

Repeatability and Performance of Commercial, High-Altitude, Balloon Flights for Solar Cell Calibration



Space Power Workshop
April 27, 2022
Casey Hare, Scott Ireton
Angstrom Designs

Balloon Flight Calibration Service

Why fly small balloons?



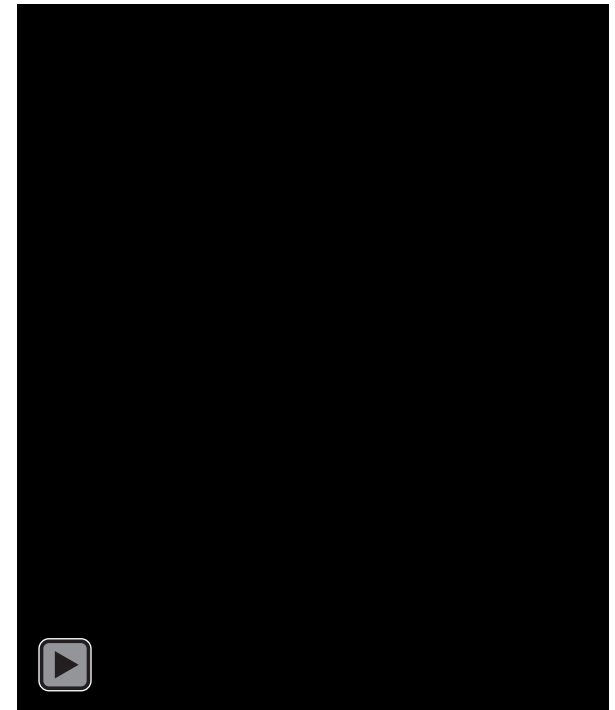
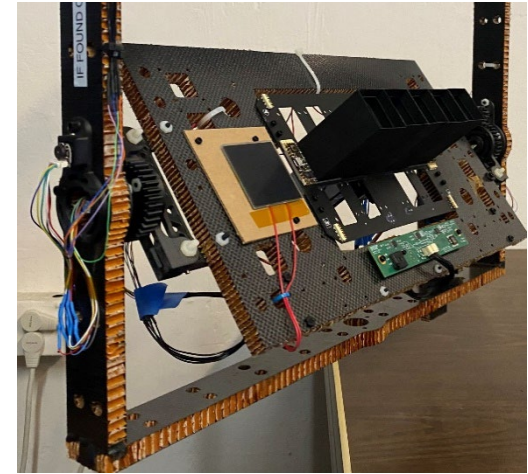
Flown cells used as
pLEDs calibration
standards

- Solar simulator calibration standards
- CFR 101 Exempt < 4 lbs.
- Simplified Logistics
- Lower Costs
- Frequent On-demand Flights

Angstrom Designs Small Balloons Platform

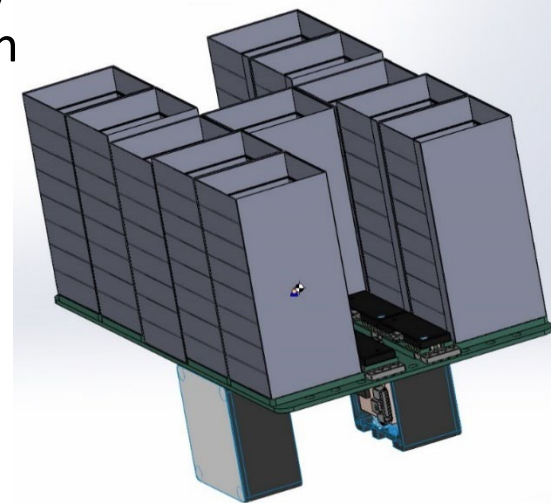
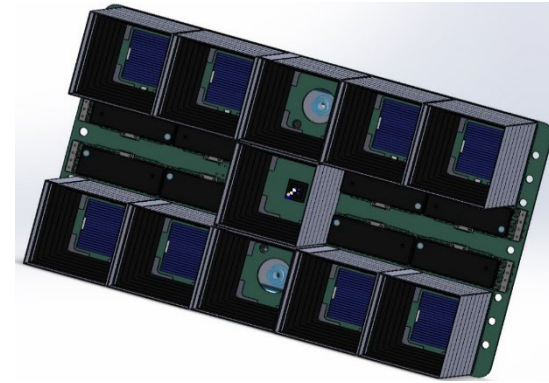
- Ultra-light
- Inertial yaw control
- Pitch control
- Redundant GPS/Satellite tracking systems
- Abundant telemetry
- Payload power supply
- 120,000 feet

Inertial yaw control shows promise for pointing at altitude.



Detailed Capabilities

- Gondola Capabilities:
 - 100,000ft and 120,000ft options
 - Year-round operation
 - Test a variety of cells from many 2x2cm cells up to a 2-per from a 6" wafer
 - Sensing: GPS, pressure, cell & ambient temperature, cameras
 - Redundant transmitters & data logging memory
 - Ground operations will enable many launches in a morning
- Aerospace AMU Capabilities:
 - Full I/V sweep capability
 - 0.2ppm current and voltage accuracy
 - <5sec per sweep, all cells can sweep simultaneously
 - >2.5A and up to 28.5V DUTs can be measured
 - A variety of ranges possible, down to 19mA and 0.2V
 - Cell heaters

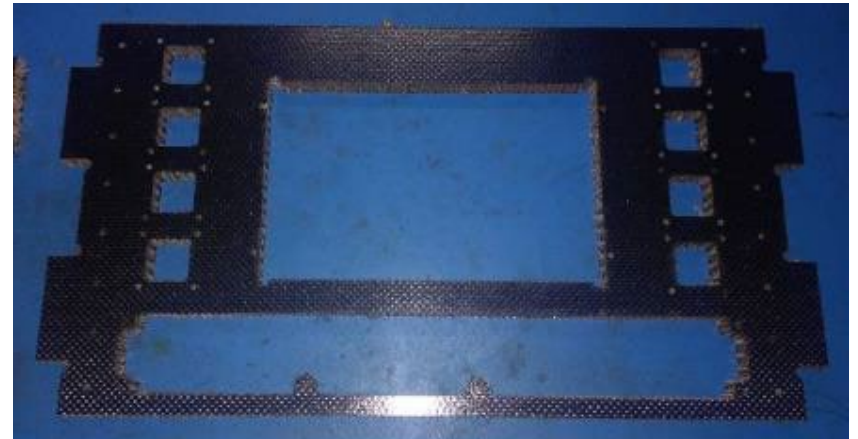
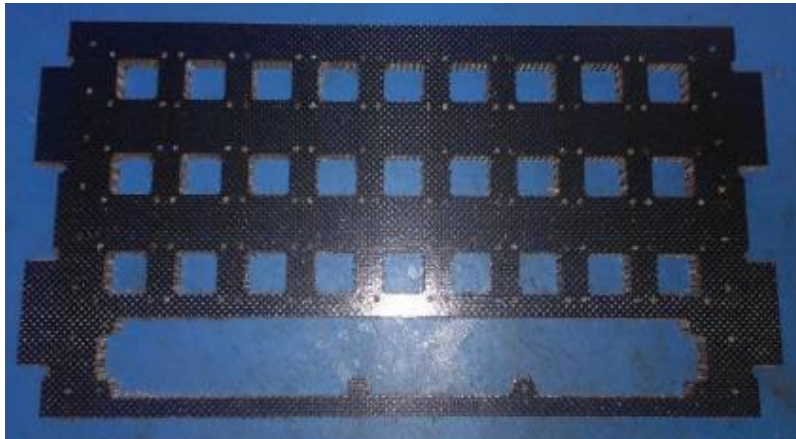
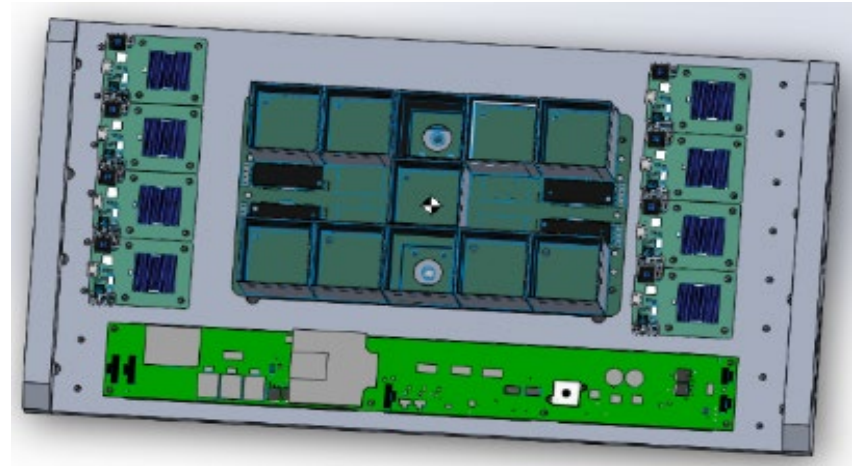
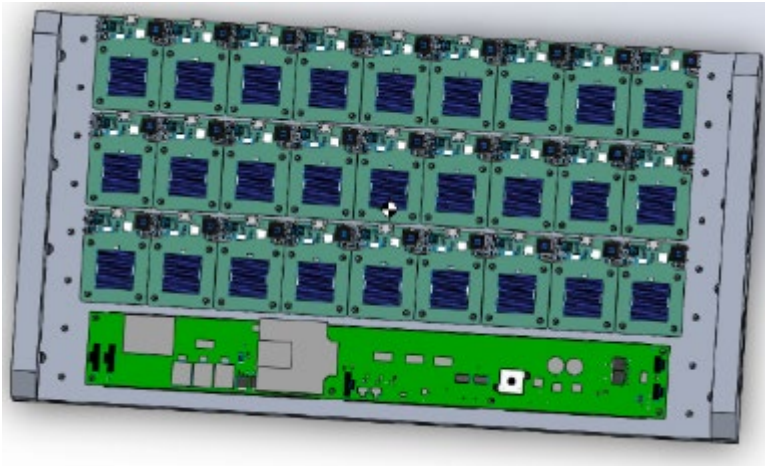


Capabilities equivalent
to old NASA JPL balloon
flights

Payload Capacity

- Customer cell capacity (in cm): 2x 15x15, 4x 7x15, 6x 8x8, 14x 4x8, 27x 2x2 (or Selenium + 8x 2x2)

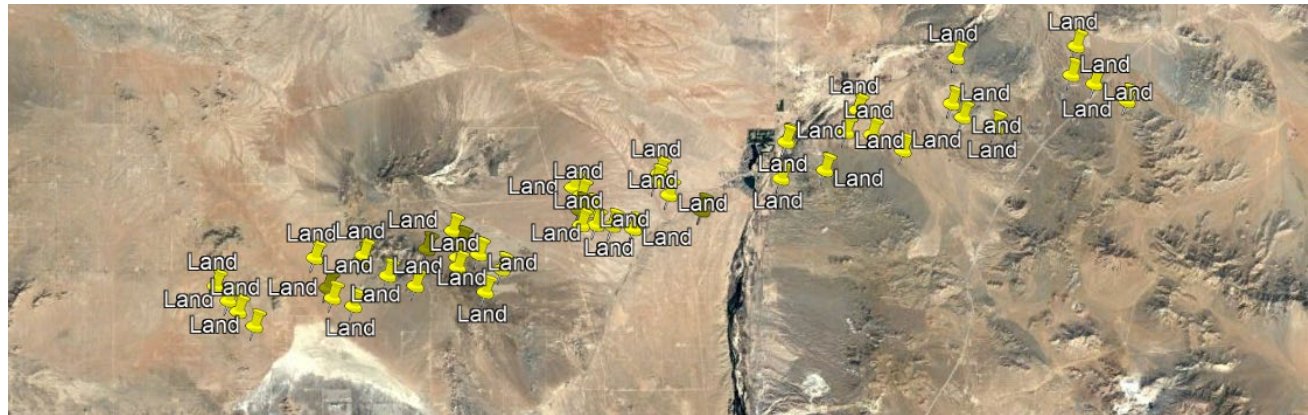
Highly configurable, high capacity payload plate



Proprietary Flight Prediction Software

- Varying flight parameters allows for worst case predictions
- Predictions below ran with the same flight parameter sets on different days

No Fly



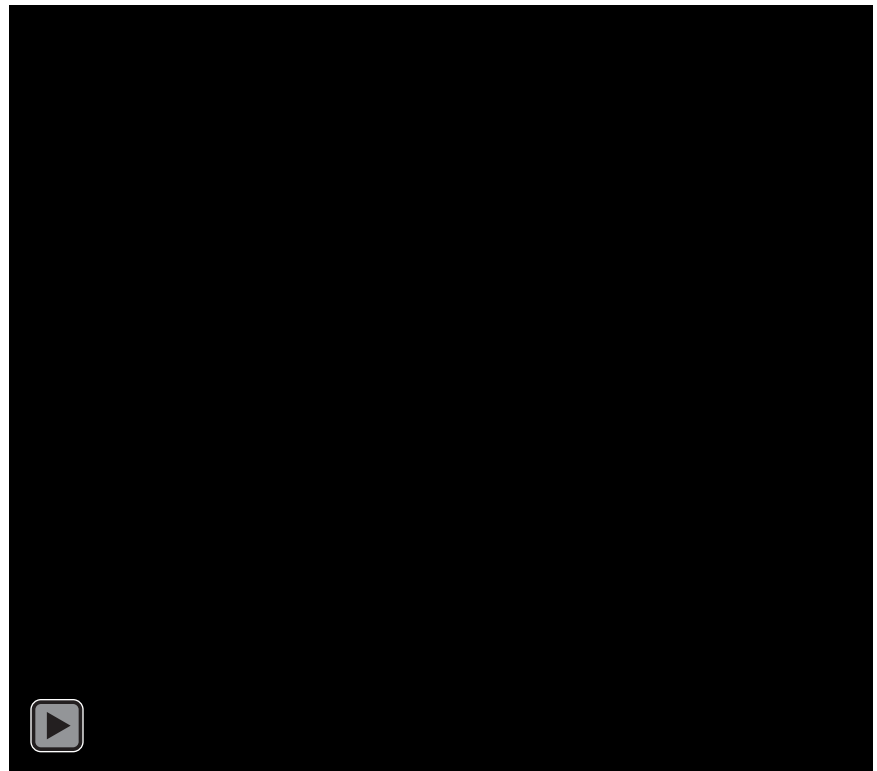
Ok To Fly



Real Time Flight Prediction

- Pre-flight predictions are rough as wind data resolution is large (and estimate) and flight parameters are not exact (ascent/descent rate)
- Angstrom Designs real time flight prediction software receives telemetry from the Gondola and re-predicts landing coordinates throughout the flight
- First used in the Feb '22 flight, the mid-flight prediction allowed the chase car to be a few hundred feet from the payload when it landed

The chase car gets navigated to highest probability landing location based on real flight parameters!



What does a flight day look like?

- 5:00 AM
 - Arrive at office and pack truck
- 7:30 AM
 - Arrive at flight location
 - Conduct ground testing and balloon fill
- 8:00 AM
 - Launch balloon
- 11:00 AM
 - Payload Recovery
- 1:30 PM
 - Return to office

Wake up early, home for (late) lunch.



Flight Reference Solar Cells



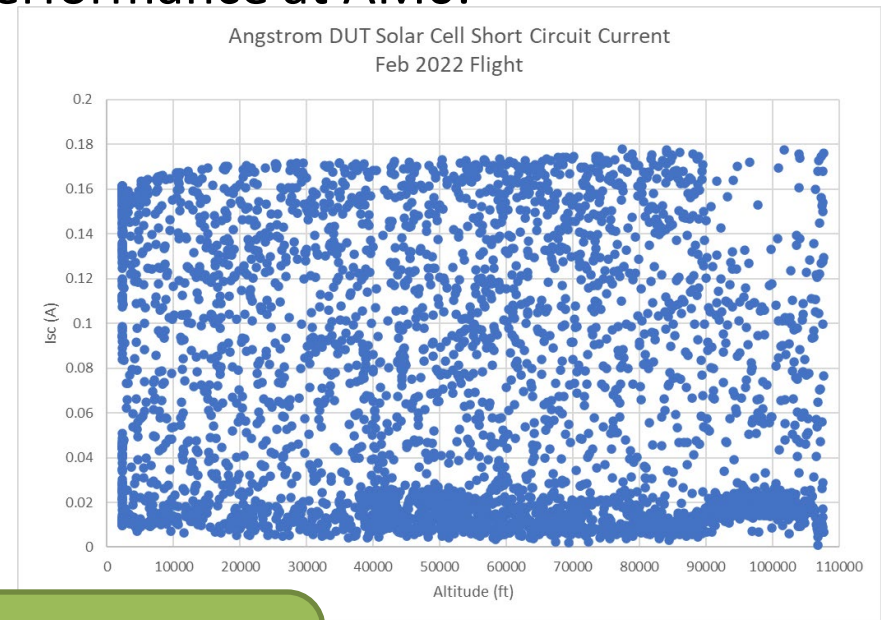
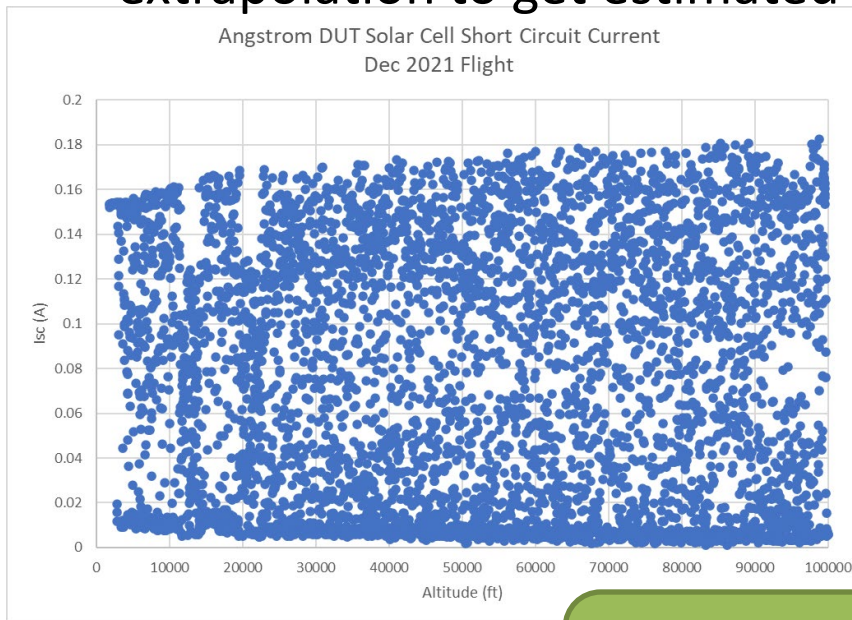
Angstrom Prototype
Reference/Test Cell

- Solar cell measurements can vary between flights due to atmospheric conditions, Angstrom Designs reference cells can be included on the flight to identify anomalies.
- Licensed Aerospace AMU and Angstrom firmware allow measurement acquisition without relying on customer payload.
- Our reference cells are still in development but will be measured in house using pLEDs and on flights to reduce uncertainty in customer DUT measurements.

Do you want your technology
to be included in our
reference cell library?

Reference Cell Short Circuit Current Repeatability

- Preliminary data is noisy but with a fast acquisition rate good measurements are achieved.
- I_{sc} clearly follows expected increase that enables Langley extrapolation to get estimated performance at AM0.

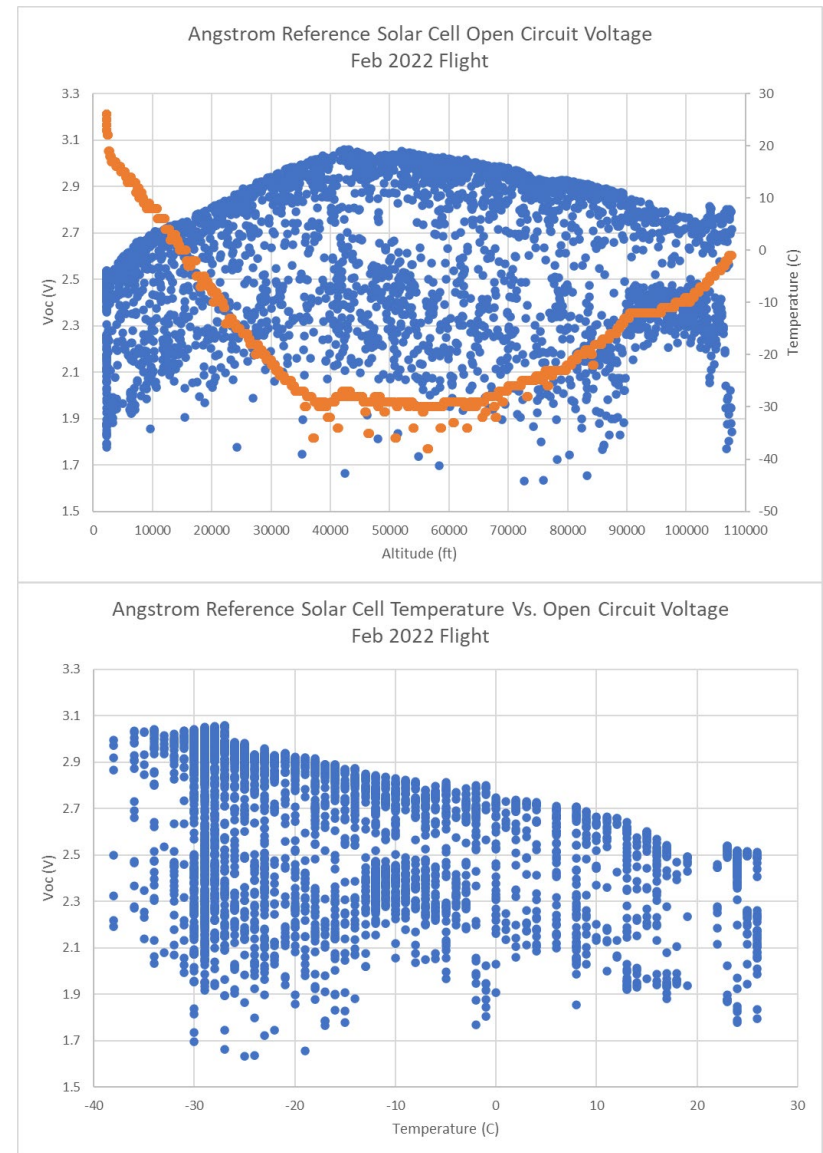


A high sample rate means collecting good data even when flight is less stable.

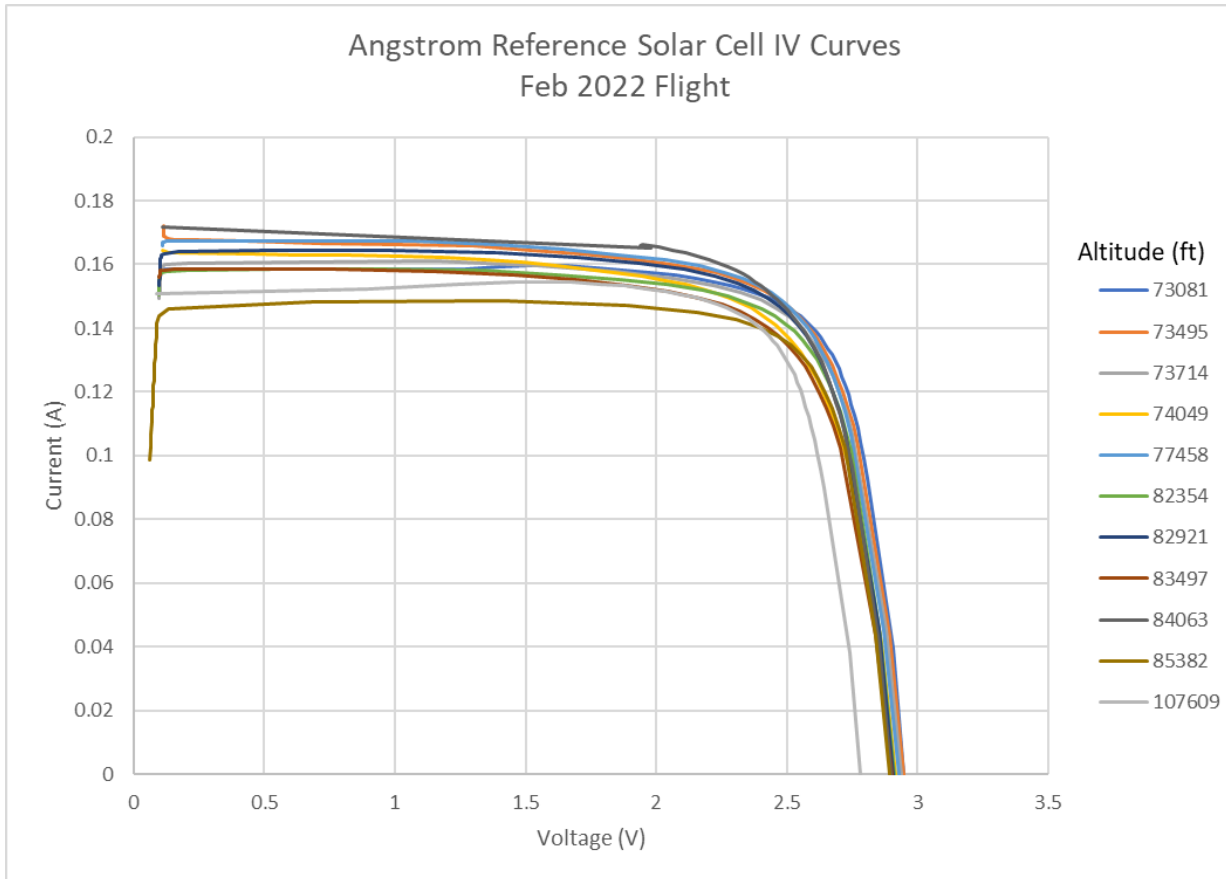
Reference Cell Open Circuit Voltage

- Voc follows temperature as expected
- Temperature measurements match known atmospheric temperature pattern over altitude

This is just the beginning, the reference cells are going to get some serious airtime.



Reference Cell IV Curves



All reference cell measurements are made using AMUs and Angstrom acquisition firmware.

Concluding Thoughts

- Angstrom Designs reference cells will allow for greater confidence in DUT measurements
- Flight logistics and Gondola hardware is mature and ready to fly your cells
- Thanks to SMC, AFRL, Aerospace, and many others for funding and expertise

