Intelligent Solar Cell Carrier for Solar Cell Calibration Standards

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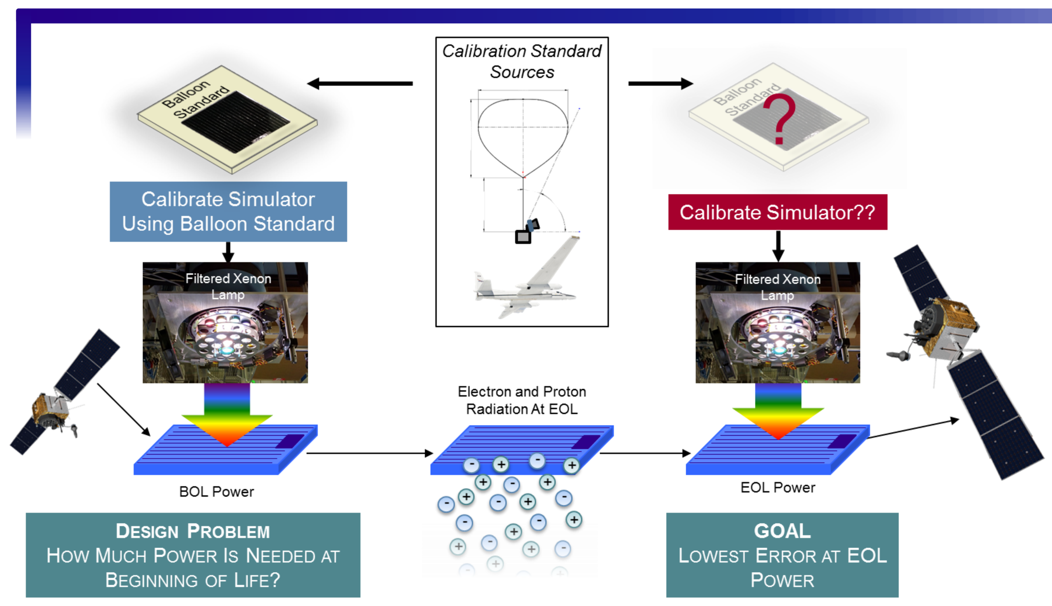
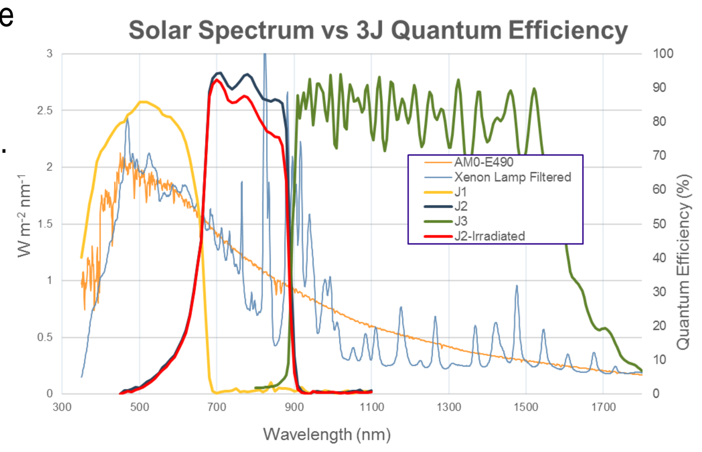
Motivation



To overcome the challenges inherent to high altitude measurement platforms, a modular cell carrier was developed to address three issues: measurement uncertainty, cost, and flight availability. We found that by miniaturizing the measurement electronics onto the cell carrier itself we could eliminate nearly all the uncertainty while also greatly reducing the weight and size of the payload. By reducing the weight and size, using low cost weather balloons becomes possible rather than the more expensive high altitude that have been used in the past.

The quantitative characterization of a solar cell technology requires the reproduction of the light source used in its application. In most cases, current solar simulator technology is inadequate on its own to accurately reproduce the spectrum of light that matches the application. The industry standard for overcoming this challenge has been to calibrate light sources using solar cells that are measured in their applicable environment and use these cells as calibration standards to tune the light source. AM0 conditions are reproduced most commonly using high altitude flights. The cell measurement made at altitude is matched in the laboratory at which point the simulator is now calibrated for other measurements of the same technology.

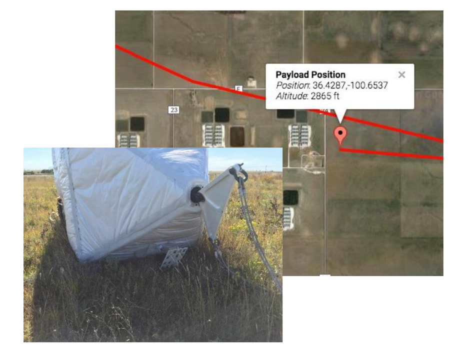


Development History

JPL MkIV gondola and high altitude balloon

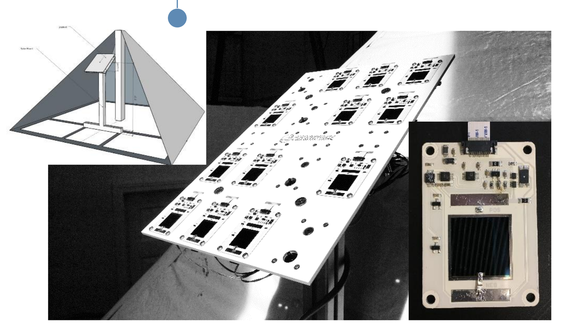

MAY 2016

- Introduction to the Upper Atmospheric Research Lab (UARL) at JPL NASA.
- UARL has sun pointing (±5°) gondola which reaches ~39km altitude. JPL MkIV instrument mounted inside gondola measures atmospheric content throughout the atmosphere.
- JPL agrees to allow small Aerospace payload mounted to side of MkIV for conducting solar cell experiments.



Successful first flight took place Sep 27, 2016

AUG 2016



Aerospace payload finished design and delivered to JPL in 3 months. 12 redundant cell carriers with data storage and full IV sweeps.

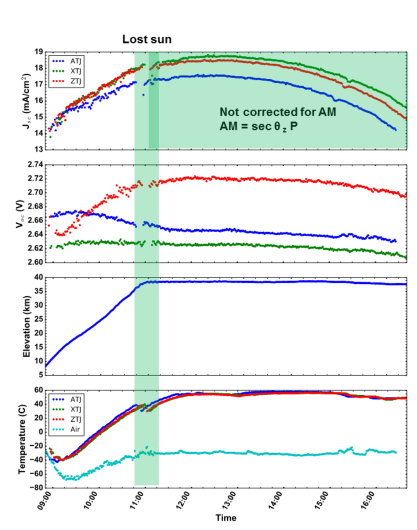
SEP 2016

2016 was a success in proving out cell characterization electronics, but the data highlighted three areas in need of improvement.

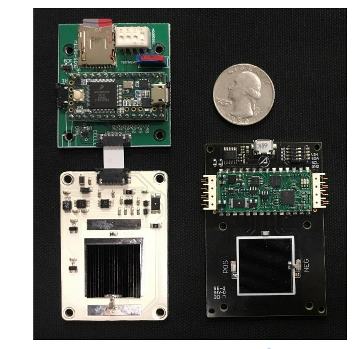
1. Reflection from balloon and Earth albedo
2. Ozone concentration needed for correction
3. Decreased size and complexity of cell holder to move towards lighter, less costly balloon platforms

AUG 2016

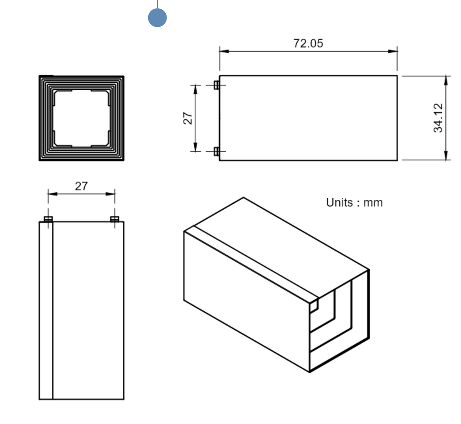
JPL 2016 Flight Data



Gen 2 cell holder incorporates µController and IV electronics on single PCB



APR 2017



Designed a baffle to be fabricated using photo etched aluminum. Before assembly is painted with Z306 flat black anti-reflective paint.

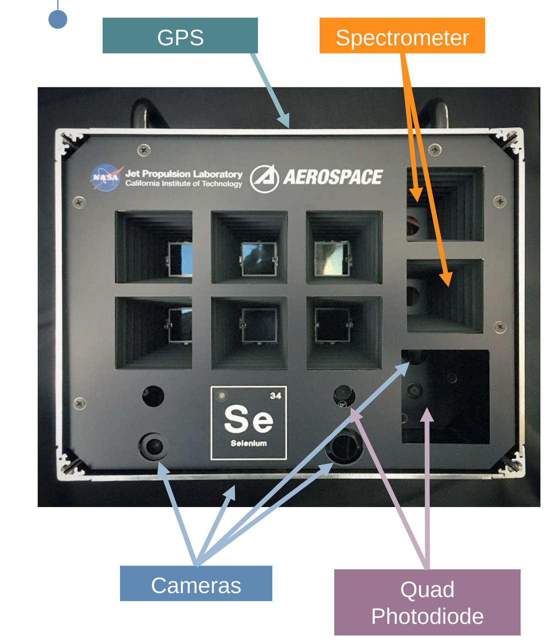
Completed 2017 payload

AUG 2017

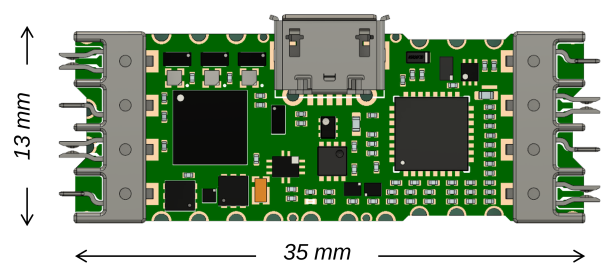
Added two miniature spectrometers with a total range of 190-800nm with 1.5nm steps.

Delivered Selenium 2017 to JPL

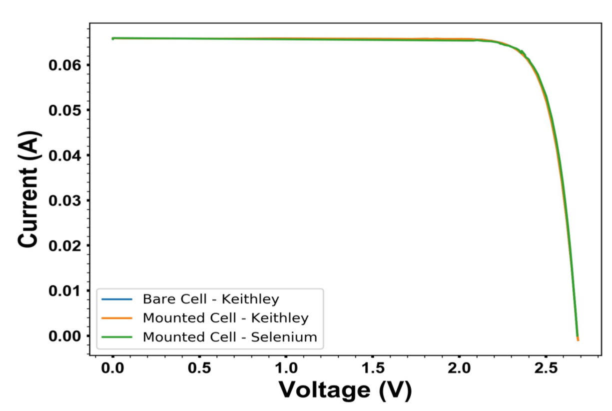
SEP 2017



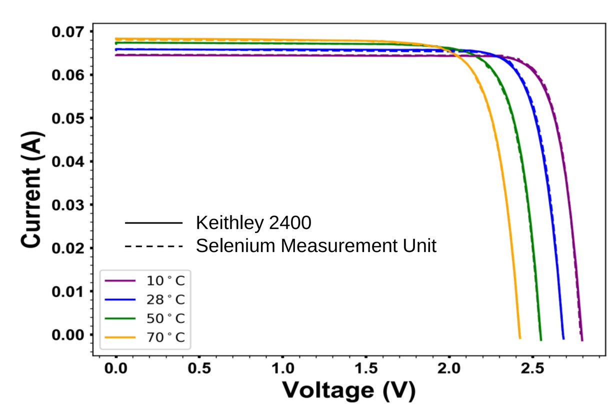
Aerospace Measurement Unit (AMU)



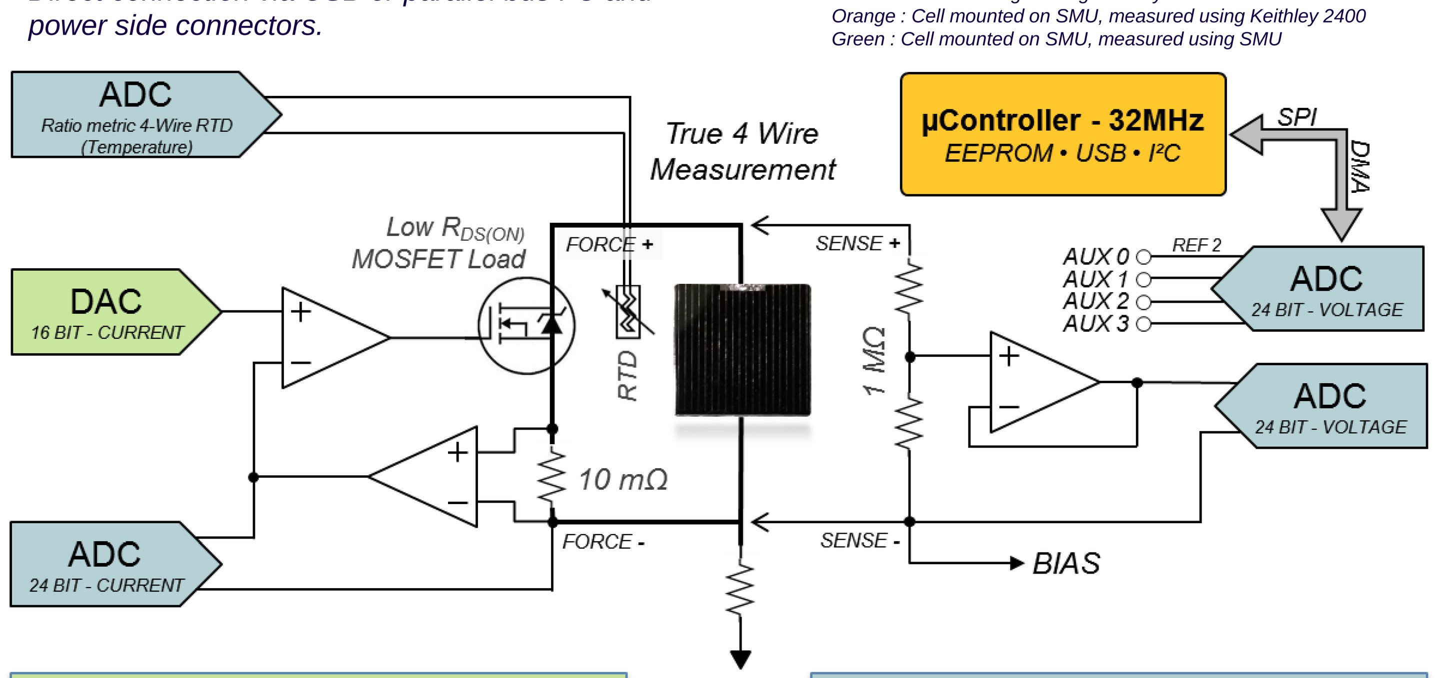
Integrated measurement unit for characterizing solar cells in a bread board or surface mount configuration. Direct connection via USB or parallel bus I²C and power side connectors.



Blue : Cell on cold finger using Keithley 2400 to measure.
Orange : Cell mounted on SMU, measured using Keithley 2400
Green : Cell mounted on SMU, measured using SMU



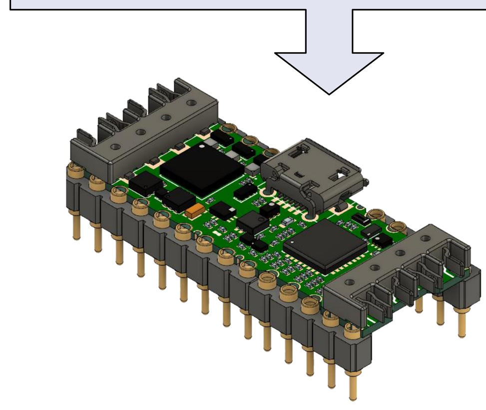
Cell mounted to carrier, measured using Keithley 2400 standard lab setup, then measured using SMU. Temperature compensated electronics remove offsets and gain error from measurements.



DAC Controlled IV Sweep
- *16 Bit Ultra Low Noise DAC 2 ppm/°C internal reference, ~38 µA step size*
- *Zero drift, low power, low noise, FET control amplifier*
- *Zero drift, low power 50X current sense amplifier*
- *3 Watt, ultra low $R_{DS(ON)}$, power MOSFET*
- *Current measurement range: 80mA,160mA, 312mA, 625mA, 1.25A, 3A*

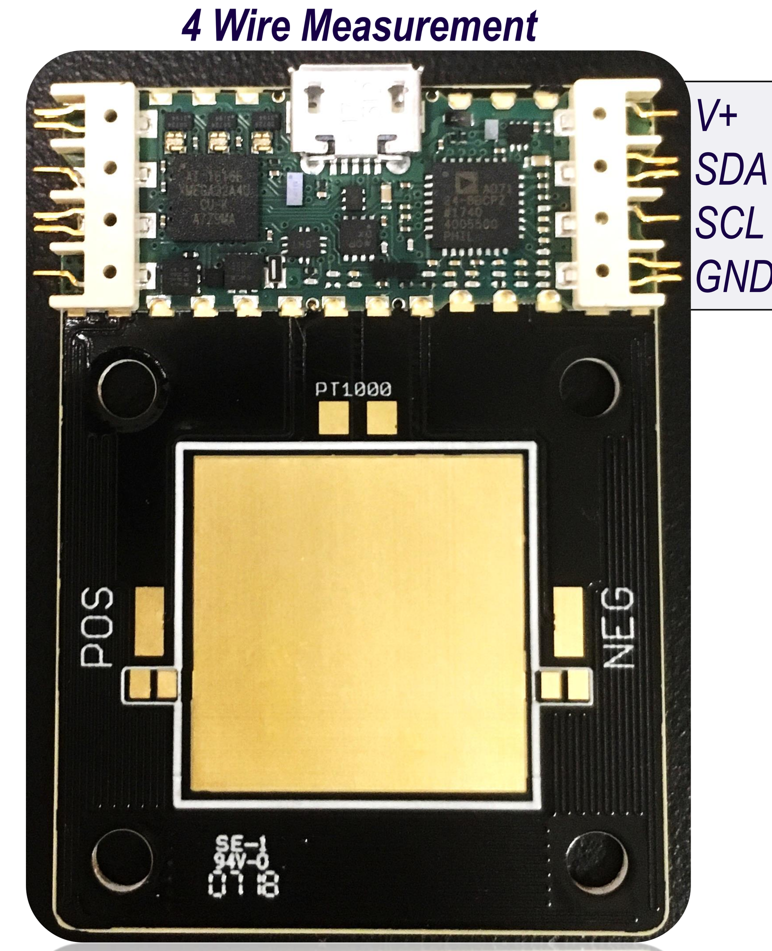
24 Bit Temperature Compensated ΣΔ ADC
- *Voltage : 0->6.5V Current : 0- 3A*
- *Scalable voltage and current ranges using internal ADC gain amplifiers*
- *Internal 2.5V reference and temperature sensor*
- *Internal current source and secondary reference for ratio metric RTD measurement*
- *4 additional ADC pins available, can be used for quad photodiode sun angle sensor*

USB Class Compliant Interface (No Hardware Driver Needed)
- *IEEE 488.2 SCPI support with software drivers for:*
  - ***LabVIEW***
  - ***Python (Raspberry PI)***
  - ***C/C++ (Arduino)***



SMU can be mounted using through hole pins to a bread board interface, or mounted directly to a cell holder using surface mount technology

2x2 Holder – 1 Layer Aluminum PCB
4 Wire Measurement

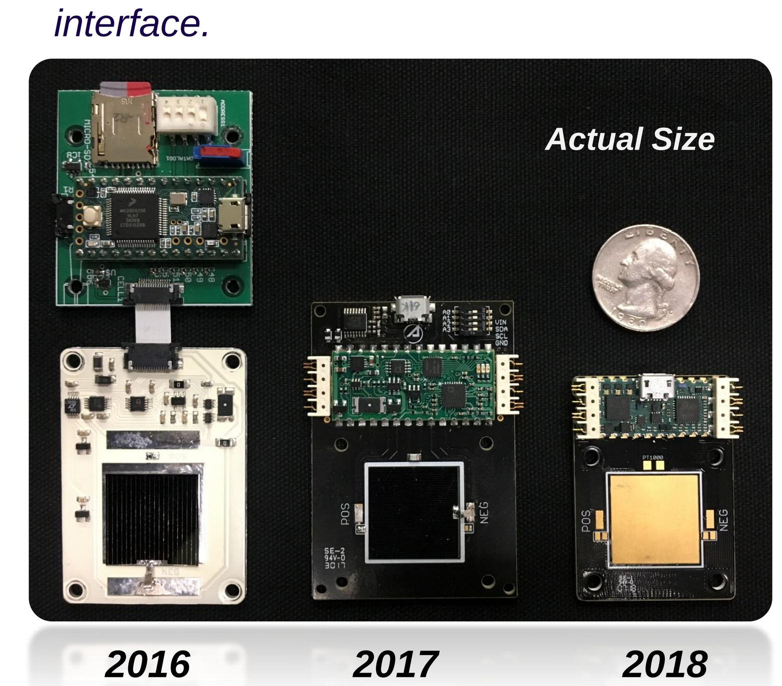


- Integrated heater
- Gold plated surface, much flatter surface than standard tin plating
- Cell is soldered down using low temperature solder Sn/Bi/Ag (Tin/Bismuth)
- High thermal conductivity dielectric minimizes RTD to cell thermal gradient

4 wire connector uses daisy chainable I²C bus for SMU configuration, measurement triggering and data collection

Using only two communication wires, dozens of devices can be connected simultaneously. Triggering of measurements can happen using a single command, for simultaneous IV sweeps.

Communication with all devices on the bus can be done from a single host microcontroller using I²C, or directly to a computer using a single USB interface.

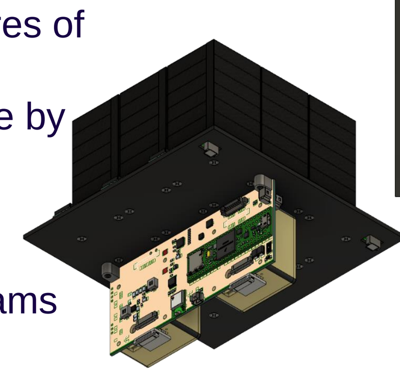


- Optimized 100 point I-V curve steps for max points at knee, ~50 points per second optimal
- 4 Wire RTD Measurement with 0.1°C accuracy
- 2 kB EEPROM stores all calibration data on device including full I-V curve
- 3 mA total current draw at 3.3V during measurement, idle state draws ~200 µA, V+ can range from 3.1V -> 5.5V
- LabVIEW, Python, C++, Arduino, Raspberry Pi Compatible
- Class compliant USB, no drivers required
- Bluetooth / coin cell attachment
- External FET for loads greater than 3 Watts
- Silicon Quad Photo diode can be mounted above SMU utilizing same 24 bit ADC
- Integrated heater (Up to 80°C using 5V USB power)
- Sun-Sensor attachment

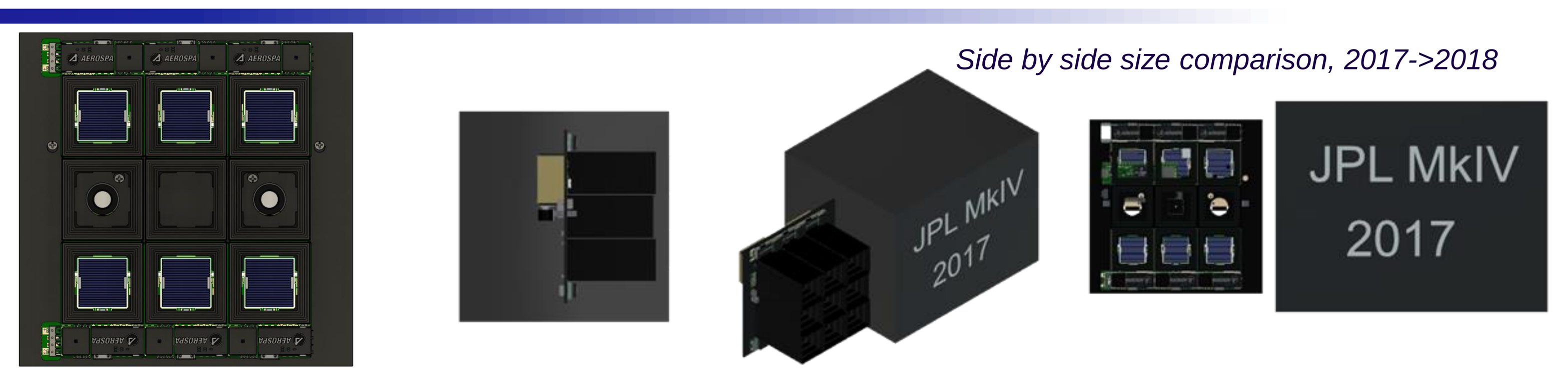
Upcoming Flights

2018 Platform

- Incorporates all features of previous versions
- Reduced power usage by 75%
- Reduced volume by > 50%
- Total weight < 500 grams



Side by side size comparison, 2017->2018



NASA Flight Opportunities Program (continues through 2019)
- BlackSky – 2 flights with the first in June
- Angstrom Designs – 2 flights with the first in July

JPL MkIV - September 2018
Aerospace AeroCube ACX
- 6 SMUs will be mounted inside a small 10 cm³ satellite
  (See Justin H. Lee poster during Thursday Space PV session)

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Flight Results / Future Work

The ability to use light weight balloon platforms rather than larger expensive delivery systems has the potential for:
- Increased flight availability (easier setup time, significantly lower cost)
- Reduces error in balloon standards to near zero.
- More frequent flight availability will result in quicker understanding of newer cell technologies.
- If flight cost is reduced enough, testing a new cell technology on a balloon may become an alternative to ground testing using non-matching cell standards

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