Miniaturized Ion and Neutral Mass Spectrometer for CubeSat Atmospheric Measurements

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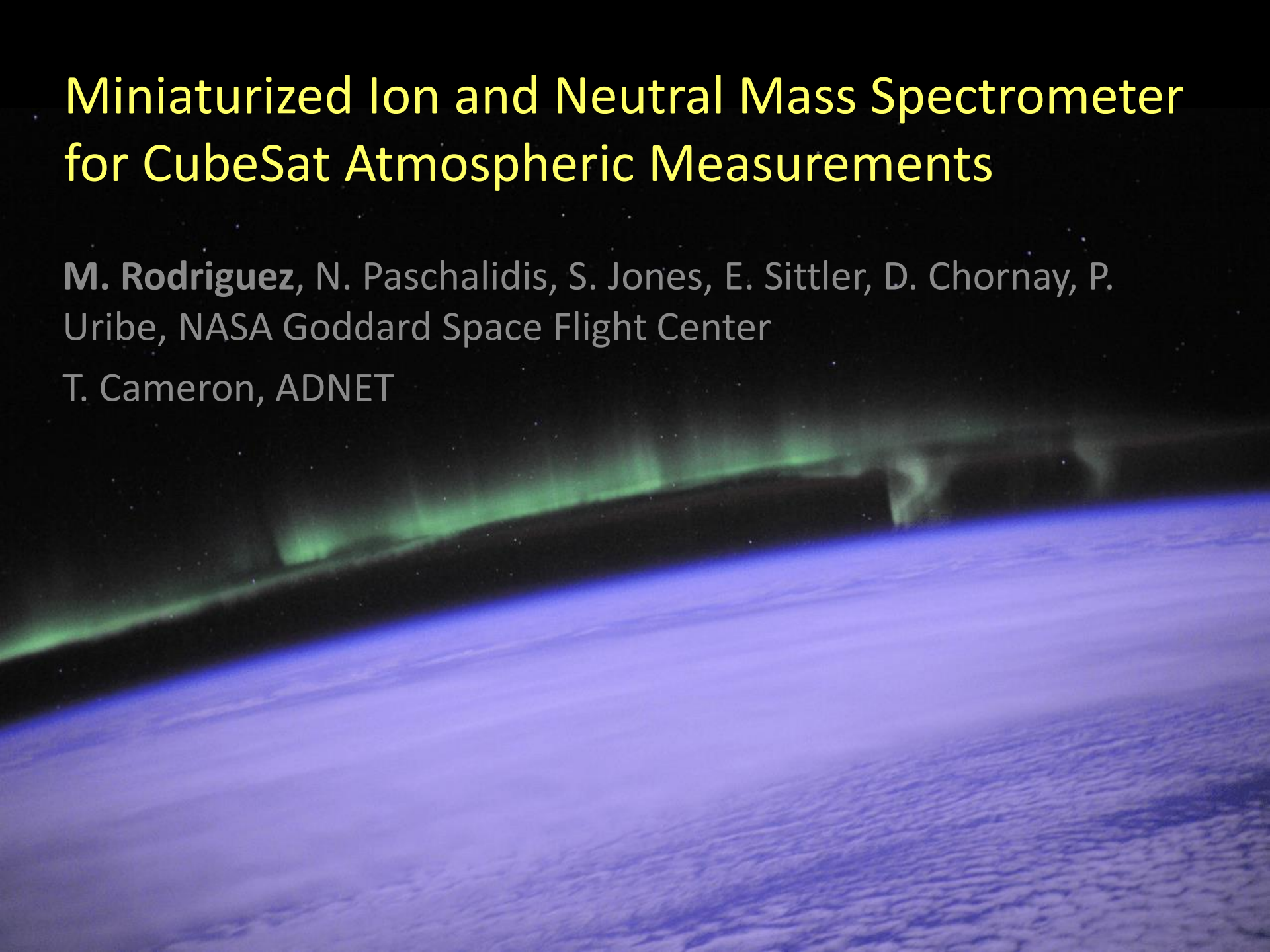
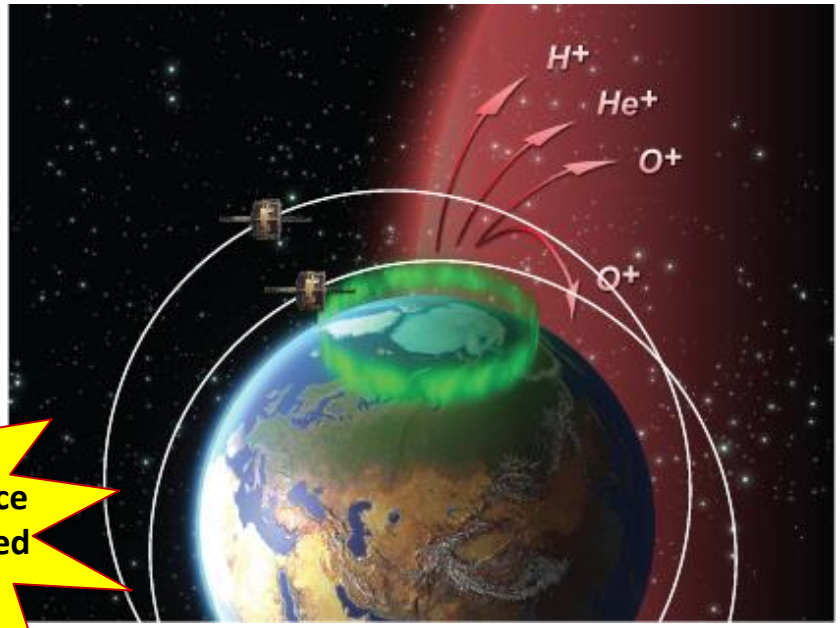
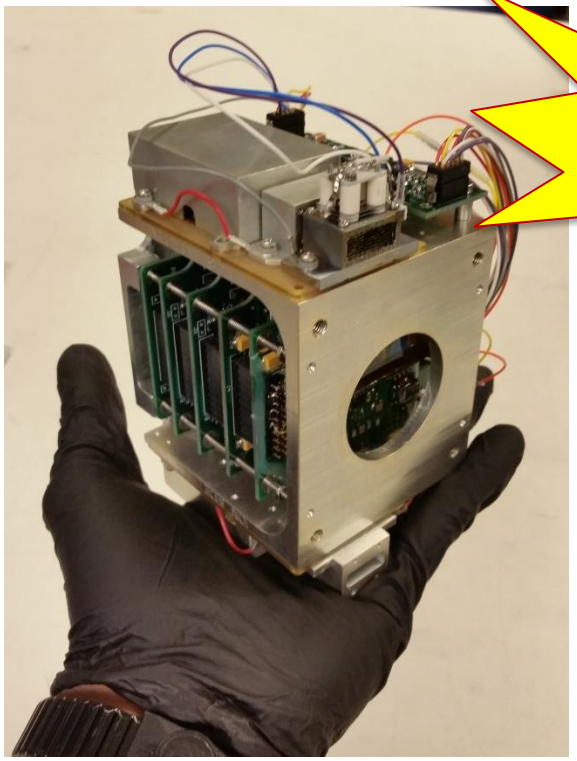


Science Need - Mini Ion Neutral Mass Spectrometer (INMS)

- Demand is high for in situ measurements of atmospheric neutral and ion composition and density
- Define the steady state background atmospheric conditions
- Study of the dynamic ionosphere - thermosphere - mesosphere system





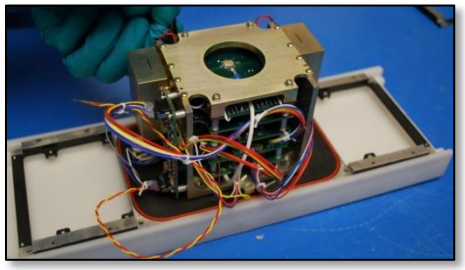
High Quality Science in an unprecedented small package!!

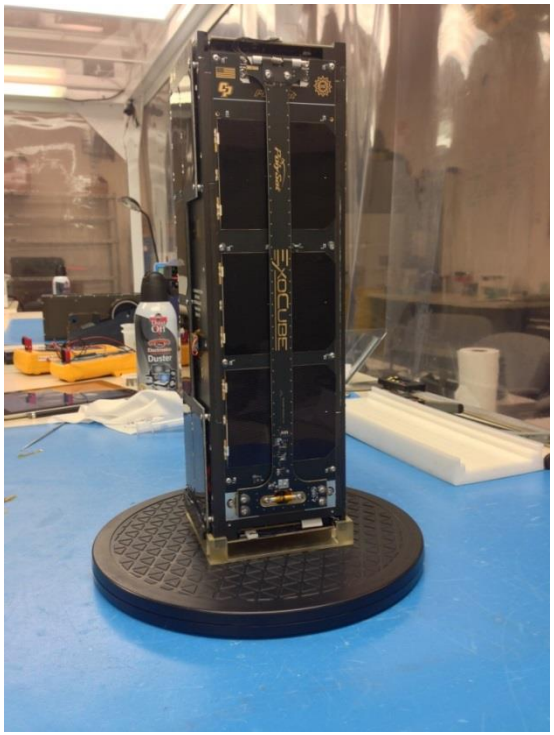
- High-resolution, in situ mass and density measurements of [H], [He], [O], [H+], [He+], [O+], will enable investigations in:
  - Global atmospheric structure and climatology
  - Atmospheric model validation
  - Quantification of charge exchange processes
  - Characterization of storm-time behavior and response
- Mini-INMS designed to address this need

Initial Opportunities

The ExoCube mission, NSF (PI John Noto, Scientific Solutions)

- First flight opportunity for Mini-INMS
- California Polytechnic State (Calpoly) University built
- 3U CubeSat bus
- 440x675km Orbit altitude, 98 degree inclination
- ELaNa-X SMAP Delta II launch January 31, 2015
- 6-12 month operation (ExoCube ended up operating ~7 months)





Delta II out of Vandenberg, CA

National Aeronautics and Space Administration

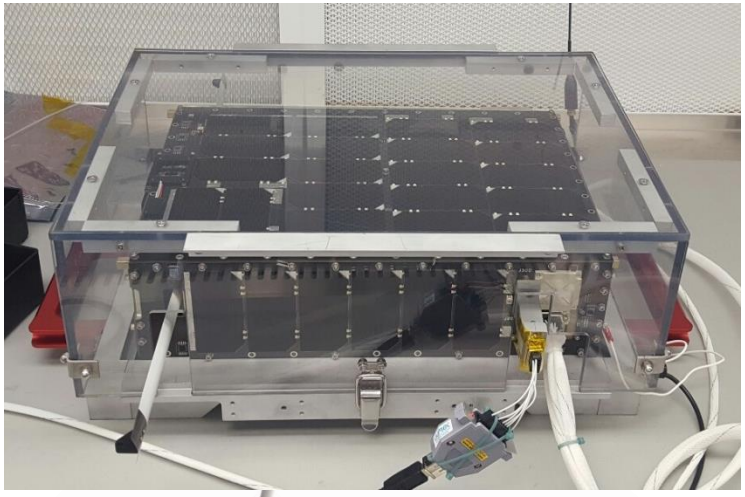
NASA

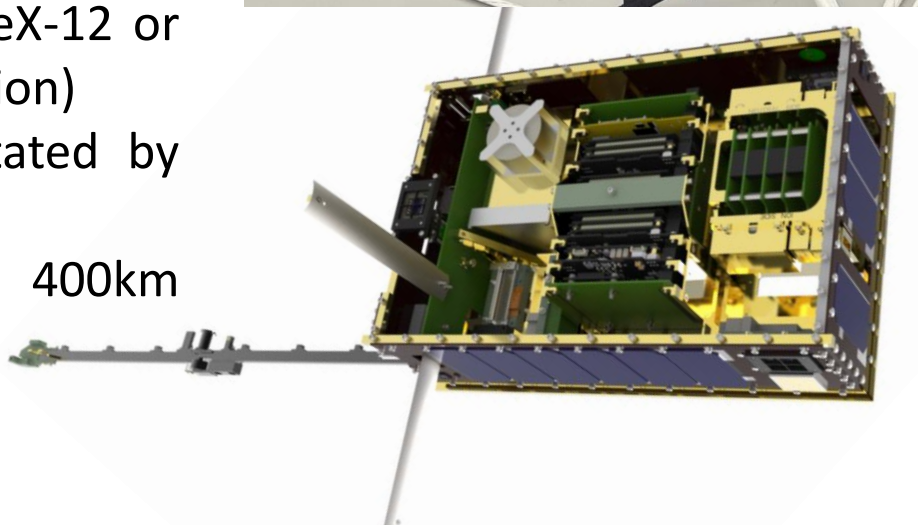
DELLINGR

A Path to Compelling Science

The Dellingr mission (NASA Goddard Space Flight Center)

- Second flight opportunity for Mini-INMS
- Internal GSFC project to gain expertise in 6U buses
- Launch scheduled for April 8th 2017
  - Manifested to fly on ISS (SpaceX-12 or OA-7 commercial resupply mission)
  - Subsequent deployment facilitated by NanoRacks (Q2/Q3 2017)
- ISS-like orbit: 51.6° inclination, 400km circular orbit

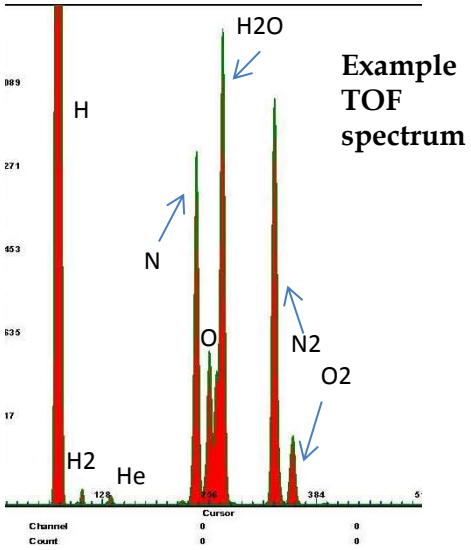


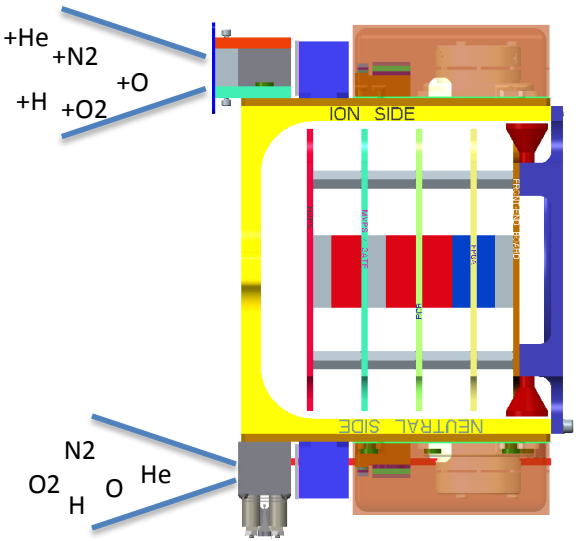


INMS Overview and Specs

Mini-INMS Overview

- Gated Time-Of-Flight instrument
  - Measuring the velocity of each ion - with time of flight over a distance d - gives the mass of the ion according to: $M/q = 2 \times E/q \times TOF^2 / d$
- The mass resolution is limited by uncertainties in energy dispersion, angular distribution and time of flight path

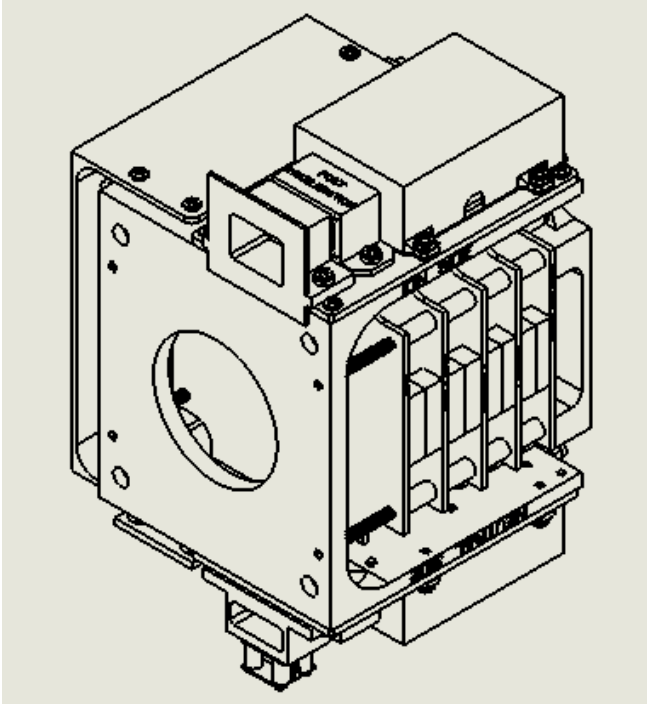




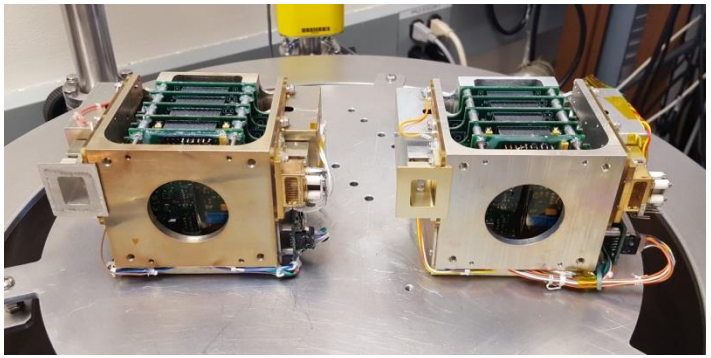
- Measures Ions and neutrals simultaneously without duty cycling
  - Two instruments packaged into one
- Neutral side features an ionization chamber and ion repeller
- In house design – simulations, optics, and all boards (HV, MV, Gate electronics, ECB, C&DH, ionizer control) developed at GSFC

INMS Specifications

Engineering Specifications	
Volume	~13.5cm x 9cm x 9cm
Mass	600g
Power	1.8W (Ions+Neutrals), 1.3W (ions only)
Data (raw data, no compression)	1.3kbps (1s sampling)
Electrical Interface	±5V, +3.3V, +12v, LVDS and SPI serial communication



Science Specifications	
FOV	±20°x ±10° around ram
Mass Dynamic Range	1-40 amu
Mass Resolution	M/dM ~12
Energy Dynamic Range	0.1-500eV
Density Dynamic Range	~10^5 / cm^3
Sampling time rate	0.1s-10s (1s default setting)

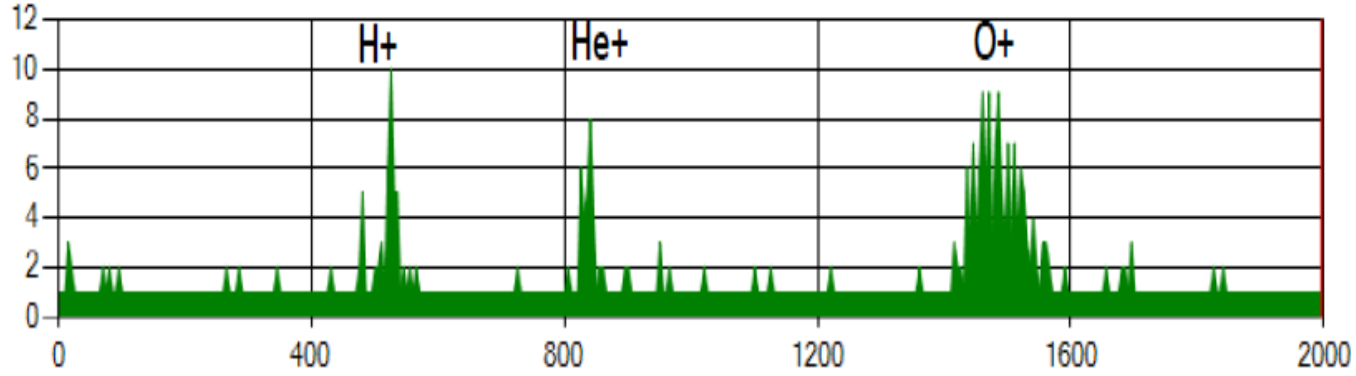


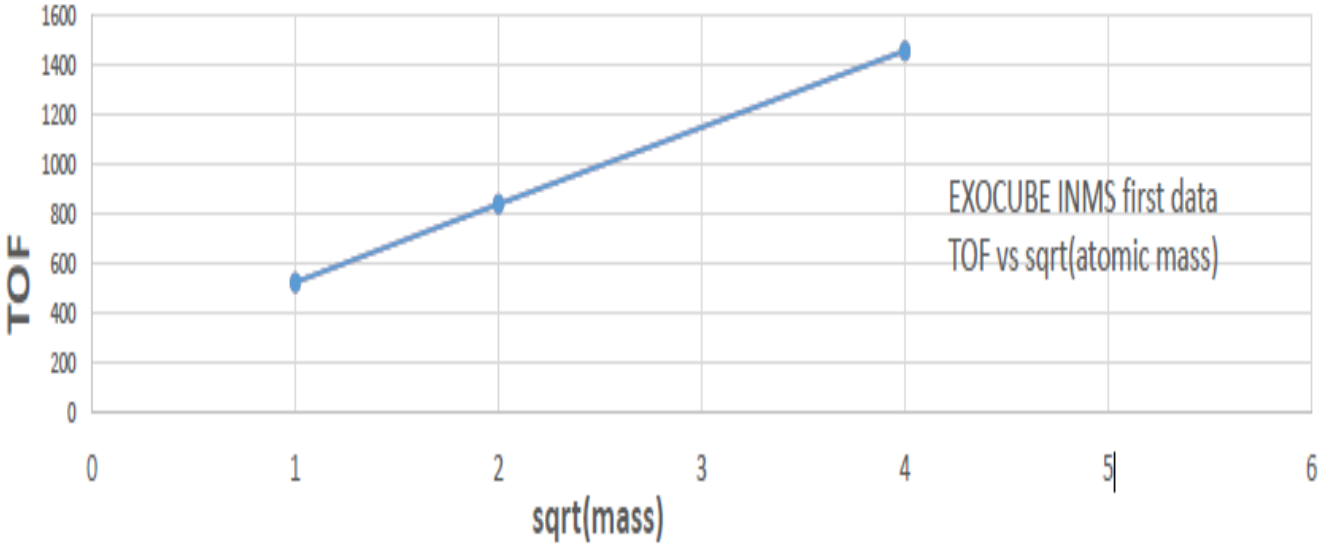
ExoCube Results

ExoCube Mission Operations

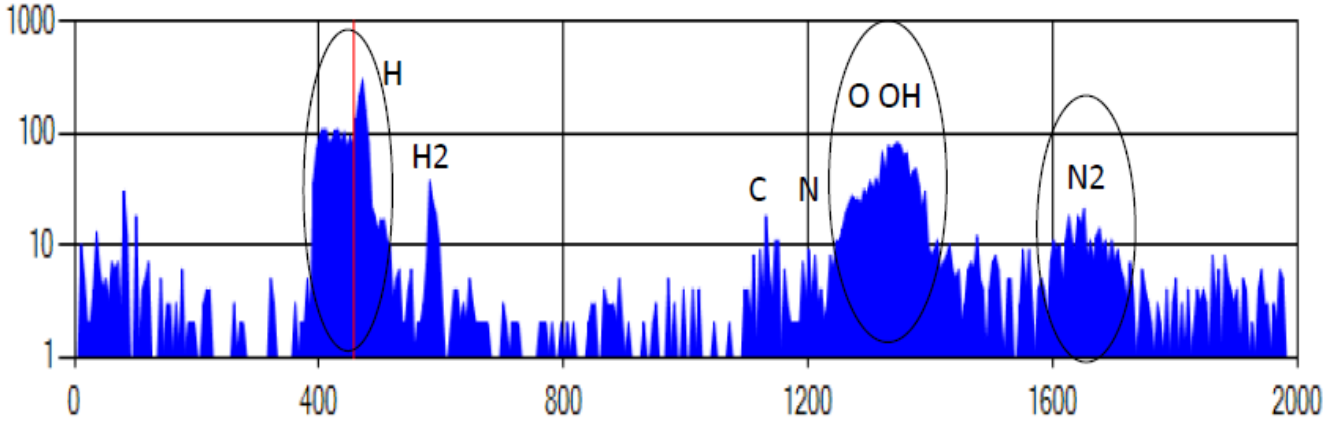
- Weak and infrequent signal due to un-deployed antenna
  - Acquired passes using SRI dish antenna, ~2 pass opportunities per week, occasional communication
- Reprioritize instrument checkout and the technology demonstration

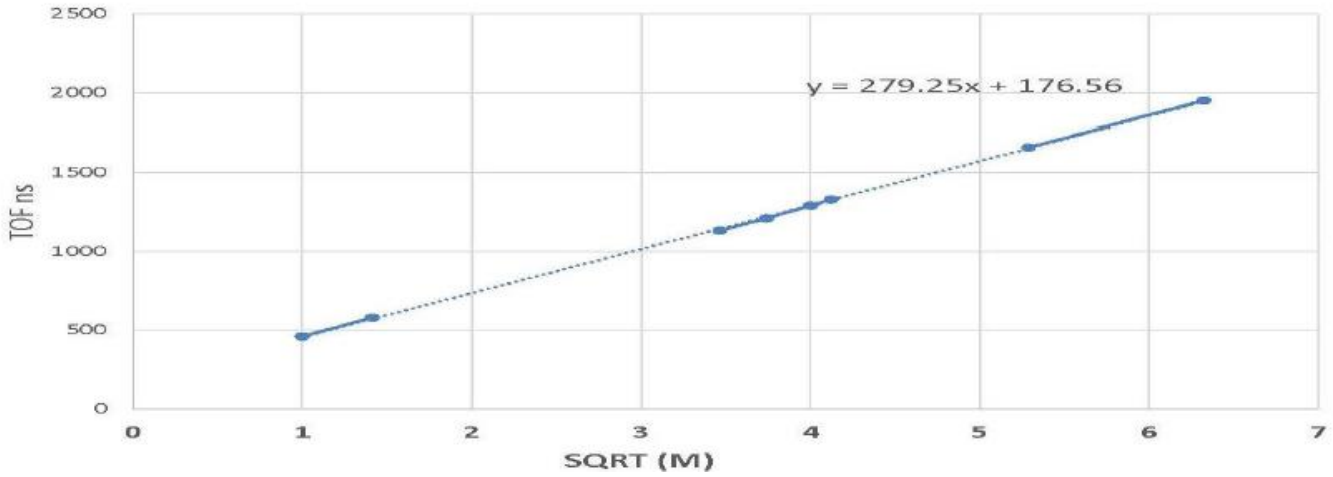
ExoCube INMS:
First Flight Ion Spectrum, May 20 2015





ExoCube INMS:
Flight Neutral Ambient and Outgassing Spectrum, July 15 2015



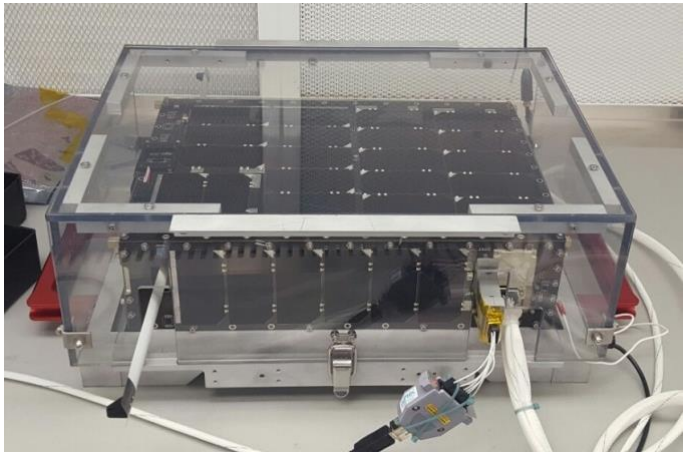


ExoCube INMS summary

- INMS functionality testing showed the instrument in good health
- All voltages and functionality were validated in flight
- ExoCube INMS flight spectra are consistent with those obtained in the lab
- Unable to obtain science data due to loss of spacecraft communications
- Successful technology demonstration brings INMS to TRL 8!

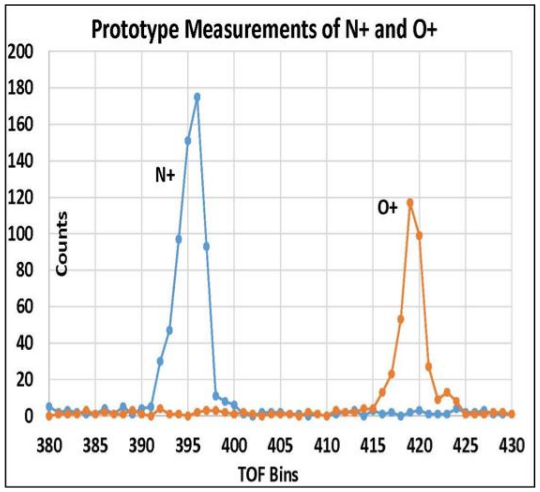
ONGOING DEVELOPMENT EFFORTS

- Delivered July 2016, Launch scheduled for April 2017
- INMS upgrades from ExoCube
  - Ion and Neutral sides are more independent
  - More flexibility to control flux throughput into detector
  - Added electrical and mechanical features for protection against arcing
  - On board calibration feature added
  - Expanded the energy dynamic range of instrument
  - Effective FOV increased

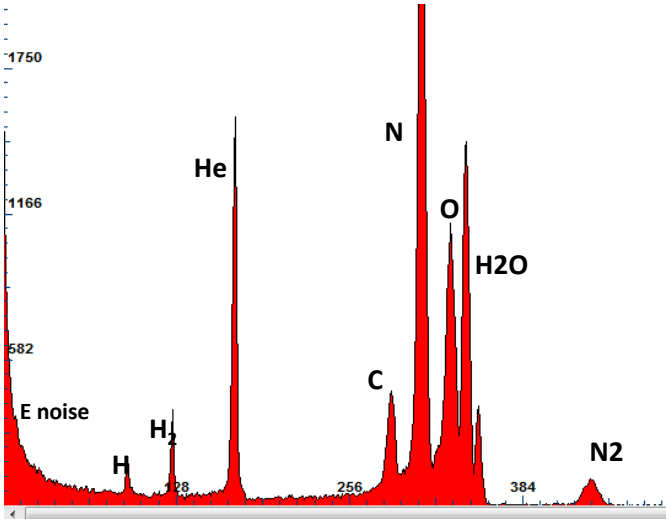


Ongoing and Future Upgrades

- Upgrades ongoing on INMS
  - Increased effective FOV
  - Higher mass resolution techniques being incorporated
  - Modular approaches for flexibility
  - Upgraded Lab and Calibration facility



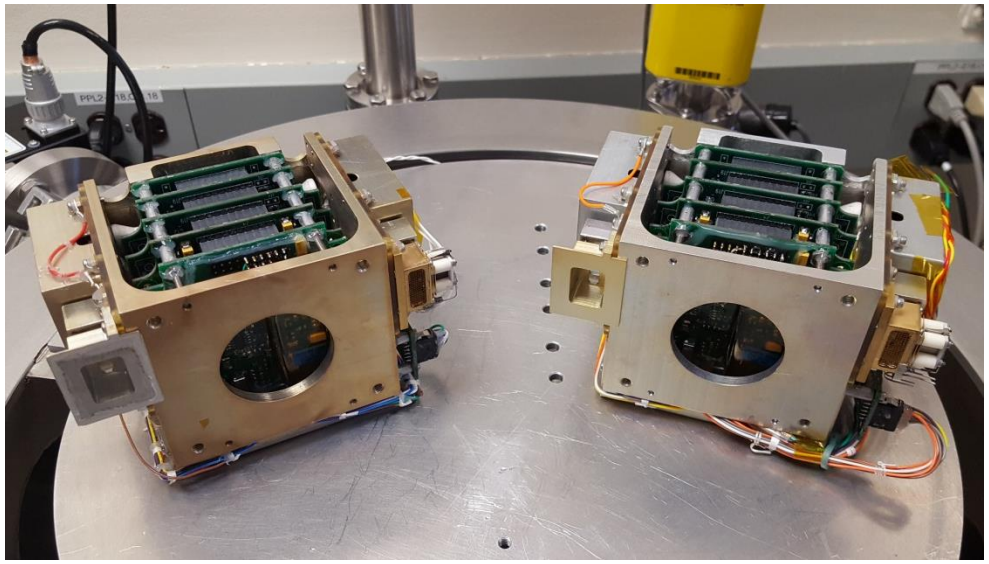
- Neutral wind and ion drift capabilities being developed for specific science applications
  - Minimal empirical measurements to date
  - None directly measured with mass distributions



Future Missions

- ExoCube 2 - NSF Rapid Proposal planned for 2017 for follow up mission
- NASA GSFC Sounding Rocket launch 2018
- Explorer MOO and SMEX mission step 1 being proposed in 2016
- Constellation missions are a prime targets to maximize science and business return
- Planetary missions are applicable
- Looking for partners to increase the flight opportunities for INMS and its upgraded successors

"Ready-to-fly" instrument available now



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