ER-2 High Altitude Solar Cell Calibration Flights

AMO Workshop
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Test Platform Overview

**Demonstrated Capabilities**
Altitude: 70,000ft+
Illuminated Area: 5.6 x 5.6 inches
Pointing Accuracy: <2° deviation
Temperature Control: (+/-) 0.5°C
Number of devices per flight: 12 Maximum
Cell Measurements: Isc, Voc, IV Curve
Fiber-optic Port for spectrometer or other sensor
Flight Season: April through September

**Instruments Flown**
Keithley 2425 Source/Measure Unit
Ocean Optics HR2000+ Spectrometer
Ocean Optics NIRQuest NQ512-1.9 Spectrometer
Equipment
Flight Profile

Ideal Regular Season Flight Path

- Start: 70,000ft
- Finish: 60,000ft
- Los Angeles
- 34° 20' Parallel

Actual Altitude Profile

Altitude vs. Time

Data Collection
Langley plot method


   a.) Linearly Interpolate ozone distribution data to flight latitude
   b.) Find polynomial fits of ozone in given levels as a function of total ozone column
   c.) Use data from the Ozone Monitoring Instrument (OMI) on board the Aura spacecraft to determine total ozone column at the time and location of the flight
   d.) Use ozone layer distribution model to interpolate and estimate of the ozone above the cell for each data point taken as the aircraft descends
2. Generate Langley Plot

a.) Correct each Isc data point for overhead ozone, ozone sensitivity coefficient, and sun elevation angle

b.) Plot log of ozone-corrected Isc vs airmass (pressure over sine of elevation angle)

c.) Extrapolate linear fit of plot to zero airmass and estimate AM0 Isc

Langley Plot shown for GRC ZTJ 2x2cm top cell flown October 10th 2014
Summary of First ER-2 Campaign

- Three flights were flown between October 8th and October 14th, 2014
- Data was taken between 55,000 and 70,000 feet
- The first flight consisted of six 2x2cm cells and a camera to observe plate illumination conditions
- The second and third flights consisted of twelve 2x2cm cells
- All flights carried two sun sensors and two Ocean Optics spectrometers
- A ZTJ top and middle 2x2cm sub cell which were previously flown on the Learjet were flown all three flights
- Thirteen other cells were flown at least once
ER-2 Takeoff and Landing
Corrected Isc Results

- Data shown for GRC 2x2cm ZTJ sub cells (two top cells and one middle)
- Ozone corrections based on established Learjet methods
- Further atmospheric correction methods are being investigated
  - SMARTS or other ozone models
  - Using only higher altitude data
  - Ozone correction coefficients using cell EQE data

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IV Curves show good repeatability over multiple flights and a predictable change with pressure
Solar Spectra

![Solar Spectra Graph](image-url)
Device Temperature Control

- Mounting Plate temperature is used for heater feedback control
- All cell temperatures are monitored independently using AD590 IC temperature transducers
- After a slight bump caused by initial solar illumination, all cell temperatures were maintained within approximately 0.25°C from the target of 25°C
- Variation of temperature for any individual cell was on the order of 0.1°C after the initial on-sun disturbance
Sun Pointing
Summary of ER-2 Capability

- Flights can be conducted once every one to two days during a campaign
- Flight season runs from April through September
- Twelve 2x2cm cells can be flown per flight, or any other configuration that fits inside of the 14.2x14.2cm illuminated area
- This capacity could be doubled if the second ER-2 pod is used
- Data supplied includes $I_{sc}$, $V_{oc}$, IV curve, and cell temperature
- Other optical or atmospheric sensors can be flown as able
Recent Results on Solar Cell Experiment on ISS
2015 GRC/AFRC ER-2 Flight Campaign for Creating Air Mass Zero (AM0) Primary Calibration Standards

• GRC announcement sent out the week of May 4, 2015

• New platform supplements the Learjet AM0 calibration capability
  • GRC Learjet flight season January–March
  • DFRC ER-2 flight season April - September

• Current 2015 ER-2 Flight Campaign:
  • July 6th – 20th, 2015