

GEM Student Tutorial: Cubesats

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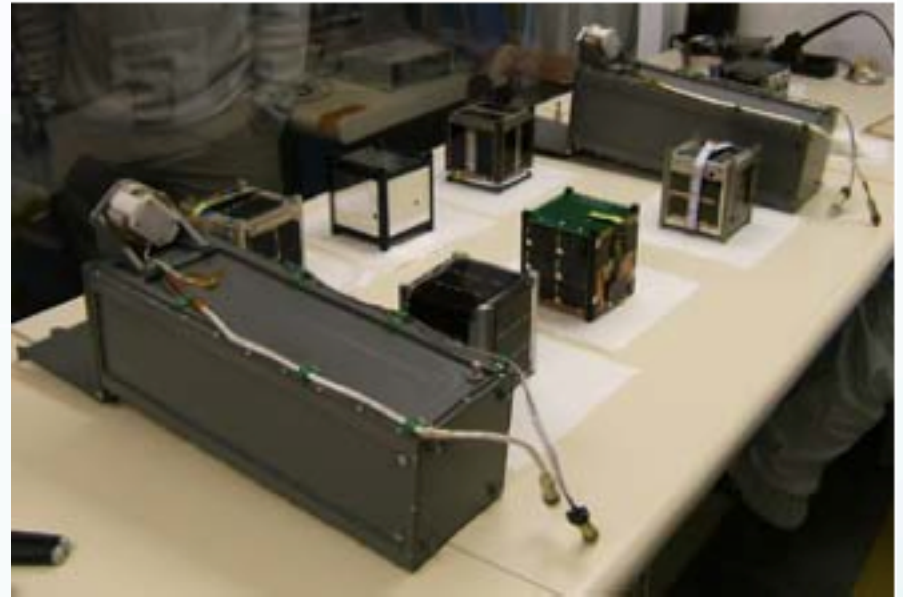


Outline

- What is a Cubesat?
- Advantages and disadvantages
- Examples of Cubesat missions

What is a cubesat?

- Originally developed by California Polytechnic State University
- Designed to provide access to space for small payloads
- Idea of a standardized micro-satellite



What is a Cubesat

- Originally idea a 10x10x10cm cube
- Now can create payloads of up to 3U (10x10x30cm) and 4kg mass
- Standardized sizing/interfaces/requirements for deployment
- Poly Picosatellite Orbital Deployer (P-Pod) is launcher for Cubesat from rocket
- Secondary payload on a rocket

Advantages and Disadvantages

- Smaller scale
- Cheaper
- Faster mission timeline
- Student (especially undergrad) involvement
- Easier to target to a specific research question

- Very resource limited (power, mass, telemetry)
- Often limited to a single instrument
- Low-budget = harder to develop new hardware
- Secondary payload means less control over orbit, schedule

Develop for a single research question

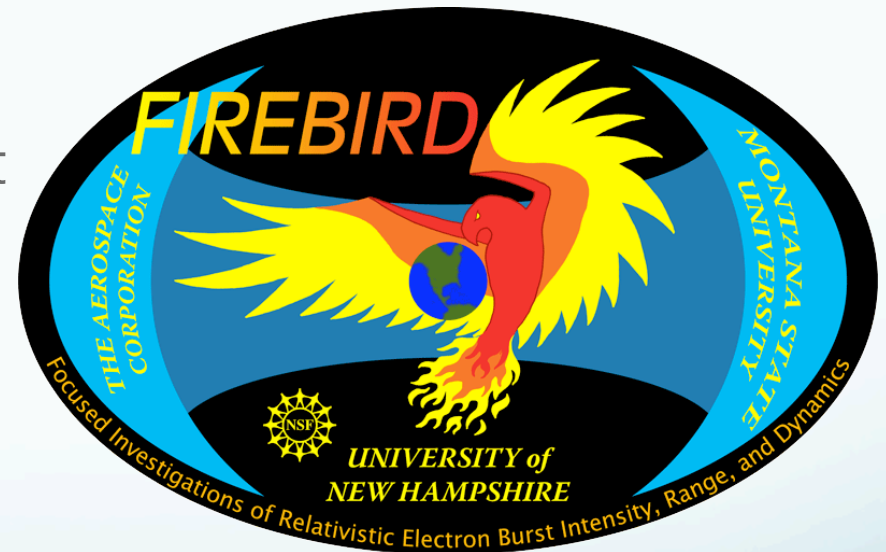
- Limited payload size/scope often mean a single instrument is all that is feasible
- Look for a science question that can be answered with a single instrument, or in conjunction with other missions
- Focus makes it easier to customize mission for the targeted science question

Examples of Cubesat Mission

- FIREBIRD—Electron Microbursts
- CSSWE (REPTile)—Radiation Belt Electrons and Solar Protons
- CINEMA—Magnetic Storms and Ring Current
- FIREFLY—link between Terrestrial Gamma Ray Flashes and Lightning
- DICE—Ionospheric response to geomagnetic storms

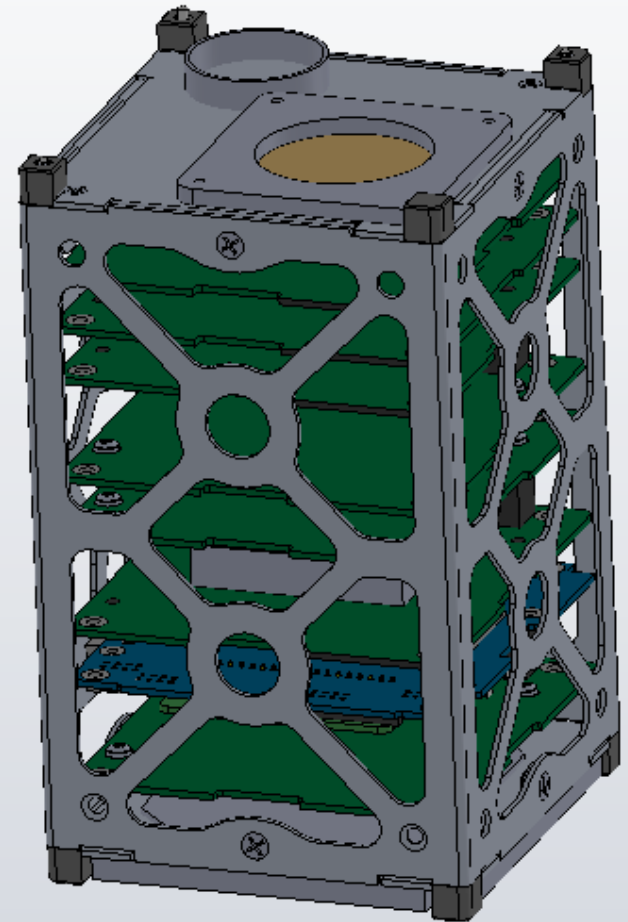
FIREBIRD

- 2 identical 10x10x15cm CubeSats
- Passive magnetic attitude control
- Each with a single instrument (FIRE) consisting of 2 solid state detectors
- Fly in a low-earth orbit with detectors staring up the field line
- Studies Radiation Belt Electron Microbursts



FIREBIRD

- Primary science question is to assess the spatial correlation scale of microbursts
- Accomplished by having the two payloads gradually separate over the course of the 120 day prime mission
- Potential conjunctions with RBSP and/or BARREL provide additional science opportunities (global scale of loss, etc)



FIREBIRD

- Telemetry limited
- Will produce about ~50MB a day of data
- Only able to downlink ~3MB a day
- Solution is to create a data proxy for Bursts that it used to identify times to request hi-resolution burst data
- Can therefore extract hi-resolution measurements of a few events at cost of broader coverage

CSSWE

- Colorado Student Space Weather Experiment
- Measure solar energetic protons and radiation belt electrons
- Complementary mission to RBSP measuring electrons near the loss cone
- Single Instrument—REPTile (*R*elativistic *E*lectron and *P*roton *T*elescope *i*ntegrated *l*ittle experiment)
 - Similar to REPT instrument on RBSP

Subsystems

1. Electrical Power System (EPS)

The EPS board (1a) collects power from the 28 solar cells (1b) laid along the length of the satellite. A series of buck converters conditions the power to charge the battery (1c) and supply 3.3V & 5V lines to the system.

2. Command & Data Handling (C&DH)

The C&DH board (2a) uses a MSP430F2618 microcontroller to collect data, timestamp it (based on the onboard real time clock) and store the data on its SD card. This data includes housekeeping, particle counts, commands from the ground, and attitude sensing. C&DH is also responsible for gathering and sending data when requested by the ground network. C&DH uses the SALVO operating system to ensure correct task timing.

3. Communications (COMM)

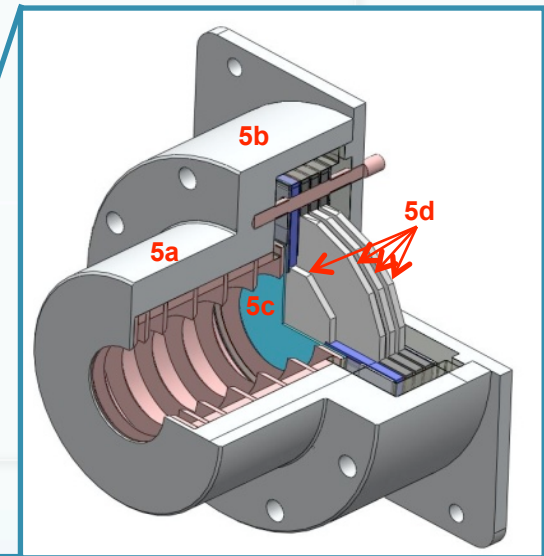
The COMM board (3a) uses AX.25 protocol to packetize and depacketize data. It also modulates and demodulates data using Gaussian Minimum Shift Keying (GMSK). COMM commands the antenna deployment module (3b) which releases the 34.3cm quarter-wave tape measure monopole antenna (3c) used for half-duplex communication.

4. Structures

A Pumpkin© 3U solid structure (4a) provides a 1.5mm thick wall of 6061 aluminum. A skeleton structure (4b) holds the science instrument in place and provides an electronics grounding path. FEA analysis concludes the structure can withstand a 125g static acceleration (3σ from the expected vibration load).

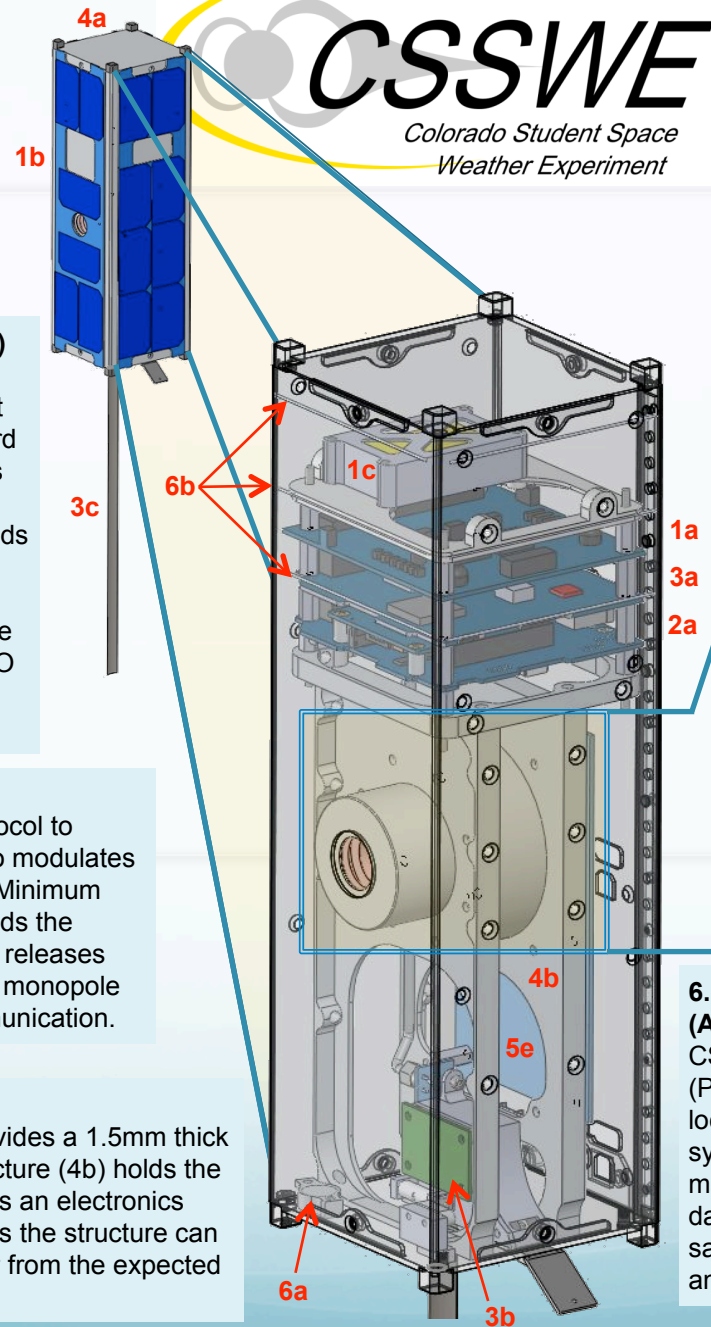
5. Relativistic Electron and Proton Telescope integrated little experiment (REPTile)

Charged particles enter through the collimator (5a); non-field of view particles are minimized using aluminum and tungsten shielding (5b). A beryllium window (5c) stops particles below 0.5 MeV (e^-) and 8.5 MeV (p^+). Particles deposit energy on each of the four 350V bias silicon detectors (5d) as they travel through the instrument boresight. An electronics board (5e) conditions the signals from each detector and applies logic to determine the number of particle counts for each energy bin.



6. Attitude Determination and Control Subsystem (ADCS)

CSSWE uses a Passive Magnetic Attitude Control (PMAC) system which aligns the CubeSat to the earth's local magnetic field line at all points in the orbit. A PMAC system uses a bar magnet (6a) in combination with soft magnetic hysteresis rods (6b) to align to the B-field and dampen the satellite, respectively. PMAC can align the satellite to within $\pm 10^\circ$ of the B-field 10 days after launch and uses <50g of mass.



Conclusions

- Cubesats represent a smaller, cheaper mode of satellite
- Provide an opportunity to do interesting science at low cost—with accompanying challenges
- More broadly accessible than large missions