FY-4A satellite commissioning latest outcome

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Outline

1. Background

2. Latest Outcome during Commissioning

3. Operational Readiness

4. Conclusion
In 11 December 2016, the 1st satellite of Fengyun-4 series was launched in Xichang successfully. Then, 6 days later (in 17 December 2016), it was positioned in 99.5°E of GEO orbit and renamed FY-4A.
FY-4A: New Era of GEO Satellite

Spacecraft:
1. Launch Weight: approx 5300kg
2. Stabilization: Three-axis
3. Attitude accuracy: 3”
4. Bus: 1553B+Spacewire
5. Raw data transmission: X band
6. Output power: >= 3200W
7. Design life: over 7 years

**GIIRS**: Geo. Interferometric Infrared Sounder
**AGRI**: Advanced Geosynchronous Radiation Imager
**LMI**: Lightning Mapping Imager
**SEP**: Space Environment Package
## Characteristics of Payloads (Specification & Main Usage)

<table>
<thead>
<tr>
<th>Spectral Coverage</th>
<th>Spectral Band (µm)</th>
<th>Spatial Resolution (Km)</th>
<th>Sensitivity</th>
<th>Main Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VIS/NIR</strong></td>
<td>0.45～0.49</td>
<td>1</td>
<td>S/N≥90 (ρ=100%)</td>
<td>Aerosol</td>
</tr>
<tr>
<td></td>
<td>0.55～0.75</td>
<td>0.5～1</td>
<td>S/N≥200 (ρ=100%)</td>
<td>Fog, Clouds</td>
</tr>
<tr>
<td></td>
<td>0.75～0.90</td>
<td>1</td>
<td>S/N≥5(ρ=1%)@0.5Km</td>
<td>Vegetation</td>
</tr>
<tr>
<td></td>
<td>1.36～1.39</td>
<td>2</td>
<td>S/N≥200 (ρ=100%)</td>
<td>Cirrus</td>
</tr>
<tr>
<td></td>
<td>1.58～1.64</td>
<td>2</td>
<td></td>
<td>Cloud, Snow</td>
</tr>
<tr>
<td></td>
<td>2.10～2.35</td>
<td>2～4</td>
<td></td>
<td>Cirrus, Aerosol</td>
</tr>
<tr>
<td><strong>Middle-wave IR</strong></td>
<td>3.50～4.00</td>
<td>2</td>
<td>NEΔT≤0.7K(300K)</td>
<td>Fire</td>
</tr>
<tr>
<td></td>
<td>3.50～4.00</td>
<td>4</td>
<td>NEΔT≤0.2K(300K)</td>
<td>Land surface</td>
</tr>
<tr>
<td></td>
<td>5.80～6.70</td>
<td>4</td>
<td>NEΔT≤0.3K(260K)</td>
<td>WV</td>
</tr>
<tr>
<td></td>
<td>6.90～7.30</td>
<td>4</td>
<td>NEΔT≤0.3K(260K)</td>
<td>WV</td>
</tr>
<tr>
<td><strong>Long-wave Infrared</strong></td>
<td>8.00～9.00</td>
<td>4</td>
<td>NEΔT≤0.2K(300K)</td>
<td>WV, Clouds</td>
</tr>
<tr>
<td></td>
<td>10.3～11.3</td>
<td>4</td>
<td>NEΔT≤0.2K(300K)</td>
<td>SST</td>
</tr>
<tr>
<td></td>
<td>11.5～12.5</td>
<td>4</td>
<td>NEΔT≤0.2K(300K)</td>
<td>SST</td>
</tr>
<tr>
<td></td>
<td>13.2～13.8</td>
<td>4</td>
<td>NEΔT≤0.5K(300K)</td>
<td>Clouds, WV</td>
</tr>
</tbody>
</table>

### LMI’s Main Usage:
Acquire lightning distribution maps for a certain coverage

- **Spatial resolution**: about 7.8Km at SSP
- **Sensor size**: 400×300 ×2
- **Wave-length at center**: 777.4nm
- **Band-width**: 1nm ± 0.1nm
- **Detection efficiency**: >90%
- **False-alarm ratio**: <10%
- **Dynamic range**: >100
- **SNR**: >6
- **Frequency of frames**: 2ms
- **Quantization**: 12 bits
- **Measurement Error**: 10%

### AGRI’s Main Usage:
Acquire multiple band, high temporal resolution, high radiation accuracy images of Earth’s surface, atmosphere and cloud

### GIIRS’s Main Usage:
Acquire atmospheric temperature and humidity profile structures under clear condition

<table>
<thead>
<tr>
<th>Spectral Parameters</th>
<th>Range</th>
<th>Resolution</th>
<th>Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWIR</td>
<td>700-1130 cm⁻¹</td>
<td>0.8</td>
<td>538</td>
</tr>
<tr>
<td>S/MIR:1650-2250 cm⁻¹</td>
<td>1.6</td>
<td>375</td>
<td></td>
</tr>
<tr>
<td>VIS</td>
<td>0.55-0.75 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LWIR/MWIR</td>
<td>16 Km SSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIS</td>
<td>2 Km SSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China area</td>
<td>5000 x 5000 Km²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesoscale area</td>
<td>1000 x 1000 Km²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China area</td>
<td>&lt;1 hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesoscale area</td>
<td>≤½ hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LWIR: 0.5-1.1</td>
<td>S/MIR: 0.1-0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIS</td>
<td>S/N&gt;200 (ρ=100%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5 K (3σ) radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 ppm (3σ) spectrum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### GIIRS

- **Frequency of frames**: 2ms
- **SNR**: >6
- **Quantization**: 10 ppm (3σ) spectrum
- **Quantization Bits**: 13 bits
1. Background

2. Latest Outcome during Commissioning

3. Operational Readiness

4. Conclusion
The whole IOT for FY-4A is composed of 3 stages:
1st stage: 20161226-20170630, testing mainly for satellite function and performance, spatial segment of FY-4A is turned over to end users;
2nd stage: 20170630-20170930, testing mainly for L1 products;
3rd stage: 20171001-20171230, testing mainly for L2+ products.

From Jan.1 to Mar.31 2018, a trial run for the whole space- and ground- systems of FY-4A is still undergoing to polish its performance gradually.
### Main Results of 1st Stage of FY-4A IOT

<table>
<thead>
<tr>
<th>Testing Items</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Platform or Space Segment System</td>
<td>OK</td>
</tr>
<tr>
<td>2. Data transmission, Telemetry &amp; Telecontrol, Data Acquisition System</td>
<td>OK</td>
</tr>
<tr>
<td>3. Combined Mission Management System Testing between Space and Ground Segments</td>
<td>OK</td>
</tr>
<tr>
<td>4. Ranging &amp; Orbit Determination System</td>
<td>OK</td>
</tr>
<tr>
<td>5. Combined Image Navigation &amp; Registration System Testing between Space and Ground segments</td>
<td>OK</td>
</tr>
<tr>
<td>6. Calibration &amp; Validation System Testing</td>
<td>OK</td>
</tr>
<tr>
<td>7. Payload: AGRI</td>
<td>OK</td>
</tr>
<tr>
<td>8. Payload: GIIRS</td>
<td>OK</td>
</tr>
<tr>
<td>9. Payload: LMI</td>
<td>OK</td>
</tr>
<tr>
<td>10. Payload: SEP</td>
<td>OK</td>
</tr>
</tbody>
</table>
Cyclone in Australia

Haze in the Bay of Bengal

Vortex in the South Pole Area

Cellular Clouds in the South Pole Area

Tropical Cyclone (local area)

Tibet and its surrounding areas

Tropical Cyclone (wide area)

Frontal Cyclone in Japan

Snow Cover Monitoring in north China
Initial measurements from GIIRS in IR spectrum: Interferogram
Initial measurements from GIIRS in IR spectrum: Spectrogram

[Graph showing CO₂ and O₃ atmospheric windows with measurements from different regions (North, Equator, South).]
GIIRS: BT animation of different layers in troposphere for China area
A typical thunderstorm occurred in West Australia during 13 February, 2017
## Typical IOT results: attitude determination error

<table>
<thead>
<tr>
<th>Specification</th>
<th>roll (arcsecond)</th>
<th>pitch (arcsecond)</th>
<th>yaw (arcsecond)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random error (arcsecond, 3σ)</td>
<td>3</td>
<td>2.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- **Daily attitude maneuver due to sunray pressure**

![Graph of daily attitude maneuver due to sunray pressure]
Typical IOT results: accuracy of orbit determination

<table>
<thead>
<tr>
<th></th>
<th>specification</th>
<th>measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-segment of curve (6h): meter</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Short-segment of curve (5m): meter</td>
<td>66</td>
<td>60</td>
</tr>
</tbody>
</table>
Typical IOT results: accuracy of AGRI INR (<1 IR pixel)
Full Disc Animation (1km)

UTC 20170330000000
CH05 CH03 CH01
0.83 0.65 0.47um
Animation of Local Area (0.5km)
Animations of Local Area

Spatial Res: 1km

Spatial Res: 4km

Animations of Local Area
Typical IOT results: accuracy of GIIRS INR (<1 IR pixel)

- **02Jun2017UTC05:11:01**
  - Position in EW (pixel)
  - Position in SN (pixel)
  - real ocean-land boundary
  - Image ocean-land boundary

- **02Jun2017UTC05:41:01**
  - Position in EW (pixel)
  - Position in SN (pixel)
  - real ocean-land boundary
  - Image ocean-land boundary

**without** thermal distortion compensation

**with** thermal distortion compensation
Typical IOT results: accuracy of LMI INR (<1 pixel) during Daytime
Typical IOT results: main performance monitoring for AGRI

Time: 30 March ~ 3 April, 2017

Time: 15-25 April, 2017

Sensitivity

CAL Slope

CAL Bias Monitoring for TEB

CAL Performance Monitoring for RSB

Bias = 0.05K
Std = 0.26K
Samples = 643
➢ Full optical-path & aperture blackbody with a space-ground combined calibration method is adopted;

➢ Under the complex thermal environment of GEO orbit, the daily calibration biases for all TEBs are less than 1K;

➢ The daily calibration bias of 10.3µm band is perfect (<0.3K).
Typical IOT results: Spectral CAL monitoring for GIIRS (< 8ppm)
Typical IOT results (CASE): Radiometric CAL bias monitoring for GIIRS

**Mean Bias: -0.64K**

FY4A_GIIRS_IASIA_INF_20170617023000_20170617024049
DwellPos: 25
Detector: 56
DeltaTime: 465 s
LONLAT: (102.855339, 2.887226)

**Mean Bias: 0.99K**

FY4A_GIIRS_IASIA_INF_20170617023000_20170617024049
DwellPos: 25
Detector: 56
DeltaTime: 465 s
LONLAT: (102.855339, 2.887226)
Typical IOT results (STA.): Radiometric CAL bias monitoring for GIIRS

\[
\text{bias}_{\text{mean}} = -0.62K
\]

\[
\text{std}_{\text{mean}} = 1.42K
\]

\[
\text{bias}_{\text{mean}} = 0.95K
\]

\[
\text{std}_{\text{mean}} = 5.27K
\]

Period: 20170801~20171031; Ref: METOP-A/IASI; Samples: 110(LW)/108(MW)
Typical IOT results: In-orbit work performance monitoring for SEP

- Geomagnetic activity
- High-energy electron
- Absolute-charge on surface
- Differential-charge on surface
- Deep-charge
- Radiation amount

Space Environment

Space Weather Effect
One big problem: sensitivity of GIIRS is worsen in partial spectrum since 8 March, 2017.
Outline

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3. Operational Readiness
4. Conclusion
1st stage of in-orbit testing for FY-4A is completed

Operation Ready

- Image Navigation & Registration
- Calibration & Validation
- Ranging & Orbit determination
- Mission Schedule / Timetable
- Data Broadcast & Distribution

Criteria for Operational Readiness

1st stage of in-orbit testing for FY-4A is completed
Mission Schedule: AGRI

- Full disc observation can be finished within 15 min at one hour interval;
- Local area (China and its surrounding) observation is restricted within 5 min;
- A complete auxiliary observations (i.e. blackbody, space and star views) is performed every 15 min;
- Every 3 hours, a combination of 3 full-disc images is done to support AMV product generation;
- During 17-19 at local time, AGRI is suspended to ensure its safety.
Local area (China and its surrounding) observation is the main mode of GIIRS, and is divided into several 15-min fragments to fulfill *(Note: totally about 2.5 hours)*;

A complete auxiliary observations (i.e. blackbody, space and star views) is performed every 15 min;

Every 3 hours, a group of landmark observations is done to support INR of GIIRS;

During 15-19 at local time, GIIRS is suspended to ensure its safety.
LMI observation is fixed on the local area (China and its surrounding);
Every 15 min, a group of landmark observations is done to support INR LMI;
LMI can continuously operate at all local;
......
Data Broadcasting & Distribution

- Direct Broadcast: in progress
- CMACast Distribution: ready
- Internet: ready

For City-level and County Met. Services

DVBS Downlink

DVBS Uplink

Communication Satellite CMACast

RAW Data

DCP Downlink

DCP Uplink

NSMC

WEB Server For All Users

Internet

WEB Data Service

CMA Intranet

Internet
Customized Data Service via Internet

- **Terminal**
  - ✓ identify on web, ordered & automatic download
  - ✓ parallel download, resume from break point mode, P2P acceleration

![Diagram showing data service flow]

- Data service on local network
  - Local network:
    - data extract
    - Q.C.
    - archive
  - DMZ for internet:
    - metadata syn.
    - QV extract
    - data deliver
  - Processes:
    - search
    - order
    - download
Main L2 Products of AGRI

CLM

CLP

CLT

CTH

CTP

CTT
Preliminary Temperature and Humidity Profiles from GIIRS

Merits:
1) Observation biases removed;
2) Observation channels optimized;
3) Physical and statistical methods are combined.
Main L2 Products of LMI

Validation for L2 products is undergoing
Outline

1. Background

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4. Conclusion
• New generation GEO meteorological satellite (FY-4) is commissioned and ready for real applications
  ■ High temporal, spatial & radiometric accuracies imager is available;
  ■ High-spectral sounder is firstly onboard in GEO platform;
  ■ Multiple sensors can coordinate with each other stably;
  ■ Scheduled to provide operational service since April, 2018

• Many detailed works need to be done further
  ■ Hyperspectral soundings utilization in regional NWP model
  ■ Integrated applications with multiple-sensors in severe weather monitoring as well as short-term climate prediction
  ■ ……
Thanks for your attention