Development of University Ground Station for Nano Satellite Operation

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• Development Concept
• Kyushu University Ground Station
  – Location
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• Conclusions
Coming nano-satellites in Japan

- **Chubusat-1**
- **QSAT-EOS**
- **Hodoyoshi-1**
- **TSUBAME**
- **Hodoyoshi-2**
- **Hodoyoshi-3**
- **Hodoyoshi-4**

**STARS-Ⅱ／香川大学**
微生物観察衛星 TeikyoSat-3／帝京大学
微小重力環境と宇宙放射線が粘菌に与える影響観察

**可視光通信実験衛星／国立大学法人 信州大学**
衛星地上間の双方向可視光通信実験

**KSAT2／鹿児島大学**
大気水蒸気の独創的観測

**芸術衛星 INVADER／多摩美術大学**
衛星データ(テレメトリ)の芸術利用

**OPUSAT／大阪府立大学**
リチウムイオンキャパシタの宇宙実証など

**ITF-1／筑波大学**
小型衛星を利用したネットワークの構築

- **Early 2014**
- **Feb. 2014**
- **Dnepr**
- **H-IIA**
Proposed Small Satellite R&D for MEXT

Objectives:
1) Development of Universal Bus System for Small Satellite
2) Development of Small Satellite for Earth Observation

① mass: 50kg  ② size: 0.5m cubic  ③ life span: 2 years  ④ altitude: H=650km (Sun synchronous Orbit)
<advanced BUS subsystem>

QSAT—EOS
→ High resolution CMOS-camera for earth observation with 5m resolution
→ Star sensor and reaction wheel for high quality attitude control system
→ High speed data transfer with Ku-band
How to manage much data from Hodoyoshi-1,2,3,4

- high efficiency of wide observation from space
- quasi-steady real time information gathering due to constellation

High spatial resolution and Multispectral Camera system
1) Alert for land slip due to climate disaster
2) Observation of plants, crops and sea food → efficient managements → senior workers

Data process system for safety of the people and preservation of national properties
In 2004, 10 universities and colleges started the Ground Station Network Project Japan (GSNPJ) in University Space Engineering Consortium (UNISEC).

So far, technology demonstration mission Amateur Radio (VHF/UHF: ~9.6 kbps in maximum)

Recently, some advanced missions by using nano-satellites e.g., 5 to 10 meter spatial resolution of Earth ground imaging Those advanced missions often require much higher data rate mission data downlink: from 10Mbps to 100 Mbps

“GHz-band Ground Station (S, X, Ku-band) is needed in University Ground Station Network”
# Ground System Category

<table>
<thead>
<tr>
<th>Segment</th>
<th>Node</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Segment</td>
<td>Ground Station</td>
<td>Antenna and Pointing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RF / Modulation / Demodulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Base-band Processing</td>
</tr>
<tr>
<td></td>
<td>Satellite Operation Center</td>
<td>Operation Planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telemetry / Command Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orbit Analysis</td>
</tr>
<tr>
<td></td>
<td>Mission Data Center</td>
<td>Primary Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data Storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data Distribution</td>
</tr>
<tr>
<td>Service Segment</td>
<td>Service Center</td>
<td></td>
</tr>
<tr>
<td>User Segment</td>
<td>User</td>
<td></td>
</tr>
</tbody>
</table>
## Characteristics of amateur VHF/UHF and GHz-band

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Typical University ground Station for amateur VHF/UHF</th>
<th>Ground Station for “GHz-band” (S, X, Ku-band)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna</td>
<td>Yagi-Antenna</td>
<td>Parabola Antenna</td>
</tr>
<tr>
<td></td>
<td>Not so large</td>
<td>Large and Complicated</td>
</tr>
<tr>
<td></td>
<td>Ease to handle</td>
<td></td>
</tr>
<tr>
<td>Tracking Performance</td>
<td>Pointing Accuracy</td>
<td>Precise Pointing control</td>
</tr>
<tr>
<td></td>
<td>is not so severe</td>
<td>is required</td>
</tr>
<tr>
<td></td>
<td>about 1 - 5 deg</td>
<td>Accuracy: 0.01 - 0.1 deg</td>
</tr>
<tr>
<td>Number of Available References</td>
<td>Relatively popular for nano-satellites operation</td>
<td>Many products for</td>
</tr>
<tr>
<td></td>
<td>like CubeSat</td>
<td>conventional satellites</td>
</tr>
<tr>
<td></td>
<td>(no business use)</td>
<td>Not so many examples for</td>
</tr>
<tr>
<td></td>
<td></td>
<td>university nano-satellite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(business use can be possible)</td>
</tr>
<tr>
<td>Cost</td>
<td>Low-cost</td>
<td>Relatively expensive</td>
</tr>
</tbody>
</table>
Strategy for Ground Station Development

• Conditions and Constraints
  – In University Environment (Operation and Maintenance by Students)
  – Cost-effective Development (Antenna and Operator Interface)
  – For S-band Telemetry/Command and X-band Mission Data Downlink

• Concept
  – Taking advantages of commercial products for conventional satellite operation
  – Reducing the number of hardware elements and interfaces
  – Taking advantages of software functions
  – Taking advantages of the universal interface of components (e.g., LAN (Local Area Network) based on Ethernet and TCP/IP)
## Location (Ito campus, Kyushu University)

<table>
<thead>
<tr>
<th>Address</th>
<th>Ito Campus, 744, Motooka, Nishi-ku, Fukuoka, Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>N 33.59879 deg</td>
</tr>
<tr>
<td>Longitude</td>
<td>E 130.21204 deg</td>
</tr>
<tr>
<td>Altitude</td>
<td>79 m</td>
</tr>
</tbody>
</table>

Kyushu University Ito Campus, Fukuoka, Japan

[Map Image of Kyushu University Ito Campus, Fukuoka, Japan]
Satellite communication station
Antenna Overview

Antenna No.1
for C-band, X-band (~40Mbps)
Cassegrain type
parabola antenna
Diameter: 2.4m

Antenna No.2
for S-band (~100kbps)
Center-feed type mesh
parabola antenna
Diameter: 2.4m
Skyline data of KUGS

KUGS 2. 4-2
# Specifications of satellite tracking system

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Mass</td>
<td>~ 900 kg</td>
</tr>
<tr>
<td>Antenna Aperture Diameter</td>
<td>2.4 m</td>
</tr>
<tr>
<td>Antenna F / D Ratio</td>
<td>0.31</td>
</tr>
<tr>
<td>Antenna Control Method</td>
<td>2-axis Control Azimuth &amp; Elevation</td>
</tr>
<tr>
<td>Control Range</td>
<td>Azimuth: -270 to + 270 deg Elevation: +5 to +95 deg</td>
</tr>
<tr>
<td>Control Unit Angle</td>
<td>0.01125 deg per 1-pulse of Servomotor Control (= 90deg / 8000 pulse)</td>
</tr>
<tr>
<td>Tracking Speed</td>
<td>Nominal: 18.8 deg/sec Max.: 33.3 deg/sec</td>
</tr>
<tr>
<td>Survival Wind Speed</td>
<td>60 m/s</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>AC 200V, 5A</td>
</tr>
<tr>
<td>Control</td>
<td>Ethernet, 100 Base-T</td>
</tr>
</tbody>
</table>
Examples of Performance Test

Test
#1 Antenna Peak Gain : SG + Reference Horn Antenna
#2 System Noise Temperature : R-SKY (ROOM-SKY) Method
#3 Beam Width : Sun Noise Observation
#4 Cross Polarization : SG + Reference Horn Antenna

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>X-band: 8.25 GHz</td>
</tr>
<tr>
<td>Antenna Peak Gain</td>
<td>45 dB</td>
</tr>
<tr>
<td>Beam Width</td>
<td>±0.7 deg</td>
</tr>
<tr>
<td>System Noise</td>
<td>326.1 K</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td>Cross Polarization</td>
<td>Tx:R – Rx: L, 20.1 dB</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Tx:L – Rx: R, 19.2 dB</td>
</tr>
</tbody>
</table>
Baseline Concept of Ground Station of Kyushu University

System Diagram (1): Outside Facilities
Baseline Concept of Ground Station of Kyushu University

System Diagram (2): Room Inside Facilities
Network Camera for Remote Monitoring

http://kugs-cam1.aero.kyushu-u.ac.jp

ID:
Pass:
Network Camera Image
Signal receiving experiments of X band from AQUA and TERRA

Frequency of X-band of AQUA is 8.160 GHz

Frequency of X-band of TERRA is 8.2125 GHz.
Concept of Ground Station of Kyushu University (X-Band)

- 2.4m antenna
- X-band horn
- X-band LNA
- X-band D/C
- X-band horn
- X-band LNA
- X-band D/C
- X-band 2nd D/C
- Spectrum analyzer
- PC for Spectrum analyzer
- Tracking system of 2.4m antenna

Control room
- Control Line
- PC for control of antenna

60m duct
- Signal line
- X-band receiver
- PC for Data mission
TERA(+10deg)

TERA(+55deg)

TERA(-50deg)
AQUA(+20deg)

AQUA(+45deg)

AQUA(-40deg)
九州大学 地上局
九州大学 地上局
追跡衛星：AQUA
TIME  AZ  EL
13:17:26  161.57  0.03
13:24:26  69.69  73.52
13:31:23  350.46  0.02
Strategy for Kyushu University Ground Station

☆ Training of young professionals
→ Including development of nano-satellite QSAT–EOS, young engineers and graduate/undergraduate students have grown up.
→ In our Department of Aeronautics and Astronautics, Kyushu University new education system stimulating graduate students for developments of nano satellite and ground station using network system
Conclusions

• In this project, we focus on the cost-effective development of new ground station for nano-satellite operation. Because current and future advanced University satellite missions need high efficient and fast telecommunications such as GHz-band (S-band to X-band).

• In the present study high efficient and fast telecommunication ground station of S-band and X-band by using two parabola antennas is installed based on the cost-effective concepts. The ground station has succeeded to receive signals of X band from AQUA and TERRA. Both results show fairly good SN ratio (ratio of signal to noise) at any antenna angle.
Acknowledgements

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• Professor Shinichi Nakasuka, University of Tokyo with excellent leadership.
Thank you for your kind attention

Please see also the poster No.23
“Performance Evaluation of Ground Station in Kyushu University”
Operation Example: UNITEC-1 Experiment

- UNITEC-1 (UNIsec Technology Experiment Carrier-1)
  - Launched and injected into Venus transfer trajectory on May 21, 2010
  - Downlink Signal: Amateur C-band (5.8GHz) CW or FSK 1200bps
  - On First day (May 21) and Second day (May 22) of the experiment, we received the signal during the expected time based on the on-board operation cycle of UNITEC-1
  - However, unfortunately, we were not able to identify the received signal as the downlink from UNITEC-1 by using the prepared analysis tool
Lessons Learned from UNITEC-1 Experiment

• Multiple tools or functions for data analysis
  – We prepared a single tool to analyze received signal.
  – In the case of unexpected result or trouble, various analysis tools should be prepared.

• Pre-flight end-to-end test
  – We were not able to conduct the end-to-end test between the telecommunications unit of UNITEC-1 and KUGS2.4 facilities.
  – If EM unit of UNITEC-1 was available, we should have confirmed the data link in the expected flight conditions.
  – Furthermore, we should have identified the failure mode of data receiving operation before UNITEC-1 launch as much as possible.