Current status of Hyperspectral Imager Suite (HISUI) onboard International Space Station (ISS)

“HISUI” has two meanings in Japanese, names of a mineral and a bird.

*Tsuneo Matsunaga1, Akira Iwasaki2, Satoshi Tsuchida3, Koki Iwao3, Jun Tanii4, Osamu Kashimura4, Ryosuke Nakamura3, Hirokazu Yamamoto3, Soushi Kato3, Kenta Obata3, Koichiro Mouri4, and Tetsushi Tachikawa4

1 National Institute for Environmental Studies (NIES), 2 University of Tokyo, 3 National Institute of Advanced Industrial Science and Technology (AIST), 4 Japan Space Systems,
What is HISUI? A Successor of Terra ASTER

- **HISUI** is a future spaceborne hyperspectral imager being developed by Japanese Ministry of Economy, Trade, and Industry (METI) as its 4th spaceborne optical imager mission.

  1) OPS onboard JERS-1 satellite (1992 – 1998)
  2) ASTER onboard NASA’s Terra satellite (1999 -)
  3) ASNARO (2014-)
  4) HISUI (2019 -)

- The objective of HISUI is to obtain data necessary to start full-scale application development of hyperspectral remote sensing for oil/gas/mineral resource exploration and other fields such as agriculture, forestry, and coastal issues.

- HISUI will be launched in **2019** and deployed on Japan Experiment Module (JEM) of International Space Station (ISS) for three year operation under collaboration with Ministry of Education, Culture, Sports, Science and Technology (MEXT) and JAXA.
HISUI Deployment on ISS JEM

- HISUI-Exposed Payload (HISUI-ExP) and HISUI-Mission Data Recorder - Pressurized Module (MDR-PM) will be delivered to ISS by Dragon / Falcon 9 cargo rocket in 2019.

- HISUI-ExP will be attached to Port #8 of JEM Exposed Facility (EF) as a nadir-viewing instrument. It also has support sensors such as a gyro, two star trackers, GPS receivers, and a mission data processor.

- MDR-PM will be installed in JEM-PM.

- HISUI data will be partially transmitted to ground stations (≈ 10 GB/day ≈ 30,000 km$^2$). The rest (≈ max. 300 GB/day ≈ 900,000 km$^2$) will be recorded in removal media and shipped back to Earth by cargo ships three or four times a year.
## HISUI Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HISUI Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging Type / Spectral Dispersion</td>
<td>Pushbroom / Grating</td>
</tr>
<tr>
<td>Spatial Resolution / Swath</td>
<td>20 m (CT) x 30 m (AT) / 20 km</td>
</tr>
<tr>
<td><strong>Spectral</strong></td>
<td></td>
</tr>
<tr>
<td>Range / Bands</td>
<td>0.4 - 2.5 µm / 185 bands</td>
</tr>
<tr>
<td>Resolution</td>
<td>10 – 12.5 nm</td>
</tr>
<tr>
<td>SNR (30% albedo)</td>
<td>≥ 450 @620 nm ≥ 300 @2100 nm</td>
</tr>
<tr>
<td>MTF</td>
<td>≥ 0.2</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>Saturated at 70% albedo</td>
</tr>
<tr>
<td>Spectral Calibration</td>
<td>VNIR : 0.2 nm SWIR :0.625 nm</td>
</tr>
<tr>
<td>Radiometric Calibration</td>
<td>Absolute : ±5%, among bands :±2%</td>
</tr>
<tr>
<td>Quantization / Data Compression</td>
<td>12 bits / Lossless (70%)</td>
</tr>
<tr>
<td>Telescope Diameter</td>
<td>≈ 30 cm</td>
</tr>
<tr>
<td><strong>HISUI ExP Dimensions / Mass</strong></td>
<td></td>
</tr>
<tr>
<td>HISUI ExP Dimensions / Mass</td>
<td>≈ 2.3 x 1.5 x 1.6 m</td>
</tr>
<tr>
<td></td>
<td>≈ Nominal / Max 550 / 570 kg</td>
</tr>
<tr>
<td></td>
<td>including Hyperspectral Imager (= 240 kg)</td>
</tr>
</tbody>
</table>

ISS altitude ≈ 400 km
## HISUI Schedule as of July 2017

<table>
<thead>
<tr>
<th>FY</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch and Operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Instrument</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual Design</td>
<td>Preliminary Design</td>
<td>Critical Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component Trial</td>
<td>Evaluation Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HISUI-ExP/MDR-PM design</td>
<td>PFM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ground Data System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>Additional Design &amp; development</td>
<td>IF test/ training/Initial Operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Design</td>
<td>Critical Design</td>
<td>Development/Installation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application Research</td>
<td>Spectral Database Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Analysis Methodology Research (JOGMEC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- We are here.
- Launch Operation
- HISUI-ExP / MDR-PM DR
- PFM
- HISUI-ExP / MDR-PM manufacturing/test
- IF test/ training/Initial Operation
- Nominal Operation
- CDR
Optical Diagram of
HISUI Hyperspectral Imager

Filter Wheel Assembly
- Bandpass filters
- NIST SRM2065 + Myler film

Lamp
(Halogen lamp)

Telescope
(Three Mirror Anastigmat Type)

Slit Assembly

VNIR Spectrometer
(Offner Type)

CMOS 2D Detector

SWIR Spectrometer
(Offner Type)

MCT 2D Detector

Stirling Type Cooling Unit

(≈145 K)
HISUI Exposed Payload (HISUI-ExP)

FRGF: Flight Releasable Grapple Fixture
HSRU: HYPER Scanning Radiometer Unit
MTC: Modified Truncated Cone
PIU: Payload Interface Unit

HISUI ExP Attached to Port 8 of JEM EF
HISUI-ExP’s Journey from Ground to ISS JEM EF

- **Launch by F9/Dragon**
- **Dragon free flight**
- **Ground Operation at SSPF (Space Station Processing Facility) of NASA KSC (Handover to NASA) and F9 Launch Site**
- **Transfer from Japan to US**
- **Development of HISUI in Japan (Manufacturing, assembling, test and inspection)**
- **Transfer from Dragon to JEM-EF by SPDM/SSRMS and JEMRMS**
- **Handover from SPDM/SSRMS to JEMRMS**
- **Transfer by JEMRMS**
- **Activation, C/O and nominal operations**

**Key Terms**

- **SPDM**: Special Purpose Dexterous Manipulator
- **SSRMS**: Space Station Remote Manipulator System
- **JEM RMS**: JEM Remote Manipulator System
1) HISUI has its own data receiving, storing, and sending devices on JEM EF and JEM PM.

2) HISUI data sent from EF device are recorded on the removable media in MDR-PM. (=300 GB/day) (TBD). After recording, the media are planned to be shipped from ISS to the ground 3 or 4 times per year (TBD). In addition, the limited amount of HISUI data are transmitted from ISS to the ground station in near-real-time.
HISUI GDS consists of the four subsystems:

- Observation and Planning Subsystem (OPS)
- Product Generation Subsystem (PGS)
- User Interface Subsystem (UIS)
- System Integration Subsystem (SIS)
HISUI Onboard and Level 1 Processing

- Spectral binning, radiometric calibration, and smile corrections are carried out on orbit.
- Level 1 processing at GDS include scene cutting, radiometric degradation correction, keystone correction, geometric correction, cloud detection, and VNIR-SWIR parallax correction using DEM.
## HISUI Product List as of July, 2017

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Raw data</td>
</tr>
<tr>
<td>Level 1A</td>
<td>Raw DN product with all radiometric calibration coefficients. Spatial resampling is not applied.</td>
</tr>
<tr>
<td>Level 1R</td>
<td>Top-of-atmosphere spectral radiance product. Spatial resampling is not applied.</td>
</tr>
<tr>
<td>Level 1G</td>
<td>Geometrically corrected / orthorectified top-of-atmosphere spectral radiance product. Parallax correction, keystone property, and spectral continuity between VNIR and SWIR spectrometers are considered.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Atmospherically corrected surface spectral reflectance product generated from L1G with QA information. This is Science Product for research purpose and not validated.</td>
</tr>
</tbody>
</table>

* Cloud statistical data are attached to L1 and L2 products.
ISS HISUI Operation and Mission Planning

HISUI OPS (Observation Planning Subsystem) will automatically create operation timing tables based on data acquisition requests (DARs), their priorities, and available resources such as instrument operation time and data downlink capability.

DAR is valid until cloud free images of the whole target area are obtained.

HISUI DAR categories (draft)

- Important Observation
  - Engineering request
  - Calibration / Validation
  - Emergency / Disaster
- Verification Observation (local area)
  - Individual application / verification sites
- Priority Region Mapping
  - Oil/gas/metal resource exploration regions
- Global Mapping (using remaining resources)
  - All land surface and shallow coastal regions

Tentative DARs for Verification Observation

Areas for Priority Region and Global Mapping
HISUI Long-term (3 years) Operation Simulation Setup

Cloud assessment and HISUI observation rescheduling

A) Emergency / Calibration Obs.
B) Verification Observation
C) Priority Region Mapping
D) Global Mapping

8 minute / orbit excluding warming up / shut-down time, 3 segments

410 km altitude

1 deg attitude fluctuation

Terra MODIS global daily 1km cloud mask for three years

20 km swath

0.4 Gbps 26 Gbyte/orbit

80 Mbps (Max.)

10 GByte/day daily transmission

300 GByte/day media transport several times per year

JEM EF MDP

JEM PM MDR-PM

C) Priority Region Mapping

D) Global Mapping


HISUI Long-term (3 years) Operation Simulation Results

Tentative 200 Verification Targets

Number of Cloud-free Observation

Completed targets*
Sun Elevation > 40°, Cloud free > 95% |
1st year | 1
2nd year | 51
3rd year | 113**

*Target size = 100 x 100 km
**3rd year = 175 with Sun Elevation > 30° / Cloud free > 85%.

Cloud-free coverage in three years:
Priority Regions ≈ 90%
Global Mapping ≈ 70%

(Source: 170616)
GEDI:
Provide the first global, high-resolution observations of forest vertical structure using a lidar.
To be deployed on the ISS in 2019.

ECOSTRESS:
Measure the temperature of plants and use that information to better understand how much water plants need and how they respond to stress.
To be deployed on ISS in 2018.

DESIS:
Provide VNIR hyperspectral data with high spectral resolution (2.3 nm). One of instruments attached to MUSES.
To be deployed on ISS in 2017.

OCO-3:
Investigate the distribution of atmospheric carbon dioxide and Fluororescence from terrestrial vegetation.
Synergy of Five Earth Observing Instruments onboard ISS

ECOSTRESS
- land surface temperature
- emissivity

OCO-3
- solar induced fluorescence
- atmospheric column CO₂
- carbon residence time
- carbon use efficiency

GESDI
- surface roughness
- root depth
- canopy functional traits
- carbon sink potential, disturbance ecology

HISUI
- height, volume, leaf area index
- aboveground biomass
- species canopy traits, nutrients

DESIS
- plant stress (temp & water)
- evapo-transpiration
- light use efficiency, nutrient use efficiency

Butterfly diagram by J. B. Fisher
HISUI Data Policy and Research Announcement

- HISUI data policy is under consideration.

- For collaborators and research announcement investigators, priority observation, priority downlink, and distribution for their requested areas will be given for free.

- The archived data will be provided for free to other science users with some conditions (e.g. submission of reports to HISUI Project).

- HISUI Research Announcement will be issued for domestic users first. HISUI RA for overseas users will be issued later.
Thank you

Contact: matsunag@nies.go.jp