Project Selenium Aerospace High Altitude Balloon Platform

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The Aerospace Corporation

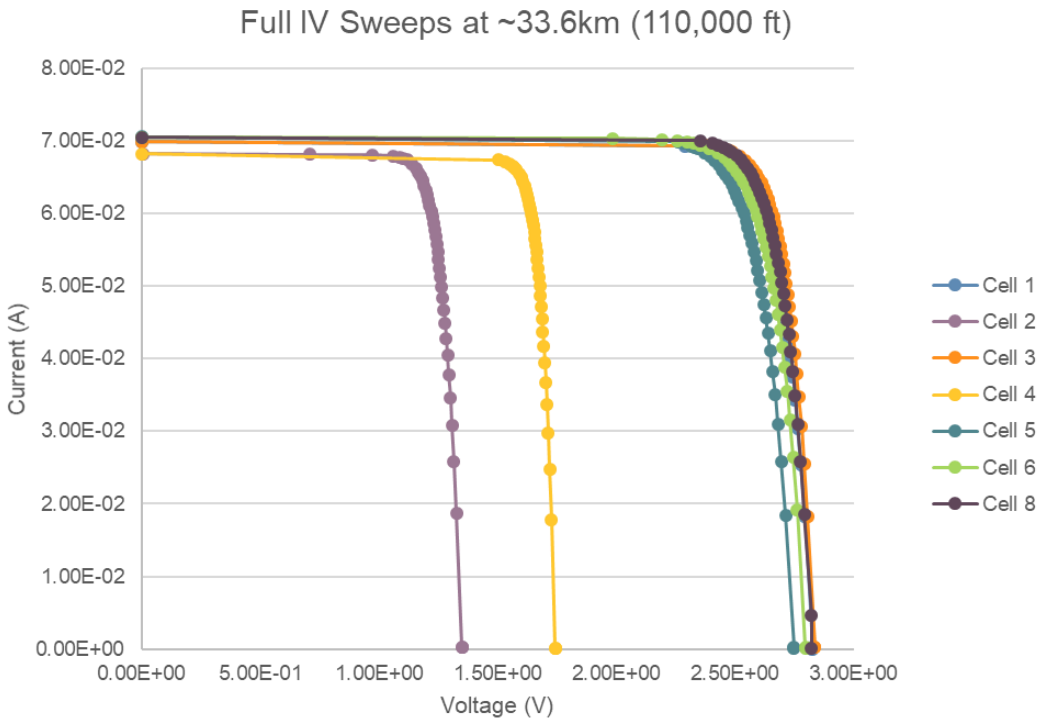
Space Power Workshop
April 2, 2019

OTR - 2019-00594

Project Selenium

Aerospace High Altitude Balloon Platform

Demonstrated the first NIST traceable measurements of solar cells on a small balloon platform above 30km.



March 15, 2019 Cell Manifest:

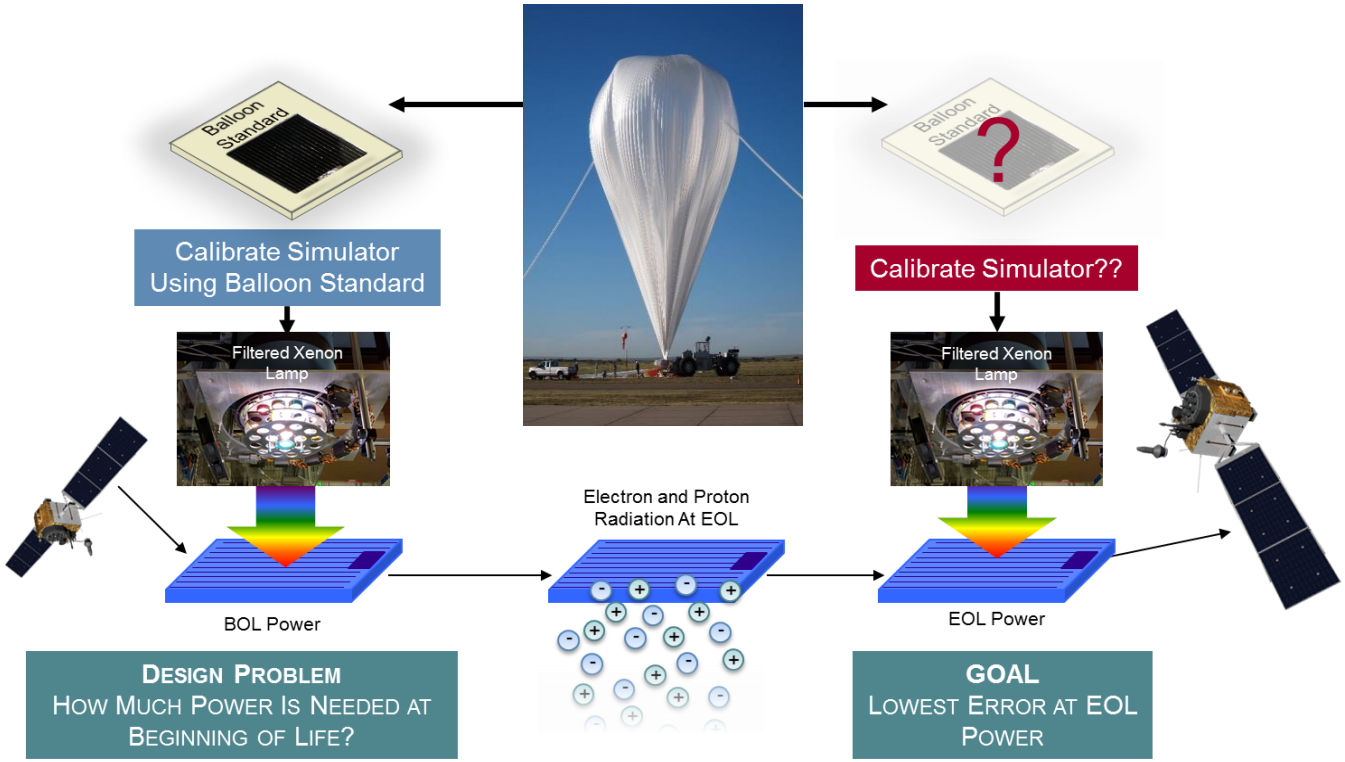
- 4 different solar cell technologies
- 2 technologies that do not have balloon standards
- J1 and J2 Isotypes

First balloon standards created in the US above 30km since JPL in 2006

Project Selenium

High Altitude Balloon Platform

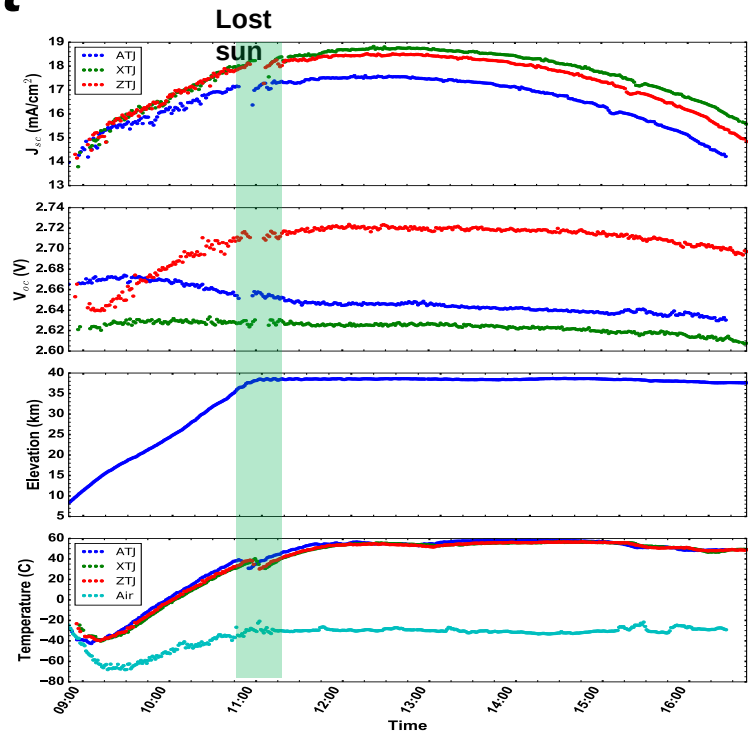
- Calibrated balloon standards are critical to measuring solar cells at beginning and end of life.
- Increased complexity of new cell technologies require balloon standards for accurate measurement.
- **No balloon flights in the US since 2006**

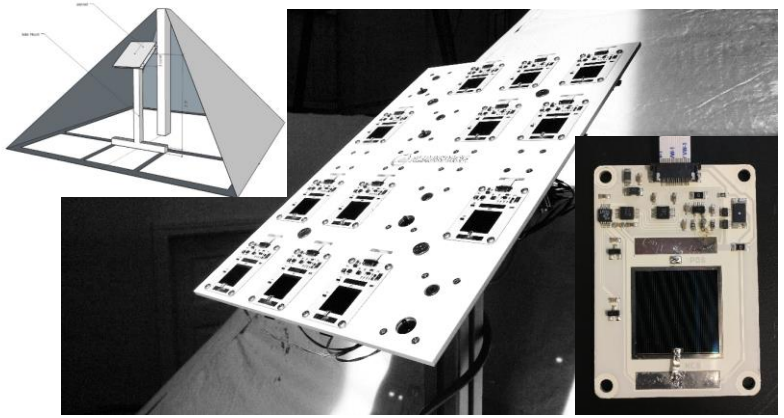


JPL MkIV Balloon Experiment

2016 Flight Results

- Proof of concept in using COTS microelectronics to characterize solar cells in the near-space environment for the purpose of creating calibration standards.
- Reflection from the balloon increased the cell current by a few percent, proving out the concept, but making the data unusable as calibration standards.



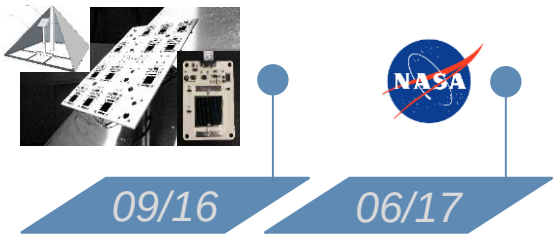


09/16

NASA Flight Opportunities Program

Awarded January, 2017

- Funding provided to evaluate commercial small balloon providers and to continue development of our payload electronics.
- Goals
  - *Obtain short circuit current with accurate temperature measurements at float (>30km)*
  - *Obtain full IV sweeps at float with temperature, sun angle, and altitude measurements*
  - *Obtain solar spectrum measurements using miniature spectrometers to evaluate air mass / o-zone correction methods*
  - *Obtain temperature coefficient measurements using onboard heaters while at float*

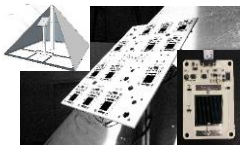


JPL MkIV II

September 2017 Flight

- Photo etched aluminum baffles
- Cell Carrier Gen 2
- Mini Spectrometers
- Quad Photodiode Sun Angle Sensors
- Onboard heaters for cell holders and spectrometers
- 15 Ah Lithium Ion Battery
- GPS Receiver, IMU, Cameras

- ***Flight campaign cancelled due to high winds in New Mexico***



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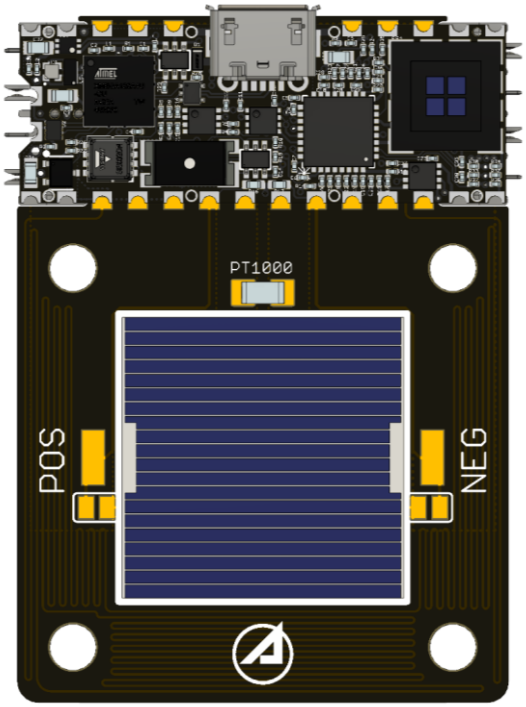
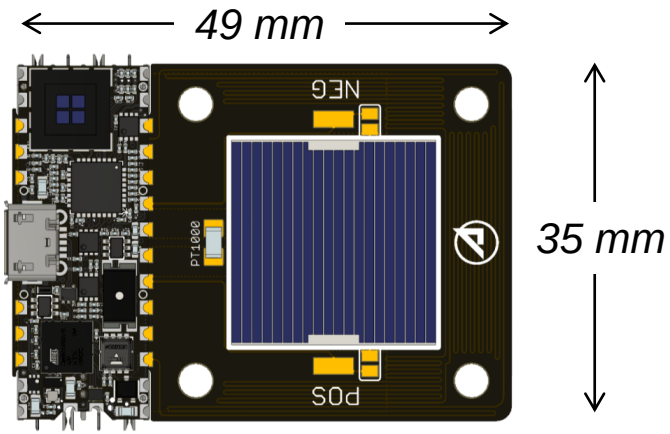
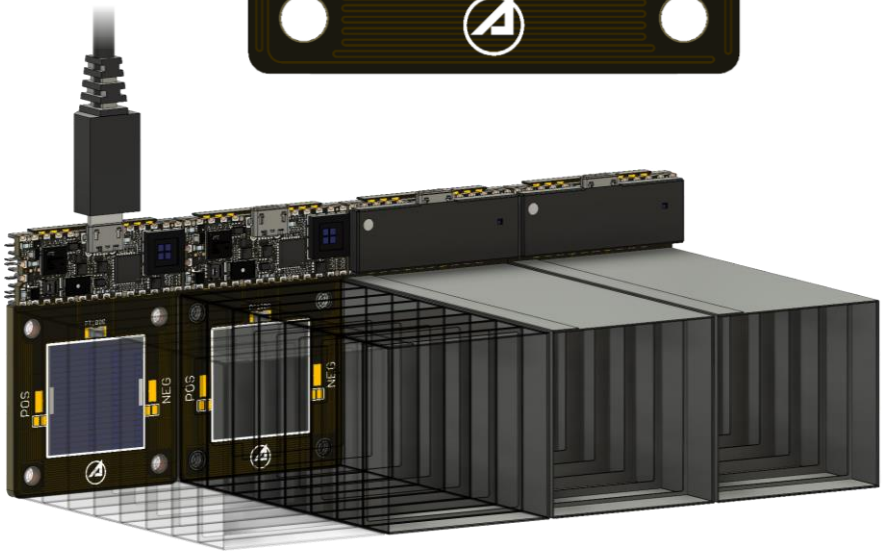
Aerospace Measurement Unit

How to get accurate measurements?

- Gold plated surface (much flatter than tin plating on standard PCB)
- Cell is soldered down using low temperature solder Sn/Bi/Ag (Tin/Bismuth)
- Integrated heater (Up to 80°C using 5V USB power)
- Sun-Sensor attachment
  - *Silicon Quad Photo diode can be mounted above SMU utilizing same 24 bit ADC*
- External FET for loads greater than 10 Watts
- Daisy chainable 4 wire connector





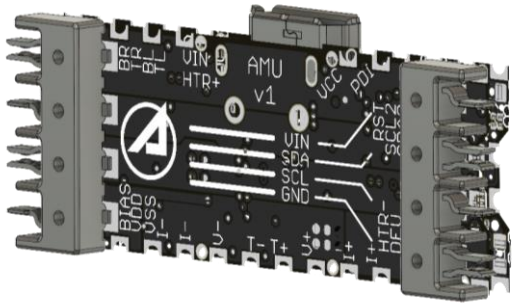


Miniature, low power, laboratory grade measurement system

AMU

Aerospace Measurement Unit

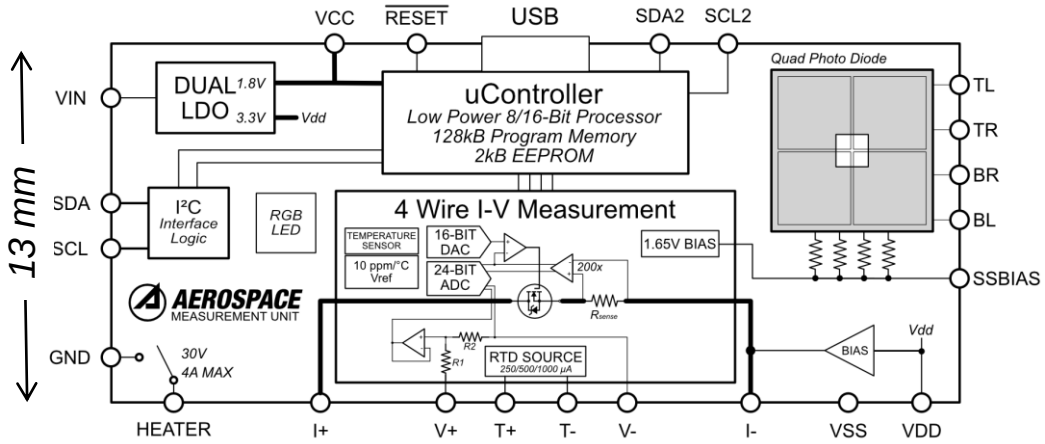
- 4 Wire Cell Measurement
- Temperature compensated ADC, 24-bit resolution
- Light I-V up to 2.5A and 30V (10W max power)
- Integrated quad photo diode for sun angle measurement with IV data
- Up to 100 datapoints with ~50 datapoints per second IV sweep
- ~1 mV from Isc, ~1 µA from Voc
- 4 wire side connectors allow daisy chaining devices across a single bus using standard I²C interface.
- Modular design can be incorporated onto any size cell holder, optimized for 2x2 cells, but could be used on large area cells as well

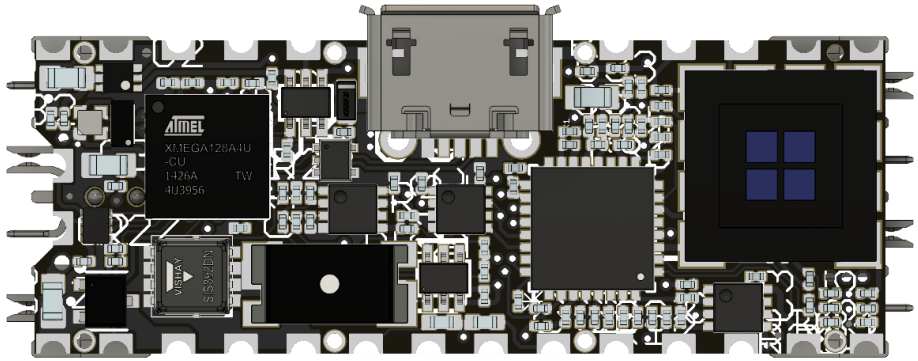


AMU Back

35 mm

13 mm

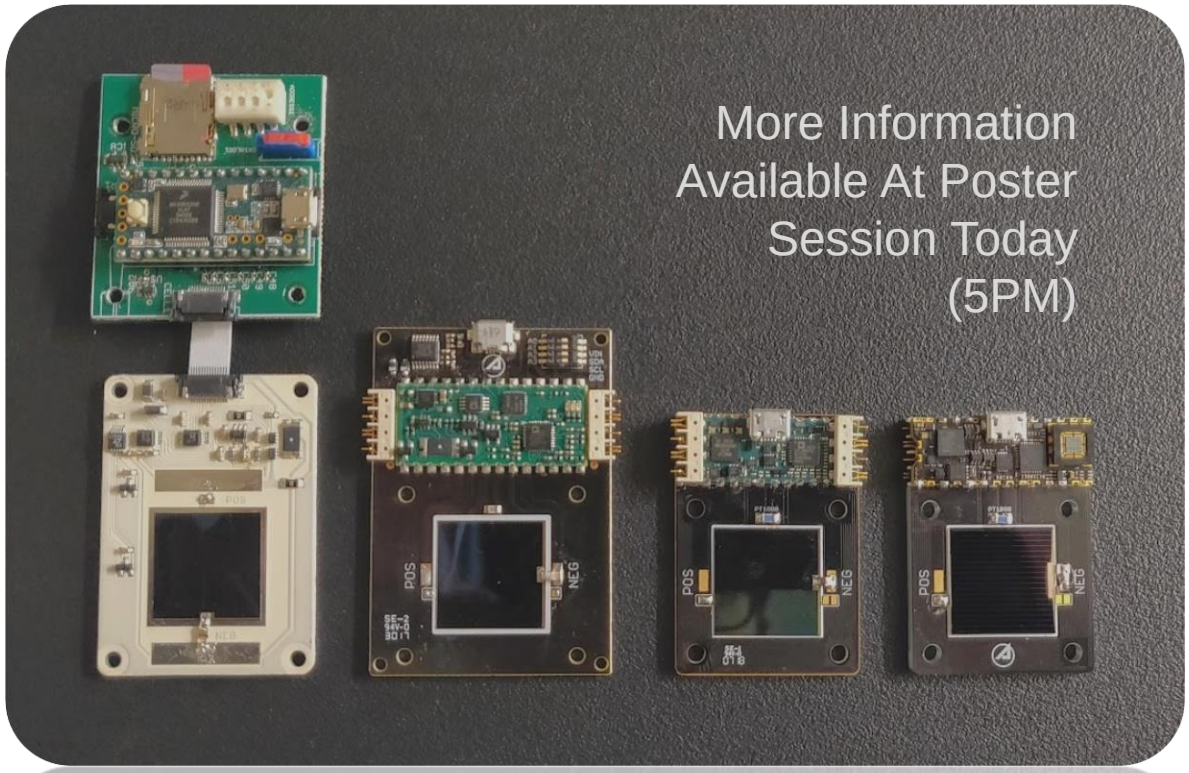




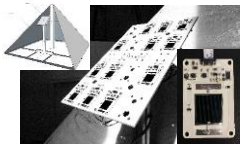
AMU Front

JPL MkIV II

September 2017 Flight



2016 **2017** **2018** **2019**



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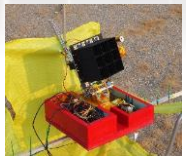

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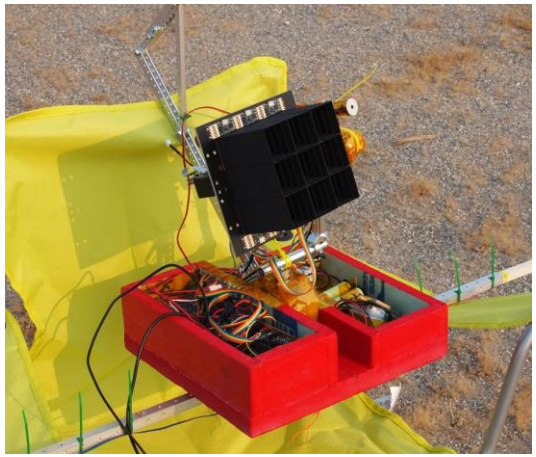
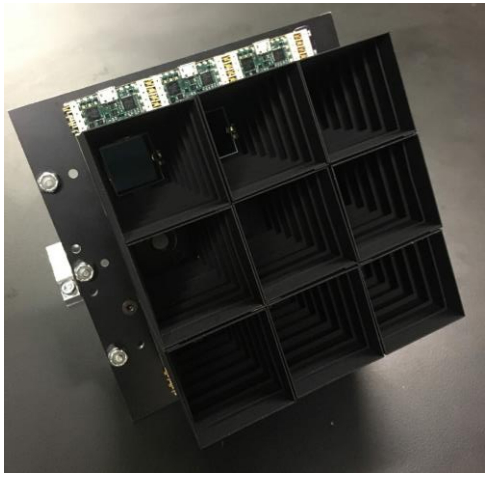
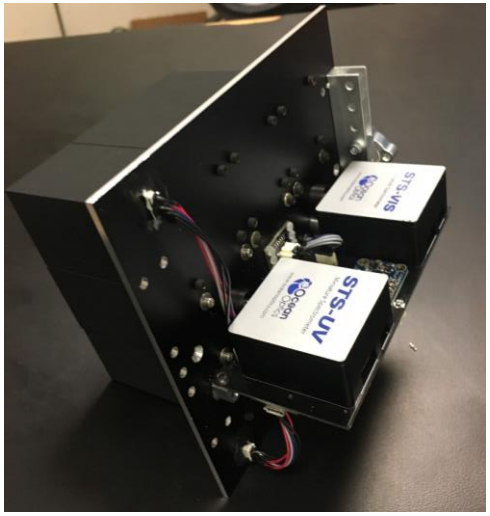
BlackSky Aerospace Test Flight

August 2018

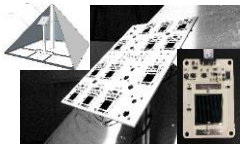




- 6 Cell Holders
- 2 Spectrometers
- Calibrated Quad Photo Diode Sun Angle < 0.1°



- ***Hardware and Software Issues of the Aerospace payload led to minimal data collection from the flight.***



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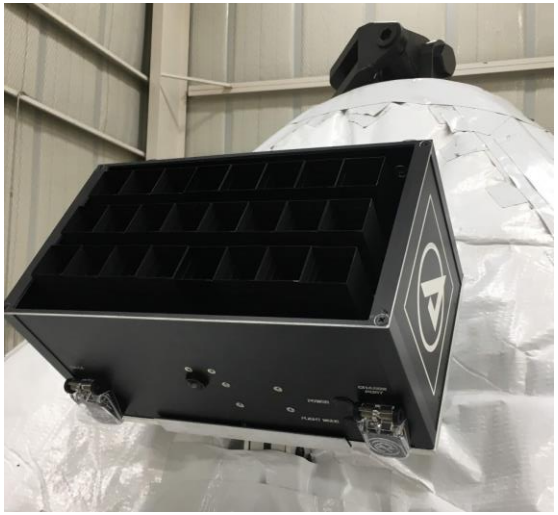
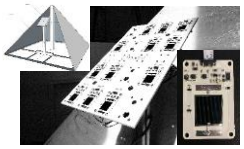
Timeline

JPL BlackJack

- 21 Cell Holders
- Cell Heaters for Temp Co. Measurements
- Larger Battery, lower power electronics
- Fine Tracking with Pan/Tilt Servos
- GPS, IMU, Cameras
- ***Flight Campaign Cancelled Due To Ground Systems Problems***





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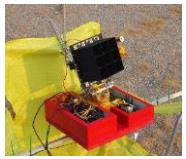

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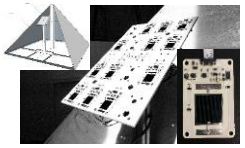
Timeline

BlackSky Aerospace Flight #1 – January, 2019



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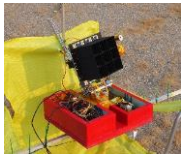

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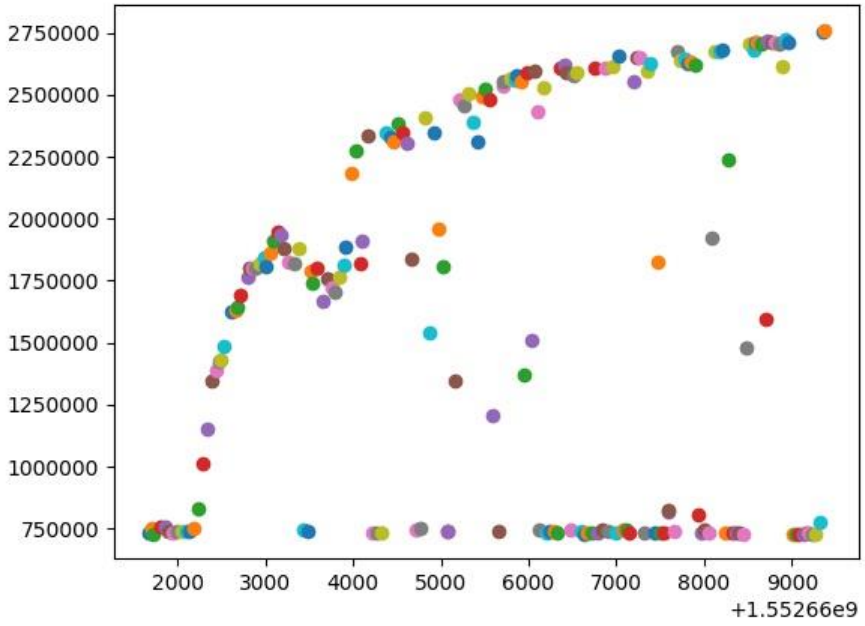
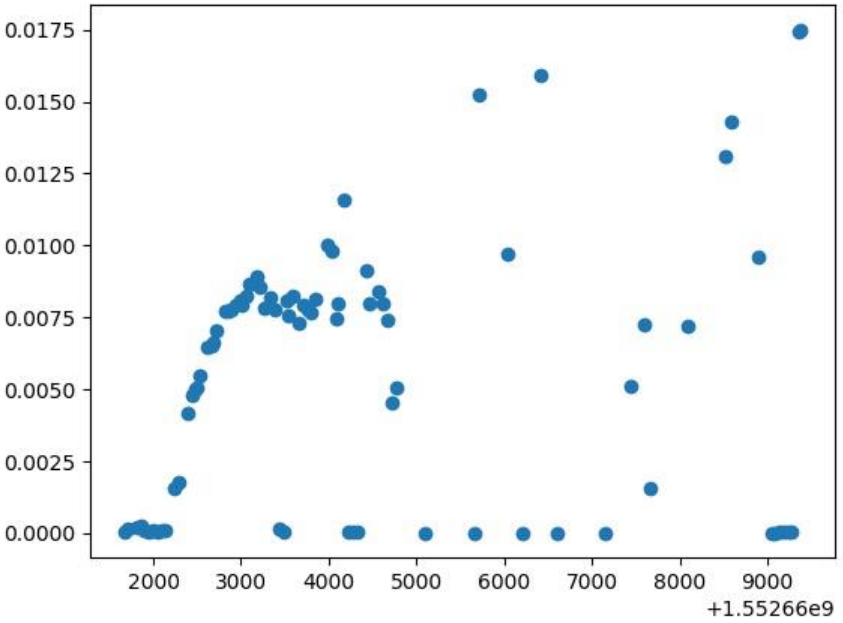
Timeline

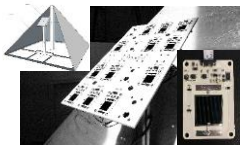
BlackSky Aerospace Flight #1

Integrated Spectrometer Data



Short Circuit Current





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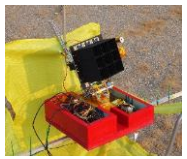

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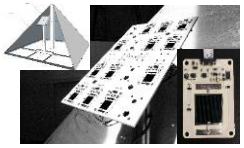
Angstrom Designs Test Flight

March 11, 2019

- 8 Gen 4 Cell Holders
- 2 Spectrometers
- GPS, IMU, Pressure Sensor, Calibrated Quad Photo Diode
- Payload fully tested for flight

- ***No data collected due to battery issues, platform released at 50k ft. due to safety mechanism triggering.***
  - ***This was a test flight of new hardware for Angstrom Designs, data collection and altitude were optional.***



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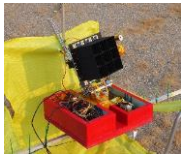

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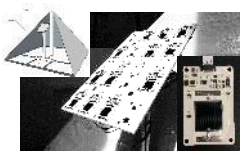
03/19

Project Selenium

2 Year Progress…

Date	Balloon	Payload	Results
09/16	JPL MkIV	12 Cells, No Baffles	Proved concept, baffles needed for useable data
09/17	JPL MkIV	Selenium, 8 Cells, 2 Spectrometers	Flight cancelled due to weather
08/18	BlackSky	6 Cells, 2 Spectrometers	Hardware issues, no data
09/18	JPL MkIV	21 Cells, Baffles, 2 Spectrometers, Heaters	Flight cancelled due to ground station problems
01/19	BlackSky	8 Cells, 2 Spectrometers	Successful flight altitude, evaluation of sun tracking
03/19	Angstrom Designs	8 Cells, 2 Spectrometers	Hardware malfunction during ascent, no tracking or IV
03/14/19	BlackSky	8 Cells, 2 Spectrometers	High Winds, unable to get payload in the air.



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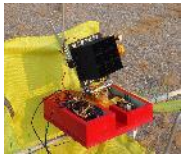

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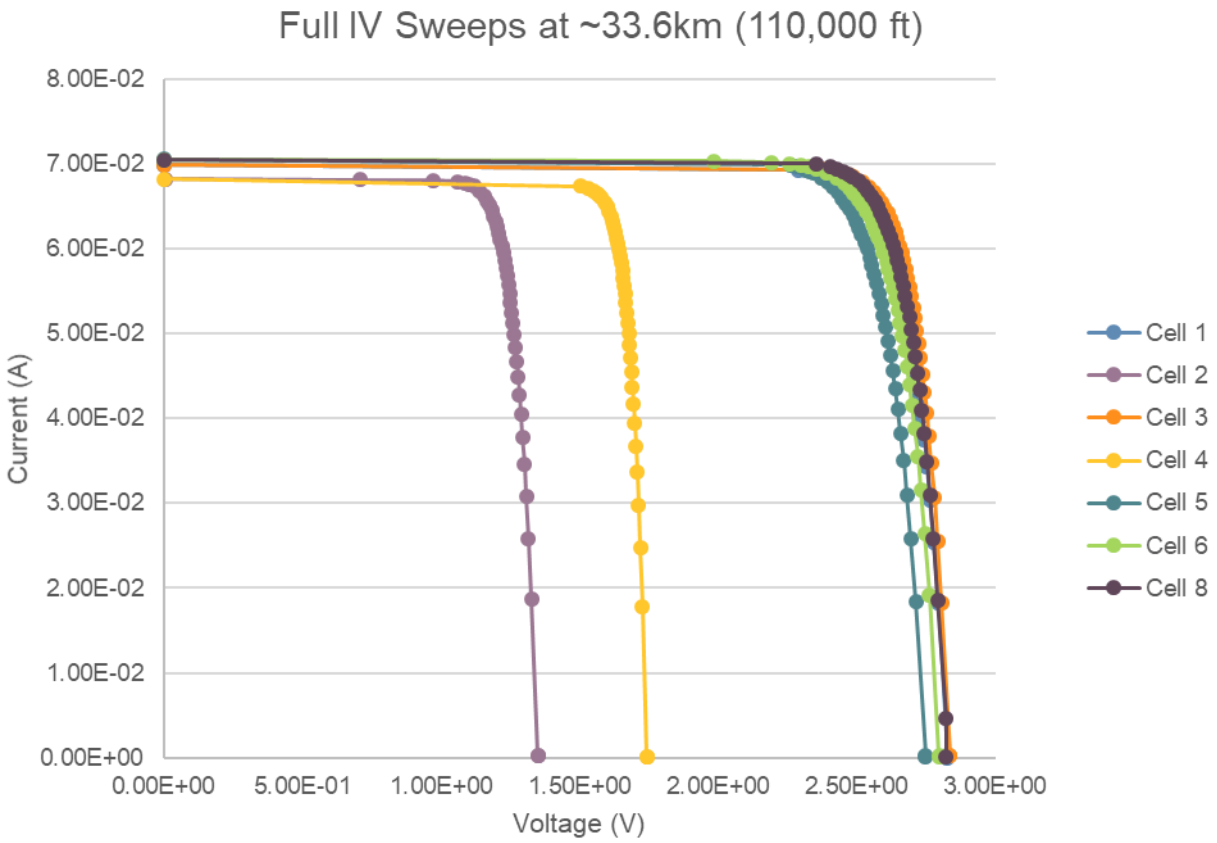
BlackSky Aerospace Flight #2

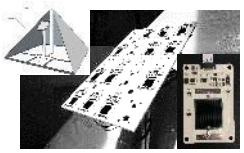
March 15, 2019

Video removed due to size constraints. Please contact colin.mann@aero.org if you would like to obtain a copy.

BlackSky Aerospace Flight #2

March 15, 2019





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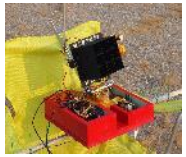

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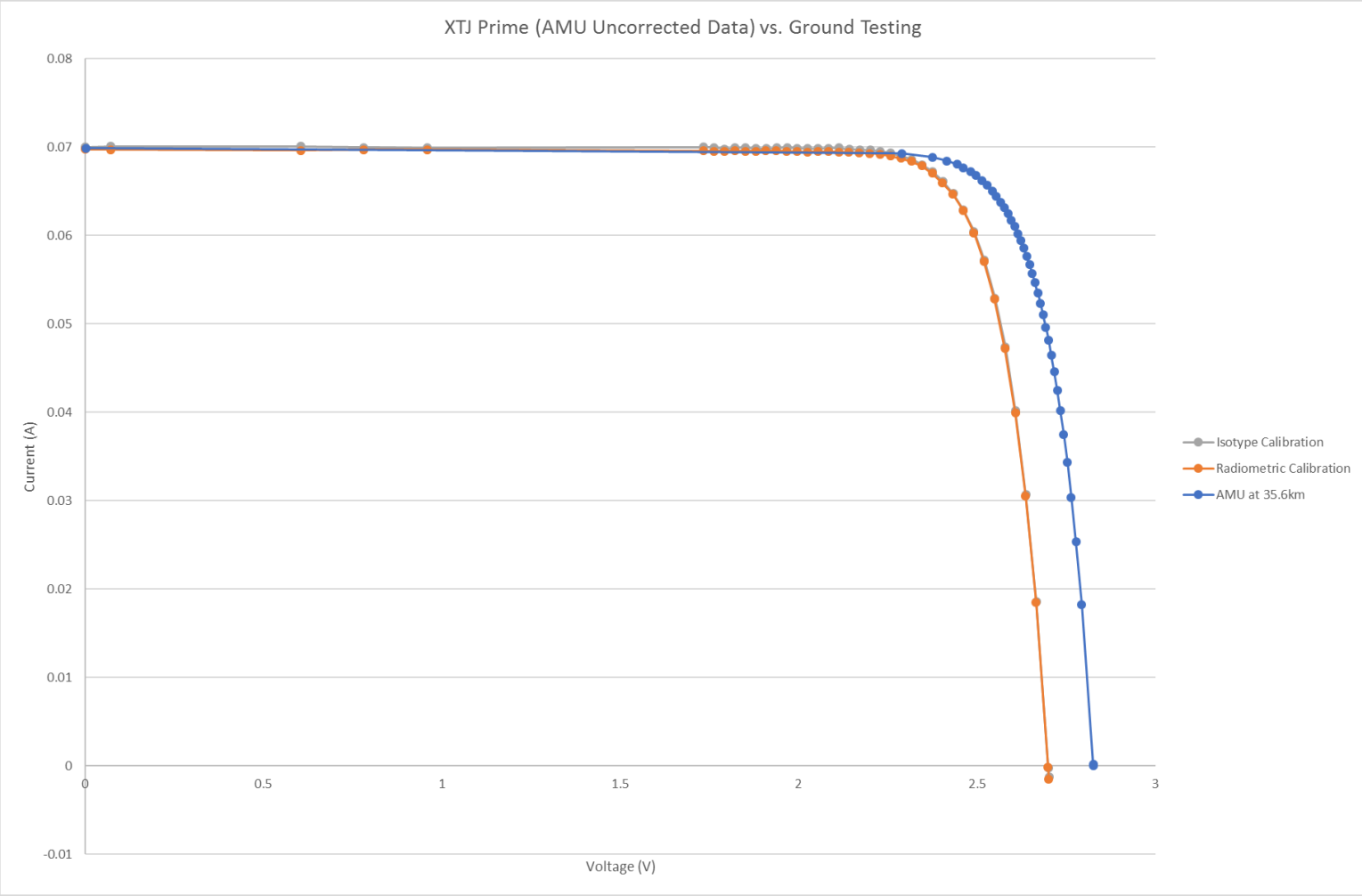
BlackSky Aerospace Flight #2

Light I-V Comparison to Laboratory Measurements



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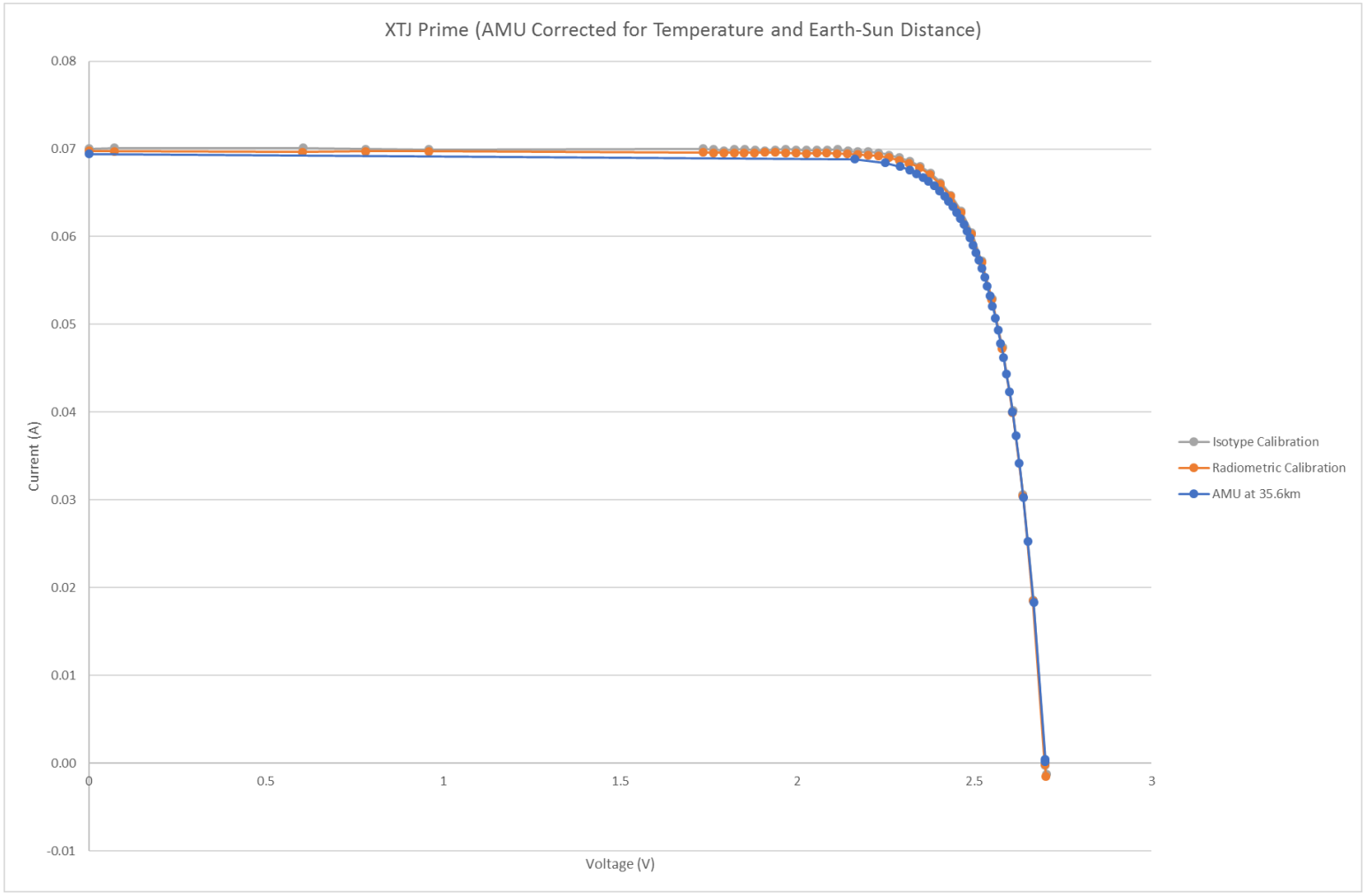
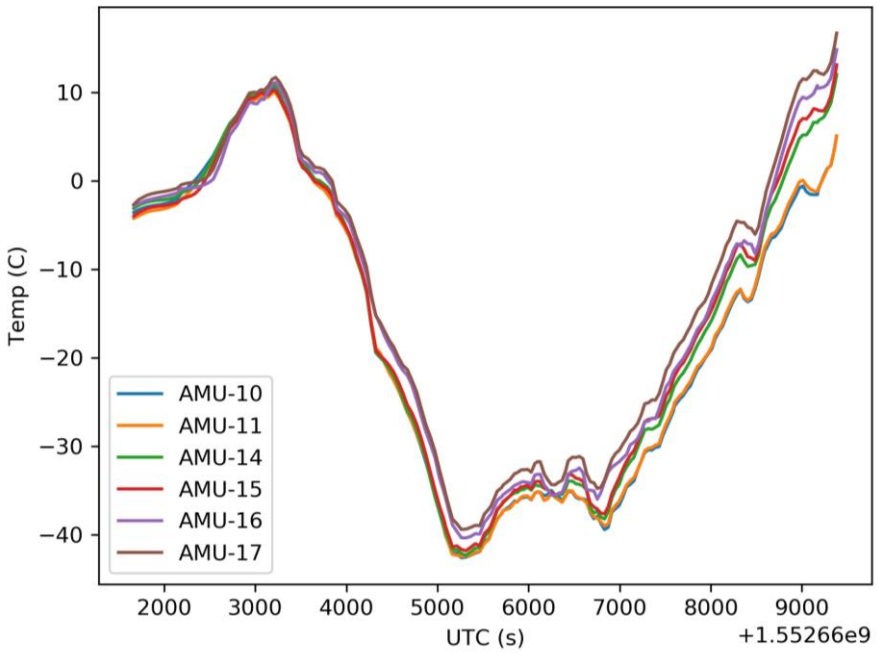


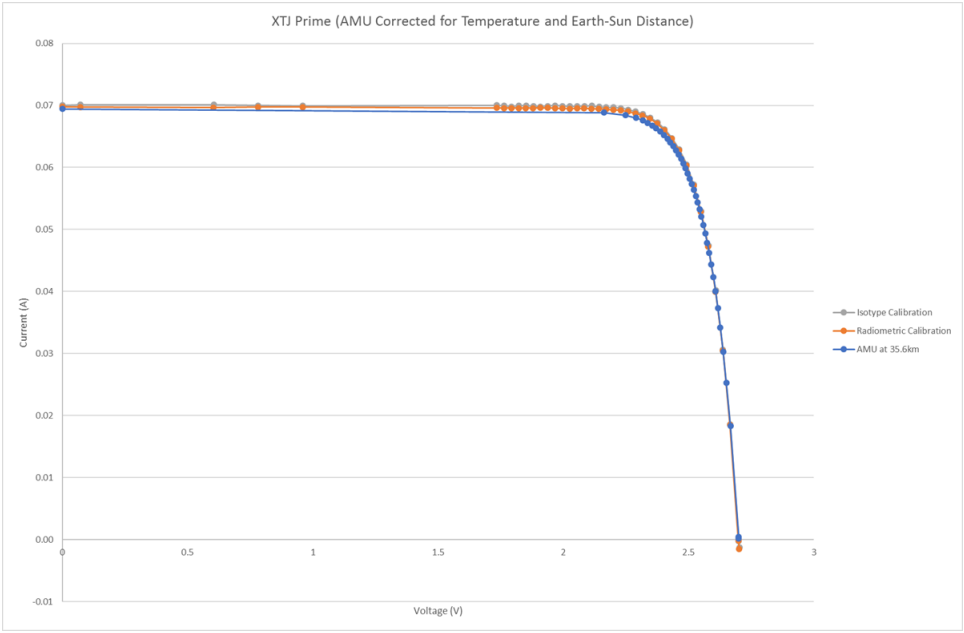
BlackSky Aerospace Flight #2

Light I-V Comparison to Laboratory Measurements

Cell Holder Temperatures
(Platinum RTD)



IV Data at Max Altitude (~36.6km)



BlackSky Aerospace Flight #2

Light I-V Comparison to Laboratory Measurements

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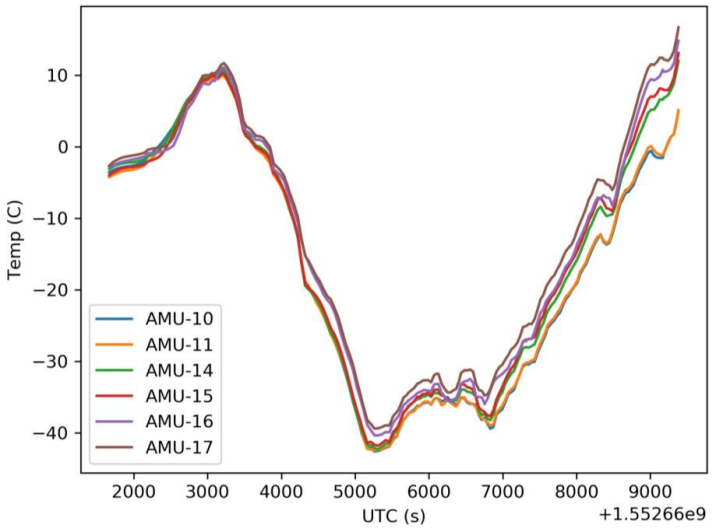

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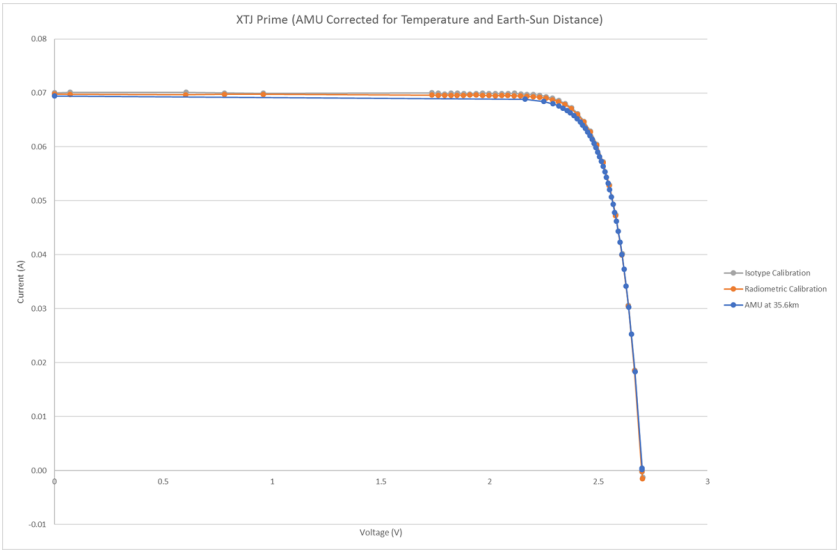
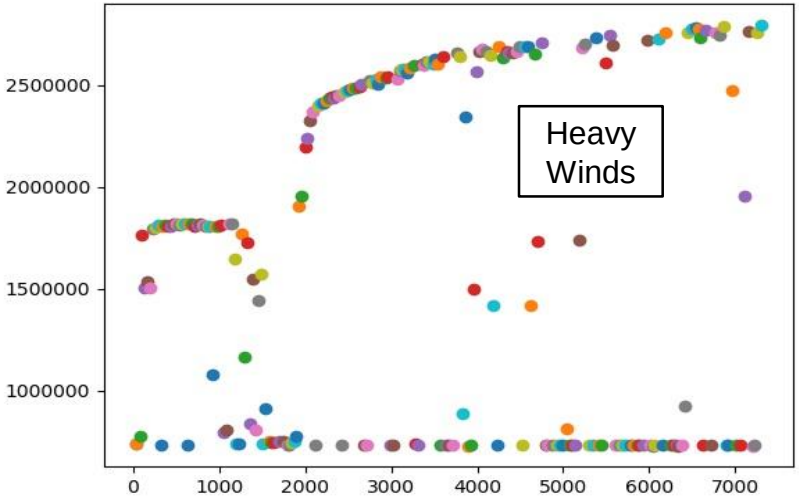


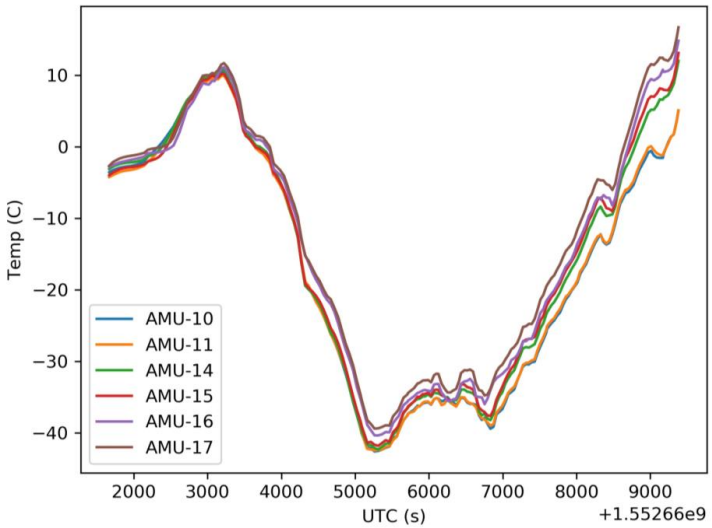
Integrated Spectrometer Data



BlackSky Aerospace Flight #2

Light I-V Comparison to Laboratory Measurements

Cell Holder Temperatures
(Platinum RTD)



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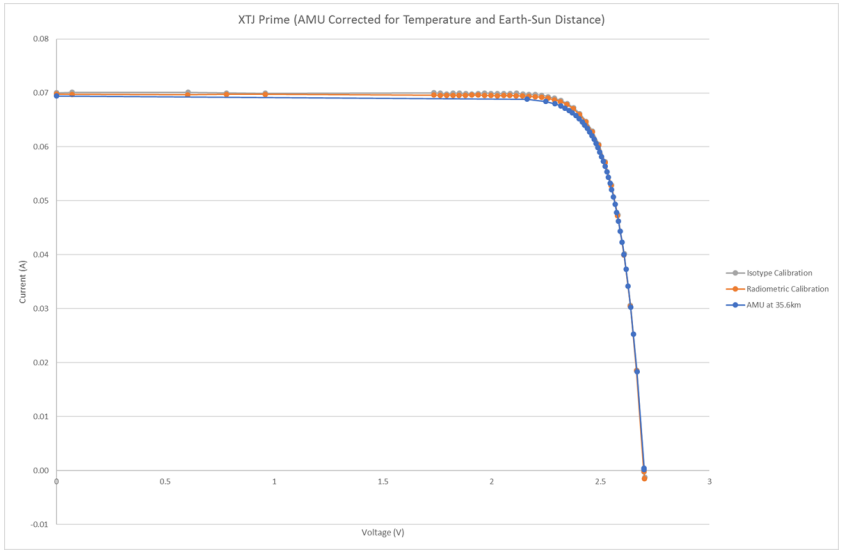
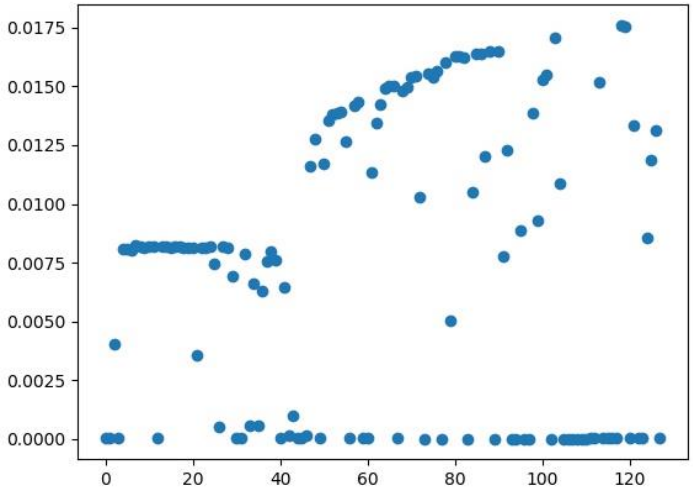
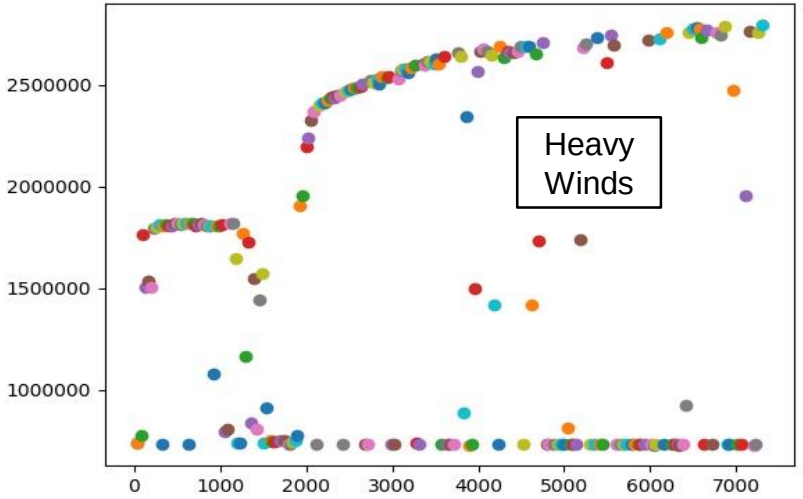


Short Circuit Current



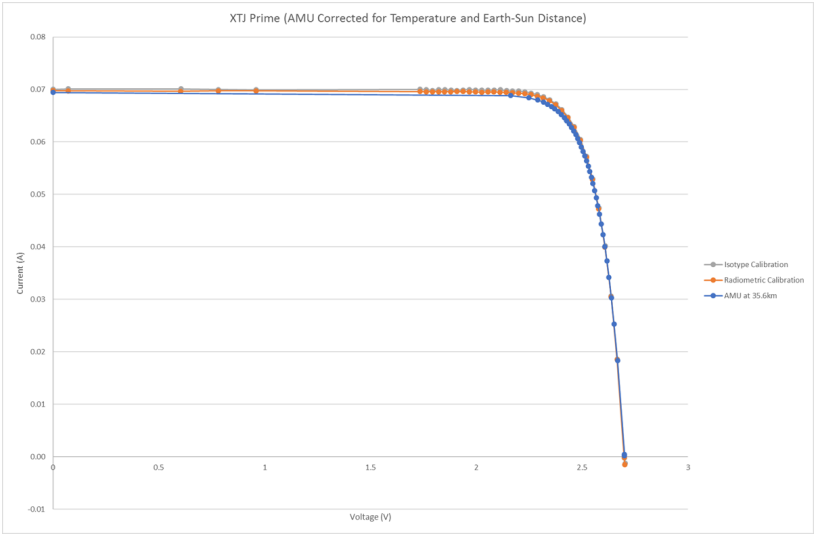
Integrated Spectrometer Data



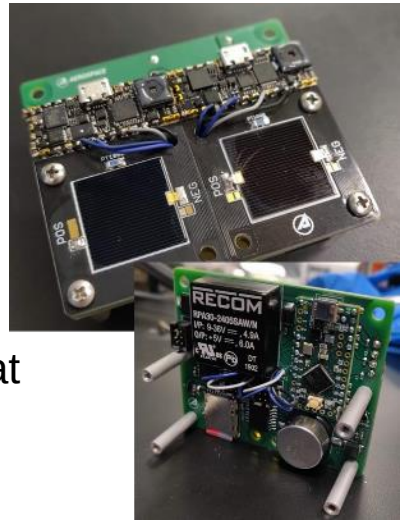
Project Selenium

Aerospace Measurement Unit

- “Test as You Fly” Solar Cell Measurements
- Quick turn-around of laboratory grade measurements at altitude allow for experiments previously not considered.



- Upcoming flight opportunities:
  - *MISSE (03/19)*
  - *CSUCI Small Balloon Platform (University Team)*
- Close to being ready to provide balloon standards at >35km.
- Turn around time between cell readiness and calibration data greatly reduced.



AlphaSpace MISSE Hardware

Acknowledgments and Questions

Jet Propulsion Laboratory
California Institute of Technology

Upper Atmospheric Research Lab

- Geoffrey Toon
- Jose Landeros
- Jean-Francois L. Blavier

AEROSPACE

Energy Technology Department

Don Walker, Simon Liu, Kevin Lopez, Bryan Pogorelsky, Justin H. Lee, John Nocerino, Yao Lao, Paul Joseph

We gratefully acknowledge the NASA Flight Opportunities Program for funding this work and the collaborative efforts from BlackSky Aerospace (Raymond Hoheisel) and Angstrom Designs (Casey Hare).