EQUiSat: Space for $3,776.61

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Mission
Accessibility

● Parts cost $3,776.61 in total
  ○ Cheaper than one subsystem in most commercially available CubeSat systems

● Fully open source hardware and software
  ○ Design documents: https://brownspace.org/equisat-resources
  ○ PCB schematics: https://github.com/BrownSpaceEngineering/EquiSat-EAGLE
  ○ Code: https://github.com/BrownSpaceEngineering/EQUiSatOS

● Public engagement
Test Lithium Iron Phosphate batteries in space for the first time
- Notable for their ability to supply high current on low notice
- Required in EQUiSat to drive the high-powered LEDs, which have been observed to draw up to 15 A each

The batteries performed as expected, but there will be more detailed analysis later in this presentation and in a paper to be released soon
Work Organization

Five different subgroups of about five members each:

- Avionics hardware
- Avionics software
- Power (payload and EPS)
- CAD
- Manufacturing

All undergraduates
Subsystems
Chassis

- Mono-Block Aluminum
- CNC Mill
- 90 Hour machining time
- tabs/shelves
- Sturdy
- Steel attachment plate Thermal
- anodization

- Chassis was manufactured from a mono-block of aluminum alloy 6061
- Positives
  - It is cheap and soft enough to be milled
  - High strength made any trusses/skeleton structure unnecessary
- Drawbacks
  - Milling process took Mono-block took between 90 and 100 hours of machine time
  - Occasionally during the drilling process of deployment switches the mill head would be dislodged and damage the chassis, rendering it useless
- Another manufacturing concern was the buckling of the chassis due to pressure from holding plates during milling
Damaged Prototype
Structure

- 4 tabs as mechanical support for the battery bank and electronics
- Steel attachment plate supports battery block on top of tabs
- Chassis and attachment plate responsible for structural support, electrical grounding and thermal sinking
  - Rails are anodized to prevent cold welding
  - Internal faces of rails were not anodized for heat transfer
- Cho-Therm 1671 was used to transfer heat from source components to the sink
  - i.e. between radio and attachment plate
Control Board & Sensors

- ATMEL SAMD21J18A processor
- 6 subgroups
- Double redundancy of OS
- Triple redundant ADS

- Central control board with processor
- 6 different schematics based on function
  - Microcontroller, LED driver board, solar panels, radio, power regulation and the sensor multiplexor
- OS stored in two radiation safe MRAM chips
- Suite of triple redundant ADS sensors
Electrical Power System (EPS)

Batteries:
- 2 3.7V Li-ion
- 4 3.3V LiFePO$_4$ (Lithium-Iron-Phosphate)

Solar cells:
- 160 TrisolX Solar Wings

Solar panel coating:
- NuSil CV 2500

Solar panel details:
- Cells arranged in 8 rows of 4 cells on 5 panels
- Generate 1.08 W minimum, 1.46 W maximum
- Power routed to MPPT (Maximum Power Point Tracking) chip which optimizes distribution to the charging circuit
- Wings were tedious to solder, coating is expensive

Battery board details:
- Batteries soldered directly to the board
  - Bad! Hard to maneuver, solder
- Software determines which bank of batteries to charge
- Connected to control with thick bundle of wires
  - We would recommend using connectors instead whenever possible
- Has performed thousands of charge-discharge cycles so far on-orbit
Flash

LEDs:
- Luminus CHM-27-50 LED
- Each draws 108 W at 36 V and 3 A

- Estimated apparent magnitude of 3
- LiFePO$_4$s required to provide high current
  - Up to 60 A per flash
- Flashed approximately 1,500 times in the year since deployment
- Not yet seen
  - Likely due to ACDS issues
  - We used passive attitude control - two hysteresis rods and a small magnet
  - We have observed consistent rotation at a very low rate on all axes
  - Makes observation of a flash significantly less likely
Radio

- XDL Micro from Pacific Crest
- Transmits in 4FSK at 435.55 GHz

- Uses proprietary encoding
- This fact escaped early designers, became a big issue when building the ground stations
- Ground stations had to have their own XDL Micros
- After deployment, we were able to reverse engineer the decoding process
- Results published on GitHub https://github.com/BrownSpaceEngineering/gr-equisat_decoder
- Online decoder at https://decoder.brownspace.org/
- Now, a significant portion of our data can come from SatNOGS
Antenna Deployment

- 20 cm nitinol antenna
- 10x10 cm face of satellite

- Tied antenna into a circle using nylon
- Nylon wrapped through nichrome loops connected to a MOSFET
- PWM signal to MOSFET cause nichrome to heat up, burning the nylon and releasing the antenna
- Triple redundant
  - One loop powered by each bank of batteries
- Tested extensively in vacuum chamber
- Nylon tying had to be triple checked
  - If it was tied at all incorrectly the antenna would stick
- Redundancy was essential
  - Early data indicates that the antenna may have not deployed right away
What’s next: PVDX
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