Taiwan’s GNSS Reflectometry Mission – The FORMOSAT-7 Reflectometry (FS-7R)

Chen-Tsung Lin
National Space Organization, Taiwan
FS-7R Satellite Mission

Scientific Mission:
- To measure the roughness and wind speed on ocean surface by the domestic developed GNSS-R mission payload

Technology Demonstration:
1) To demonstrate the domestic developed GNSS-R Payload
2) OBC and PCU are heritage from FS-5 program and are been optimized in terms of volume, mass, and power consumption
3) To demonstrate a domestic developed H$_2$O$_2$ Propulsion System
4) To demonstrate attitude control components and algorithms, include Fiber Optical Gyro (FOG), GPS receiver (GPSR), Gyro/Stellar attitude determination algorithm, and Gyro-less attitude determination algorithm
5) To demonstrate micro-stepping solar array driving system and peak-power tracking system
FS-7R vs. FS-7 Mission Satellite

FS-7R Satellite

FS-7 Mission Satellite

Common components:
- Propulsion system
- Solar Array
- S-band transceiver
- Reaction wheel
- Magnetometer
- Coarse sun sensor
- Torquer
- Battery

GNSS-R Mission Payload

TGRS Mission Payload
FS-7R Satellite Configurations

Deployed Configuration

- GNSS-R High-gain Nadir Antenna
- Solar Array
- GPS Receiver
- Fiber Optical Gyro

Stowed Configuration

- H₂O₂ Propulsion System

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FS-7R Key Parameters and Milestone

- **Spacecraft key parameters and performance:**
  - Volume (Stowed): 100x120x125 (cm)
  - Mass: less than 285 kg
  - Design life time: 5 years
  - Mission orbit altitude: circular 550~650 km
  - Mission orbit inclination: > 24° (TBD)
  - Attitude control accuracy: better than 0.1 degree, 3 sigma
  - Attitude knowledge: better than 0.1 degree, 3 sigma
  - Science data storage: >2 G-bit

- **Development milestone:**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
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<tbody>
<tr>
<td>2012</td>
<td>Kick-off</td>
</tr>
<tr>
<td>2013</td>
<td>SDR</td>
</tr>
<tr>
<td>2014</td>
<td>PDR</td>
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<tr>
<td>2015.06</td>
<td>CDR</td>
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<tr>
<td>2017.11</td>
<td>ITR</td>
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<tr>
<td>2020.03</td>
<td>PSR</td>
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SDR: System Design Review  
ITR: Integration and Test Review  
PDR: Preliminary Design Review  
PSR: Pre-Shipement Review  
CDR: Critical Design Review
FS-7R Satellite I&T Status

- Most components fit-check are completed.
- Harness installation is completed.
- OBC/PCU installation is completed.
- EGSE validation is completed.
- Satellite is ready for electrical integration and test.
# GNSS-R Science Mission Goal

<table>
<thead>
<tr>
<th>Goal</th>
<th>Measurement requirements</th>
<th>Expected performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed retrieval under TC (Wind-speed &gt;20 m/s)</td>
<td>Measurement under precipitation condition</td>
<td>&lt; 120mm/hr (TBD)</td>
</tr>
<tr>
<td>Wind-speed range</td>
<td></td>
<td>&lt; 70 m/s</td>
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<tr>
<td>Wind-speed error</td>
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<td>10%</td>
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<tr>
<td>Resolution</td>
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<td>25 km (TBD)</td>
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<tr>
<td>Wind speed under regular conditions</td>
<td>Wind-speed range</td>
<td>3-20 m/s</td>
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<tr>
<td>Wind-speed error</td>
<td></td>
<td>2 m/s (TBD)</td>
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</table>
Spacecraft and GNSS-R Payload Interfaces

L1/L2 Omni Zenith Antenna

L1/L2 High-gain Nadir Antenna

L1/L2 LNA

L1/L2 LNA

GNSS-R Payload

GNSS-R Receiver

Power I/F: +28V

Science Data I/F: Space-wire

TM/TC I/F: RS422/UART

PPS I/F: RS422

Power Control Unit (PCU)

On Board Computer (OBC)

Spacecraft Bus

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GNSS-R Receiver

Functional Block

**Navigation Unit**
- Acquisition
- Tracking
- Navigation

**Science Unit**
- Reflection Parameter Calculation

- **Local Oscillator**
- **PRN code generator**
- Different Code Delay
- **90°**

- **CIC Filter**
- **FFT**

- **Delay-Doppler Map (DDM) Processing (FPGA)**

- **Extract Desired Region**

Science Data (DDM) Output

satellite position
satellite velocity
Receiver position, velocity, time, time drift
Reflection point
Extra range estimation
Doppler estimation (CPU)
GNSS-R Payload Development Approach

- High-gain Antenna (ITRI)
- Low Noise Amplifier (LNA) (ITRI)
- Zenith Antenna Screening (NSPO)
- Airplane Flight Test (NSPO/NCKU)
- Digital Module and Mechanism (NSPO)
- RF Front End Module (ITRI)
- GNSS-R Receiver Integration and Test (NSPO)
- Data Validation (NCKU)

NSPO: National Space Organization
NCKU: National Cheng-Kung University
ITRI: Industrial Technology Research Institute
GNSS-R Payload Status

- GNSS-R receiver: EQM has been completed TC testing and the dynamic test is under planning.
- GNSS-R has integrated on Engineering Development Model (EDM). TM/TC and science data has been validated with the EDM.
- Still working on optimizing calibration algorithm…
The L1/L2 LNA flight model is ready.

(Data taken during random-vibe test)

(Data taken during T/C test)
The L1/L2 Nadir High-Gain Antenna flight model is ready.
GNSS-R Payload Validation Status

- Two Airplane Flight Tests were conducted

A: A GNSS-R Prototype, a PC/Laptop & a Power Supply on AIDC Console. 115V/60Hz power is required on console.

B: A Nadir Antenna mounted underneath a modified RTT-9 Tow Target. A RF Cable be routed from AIDC Console (through Pylon & Tow Winch Machine) to Nadir Antenna.

C: A Zenith Antenna & RF Cable ready for DOTSTAR Program.
GNSS-R Payload Validation Status

- Two Airplane Flight Tests were conducted (Cont’d)
GNSS-R Payload Validation Status

- Two Airplane Flight Tests were conducted (Cont’d)

Flight parameters:
- Height 8000m
- Speed around 600 km/hour
- 30 minutes data collection

Wind Speed Retrieval
Level 1a calibration will be now implemented on-board GNSS-R receiver.
謝謝，敬請指教!
Thank you for listening!