Antarctic Glacier and Sea Ice Observation With a Chinese Cube-Satellite

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- STU-2 Mission & Satellite
- Camera Design
- In-Orbit Data Analysis & Results
- Lessons Learned
- Summary
SECM: Shanghai Engi Centre for MicroSat

SECM was founded on Sep.15, 2003
- Founded by Chinese Academy of Sciences (CAS) and Shanghai City Government
- To build a technical platform and innovation base for micro/small satellites

- Located in Pudong of Shanghai
  - Offices: ~15,000 m^2
  - AIT area: ~12,000 m^2

- Able to manufacture 20+ satellites simultaneously

SECM: Mission Accomplished

Over past 12+ years, SECM has launched into orbit 15+ micro/small/large satellites (2-1800kg), accumulated 40+ orbit-year of satellite operation.

Commnication, Micro/Nano Satellite, Navigation & Science

2003 · CX-1(01)
2008 · CX-1(02)
2008 · BX-1
2011 · CX-1(03)
2014 · CX-1(04)
2015 · STU-2 (TW-1) 3 CubeSats
2015 · Nav-1
2016 · Nav-2
2016 · DarkEnerge
2016 · Quantum
STU-2 Mission Requirements

- Monitoring sea ice status in polar regions
- Gaining the maritime traffic information via AIS receiver
- Monitor civil aircraft traffic information via ADS-B receiver
- New technology demonstration & validation of Micro-propulsion, dual-band GPS-BD receiver, and Gamalink
- Demonstration of autonomous rendezvous (RVD) flight

STU-2 Mission Configuration

- 3 Cube Satellites to carry different payloads
- 2 Ground Stations (UHF band) in Shanghai and Nanjing of China
- 1 Data Receiving Station (S-band) in Shanghai
- Orbit: SSO, 480km, 8:00am
- Launch: Sept 25th 2015 Jiuquan, China
Satellites Configuration

- **STU-2A: 3U CubeSat**
  - Gamalink
  - Camera
  - GPS/BD Receiver
  - Micropropulsion
  - S-band transmitter

- **STU-2B: 2U CubeSat**
  - Gamalink
  - AIS receiver
  - GPS/BD receiver

- **STU-2C: 2U CubeSat**
  - ADS-B Receiver
  - GPS/BD receiver

Project Schedule

- **Phase A/B**
  1. Mission Analysis & Design
  2. System design
  3. SRR, PDR

- **Phase B/C**
  1. Procurements
  2. Subsystem testing
  3. Ground electrical testing
  4. ... ...

- **AIT & Launch**
  1. AIT
  2. Testing
  3. Launch campaign
  4. LEOP & operation

Earth Observation and Marine/Air Traffic Monitoring with a Multiple CubeSat Constellation

S. Wu, 67th IAC, Sept 28th 2016, Guadalajara, Mexico
STU-2A CubeSat

Body mounting solar panel, 3-axis attitude stabilization and control based on momentum wheels and star tracker, UHF TT&C, and S-band transmitter.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Dimension [mm]</td>
<td>340.5x100x100</td>
</tr>
<tr>
<td>ADCS</td>
<td>Attitude Knowledge [°]</td>
<td>±1° (3σ)</td>
</tr>
<tr>
<td></td>
<td>Pointing Accuracy [°]</td>
<td>±0.1° (3σ)</td>
</tr>
<tr>
<td></td>
<td>Pointing Stability [°/s]</td>
<td>0.1°/s</td>
</tr>
<tr>
<td>Thermal</td>
<td>Internal temperature [°C]</td>
<td>-10°C ~ 35°C</td>
</tr>
<tr>
<td>EPS</td>
<td>Bus voltage [V]</td>
<td>13.2V ~ 16.8V</td>
</tr>
<tr>
<td></td>
<td>Battery properties</td>
<td>2.6 Ah, 1 Year</td>
</tr>
<tr>
<td>TT&amp;C</td>
<td>Frequency [MHz]</td>
<td>1449.433 ~ 438 MHz</td>
</tr>
<tr>
<td></td>
<td>Modulation [kbps]</td>
<td>2-FSK</td>
</tr>
<tr>
<td></td>
<td>Uplink</td>
<td>4.8 kbps</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>4.8 kbps</td>
</tr>
<tr>
<td>S-band transmitter</td>
<td>Date rate [kbps]</td>
<td>125 kbps</td>
</tr>
<tr>
<td></td>
<td>Frequency [MHz]</td>
<td>2.425 GHz</td>
</tr>
<tr>
<td></td>
<td>Modulation [kbps]</td>
<td>QPSK</td>
</tr>
<tr>
<td></td>
<td>BER</td>
<td>&lt; 10^-6</td>
</tr>
<tr>
<td>OBC</td>
<td>Process capacity [Mbps]</td>
<td>20 Mbps</td>
</tr>
<tr>
<td></td>
<td>Process storage [M, Flash]</td>
<td>RAM &gt; 2 M, Flash &gt; 256 K</td>
</tr>
</tbody>
</table>

STU-2A Cubesat-Payload

**Optical Camera**
- **Structure**
  - Mass: 466g
  - Dimension: 90 x 90 x 72 mm$^3$
- **Electrics**
  - Power: < 8.2 W (ave), < 8.75 W (peak, < 10 ms)
- **Observation**
  - Resolution: 94.4 m
  - Swatch: 222 x 160 km$^3$

**BD/GPS Receiver**
- **Structure**
  - Mass: 4g
  - Dimension: 22.4 x 17 x 2.2 mm$^3$
- **Electrics**
  - Power: 0.5 W
- **Position**
  - Horizontal: 93 m
  - Altitude: 217.8 km
  - Velocity: 1 m/s
**STU-2A Camera Design**

**Table 1 Mission Requirements on Camera**

<table>
<thead>
<tr>
<th>Imaging function</th>
<th>Swath</th>
<th>&gt;200km@481km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GSD</td>
<td>&lt;100m</td>
</tr>
<tr>
<td></td>
<td>spectrum band</td>
<td>0.43-0.67um</td>
</tr>
<tr>
<td></td>
<td>fps(tunable)</td>
<td>1/5 1/10 1/15</td>
</tr>
<tr>
<td></td>
<td>image type</td>
<td>RAW/RGB</td>
</tr>
<tr>
<td></td>
<td>exposure time</td>
<td>manual/auto</td>
</tr>
<tr>
<td></td>
<td>image size</td>
<td>512 x 512, 1024 x 1024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2352 x 1728</td>
</tr>
<tr>
<td></td>
<td>image number one time</td>
<td>manual set</td>
</tr>
</tbody>
</table>

**Hardware**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>&lt;0.72U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power consumption</td>
<td>&lt;8W(average)</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt;485g</td>
</tr>
<tr>
<td>Mass memory</td>
<td>&gt;4GB</td>
</tr>
</tbody>
</table>

**Interface**

<table>
<thead>
<tr>
<th>Interface between transmitter</th>
<th>SPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface between OBC</td>
<td>I2C</td>
</tr>
</tbody>
</table>

**Camera Electronic Design**

**Detector: CCD vs CMOS APS**

**Table 3 parameters of the CMOS sensor**

<table>
<thead>
<tr>
<th>pixel number</th>
<th>2352 x 1728</th>
</tr>
</thead>
<tbody>
<tr>
<td>pixel size</td>
<td>7.4um x 7.4um</td>
</tr>
<tr>
<td>data rate</td>
<td>160MHz x 2</td>
</tr>
<tr>
<td>Fps</td>
<td>62 fps at full resolution</td>
</tr>
<tr>
<td>dynamic range</td>
<td>57dB</td>
</tr>
<tr>
<td>ADC</td>
<td>8/10bit</td>
</tr>
<tr>
<td>Shutter</td>
<td>global electronic shutter</td>
</tr>
<tr>
<td>power consumption</td>
<td>2.2W(62 fps)</td>
</tr>
<tr>
<td>Power</td>
<td>3.3V</td>
</tr>
</tbody>
</table>

**Control Panel: FPGA**

- FPGA control panel
- Image buffer
- Image data interface
- Control time sequence interface
- CMOS control time sequence
- CMOS serial time sequence
- Image processing
- Image data output

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Camera Optics Design

Table 4 Lens Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite altitude</td>
<td>481km</td>
</tr>
<tr>
<td>Pixel size</td>
<td>7.4um</td>
</tr>
<tr>
<td>F</td>
<td>37.8mm</td>
</tr>
<tr>
<td>F</td>
<td>1/5</td>
</tr>
<tr>
<td>GSD</td>
<td>94m</td>
</tr>
<tr>
<td>Swath</td>
<td>221km × 162km</td>
</tr>
<tr>
<td>FOV</td>
<td>26° × 19°</td>
</tr>
</tbody>
</table>

Camera Structure Design

Titanium alloy and hollowing material
In-Orbit Data Analysis

**Detumbling Phase**

94 minutes after launch, the first received signals showed that the satellite had completed rate damping (three axis angular velocity have been reduce within 0.3º/s) within one orbit period time and entered Sun Pointing Mode automatically.

The in-orbit result was in conformity with simulation.

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**Nadir Pointing Mode**

Three attitude angles were constrained within 1º. The time period is from 08:20 to 08:26, 30th Sep, 2015.
In-Orbit Data Analysis

● Thermal Behavior (STU-2A)

![Thermal Behavior Graph]

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In-Orbit Results

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Earth Observation: Nov 2015

Location: North Brasil, crossing region of the Tapajos river joining the Amazon river

Antarctic Observation: Feb 20 2016

STU-2A pictures as placed into Modis250 data background
Comparison of STU-2A with Modis250 image

STU-2A's image has a resolution at 100m, much better than the resolution of 250m of the Modis250 images.

Antarctic Observation: Feb 23 2016

STU-2A pictures as placed into Modis250 data background No. 21, 22, 23, 24
Imagine No 22, Feb 23 2016

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Imagine No 23, Feb 23 2016

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Lessons Learned

- Structure design must careful to avoid the interferences between electronic boards and optical structures: components height might be bigger in reality.

- Vibration tests and thermal vacuum tests are essential for the camera development, to avoid potential mechanical interference and electrical short-cut.

- EMC is a critical issue in system design and final testing.

- Redundant key sensors/actuators could greatly improve the reliability, providing more measures to tackle irregular cases.

- The impact of magnetic residual remains to be very critical. It can affect attitude stability.

- Magnetometer should be placed as far as possible from large current devices, e.g. PC-104 socket, batteries, etc.

Summary & Acknowledgement

1. CubeSat is successfully used for polar region observation
2. NanoSat at 2.9kg can perform sensible tasks like glacier operation
3. IOD of a few new technology/products: BD/GPS receiver, Cold-gas micro-propulsion module from NanoSpace, …
Thanks!

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