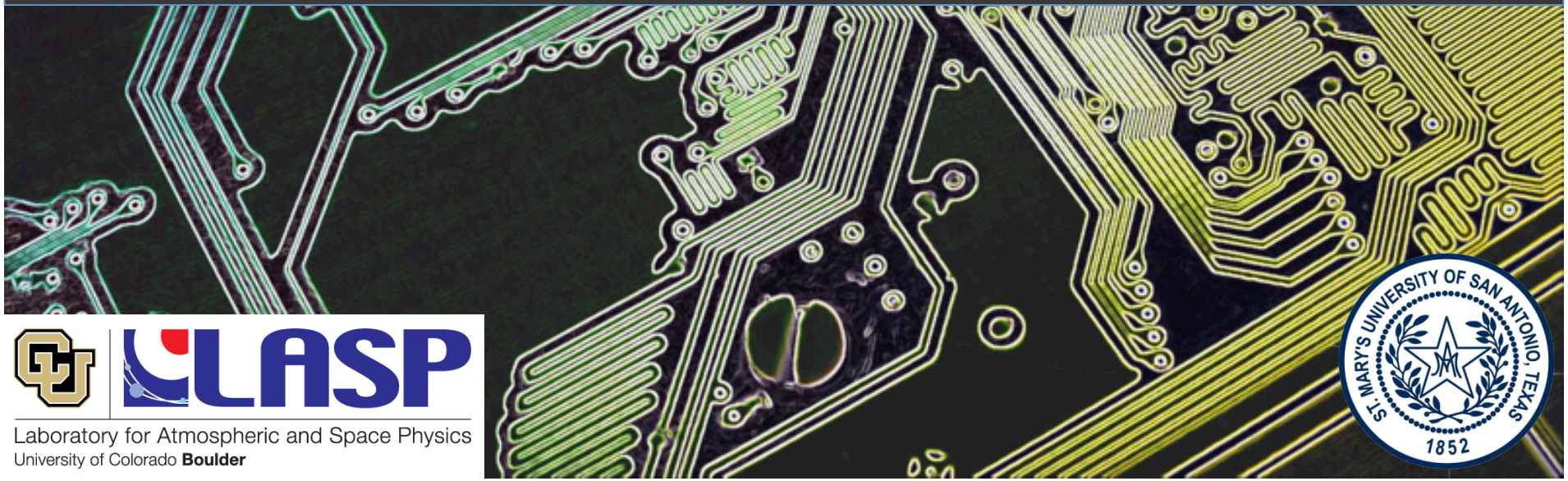
Performance and Verification Testing of an Electrical Power System for a CubeSat

Seth Folley
St. Mary's University of San Antonio, Texas
Mentors: Tom Woods, Chris Sawyer, Matt Carton, Amir Caspi, James Mason



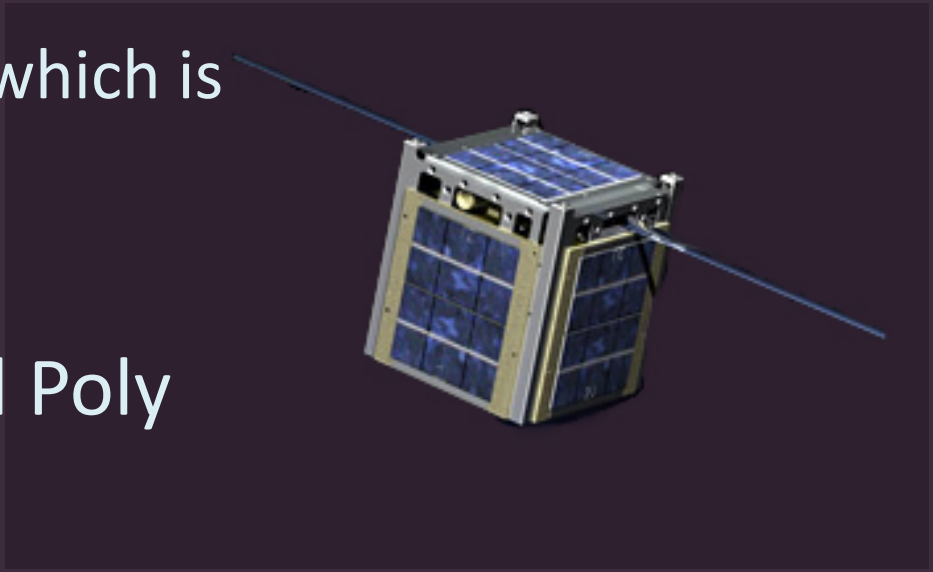
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Goals

- Develop monitoring software for the Electrical Power System for CubeSat mission
- Test/verify the performance of the Electrical Power System

CubeSats

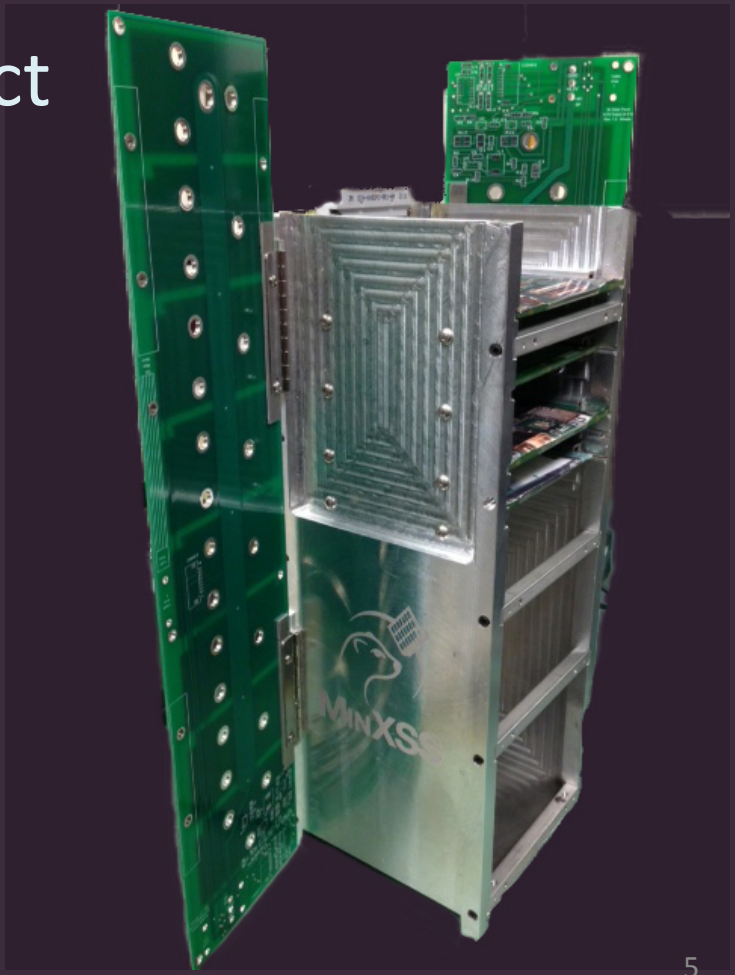
- Small satellites
- Standard in Pico satellites
  - 10cm x 10cm x 10cm which is 1 unit or 1U
  - 1.33 kg limit per 1U
- Idea developed by Cal Poly and Stanford
- Experience for students



MinXSS: Miniature X-ray Solar Spectrometer

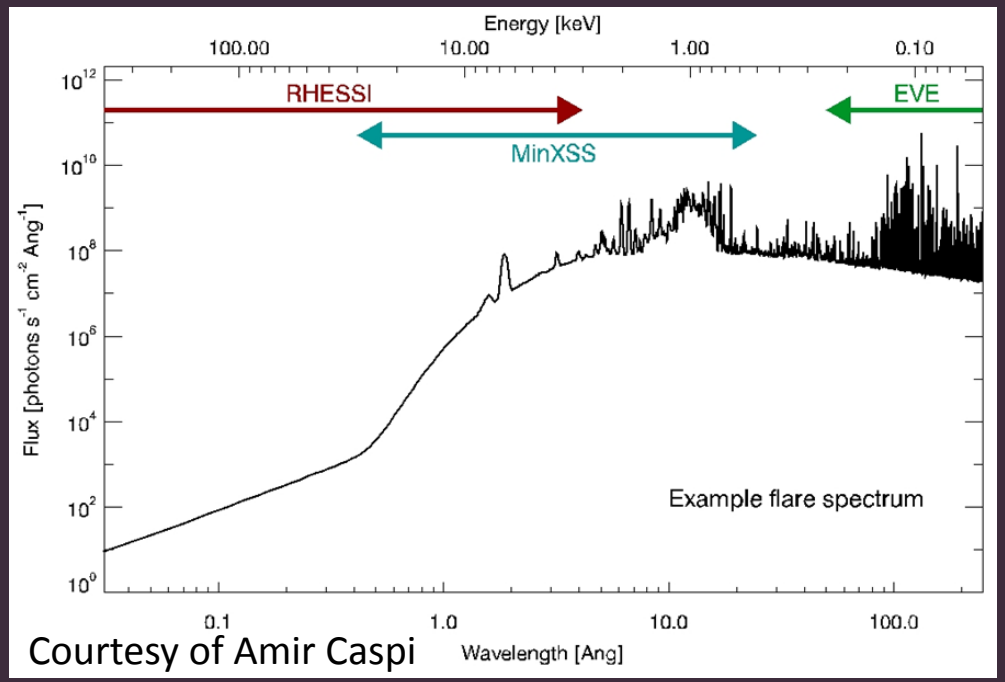
MinXSS

- 3 year Grad Student project
- 3U CubeSat
- Low earth orbit

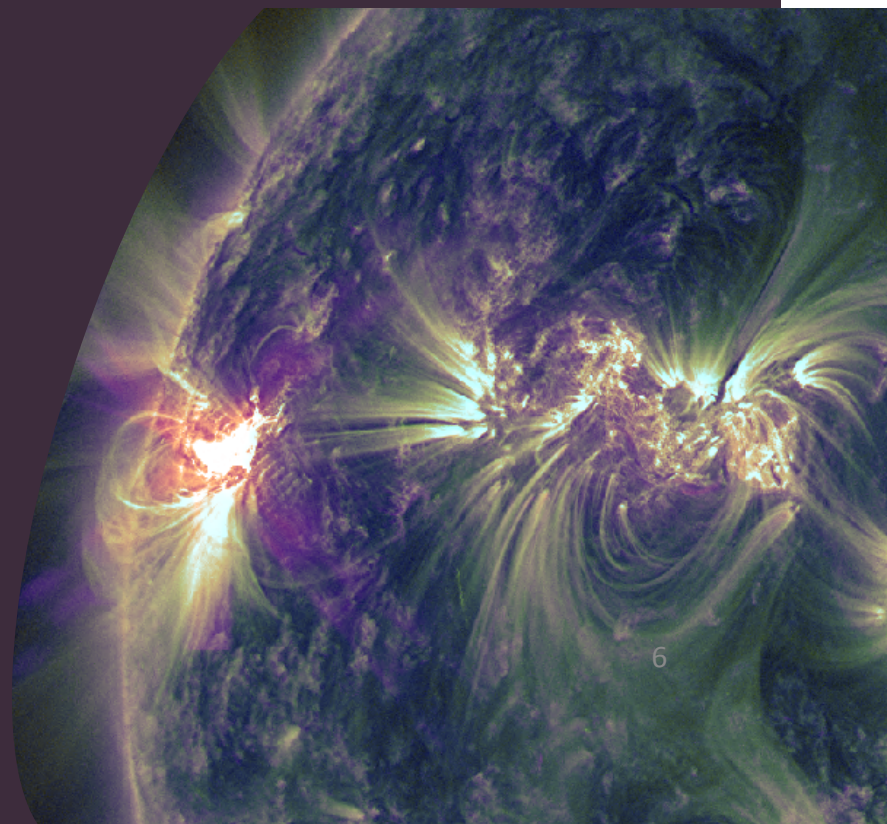


MinXSS

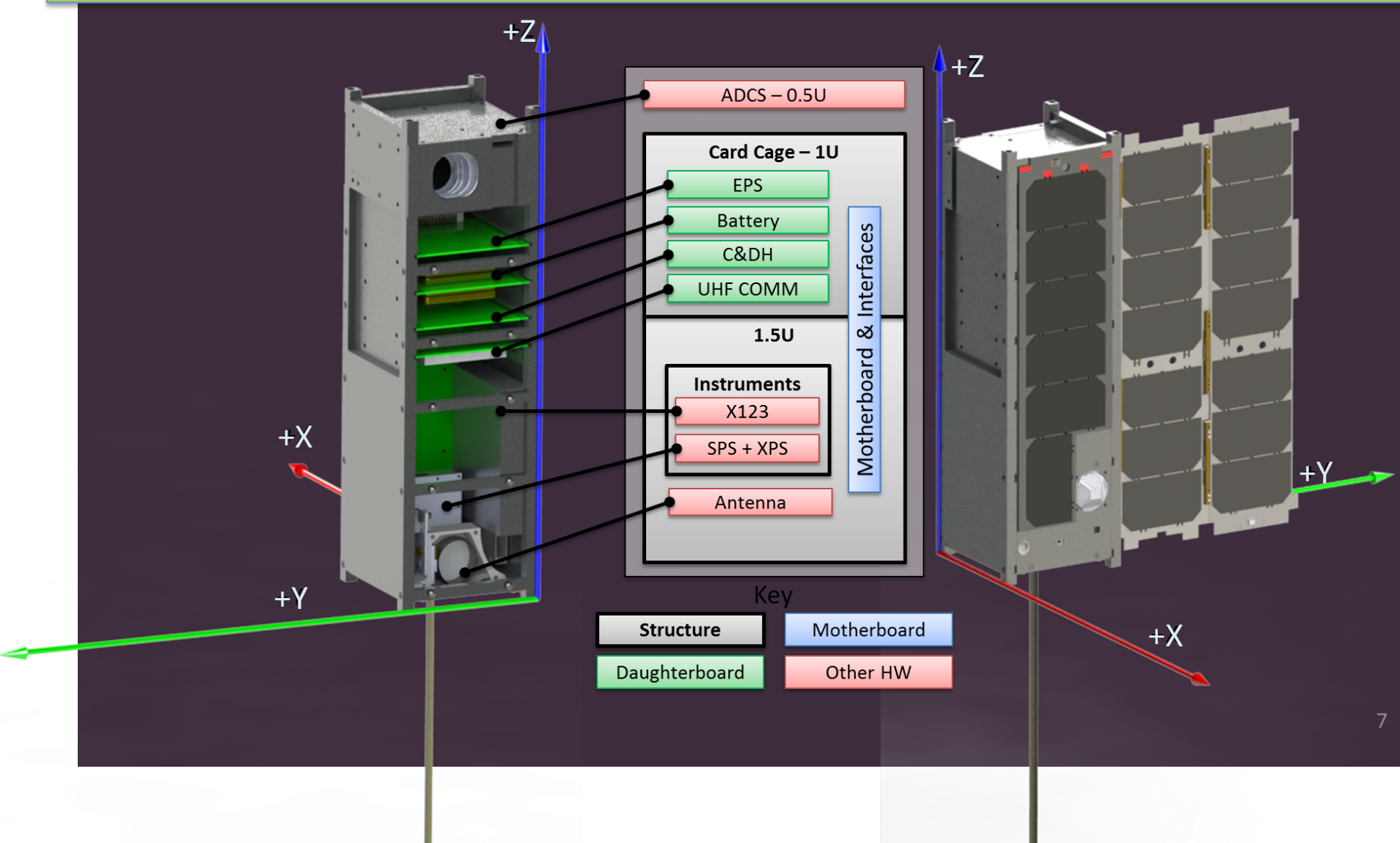
- Will measure the intensity of the soft x-ray spectrum, 0.6 keV (20 Å) to 30 keV (0.4 Å)



Courtesy of Amir Caspi



Mechanical Model

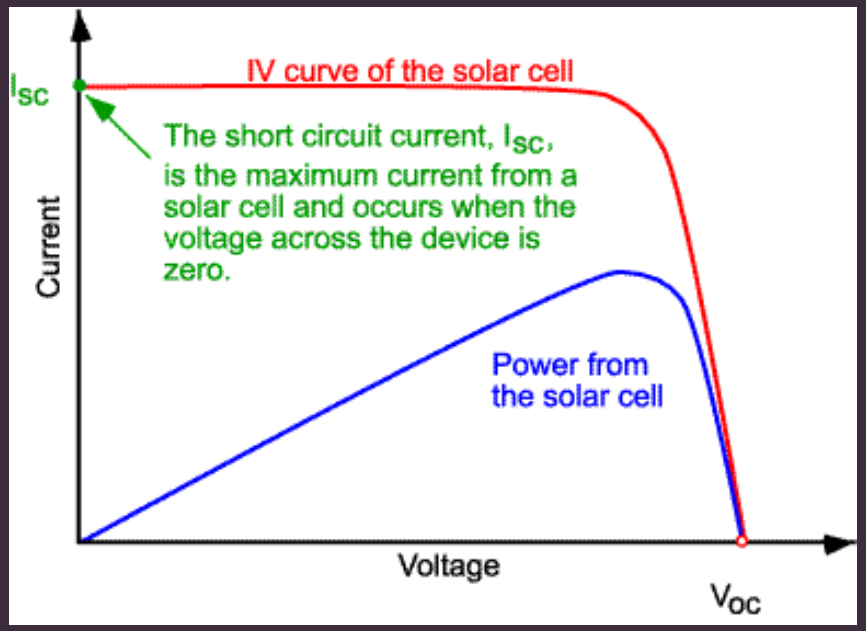


Command and Data Handling

- The brains of MinXSS
- Gathers housekeeping data
- Commands various instruments

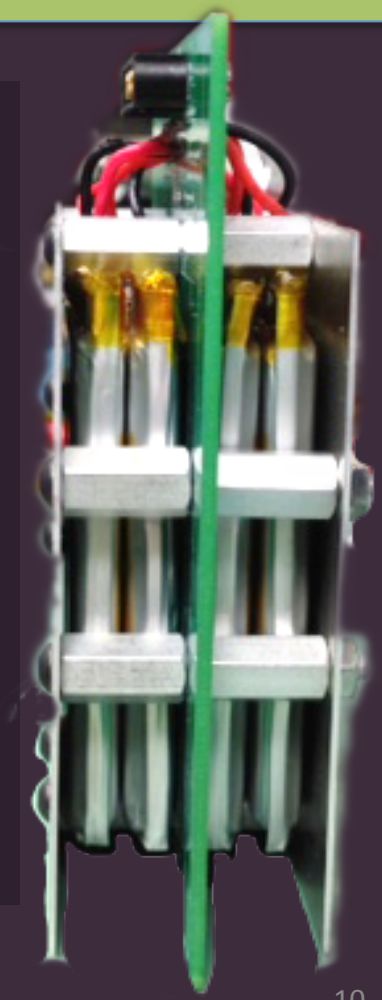
Solar Cells

- Triple Junction
- Triple Junction is more efficient, up to 44% efficiency in labs, 30% commercial

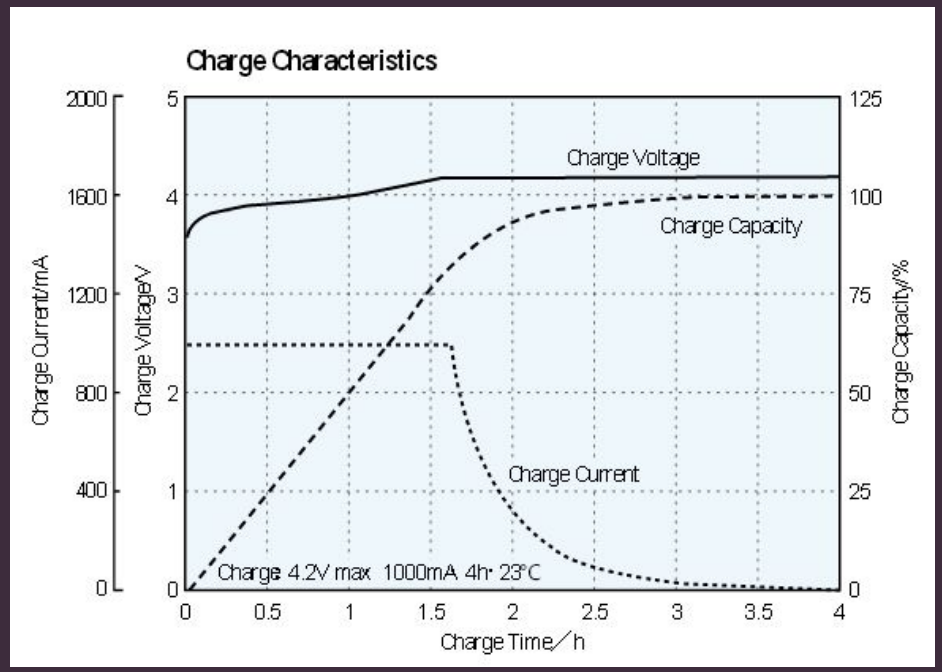


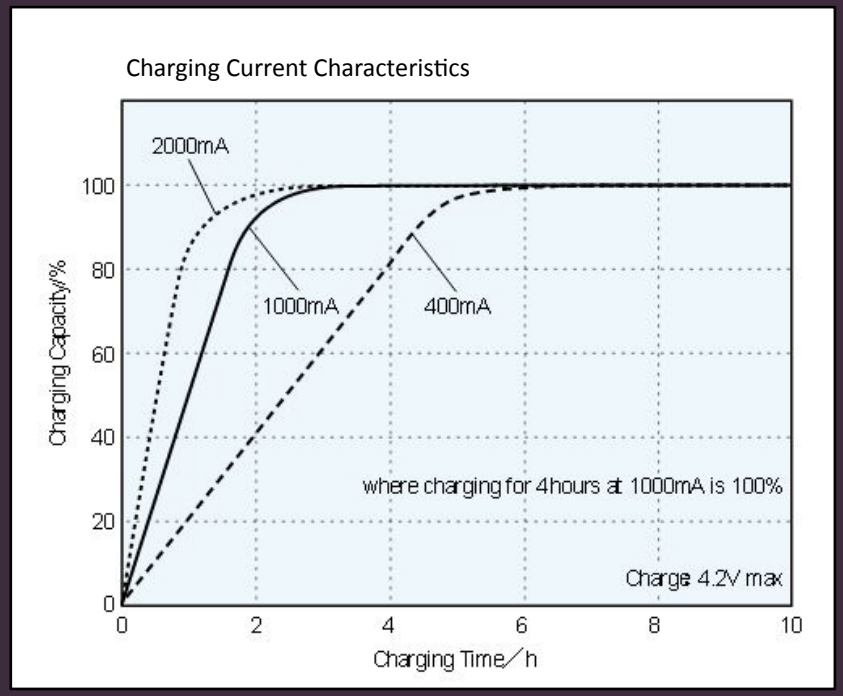
Batteries

- Lithium Polymer
- 4 batteries total
- 8.4 V max
  - 2 sets in series at 4.2V each
- 4 Ah

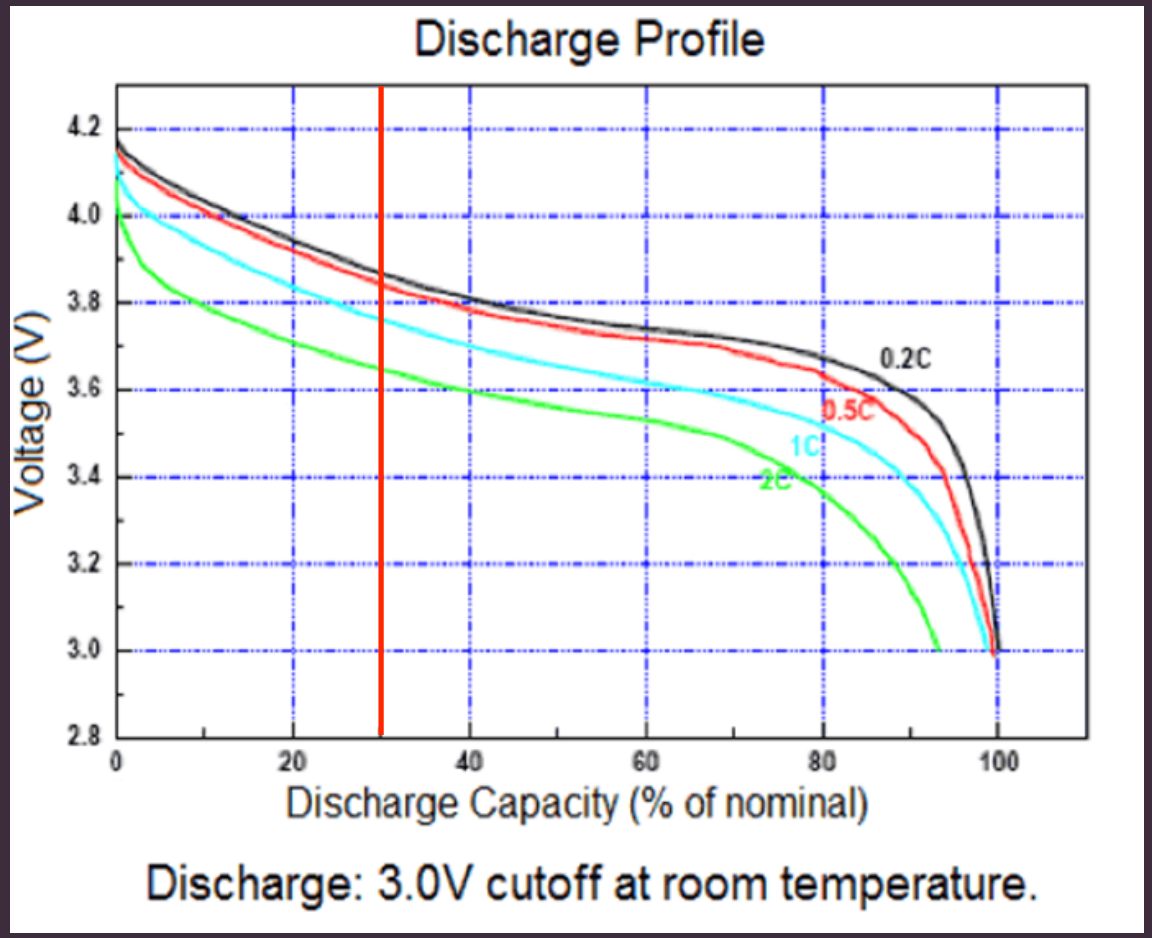


Batteries

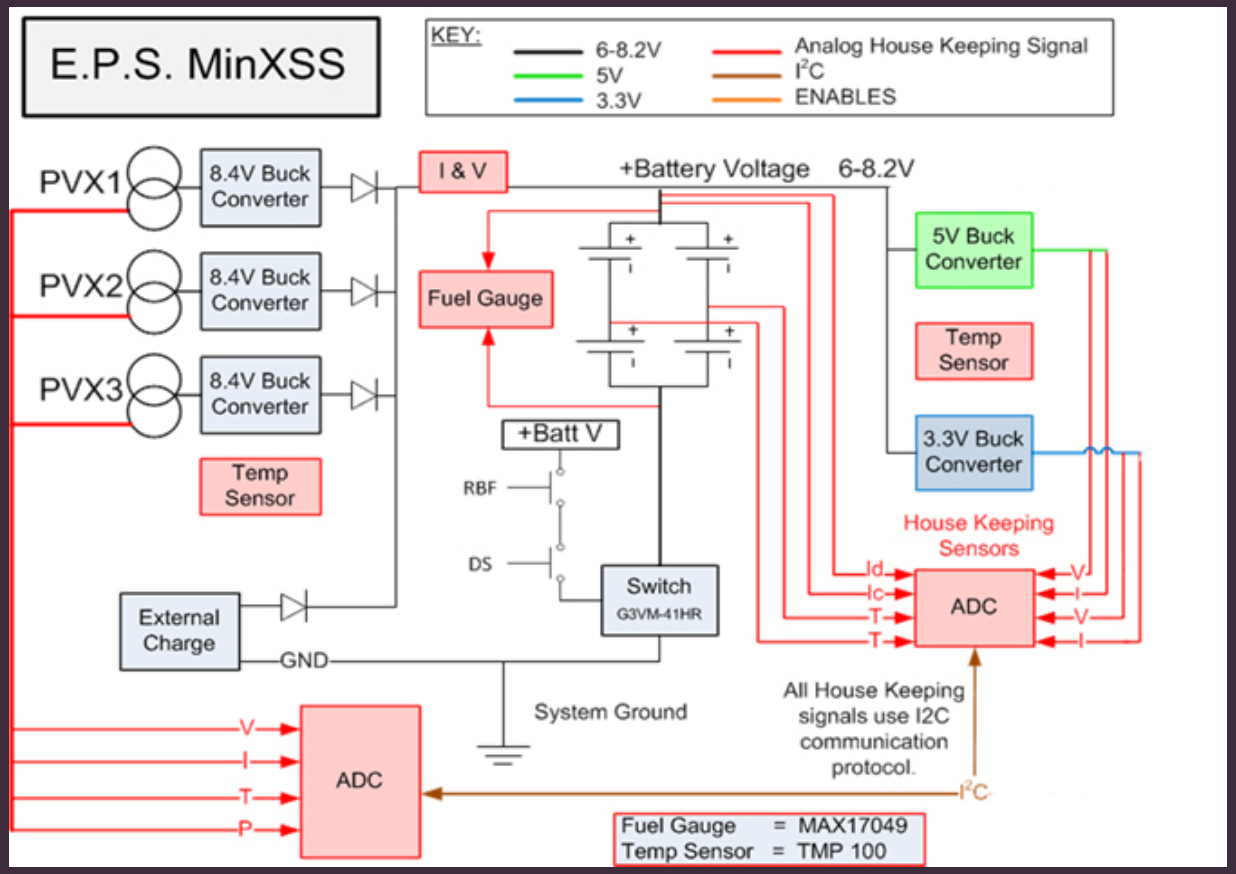

Charge Characteristics
Charge Voltage
Charge Capacity
Charge Current
Charge 4.2V max 1000mA 4h 23°C
Charge Current/mA
Charge Voltage/V
Charge Capacity/%
Charge Time／h
2000
1600
1200
800
400
0
5
4
3
2
1
0
125
100
75
50
25
0
0
0.5
1
1.5
2
2.5
3
3.5
4


Charging Current Characteristics
2000mA
1000mA
400mA
where charging for 4hours at 1000mA is 100%
Charge 4.2V max
Charging Capacity/%
Charging Time／h
100
80
60
40
20
0
0
2
4
6
8
10

Batteries

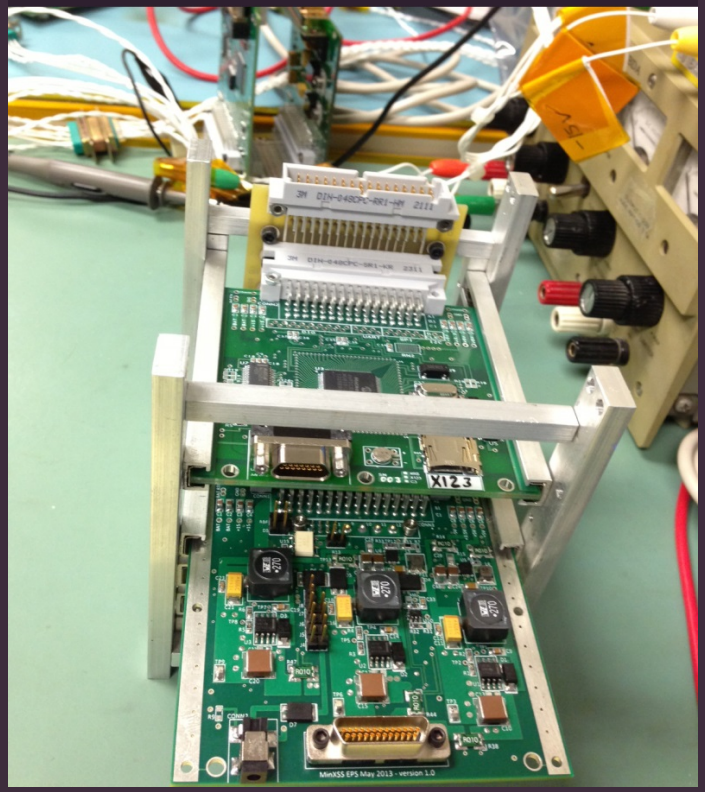

Discharge Profile
Voltage (V)
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
0
20
40
60
80
100
Discharge Capacity (% of nominal)
0.2C
0.5C
1C
2C
Discharge: 3.0V cutoff at room temperature.

Electrical Power System



Electrical Power System

- Regulates Power going to the various subsystems
- Solar Panel input
- Battery Charging



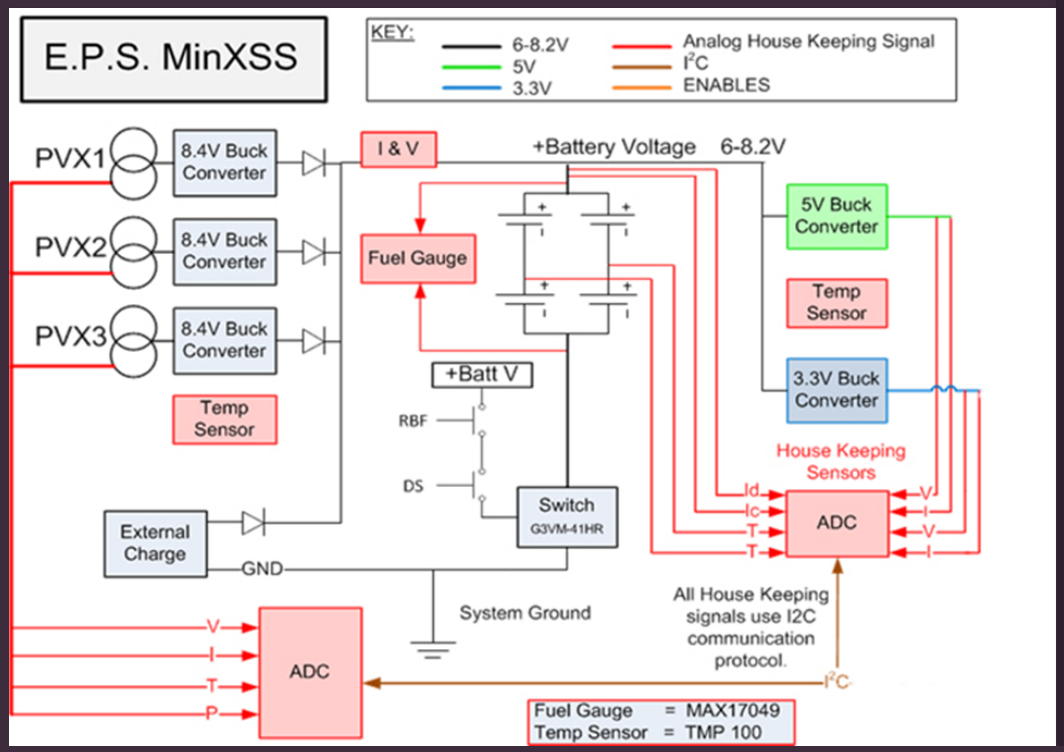
Software

- Communicate to various devices through Inter-Integrated Circuit or I^2C
- Read in raw data numbers and convert to Volts, Amps, and Temperatures

EPS Raw_07_22_13_11-16 - Notepad

File Edit Format View Help

```
>T1052212877.288 >VI(2)     12 mA   7832 mV     64 mA   3480 mV      8 mA   5008 mV <Z>
>T1052212877.513 >ADC(4)    282      280        284      283    <Z>
>T1052212877.918 >ADC(8)   3246     3041       2634     2092       39     1238       42     4092    <Z>
>T1052212878.098 >EPS(T)    28.3C    26.2C    27.3C<Z>
>T1052212878.233 >FG    50112        70    <Z>
>T1052212878.548 >VI(1)      0 mA    136 mV      0 mA    144 mV      0 mA    120 mV <Z>
>T1052212878.863 >VI(2)     12 mA   7832 mV     64 mA   3480 mV      8 mA   5008 mV <Z>
>T1052212878.933 >A 2051 2952    3  462<Z>
```



Software: Lessons Learned

- Talking to the various chips
- Understanding the raw data
- Making sure read data was correct data
- What if the problem wasn't software?
- Staying organized and commenting

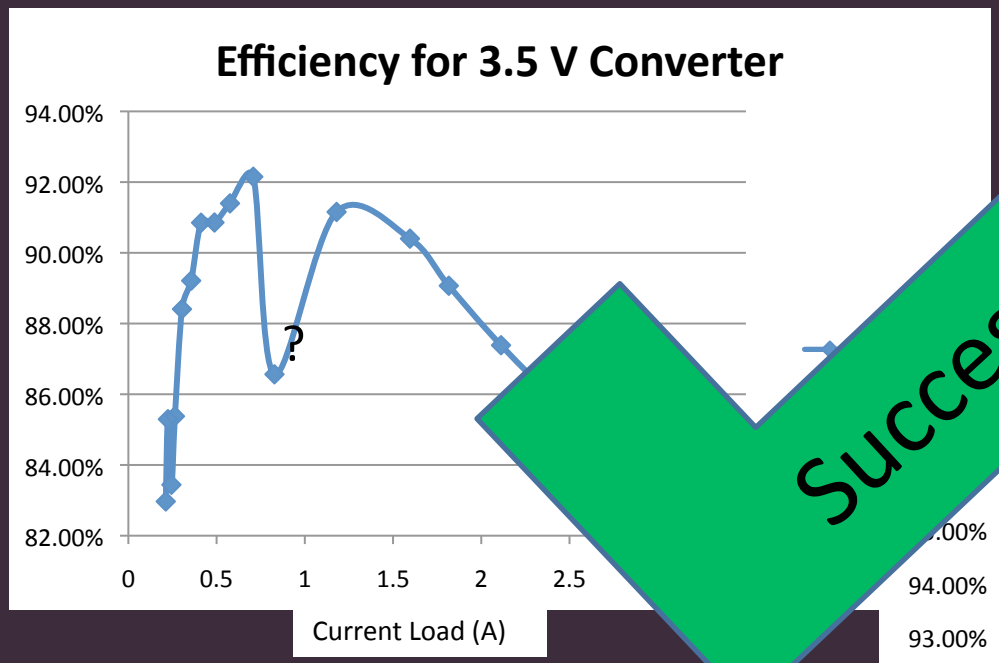
Testing: Why?

- Comparing modeled vs. actual
- To know and understand the limits of the EPS
- To know the efficiencies of the EPS design

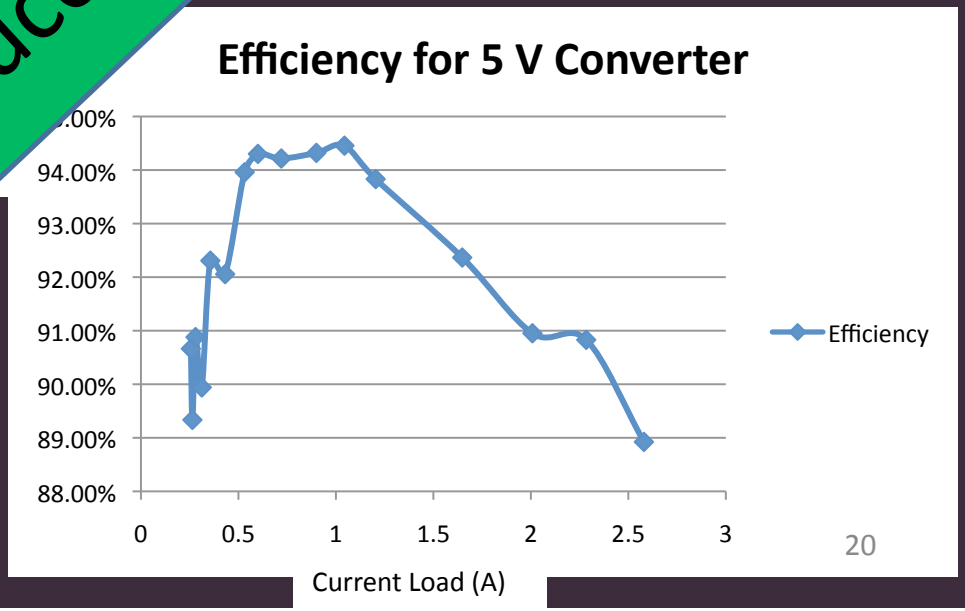
Testing: What?

- EPS components
  - Solar panel regulators
  - 3.5 V and 5 V regulators
- Batteries
  - Capacity
- Mission Simulation: “A Day in the Life”
  - Orbiting day and night

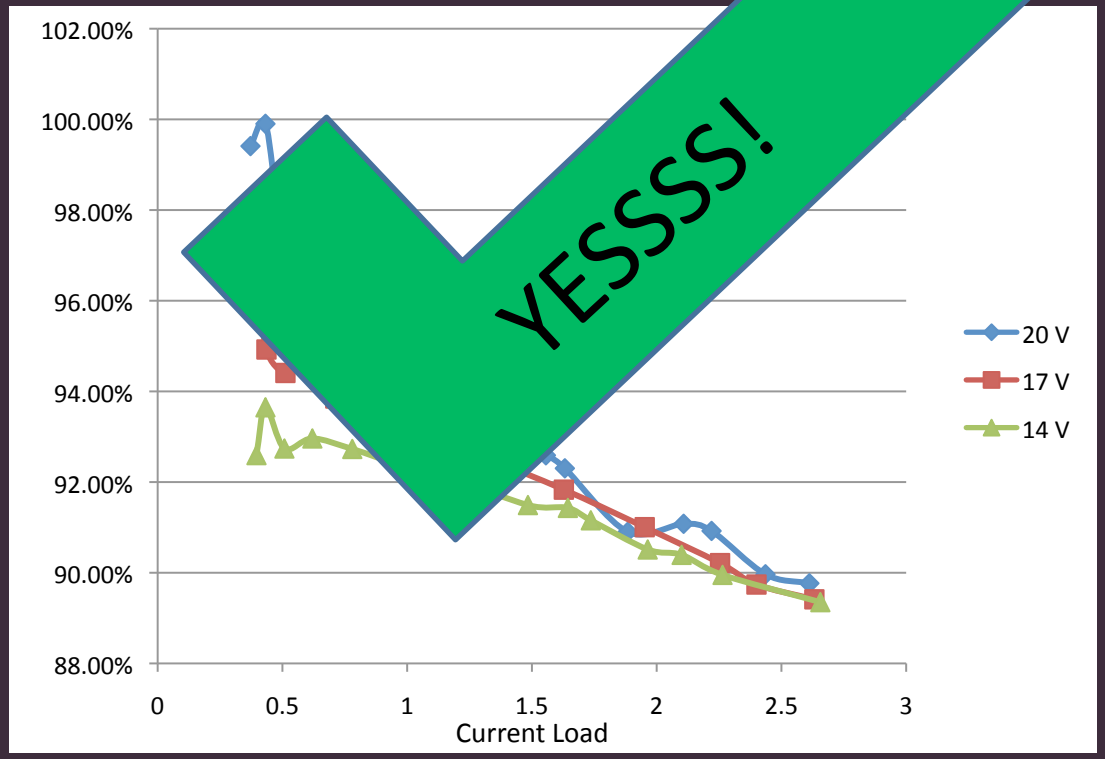
Testing: 3.5 V and 5 V Efficiency



Success!

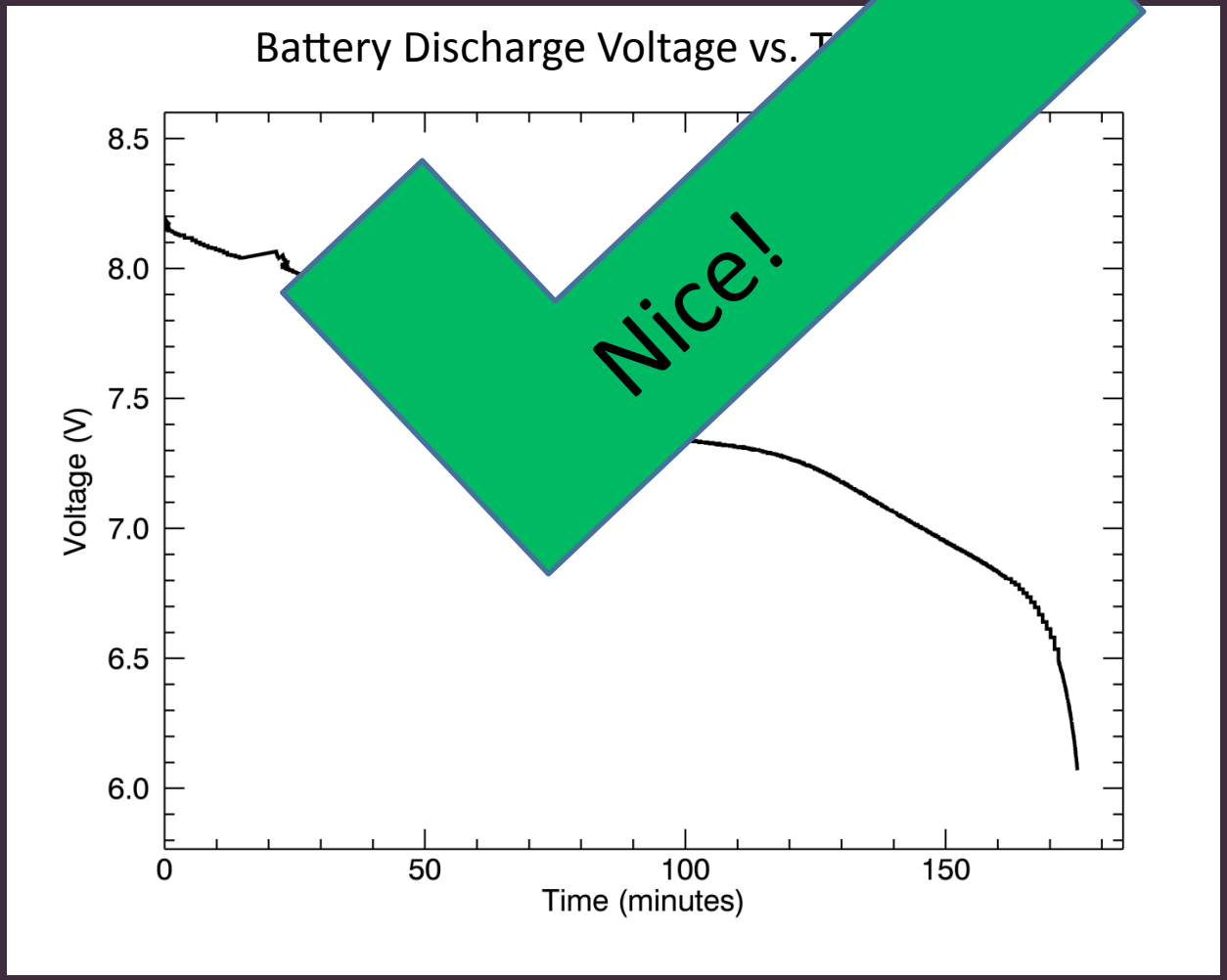


Testing: Panel Efficiency

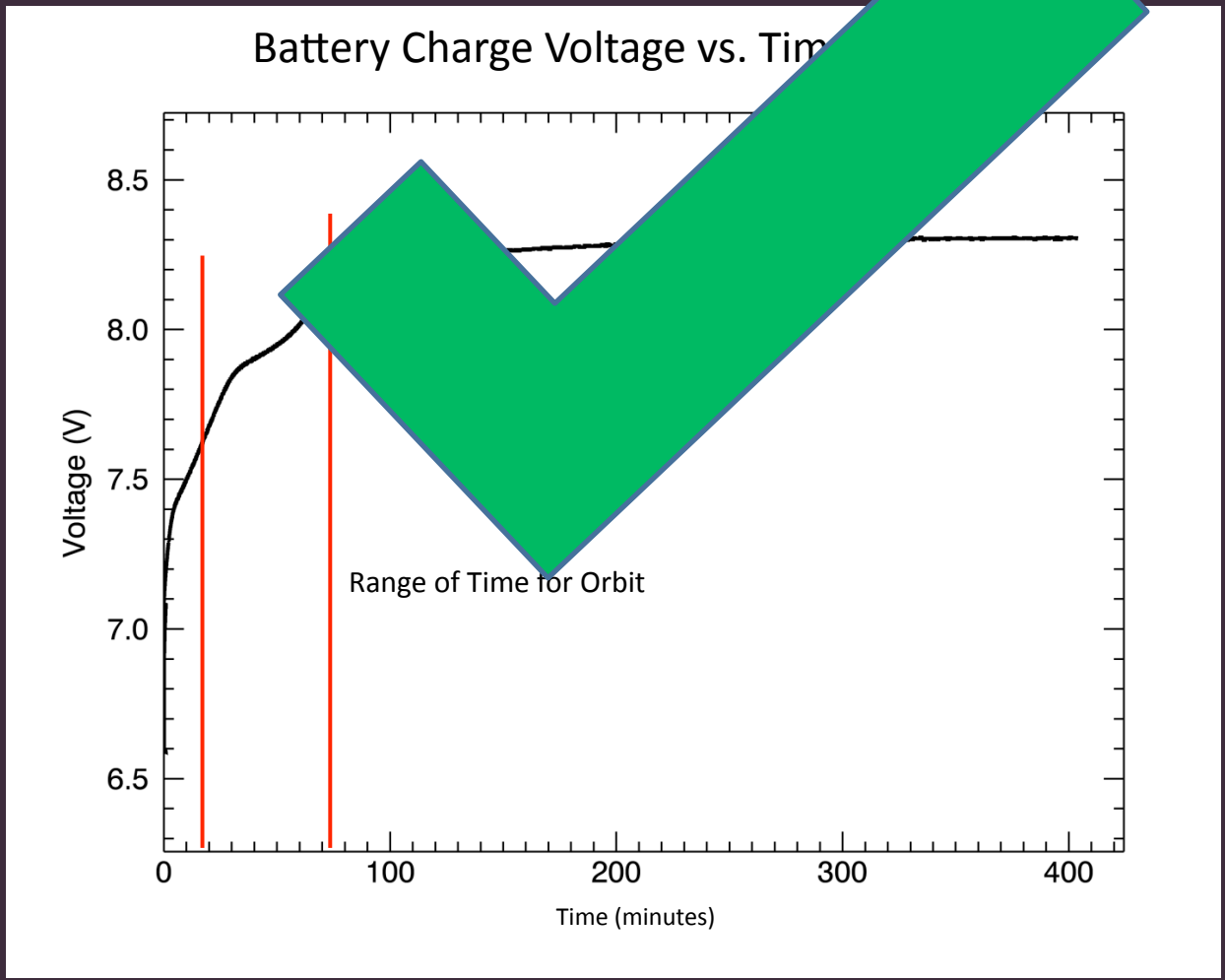


YESSSS!

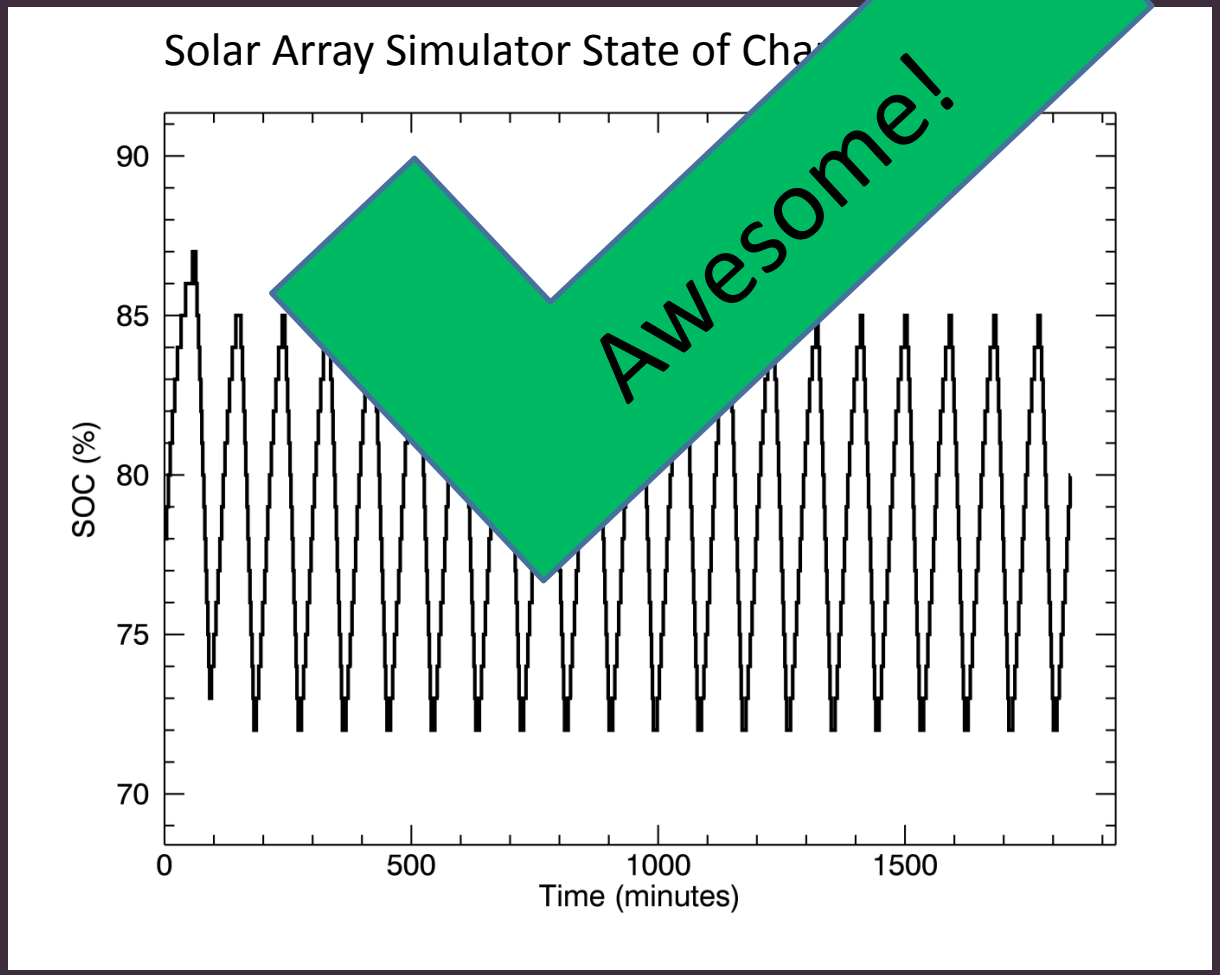
Testing: Battery Discharge Results



Testing: Battery Charge Results

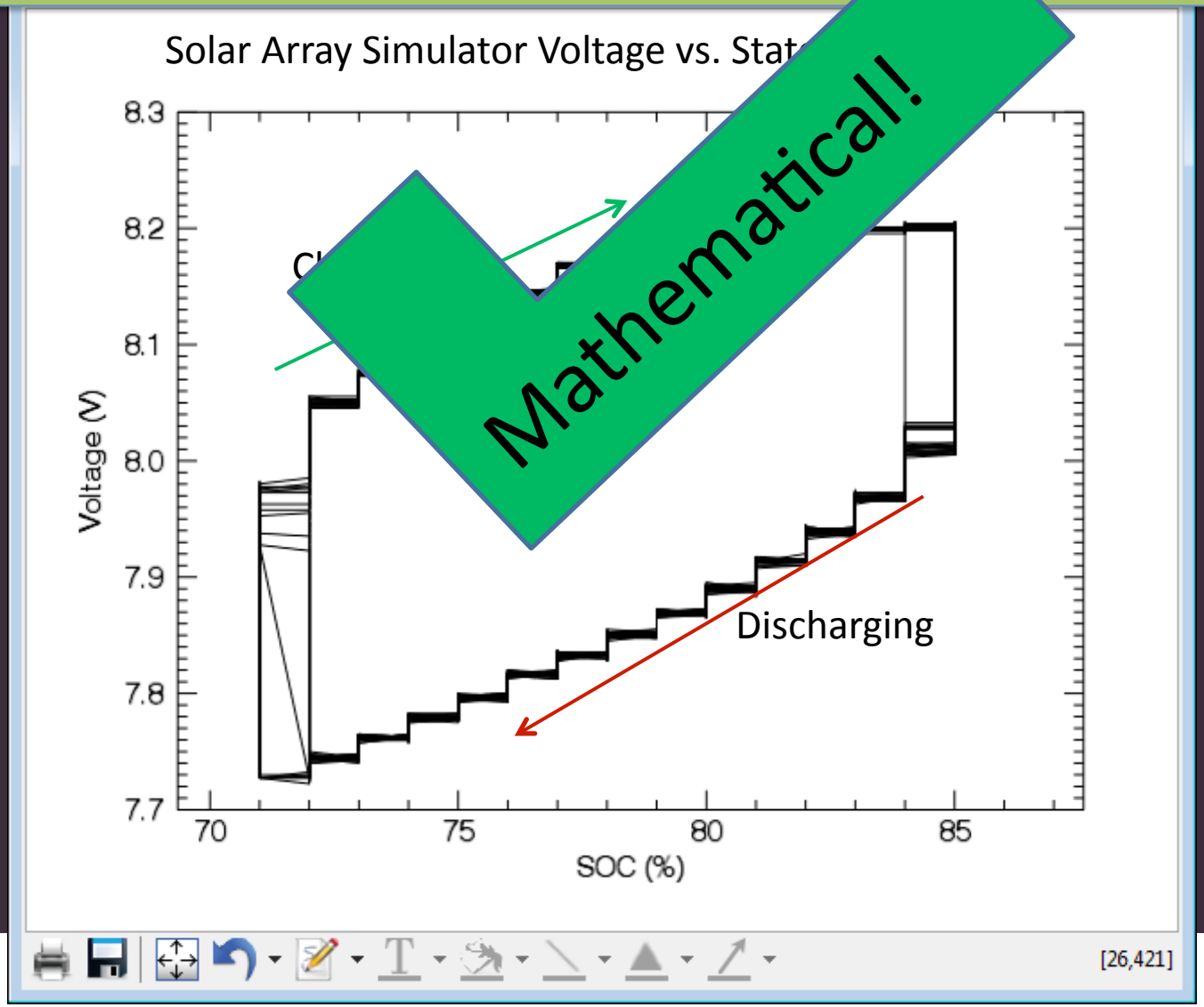


Testing: Mission Simulation Reveals Robust Desi



Awesome!

Testing: Mission Simulation



Conclusion

- The EPS board is populated correctly
- EPS design runs correctly and is efficient
- Slight modifications to improve battery charging

Acknowledgements

- Tom Woods
- Grad Students: Chris Sawyer, Matt Carton, James Mason
- Everyone on the MinXSS team
- Marty and Erin
- All the REU students
- Boulder for being awesome