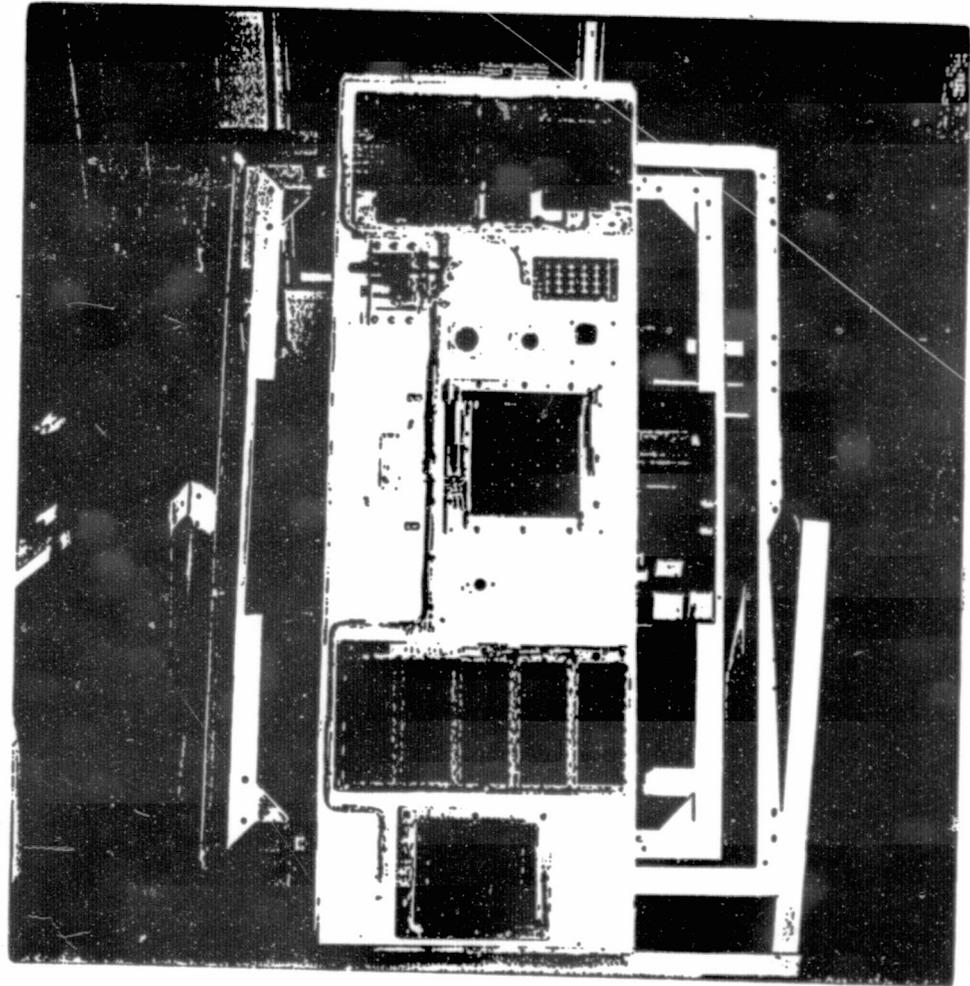
 SHELF PENETRATION

0 0.5 1.0
FEET

PASP PLUS FLIGHT HARDWARE



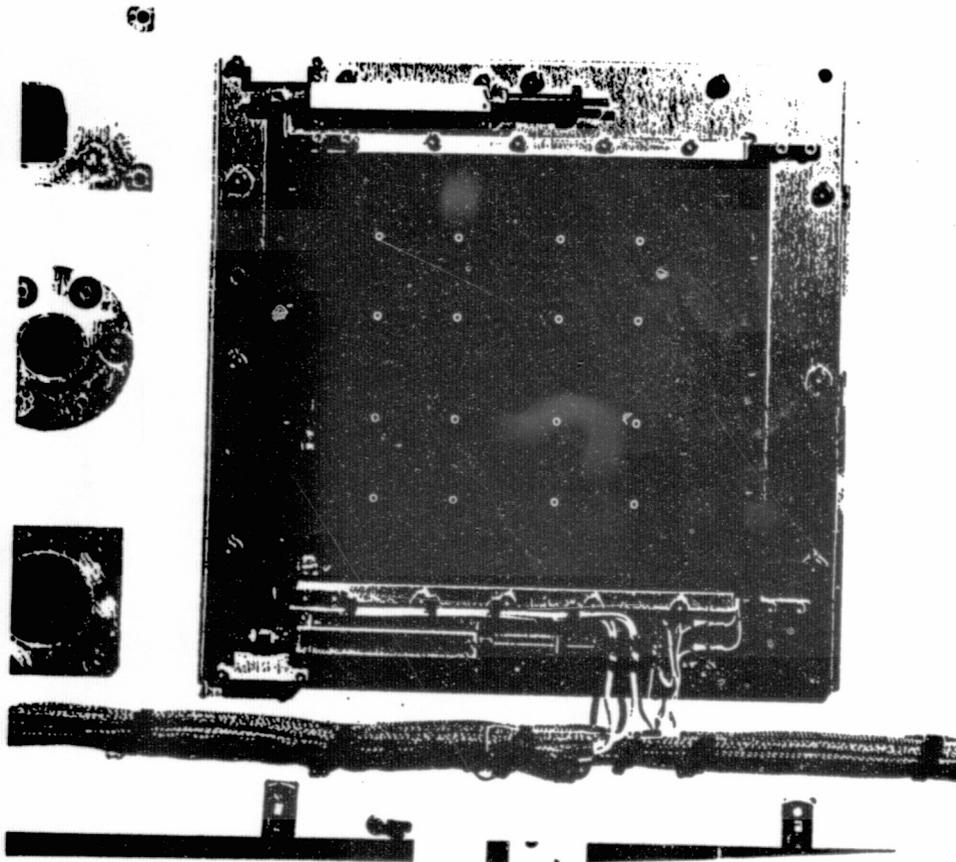
Payload Shelf



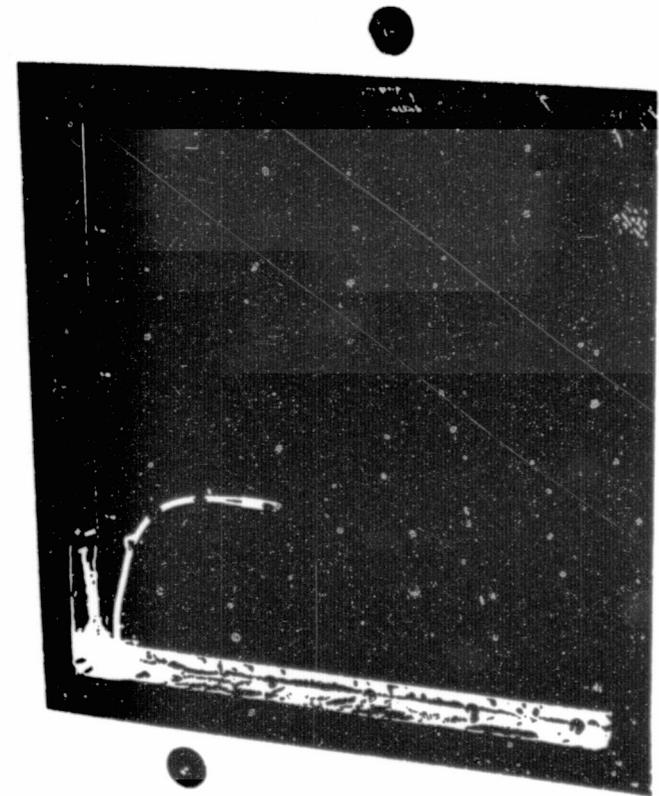
Deployed Panel

PASP PLUS FLIGHT EXPERIMENT

(Experiments relating to NASA-sponsored technology)



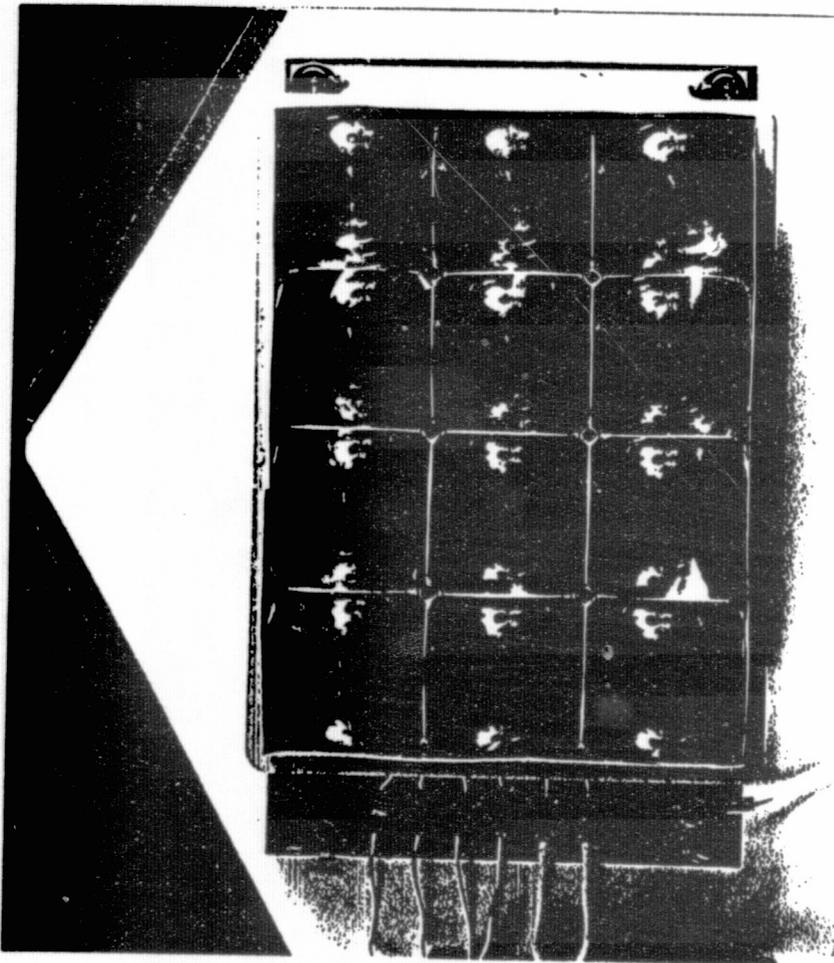
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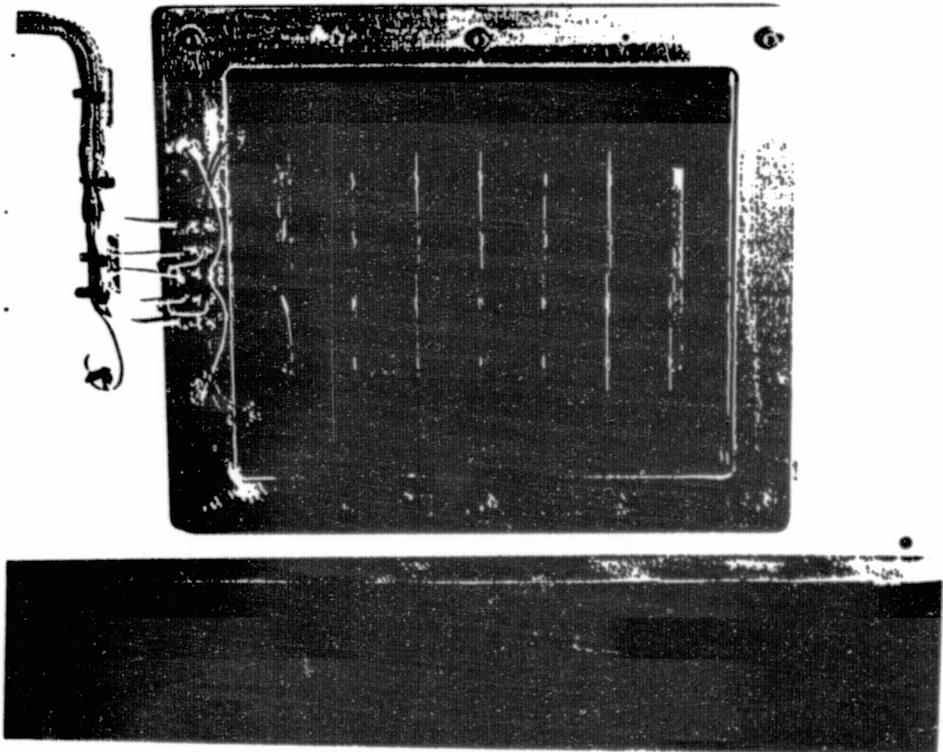
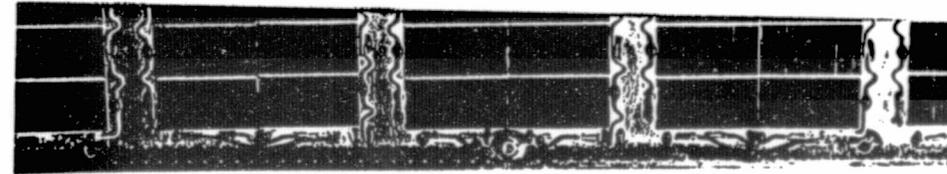
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PASP PLUS FLIGHT EXPERIMENT

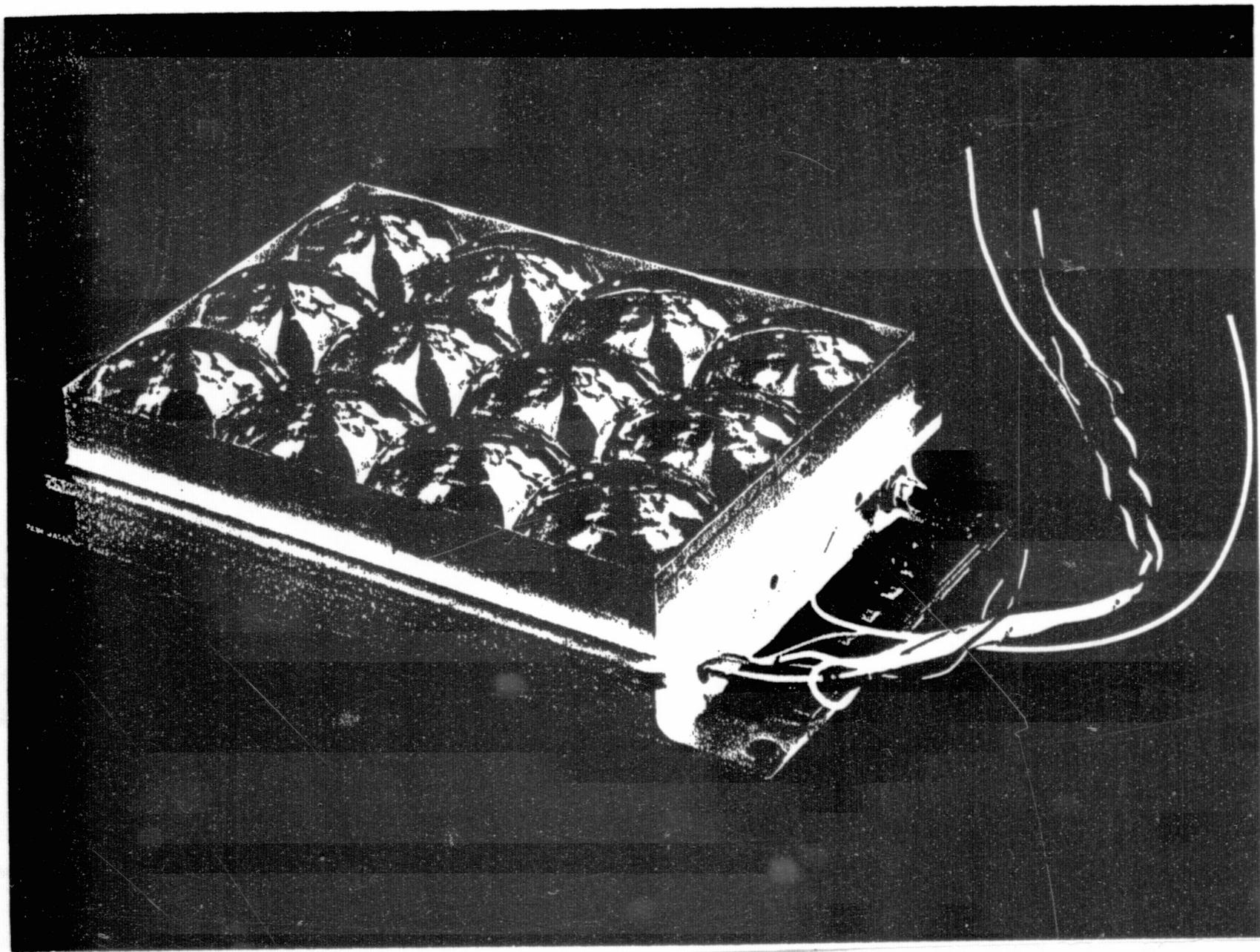
(Experiments relating to NASA-sponsored technology)



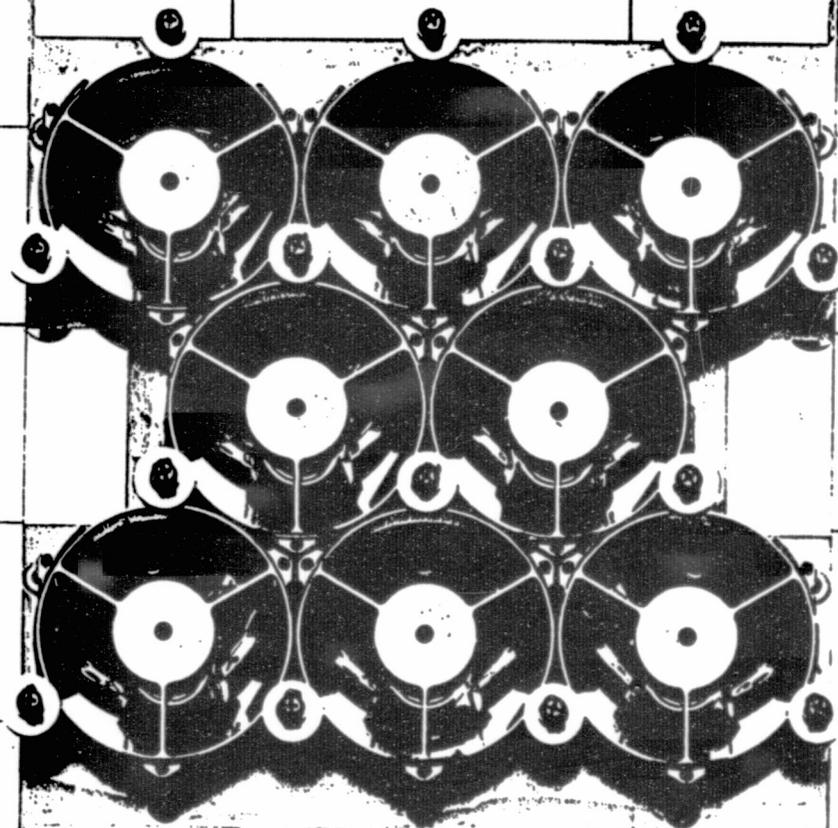
Mini-Dome Fresnel Lens
Photovoltaic Concentrator



Advanced Photovoltaic
Solar Array (APSA)



CM NASA
0 2.5



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 μ A 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**



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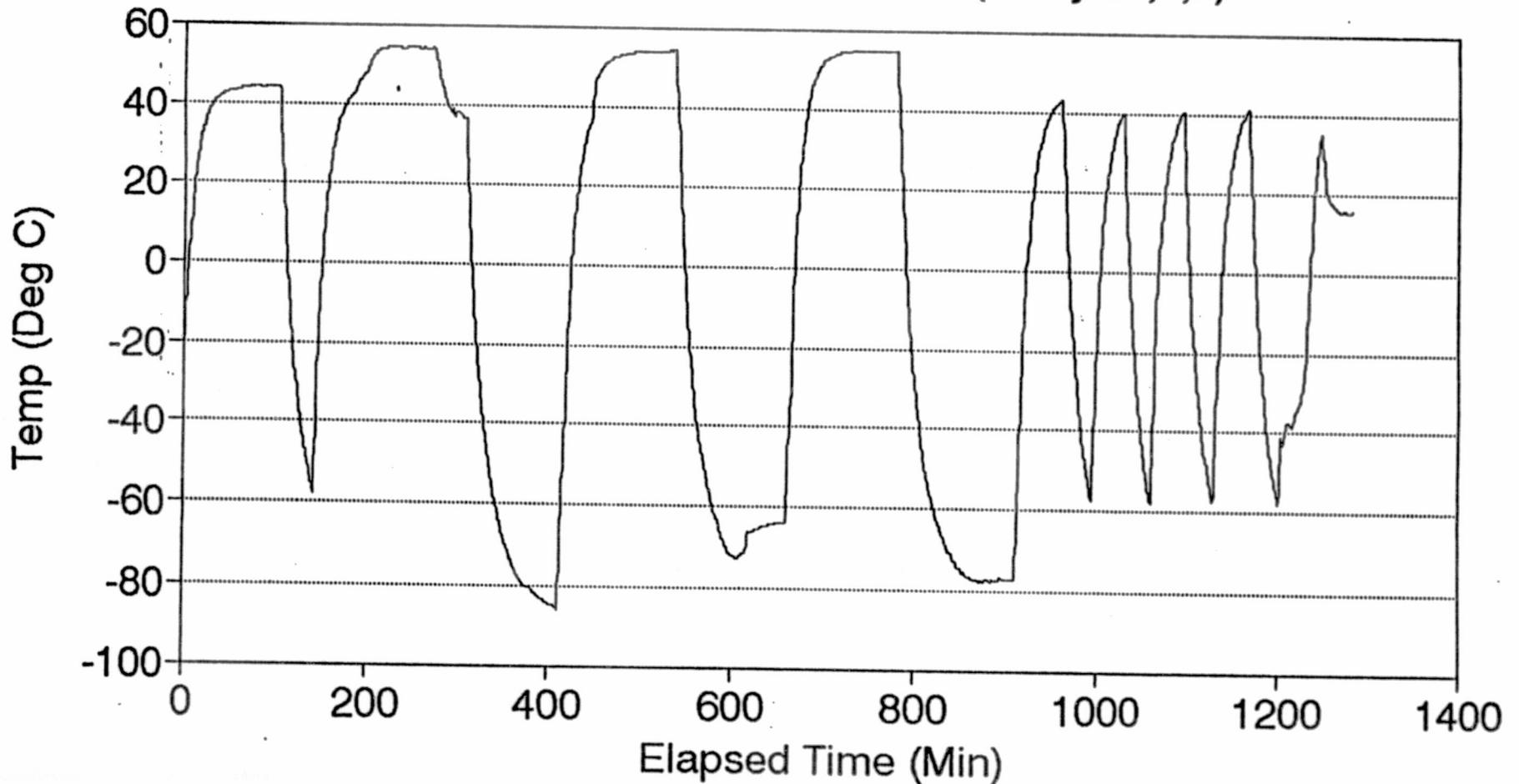
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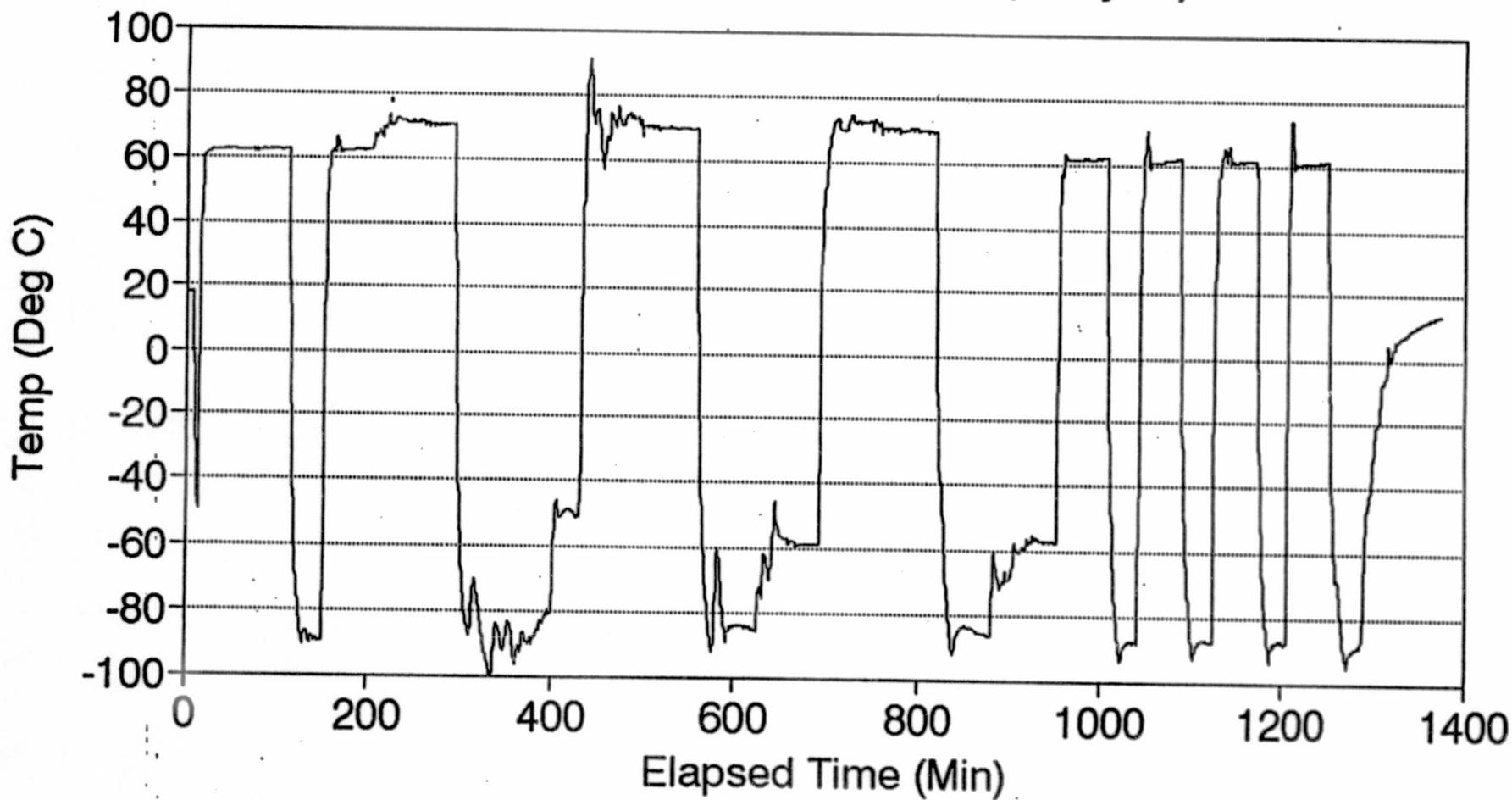
PASP PLUS FLIGHT EXPERIMENT ILLUMINATED THERMAL-VAC TESTING

PV MODULE TEMPERATURE PROFILE (Array #0,1,2)



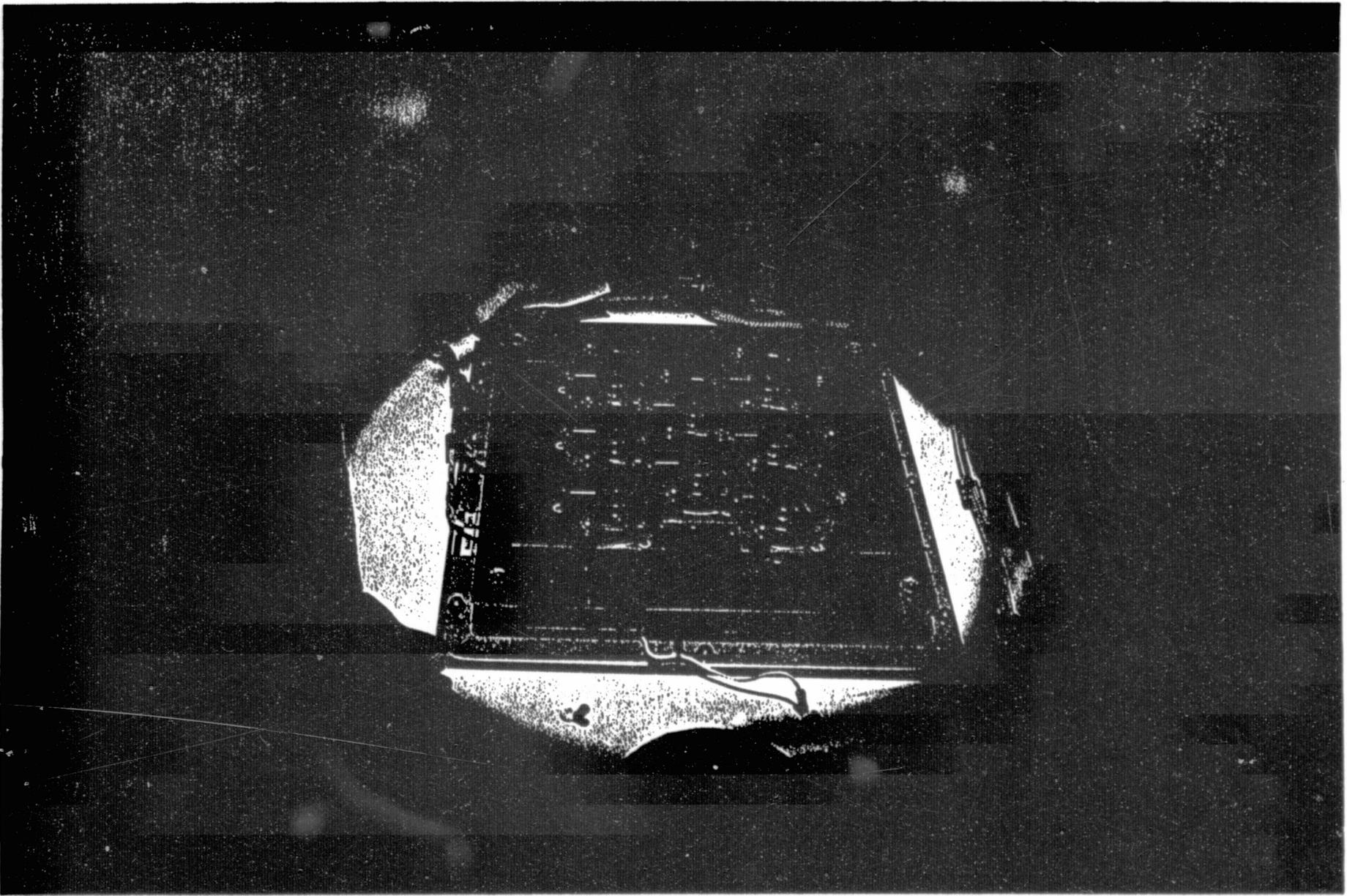
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PV MODULE TEMPERATURE PROFILE (Array #3)



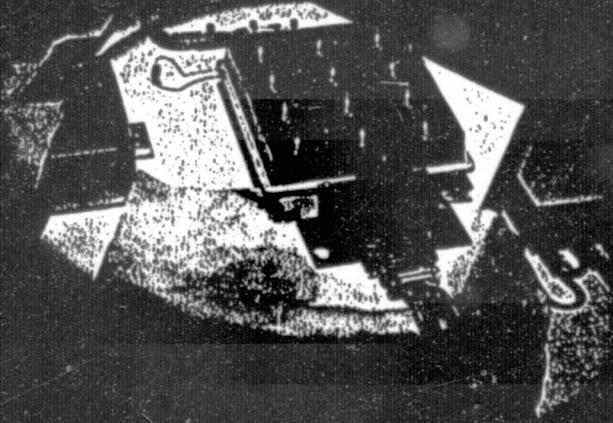
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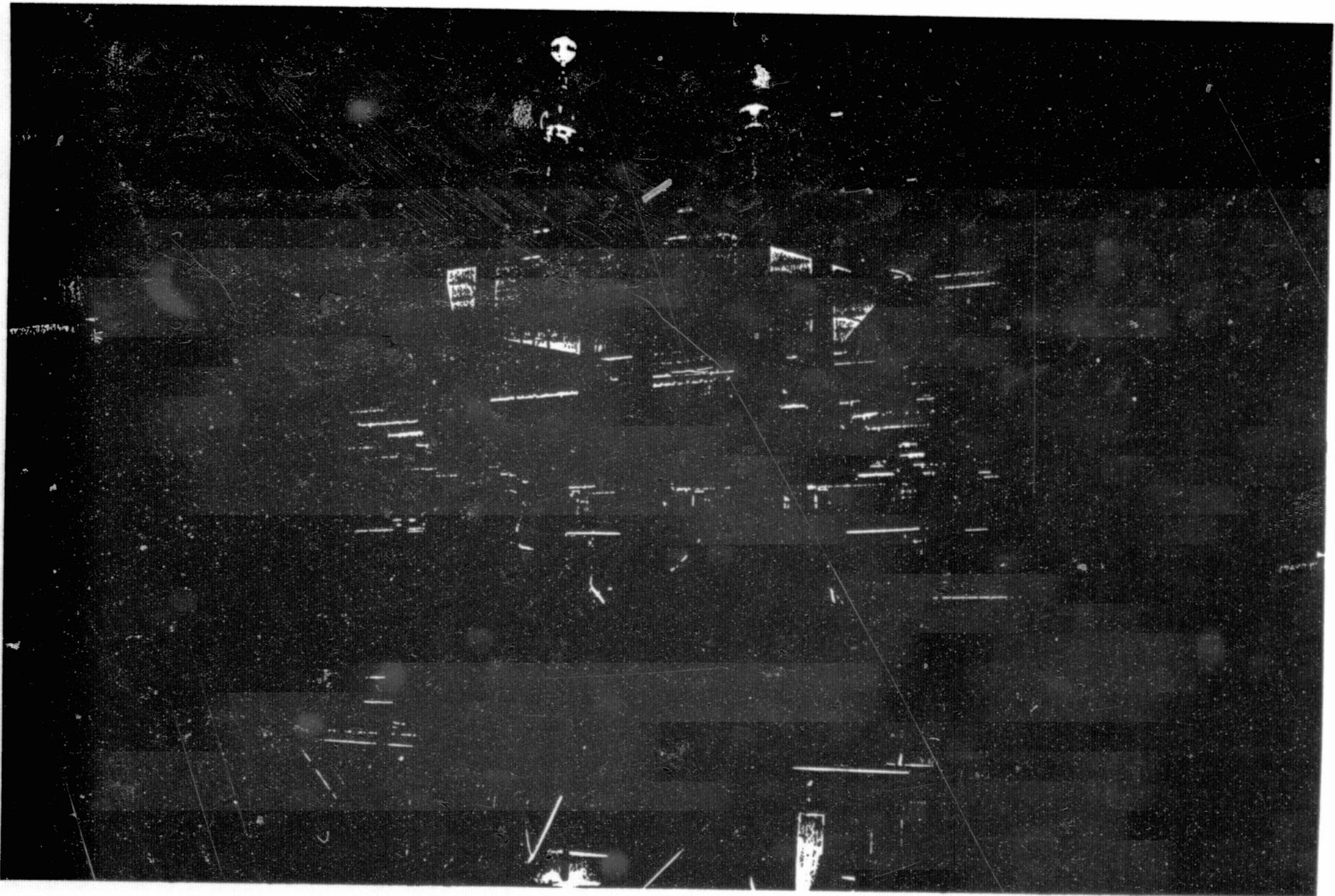
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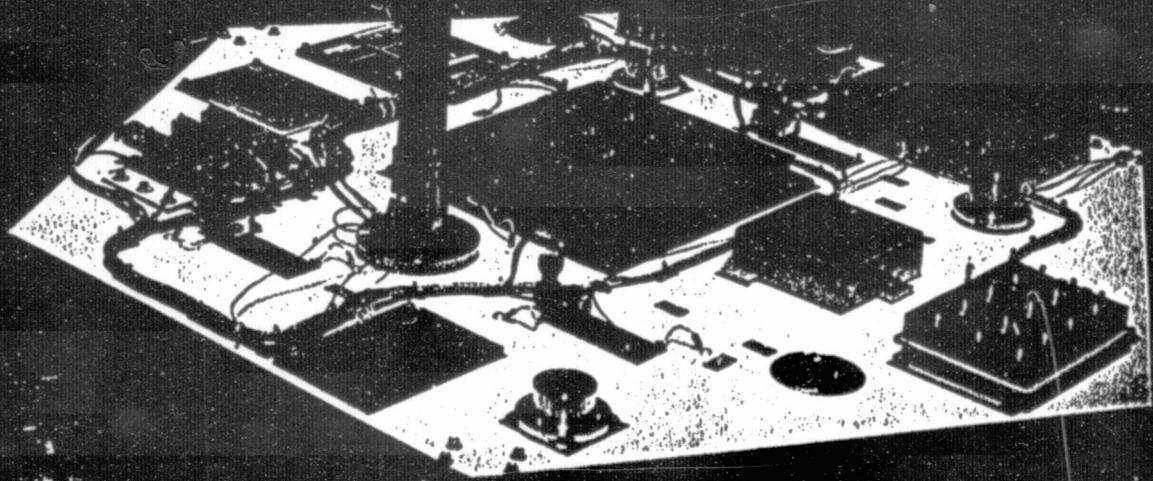




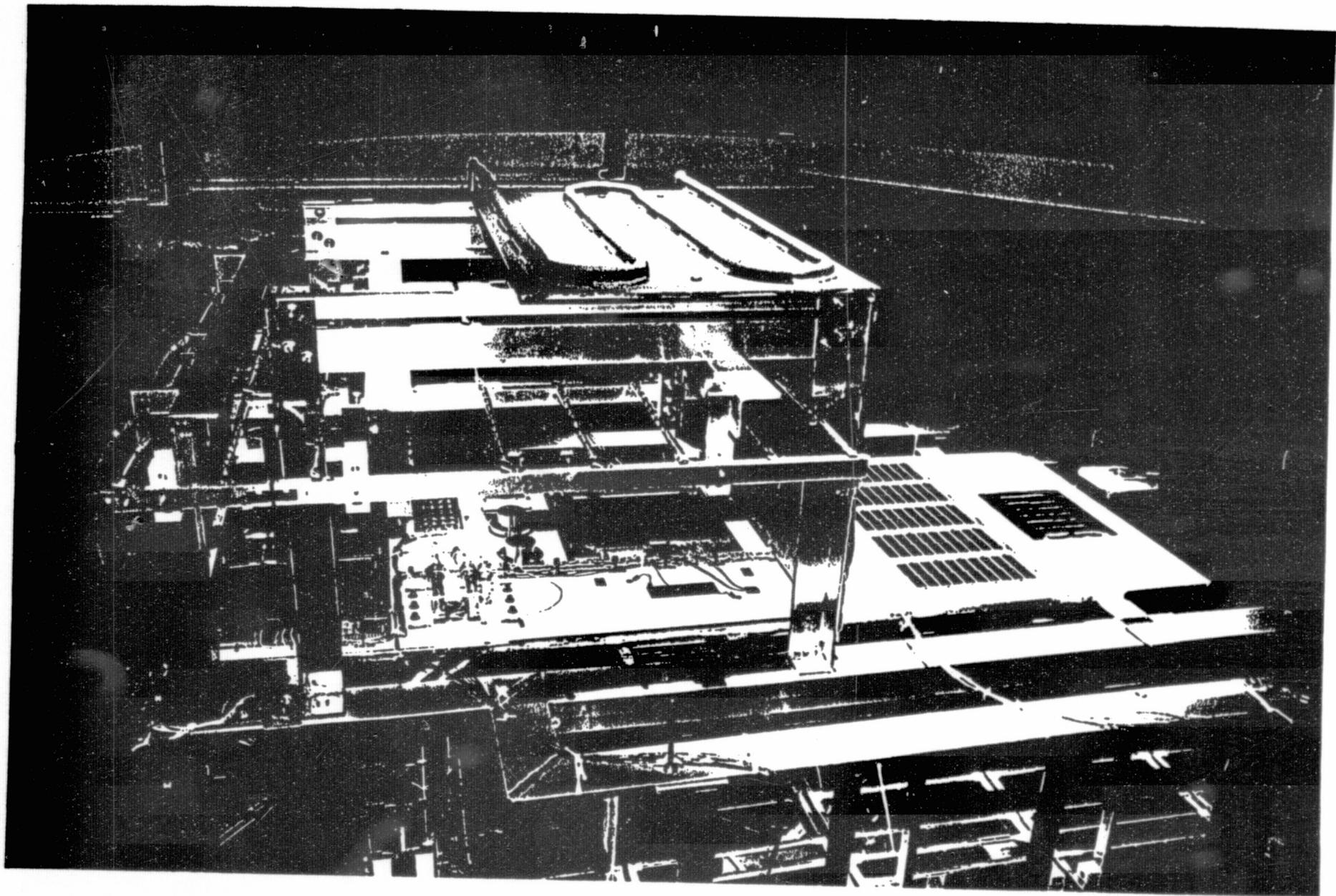
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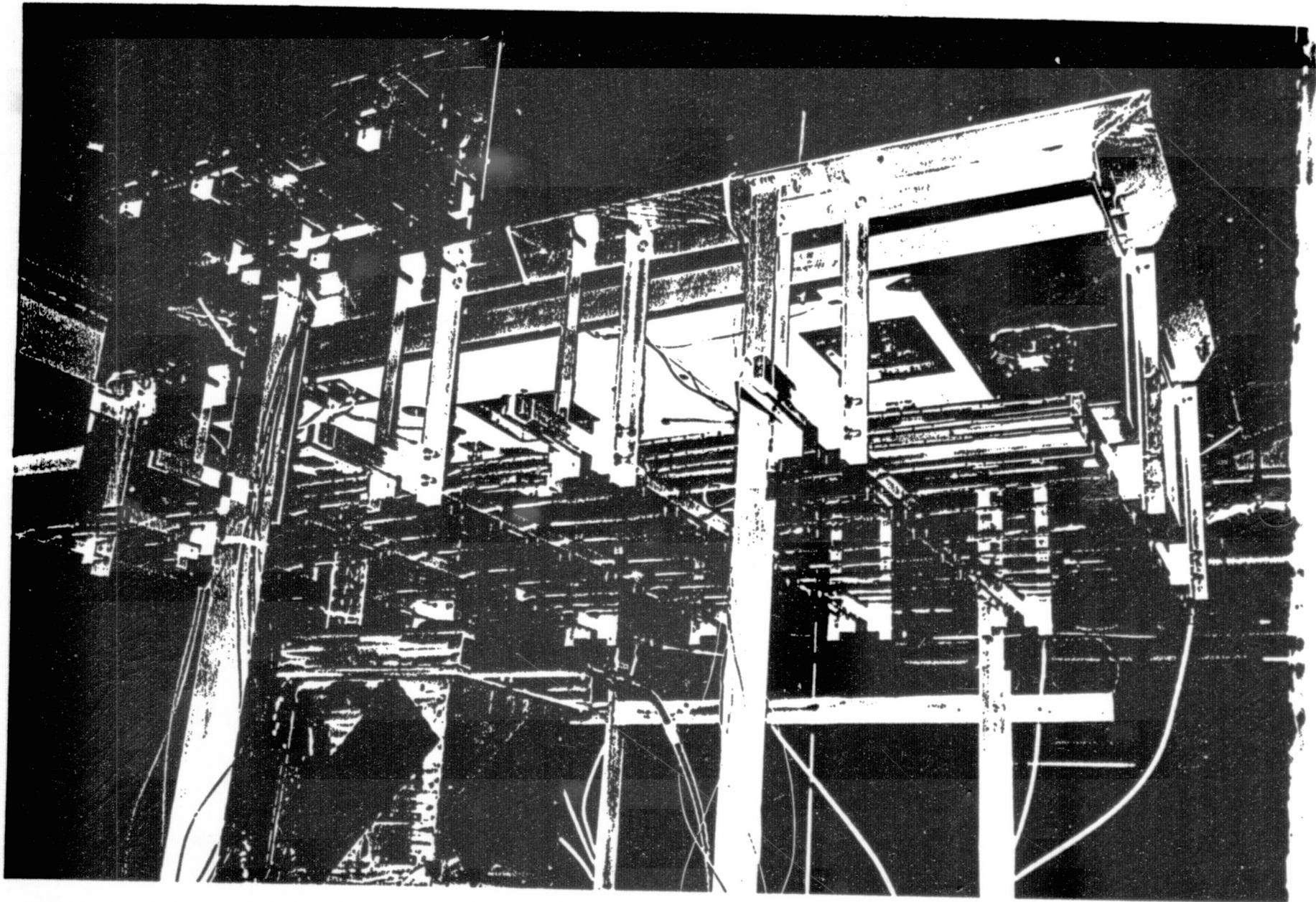
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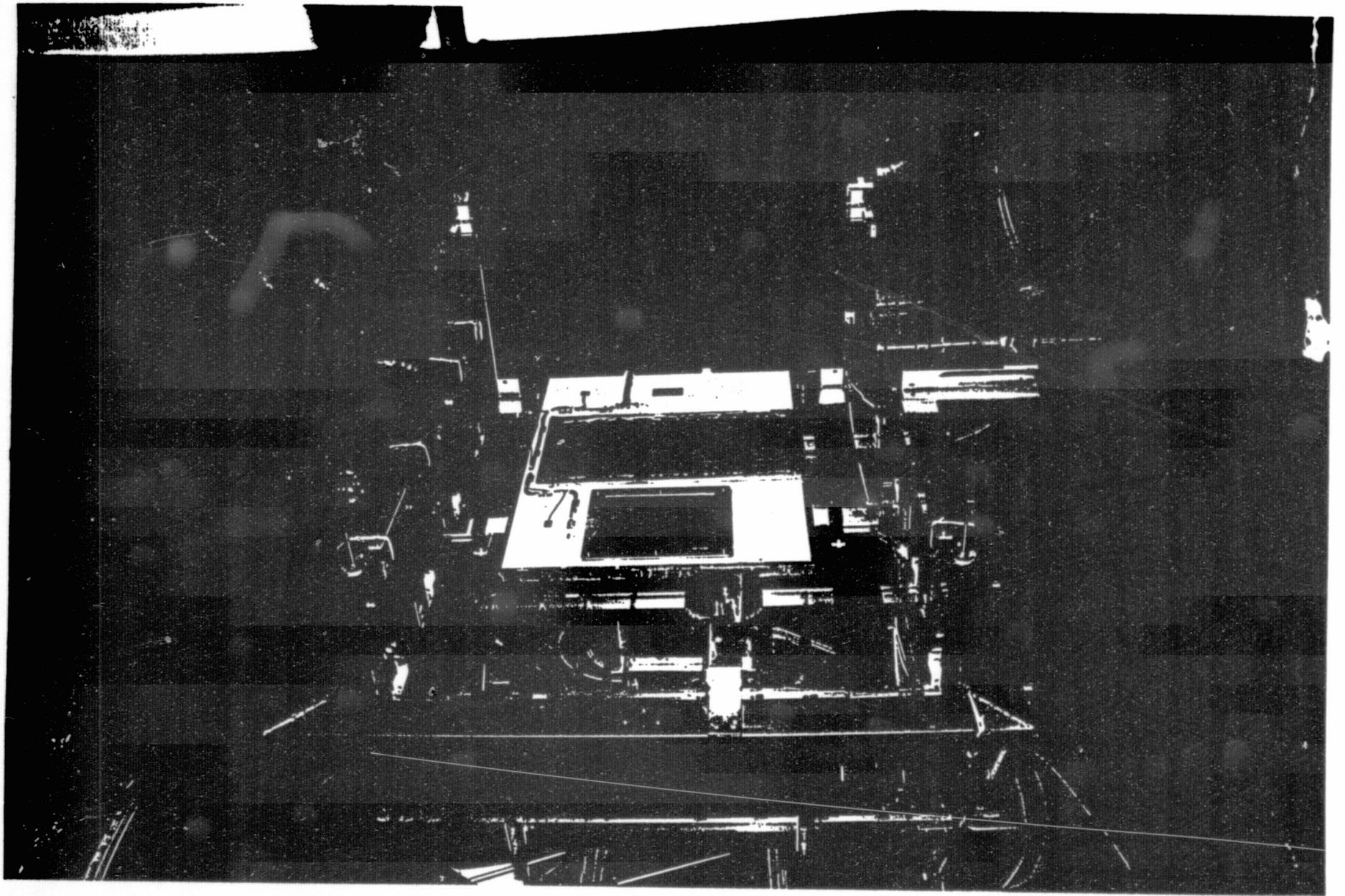


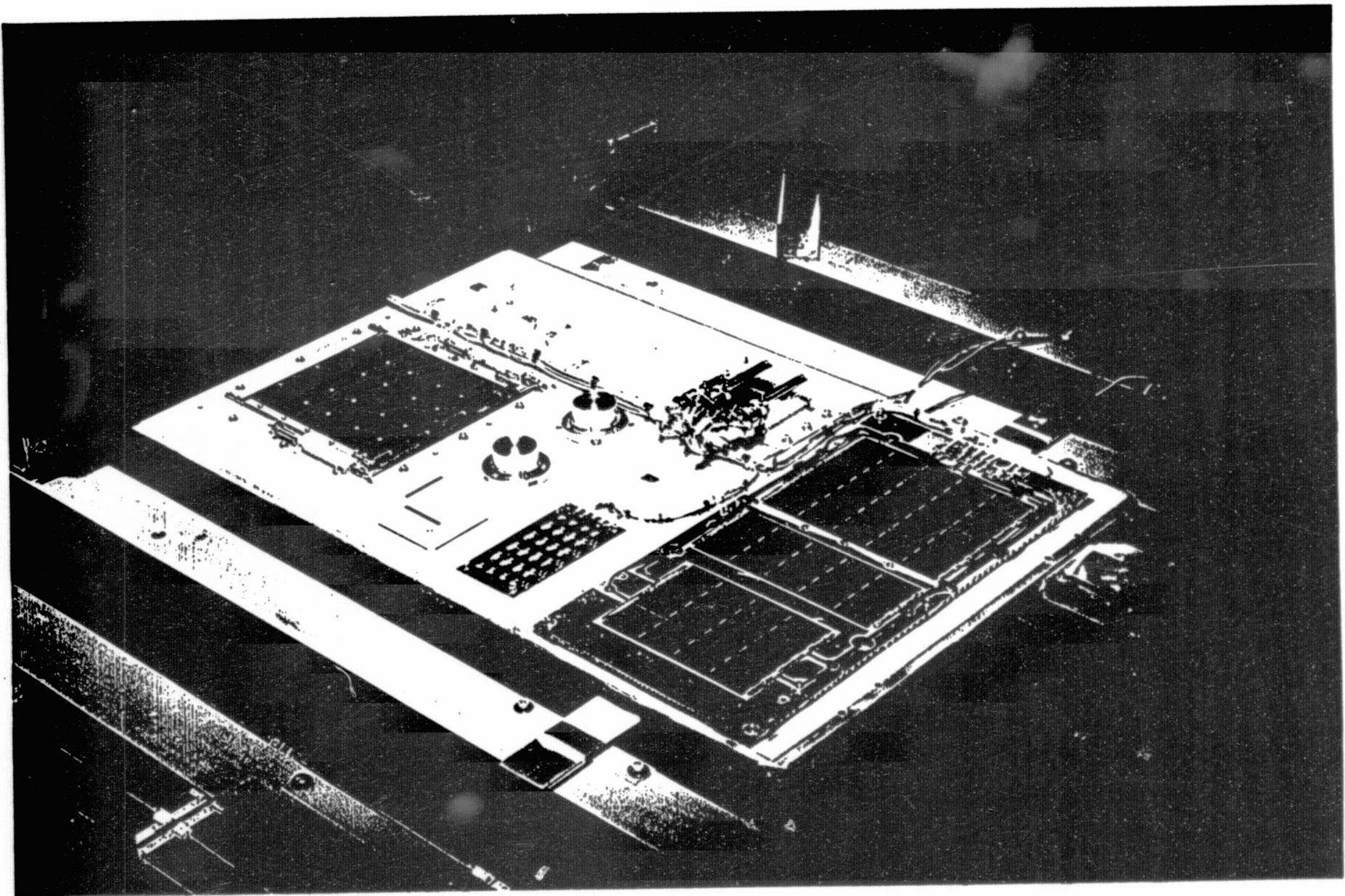


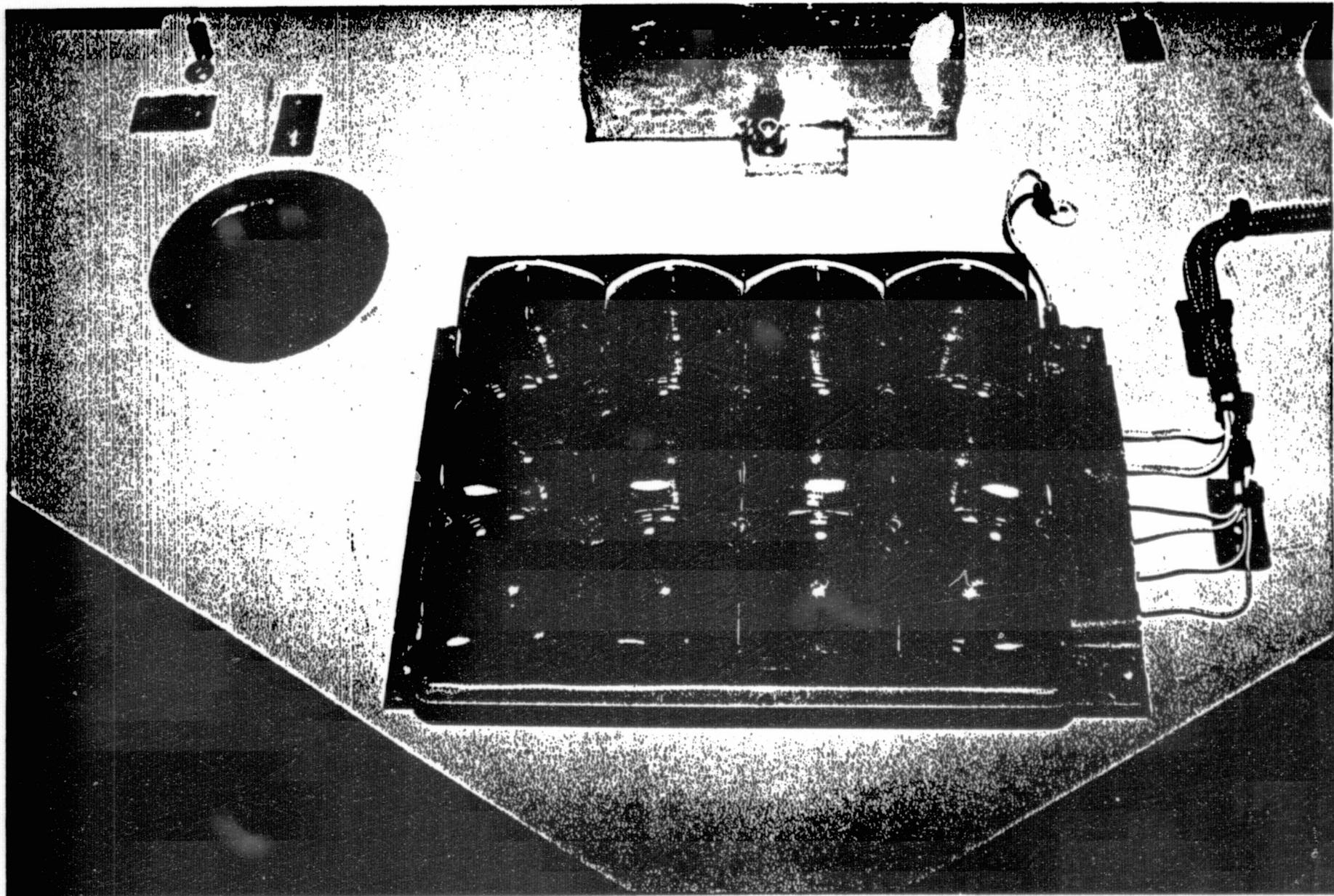
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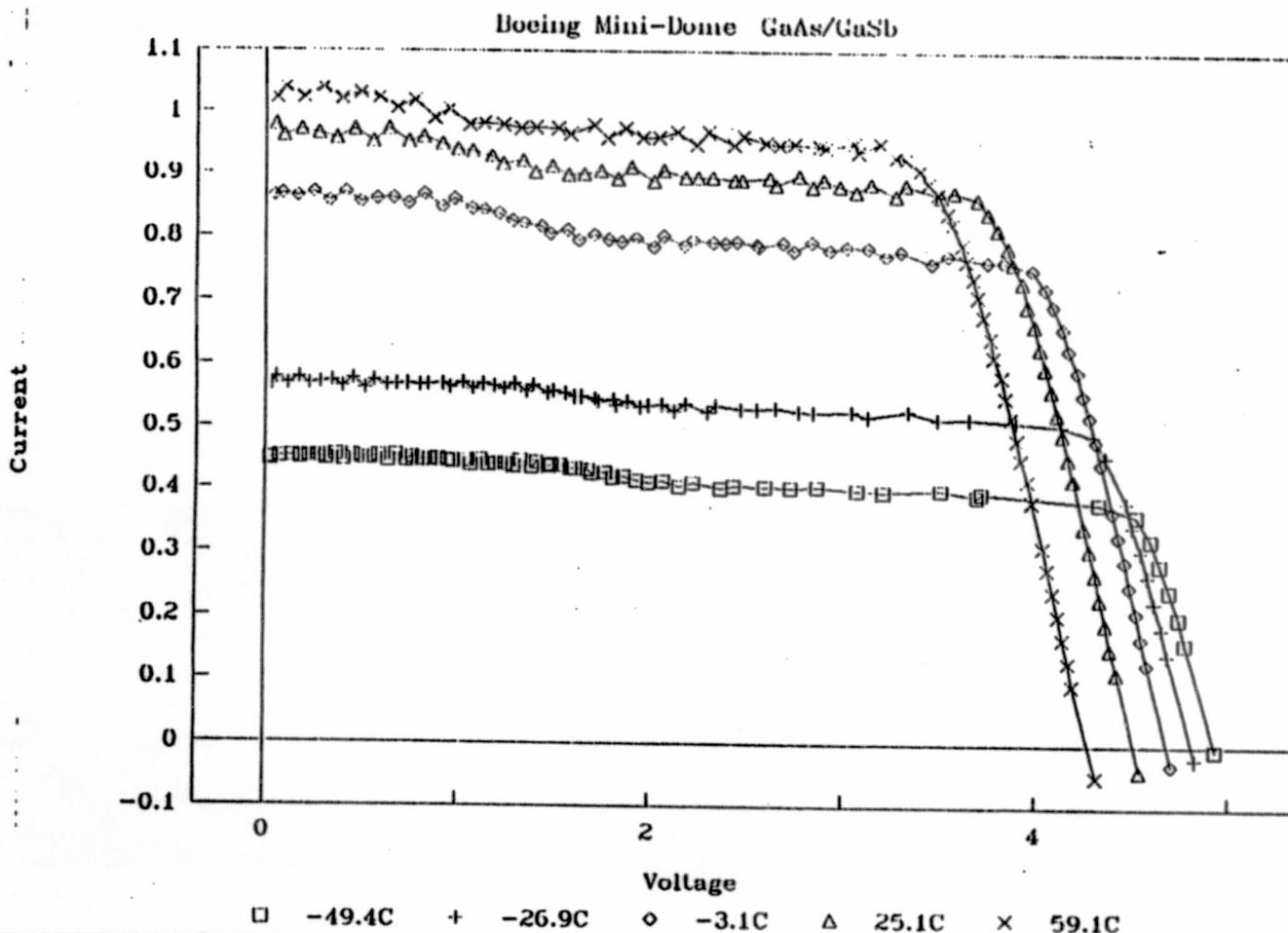
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PASP PLUS FLIGHT EXPERIMENT ILLUMINATED THERMAL-VAC TESTING

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**