Doing Science with University Cubesats

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The U.S. National Science Foundation

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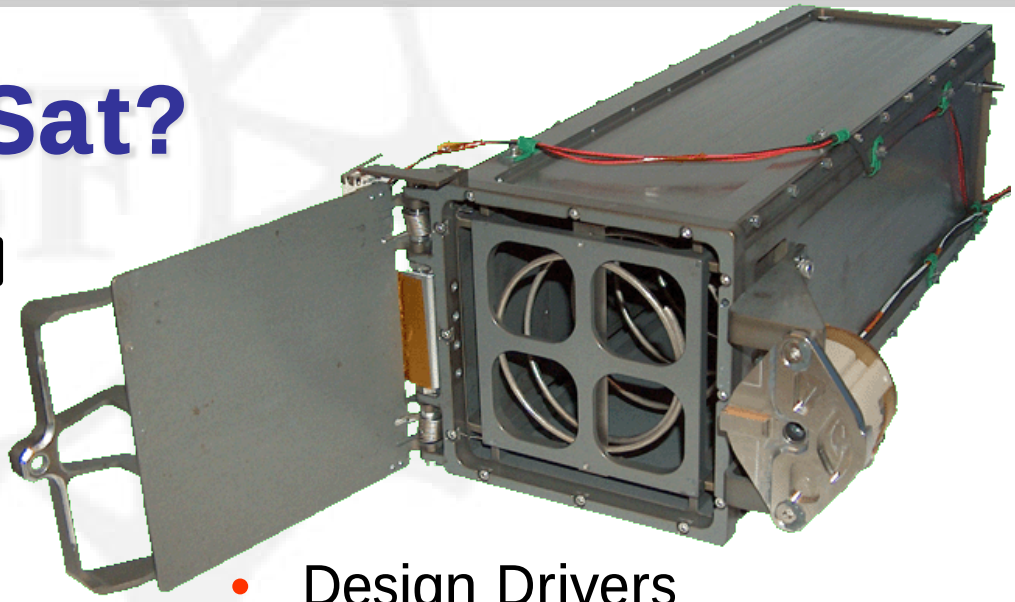
NSF and Cubesats

- **Measurements from space are essential for scientific progress in many areas & for solving critical problems facing society**
- **Growing need for continuous, dense, global observation networks**
- **Exploring untraditional, creative, and low-cost ways to provide space measurements**

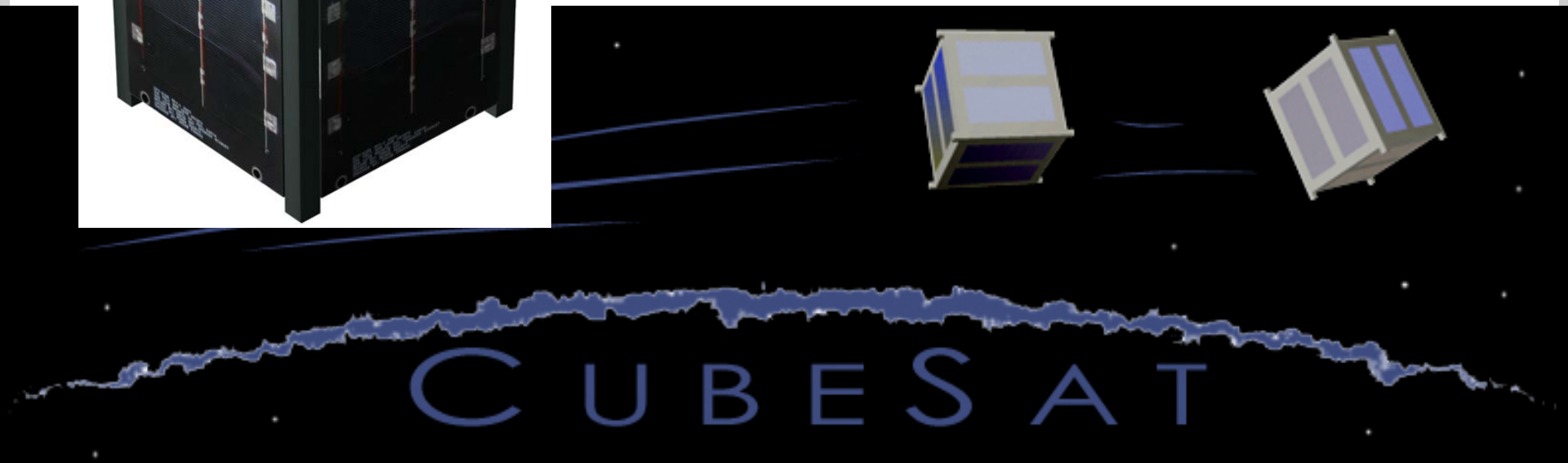
What is a CubeSat?

A pico-satellite Standard

1999 by Puig-Suari, CalPoly and Twiggs, Stanford

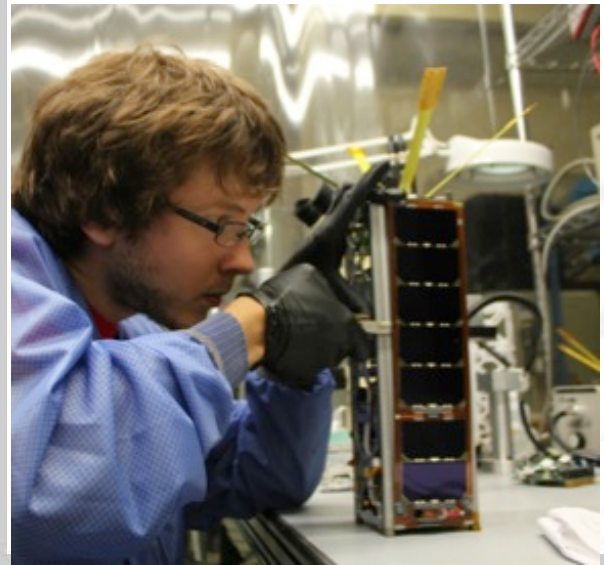


- Design Drivers
  - Simple and low-cost, but safe
  - Available COTs components
  - P-POD deployer system



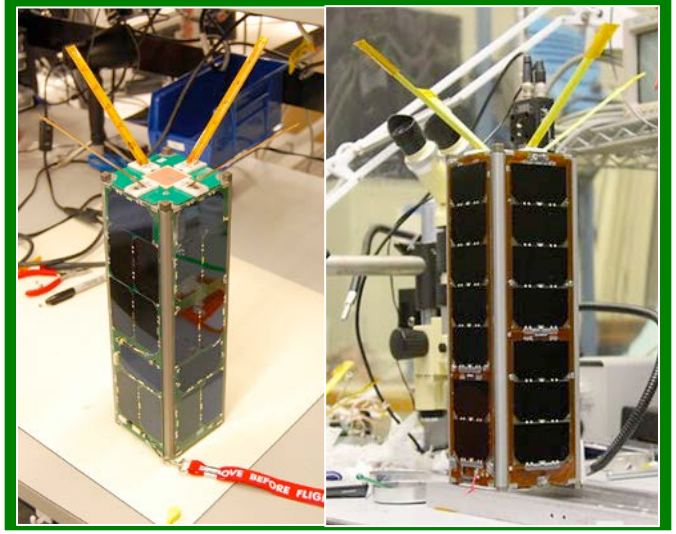
NSF Cubesat Program since 2008

- Geospace & atmospheric science and education
- ~2 new projects per year
- 5 competitions; 122 proposals
- 15 projects funded
- Grants $900,000 total cost and 3 year duration

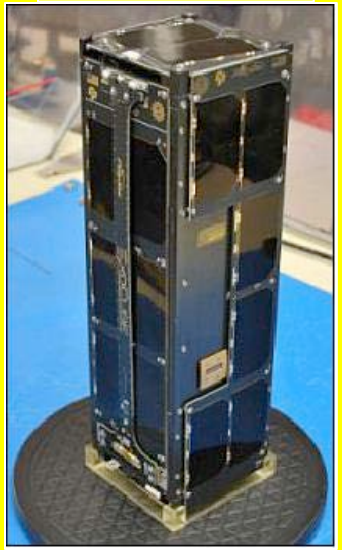


FIREFLY

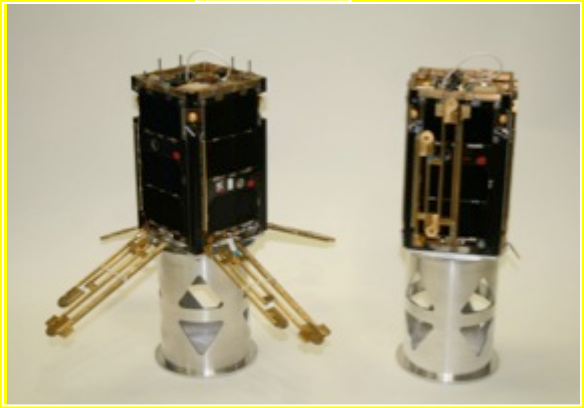
RAX I & II



EXOCUBE

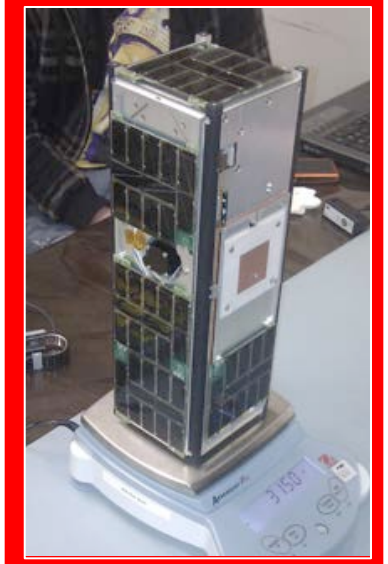


DICE

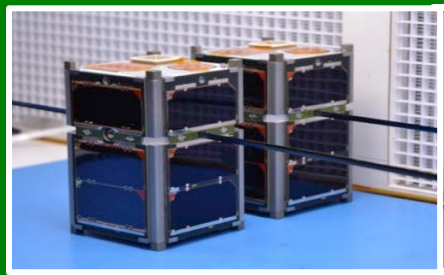


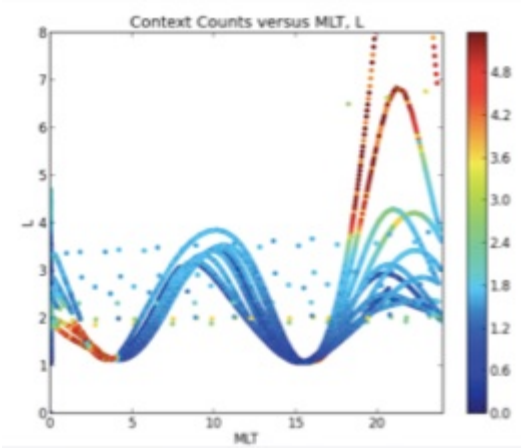
CSSWE

CINEMA

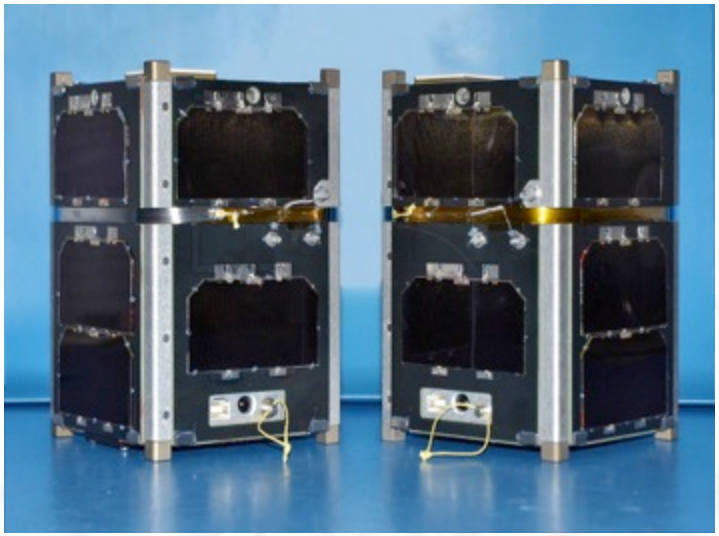


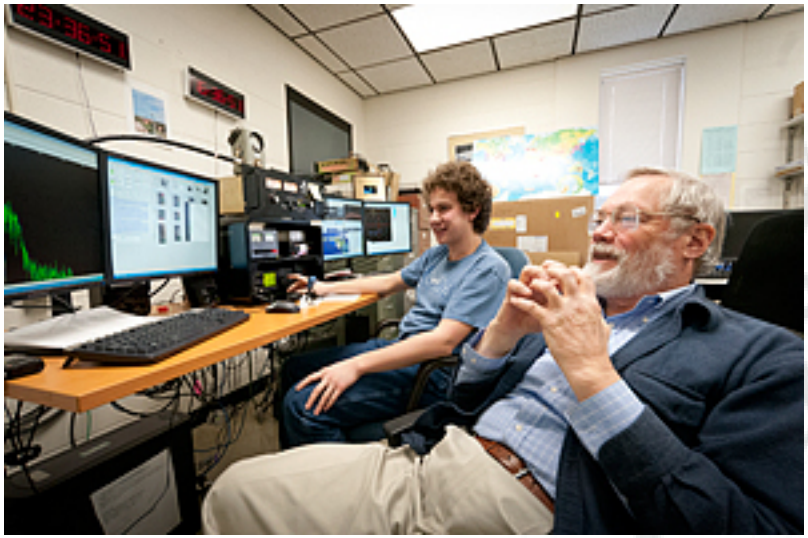
FIREBIRD I & II





- U. New Hampshire; Montana St. U & Aerospace Corp.
- Relativistic Electron Microbursts
- 2 identical 1.5U cubesats
- Energetic electrons (0.3-1MeV) with high time resolution (20ms)
- Launched Dec 2013 & Jan 2015
- All satellites fully operational
- Simultaneous measurements 2015





FIREBIRD Science Result

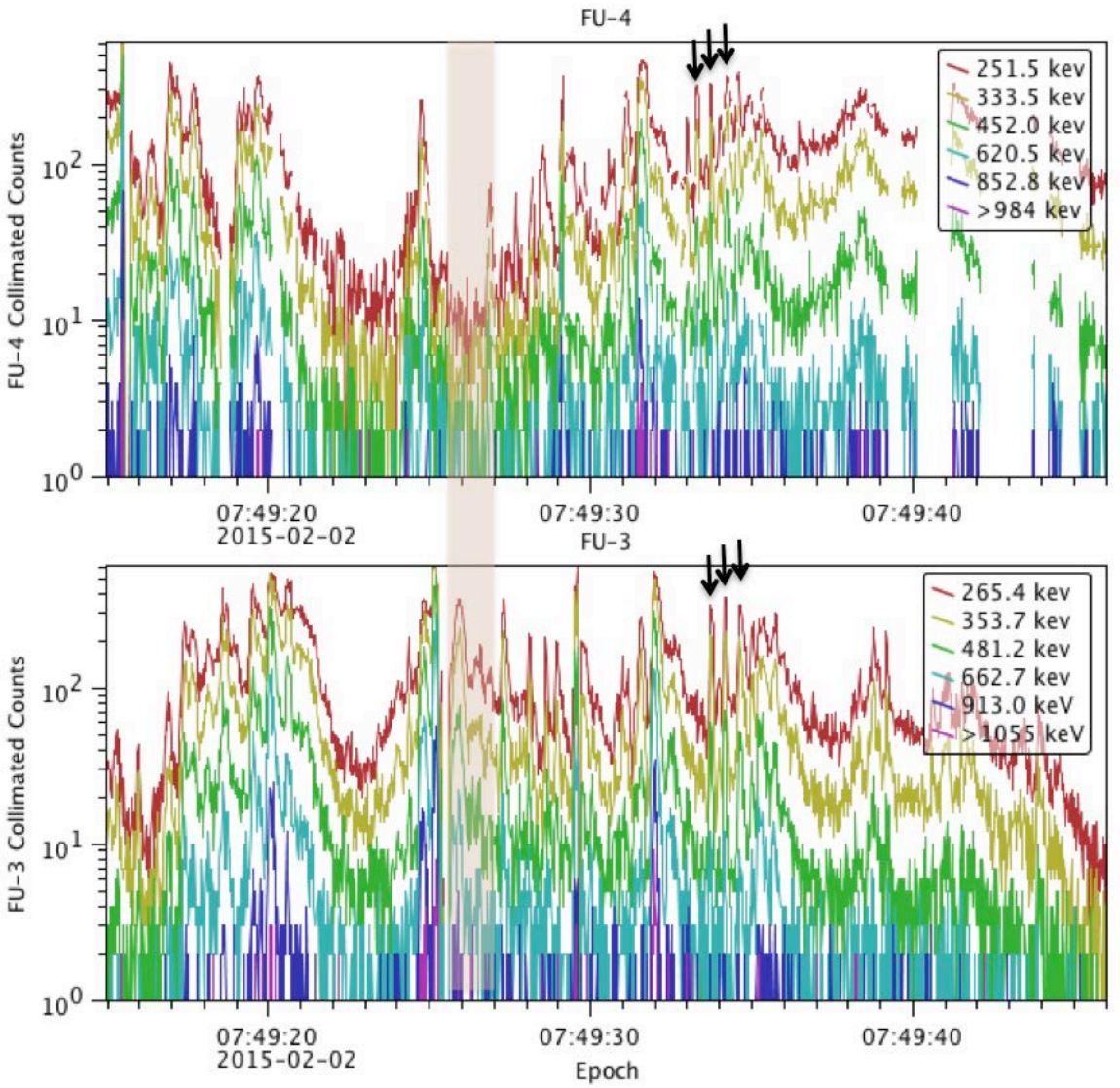
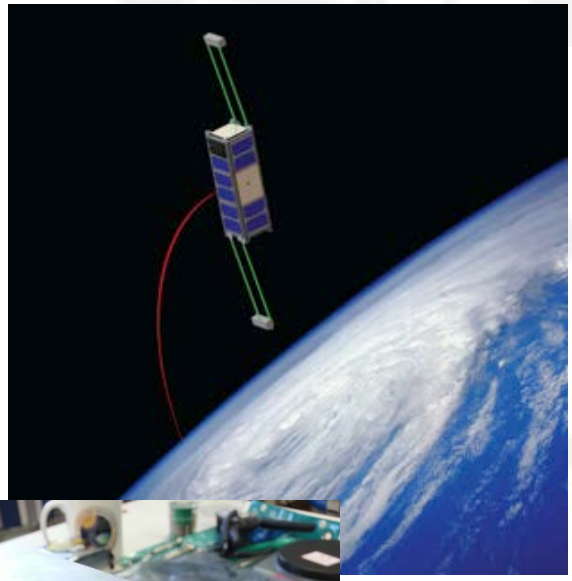
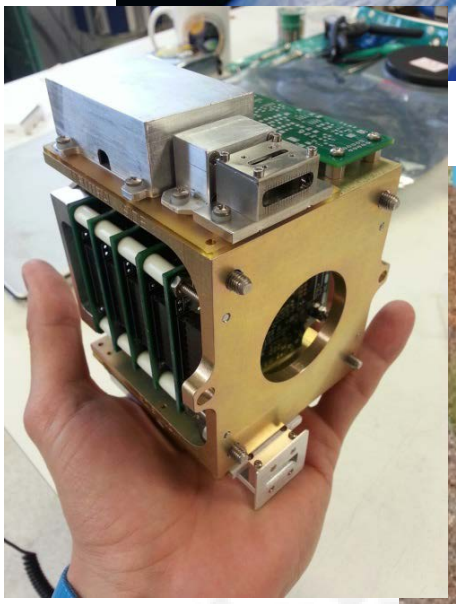


Figure 3 from Crew et al., First Multipoint In Situ Observations of Electron Microbursts: Initial Results From the NSF FIREBIRD-II Mission, to be submitted to JGR, 2015.

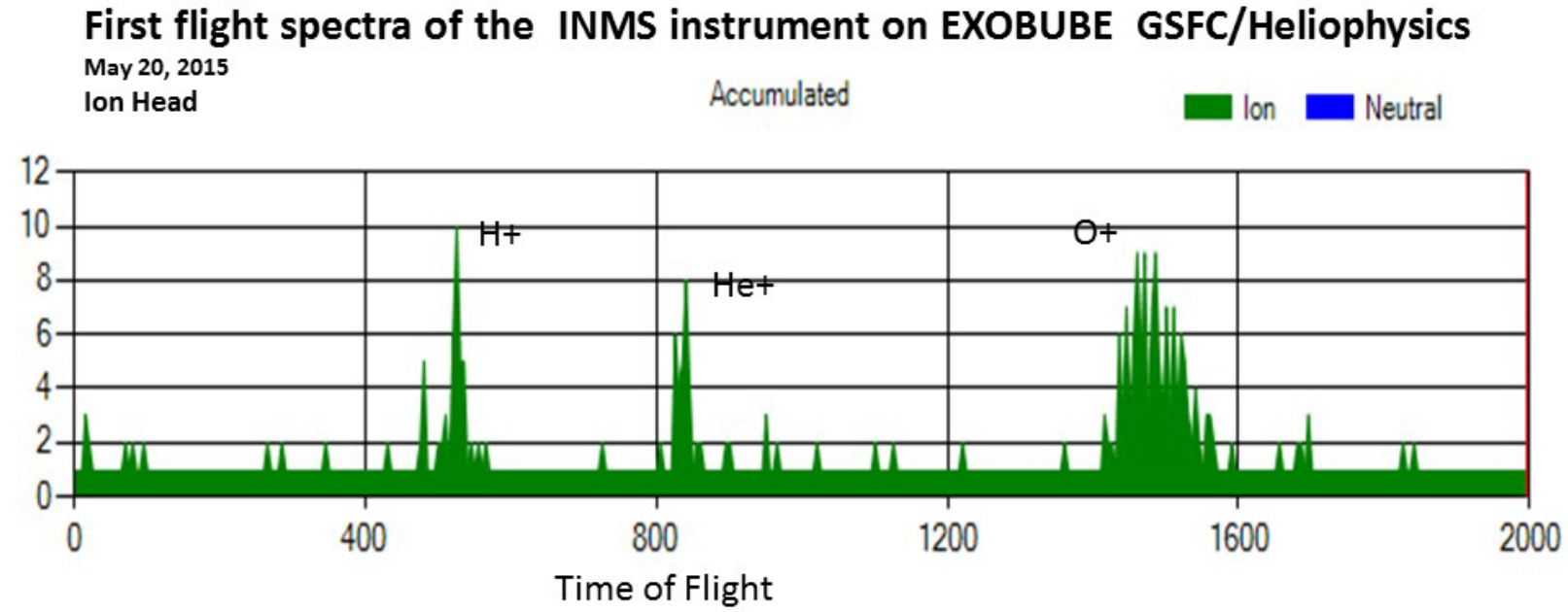
ExoCube

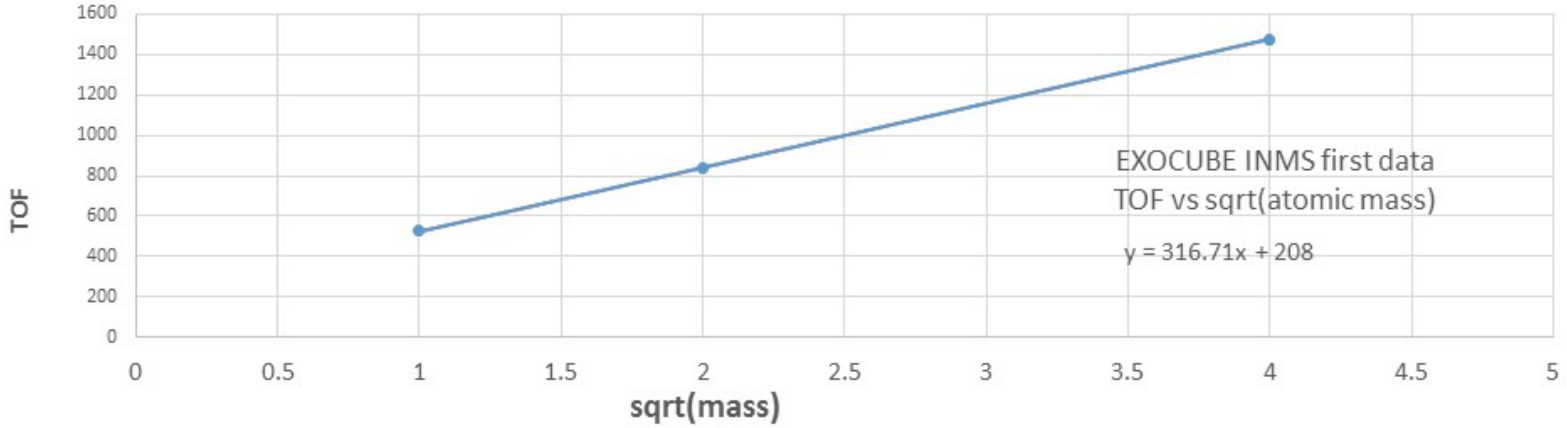


- **Scientific Solutions, Inc; CalPoly; NASA Goddard; U. Wisconsin & U. Illinois**
- **Composition of the upper atmosphere**
- **3U cubesat**
- **Miniature mass spectrometer; H, He, and O and ions**
- **Launched Jan 2015**



ExoCube INMS Data





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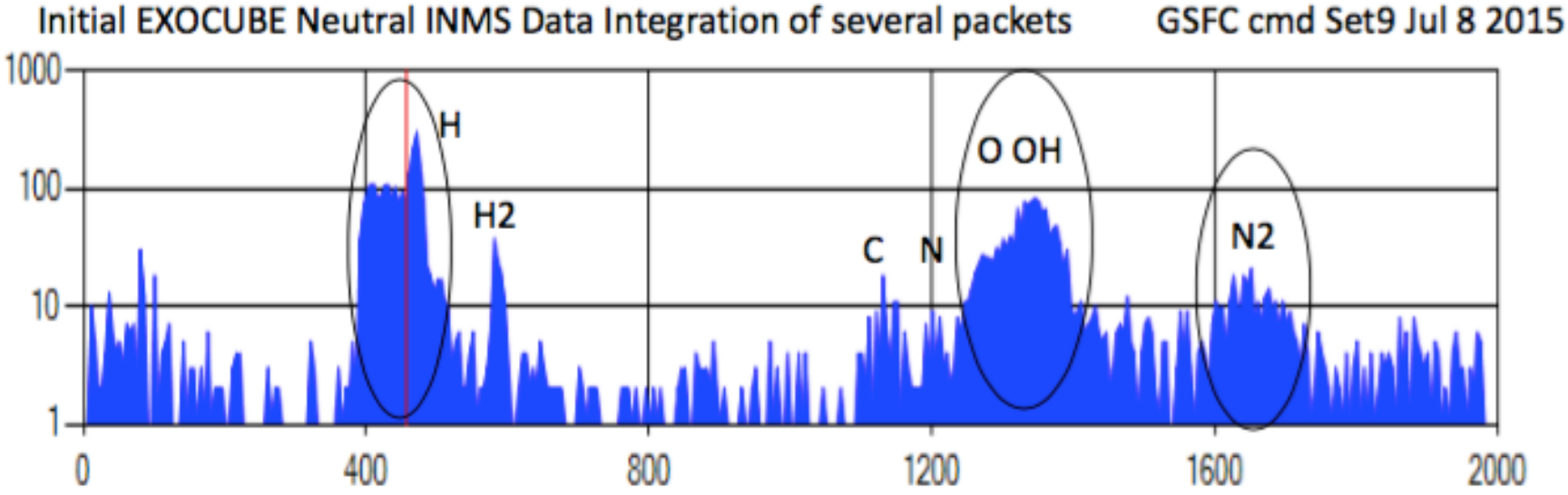
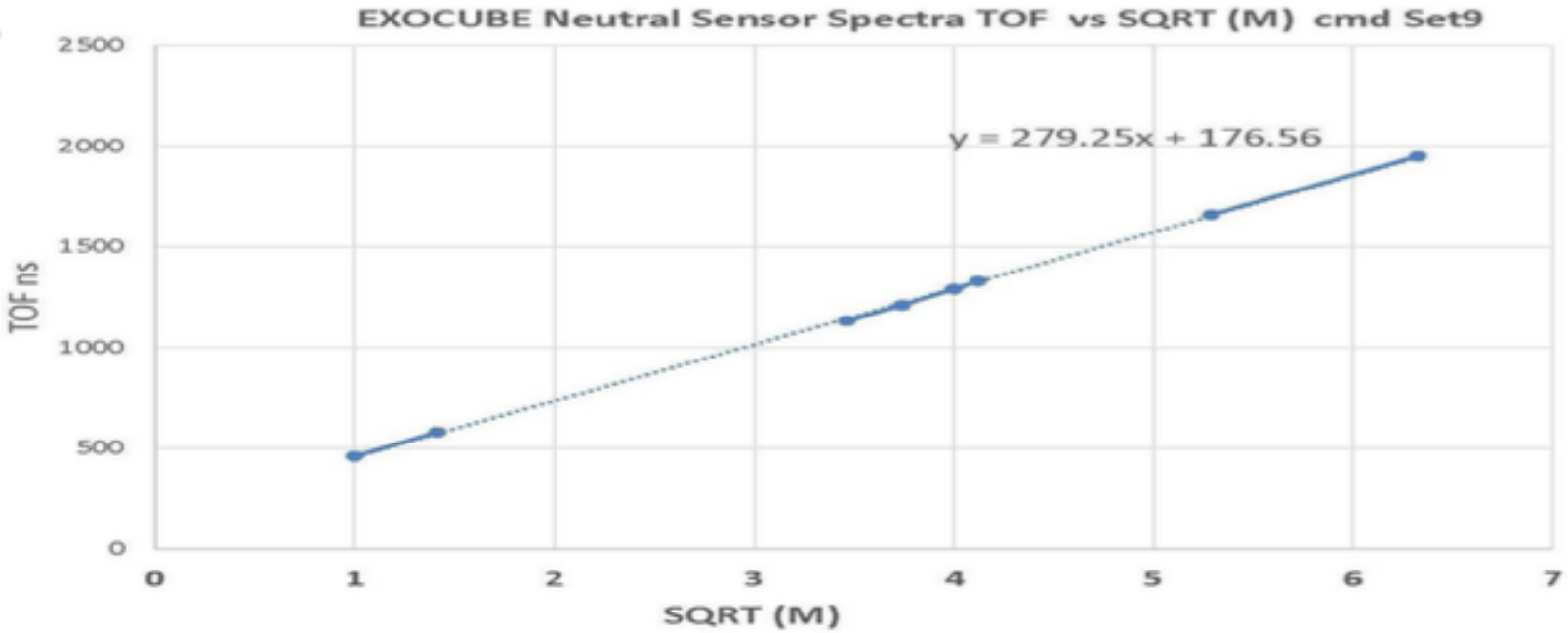
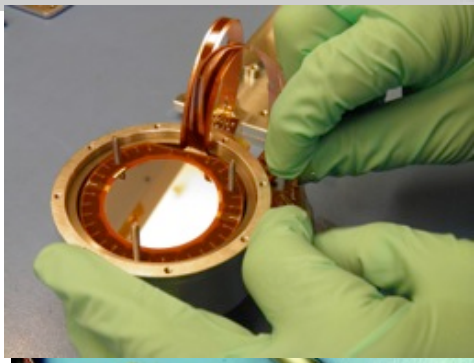


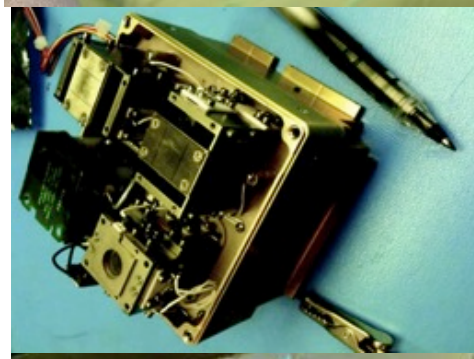


Accomplishments

- Scientifically valuable CubeSat missions
- Creative mission ideas and successful implementations
- Increased recognition of cubesats as a viable alternative for space
- Scientific data & publications
- Big educational impact

Cubesats in LEO





- **Powerful capabilities already demonstrated, or will be soon for:**
- **In-situ fields, energetic particles, and plasma and neutrals densities, winds, and composition**
- **Remote sensing photometers, spectrometers, imagers, advanced radio receivers**
- **Power & Data downlink main limitations**

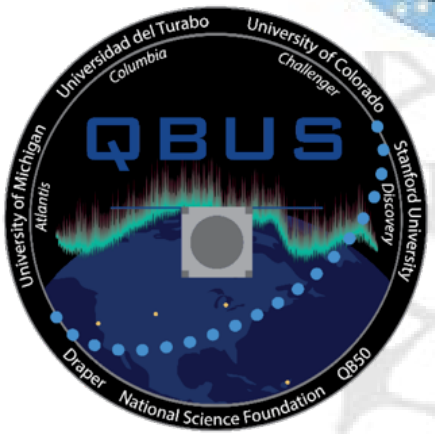
The Future

- Expansion to other science areas
- Large constellations: European QB50 project
- Cubesats everywhere: beyond LEO
- Technical challenges:

  communication & power

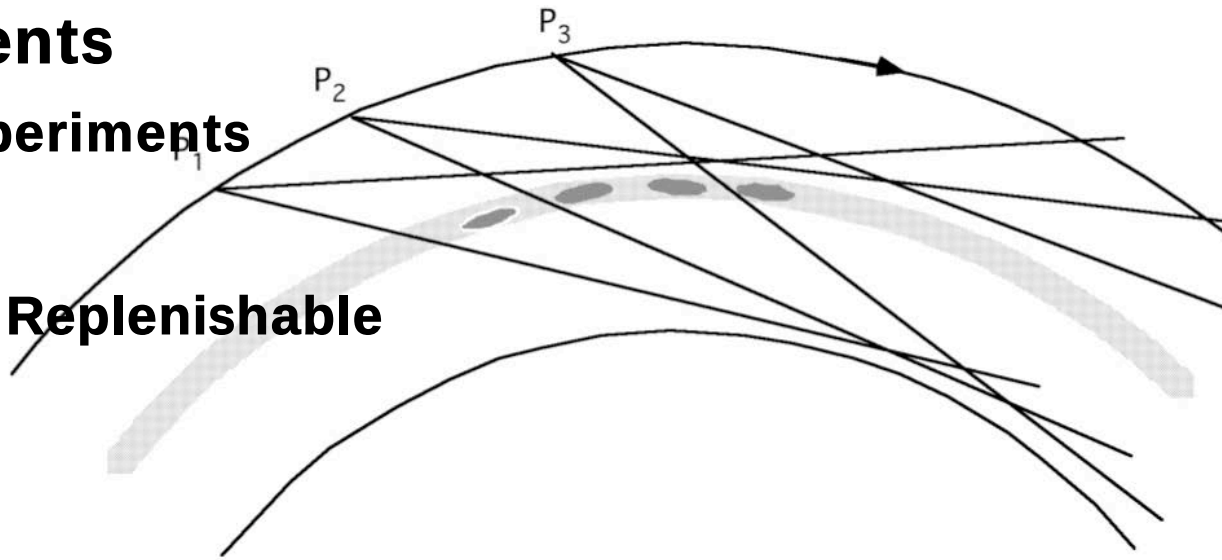
  radiation hardiness

  maneuverability



Cubesats: What can they contribute?

- **Fill-in gaps in coverage**
  - ❑ **geographic, local time, sky-view, long-time monitoring**
- **Small-scale structure**
  - ❑ **Multi-point measurements to avoid space-time aliasing**
- **Interferometry & Tomography**
  - ❑ **Satellite constellations**
- **New measurements**
  - ❑ **Technology experiments**
- **New regions**
  - ❑ **Dispensable & Replenishable**



Frey, S. et al (2001) *J. Geophys. Res.*, *106*(A10).

Cubesats: Change of mindset

Powerful concepts:

- **Building to a standard**
- **Containerized launch**

New paradigm:

- **Low cost**
- **High risk acceptance**
- **Broad participation:**
  - **high influx of innovation & widespread expertise**