An Affordable Test Equipment and Simulation Suite for CubeSat Development

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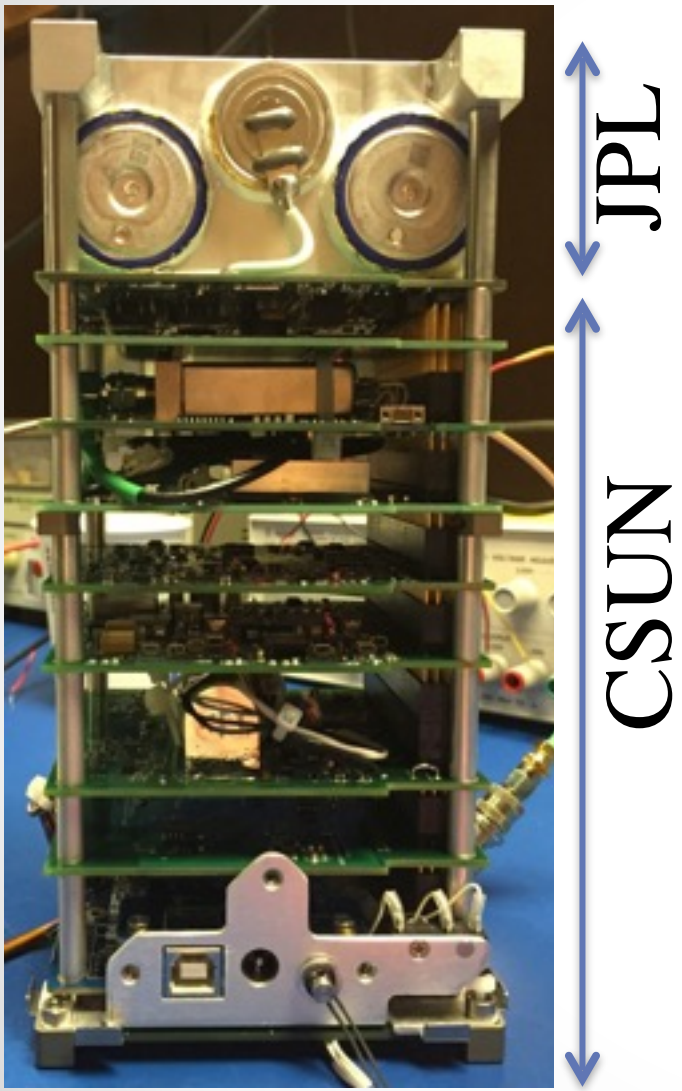
CSUNSat1: Project Overview

- CSUN / JPL Collaboration
- NASA STMD SmallSat Technology Partnership Grant funding
- Goal: Space test a JPL low temperature capable Li-ion battery / super-capacitor hybrid power system
- Mission Phases:
  - Run charge/discharge cycles on the power system at different temperatures
  - Transfer experimental payload battery into role of primary energy storage for the spacecraft

CSUNSat1: Spacecraft Overview

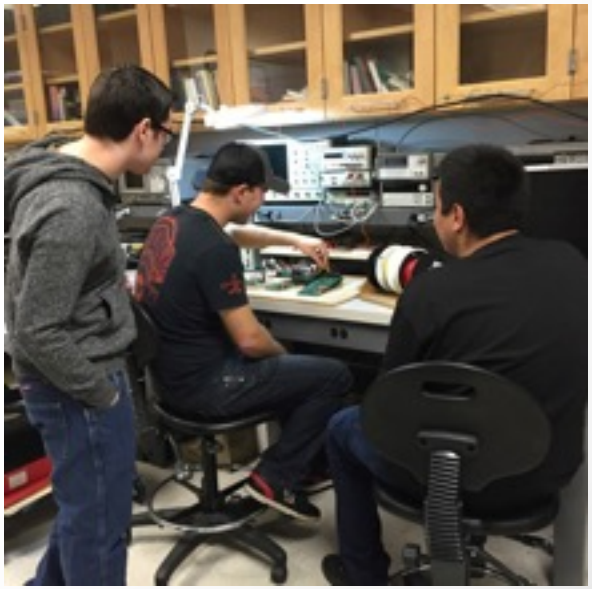


Team of 70+ CSUN students:

- Designed, built, tested customized power system
- Integrated Li-2 radio + Morse Code Beacon into comm system
- Wrote custom satellite software with no RTOS
- Created mission control and tracking software for ground station

CSUNSat1: Challenges/Solutions

- Challenges:
  - Our first CubeSat
  - Modest funding
  - No infrastructure other than standard classroom lab bench equipment
  - Power considerations are critical to mission
- Solution: Design a custom suite of test equipment
  - Battery simulator
  - Load simulator
  - Solar simulator



Solar Simulator: Overview

- Needs vs. Constraints
- Implementation
- Results

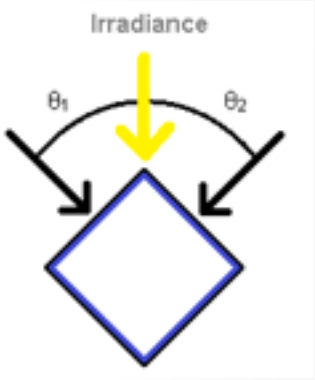
Needs vs. Constraints

- Needs
  - Power budget critical.
  - Decision made to system test from beginning.
  - Need to find problems as soon as possible.
  - Need to change battery in mid-mission.
- Constraints
  - Limited budget.
  - No existing infrastructure.
  - Aggressive timeline.
  - Zero space heritage – innovative design.
  - Long lead time for panel fabrication

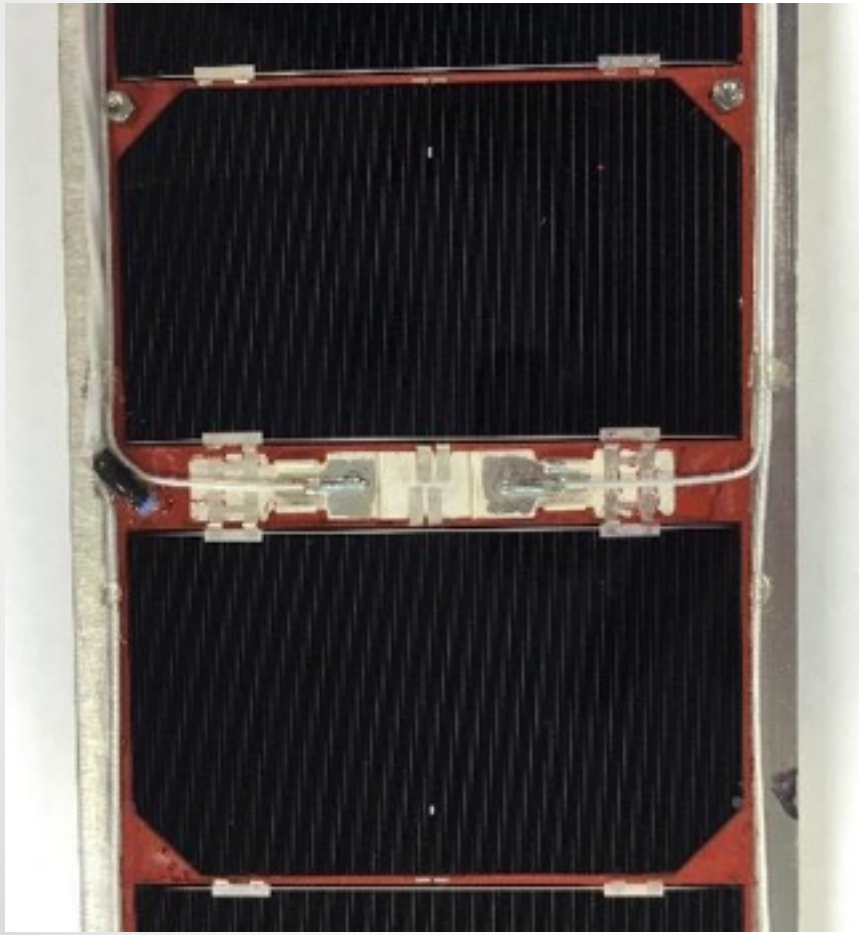
Bottom Line: Make our own "Sun and Panels"

Implementation: Requirements

- Simulator needed to simulate:
  - Impedance of solar panel for shunt regulator
  - Effects of attitude (tumbling)
  - Effects of eclipse/daylight periods
- Accurate to first order.
- Most concerned about area on I-V curve where shunt regulator would operate.

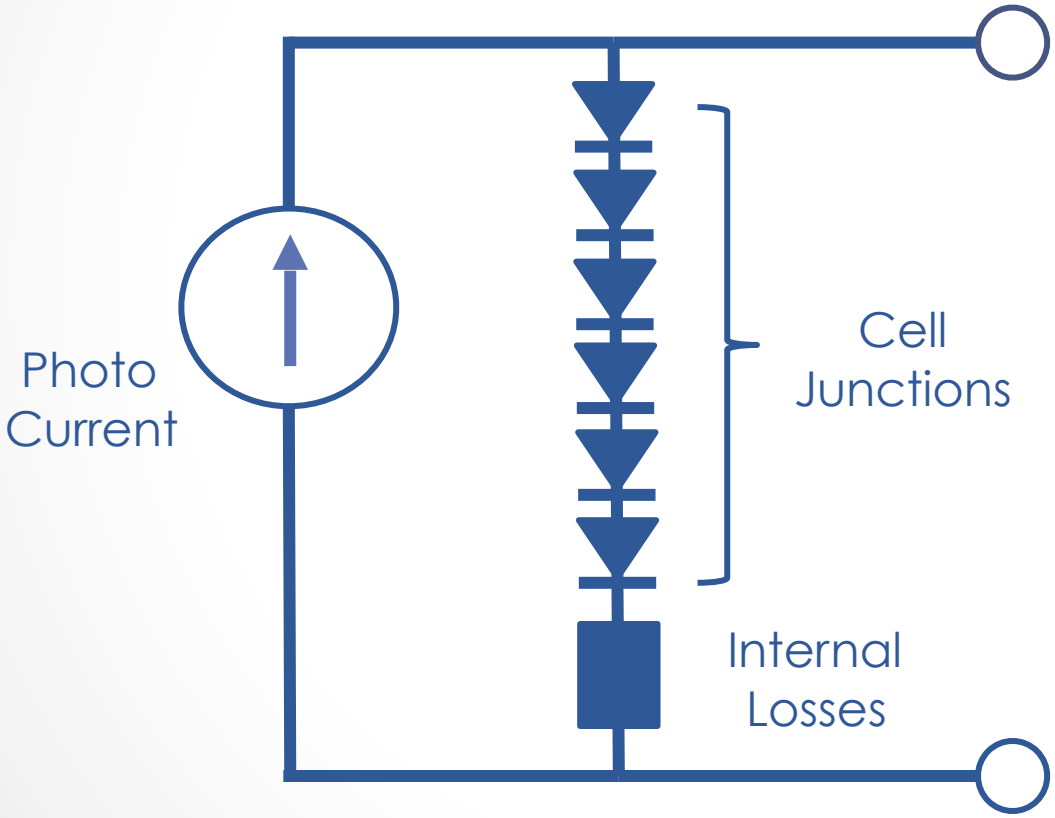


SpectroLabs XTJ Cell

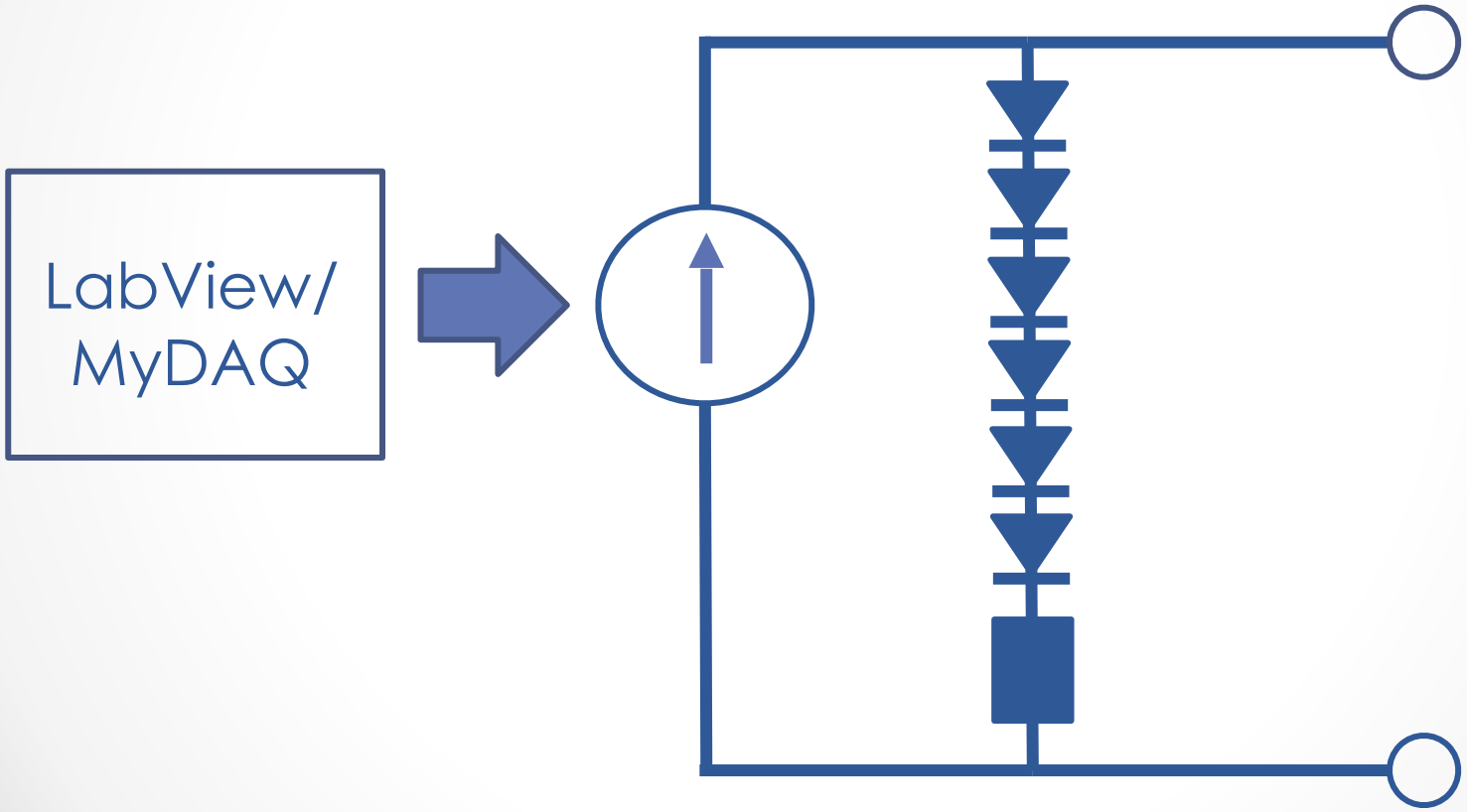


- Specifications (AM0):
  - 29.5% Efficiency
  - 17.8 mA/cm^2 Short Circuit Current
  - 2.6V Open Circuit Voltage
- Each panel has two sets of two in series combined through diodes in parallel.
- No panels on +Z or –Z sides

First Order Cell Model

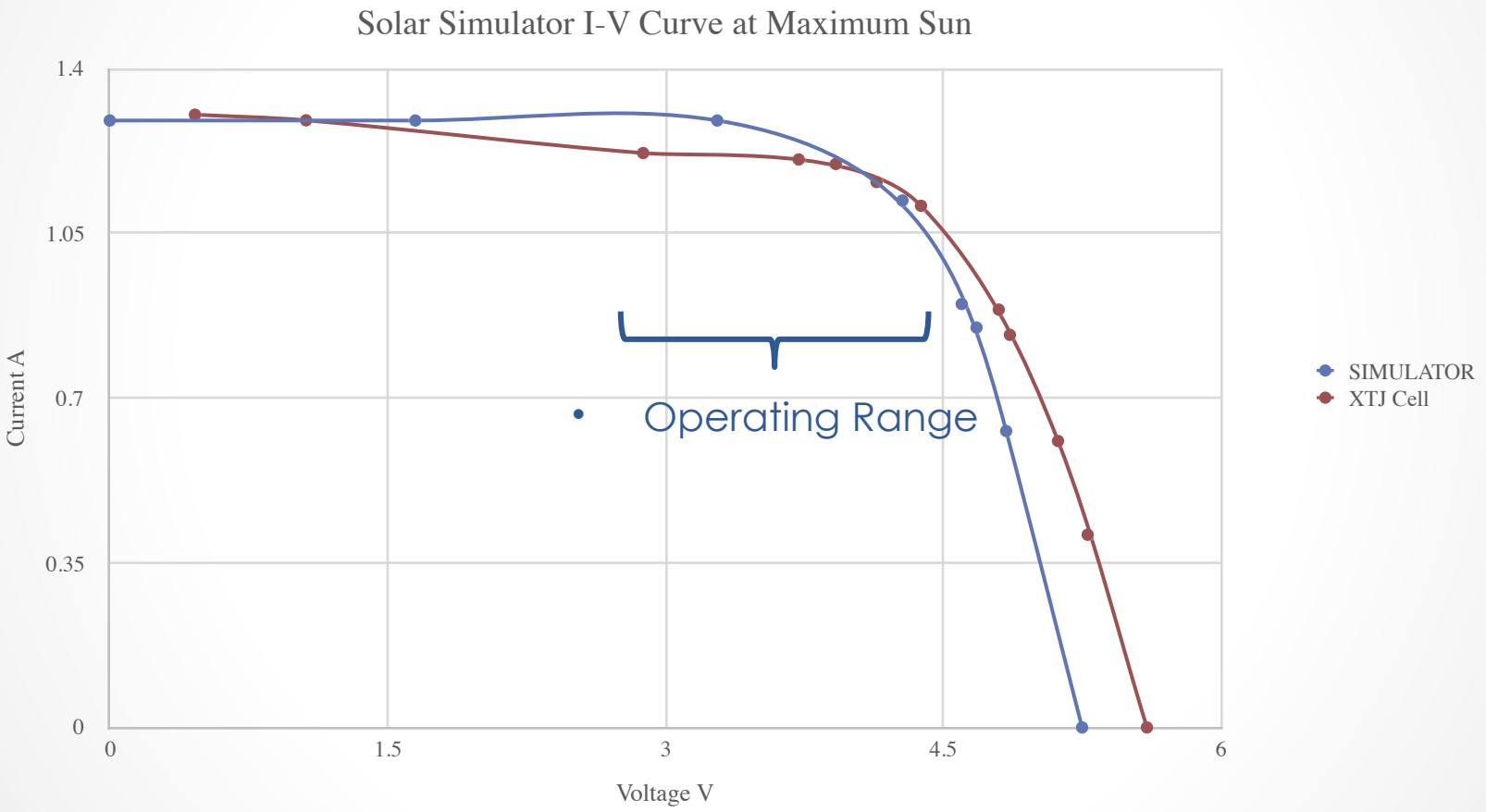


Implementation: Simulator



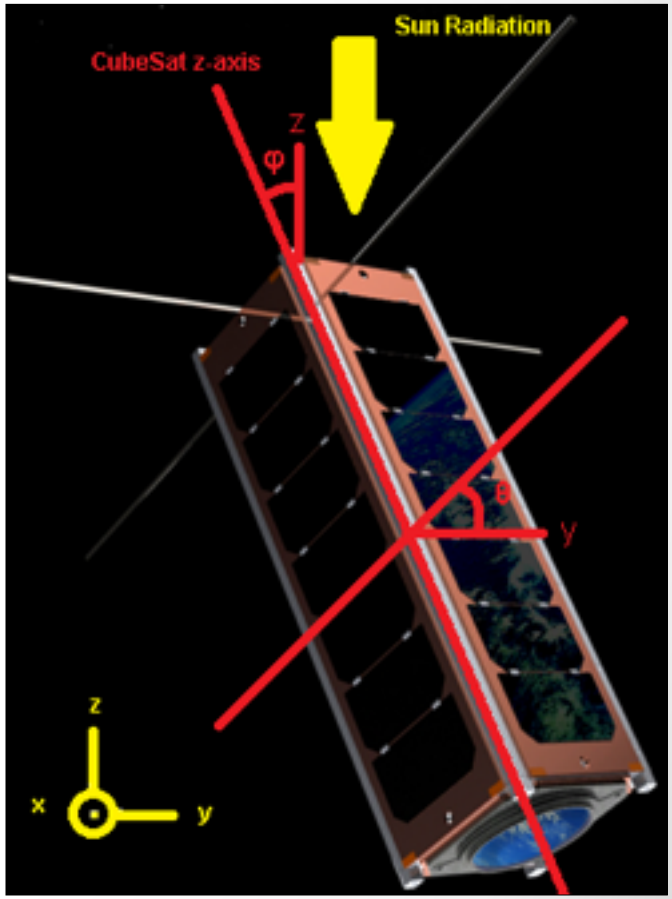
Simulate tumbling by controlling photo current source.

Implementation: Simulated vs. Actual



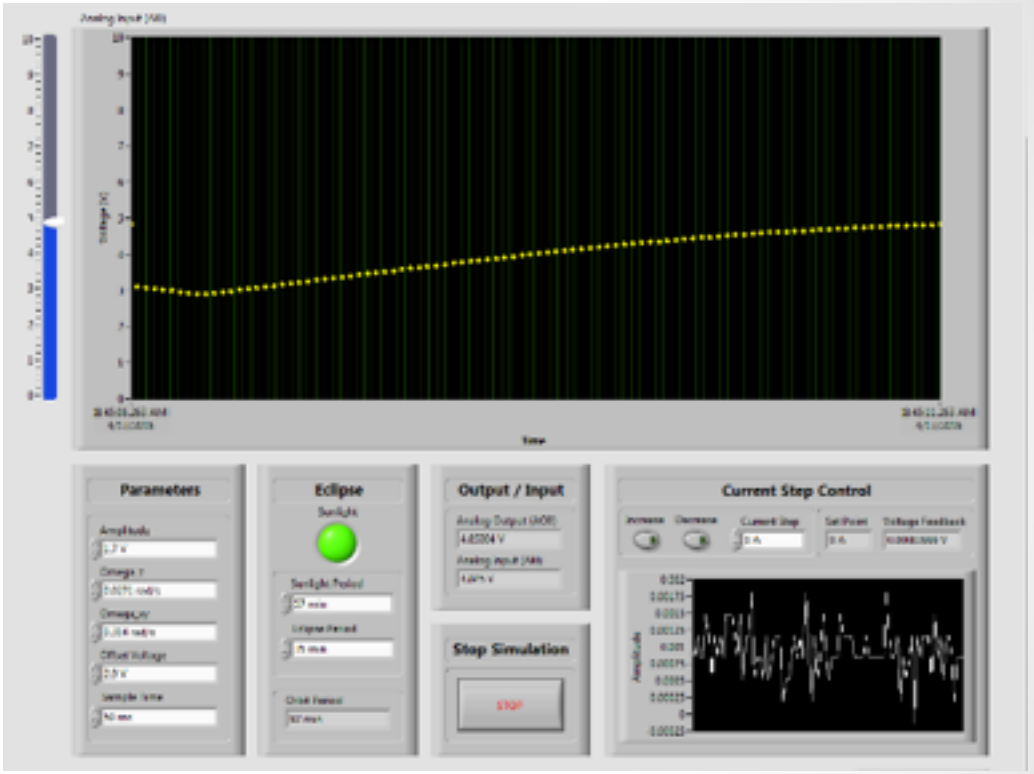
Implementation: Assumptions

- Photo Current = Ksinφ
  - Ignores cover glass refraction and slant distances between junctions
  - More conservative than reality
- Ignore thermal voltage change with temperature
  - TC_{VT} = -2.0mV/°C/junction or about -12mV/°C/panel
- Spacecraft will rotate about two axes. Ignore third axis since it does not affect incidence angle



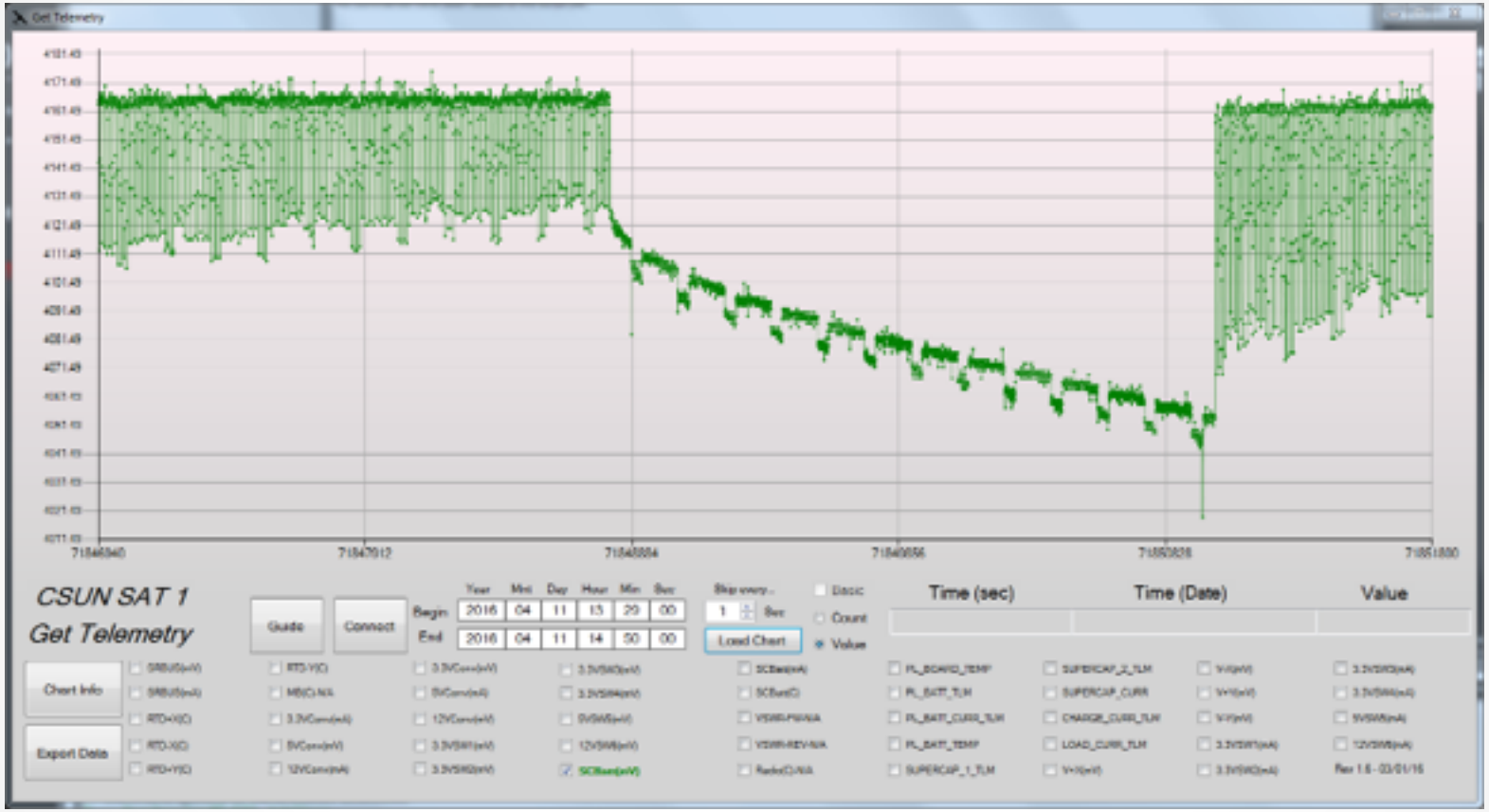
Implementation: LabView VI

- Controls:
  - Eclipse/Daylight times
  - Rotation Rates
  - Short Circuit Panel Current
- Simulates more than one panel in daylight
- Pin for pin replacement for solar panels



Total cost: under $100 (+ student labor)

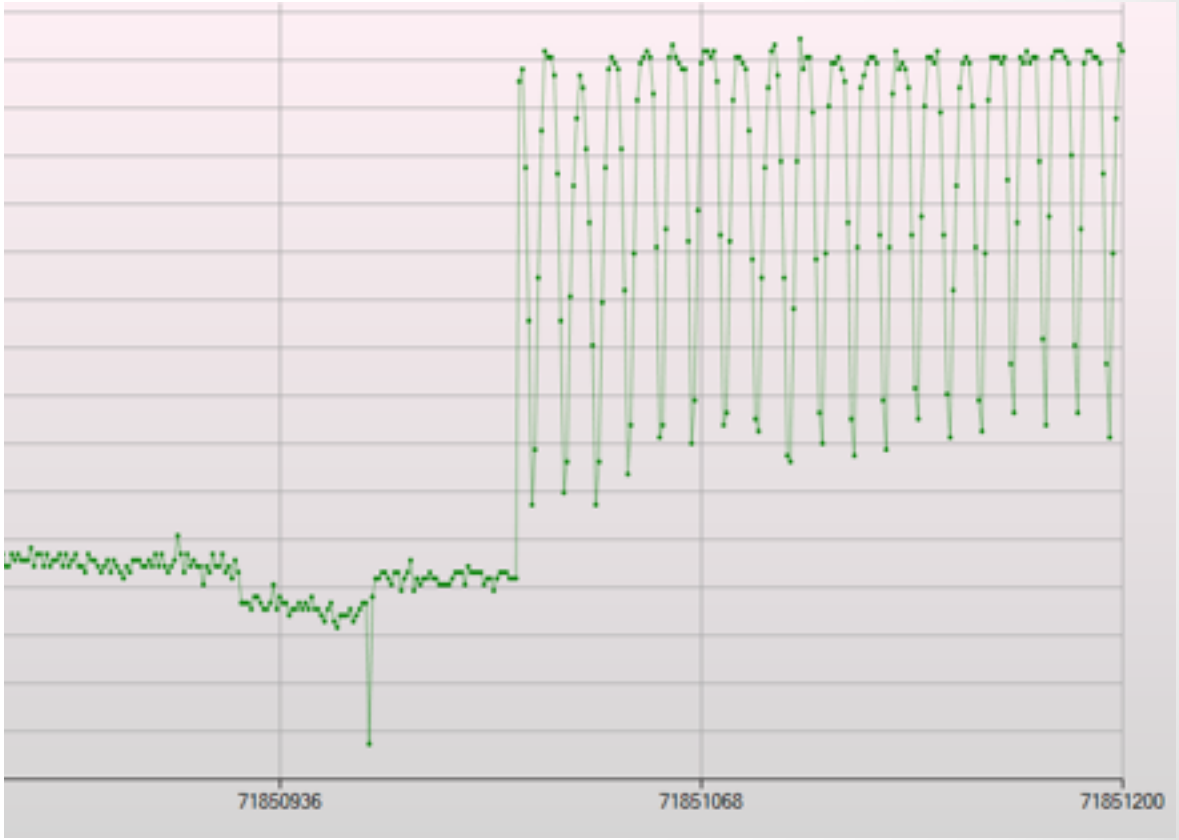
Results:



Over 16,000 hours of continuous operation!

Results

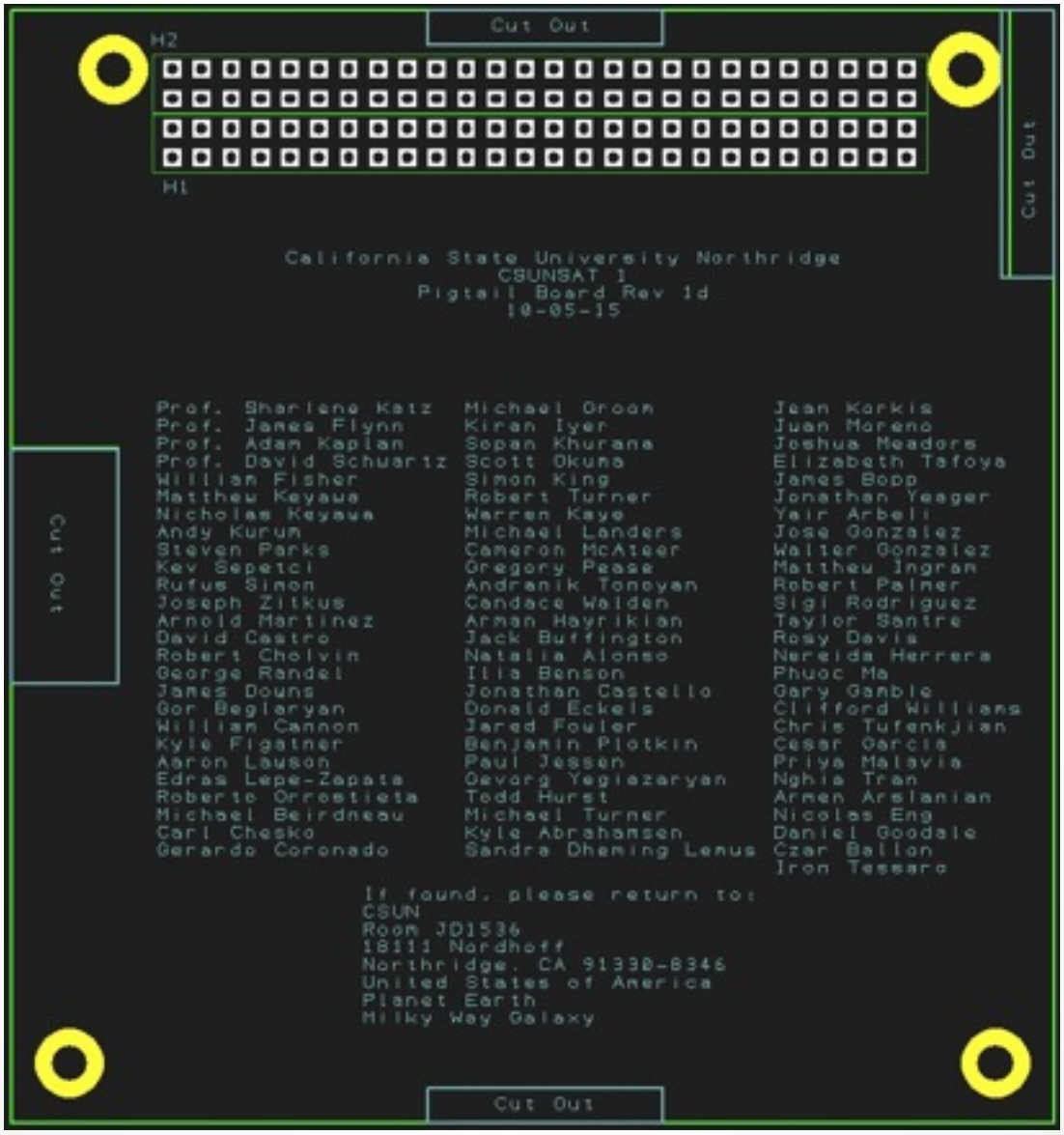
- Validated Power Budget Under Various Orbits: ISS, Polar, etc.
- Tested Initialization, Recovery From Dead Battery
- Allowed Long-Term Integrated System Testing
- Successful Battery Change - Over Without Restart



Summary

- CSUN has designed and implemented a low cost Solar Simulator for bench testing of CubeSats using LabVIEW and widely available components
- CSUNSat1 is complete and ready for launch (tentatively scheduled for Dec. 2016). CSUN is currently looking for a new CubeSat project.

Questions?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