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)
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: $M/q = 2 \times E/q \times \text{TOF}^2 / d$

• 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

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Volume</td>
<td>~13.5cm x 9cm x 9cm</td>
</tr>
<tr>
<td>Mass</td>
<td>600g</td>
</tr>
<tr>
<td>Power</td>
<td>1.8W (Ions+Neutrals), 1.3W (ions only)</td>
</tr>
<tr>
<td>Data (raw data, no compression)</td>
<td>1.3kbps (1s sampling)</td>
</tr>
<tr>
<td>Electrical Interface</td>
<td>±5V, +3.3V, +12v, LVDS and SPI serial communication</td>
</tr>
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### Science Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>FOV</td>
<td>±20° x ±10° around ram</td>
</tr>
<tr>
<td>Mass Dynamic Range</td>
<td>1-40 amu</td>
</tr>
<tr>
<td>Mass Resolution</td>
<td>M/dM ~12</td>
</tr>
<tr>
<td>Energy Dynamic Range</td>
<td>0.1-500eV</td>
</tr>
<tr>
<td>Density Dynamic Range</td>
<td>~10^5 / cm^3</td>
</tr>
<tr>
<td>Sampling time rate</td>
<td>0.1s-10s (1s default setting)</td>
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</tbody>
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ExoCube Results
ExoCube Mission Operations

• Weak and infrequent signal due to undeployed 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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