Power Subsystem for Radar Microsatellite - Modular Hardware Development and Operational Experience

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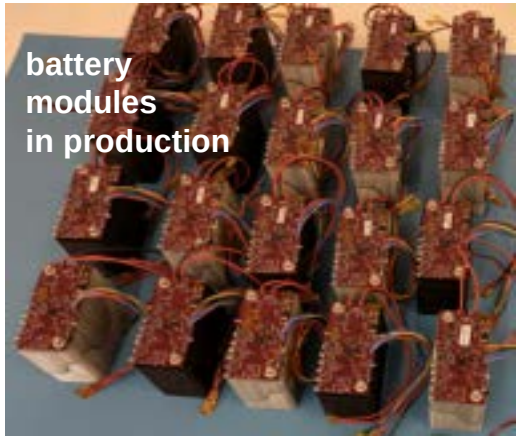
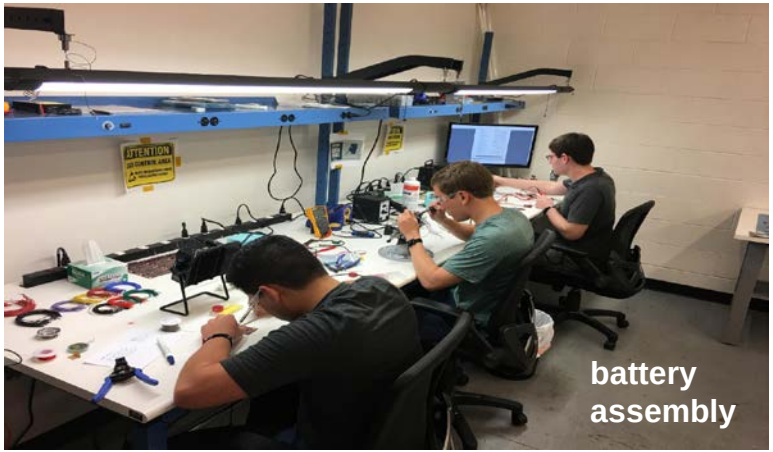
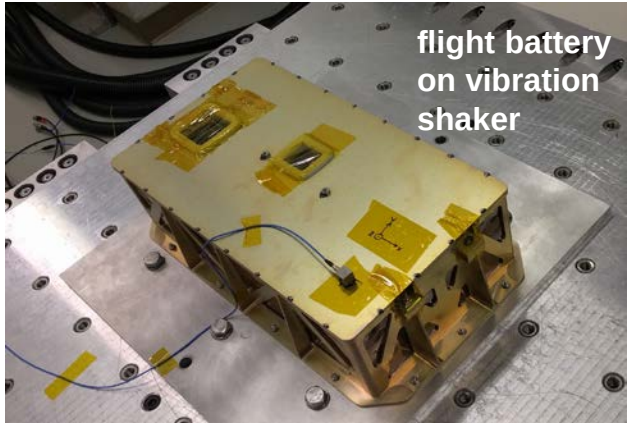
Space Power Workshop, Program Experience - 04/02/2019

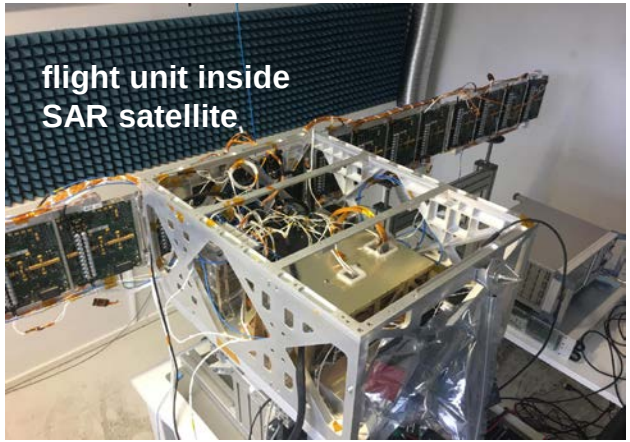
Who is Stellar Exploration, Inc.?





Smart Battery Production





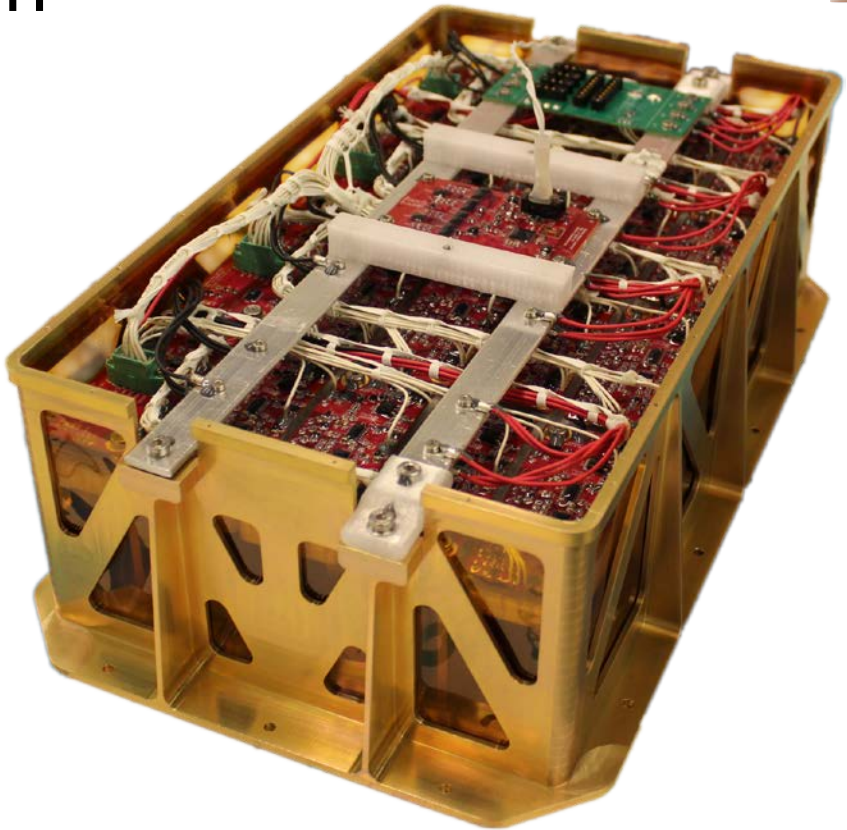
Iceye SAR Microsatellite Design Requirements

- Battery system to deliver 3kW for 30sec every 90 minutes
  - ~15,000 SAR images in 3 Years
- Battery packs, unregulated +28V (26-34V), are charged by solar panels
- Interface with Solar panels — 17 cells x 12 strings
  - ~ 200 W (peak) @ 34-44 V (load, hot/cold), up to 52 V (OC, cold)
- Charging current ~10 A
- mass ~11 kg

POWER SHOULD BE SIMPLE → ELIMINATE DESIGN COMPLEXITY while MAINTAINING BATTERY INTELLIGENCE

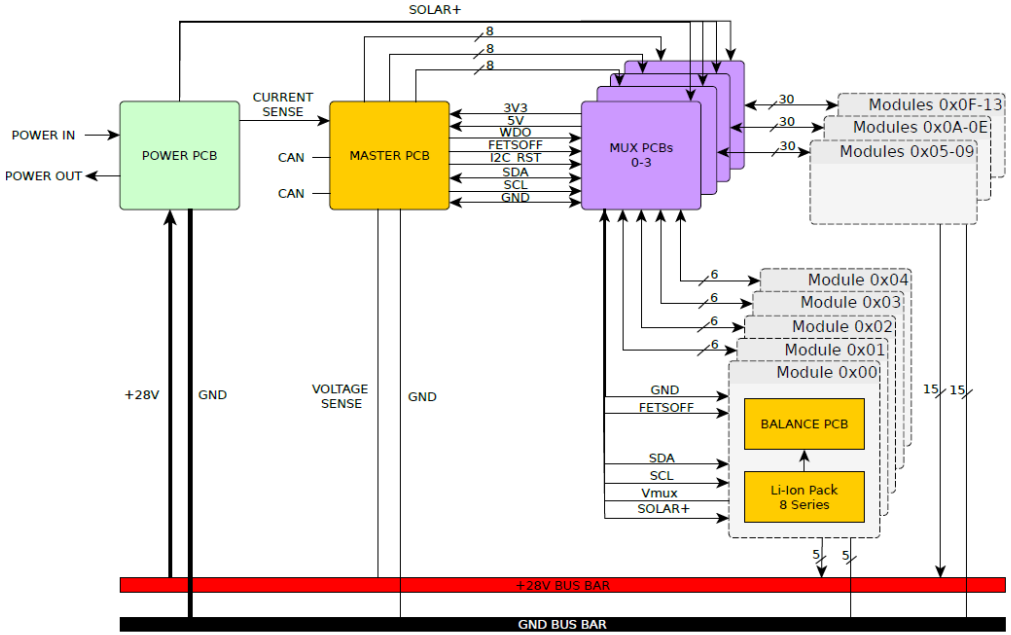
Battery Specification

Function	Value
Maximum Dimensions	429.5 x 249 x 128 mm
Total Mass	11.13 kg
Output Voltage	28 V
Maximum Capacity	1400 Wh
No Load Standby w/ Modules Awake	120 Days
No Load Standby Time w/ Modules Shutdown	350 Days
Gravimetric Energy Density	126 Wh/kg



HIGHEST POWER DENSITY PER WEIGHT

Smart Battery Block diagram



Balance PCB:

1. Module monitoring
2. Balancing functions
3. Cell charging
4. Input and output protection

Mux PCB:

1. Communicate with the master

Master PCB:

1. Aggregate data
2. Overall Battery Current/Voltage
3. CAN interface with spacecraft

✔ **Battery BMS - Health and Performance Monitoring**
✔ **Cell Balancing and Protection**

Why Li-ion 18650 Cells?

Samsung INR18650-25R

Charging to 4.2V/cell and discharging down to 2.75V

High Energy Density

Calm and Cool during charge

No rapid self discharge

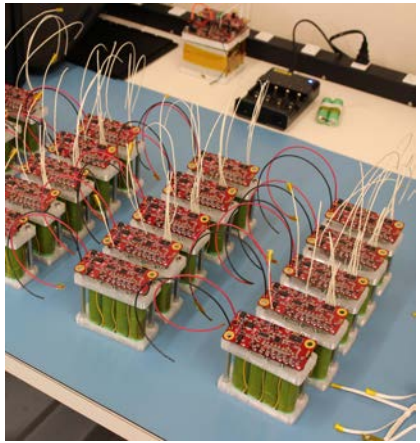
Item	Specification
Nominal Discharge Capacity	2,500mAh **Charge**: 1.25A, 4.20V,CCCV 125mA cut-off, **Discharge**: 0.2C, 2.5V discharge cut-off
Charging time	Standard charge : 180min / 125mA cut-off Rapid charge: 60min (at 25℃) / 100mA cut-off
Max. continuous discharge (Continuous)	20A(at 25℃), 60% at 250 cycle
Cell weight	45.0g max

http://dalincom.ru/datasheet/SAMSUNG%20INR18650-25R.pdf

Industry Qualified
&
Lightweight with Exceptional Performance

Modularity and Redundancy

- The battery is made of 160 18650 (2500mA) cells
- 8 cells per module
- 5 modules per columns
- 4 columns per battery -> 850Wh, max 1400Wh
- Master PCB has 4 possible inputs of power



This allows for per module redundancy

A watchdog can re-start a battery when such failure is detected

One module can fail, however ALL other 19 modules will still be operational

Mechanical Structure Design

- 3D Printing module encasing
  - Polycarbonate
    - Strength properties
    - Strong, very resistant to impact, extremely tough and durable thermoplastic material (very resistant to temperature)
    - Perfectly good use for radar satellite
  - PEEK
    - Exceptional mechanical, thermal, and chemical resistance properties
    - Better use for optical application due to lower outgassing
- Use off the shelf mechanical components
- Chassis is aluminum CNC + Chromate Coating
  - No weld joint failures

Rapid Mechanical Structure Iterations

Software Design

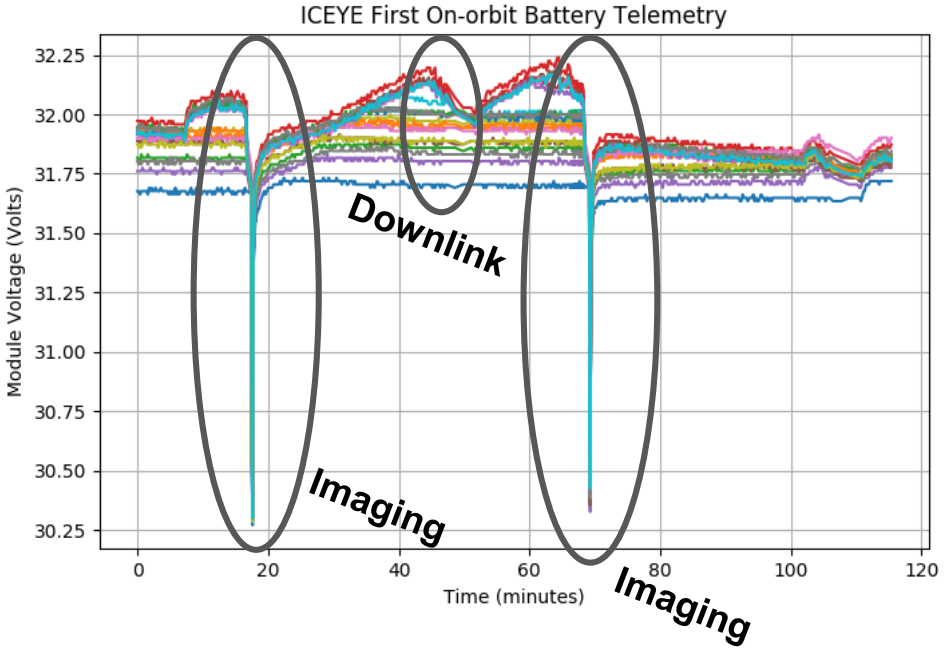
- FreeRTOS
  - Professionally developed, strictly quality controlled, robust, supported, does not contain any intellectual property ownership ambiguity
  - Free to use in commercial applications without any requirement to expose your proprietary source code

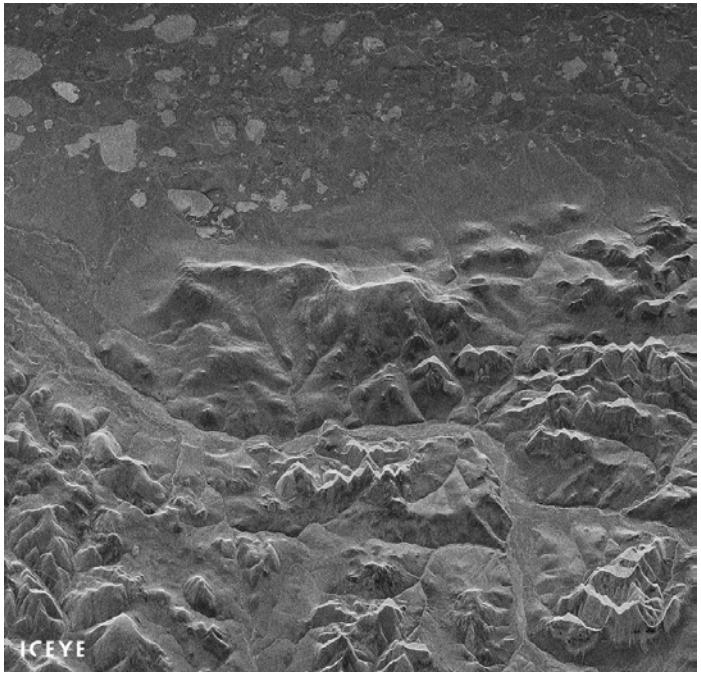
- OBC reference package
  - Python scripts to allow communication with the battery pack using the same interface as the onboard computer will use
  - Scripts are written in such that it should be easy to swap this out for any other CAN interface hardware

Reliable, Robust, and Agile Software

Operational Experience

- 10 Batteries built to date
- 3 batteries in orbit right now

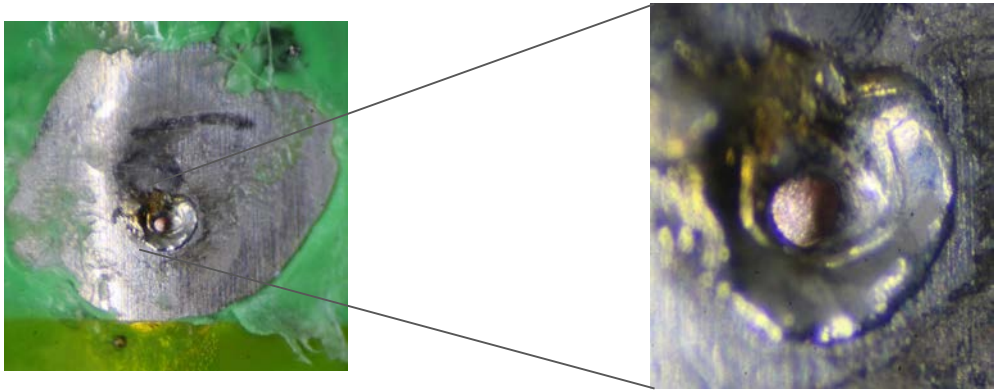




ICEYE-X1, Noatak National Preserve, Alaska

Lesson Learned

- Choose reliable Power Management/Balance IC for cells
- Allow for plenty of margins when it comes to component selection
- Redundancy is important! Design for low level redundancy to eliminate system failure
- 3D printing allows for design flexibility
- Maintain patience



THANK YOU FOR LISTENING!

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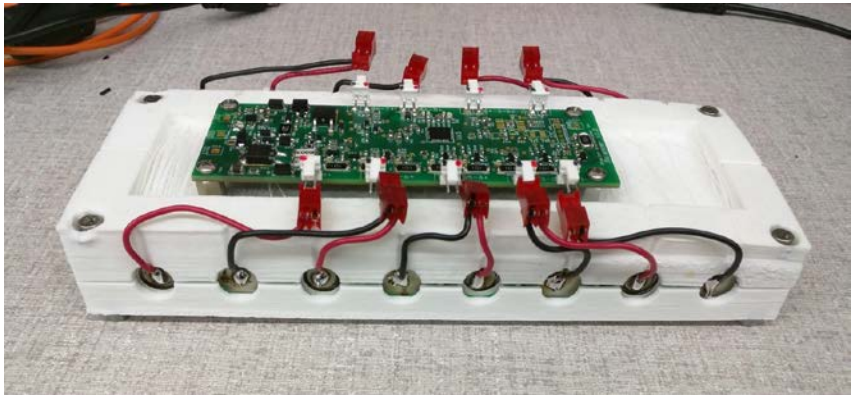
Q&A Session

Backup Slides

Testing Procedure

1. Module Level
    a. Telemetry link
    b. EEPROM programing
2. Column Level
    a. Appropriate telemetry
    b. Discharge/Charge test, Short circuit test
3. System Level
    a. Vibe testing
    b. 50 Cycle Test (~120A with a ¼ Ohm load for 30 seconds and then allowed to charge for 16 minutes)
    c. Vacuum Charge/Discharge

Original Design



VS.

Current Design