IT-SPINS
Ionospheric Imaging Mission

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IT-SPINS  Ionosphere-Thermosphere Scanning Photometer for Ion-Neutral Studies

- Mission Overview
- Science Sensor
- Attitude Control
- Flight Subsystem Status
Science Goals

- Study how dominant O\(^+\) ions are lost to charge exchange with H and He atoms at the top of Earth’s ionosphere
- Image disruptive ionospheric structures - polar cap patches, mid-latitude density plumes, and equatorial bubbles
Ionospheric Nightglow

- O$^+$ ions constitute the primary ionospheric species in the F-region

- In the nighttime F-region ionosphere, UV photons are emitted spontaneously from the recombination of atomic oxygen ions,

$$O^+ + e^- \rightarrow O\ (5P) + h\nu_{135.6}$$

- O$^+$ and e$^-$ are in equal number and 135.6 nm emission is proportional to the path integral of [O$^+$] squared
Mission Design

- Sample atomic oxygen nightglow in orbit plane from a spinning 3U spacecraft to enable 2D tomographic inversions of 135.6-nm volume emission rate
- Clone 135.6-nm CTIP photometer from the AF/SMC supported SENSE CubeSat mission
- Build bus with significant heritage from MSU FIREBIRD mission
- Develop ADCS approach with IR Earth limb sensing as the primary knowledge sensor for a 2 RPM pitch rate
Mission Implementation

2 RPM Pitch Rate

Orbit Plane Geometry
SNR Simulation

• Given the satellite orbit and a background ionosphere (from MSIS), we simulate the looking directions and compute the measured SNR.

\[
\text{Signal} = \text{Sensitivity} \times \text{Brightness} \times \text{Integration Time}
\]

\[
\text{SNR} = \frac{\text{Signal}}{\text{Signal} + \text{Dark Current} \times \text{Integration Time}}
\]
SNR Simulation

Orbit: 450 km

Orbit: 600 km
# CubeSat Tiny Ionospheric Photometer - CTIP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>400 counts/R-s</td>
</tr>
<tr>
<td>Dark Current</td>
<td>~100 counts/s</td>
</tr>
<tr>
<td>Minimum Detectable Signal at ( \Delta t = \frac{1}{2} ) sec</td>
<td>0.7 R (SNR = 10)</td>
</tr>
<tr>
<td>Field of View</td>
<td>3.8°</td>
</tr>
<tr>
<td>Stray Light Rejection</td>
<td>(&lt; 10^{-6} )</td>
</tr>
<tr>
<td>Orbit Averaged Power</td>
<td>1.6 W*</td>
</tr>
<tr>
<td>Stowed Form Factor</td>
<td>9.5 cm X 9.5 cm X 9 cm</td>
</tr>
<tr>
<td>Mass (Margin)</td>
<td>482 g (79 g)</td>
</tr>
<tr>
<td>Volume</td>
<td>875 cm(^3)</td>
</tr>
<tr>
<td>Electrical Power &amp; Communication</td>
<td>5 ( \pm 0.2 ) Vdc</td>
</tr>
<tr>
<td></td>
<td>RS422 Serial</td>
</tr>
</tbody>
</table>

*Assumes 45 minutes standby mode and 5 minutes preheat per orbit
CTIP Status

- Both Engineering Model and Flight Model at MSU.
- Flight Code at 100% completion.
Spin long axis of the spacecraft about orbit normal at 12°/sec ± 1.2°/sec per second in the direction of the velocity vector

Maintain spin axis within a +/-1.5° cone about orbit normal

Control rotation rate of the spacecraft to 0 ± 3°/sec about the two axes normal to the spin axis

Determine angular orientation of spacecraft to within 0.3° (TBR)

Determine the angular rates of spacecraft to within 0.12°/sec

Orient payload FOV within a +/- 1.5° cone about the nadir vector (and other targets TBR) during payload commissioning and spectral calibration operations.
ADCS Design – “Enhanced” MAI-400 from Maryland Aerospace

- 3 Reaction Wheels
- Magnetometer
- 6 Sun Sensors
- Dedicated ADCS CPU, accelerometers and rate gyros
- 3 IR Earth Sensors
- 3 Torque Rods
ADCS Current State

Status:
• Final Simulation Program delivery soon.
• Hardware delivery soon.
• Space Flight Computer FSW at 80% Completion
• Current Hardware in the loop simulations

Features:
• IT-SPINS Specific “Spin Mode” added to MAI 400 ADCS.
  – Additional Limb Crossing sensors
  – Faster processing
Subsystem Integration

- 3U Solid-Wall CubeSat Chassis from Pumpkin
- Extensive reuse of secondary structural elements from FIREBIRD
- Mass distribution is a key driver
  - MOI and CG
- Major structural modifications:
  - CTIP and ADCS FOVs
  - Cutouts for antenna system and solar array harnesses
Flight Subsystems - Space Flight Computer (SFC)

Status:
• SFC Functional
• Flight Model and Engineering Model Built
• Flight Code at 90% Completion

Features:
- NOR Flash for CMD Sequences
- NAND For Telemetry Storage
- ADCS interface
- Payload (CTIP) interface
Integration Status – Electrical Power System (EPS)

Status:
• EPS is Functional
• Engineering Model Built
• Flight Code at 100% completion

Features:
• Watch Dog Timer (WDT) for system power
• ADCS power not under WDT control, but is resettable.
• EGSE connection which allows any processor to be reprogrammed.
Integration Status – Communication Subsystem

Status:
• Basic functionality with workarounds developed at MSU.
• MSU team awaiting final programming guide from Astrodev LLC.

Off-Nominal Features:
• None.
Integration Status – Electrical Ground Support Equipment

Status:
• EGSE is Fully Functional
• Engineering GSE Built
• EGSE Code at 100% Completion

Features:
• Foot-Switch Deploy simulated
• Battery Charge
• External Power
• Can Program any PIC on Satellite
• Quad FTDI Chip for GSE status, IT-SPINS GSE Link, and ADCS Telemetry.
• TVAC Chamber Power/Telemetry Link
Flight Subsystem – Full Integration

Status:
• Chassis is currently out to fab.
• 3D printed ULTEM battery bracket complete
• Build-up expected to start by end of May
IT-SPINS ELaNa-18 Launch

Mission manifested with ICEsat-2 on a Delta-II vehicle currently scheduled for a late 2018 launch