The NSF Cubesat Program

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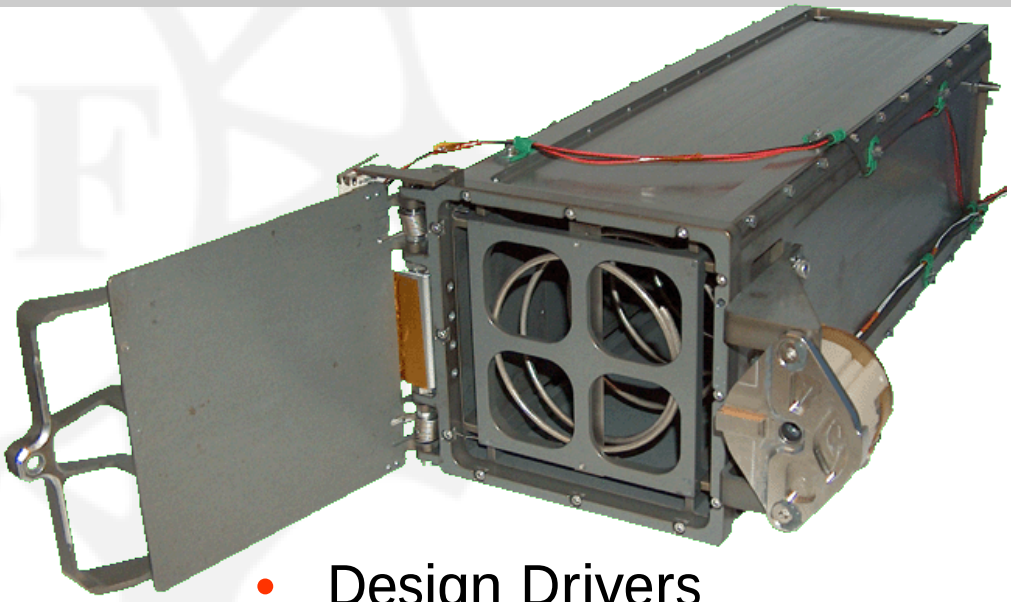
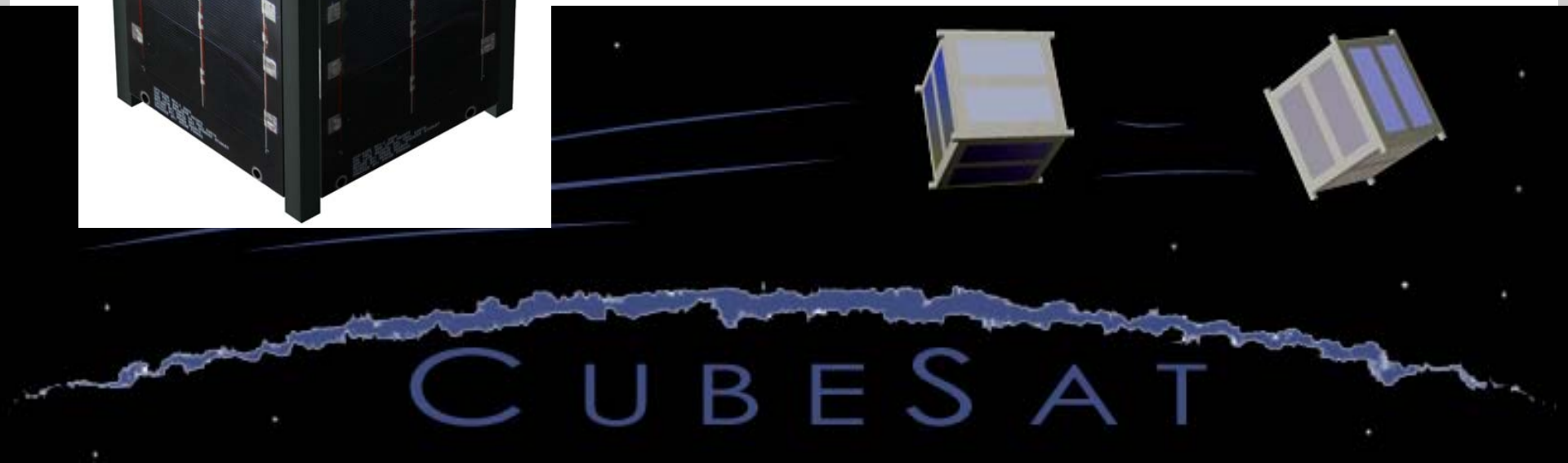
What is a CubeSat?

A pico-satellite Standard

1999 by Puig-Suari, CalPoly and Twiggs, Stanford

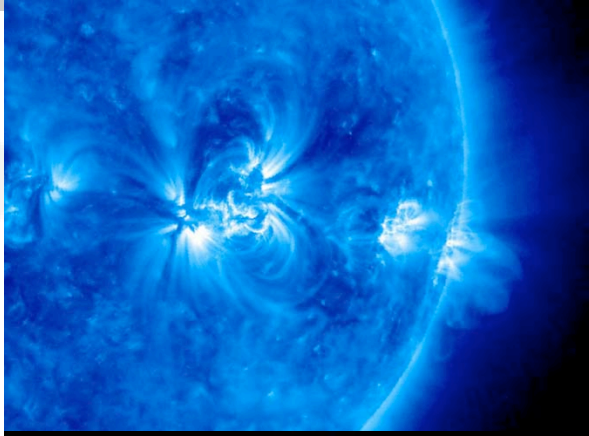


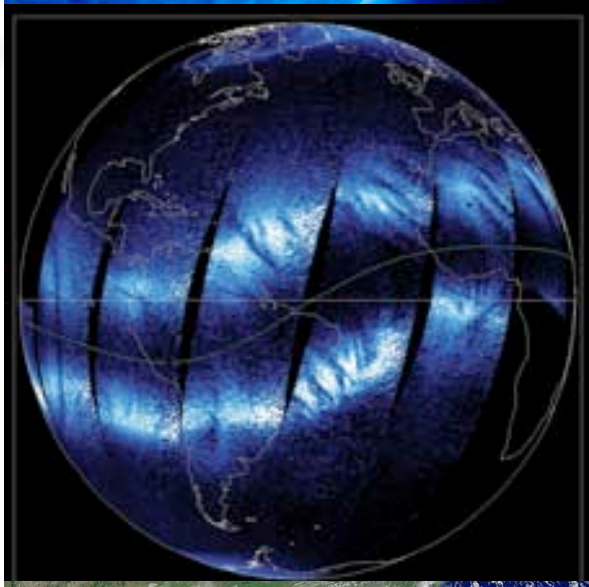
- Design Drivers
  - Simple and low-cost, but safe
  - Available COTs components
  - P-POD deployer system



Cubesat Science

- advance research in many science areas
- spur innovation, creativity and technology development
- space missions within the scope of traditional NSF grants
- enhance university participation in space activities



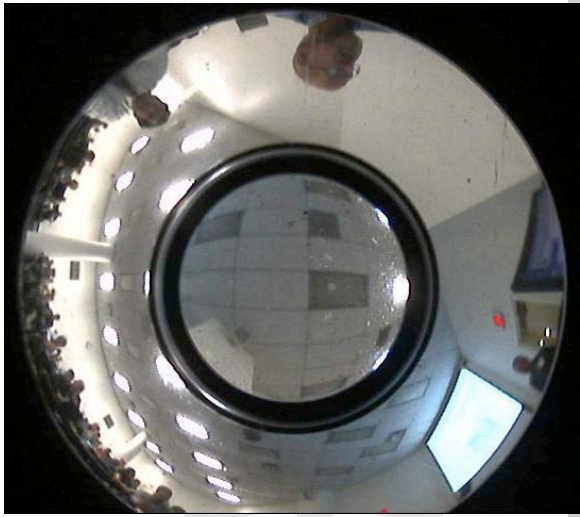


Education and Workforce

- train the next generation of scientists and engineers in space
- full, end-to-end mission experience
- spur new excitement for science & engineering

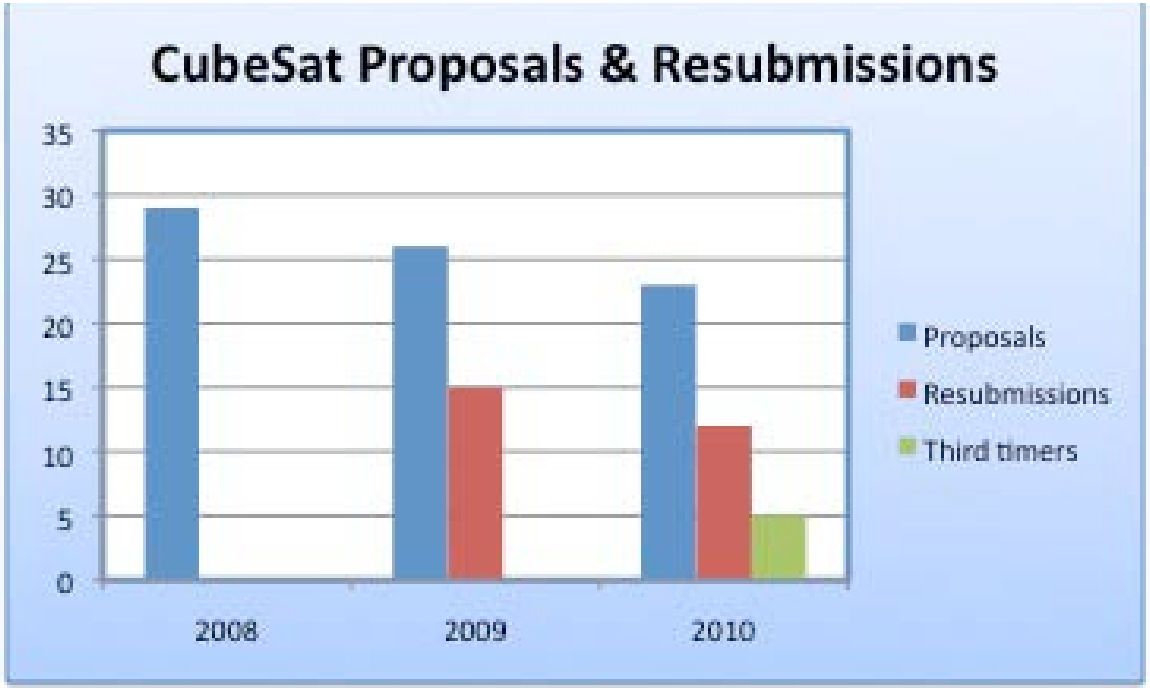
A New NSF Program

- **Program conceived 2007; first solicitation 2008**
- **Utilize CubeSat and P-POD technology development**
- **Space weather & atmospheric research and education**

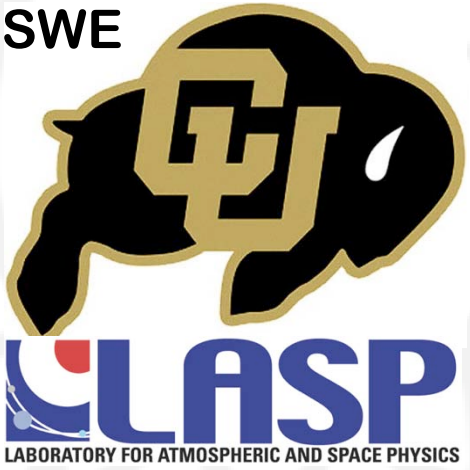


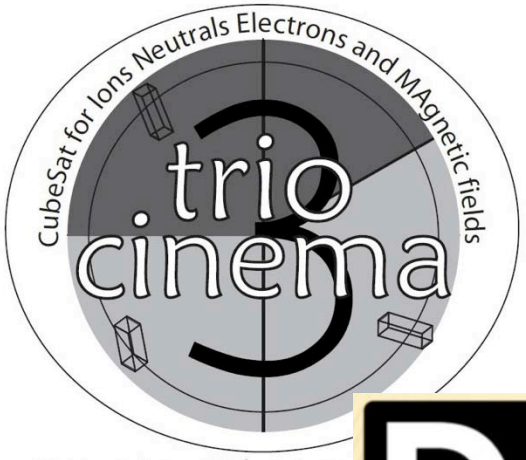
Cubesat Competitions 2008-2012

FY	Projects	Selected	Panel
2008	29	**2**	21
2009	26	**4**	20
2010	23	**2**	19
2012	23	**2**	19

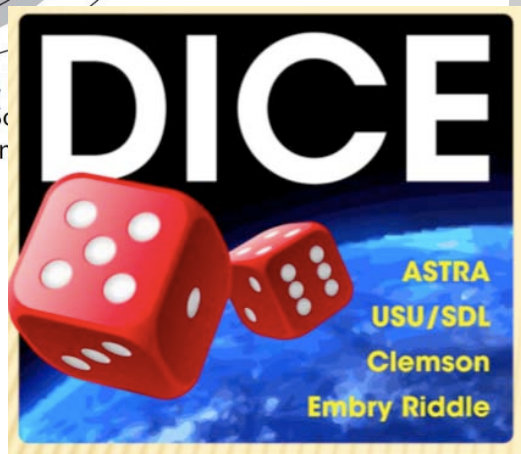


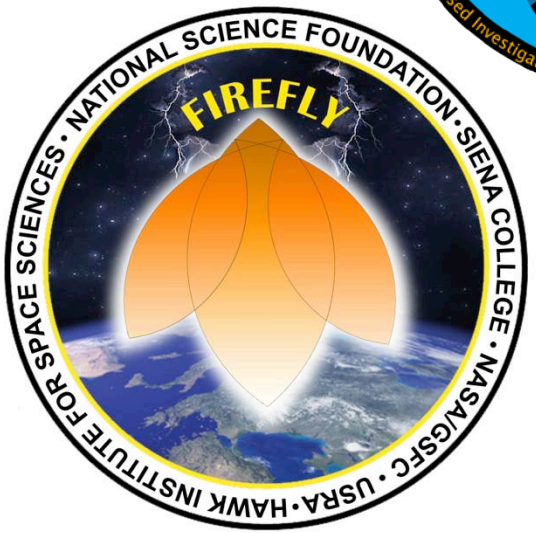
CSSWE



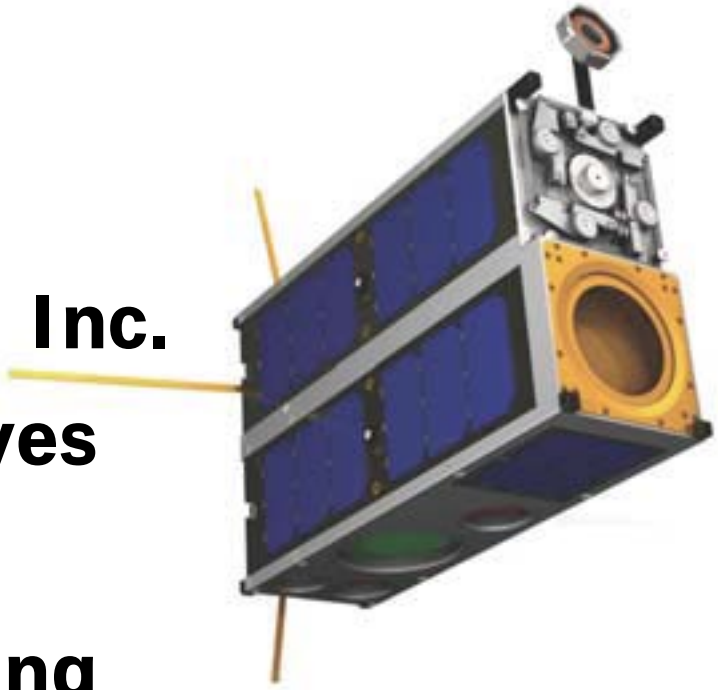


Space Sciences Laboratory,
Kyung Hee University of Sc
Imperial College Lor



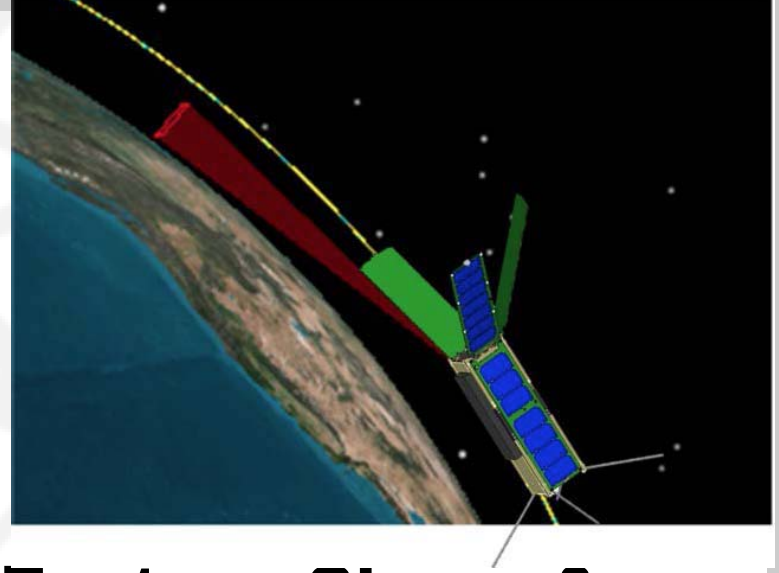


LAICE 2013



- Virginia Tech; U. Illinois; Aerospace Corp.; NWRA, Inc.
- Atmospheric gravity waves
- 6U cubesat
- In-situ and remote sensing
  - Ion T & density
  - Neutral density
  - Airglow ~90km
- Start May 2013

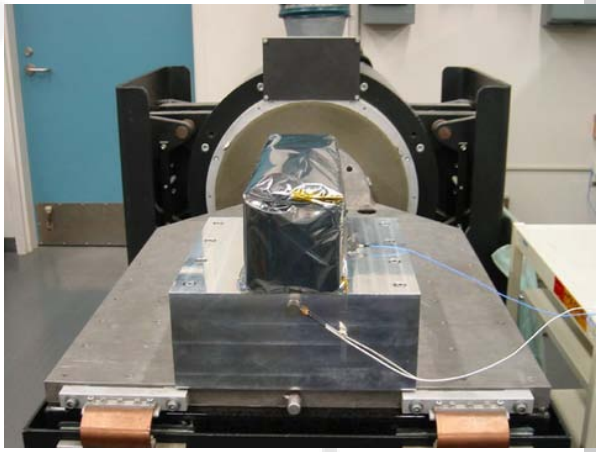
OPAL 2013



- Utah St. U.; U. Maryland Eastern Shore & HISS; Dixie St. College; NRO
- Neutral temperature profiles 90-140km
- Boeing 3U satellite
- High res, hyper-spectral imaging spectrometer
  - Daytime airglow O2 760-770nm
- Award pending 2013

Mission Support at NASA Wallops Flight Facility

- Integration, testing, documentation
- Technical POC for satellite developer and launch provider
- Other technical and management support
- UHF and S-Band CubeSat Groundstation support



Launch Support

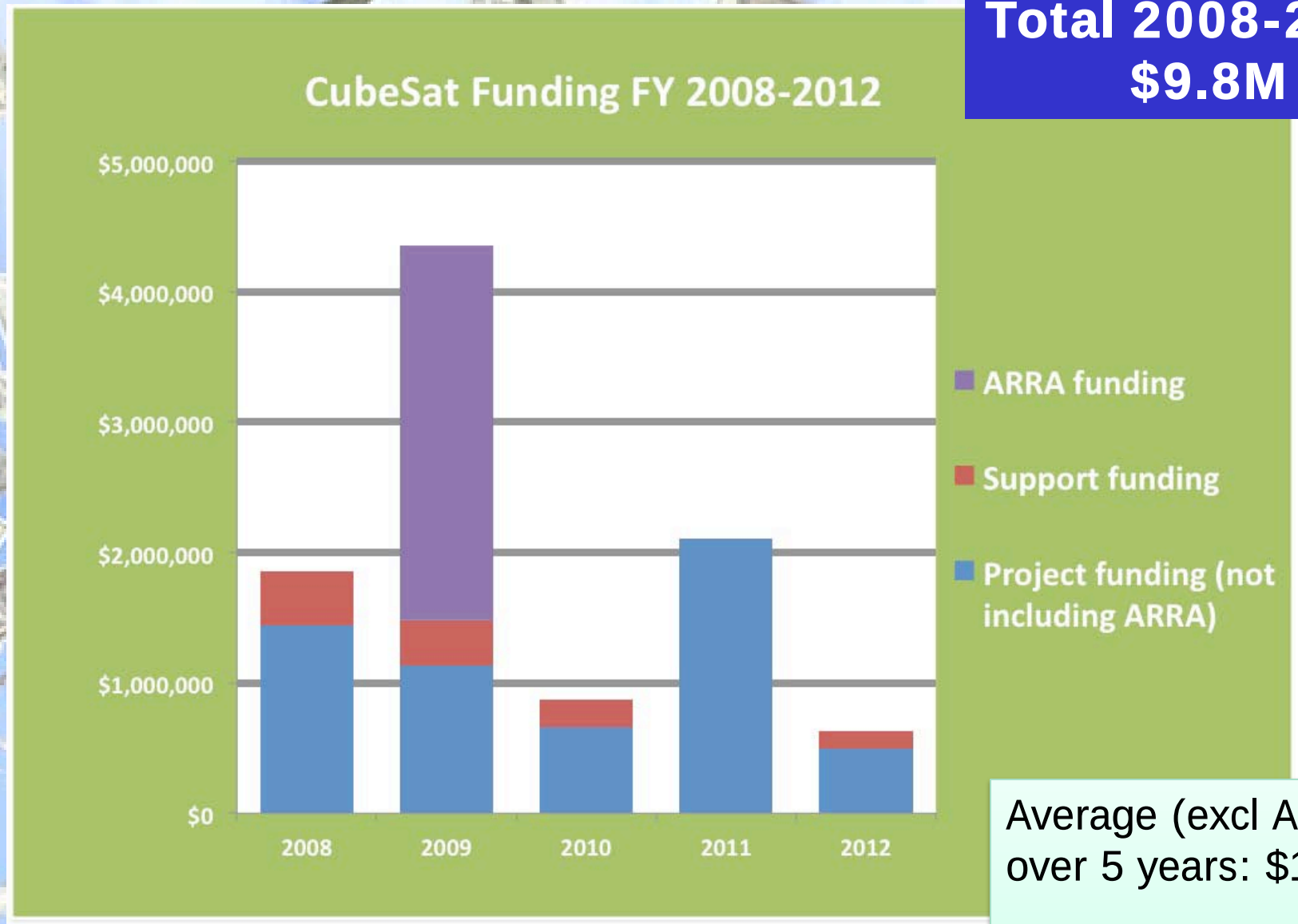
- **DOD STP, S26, Nov 2010, Minotaur IV, Kodiak**
- **NASA ELaNa, NPP, Oct 2011, Delta II, Vandenberg**
- **NRO/NASA ELaNa NROL-36/ OutSat, Sep 2012, Atlas V, Vandenberg**
- **Future manifests with NASA ELaNa and NRO**

Next Up

- **Firefly launch Nov 4, 2013**
  - **ORS STP-3 on Minotaur-1 from Wallops Island with 15 other cubesats**
- **Firestation was delivered to ISS in August.**

- **Firebird launch Dec 5, 2013: NRO L-39 on Atlas-V from Vandenberg together with 13 other cubesats**

Total 2008-2012: $9.8M

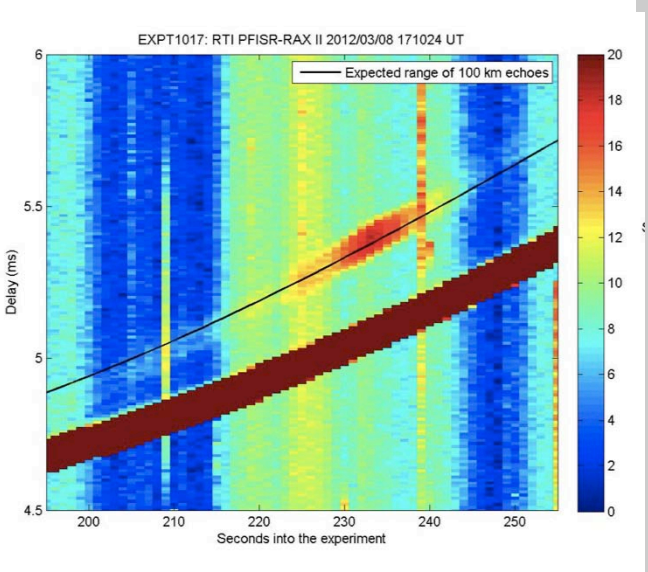


Average (excl ARRA) over 5 years: $1.4M

ARRA provided 2 satellite projects and a REU site

Accomplishments

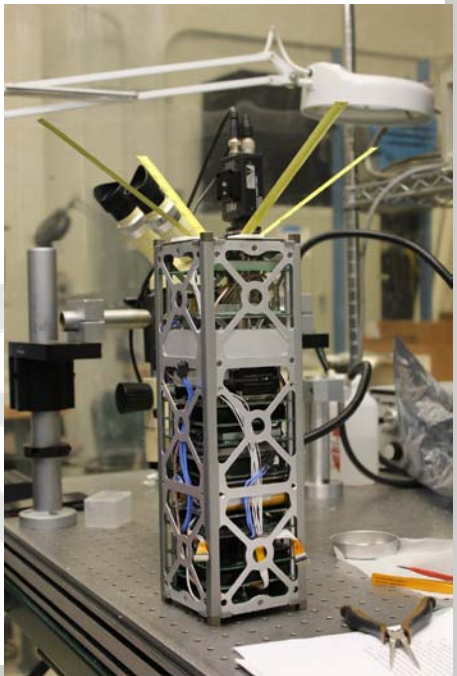
- Scientific value of CubeSat missions confirmed
- Creative mission ideas and successful implementations
- Scientific papers and data
- Big educational impact
- Increased recognition of cubesats as a viable alternative for space

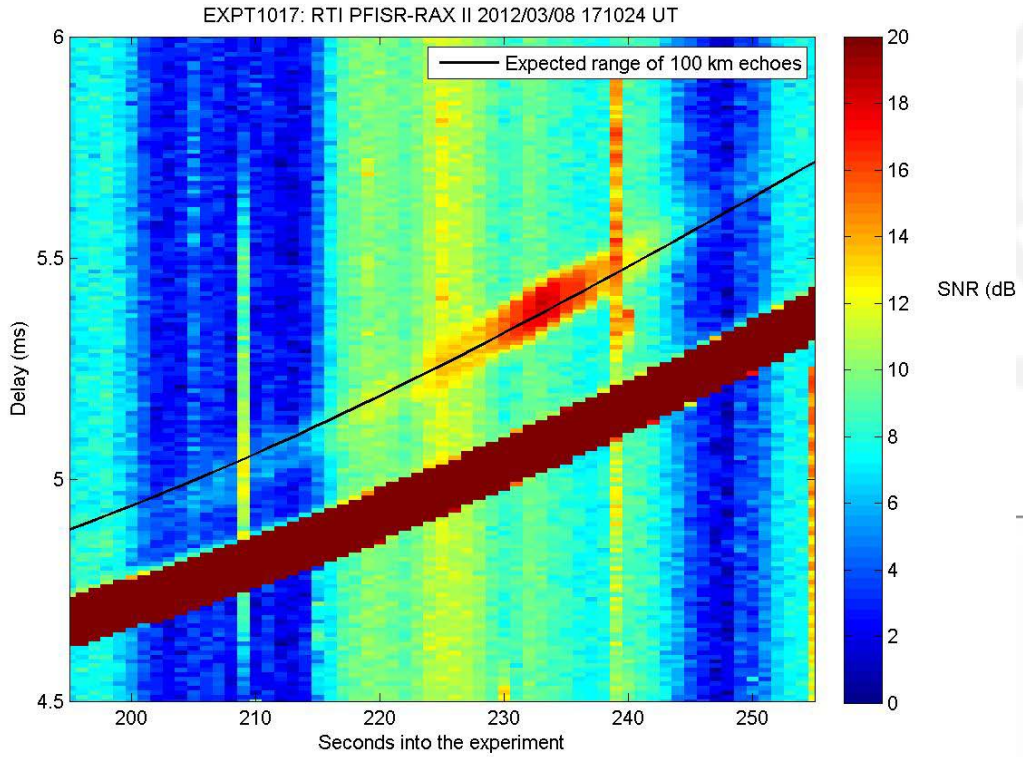


- ✔ SRI International & U. Michigan
- ✔ UHF Radar receiver, ionospheric irregularities
  - ✗ 3U CubeSat
- ✔ RAX-1 Launched Nov 2010
  - ✗ A few experiments; Premature power system failure
- ✔ RAX-2
  - ✗ Launched Oct 2011; Many successful experiments; Scientific publications

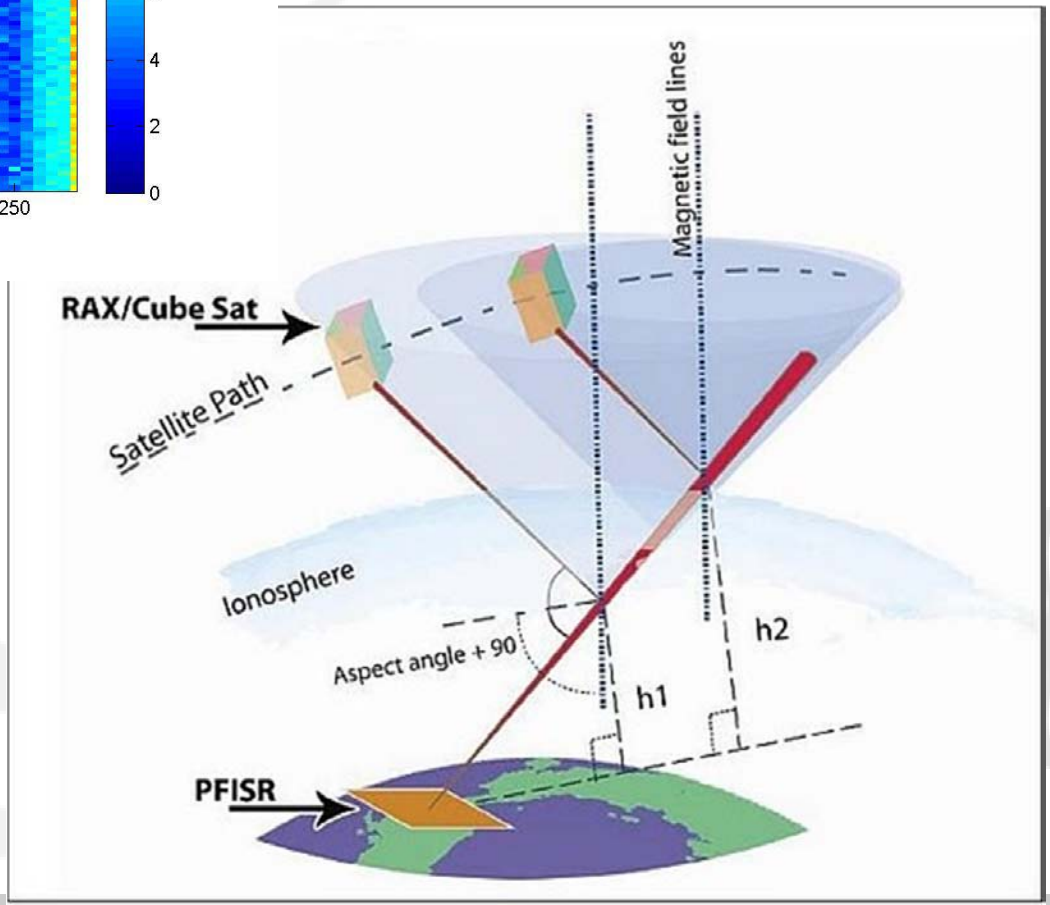
400x820km polar orbit

RAX
Radio Aurora Explorer



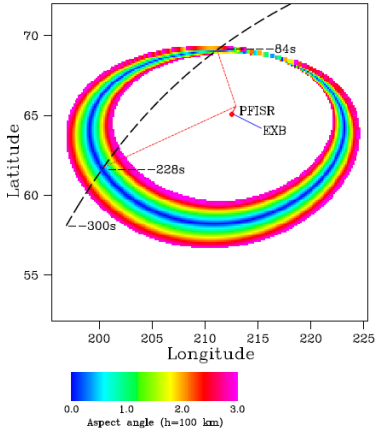


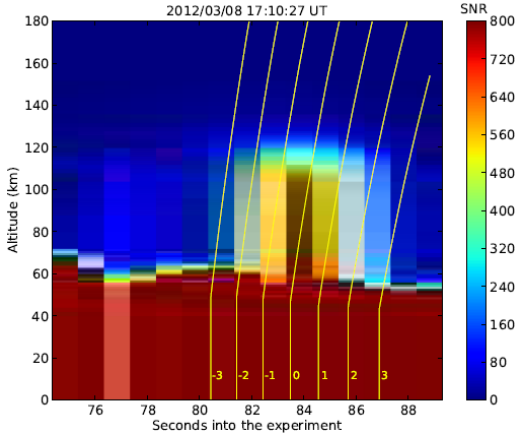
RAX observes auroral turbulence

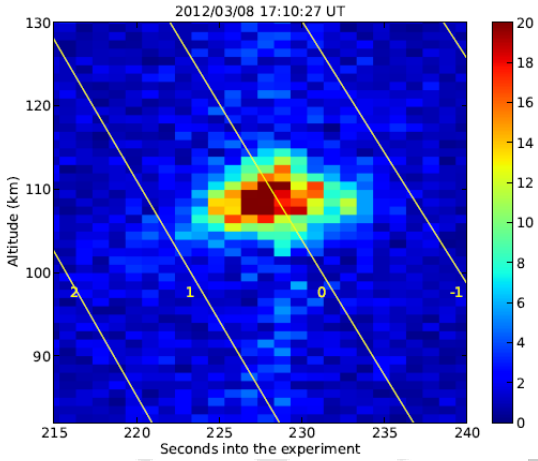


RAX Science Results

- Completed 30 experiments with PFISR and RISR, including HAARP heating
  - 4 events during diverse ionosphere conditions; 700-1600m/s drifts
- Findings, important for understanding E-region plasma heating and chemistry:
  - Submeter-scale irregularities extremely field-aligned
  - Confined to narrow (~5km) altitude range around 110km
- 9 science and engineering papers; 16 conference presentations.

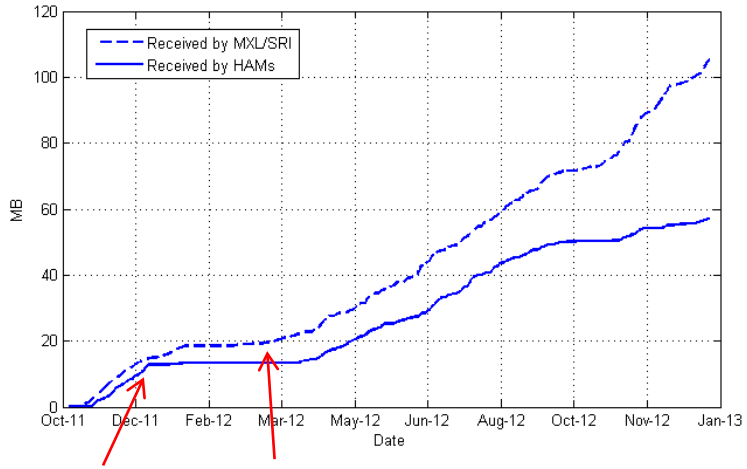






Latest data download numbers (9600 bps radio)

Data downloads



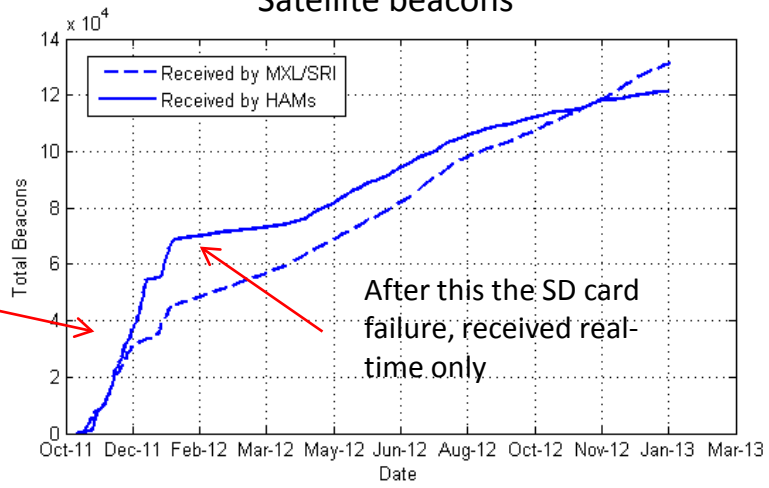
SD card failure

Download scheduling restored

These files are primarily science data, some housekeeping data as well.

162.5 MB total
105.4 MB via Umich/SRI GS
57.1 MB via amateur community

Satellite beacons



Downloaded batches of beacons stored on board early in the mission

Beacons are periodic transmissions with health/telemetry data

252,426 beacons and counting
131,106 via Umich/SRI GS
121,320 via amateur community

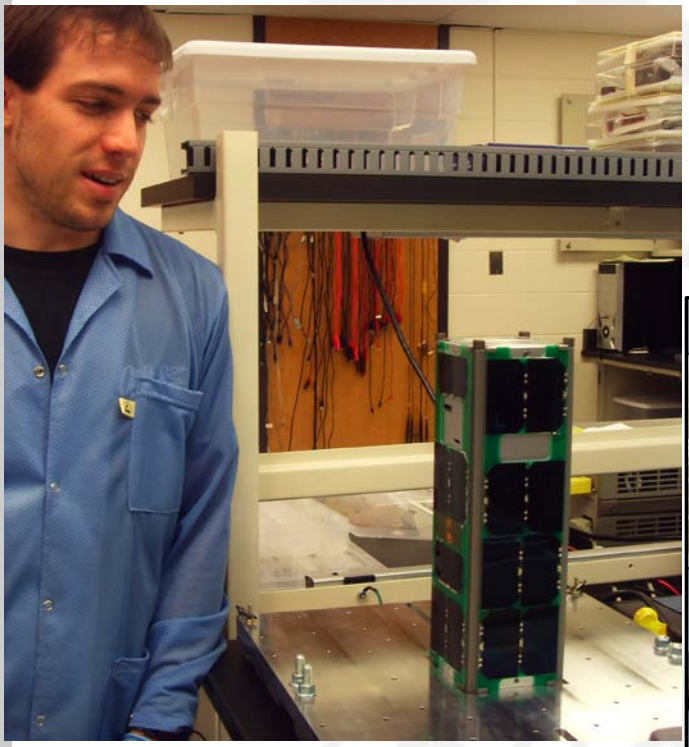
The manual is in my brain – Matt

AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

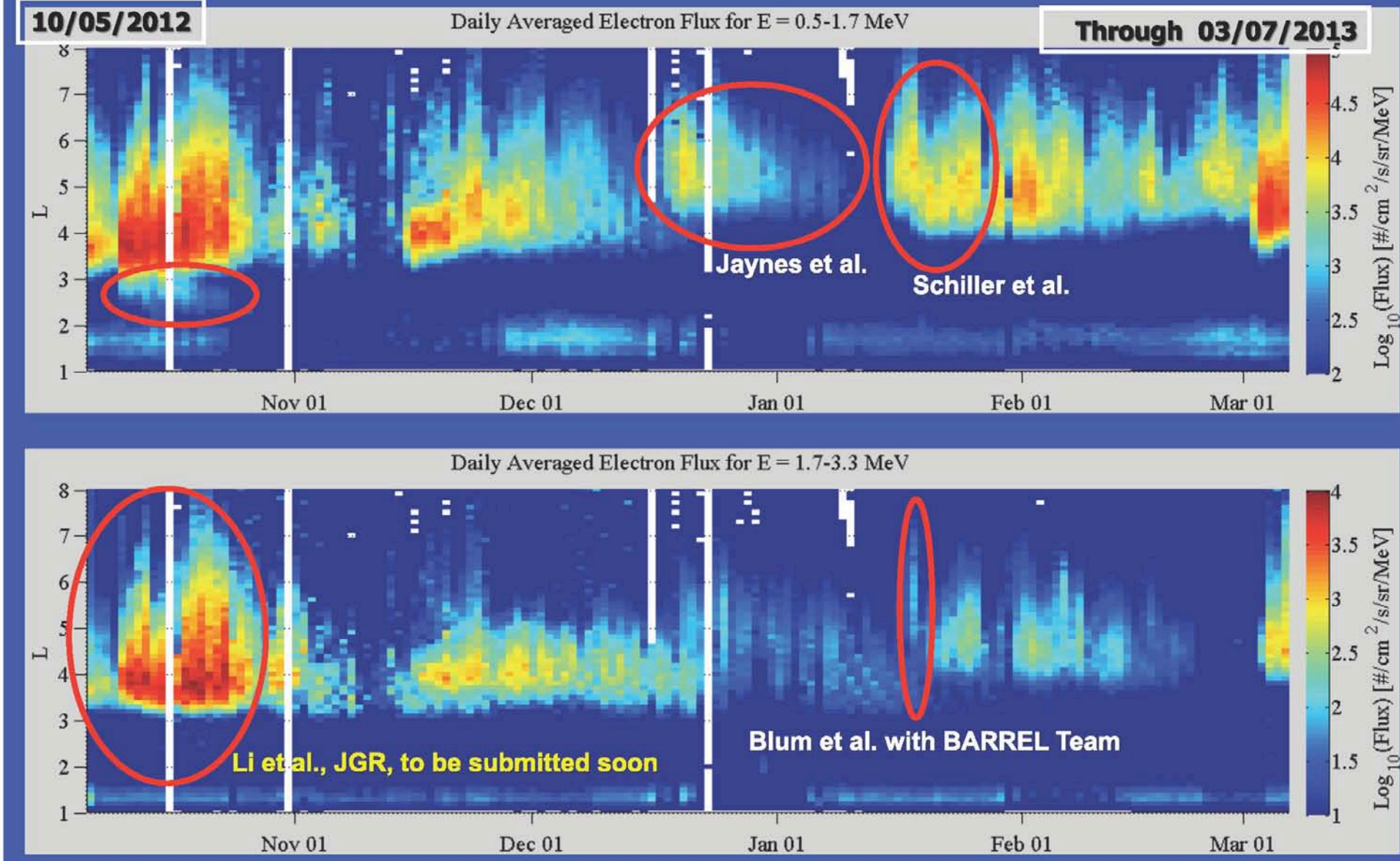
The manual is in my brain – Matt

CSSWE
Colorado Student Space Weather Experiment

- ✔ U. Colorado, Boulder
- ✔ Solar Proton Events, CMEs, and radiation belt dynamics
  - ✗ 3U CubeSat
  - ✗ Energetic electrons (0.5-3MeV) and protons (10-40MeV)
- ✔ Launched Sep 2012
  - ✗ Fully operational, high quality data
  - ✗ Complements NASA Van Allen Probes



REPTile electron measurements up to March 7, 2013



CSSWE Science & Education Results

- Valuable data on the complicated dynamics of the Earth radiation belts
  - energy and pitch angle dependencies of electron acceleration and loss

- Low altitude complement to Van Allen probes
- 5 science and engineering papers; 4 conference presentations; many more on the way
- 60 students from many disciplines
  - Winning scholarship prices
- Results supporting 2 science and 1 engineering PhD

Essential Elements

- Strong science and engineering collaborations
- Thorough proposal review and selection as guarantee for success
- Requirements dictated solely by launch acceptance
- Minimal prescriptions for project management (testing, review, and documentation)
- Open inter-team discussions
- Funding for students

The Future

- Expansion to other science areas
- Larger constellations (European QB50 project)
- Frequency allocation & space debris concerns
- Barriers to space-based activities & aerospace engineering at NSF
- Metrics for success

Thank You All
For 5 Amazing Years!