Micro/Nano-satellite Activities by Japanese Universities and Vision towards International Contribution

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Contents

• Significance of micro/nano-satellite development

• Japanese universities’ history of micro/nano/pico-satellite development and recent stepping-up from education to practical use

• Governmental “Hodoyoshi” program for micro/nano-satellite development and utilizations

• Future vision: How Japan can contribute to the other nations in this fields: education, capacity building, and collaborative missions, etc.
Emerge of Nano/pico-Satellites in Japan

Success of CubeSat (1kg) by Univ. Tokyo and Titech (2003.6.30)

- University level budget (30K$)
- Development within 2 years
- Surviving in space for >8 years
- Ground operations, frequency acquisitions, launch opportunity search processed by ourselves

1~50kg (Micro/Nano-sat): Starting from education but higher level satellites appears
Significances of Micro/Nano/Pico-Satellite Projects

- **Initial phase contributions: Education**
  - Practical Training of Whole Cycle of Space Project
  - Feedbacks from the real world to evaluate design, test, etc.
  - Learning from failures (while project cost is small)
  - Training for project management
  - International cooperation, negotiation, mutual understanding
    - Also contribute to other technology areas!

- **Create a new paradigm of space development and utilizations with low cost and quick development**
  - Will introduce new players (individual, company, local government, research institute, etc.) seeking for their own use
  - Will create novel ways of space utilizations
  - Will lead to participations of more nations
Starting Point: CanSat (since 1999)
ARLISS (A Rocket Launch for International Student Satellites)
- Annual suborbital launch experiment -

- ARLISS 1999: Sept. 11 (Japan:2, USA:2)
  - Univ.of Tokyo, Titech, Arizona State, etc.
- ARLISS 2000: July 28-29 (Japan:4, USA:3)
- ARLISS 2001: August 24-25 (Japan:5, USA:2)
- ARLISS 2002: August 2-3 (Japan:6, USA:3)
- ARLISS 2003: Sept.26-27 (Japan:6, USA:3)
- ARLISS 2004: Sept.24-25 (Japan:6, USA:3)
- ARLISS 2005: Sept.21-23 (Japan:7, USA:3)
- ARLISS 2006: Sept.20-22 (Japan:8 USA:3 Europe:1)
- ARLISS 2007: Sept.12-15 (Japan:10 USA:3 Korea:1)
- ARLISS 2008: Sept.15-20: 10th Memorial ARLISS!
- ARLISS 2009: Sept.15-19 (Japan:12 USA:3 Korea:1)
- ARLISS 2010: Sept.13-17 (Japan:13 USA:2 Korea:1)
- ARLISS 2011: Sept.12-16 (Japan:14 USA:2 Korea:1)
- ARLISS 2012: Sept.10-14
University of Tokyo’s History of Nano/pico-satellite Developments

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>CubeSat XI-IV (ROCKOT) 2003/6</td>
</tr>
<tr>
<td></td>
<td>Education, camera test</td>
</tr>
<tr>
<td>2005</td>
<td>CubeSat XI-V (COSMOS) 2005/10</td>
</tr>
<tr>
<td></td>
<td>Education, CIGS solar cells</td>
</tr>
<tr>
<td>2006</td>
<td>PRISM (H-IIA) 2009/1</td>
</tr>
<tr>
<td></td>
<td>Astrometry (top-science)</td>
</tr>
<tr>
<td>2007</td>
<td>HODOYOSHI-1 2012</td>
</tr>
<tr>
<td>2008</td>
<td>NANO-JASMINE (CYCLONE-4) 2013</td>
</tr>
<tr>
<td>2009</td>
<td>30m GSD Remote Sensing</td>
</tr>
<tr>
<td>2010</td>
<td>Development</td>
</tr>
<tr>
<td>2011</td>
<td>Launch</td>
</tr>
<tr>
<td>2012</td>
<td>Development</td>
</tr>
<tr>
<td>2013</td>
<td>Launch</td>
</tr>
</tbody>
</table>
CubeSat “XI-IV (Sai Four)”

**Mission:** Pico-bus technology demonstration in space, Camera experiment  
**Developer:** University of Tokyo  
**Launch:** ROCKOT (June 30, 2003) in Multiple Payload Piggyback Launch

<table>
<thead>
<tr>
<th>Size</th>
<th>10x10x10[cm] CubeSat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>1 [kg]</td>
</tr>
<tr>
<td>Attitude control</td>
<td>Passive stabilization with permanent magnet and damper</td>
</tr>
<tr>
<td>OBC</td>
<td>PIC16F877 x 3</td>
</tr>
<tr>
<td>Communication</td>
<td>VHF/UHF (max 1200bps) amateur frequency band</td>
</tr>
<tr>
<td>Power</td>
<td>Si solar cells for 1.1 W</td>
</tr>
<tr>
<td>Camera</td>
<td>640 x 480 CMOS</td>
</tr>
<tr>
<td>Mission life</td>
<td>more than 8 years</td>
</tr>
</tbody>
</table>

Captured Earth Images and Distribution to Mobile Phones
CubeSat “XI-V (Sai Five)”

**Mission:** CIGS solar cell demonstration, Advanced camera experiment  
**Developer:** University of Tokyo  
**Launch:** COSMOS (October 27, 2005) deployed from “SSETI-EXPRESS”

- **Size:** 10x10x10[cm] CubeSat  
- **Weight:** 1 [kg]  
- **Attitude control:** Passive stabilization with permanent magnet and damper  
- **OBC:** PIC16F877 x 3  
- **Communication:** VHF/UHF (max 1200bps) amateur frequency band  
- **Power:** Si, GaAs, CIGS cells  
- **Camera:** 640 x 480 CMOS  
- **Mission life:** > 5 years

JAXA/NEDO CIGS Solar Cells  
Captured Earth Images
**PRISM “Hitomi”**

**Mission:** Earth Remote Sensing (20 m GSD, RGB) with Deployable Boom

**Developer:** University of Tokyo

**Launch:** H-IIA (Jan 23, 2009) Piggyback with GOSAT (CO₂ monitoring sat)

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**Size**
- 20x20x40[cm] in rocket
- 20x20x80[cm] in space

**Weight**
- 8.5 [kg]

**Attitude control**
- 3-axis stabilization with Sun, Magnet sensor, MEMS gyro magnetic torquers

**OBC**
- SH2, H8 x 2, PIC x 2

**Communication**
- VHF/UHF (max 9600bps)

**Mission life**
- > 2.5 years

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**Captured images**

Mexico Seashore  
US Desert  
Kita-Kyushu (Japan)  
Wide Angle Camera
**Nano-JASMINE**

**Mission:** Astrometry (Getting precise 3D map of stars and their movements)

**Developer:** University of Tokyo, National Astronomical Observatory of Japan, Shinshu University, Kyoto University

**Launch:** Cyclone-4 (planned within 2013) from Alcantara Launch Site

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Size</td>
<td>50 [cm-cubic]</td>
</tr>
<tr>
<td>Weight</td>
<td>33 [kg]</td>
</tr>
<tr>
<td>Attitude control</td>
<td>3-axis stabilization with:</td>
</tr>
<tr>
<td></td>
<td>Star, Sun, Magnet sensor, FOG, RW, Magnetic torquers</td>
</tr>
<tr>
<td>OBC</td>
<td>FPGA</td>
</tr>
<tr>
<td>Communication</td>
<td>S-band 100 [kbps]</td>
</tr>
<tr>
<td>Mission life</td>
<td>2 [year]</td>
</tr>
</tbody>
</table>

**Special features:**
- Attitude Stability: 0.8 arcsec for 8.8 sec
- Thermal Stability: < 0.1K (at -50 degree)
- Map Accuracy: Compatible with “Hipparcos” Satellite (‘89)
- Telescope: two CCDs with TDI
Satellites made by Japanese Universities

As of May 2012

- XI-IV
  - The University of Tokyo
- Cute-I
  - Tokyo Institute of Technology
- SEEDS (FM1)
  - Nihon University
- HITSAT
  - Hokkaido Institute of Technology
- Cute-1.7 +APD
  - Tokyo Institute of Technology
- SEEDS (FM2)
  - Nihon University
- XI-V
  - The University of Tokyo
- PRISM
  - The University of Tokyo
- SPRITE-SAT
  - Tohoku University
- KSAT
  - Kagoshima University
- KKS-1
  - Tokyo Metropolitan College Of Industrial Technology
- UNITEC-1
  - UNISEC
- Nega☆
  - Soka University
- WASEDA-SAT2
  - Waseda University

As of May 2012
Governmental “First” Program
”Hodoyoshi-project” (2010-2015)

• Reliability concept for micro/nano/pico-satellites
  – “So-so and not expensive (Hodoyoshi)” reliability
    (compromise between cost (workload) vs. reliability)

• Component technology development
  – Should solve “size and power problem”

• Development process innovation
  – Software architecture
  – Ground test, etc.

• Create novel applications and use communities
  – Non-government users as individuals, companies, local government, research institute can seek for their interest
Missions Creation for Hodoyoshi Program

- Low-cost and small size realize satellite constellation
  - More frequent (ex. semi-daily) observation of the same areas
- Formation flight
  - Many scientific applications such as interferometer, multi-site observation, stereo vision
- “Personal Satellite” “My Satellite”
  - Novel ways of utilization including entertainment, education, contents, etc
  - Just like “PC and internet” innovation which has changed the world

Constellation of a hundred satellites
Stereo Vision

“Furoshiki” satellite
#1 : 6.8m GSD 4 band remote sensing
- *Data is open to private users so that they can test their utilizations* (developed by AXELSPACE)

#2 : Foreign space science mission
- *5 Mission payloads will be onboard (from foreign research institutes)* (developed by Tohoku University)

#3 : Constellation of 2 satellites
- *5, 40, 200m GSD, rental space, Store and forward missions* (developed by Univ. Tokyo and NESTRA)
Capacity Building Support Program
UNIFORM (UNiversity International FOrmation Mission)

- Each country develops one micro-satellite (< 50kg)
  - To be operated in constellation manner
  - Standardization of bus/component
  - Training of satellite development is supported by Japanese Universities
  - Equipment cost partially supported by Japanese government (in negotiation)

- Ground Station Network
  - Low-cost GS is developed to realize one GS in each country (S/X-band)

- Missions
  - Common mission + individual mission
  - Common mission will be determined by discussions within community

(Funded by MEXT, Japan)
Introduction to UNISEC
University Space Engineering Consortium

• UNISEC is a non-profitable organization to facilitate and promote practical space development activities, such as designing, developing, manufacturing, and launching micro/nano satellites and hybrid rockets at university level.

• Established in 2002

• 57 laboratories/groups from 39 universities

• About 500 student members and 220 supporters
Vision 2020-100

By the end of 2020, let’s create the world where university students can participate in practical space projects in more than 100 countries.

<Examples of programs>
1) CanSat Leader Training Program (CLTP)
2) Nano-Satellite Mission Idea Contest (MIC)
3) Nano-Satellite Symposium

Let’s establish UNISEC-xxx (your country)
Let’s start “UNISEC-International” together!
CLTP was established in 2011 to contribute to capacity building in space technology and to improve teaching methods in space engineering education.

- A one month course gives training through whole cycle of CanSat development including sub-orbital launch experiments
- Participants are expected to teach their students CanSat program in their countries
- Aiming at “international CanSat education network”

http://www.cltp.info
CLTP Participants

**CLTP1 (Wakayama Univ. in Feb-March, 2011)**
12 participants from 10 countries, namely Algeria, Australia, Egypt, Guatemala, Mexico, Nigeria, Peru, Sri Lanka, Turkey, Vietnam.

**CLTP2 (Nihon Univ. in Nov-Dec, 2011)**
10 participants from 10 countries, namely Indonesia, Malaysia, Nigeria, Vietnam, Ghana, Peru, Singapore, Mongolia, Thailand, Turkey.

**CLTP3 (Tokyo Metropolitan Univ. in July-August, 2012)**
10 participants from 9 countries, namely Egypt, Nigeria, Namibia, Turkey, Lithuania, Mongolia, Israel, Philippines, Brazil
2) Mission Idea Contest (MIC) for Micro/nano Satellite Utilization

- **Objective:** Encourage innovative exploitation of micro/nano-satellites to provide useful capabilities, services or data.
- **Requirement:** Propose innovative
  - category 1: mission idea and satellite design
  - category 2: mission idea and business model using micro/nano satellite weighing less than 50kg.
- **Regional coordinators:** 33 regions
- **72 applications from 29 countries.**
- **Oct 10, 2012 Final Presentation**

**http://www.spacemic.net**
3) UN/Japan Nano-Satellite Symposium

NAGOYA, Japan

Oct. 10-13, 2012

Under the Basic Space Technology Initiative (BSTI) of the United Nations Programme on Space Applications

http://www.nanosat.jp/
Global network through Mission Idea Contest and CanSat Leader Training Program (MIC:33, CLTP: 21 countries) 38 countries in total

🌟: CLTP participant  🌟: MIC coordinator
Micro/nano-satellite and future

• Large educational effect not only for space, but also for many technological areas

• New paradigm of space development and utilization with low-cost and quick development

• International network through micro/nano-satellites