On-Orbit Demonstration of the Space Weather and Meteor Impact Monitoring Network

Presenters: Victor Hernandez, Aaditya Ravindran
Advisors: Erik Asphaug, Jekan Thanga
Presentation Outline

1. Mission Overview
2. Concept of Operations
3. Science
4. Subsystems
5. Demonstration Video
Mission Overview
Mission Overview

Name - SWIMNet: Space Weather and Meteor Impact Monitoring Network
Or SWIMSat Network

Primary Mission - Autonomously detect, image, and selectively downlink a meteor impact event or analogous event from a LEO satellite

Secondary Mission - Track and image the same event using a ground telescope

Tertiary Mission - Perform characterization of the effects of drag upon reentry of objects into the upper atmosphere

Chelyabinsk Meteor
Mission Overview

The SWIMNet consists of two 3U CubeSats for imaging, called OSat (Observational Satellite) and will be accompanied by the RockSat (Rock Satellite), a 6U CubeSat carrying a meteor payload.
Concept of Operations
Concept of Operations

1. Deploy OSats
2. Deploy RockSat
3. Commission Satellites
4. Image Testing & Calibration
5. Propulsive Maneuvers
6. Meteor Ejection
7. Reentry
8. Detection & Imaging
9. Monitor
10. Decommission

L + 24 hrs
T = 0
T = 9 hrs
T = 6 wks
+1 day
+1 yr

Launch
ISS Storage
Deployment & Early Operations
Calibration & Testing
Primary Mission
Post Mission
Disposal
Concept of Operations
Science
Science

Example observation of a Draconid meteor ablating

Science Relevance

Releases raw images to scientific community

- Provides empirical data to validate existing models

Example: Calculate Meteor Mass

Dynamic Mass Model

\[
\frac{dv}{dt} = - \frac{\Gamma A}{m^3 \rho^3 m} \rho_a v^2
\]

Photometric Mass Model

\[
I = \frac{1}{2} \frac{dm}{dt} v^2
\]

Source: Campbell-Brown, et al.. Photometric and Ionization Masses of Meteors with Simultaneous EISCAT UHF Radar and Intensified Video Observations.
Subsystems
Subsystems - Command and Data Handling

OSat Software Architecture

- **Camera**
  - Captures frames at variable frame rates
  - Process Image

- **Data Logging**
  - Images logged based on key frames
  - Diagnostics LOG

- **ADCS**
  - ADS and ACS software programmed
  - Control mode implementation for SWIMSat

- **OBC**
  - Change the modes of operation
  - Inter module communication

- **Communication Subsystem**
  - SATCOMM process
  - Command format decode/encode

- **Power**
  - Get power generation status
  - Switch between power modes
  - Prevent bus faults

- **Maintenance Subsystem**
  - Watchdog process
  - System manager process begin

RockSat Software Architecture

- **Camera**
  - Captures frames at variable frame rates
  - Process Image

- **Data Logging**
  - Images logged based on key frames
  - Diagnostics LOG

- **ADCS**
  - ADS and ACS software programmed
  - Control mode implementation for SWIMSat

- **OBC**
  - Change the modes of operation
  - Inter module communication

- **Communication Subsystem**
  - SATCOMM process
  - Command format decode/encode

- **Release Mechanism**
  - Release time
  - Force

- **Propulsion**
  - Thruster burn timing
  - Open and close valve

- **Maintenance Subsystem**
  - Watchdog process
  - System manager process begin

- **Power**
  - Get power generation status
  - Switch between power modes
  - Prevent bus faults
Subsystems - Command and Data Handling

CDH Requirements:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU Frequency</td>
<td>&gt; 400 MHz</td>
</tr>
<tr>
<td>Power</td>
<td>&lt; 10 W</td>
</tr>
<tr>
<td>Data Storage Interfaces</td>
<td>Shall provide support for high speed devices</td>
</tr>
<tr>
<td>Fault Tolerance</td>
<td>Device level fault tolerant support</td>
</tr>
<tr>
<td>Event Scheduling</td>
<td>Priority based event handling for event scheduling</td>
</tr>
</tbody>
</table>

Component selected: SpaceCube Mini
Subsystems - Command and Data Handling

Downlink multiple images from the OSat after performing image compression

Summary of the data budget:

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Total Downlink data</th>
<th>Total Uplink data</th>
</tr>
</thead>
<tbody>
<tr>
<td>RockSat</td>
<td>5.607 MB</td>
<td>20.79 kB</td>
</tr>
<tr>
<td>OSat</td>
<td>161.28 MB</td>
<td>20.79 kB</td>
</tr>
</tbody>
</table>
Subsystems - Communication

Link Budget Summary:
1. Four cases considered for the link budget
2. S band => higher data transfer rate
3. UHF band => higher link margin

<table>
<thead>
<tr>
<th>Band</th>
<th>Uplink Link Margin (dB)</th>
<th>Downlink Link Margin (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHF band uplink and S-band downlink</td>
<td>10.0</td>
<td>7.6</td>
</tr>
<tr>
<td>S-band uplink and UHF band downlink</td>
<td>7.0</td>
<td>10.6</td>
</tr>
<tr>
<td>UHF band uplink and downlink</td>
<td>11.9</td>
<td>10.6</td>
</tr>
<tr>
<td>S-band uplink and downlink</td>
<td>7.7</td>
<td>7.6</td>
</tr>
</tbody>
</table>

S Band data rate: 16 kbps,
UHF Band data rate: 9.6 kbps
Subsystems - Communication

Component selected:

Endurosat S/UHF band transceiver

Factors in component selection:

- Supports both S and UHF bands via independent half-duplex transceivers
- Has a good transmit power of 2W in the S band and 1.5W in the UHF band
- Supports variable data rate
Subsystems - Attitude Determination and Control

Modes of Operation:
1. Detumble – post deployment
2. Communication – pointing to Earth
3. Thrust vector for the RockSat – align the thrust vector to lower the altitude
4. Scan mode for the OSat – points the camera towards the RockSat.
Subsystems - Attitude Determination and Control

OSat ADCS Architecture

- GPS
- ADS
- Sun Sensor
- Magnetometer
- Gyro
- OBC
- Reaction Wheels
- Magneto-Torques

RockSat ADCS Architecture

- GPS
- ADS
- Accelerometer
- Sun Sensor
- Magnetometer
- Gyro
- OBC
- Reaction Wheels
- Magneto-Torques

= MAI-400 ADCS by Maryland Aerospace
**Subsystems - Electrical Power System**

Component selected:
- GOMspace NanoPower BP4 for the OSat (low power)
- GOMspace NanoPower BPX for the RockSat

**Battery Specifications:**

<table>
<thead>
<tr>
<th>Model</th>
<th>NanoPower BPX</th>
<th>NanoPower BP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (Wh)</td>
<td>77</td>
<td>38.5</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Li Ion</td>
<td>Li Ion</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>500</td>
<td>270</td>
</tr>
</tbody>
</table>
Subsystems – Propulsion (RockSat)

Maneuver overview:

- Two maneuvers –
  - Rendezvous maneuver: Reducing perigee to 250 km – required $\Delta V = 53$ m/s
  - Final maneuver: Atmospheric entry – required $\Delta V = 15$ m/s

- Component Selected:

<table>
<thead>
<tr>
<th>Individual Thrusters (1U and 2U)</th>
<th>Expected Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput Limit: 0.5 kg</td>
<td></td>
</tr>
<tr>
<td>Pulse Limit: 5000</td>
<td></td>
</tr>
<tr>
<td>Impulse Limit: 600 N-s</td>
<td></td>
</tr>
<tr>
<td>MIB (BOL): 0.003 N-s</td>
<td></td>
</tr>
<tr>
<td>SS BOL Thrust*: 1.5 N (~0.4 lbf)</td>
<td></td>
</tr>
<tr>
<td>SS Isps: 240 seconds</td>
<td></td>
</tr>
</tbody>
</table>

Aerojet MPS-130 Green Monopropellant
Demonstration Video
Thank you for your attention.

Questions?
Backup Slides
Meteor Ablation Regimes

![Diagram showing different meteor ablation regimes based on altitude and body radius, with labels such as Radio Meteors, Meteors, Fireballs, and Great Fireballs.](image)

Source: Romig, Mary F.. The Physics of Meteor Entry.
Fireball Distribution

Fireballs reported by government sensors from 1988 - 2017

Source: https://cneos.jpl.nasa.gov/fireballs/
Subsystems - Communication

Communication subsystem architecture:
Subsystems - Attitude Determination and Control

Attitude Control Strategies:

- Detumble
- Communications
- Thrust Vector
- Scan

B Dot Controller

Align Body & Orbit Frames

Quaternion Tracking

Align Osat(s) Z-axis & GPS Vector
Subsystems - Attitude Determination and Control

ADCS Specifications:

<table>
<thead>
<tr>
<th>Specification</th>
<th>MAI-400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>0.694 kg</td>
</tr>
<tr>
<td>Dimension</td>
<td>10 x 10 x 5.16 cm</td>
</tr>
<tr>
<td>Power (Nominal)</td>
<td>1.13 W</td>
</tr>
<tr>
<td>Power (Max torque)</td>
<td>2.05 W</td>
</tr>
<tr>
<td>Magnetic Dipole Moment</td>
<td>0.108 Am²</td>
</tr>
<tr>
<td>Pointing Accuracy</td>
<td>&lt;&lt; 1°</td>
</tr>
<tr>
<td>Momentum Storage</td>
<td>11.076 mNms</td>
</tr>
<tr>
<td>Max Torque</td>
<td>0.64 mNm</td>
</tr>
<tr>
<td>Reaction Wheel Stability</td>
<td>&lt; 0.2 arcsec</td>
</tr>
</tbody>
</table>
## Subsystems – Propulsion (RockSat)

### Trade Study:

<table>
<thead>
<tr>
<th>Parameter/Technology</th>
<th>Green Mono.</th>
<th>Cold Gas</th>
<th>Elec. Prop</th>
<th>Hydrazine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust</td>
<td>High</td>
<td>Low</td>
<td>Very Low</td>
<td>High</td>
</tr>
<tr>
<td>Isp</td>
<td>High</td>
<td>Low</td>
<td>Very High</td>
<td>High</td>
</tr>
<tr>
<td>Safety</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>