Report on the current state of "Japanese University Micro/Nano/Pico-satellite Projects"
Second Edition

October 2012
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October 2012
## CONTENTS

**Introduction** .................................................................................................................................................. vi

**Report on Japanese University Micro/Nano/Pico-satellite Projects** .......................................................... 1

- **A**
  - Aichi University of Technology ............................................................................................................. 3

- **H**
  - Hokkaido Institute of Technology ........................................................................................................... 5

- **K**
  - Kagawa University - Nohmi Laboratory ................................................................................................. 11
  - Kyushu Institute of Technology - Center for Nanosatellite Testing ....................................................... 15
  - Kyushu University - Space Systems Dynamics Laboratory .................................................................. 27

- **N**
  - Nihon University – Miyazaki Laboratory ............................................................................................... 33

- **O**
  - Osaka Institute of Technology - Advanced Rocket Laboratory .............................................................. 39
  - Osaka Prefecture University - Small Spacecraft Systems Research Center ............................................ 47

- **S**
  - Shizuoka University - Yamagiwa Laboratory .......................................................................................... 53
  - Soka University - Aerospace Laboratory of Innovative Engineer’s ....................................................... 57

- **T**
  - Tokyo Institute of Technology - Structural Dynamics Design Laboratory ............................................. 61
  - Tokyo Metropolitan College of Industrial Technology ............................................................................ 63
  - Tokyo Metropolitan University - Space Systems Laboratory ................................................................. 65
  - Tokyo University of Science - Kimura Laboratory ................................................................................ 69
  - University of Tsukuba Network Satellite ' 結 (YUI) ' Project ................................................................. 71

- **W**
  - Wakayama University Institute for Education on Space (IfES) .............................................................. 75
  - Wakayama University ............................................................................................................................. 79
  - Waseda University - Light Weight Structure Project Team in Waseda University ................................. 83

**Other Important Universities** .................................................................................................................. 87

*(iv)*
Introduction

University Space Engineering Consortium (UNISEC) has compiled a report on the current state of "Japanese University Micro/Nano/Pico-satellite Projects" in October 2012. The latest version of report will be also been made available on the Internet at the UNISEC web site. http://www.unisec.jp/member/jusat-e.html

In response to requests, the UNISEC continues this activity and will publish a revised and updated edition of the above directory in the future.

We hope this report can support professionals and students who are interested in Space Engineering Education in Japanese Universities.

Comments, queries and information with respect to this report are most welcome.
Report on Japanese University Micro/Nano/Pico-satellite Projects
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Contact | Tel:+81-533-68-1135 | Email: okuyama-kei@aut.ac.jp  
URL | http://www1.aut.ac.jp/~okuyama-lab/index.html  

【1】Overview and Science Highlights of the project

1 Structural system of UNITEC-1, Design and manufacturing  
2 Structural material of the ‘HODOYOSHI’ satellite, Research and development  
   (Implementing)  
3 A satellite which proves that it is possible to use an advanced structural material in the space  
   (Planning)

【2】Achievements in Space Engineering Education through CanSat Activities (or Plan)

1 Rover type robot which adopted an autonomous control, ARLISS2007 to ARLISS2008  
2 Rover type robot which adopted an autonomous control, ARLISS2011  
   (Implementing)
[3] Papers

In from 2009 to 2011, several papers which were released in international societies shows below.


[4] Recent overseas researchers who collaborated with us (for a short period)

1. A research concerning a heat shield material which can be used for several spacecraft which can enter the atmosphere of our Earth, Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), German, From 2011 (Continue)

   At present, our university is preparing an opportunity of the R&D of several students who belongs to several foreign universities.
   These Students will be registered as students at our university can attend lectures, seminars, tutorials and researches concerning the space development.
   (Planning)
【1】Overview and Science Highlights of the projects

1. HIT-SAT Project

HIT-SAT is the first nano-satellite made in Hokkaido, which was developed by graduate students, researchers and volunteers in Hokkaido. HIT-SAT was launched at September 23th from Uchinoura launch site as a sub-payload of M-V-7#.

<table>
<thead>
<tr>
<th>Specifications of HIT-SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight</td>
</tr>
<tr>
<td>size</td>
</tr>
<tr>
<td>power</td>
</tr>
<tr>
<td>orbit</td>
</tr>
<tr>
<td>attitude control</td>
</tr>
<tr>
<td>communication</td>
</tr>
<tr>
<td>system</td>
</tr>
</tbody>
</table>
2. HyperSpectral Camera HSC-III

Hyperspectral sensor acquires more spectral information from objects with a high spectral resolution compared with multispectral sensors. It enables to distinguish a targeted object with a high accuracy and give us lots of important information.

Satori laboratory have studied and developed the visible and near infrared range VNIR hyperspectral sensor for nano-satellites since 2003.

![Image of Hyperspectral data](image1.png)

![Space borne Hyperspectral Camera HSC-III](image2.png)

Fig.1 Image of Hyperspectral data  Fig.2 Space borne Hyperspectral Camera HSC-III

<table>
<thead>
<tr>
<th>Item</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging type</td>
<td>Push bloom</td>
</tr>
<tr>
<td>Ground Sampling distance</td>
<td>15m</td>
</tr>
<tr>
<td>Spatial effective resolution</td>
<td>50m ~ 60m</td>
</tr>
<tr>
<td>Swath width</td>
<td>15km</td>
</tr>
<tr>
<td>Wavelength range</td>
<td>450-1000nm</td>
</tr>
<tr>
<td>Spectral sampling interval</td>
<td>5nm (Average)</td>
</tr>
<tr>
<td>Frame rate</td>
<td>500Hz</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>10bit</td>
</tr>
<tr>
<td>Telescope aperture</td>
<td>15cm</td>
</tr>
<tr>
<td>Mass memory</td>
<td>32GByte</td>
</tr>
<tr>
<td>Instrument mass</td>
<td>10 kg</td>
</tr>
<tr>
<td>Electrical interface</td>
<td>Space Wire</td>
</tr>
<tr>
<td>Nominal altitude</td>
<td>620km</td>
</tr>
</tbody>
</table>
CanSats have been fabricated by undergraduate students as space engineering skill up education in Hokkaido Institute of Technology. These CanSats were launched 2-3 times per year by Camui Hybrid Rocket which was developed by Prof. Nagata of Hokkaido University.

Fig. CanSat “Hachi-go-kan” was launched by Camui Hybrid Rocket at 11th Dec. 2010

Fig. CAMUI HYBRID ROCKET and students & staffs
[3] Papers

✧ Journal Publications


✧ Contributions (in Japanese)


✧ Books


✧ Dissertations


✧ Master's thesis


✧ Doctor’s thesis

- Tomohiro Ishikawa, “Attitude Control of Nano-satellite by means of Image Processing”, 2003
[4] Recent overseas researchers who collaborated with us (for a short period)

| n/a |

[5] Important mention

| n/a |
Keywords

Tether, Robotics, Mother-daughter satellite

[1] Overview and Science Highlights of the project

**STARS-II (planned to be launched by the H-IIA rocket in 2013-2014)**

“STARS-II” consists of Mother Satellite (MS) and Daughter Satellite (DS) connected by Electro Dynamic Tether (EDT).

MS deploys EDT having DS at its end. DS has one arm, and EDT is attached at its end. Then attitude control by arm link motion using tether tension is possible.

Main missions are follows.

1. **Electro Dynamic Tether (EDT) deployment by gravity gradient.**
   EDT is deployed by initial velocity applied by the deployment springs, after stabilization of MS and DS attitude under the docking condition. And then, whole system can be stabilized by gravity gradient.

2. **Electrical current gathered by EDT.**
   Electrons in space plasma are gathered by EDT which is a bare tether, and they are emitted from DS. As a result, electrical current is passed through EDT.

3. **Attitude control by arm link motion based on tether tension due to gravity gradient.**
   DS controls its attitude by arm link motion using tether tension (on EDT), which is applied by gravity gradient.

4. **Tether deployment and retrieval by tether tension control.**
   EDT is connected to Kevlar tether at its end. By tension control of Kevlar tether by the reel, relative positions of MS and DS can be controlled.
KUKAI was successfully launched on January 23, 2009 by the H-IIA rocket of JAXA (Japan Aerospace Exploration Agency) with the main satellite “GOSAT.” The planned orbit is sun synchronous (Altitude: 666km, Inclination: 98deg). Main characteristics of KUKAI are: (i) it is two satellites system, mother and daughter; (ii) it becomes a 5m tethered system on orbit at the maximum; (iii) the daughter satellite is a tethered space robot, whose attitude can be controlled by its own arm link motion. The mother satellite has tether deployment and tension control systems, and it deploys the daughter satellite and retrieves it. The daughter satellite is a tethered space robot, and it has one arm link attached to the end of the tether.

Mother satellite Mass: 4.2 kg,  
Scale: 160 x 160 x 253 mm,  
(without solar paddles and cone),

Daughter satellite Mass: 3.8 kg,  
Scale: 160 x 160 x 158 mm,  
(without solar paddles and arm link).

[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

In our project, students develop CanSat for learning techniques and procedure of satellite development. They attended ARLISS in 2005 (350ml*1), 2006 (350ml*1, Open Class*1), 2007 (350ml*1 Open Class*1), and 2009 (350ml*1). Most of them have GPS, CPU, and servomotor, for comeback competition, and a transmitter of GPS data. Open Class CanSats have sensors: gyro, acceleration, magnet, etc.

Also, we have Kagawa CanSat Festival every year. In the past Kagawa CanSat, participants were mainly students who will attend ARLISS, and also class students in regular curriculum, and other universities in the west JAPAN.
[3] Papers

- **Journal Publications**

- **International Conference**
1. Name and Affiliation of Co-researcher
   Research Theme
2. Name and Affiliation of Co-researcher
   Research Theme

n/a
【1】Overview and Science Highlights of the project

Kyushu Institute of Technology established Center for Nanosatellite Testing (CeNT) in the Tobata campus on July 7, 2010. CeNT is made of specialized test facilities, such as thermal vacuum, vibration, outgass measurements, mechanical shock, thermo-optical measurements, thermal cycle, thermal shock, antenna pattern, capable of space environmental tests for nanosatellite up to 50 cm in length and a mass of 50kg. To verify operation in the extreme space environment, various environmental tests are required. A lack of a centralized facility for environmental testing has made entry into the space sector through nanosatellites development difficult. A centralized environmental testing facility will streamline and reduce time for satellite development and maintain the traceability and consistency of the test data.

The mission of CeNT is to find the optimum solution to keep the reliability of nanosatellites while keeping the nature of low cost and fast delivery. CeNT will also develop innovative test methods suitable for nanosatellites. Being at a university, CeNT will also offer students OJT training opportunities through the testing and systems engineering education in terms of system verification.

CENT will serve as a One-Stop-Shop of nanosatellite testing to lower the barrier against entering the space sector for companies that have been outside the community. Especially for local small business companies, CeNT will serve as a place where the companies can test their products immediately after they make the prototypes.

So far, CENT has carried out the testing for the following satellites,

- Kagoshima satellite [Hayato]
- Venus probe satellite [Shinen](UNITEC-1)
- High Voltage Technology Demonstration Satellite Horyu-2
- Kyushu satellite QSAT-EOS
- Kagawa University satellite STARS-2
- UNIFORM
- CHUBUSAT

Through testing many more satellites, CeNT will accumulate the test experience and carry out academic research to improve the satellite reliability through a better and more effective test and verification method. The strategic goal of CeNT is to establish international standards on environment testing suitable for nanosatellites to promote the wider and innovative use of nanosatellites in various space applications.
High Voltage Technology Demonstration Satellite, HORYU-II

HORYU-2 is a nanosatellite of 30cmx30cmx30cm size weighing approximately 7kg. It was launched as an auxiliary payload onboard a H2-A rocket to Sun-synchronous orbit of 680km altitude on May 18, 2012 (JST). Its main mission is to demonstrate high voltage solar array design capable of generating power without discharge at a voltage as high as 300V in Low Earth Orbit. Although similar space experiments were done in the past, all of the past high voltage solar array experiments used DC power supplies to bias the solar array with respect to the satellite body. HORYU-II is the first space experiment that generates the voltage by its own solar array. Solar array design to mitigate discharge has been developed at Kyushu Institute of Technology (KIT) for the past 10 years. In laboratory experiments, solar array covered by transparent polymer film showed no discharge up to 800 volts. During the HORYU-II flight, the effectiveness of the film solar array on suppressing discharge will be demonstrated. HORYU-II will also carry various spacecraft environmental interaction related mission payloads, such as spacecraft potential monitor, electron emitting film for spacecraft charging mitigation, and debris impact sensors. Verification of those mission payloads is currently underway at KIT.

On July 8, 2012 (JST), HORYU-2 successfully demonstrated 300V power generation in orbit. As of July 11, 2012, HORYU-2 is functioning normally.

HORYU-2 was also developed as a test bed of environmental test facilities of Center for Nanosatellite Testing (CENT) at Kyushu Institute of Technology. All of the environmental test of HORYU-2, except the separation shock test of the flight model was carried out at CENT. CENT aims to find the optimum balance between the reliability and the low cost/fast delivery by accumulating the test experience of nanosatellites and by developing innovative test methods suitable for nanosatellites. While carrying out all the environmental tests for HORYU-II, we calculated the cost associated with the environmental test and the system verification. The number would be a useful index to find the ways to reduce the systems verification cost while maintaining reliability.
We are using CANSAT in a laboratory workshop of first year graduate students of Department of Applied Science for Integrated System Engineering. A group of five or six students are assigned a task of developing a CANSAT rover that carries a servo motor, GPS, a digital compass and ultrasonic sensor. Each student is assigned a subsystem and responsible for developing software and hardware. After development of each subsystem, it is integrated into one and tested. The course consists of 2.5 hours laboratory work, twice a week. In total, the students are expected to finish the rover in 30 hours including the final presentation.


❖ Books
Guide to Spacecraft Charging and Mitigation, AIAA Progress in Astronautics and Aeronautics Series, September, 2011

❖ Dissertations
2008
1. Principle demonstration of high frequency plasma probe for nanosatellite QSAT.
2. Development of thermal vacuum and thermal equilibrium test facility for nanosatellites
3. Operational simulation of electron-emitting film for spacecraft charging mitigation
4. Spacecraft charging simulation in the polar earth orbit environment using MUSCAT
5. Lunar surface charging simulation using Multi Utility Spacecraft Charging Analysis Tool (MUSCAT)
6. Laboratory test of dynamic instability of electrodynamic tether induced by discharge
7. Time-of-flight measurements of Atomic Oxygen Velocity using Spectrometry and QMASS
8. Development of secondary electron emission yield measurement device
9. Experimental research of ESD inception mechanism on the ITO glass plate surface which simulated thin-film solar cell
10. Research on mitigation method against secondary arcing on solar array which enhanced insulation by coating and changing the thickness of adhesive under the cell

2009
1. Charge-discharge Characteristics on Solar Array in LEO and GEO environment under cryogenic temperature
2. Development of Photoelectron Emission Measurement Facility for Space Materials
3. Development of reproduction experiment system of particulate electrification and floating phenomenon in lunar surface
4. Study on machine characteristic degradation with thermal and electron beam in space environment on Composite materials for high accuracy large antenna satellite
5. Development of Ground Operation Softwares for Nano-satellite Horyu
6. Research on creeping discharge generated on solar array
7. Development of Mission Payloads onboard High Voltage Technology Demonstration Satellite HORYU-II
8. Examination of surface potentiometer probe in thermal space environment for payload application
9. Study of discharge characteristics of Electrodynamic Tether system for on-orbit verification test

2010
1. Verification of engineering model of spacecraft potential monitor made of parallel plate electrostatic analyzer
2. Thermal design of high-voltage demonstration satellite Horyu2
3. Structural design and environment test of high voltage technology demonstration satellite, HORYU-2
4. Test of performance of adhesive for sample return from asteroid in vacuum
5. Development of Measurement System of Field Electron Emission from Electron-Emitting Film for Spacecraft Charming Mitigation
6. Research and Development of Debris Removal Method Using Interaction Between Space and Electrode with Applied Voltage
7. Basic research of Vacuum Arc Thruster for Nano-Satellite
8. Isolation performance evaluation of high voltage cable for SSPS in space environment
9. Measurement of Electric Charge Flowing into Discharge Point in a Normal Gradient Potential
10. Measurement of Distribution of Atomic Oxygen Flux using the Quartz Crystal Microbalance
Master's thesis

2008

1. Development of electron emitting film for spacecraft charging mitigation and the improvement of its performance
2. Development of Onboard Computer System for nano satellite HORYU
3. Simulation of charging and levitation of dust particles in lunar plasma environment
4. Difference between primary arc on charge discharge experiments at low and room temperature
5. Relationship between electrostatic discharge inception on satellite solar panel and adsorbed water
6. Circuit analysis of surge voltage induced by discharge on satellite solar panel
7. Development of discharge triggering method to be applied for electrostatic discharge test of satellite solar panel
8. Research on degradation and crack detection on the insulation material of electrical power cable
9. Development of flashover current simulator for discharge ground test of solar cell for space

2009

1. Development of communication subsystem for nanosatellite HORYU
2. Program management of nanosatellite Horyu
3. Effects of UV source on the degradation of thermal and mechanical properties of fluorine polymers
4. Development of numerical simulation tools of the electron beam in traveling wave tubes for satellite communications
5. Development of electron field emission distribution measurement device
6. Proposal of a debris removal technique using interference between space plasma and the voltage electrode
7. Evaluation of insulation strength in space environment of high voltage cable for space solar power system
8. Simulation of contamination on spacecraft and its effect on spacecraft charging

2010

1. Development and verification of power supply system for Nano Satellite HORYU
2. Development of thermal vacuum test facility for nanosatellite
4. Research on evaluation of resistance of electron-emitting film to space environment and performance improvement for spacecraft charging mitigation
5. Research on space applicability of COTS antistatic coating for spacecraft surface charging mitigation, its radiation and thermal cycle resistance
6. Development of onboard computer system for nanosatellite HORYU
7. Development of secondary electron emission yield measurement device for space materials
8. Effects of adsorbed water on electrostatic discharge on space solar pane
10. Research on development and evaluation of mitigation method against sustained arcing on solar array

2011
1. Research on the radiation deterioration and the space environment simulation test of CFRP
2. Development of computer systems onboard high voltage technology demonstration satellite HORYU-II
3. The power system development and verification of high voltage technology demonstration satellite HORYU-II
4. Research of sustained arc test and simulated flashover current
5. Temperature Dependence on Electrostatic Discharge on the solar array for space
6. Application of commercial-off-the-shelf voltmeter technology for monitoring of spacecraft surface potential
7. Development of photoelectron emission coefficient measurement facility with vacuum-ultraviolet light.
8. Dust particle levitation mechanism and derivation of levitation threshold voltage in simulated lunar environment
9. Development of mission payloads onboard high voltage technology demonstration satellite HORYU-II

 Doctor’s thesis
2009
Verification of Operational Principle of Small-sized Satellite Potential Monitor via Measurement of Particle Energy
2010
Effect of atomic oxygen exposure on spacecraft charging properties
Recent overseas researchers who collaborated with us (for a short period)

1. Prof. Joseph Jiong Wang, University of Southern California (USA)
   Spacecraft environment interactions and nanosatellite development
2. Space Systems Loral (USA)
   Environmental test of satellite power system
3. Beijing Institute of Space Environment Engineering (China)
   Effect of charging on contaminant particles
4. Indian Space Research Organization (India)
   Electrostatic Discharge test methods on satellite solar panel
5. CNES (French Space agency) and ONERA (French National Aerospace Laboratory) (France)
   International Standardization of Electrostatic Discharge test methods on satellite solar panel
6. Ohio Aerospace Institute and NASA (USA)
   International Standardization of Electrostatic Discharge test methods on satellite solar panel
7. Prof. Shentao Li, Xian Jiaotong University (China)
   Charging properties of space dielectrics

Important mention

International Course on Space Engineering
Kyushu Institute of Technology will launch a new graduate course titled “International Course on Space Engineering” from October 2013. The course is intended for graduate students at Master and Ph.D. levels. The course will offer variety of lectures related to space engineering, such as “Space Systems Engineering”, “Spacecraft Environmental Interaction”, “Satellite Environment Testing”, “Spacecraft Power System”, etc in English. “Space Environment Testing Workshop” will be offered using facilities of Center for Nanosatellite Testing. Students are also required to attend “Practical System Engineering – Design” to do satellite design as a team work in collaboration with other students including Japanese students. By satisfying the required course works and defending Master or Ph.D. thesis, the students will be awarded the degree of Master of Engineering or Doctor of Engineering.
United Nations/Japan Long-term Fellowship Programme Doctorate in Nano-Satellite Technologies (DNST)

Developing countries that in the past have mostly focused on applications-oriented aspects of space technology are increasingly also interested in building indigenous capacities for basic space technology development. A nano-satellite development program is an ideal first-step to establish such a basic capacity. Experience gained through on-the-job training, going through the complete cycle of designing, building and testing a satellite, is crucial to gain this capacity. To fill that demand there is a need for educational institutions to offer appropriate on-the-job training opportunities.

In 2010, Kyushu Institute of Technology and the United Nations Office for Outer Space Affairs launched a long-term fellowship programme on nano-satellite technologies for post-graduate level students from developing countries and countries with economies in transition. The students supported by the fellowship programme enroll in Kyushu Institute of Technology in October every year from 2011. The length of the fellowship programme for each student is three years. Students work in the newly established Centre for Nanosatellite Testing, which can handle a full range of environmental tests required for a 50cm-class nano-satellite. Because all tests can be conducted with the facilities available inside the campus, intensive and efficient cycles of designing, building and testing become possible.

The application package for the fellowship programme is available at the UNOOSA website, http://www.unoosa.org/oosa/en/SAP/bsti/fellowship.html. The completed application forms have to be submitted to the United Nations no later than early (exact date TBD) 2013 (for the class of 2013).
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http://ssdl.aero.kyushu-u.ac.jp/?EN%2FHome

Space debris, In-situ measurement, Constellation, Space situational awareness

[1] Overview and Science Highlights of the project

Space systems dynamics laboratory at Kyushu University has initiated the project for in-situ debris environment awareness (IDEA), aiming to establish an in-situ and real-time measurements network to monitor micron-size debris in the low Earth orbit region. Today, information on micron-size debris has not been continuously available yet in any orbital regimes though its impact can be trigger of a critical damage to a spacecraft. The IDEA project intends to deploy a group of 50-cm cubic satellites (IDEA satellites), installing dust sensors under the research and development by JAXA, into a congested orbital altitude of which micron-size debris are to be monitored (Figs. 1 and 2). The IDEA's monitoring system has an advantage to bring monitoring data from various orbits. IDEA satellites plan to be launched sequentially in a piggyback fashion with a primary satellite to a near altitude, in which case it is possible to measure the debris environment for the primary satellite at the same time. Currently, the first satellite, IDEA-1 is under development, and aim to be launched in FY2014 or later.

Fig. 1. IDEA constellation.  
Fig. 2. IDEA conceptual image.
CanSat project in our laboratory has been initiated in 2000. Students, who join our laboratory newly, work on developing CanSat for half a year to study basic knowledge of satellites and systems engineering, and experience the lifecycle of a technological project, including planning, managing, operating, and evaluating their mission (Figs. 3 and 4).

As an opportunity for the operating, we have participated in ARLISS or Noshiro-space event. In those events, we have received a lot of prizes such as 1st prize at ARLISS mission competition in 2009. Moreover, the CanSat has carried out various missions, such as, fly-back by parafoil or kite-plane, measuring temperature or pressure of atmosphere, downlinking mission data to ground station, and video recording from CanSat.

In 2011, we performed the demonstration of some system architectures in the C&DH subsystem, which are partly adopted in the IDEA-1. Concretely, our CanSat installed with three microcontrollers controlled by the predominant commands determined via logical algorithm. This new challenge motivated lab students to develop CanSat. Long operation period was favorable to evaluate our proposed mission. Thus, we decided to carry out the mission in the way of run-back, which generally takes longer time than fly-back. This was the first time for us to develop a rover-type CanSat (Fig. 5). The knowledge and technical know-how acquired from the demonstration have helped the development of C&DH subsystem in IDEA-1 (Fig. 6). In addition, the experience throughout developing CanSat is very useful fruitful for becoming a full-fledged engineer, and not got achieved in classroom lecture.

![Fig. 3. CanSat in 2007.](image1)

![Fig. 4. Kite-plane CanSat in 2009.](image2)

![Fig. 5. Rover CanSat in 2012.](image3)

![Fig. 6. CanSat C&DH board.](image4)
[3] Papers

✧ Journal Publications

• T. Hanada, J.-C. Liou, T. Nakajima, E. Stansbery, “Outcome of Recent Satellite Impact


## Contributions (in Japanese)


## Bachelor Dissertations


## Master Dissertations


## Doctor Dissertations


**[4] Recent overseas researchers who collaborated with us (for a short period)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Researchers</th>
<th>Project/Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>A. Rossi (ASI), CNES, CNSA, ESA, ISRO, JAXA, NASA, ROSCOSMOS, H. Lewis (UKSA)</td>
<td>Identify Sources of HAMR Objects Starting From Elements and AMR</td>
</tr>
<tr>
<td>3.</td>
<td>A. Rossi (ASI), CNES, CNSA, B.B. Virgili (ESA), R.K. Sharma (ISRO), J.-C. Liou (NASA), ROSCOSMOS, UKSA</td>
<td>Identify Sources of HAMR Objects Starting From Elements and AMR</td>
</tr>
</tbody>
</table>

**[5] Important mention, if any**

Our laboratory focuses on two guidelines adopted in the space debris mitigation guidelines of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. The first guideline limits the long-term presence of spacecraft and launch vehicle orbital stages in the low Earth orbit region after the end of their mission. Small satellites as secondary payloads may not be allowed to have propulsions or pressurized vessels. Such small satellites can expect only natural orbital decay due to the atmospheric drag, so that they have to enlarge their average cross-sectional area at the beginning or after the end of their mission to comply with the guideline. However, enlargement of the average cross-sectional area may conflict with the second guideline that limits the probability of accidental collision because the probability of accidental collision is a function of the effective cross-sectional area. Therefore, our laboratory tries to optimize the average cross-sectional area in terms of the two guidelines as a better effort.
Keywords

Deployable Structure, Gossamer Structure, Space Education, CubeSat, Cansat

[1] Overview and Science Highlights of the project

We have been developing pico-satellites for space education and verification of our research on space systems. We launched two 1U CubeSats, and will launch larger pico-satellite next year. Our laboratory is a member of “HODOYOSHI” project (Japanese national nano-satellite development and utilization project led by Prof. Nakasuka in University of Tokyo) and developing deployable panel structures for nano-satellites and devices for deployable structures such as hinges and hold-release mechanism.

Furthermore, we have been collaborating with JAXA on the research and development of gossamer structures such as solar sails and inflatable structures, especially on the numerical analysis of deployment dynamics.

1. SEEDS-II

We launched 1U CubeSat named SEEDS-II (Space Engineering Education Satellite) by Indian PSLV-C9 rocket in 2008. SEEDS-II is still working very well, and the students have been operating SEEDS every day for more than four years. You can hear the voice from SEEDS as well as get the photo images and the satellite state data.

2. SPROUT

We will launch 20cm-cube, 6.7kg pico-satellite named SPROUT (Space Research On Unique Technology) by Japanese H-IIA rocket in 2013. We will demonstrate the deployment of the combined membrane structure (1.5m-sided triangular membrane supported with two space-inflatable tubes) and 3-axes attitude control technology. The amateur radio people in the world can partially operate SPROUT, i.e. you can take the photos by using the camera mounted on SPROUT, and send your voice to all over the world relayed by SPROUT.
3. Deployable Structures in “HODOYOSHI” project

We are developing a high-precision deployable panel structure for space antenna, simple and reliable devices for deployable structure, and researching on the theoretical estimation of performance of deployable structure such as shape accuracy and smooth deployment. We think such a pre-flight estimation is quite important to reduce the development cost of nano satellites.

4. Other activities

- We have been researching on the drag-chute for the deorbit of pico/nano satellites. The combined membrane structure of SPROUT is also one example of the deorbit devices.
- We are a member of JAXA’s solar power sail working group and have joined IKAROS project (demonstration spacecraft of solar power sail) which was launched in 2010 and is the world’s first interplanetary solar sail. We have contributed to the deployment analysis of the dynamics of solar sail membrane and other topics on structural dynamics.

Simulation of sail deployment of IKAROS
We are a member of SIMPLE which is the project of a space demonstration of inflatable structures at the space exposed facility of the Japanese Experimental Module in the International Space Station. The experiment system is a 50cm cube in launch configuration and it will extend 1.3m inflatable mast (IEM), and deploys a small terrarium (IST) and a material pallet (IMP). It will be launched by H-IIB in July 2012 and the demonstration will be conducted in August 2012.

We place the Cansat activities as the first training course to get the skill of the development of pico-satellites. The Cansat can be a BBM (bread board model) of the pico-satellite or that of the equipment for the pico-satellite. In 2002, we made the Cansat named “Cube-Can” which is the BBM of SEEDS. We participated in ARLISS (Suborbital launch experiment of Cansat held in the Black Rock desert in U.S.A. [http://www.arliss.org/]). After that, we made the EM (engineering model) and FM (flight model) of SEEDS-I in 2004. In 2006, we made the BBM of SPROUT named “SPROUT-Can”, and conducted the experiment in ARLISS.

We convince that the Cansat is a very good training tool to understand the basic system of pico-satellite and to get the skill necessary for the development of pico-satellites.

Cansat is also a good training tool for the space engineering education of young students. We developed a freshman training program for the beginners, especially for 1st degree students of our university. The program begins in April (the beginning of fiscal year in Japan) and ends in December. The participants take seminars on space engineering and pico satellite, lessons on the electric circuit design, manufacturing of the printed circuit board, soldering, the programming of micro-computer, and machining tools. They make a printed circuit board (PCB) with micro-computer PIC personally and a more complicated PCB in a group. During those lessons, they should pass the achievement test. After that, they make a Cansat in the group and conduct the drop experiment of the Cansat with a parachute from a captive balloon. Finally, they have the presentation on the result of their Cansat project and make a final report. Some of the students who finished this program are the members of SPROUT project or have started a new CubeSat project, or have joined the “HODOYOSHI” project. Thus the Cansat opens up the opportunities for pico/nano satellite project.

[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

We place the Cansat activities as the first training course to get the skill of the development of pico-satellites. The Cansat can be a BBM (bread board model) of the pico-satellite or that of the equipment for the pico-satellite. In 2002, we made the Cansat named “Cube-Can” which is the BBM of SEEDS. We participated in ARLISS (Suborbital launch experiment of Cansat held in the Black Rock desert in U.S.A. [http://www.arliss.org/]). After that, we made the EM (engineering model) and FM (flight model) of SEEDS-I in 2004. In 2006, we made the BBM of SPROUT named “SPROUT-Can”, and conducted the experiment in ARLISS.

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3 Papers

- Journal Publications
Recent overseas researchers who collaborated with us (for a short period)

1. Dr. Freddy Pranajaya, University of Toronto (Canada): Piggy-back launch of pico satellite
2. Dr. Simon Guest, Cambridge University (UK): Design and analysis of deployable Structure
3. Dr. Vaios Lappas, University of Surrey (UK): Inflatable Structure, Deorbit membrane structure
1. Making use of these experiences on the freshman training program using Cansat, we hosted CLTP2 (Cansat Leader Training Program 2) in 2011 (http://cltp.info/). CLTP is one of the activities of “HODOYOSHI” project, and is organized by UNISEC. CLTP was established in 2010 to contribute to capacity building in space technology and improve teaching methods-based space engineering education. We hosted CLTP2 (Cansat Leader Training Program 2) in 2011. You can see the digest of CLTP2 at http://www.youtube.com/watch?v=SwK3dIrUmEQ. We will be very glad if you are interested in our Cansat activities and have contact with us.

2. We always welcome to collaborate in development of utilization of pico satellite, and research on gossamer structure with oversea organizations.
Electric rocket, Electric propulsion, Nano-satellite, Powered flight, Earth observation, Moon exploration, Pulsed plasma thruster, Hall-type ion thruster, Direct-current arcjet thruster

[1] Overview and Science Highlights of the project

Development of Nano-Satellite PROITERES-Series with Electric Rocket Engines at Osaka Institute of Technology

1. Introduction

The Project of Osaka Institute of Technology Electric-Rocket-Engine onboard Small Space Ship (PROITERES), as shown in Fig.1, was started at Osaka Institute of Technology in 2007. In PROITERES, a nano satellite with electrothermal pulsed plasma thrusters (PPTs) will be launched in 2012, because the launching was delayed from the end of 2011 due to change of schedule of Indian PSLV launcher. The main mission is to achieve powered flight of nano-satellite by an electric thruster and to observe Kansai district in Japan with a high-resolution camera. The raising in Sun Synchronous Orbit will be carried out by the PPTs.

Our satellite R&D groups are divided into eight sections. We take a student and staff member meeting one time a week and examine the satellite system. Each section developed Bread Board Model (BBM) and Engineering Model (EM) of the satellite in 2007-2009. In this paper, we introduce the final progress of PROITERES Flight-Model (FM) including PPT system. Furthermore, the research and development of the 2nd and 3rd PROITERES satellites with electric thrusters are also introduced.

2. “PROITERES” Satellite Overview and Main Mission Systems

The specification of the satellite, as shown in Table 1 and Fig.2, is as follows. The weight is 15 kg; the configuration is a 0.29 m cube; and the minimum electric power is 10 W. The altitude is 670 km in Sun Synchronous Orbit. The lifetime is above one year. The launching rocket is PSLV in India, and the window will be July-Sept. of 2012.
2.1. Powered flight by electric thruster

Pulsed plasma thrusters, as shown in Fig.3, are expected to be used as a thruster for small/nano satellites. The PPT has some features superior to other kinds of electric propulsion. It has no sealing part, simple structure and high reliability, which are benefits of using a solid propellant, mainly Teflon® (poly-tetrafluoroethylene: PTFE). However, performances of PPTs are generally low compared with other electric thrusters. At Osaka Institute of Technology, the PPT has been studied since 2003 in order to understand physical phenomena and improve thrust performances with both experiments and numerical simulations. We mainly studied electrothermal-acceleration-type PPTs, which generally had higher thrust-to-power ratios (impulse bit per unit initial energy stored in capacitors) and higher thrust efficiencies than electromagnetic-acceleration-type PPTs. Although the electrothermal PPT has lower specific impulse than the electromagnetic PPT, the low specific impulse is not a significant problem as long as the PPT uses solid propellant, because there is no tank nor valve for liquid or gas propellant which would be a large weight proportion of a thruster system.

In our study, the length and diameter of a Teflon discharge room of electrothermal PPTs were changed to find the optimum configuration of PPT heads in very low energy operations for PROITERES satellite. Initial impulse bit measurements were conducted, and long operations and endurance tests were also carried out with the optimum PPT configuration.

Figure 4 shows a thrust stand in a vacuum chamber for precise measurement of an impulse bit. The PPT and capacitors are mounted on the pendulum, which rotates around fulcrums of two knife edges without friction. The displacement of the pendulum is detected by an eddy-current-type gap sensor (non-contacting micro-displacement meter) near the PPT, which resolution is about ±0.5 μm.

Figure 5 shows a vacuum chamber 1.25 m in length and 0.6 m in inner diameter, which is evacuated using a turbo-molecular pump with a pumping speed of 3,000 l/s. The pressure is kept below 1.0x10⁻² Pa during PPT operation. We carried out endurance tests with the optimum cavity shape 9.0 mm in length and 1.0 mm in diameter at a discharge energy per one shot of 2.43 J/s. Table 2 shows the operational condition of endurance test. The repetitive frequency is 1.0 Hz.

Figure 6 shows the shot-number history of impulse bit, mass loss, specific impulse and thrust efficiency. Both the impulse bit and the mass loss, as shown in Fig.6(a), rapidly decrease with increasing shot number. Specially, the impulse bit decreases from 250 μNs at initial condition to 75 μNs after about 50,000 shots. Although a few miss fires occurred around 53,000-shot, a total impulse of about 5 Ns was achieved. As shown in Fig.6(b), the specific impulse increases with increasing shot number, and the thrust efficiency is around 0.2 during the repetitive operation. The cavity diameter, as shown in Fig.7, increases from 1.0 mm to about 6.0 mm of the anode diameter after 50,000 shots. The discharge feature, as shown in Fig.8, changes from a long plasma plume with intensive emission light at 1-10,000 shots to a very short plume with weak emission. This is expected because of lowing pressure and ionization degree in the cavity when enlarging cavity diameter. We designed the flight model of a PPT head and its system.
Figures 9 and 10 show the structure, illustrations, and photos. The PPT head has a simple structure, and two PPT heads are settled on the outer plate of PROITERES satellite. As shown in Fig.10(b), the power processing unit and the 1.5-µF capacitor are mounted in the satellite. The final endurance test of the PPT system was successfully finished.

2.2. Observation of Kansai district

A high-resolution camera system was developed for PROITERES satellite. Figure 11 and Table 3 show the flight model of the optical system and the specification. The optical system has five-lens system with a focal length of 85.3 mm and a F number of 3.6. The mass is 230 g, and the length and diameter are 109 mm and about 50 mm, respectively. Accordingly, the optical resolution is 30 m for the CMOS sensor. After accurate alignment between the optical system and the CMOS sensor with a special facility shown in Fig.12, the camera system was onboard the satellite. As shown in Fig.13, we will be able to observe the Kansai district with Yodo River from PROITERES satellite.

![PROITERES image on orbit and flight-model.](image)

<table>
<thead>
<tr>
<th>Table 1 Specification of PROITERES satellite.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>Outside dimension</td>
</tr>
<tr>
<td>Orbit</td>
</tr>
<tr>
<td>Altitude</td>
</tr>
<tr>
<td>Commencing time</td>
</tr>
<tr>
<td>Life time</td>
</tr>
<tr>
<td>Rocket</td>
</tr>
<tr>
<td>Launch</td>
</tr>
<tr>
<td>Attitude control</td>
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</table>
Table 2. Experimental conditions of endurance test.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Capacitor, μF</td>
<td>1.5</td>
</tr>
<tr>
<td>Charging voltage, V</td>
<td>1800</td>
</tr>
<tr>
<td>Stored energy, J</td>
<td>2.43</td>
</tr>
<tr>
<td>Cavity</td>
<td></td>
</tr>
<tr>
<td>Length, mm</td>
<td>9.0</td>
</tr>
<tr>
<td>Diameter, mm</td>
<td>1.0</td>
</tr>
<tr>
<td>Nozzle</td>
<td></td>
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<tr>
<td>Length, mm</td>
<td>23</td>
</tr>
<tr>
<td>Half angle, degree</td>
<td>20</td>
</tr>
</tbody>
</table>
Fig. 7 Change of cavity diameter before and after 50,000 shots.

Fig. 8 Features of plasma plume.

Fig. 9 Inner structure of PPT.

Fig. 10 PPT system flight model.

Photos of PPT head, and power processing unit and 1.5-μF capacitor of flight model of PPT.

Fig. 11 (a) Cross-sectional drawing of optical system, (b) Outline view of optical system, (c) Side view of optical system, (d) Front view of optical system.

<table>
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<tr>
<th>Parameter</th>
<th>Typical Value</th>
</tr>
</thead>
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<td>Model number</td>
<td>MT9T001</td>
</tr>
<tr>
<td>Size</td>
<td>14.22mm × 14.22mm</td>
</tr>
<tr>
<td>Active imager size</td>
<td>6.55mm(H) × 4.92mm(V)</td>
</tr>
<tr>
<td>Active pixels</td>
<td>2048H × 1536V</td>
</tr>
<tr>
<td>Pixel size</td>
<td>3.2μm × 3.2μm</td>
</tr>
</tbody>
</table>

Fig. 12 Aliment device.

Fig. 13 Photography image of Kansai district.
3. 2nd and 3rd PROITERES Satellite R&D

As next projects, we started the research and development of the 2nd and 3rd PROITERES satellites in Oct. 2010. The 2nd satellite of PROITERES series, as illustrated in Fig.14, is a 50-kg earth-observation satellite with high-power and large-total-impulse pulsed plasma thruster system for practical use. The PPT system with 10-15 kg is provided with four thruster heads with Teflon feeding mechanisms, and the total impulse per one thruster head is 2500 Ns at an input power of 25 W. As a result, we can change totally the altitude of the satellite up to 400 km, and on the lower orbit of 200 km we can keep the altitude up to one month.

The 3rd satellite of PROITERES series is a 50-kg moon-exploration satellite with cylindrical-type Hall thruster system for powered flight from the low earth orbit to the moon orbit. The Hall thruster system will produce specific impulses of 1500-2000 sec at xenon mass flow rates of 0.1-0.3 mg/s with an input power of 30 W. The trip time to the moon is within 3 years.

The 2nd and 3rd PROITERES satellites are under development.

Fig.14  Illustration of 2nd PROITERES satellite.
[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

n/a

[3] Papers


[4] Recent overseas researchers who collaborated with us (for a short period)

1. Prof. Manuel Martinez Sanchez, MIT, USA
   R&D of Hall thrusters

2. Prof. Wonho Choe, KAIST, Korea
   R&D of electric thrusters for nano-satellites

[5] Important mention, if any

n/a
University/Organizer | Osaka Prefecture University - Small Spacecraft Systems Research Center  
--- | ---  
Supervisor | Hiroshi Okubo, Professor / Yohsuke Nambu, Assistant professor  
Contact | +81-72-254-9238  
Email: nambu@aero.osakafu-u.ac.jp  
URL | http://www.sssrc.aero.osakafu-u.ac.jp/E_SSSRC_HP/index.html  

Keywords  
Small Satellite, CubeSat, Cansat, Technology transfer, Space education  

[1] Overview and Science Highlights of the project  

**OPUSAT Project (2010-)**  
OPUSAT is a 1U CubeSat that is being developed by Osaka Prefecture University. The primary objective of this satellite is to demonstrate advanced hybrid power supply system using Lithium-ion Capacitor (Li-C) and Lithium-ion battery. Li-C enables long term operation in high power discharge and in deep charge-discharge cycle. It works well in space environment, even without a heater. These advantages are very useful for small satellite especially when it uses active sensors or quick attitude control devices. OPUSAT also has deployable solar array paddles, and is equipped with a spin stabilization system using magnetic torquers. These instruments give abundant power to this CubeSat. This bus system makes CubeSats more attractive. OPUSAT is to be launched by H-IIA rocket as a piggyback satellite in 2014 from Tanegashima Space Center. With BBM#1 of OPUSAT, we challenged the idea competition in ARLISS 2011. Currently, we are developing EM of this satellite.
## Specification sheet of OPUSAT

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Item</th>
<th>Specification</th>
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<tbody>
<tr>
<td><strong>Size and Weight</strong></td>
<td>type</td>
<td>1Unit CubeSat</td>
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<tr>
<td></td>
<td>size</td>
<td>W 100 x D100 x H122 mm</td>
</tr>
<tr>
<td></td>
<td>weight</td>
<td>about 1.4 kg</td>
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<tr>
<td><strong>Power</strong></td>
<td>solar cells</td>
<td>2 series x 1 parallels x 4 (deployment paddle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 series x 1 parallels x 6 (body mount)</td>
</tr>
<tr>
<td></td>
<td>control</td>
<td>MPPT controller</td>
</tr>
<tr>
<td></td>
<td>batteries</td>
<td>2-cells Lithium-ion</td>
</tr>
<tr>
<td></td>
<td>power</td>
<td>1 W (nominal), 3 W (maximum)</td>
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<tr>
<td></td>
<td>consumption</td>
<td>&lt; 1.0W (at typical mode)</td>
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<tr>
<td></td>
<td></td>
<td>4.2W (at panel deployment mode)</td>
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<tr>
<td><strong>Communication</strong></td>
<td>CPU</td>
<td>PIC16F877, LPC1768</td>
</tr>
<tr>
<td></td>
<td>uplink</td>
<td>FM 1200bps (144MHz) at OPU station, Japan</td>
</tr>
<tr>
<td></td>
<td>downlink</td>
<td>CW 50wpm (430Mhz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FM 1200bps(AFSK) / 9600bps(GMSK)</td>
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<tr>
<td><strong>Attitude Determination and Control</strong></td>
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<td>3 axis gyro sensors</td>
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<tr>
<td></td>
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<tr>
<td></td>
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<td>2 magnetic torquers</td>
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<td>SD card</td>
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<td><strong>Structure and Thermal</strong></td>
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<td>aluminum alloy</td>
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<tr>
<td></td>
<td>mechanism</td>
<td>deployment paddle (by wire cutting-off)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>deployment antenna (by wire cutting-off)</td>
</tr>
<tr>
<td></td>
<td>heaters</td>
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</tr>
<tr>
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<td>sensors</td>
<td>thermistor</td>
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</tbody>
</table>
Fundamental education for fresh students (2011-)

It is the most important issue for present members to pass knowledge, culture, and passion on to fresh members of satellite programs, in university. Our fundamental education program for fresh students is divided into two parts. Firstly, fresh students learn the fundamentals of satellite design and development, such as CAD software, programming for micro computer, soldering, and electrical circuits, before summer vacation. Secondly, they struggle to develop a CanSat, in order to learn project management and systems design. All programs are planned and implemented only by the students. Through this program, fresh students work together with senior members who perform mentors. We expect that the knowledge, culture, and passion smoothly flow from senior to fresh students with this mentors system. The last fresh students who attended this educational program in 2011 are dependable members of OPUSAT project now.

MAIDO-1 Project (2003-2009)

A 50 kg class micro-satellite “MAIDO-1(SOHLA-1)” was launched, together with other six piggy-back sub-satellites, by a Japanese H-2A rocket on January 23, 2009. The satellite was developed by Space Oriented Higashiosaka Leading Association (SOHLA), a corporation of middle-sized enterprises in Higashi-Osaka City and Kansai district, Japan. The major part of the fundamental and detailed designs of the satellite has been carried out by the students of Osaka Prefecture University and Ryukoku University under the technical support of Japan Aerospace Exploration Agency (JAXA). The students have actively participated in the design and development of the bus-system and subsystems.
Achievements in Space Engineering Education through CanSat Activities (or Plan)

CanSat Project (2005-)
Noshiro Space Event 2007-
Tanegashima Rocket Contest 2007-
ARLISS 2007, Comeback Competition 1st Place,
ARLISS 2010, Comeback Competition 4th Place
ARLISS 2011, Mission Competition 4th Place
JST CanSat Workshop for junior and senior high school students (2011)

Papers

- Journal Publications

- Contributions (in Japanese)
<table>
<thead>
<tr>
<th></th>
<th>Recent overseas researchers who collaborated with us (for a short period)</th>
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Electrodynamic Tether system

Electrodynamic Tether (EDT) system is one of the promising electric propulsion systems because it can generate thrust without propellant. Since it requires geomagnetic force, it is expected to apply it to orbital transportation and disposal of space debris as thrust system without propellant.

In our research group, we are planning to launch the world’s first demonstration experiment of EDT system with a micro-satellite.

Principle of EDT

A concept of EDT system is shown in Fig.1. EDT system consists of an electrodynamic tether and an electron collector to collect electrons at one end and an electron emitter to emit electrons at the other end. When the electrodynamic tether with \( L \) in length extends to the direction of orbital radius at one orbit and moves at orbital velocity \( \mathbf{v} \) through the geomagnetic field \( \mathbf{B} \), it produces induced electromotive force \( \mathcal{E} = (\mathbf{v} \times \mathbf{B}) \cdot \mathbf{L} \) and the upper end of the tether is charged positively and the lower end of the tether is charged negatively than the ambient plasma voltage. When it collects electrons at the upper end of tether and emits electrons at the lower end of the tether, the electric current flows through the tether by closing the circuit via the ambient plasma. Lorentz force \( \mathbf{F} = (\mathbf{I} \times \mathbf{B}) \cdot \mathbf{L} \) is generated by the interaction with the electric current and the geomagnetic field and EDT system can provide deceleration. This is called “Deceleration mode”.
Another application is as follows. When higher voltage than the electromotive force is applied to the lower end of the tether, the lower end collects electrons resulting in that the current flows inversely. In this case, the EDT system can provide thrust. This is called “Thrust mode”.

3. Outline of our project

In our research group, an orbital motion of micro-satellite with the EDT system has been numerically analyzed. As a next step, we are planning to demonstrate the EDT system in space as a part of STARSII project by Kagawa University in 2013.

A concept of our EDT system is shown in Fig.2. In this experiment, a bare tape tether is used. Since the bare tape tether is covered with aluminum, the higher electron collection efficiency is expected than a spherical probe collector. As an electron emitter, a filament cathode made from Thoriated-Tungsten wires is used. Due to the limitation of electric power by a satellite, the tether length is set to 300 m in which the collection current of 24 mA is expected by OML theory. Although the generated thrust of 0.2 mN at maximum may be too small to be found, the current collection by the bare tape tether is the first demonstration in the world.
Achievements in Space Engineering Education through CanSat Activities (or Plan)

In 2009, Shizuoka university Aerospace Technology Training Club (SATT) is established to promote space engineering education for undergraduate students in Hamamatsu Campus. Currently, eleven students belong to the club from departments of mechanical engineering and electrical and electronics engineering. They are developing a parafoil type cansat to participate in a comeback competition in the Noshiro space event.

Fig. 3 Cansat “Yaramaican” (left) and photo in 2011 Noshiro space event (right).
【3】Papers

✧ Journal Publications

*Takanori Yoshimura, Toru Miwa, Shuhei Miwa, Yoshiki Yamagiwa and Makoto Matsui “The Numerical Analysis of Orbital Motion and Attitude of Micro-Satellite with an Electrodynamic Tether(EDT) System” The 55th Symposium on Space Science and Technology

*Takanori Yoshimura, Shuhei Miwa, Yoshiki Yamagiwa and Makoto Matsui “The Study of Orbital Analysis and Attitude Control of Micro-Satellite with an Electrodynamic Tether System” The 28th International Symposium on Space Technology and Science

*Takanori Yoshimura, Yoshiki Yamagiwa and Makoto Matsui, Shuhei Miwa, Atsushi Nakajima “The Study of Orbital Analysis and Attitude Control of Micro-Satellite with an Electrodynamic Tether System” Space Transportation Symposium in 2010


✧ Master's thesis

*Takanori Yoshimura “The Numerical Analysis of Orbital Motion and Attitude of Micro-Satellite with an Electrodynamic Tether(EDT) System”, 2011

【4】Recent overseas researchers who collaborated with us (for a short period)

1. Name and Affiliation of Co-researcher
   Research Theme

2. Name and Affiliation of Co-researcher
   Research Theme

【5】Important mention, if any

n/a
Keywords

Pico-satellite (CubeSat)

[1] Overview and Science Highlights of the project

A pico-satellite Negai at Soka University was launched on May 21st, 2010 at Tanegashima Space Center, Japan to decay on June 26th, 2010 with missions completed. The satellite is a CubeSat that measures just ten centimeters cubic and weighs a mere kilogram. Its orbit is 300km altitude with 30 degree inclination. At 300km altitude, the satellite plunges back into the atmosphere, creating an artificial “shooting star” after a few weeks. Hence it is named Negai or “Wish upon a shooting star.”

The technical mission is to prove in space the high functional information system with inside triple-redundant fault-tolerant soft-core CPU embedded in a FPGA and reliable picture transmission system.

Fig.1 Negai(FM)
Achievements in Space Engineering Education through CanSat Activities (or Plan)

CanSat related to CubeSat "Negai".
2005- CanSat NAME: Mo.P.-Sat (Movie and Picture - Sat)
   MISSION: Establishment of the imaging system for CubeSat.
   Shooting still pictures and movie.
   ARLISS: CanSat shot nineteen pictures and movie including the scenes of separation from the rocket and landing on the ground.

CanSat NAME: Nexus
MISSION: A telecommunication test with the ground station.
Reconfiguration of on board FPGA.
ARLISS: Telecommunication test and FPGA reconfiguration test were successful.

2006- CanSat NAME: JACSAT(JPEG And Communications SAT)
MISSION: Establishment of a still image compression for CubeSat
ARLISS: Lost the memory data.

Papers

- Contributions (in Japanese)
  - Seiji KUROKI, Tuyoshi NAGAO --- 超小型衛星の時代-大学手作り衛星の開発- --- Information Processing Society of Japan Vol.47 No.7
- Master's thesis
  - Kiyoshi KANEKO --- A Study on Still-Image Shooting Subsystem for Small Satellite --- 2011
  - Kensei ONO --- A Study on System Safety for Negai pico-satellite of Soka University --- 2011
  - Tomohito YAMADA --- A Study on Versatile Structure for Pico-satellites --- 2011
  - Souichiro URASTUJI --- A Study on Earth Image Data Interpolation System of a Pico-satellite Negai --- 2011
  - Mayumi MORIMI --- A study on flat antenna for CubeSat --- 2010
  - Akio OGURA --- A study on selection of peripheral devices for Flexible Step-Down Space DC-DC Converter --- 2010
  - Hironobu KUME --- Study of image compression technique of the earth images --- 2010
  - Tetsuya SATO --- A study on an earth image data acquisition system from a pico-satellite --- 2010
  - Eiji ONO --- Efficiency Optimization for Flexible Step-Down Space DC-DC Converter --- 2009
  - Takashi FUJINAMI --- A study on variable directional antenna for small Satellite --- 2009
  - Yuusuke MURASHIMA --- A Study on Reconfigurable system for Pico-satellite --- 2009
  - Noriko YAMAMOTO --- Examination of compressed image restoration method for pico-satellite --- 2009
[4] Recent overseas researchers who collaborated with us (for a short period)

n/a

[5] Important mention, if any

n/a
【1】Overview and Science Highlights of the project

n/a

【2】Achievements in Space Engineering Education through CanSat Activities (or Plan)

Structural Dynamics Design Laboratory (SDDL) at Tokyo Institute of Technology makes research on dynamic analysis and design of space structures. SDDL uses CanSat development for inspiring and educating students. Through CanSat development, students experience the excitement as well as harshness of space missions, and learn basic technical knowledge about space systems. In addition, the project management skill obtained through the CanSat development will be quite useful for students’ own research projects and for their professional career after graduation.

SDDL has joined ARLISS (A Rocket Launch for International Student Satellites) held at Nevada, USA, since 2008. Students at SDDL focused on realizing “hybrid-type” CanSat, which is capable of flight control using a para-glider in the air, and of locomotion control using a rover mechanism on the ground (see Fig. 1).

Furthermore, Dr. Sakamoto, Assistant Professor at SDDL, provides an educational program for all UNISEC students who develop CanSat. The program aims at teaching Systems Engineering through CanSat development. The program consists of two seminars and some design reviews. It started in 2010, and the contents have been significantly improved in 2011 and 2012. Figure 2 shows a picture taken at the oral debriefing session after ARLISS 2010.

Fig. 1  SDDL’s CanSat developed in 2008 (left) and in 2009 (right)

Fig. 2  Participants to the Systems Engineering educational program
【3】Papers

- Conference papers
  - H. Sakamoto, N. Kohtake, S. Shirasaka, K. Yamada, Y. Sudo, S. Toki, and Y. Kakehashi,
    "Introduction of Systems Engineering to Cansat Project - Construction of PBL-type Educational
    Program -," ISTS 2011-t-14, presented at the 28th International Symposium on Space Technology and
    Science (ISTS), Okinawa, Japan, June 2011.
    Application of Systems Engineering to Cansat Project - Operation of PBL-type Educational Program in
    Seven Universities in Japan -," ISTS 2011-t-15, presented at the 28th International Symposium on
    Space Technology and Science (ISTS), Okinawa, Japan, June 2011.

【4】Recent overseas researchers who collaborated with us (for a short period)

n/a

【5】Important mention

n/a
**University/Organizer**
Tokyo Metropolitan College of Industrial Technology

**Supervisor**
Tomohiro Ishikawa, Associate Professor

**Contact**
+81-03-3801-0145
Email: t-ishikawa@acp.metro-cit.ac.jp

**URL**

**Keywords**
15 to 22 years old.
KISEKI satellite (KKS-1 satellite).
Micro Thruster.

---

**[1] Overview and Science Highlights of the project**

The Tokyo Metropolitan College of Industrial Technology, a five-year school for students 15 years old and over, had been performing well in satellite design contests for many years. On January 23, 2009, Japan launched Ibuki(GOSAT) satellite for monitoring the entire planet’s volume of greenhouse gases. At the same time, several smaller satellites made by universities and companies were also launched into orbit by piggybacking on the H-IIA rocket. One of the small satellites is our satellite.

Our satellite name is “KISEKI” (code name is KKS-1). It’s a big Cubesat that measures 15 centimeters cubic and weighs a 3.1 kg. Its orbit is 636km altitude with 98 degree inclination.

KISEKI’s Mission:
- Mission 1: Getting the satellite health data via beacon signal. → Success!
- Mission 2: Getting the camera image data. → Failure…
- Mission 3: Micro thruster(<1mN/1shot) → Failure…
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)</td>
<td>n/a</td>
</tr>
<tr>
<td>[3] Papers</td>
<td>n/a</td>
</tr>
<tr>
<td>[4] Recent overseas researchers who collaborated with us (for a short period)</td>
<td>n/a</td>
</tr>
<tr>
<td>[5] Important mention, if any</td>
<td>n/a</td>
</tr>
</tbody>
</table>
### Overview and Science Highlights of the ABC project

1. **ORBIS project**
   
   As of this year we started up new project of a micro satellite development. This satellite, named Orbiting Binary black-hole Investigation Satellite (ORBIS), is going to observe binary black-hole (BBH) in X-ray region to reveal a mechanism of galaxy growth. ORBIS concept design won the best design award of the 18th Satellite Design Contest. We make the design of ORBIS more sophisticated now and advance the development with scientific experts by 2015. Although previous micro satellites were generally utilized for an experiment of engineering, by ORBIS, we will demonstrate the potential of micro satellites for a scientific mission.

   ![ORBIS Facts](image)

   **ORBIS Facts**
   
   - **Mass**: 36 kg
   - **Orbit**: 545 km, 96 deg (Sun-synchronous orbit)
   - **Dimensions**: Approximately 430 x 430 x 830 mm
   - **Stabilization**: 3-axis, zero momentum
   - **Communication**: S-band transceiver
   - **Design Life**: 1.5 years
   - **MISSION**: Observing binary black-hole

   *All data are conceptual level.*

2. **Propulsion system**
   
   We predicted that a propulsion system was necessary for the microsatellite to accomplish the space mission, and we have been developing a propulsion system for microsatellites based on 60 wt% hydrogen peroxide since 2004. We completed this propulsion system for microsatellite based on the SAFETY FIRST policy and EFFECTIVE COTS, by the beginning of 2008. Now, we have conducted development and environmental tests for several microsatellites.

### Achievements in Space Engineering Education through CanSat Activities (or Plan)

From the year 2008 on, our laboratory has been joined the CanSat competitions in Noshiro Space Event, and A Rocket Launch for International Student Satellites (ARLISS). After a student struggled in the competitions, three teams consisted of over 10 students will join this year’s ARLISS.

Related above, our laboratory is progressing a microsatellite project, ORBIS, and it is a part of the project that we manufacture CanSats and join the competitions.
[3] Papers

✦ Journal Publications

✦ Contributions (in Japanese)
- Yuzinuke Okano, “Prospective 3-axis Attitude Control for Microsatellite by Using Solar Radiation Pressure,” 2009.
[4] Recent overseas researchers who collaborated with us (for a short period)

3rd CanSat Leaders Training Program (CLTP3)

[5] Important mention

Our laboratory started in 2008 with the policy of “Create the future space,” and is being engaged in the concerning themes such as propulsion, attitude control, orbit transfer, and so on. If you are interested in Space Technology for our future, we welcome you.
<table>
<thead>
<tr>
<th>University/ Organizer</th>
<th>Kimura Laboratory - Tokyo University of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
<td>Professor Shin-ichi Kimura</td>
</tr>
<tr>
<td>Contact</td>
<td>+ 81-4-7124-1501 Ext. 3741</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://www.kimura-lab.net/">http://www.kimura-lab.net/</a></td>
</tr>
<tr>
<td>Email</td>
<td><a href="mailto:skimura@rs.noda.tus.ac.jp">skimura@rs.noda.tus.ac.jp</a></td>
</tr>
</tbody>
</table>

### [1] Overview and Science Highlights of the project

Kimura Laboratory’s basic interest is on-orbit robotic servicing such as space debris mitigations, and/or high performance on-orbit autonomy that enable us to expand possibilities of space system. To achieve these applications, they are studying various technical issues, intelligent control and on-orbit autonomy technologies, space robotic technologies, orbit dynamics and control technologies, and tele-operation technologies. They have high capability in COTS utilization technologies to realize high performance controllers. Based on these capabilities they developed high performance monitoring cameras, and utilized as monitoring system of IKAROS, and now developing various kind of camera system. They also have high capability on the software technologies. Based on these capabilities, they are now developing high performance on-board computer and their software development system including software development architecture and verification systems.

### [2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

Bachelor members of Kimura Laboratory participate CanSat activities, such as Noshiro Space Event and ARLISS to improve basic skill on system designing.
[3] Papers

❖ Journal Publications


[4] Recent overseas researchers who collaborated with us

n/a

[5] Important mention

n/a
Keywords
Cubesat, Easy reception, New application, Education, Human network, Enlightenment, FRAM, International collaboration, Tsukuba Science City

[1] Overview and Science Highlights of the project

1. Overview of the project
Our satellite will be launched as a piggyback satellite of GPM mission (planned in early 2014). Current activity is mainly based on design and development of various mission equipment and satellite bus. It is pursued by inter-department 12 student members as follows:
   8 undergraduates (3 sophomores, 1 junior, 4 seniors), 4 graduates
   9 engineering, 2 computer science, 1 physics
New members from other grade and/or different field are also anticipated.
Taking advantage of the location of our university, Tsukuba Science City, the Hometown of JAXA, we are building up various relationships for both educational and research oriented purpose.

2. Satellite characteristics and mission
Characteristics
   • 10x10x10 cm 1U size Cubesat
   • Weight 1.5 kg
   • Downlink 435 MHz Ham radio band
   • Uplink 435MHz and 145MHz Ham radio band
Mission 1: Create a Network

YUI sends information about voltage, temperature, and call sign in 435MHz amateur radio band with F2 (audio-frequency modulated Morse code).

- We suppose FM handheld transceiver for receiving information.
- TNC (digital wireless modem) is not required.
- Low orbit (400kms’ height): Low-transmission power is enough to receive information even for F2 signal.
- High orbital inclination (65 degrees): Many people in many regions can receive information from the satellite.

Mission 2: Validation of new type microprocessor operation

In addition to PIC, which is generally believed to be reliable against irradiation, we introduce a new anti-irradiation FRAM (Ferroelectric RAM) based microcomputer as an audio tone generator for F2 code. In order to avoid other mission failure, the satellite uses two different microcomputers by switching.

Mission 3: Validation of a ultra-small antenna

A ultra-small antenna developed for MEMS devices is used and a trial model is to be manufactured with AIST*1 soon

- Demonstration of reliability as a redundant system for receiving antenna.
- High reliability exists since no deployment mechanism required.
- The satellite can save the space because of its small profile.

*1) AIST: National Institute of Advanced Industrial Science and Technology
[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

n/a

[3] Papers

✧ Journal Publications
  n/a

✧ Contributions (in Japanese)
  n/a

✧ Books
  n/a

✧ Dissertations
  • Evaluations of Consumer Transceiver for Satellite Application, Mar. 2012, College of Engineering Systems, University of Tsukuba

✧ Master's thesis
  n/a

✧ Doctor’s thesis
  n/a

[4] Recent overseas researchers who collaborated with us (for a short period)

n/a

[5] Important mention, if any

This project is not a research laboratory oriented, but opened to all students studying at University of Tsukuba. This style might be still rare in Japan, however, we believe space development should be global activities not limited within Science and/or Engineering field.
Wakayama University has been working on setting up experiment sites for student space projects in Japan. As a result, we have a “playgroud” at Kada (Wakayama pref.) for Can-Sat and Balloon-Sat experiments. Therefore, students can use well-equipped machine tools and measurement devices for their activities. These convenient site and facilities are available for any student projects almost anytime. Please contact us, if you need them!

Wakayama Space Project (WSP) is a student project in Wakayama univ. which has two themes: hybrid-rocket and Balloon-Sat. This project isn’t based on any laboratories and any departments, so any grade/department of students can join this project.

The Balloon-Sat mainly consists of a balloon, a parachute, and a payload (see Fig.1 in detail). These components are roped each other. The mission of the Balloon-Sat is shown in Fig.2. The launched Balloon-Sat goes up, and the Balloon gradually expands due to lower air pressure at higher altitude. Air pressure and temperature are 5/1000 [atm] and 210 [K] at the highest point (30 km altitude). The balloon bursts and starts to free-fall. The parachute opens and the payload suffers shock due to inertial force, which is called as “opening shock”. The Balloon-Sat falls at the constant speed, and lands on the ground or the sea.
WSP has launched five Balloon-Sats, the history is as follows.

<table>
<thead>
<tr>
<th>Date</th>
<th>Purpose</th>
<th>Site</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/07</td>
<td>Observation of eclipse shade on the Earth</td>
<td>Kagoshima</td>
<td>GPS disconnection</td>
</tr>
<tr>
<td></td>
<td>Same as above</td>
<td>Same as above</td>
<td>Fall in the mountain</td>
</tr>
<tr>
<td>2009/12</td>
<td>Making movie at 30km altitude</td>
<td>Kouchi</td>
<td>GPS disconnection (due to opening shock?)</td>
</tr>
<tr>
<td>2012/02/16</td>
<td>Offer from TV news program</td>
<td>Kouchi</td>
<td>Short trajectory</td>
</tr>
<tr>
<td>2012/02/17</td>
<td>Same as above</td>
<td>Kouchi</td>
<td>Short trajectory</td>
</tr>
</tbody>
</table>

Two balloons launched in 2009/07 could not reach at an altitude of 30 km due to rain. The balloon launched in 2009/12 had a GPS problem due to an “opening shock”. A shock absorber was installed in the balloon launched in 2012/02 and GPS system worked well during the mission. However, the balloon burst before it reached at 30 km altitude, so its trajectory was shorter than their plan. It is probably caused by small cracks on the balloon. WSP members are planning to launch the Balloon-Sat in 2012/09.
[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

| n/a |

[3] Papers

<table>
<thead>
<tr>
<th>Journal Publications</th>
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<tr>
<td>Doctor’s thesis</td>
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</table>

[4] Recent overseas researchers who collaborated with us (for a short period)

| 1. Name and Affiliation of Co-researcher | Research Theme | N/A |
| 2. Name and Affiliation of Co-researcher | Research Theme | N/A |

[5] Important mention, if any

| n/a |
**Keywords**

UNIFORM, Capacity Building, Ground Station Network, Wildfire Monitoring, Microsatellite, Constellation

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**[1] Overview and Science Highlights of the project**

UNIFORM is developing a wildfire monitoring system with micro satellite constellation. The advantages of using micro satellites over, say, traditional huge satellite are that it is low-cost, quick to adopt the latest technology, short development time, little lower spec but still durable quality, perfect for education. Amongst of all, the most characteristic aspect is that it can achieve high-time resolution inexpensively. Also, a new type of strategy to achieve the system is possible, i.e. several countries can collaborate together and make their own satellites and put them into constellation. The 1st UNIFORM satellite will be launched at September, 2013.

Our goal is the development of wildfire detection system using microsatellite constellation through international collaboration.

**Constellation**

For high time-resolution observation with LEO satellite it is necessary to operate multiple satellites.

**Enhanced Ground Systems**

For effective earth observation system, consisting ground systems must be designed to be integrated over network.

**Sustainability**

For a system to be practical it is necessary to associate it with sustainable financial architecture. Constraints accompanied with microsatellite must be taken into account.

International collaboration is an essential factor of the UNIFORM Project.

- Flight Segment Collaboration
- Ground Station Segment Collaboration
- User Segment Collaboration
Flight Segment Collaboration

This segment is to actually develop UNIFORM type satellites in Japan.

Participants will gain a great experience and knowledge among various experts through development with us. The satellite will then join the constellation to achieve higher time resolution.

Bread-Board Model of UNIFORM Satellite

Ground Station Segment Collaboration

This segment is to collaborate by downlinking the satellite data at your organization with UNIFORM compatible antenna. This will contribute to realize more 'real time' observation.

As you are not necessary come to Japan, there is no 'strict' criteria for joining UNIFORM with ground station segment. We are happy to provide you with the system detail, or even provide technical information.

The ground station with a 12m antenna for UNIFORM type satellites in Wakayama University

User Segment Collaboration

We ultimately want to evaluate the effectiveness of the system, i.e. high-time resolution by micro satellite constellation.

We welcome to use the UNIFORM satellite data for any purpose.
### [2] Achievements in Space Engineering Education through CanSat Activities (or Plan)

| n/a |

### [3] Papers

- Journal Publications
  - N/A
- Contributions (in Japanese)
  - N/A
- Books
  - N/A
- Dissertations
  - N/A
- Master's thesis
  - N/A
- Doctor’s thesis
  - N/A

### [4] Recent overseas researchers who collaborated with us (for a short period)

<table>
<thead>
<tr>
<th>Name and Affiliation of Co-researcher</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vu Trong Thu</td>
<td>System Design of Microsatellite</td>
</tr>
<tr>
<td>Nguyen Thanh Tuan</td>
<td>Power Budget Estimation Simulation</td>
</tr>
<tr>
<td>Landzaat Robin</td>
<td>Development of Efficient and Reliable Software Development Environment</td>
</tr>
<tr>
<td>Nam Duong</td>
<td>Harness Design of Microsatellite</td>
</tr>
<tr>
<td>Mr. Kim</td>
<td>Structure Analysis of Microsatellite</td>
</tr>
<tr>
<td>Kiichiro Ichinose</td>
<td>Constellation System Simulation Using STK and MATLAB</td>
</tr>
</tbody>
</table>

### [5] Important mention, if any

| n/a |

- 81 -
University/Organizer | Light Weight Structure Project Team in Waseda University
---|---
Supervisor | Tomoyuki Miyashita, Professor
Contact | Tel:+81-3-5286-3249 Email: tomo.miyashtia@waseda.jp
URL | http://www.miyashita.mmech.waseda.ac.jp

**[1] Overview and Science Highlights of the project**

WASEDA-SAT is a satellite where Waseda super-light space structure society is advancing the development. This satellite is selected as one of the small sub-satellites ridden together at the launch of Venus probe "PLANET-C" which Japan Aerospace Exploration Agency (JAXA) was scheduling the launch in 2010.

In the mission of this satellite, the design and the development of the satellite are advanced whether the basic experiment of the data communication technology between optical satellites using the verification whether the posture of the satellite can be stabilized according to the obtained wind drag and the QR code when the development paddle is developed on the orbit.

At this launch, the turning on orbit altitude of WASEDA-SAT will rush into the atmosphere low in about several weeks. To the success of the mission, we need to collect data efficiently from satellite during the short time. So, we wish to get a license as amateur satellite which can be cooperated by many eager satellite enthusiasts.

For satellite enthusiasts, we disclose on the website which would be created that "satellite housekeeping data such as its position data, frame configuration and the way to decipher". Thereby, we ask for the cooperation of amateur satellite enthusiasts, we would like to success the mission with them.

As a basic experiment of an optical data communication, WASEDA-SAT display QR-code at LED panel in a inside structure and take picture it and send to the ground by radio waves. Amateur radio operator receiving a wave can read out a QR-code by software we publish after.

Many of amateur satellite use 144MHz band for uplink, 430MHz band for downlink. Although it's thought that it will be promoted that utilization of microwave band afftertime, it have possibilities to be developed satellites using low-frequency band like 29MHz band, and in that case it is expected that tether satellite is used for reasons of constructional constraint of antenna and relay receiver. It is thought that an optical satellite communication becomes effective in such a satellite.

For the mission achievement, specifically, we disclose time on our homepage that is possible to down-link.

**[2] Achievements in Space Engineering Education through CanSat Activities (or Plan)**

n/a
【3】Papers

- Journal Publications
  - Multidisciplinary Design Optimization between structural and thermal problems for small satellite, ISSMO, CD-ROM of WCSPMO09, 2009
  - A study on optimization of nano-satellite structure, JSME, Design and Systems Division Conference, 2009
  - A study on multidisciplinary design of the nano-satellite considering damping and heat transfer characteristics, JSME, Design and Systems Division Conference, No.08-02, 2008
  - Fundamental examination for modeling and the shape control of the creased membrane, Proceedings of the Space Sciences and Technology Conference No.1977 (CD-ROM), 2008
  - A study on multidisciplinary design of the nano-satellite considering damping and heat transfer characteristics, Proceedings of the Space Sciences and Technology Conference No.283 (CD-ROM), 2008
  - A study on optimization of nano-satellite structure, Proceedings of the Space Sciences and Technology Conference, 3E05, 2008
✧ Contributions (in Japanese)
   ・ Overview of WASEDA-SAT Project, Nikkei BP, pp.32-33, 2009

✧ Dissertations
   ・ Development of control system of satellite
   ・ Development of data processing unit for satellite
   ・ Vibration control of satellite using MR-fluid under small gravity
   ・ Design of deployment structure and deployment plan
   ・ Optimization of electrical production and consume plan for satellite
   ・ Light weight structure for small satellite
   ・ Thermal design for small satellite

✧ Master's thesis
   ・ Development of control system of satellite
   ・ Development of data processing unit for satellite
   ・ Vibration control of satellite using MR-fluid under small gravity
   ・ Design of deployment structure and deployment plan
   ・ Optimization of electrical production and consume plan for satellite
   ・ Light weight structure for small satellite
   ・ Thermal design for small satellite

✧ Doctor’s thesis
   ・ Vibration reduction of small satellites, 2010

[4] Recent overseas researchers who collaborated with us (for a short period)

n/a

[5] Important mention

n/a
## Other Important Universities

This is a list of Japanese universities that you may want to check their activities. The information will be added into this report in the near future.

<table>
<thead>
<tr>
<th></th>
<th>University and Project Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ISSL (Intelligent Space Systems Laboratory = Nakasuka Lab) of The University of Tokyo</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.space.t.u-tokyo.ac.jp/nlab/index_e.html">http://www.space.t.u-tokyo.ac.jp/nlab/index_e.html</a></td>
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<td>2</td>
<td>The Space Robotics Lab, Tohoku University</td>
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</tr>
<tr>
<td></td>
<td>RISING (SPRITE-SAT) Project, Tohoku University</td>
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</tr>
<tr>
<td></td>
<td>RISING-2 Project, Tohoku University</td>
</tr>
<tr>
<td></td>
<td>RAIKO Project, Tohoku University</td>
</tr>
<tr>
<td>3</td>
<td>Laboratory of Spacesystems, Division of Mechanical and Space Engineering, Graduate School of Engineering, Hokkaido University</td>
</tr>
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<td></td>
<td><a href="http://mech-m.e.eng.hokudai.ac.jp/~spacesystem/index_e.html">http://mech-m.e.eng.hokudai.ac.jp/~spacesystem/index_e.html</a></td>
</tr>
<tr>
<td>4</td>
<td>The Graduate School of System Design and Management of Keio University (Keio SDM)</td>
</tr>
<tr>
<td>5</td>
<td>Space Systems Laboratory, Teikyo University</td>
</tr>
<tr>
<td></td>
<td><a href="https://sites.google.com/site/spacesystemteikyo/">https://sites.google.com/site/spacesystemteikyo/</a></td>
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<tr>
<td>6</td>
<td>Takadama Laboratory, The University of Electro- Communications</td>
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<tr>
<td>7</td>
<td>Tokai Satellite Project, Tokai University</td>
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<td></td>
<td><a href="http://tsp.ea.u-tokai.ac.jp/">http://tsp.ea.u-tokai.ac.jp/</a></td>
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