Design and Development of AOBA VELOX-IV nanosatellite for future Lunar Horizon Glow mission

presented by

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Satellite Research Centre (SaRC)
AOBA VELOX-IV

- Technology demonstration of attitude and orbit control by pulsed plasma thruster (PPT) and low-light camera for future Lunar Horizon Glow observation mission

- Success criteria
  - Momentum dumping of 0.0001 Nms for short axis in 1 hour
  - Orbit maneuvering of $\Delta V=60\text{m/s}$ by PPT in 1 year
  - Capturing images of Earth horizon while entering eclipse, and Earth at night
  - Capturing the Earth-rim image with upper-atmosphere luminous phenomena
  - Obtaining new science data from the captured images

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32nd Annual AIAA/USU Conference on Small Satellites
## Satellite (1/3) – Specifications

<table>
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<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Orbit</strong></td>
<td>Sun-synchronous 500-km orbit</td>
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<tr>
<td><strong>Design lifetime</strong></td>
<td>1 year in LEO</td>
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<tr>
<td><strong>Dimensions</strong></td>
<td>Launch: 113 x 113 x 227 mm³</td>
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<td><strong>Mass</strong></td>
<td>2520 grams</td>
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<td><strong>AOCS</strong></td>
<td>3-axis gyro, 2 fine sun sensors each with 120°-FOV, 6 coarse sun sensors, 3 reaction wheels, 1 PPT</td>
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<td><strong>Data handling</strong></td>
<td>OBC with 2GB storage, I²C and UART interfaces</td>
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<tr>
<td><strong>Communication</strong></td>
<td>UHF half duplex 4800bps GMSK downlink/uplink, dipole antenna</td>
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<tr>
<td><strong>Power</strong></td>
<td>4 deployable and 2 body-mounted solar panels for 18W peak BOL 5.8 Ah Li-Ion battery at 7.2 V nominal</td>
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<tr>
<td><strong>Structure</strong></td>
<td>Al. 7075-T7351 chassis with stainless steel load bearing parts</td>
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<td><strong>Thermal control</strong></td>
<td>Battery heaters</td>
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<tr>
<td><strong>Payloads</strong></td>
<td>Low-light camera, four-head PPT</td>
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</table>
Satellite (3/3) – Power Budget

<table>
<thead>
<tr>
<th>Per Orbit</th>
<th>Sun tracking</th>
<th>Flight path</th>
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<tbody>
<tr>
<td>Energy from SP</td>
<td>17.82 Wh</td>
<td>17.82 Wh</td>
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<tr>
<td>Energy to Battery (sys. efficiency 64%)</td>
<td>11.40 Wh</td>
<td>11.40 Wh</td>
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<td>COM</td>
<td>0.97 Wh</td>
<td>0.31 Wh</td>
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<td>OBC.AOCS</td>
<td>3.78 Wh</td>
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<td>EPS</td>
<td>2.45 Wh</td>
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<td>Camera &amp; PPT</td>
<td>0.00 Wh</td>
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<tr>
<td>Energy used</td>
<td>7.19 Wh</td>
<td>6.54 Wh</td>
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<tr>
<td>Energy gain/loss</td>
<td>3.54 Wh</td>
<td>4.20 Wh</td>
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<tr>
<td>∆ SOC (BOL)</td>
<td>8.84%</td>
<td>10.05%</td>
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Note: Orbit duration 96 minutes, in sunlight 60 minutes
Innovation

- AOCS suite for lunar orbit operation
  - Miniature PPT for orbit maintenance, attitude control, and momentum dumping
  - Low-light camera for horizon sensing
  - Synchronized ground stations to locate satellite using downlink signals

- Miniature four-head PPT
  - Based on proven dual-axis PPT of AOBA VELOX-III
  - 0.5U volume, 5.72 g Teflon each head, power 2.25 W, $I_{\text{bit}}$ 25.2 μNs, and $I_{\text{sp}}$ 676 s
Design (1/2) – Deployment Mechanism

- Two inhibits required to prevent accidental deployment during launch
- Deployable Solar Panels (DSP)
  - Two-fold panel with 2 retaining lines and 2 thermal knives
  - Load on each line is 1.33N (135 gf) max
  - Dyneema line with 75.5 N strength, melting at 144°C
- Antenna
  - In-built deployment mechanism bypassed
  - Two elements held down by DSP which has two inhibits
Design (2/2) – Power Inhibits

- Three inhibits required to keep satellite power off during launch
- Revised EPS
  - Three deployment switches (DS) SW2, SW3, SW4 to cut off battery
  - DS SW1 to disconnect solar panels
  - RBF kill switches SW5a/b and SW6a/b to keep satellite off during handling
Development

- Flat Satellite + Structural Thermal Model (STM) → Proto-Flight Model (PFM)
Testing (1/3) – Overview

- Environmental requirements by JAXA for Epsilon launch vehicle
- STM qualification and PFM acceptance

**FlatSat**
- Interface check
- Functional test
- Mission simulation

**STM**
- Functional test
- Vibration/shock test
- TVAC + Depl. / TCT
- Functional test
- RF test
- EMI/EMC
- HIL AOCS test

**PFM**
- Functional test
- TVAC + Deployment
- Vibration/shock test
- Functional test
- Adapter fit check
- End-to-end test
Testing (2/3) – TVAC, TC, Vibration

- **Thermal Vacuum Test in NTU**
  - 4 Cycles, 1E-5 Pa, 2-hour dwellings, -10°C to 60°C (QT) and -10°C to 50°C (AT)
  - Deployment at -10°C, thermal knives on each panel ON for 60 seconds

- **Thermal Cycle Test in NTU for STM**
  - 4 Cycles, 2-hour dwellings, -10°C to 45°C
  - Deployment at 45°C
  - RF tests with mobile ground station

- **Vibration/Shock Test in Kyutech**
  - Stiffness required: 1st mode > 113 Hz
  - Only 1 retaining wire for each solar panel to simulate worse case (QT)
  - Inhibits remain & satellite stays off during tests, confirmed by Reset count
Testing (3/3) – Other Tests

- Deployment tests in clean room at ambient temperature
  - Record movement of solar panels and antennas
- Delay tests – No deployment and transmission allowed during first 200s
- Inhibit check – Satellite turns off when any switch pressed or RBF pin inserted
- Battery capacity tests for PFM before & after vibration/shock tests
- Hardware in the loop AOCS algorithm test
  - Detumbling of each axis
  - Sun tracking
Thank you!

Q & A