Tune

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Tohoku University Research News of Engineering

From Tohoku To Mars

Cross Talk Interview by Three Researchers

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Message from Dean

I warmly welcome you to the inaugural issue of our new periodical, "Tune" - Tohoku University Research News of Engineering . Here you will find the latest news and results on our cutting-edge research and faculty, which covers a wide range of fields in Engineering. We launch this first issue with a focus on Space Engineering, a field which will brighten our future with its advanced technology.
Upon realizing a sustainable/resource-circulating but affluent society today, with an extended yet healthy life, we are faced with many great challenges. Science and technologies must take the lead in dealing with global problems that require an interdisciplinary viewpoint and international cooperation, along with intergenerational action. Our goal is for this publication to be shared by leading lights around the world as part of a global network, enabling it to become a key in solving such problems.
Tohoku University, with more than a century of history, has over the years contributed greatly to both Japan and the rest of the global society. In particular the School of Engineering (SoE) is renowned for its past research accomplishments. Now, SoE has about a thousand professors instructing about 6,000 students encompassing 2,000 graduates including 500 doctoral candidates involved in research activities. They and our alumni also constitute another of the many networks that our national university, being the third oldest in Japan, can be proud of.
In concluding my message I hope all of you who read our "Tune" will pass on the message to those who are interested in our objectives. Thank you.

Hiroshi KANAI
Professor and Dean

Cross Talk Interview by Three Researchers

Text by S."Tex"POMEROY / Photographs by Masayoshi HARABUCHI

Three Innovators in Our Midst

Since its School of Engineering (SoE) opened its doors in 1923, Tohoku University has been at the forefront of engineering research which encompasses a wide range of disciplines. These now include technologies crucial in enabling faster and safer yet cost-effective exploration of the heavens via rocketry and other means. Engineering at SoE, mostly based in Sendai, covers all areas encompassed by "aerospace" engineering, which has culminated in the successful launch earlier this year of a micro satellite. More such satellites are slated to go aloft successively in wake of this “orbital frontier” established by Tohoku University. In addition, Tohoku University today has a trio of leading lights covering space development in their respective fields. The three men are all carrying on work related to aerospace at SoE.

The trio comprises: Professor Akira Ando, of the Department of Electrical Engineering who is a plasma* physics authority at present focusing on electric propulsion in addition to supersonic flow in space, not to mention power systems in general; Professor Keisuke Asai, of the Department of Aerospace Engineering whose research concerns experimental aerodynamics of aerospace systems, including experimental simulation of aerial flight conditions as well as development of image-based measurement techniques; and, Associate Professor Kanjuro Makihara, of the Department of Aerospace Engineering, who has research interests in “energy harvesting” from space stations and other such spaceborne structures.

In view of this, the “tech triumvirate” at center stage of current space exploration efforts were asked to talk about their research perspectives while elaborating on their visions for the future.

The session started off with the moderators noting that Dr. Asai is a former Japan Aerospace Exploration Agency (JAXA) researcher well known for his international links including National Aeronautics and Space Administration (NASA) . He is now collaborating closely with Dr. Ando, whose space propulsion work has been highlighted since the successful electrical engine maneuvering of the Japanese Asteroid Explorer “Hayabusa” mission. It was underscored that Dr. Makihara is the most recent of the three professors to join Tohoku University; nevertheless, as he is still associated with the JAXA/ISAS (Institute of Space and Astronautical Science), he is also able to fully utilize JAXA collaboration links.

*— Dr. Makihara, your field covers use of energy-harvesting and motion control systems in the space environment. For this you make use of “Smart Materials” like PZT** that exhibit piezoelectric effects. But you utilize other types of Smart Materials as well, like color-changing and “shape memory” products, in order to diagnose and “self-repair” damaged space structures. This means opening up ways to deal with damages from space debris*** in-flight. Can you tell us more about this?*

Dr. Makihara: Yes, today I brought along a cross-section of the International Space Station (ISS) hull which we used for experimentation. The outer portion has been pierced by a debris but the inner portion is intact. ISS is located in Earth’s orbit which is peppered with discarded items, a clear and present danger to space development. I was able to, through connections made with other university scientists while working on a JAXA project, apply their research results for damage diagnosis. The color changes due to monochromism are seen realizing easy diagnosis through visual observations.

Dr. Asai: That is quite interesting, because I am also using “color change” in my research. In my case the research focuses on measurement and flow simulation as used in aerodynamics. I conduct aerodynamic experiments using several unique wind-tunnel facilities. These not only include the Low-Turbulence Wind Tunnel at the Institute of Fluid Science, but also the world’s only “Mars Wind Tunnel” (MWT). However, I also use advanced optical measurement techniques like pressure-sensitive paint, temperature-sensitive paint and fluorescent oil-film skin-friction meters as part of our studies of aerospace systems.

Dr. Ando: My research covers plasma science and technology, is related with Dr. Asai’s research regarding space vehicle and aircraft surface improvements. Plasma can be used to “coat” the surface and also to see how the outer portion can be altered in response to changes in environmental conditions. I’ve been told my work on Magneto-Hydro-Dynamics (MHD) in plasmas and electric thrusters utilizing plasma, which can carry human and materials to Mars, is well known, which I find flattering. I am also involved in development of plasma diagnostics and applications in nano-, bio- and enviro-technologies as well. By the way, I would like to note that Dr. Asai is keenly interested in biomimetics due to his Mars airplane work too.

Dr. Asai: I aim to help develop a "Mars airplane” which can fly under thin

A. ANDO × K. ASAI × K. MAKIHARA

atmospheric conditions like those found on Mars, our nearest planetary neighbor. I am proud to be using our MWT for this purpose. Yet the fact is that earthly creatures such as insects provide hints to Mars airplane designs, for example the dragonfly or the butterfly. We have adopted an approach different from NASA's where its Mars exploration project is designed for a ground-hugging robot dubbed “Curiosity” to scrutinize Mars surface. We can facilitate the effort by using the Mars airplane in transporting the probes quickly and to distant locations on the surface. As an aside, I have found many Earth-bound creatures to be hint-providers as well, as they live in an environment where viscous force make life “sticky” to say the least.

— Speaking of sticking points, how will the rover and the airplane be powered? The batteries and solar panels can be a real burden on the mission, no? The batteries are heavy while the panels can be prone to failure, are they not?

Dr. Makihara: Vibrations in space come and go throughout the structure since there is nothing to absorb them, leading to stress and eventual failure of the structure. To overcome this problem, I developed a digital self-powered circuit which suppresses such vibration. I advanced this invention to yield a complementary system to harvest energy at the same time as suppressing these vibrations. Hopefully my research will come in handy for work on Mars also, as energy-harvesting and Smart Materials are applicable to distantly-located systems, beyond easy repair. Self-propelled mechatronic systems can be powered and maintained in such situations. Energy harvesting also dispenses with the need to send heavy items to Mars, cutting down costs.

— Yes, I believe you noted after your invention was unveiled that “battery-less” systems will appear on Earth soon in the near future, as “wearable devices” generating its own power.
Of course, for Mars and other distant locations in space we need to reach them, and that is where Dr. Ando’s work becomes crucial.

Dr. Ando: The space environment is a violent one. There are prominent MHD phenomena like anomalous heating in a solar corona, magnetic reconnection in the Earth magneto-tail accompanied by a powerful aurora and more. Strong irradiation of cosmic ray is harmful to human body. Propulsion using electrical energy and plasma in space enables us to reach Mars and return to Earth within a year. For example, ion engines and Hall-effect thrusters can be used for interstellar transport, but more powerful plasma thrusters are necessary to realize this transport system.

Mars and Beyond

— When it comes to Mars many academics recall that for nearly half a century from the late 1800’s onwards, people gazed upon that planet wondering what kind of engineering marvels made those "canals" possible. Yet in 1903 powered human flight was fact, spawning a new set of amazing feats closer to Earth and drawing attention away from “science fiction”; nevertheless it may turn out the production of the Mars airplane will make an aircraft which can make high-altitude flights within Earth's atmosphere feasible. What are your views regarding science fiction?

Dr. Asai: The motivation behind space exploration might have started due to human fascination with the skies and the stars, but I think in modern times this motivation is being driven by science fiction. In my case though, one motivator was the “Star Blazers” Anime, which left a great impression on me. For us, aerospace engineers, this might be science fiction, which makes our research move ahead but I think for the majority of the researchers it is this imagination which drives us towards achieving a world-class research.

Dr. Ando: Yes, I daresay I am in the same age bracket as Dr. Asai. Indeed, the “Star Blazers” space propulsion system, a system brought to Earth from space, is still quite intriguing. I do believe that "Star Blazers" Anime certainly had an impact on many scientists of our generation.

Dr. Makihara: I am somewhat familiar with “Star Blazers” but perhaps I am more in the "Gundam/Transformers" generation. Yet, such interests do provide as much an impetus in promoting aerospace studies as "hard" science, and motivation can take different forms. Results beckon.

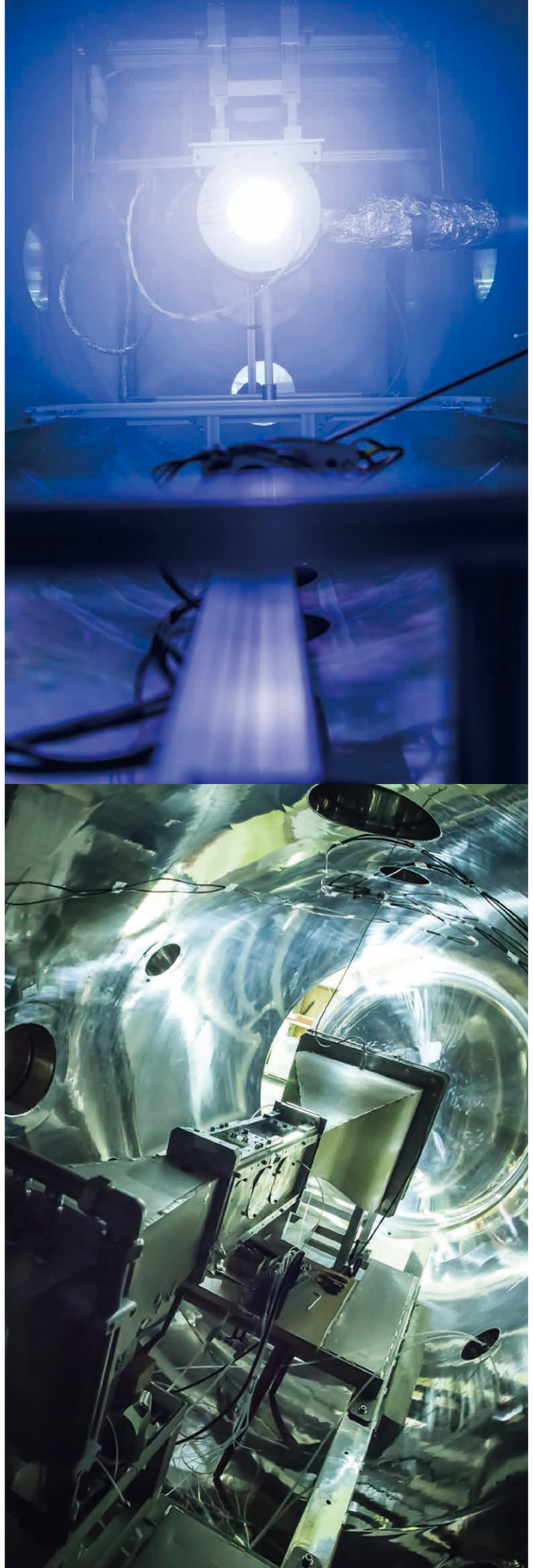
Concluding on A Strong Note

— As for strong points of SoE in the aerospace field, these include hallmarks such as satellites, simulation, robotics and information-communication technologies. Japan is maintaining its high ranking in terms of R&D for this discipline, even against changes in circumstances like progress in privatization. Japan is showing an increased emphasis on cost-effectiveness and diversification of career paths for graduates. But is there more?

Dr. Asai: Well, I think I can speak for all of us when I say Tohoku University is one of the leading institutions in the field of space engineering, an institution providing great benefits to society. We can continue to offer excellence in research. I feel there are innumerable linkages to science available on campus here without restriction, not just to “astronomy” but to a diverse range of research areas. These are more strong points of our university and SoE makes them available to all those interested in aerospace studies.

Dr. Ando: Yes, I concur about the description and would like to underscore the fact that Tohoku University is an institution “open” not just to the rest of Japan and Asia but to the entire world too. I have had the opportunity to experience this first-hand through the many joint activities carried out together with researchers from around the globe. Moreover, SoE offers a great deal of freedom in dealing with the topic of “space”... we can offer new pathways to the future.

Dr. Makihara: I agree and would like to sum up by saying to all those, whether student or researcher, who are considering coming here by pointing out that the



interdisciplinary settings will provide all of you the resources that you need. If there are people who think this field is of interest and wish to explore what is on offer, we seriously encourage you to take a look at Tohoku University. In fact, as per our discussion, SoE not only covers aerospace but other interesting areas as well. Perhaps one's future beckons!”

*Plasma: A plasma encompasses ionized and energized gases emitting photons, which include positive and negative ions, electrons, and neutral atoms and/or molecules including radicals. The charged particles (ions and electrons) can be further energized by the interaction with electrostatic and electromagnetic fields and provide thrust in space for satellites or other interstellar vehicles.

**PZT: Acronym for lead zirconate titanate, one of the most common "piezoelectric device ingredients"; the ceramic material can be used to produce items that act as an electric power generator ("piezoelectric effect") as well as an actuator ("inverse piezoelectric effect").

***Space debris: Also known as "orbital debris" usually pertain to defunct items such as spent rocket parts and obsolete satellites. Found in "space," i.e., the area beyond 100km line above sea level in altitude, waste materials large and small can include those less than 1cm in size are orbiting Earth.

Akira ANDO

Professor of Electrical Engineering at School of Engineering, Tohoku University. He received a bachelor degree in Physics from Faculty of Science, Kyoto University in 1981 and his Ph.D. degree (Doctor of Science) in Plasma Physic from Graduate School of Science, Kyoto University in 1987. He was a Research Associate at Plasma Laboratory in Nagoya University from 1987 and in National Institute for Fusion Science from 1989, and devoted himself to the development of plasma heating devices, especially a large negative hydrogen ion source and beams. After serving as a Visiting Researcher at Culham Laboratory, U.K., in 1993, he started researching electric propulsion as an Associate Professor at Tohoku University in 1995. He has been in his current position as a Professor in Electrical Engineering, Tohoku University since 2009. His current research interests involve dynamics of fast flowing plasmas, development of electric propulsion devices with high power, large negative ion beams and plasma applications to the environment.

Keisuke ASAI

Professor of Aerospace Engineering at School of Engineering, Tohoku University. He received a bachelor degree in Aeronautical Engineering from Kyoto University in 1980 and a Ph.D. degree in Aeronautics and Astronautics from University of Tokyo in 1995. He was a research scientist at National Aerospace Laboratory of Japan from 1980 to 2003. During 1988-1989, he was a Visiting Researcher in Experimental Techniques Branch at NASA Langley Research Center. From 1999 to 2003, he managed the Techno-Infrastructure Program called “MOSAIC” to develop molecular sensor technology for aerodynamic measurements. He has been in his current position as Professor in Experimental Aerodynamics since 2003. His current research interests involve the development of advanced measurement techniques for unsteady flows, dynamic wind-tunnel testing, flight dynamics and aerial exploration on Mars.

Kanjuro MAKIHARA

Associate Professor of Aerospace Engineering at School of Engineering, Tohoku University. He received his bachelor degree in Aeronautics and Astronautics from The University of Tokyo in 1998 and his Ph.D. degree in Aeronautics and Astronautics from The University of Tokyo’s Graduate School of Engineering in 2004, Doctor of Engineering. He was an Aerospace Project Research Associate at JAXA/ISAS since 2004, and devoted himself to energy-recycling vibration suppression for space structures. After serving as a Visiting Researcher at the Department of Engineering, University of Cambridge, U.K., he has been an Associate Professor of Aerospace Engineering at School of Engineering, Tohoku University since 2011. He has also been a Visiting Associate Professor at JAXA since 2012. His current research interests involve semi-active vibration suppression, self-powered energy-harvesting, dynamics of flexible space structures, and space debris issue.

NEXT TALK

On March 11, 2011, a magnitude 9 earthquake hit the Tohoku region and made Japan face its most terrible crisis of these last decades. School of Engineering, Tohoku University has taken since steps toward recovery and has engaged in leading research on more efficient risk management, better energy policy and faster recovery. The second volume will “Tune” into these crucial issues inherent for a sustainable and safer society.

Research Highlight

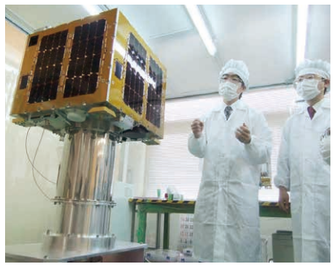
Text by S."Tex"POMEROY / Photographs by Masayoshi HARABUCHI

RISING-2 Seen Meeting Future Challenges

As our readers may know, artificial satellites are being developed by many universities around the world today after the first 1kg satellite "cubesat" was launched in 2003. With this background, we are the world's leading research & development laboratory within the academic micro- and nano-satellites community. Our laboratory has much experience in satellite development and operation, now totaling at 5 satellites. The first micro-satellite SPRITE-SAT (RISING), launched in 2009, is currently in space, and our first 2.6-kg cubesat RAIKO was released into space from International Space Station in 2012.

Yuji SAKAMOTO

Received his bachelor degree in the Department of Aerospace Engineering from Kyushu University in 1998 and his Ph.D. degree in the Department of Aeronautics and Astronautics from Kyushu University's Graduate School of Engineering in 2004. As a Doctor of Engineering, he was a Researcher at Institute for Q-shu Pioneers of Space, Inc. since 2004, and devoted himself to system design, analysis and evaluation for micro-satellites.
He has been an Assistant Professor of Aerospace Engineering at School of Engineering, Tohoku University since 2006. His current research interests involve satellite orbit determination, attitude determination and control, and ground operation system.



Recently our second micro-satellite RISING-2 entered into orbit at 628km altitude by the Japanese H-IIA rocket, on May 24, 2014. A month later, color images of the Earth surface were observed at about 5m spatial resolution by utilizing the High Precision Telescope (HPT). This spatial resolution holds the world record in the under-50kg category for micro-satellites. HPT can observe multi-spectrum images selected from 400-band wavelength using a liquid crystal tunable filter (LCTF), this being a world-first trial in space. To help deal with climate phenomena, such as cumulonimbus clouds and isolated heavy rains, a wide-field bolometer array with a mid-infrared imaging sensor is also installed. The success of these experiments will offer a new Earth observation method that equals those of traditional large or mid-sized satellites. This is a gigantic first step for micro-satellites to become part of a socially beneficial infrastructure in the near future. Now, we are developing the upcoming next-generation micro-satellite RISESAT with five international science missions.

Upon development of RISING-2 commencing from 2009, I controlled the budget of about US$3.8 million, the schedule and the team including seven graduate students, as project manager.

The detailed designs handled mainly by students followed, such as structure design as well as the electrical hardware and software design related to attitude control and determination. The efficient processes of design, fabrication and testing were made possible; thus, the flight model was completed in just 18 months.

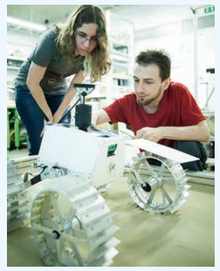
Keen interest from around the world is being focused upon our frontline technology and seasoned proficiency regarding the development of artificial satellites. In tandem with our development work, we are implementing the concept of high-frequency Earth observations at multi-points based on the use of 48 cluster satellites with multi-spectrum HPTs. For the students and researchers who want to join the research team, their time with us will offer an invaluable experience.

Reference:
N. Sugimura, K. Fukuda, Y. Tomioka, M. Fukuyama, Y. Sakamoto, T. Kuwahara, T. Fukuhara, K. Yoshida, Y. Takahashi, "Ground Test of Attitude Control System for Micro Satellite RISING-2," IEEE/SICE International Symposium on System Integration (SII 2012), pp.301-306.

Voice from Young Scientists

Our X-Prize Team, Paving a Road to the Future of Private Lunar Development

I have been working under Professor Yoshida at The Space Robotics Lab at Tohoku University, in partnership with the Google Lunar X-Prize Team, Hakuto, since 2010. It is becoming increasingly exciting as we continue to approach our goal of launching our robots to the Moon in 2015. If our mission is successful, Tohoku University and our partners will be part of the first privately funded mission to land operable machinery on the surface of the Moon. Proving that this scale of mission is possible is important for the next stage of space infrastructure development which requires cheaper, more affordable missions which utilize lunar resources.
Our mission in particular is to explore the interior of a lunar "skylight", or collapsed lunar lava tube. Skylights are the best known candidates for building lunar habitats and staging areas for large-scale lunar development. It is our hope that in the long term, construction and refining rocket fuel from lunar resources will allow us to reach out beyond the moon for only a fraction of the cost it takes to do so today.
I came here with a Computer Science background and have had the opportunity to apply my skills to lunar robotics while also learning new things along the way in mechanical design, power electronics, control engineering and terramechanics. Tohoku University has allowed me the opportunity to break into Robotics and Aerospace Engineering, which has been an invaluable experience in my life.



Nathan BRITTON

Nathan Britton was born in Colorado, USA. He came to Tohoku University as a Monbusho Scholar, where he is currently in his last year of the PhD Program.

Reusable Rocket Engine Research for the Future

To link "space development" into our future lives as an essential item, we must reduce related costs markedly. One way of accomplishing this is to realize the reusability of the rocket. As part of this effort, Japan Aerospace Exploration Agency (JAXA) R&D is working on the reusable engine for a sounding rocket. Japanese researchers have set two major objectives in producing a reusable rocket engine. One is to turn the engine into a durable one, usable for multiple flights. The other is to develop a fault tolerance system, meaning an engine which can be stopped immediately and safely even if an engine fault occurs during flight. To realize the latter, the engine condition must be accurately monitored, with the fault being detected as soon as possible upon occurrence. This process is known as "Health Monitoring System" (HMS). Since I am focusing on HMS in rocketry, especially for the reusable rocket engine, I chose the JAXA endeavor as the theme for my master's course at School of Engineering, Tohoku University. Currently I am drawing up plans for a reusable rocket engine system and a HMS by carrying out studies on past JAXA activities. At Kakuda, ten firing tests for a reusable rocket engine have already been conducted and many more firing tests are to be performed during this academic year. I hope my research concerning data from these tests will help make the reusable rocket engine possible. I look forward to continued involvement in this R&D field.

Yusuke NARUMI

Master course student supervised by Associate Professor Toshiya Kimura at Future Space Transportation Engineering Laboratory cooperated with JAXA, School of Engineering, Tohoku University.

News

French Delegation on "Advanced Materials for Energy Future"

On July 3, a delegation of scientists from French National Research Institutions and French companies came to School of Engineering, Tohoku University. Their visit followed the Japan-France Symposium on "Advanced Materials for Energy Future" held in Tokyo on June 30 and July 1, co-organized by the Science Council of Japan, the French Embassy and the French Academy of Science. Their one-day trip in Sendai consisted of visits to laboratories conducting the same research as theirs, covering various themes such as high temperature materials, storage energy, and metallurgy.

RISING-2 Captures Highest Resolution Image of Earth's Surface

On July 4, the Microsatellite RISING-2 succeeded in capturing high precision images of the Earth's surface. Using a High Precision Telescope (HPT), it has successfully taken color images at a spatial resolution of 5m, the highest in the world among 50kg-class satellites.
RISING-2 is a microsatellite developed by Tohoku University and Hokkaido University. It was launched from the Tanegashima Space Center, Japan, on May 24, 2014, and has been conducting various test operations. Dayside cloud imagery and night views of city lights and air glow have been acquired so far using a Wide Field-of-view CCD camera (WFC), and high resolution imaging experiments using HPT have recently started. With an aim to conduct highly practical observations, operations to establish more accurate control of the satellite attitude are scheduled to be carried out. Rising-2 will also make a challenge to obtain multispectral images with the world's first space liquid crystal tunable filter(LCTF)that allows wavelength-selection.

Tohoku University Engineering Summer Program 2014 on Robotics (TESP)

From July 28 to August 8, the School of Engineering, Tohoku University offered for the fourth consecutive year a two-week graduate-level summer program focusing on "Robotics" a program designed to inspire graduate level students or young professionals in the field of Engineering. The program provides a series of lectures taught in English and hands-on activities on the advanced topics of robotics. In addition, the program includes various activities that expose the participants to Japanese culture to enrich their academic experience. The program overall aims at providing students with rich academic and cultural experiences for their academic and global insight.

First International Joint Program between Tamkang University, Taiwan, Sendai National College of Technology and Tohoku University

Tamkang University, Taiwan, Sendai National College of Technology and Tohoku University held an International Joint Program in Sendai on "Implementation for Robotic Systems with Wireless Chargers" on September 1-3. This short-term summer project represented the first official academic cooperation between these institutions and consisted of a series of lectures and the realization of a practical project. Tamkang University provided the courses on robotics while Sendai National College of Technology and Tohoku University provided the courses on wireless charger. The scope of the Joint Program was to enhance the technical skills of the participants and foster their communication skills on an international level.

School of Engineering to Host RENKEI 2014 Summer Program

Within the period of September 8-12, the RENKEI Program Summer School gathered 17 students at School of Engineering, Tohoku University, on the theme of "Energy Supply within Traditional and Environmentally Conscious Growth Models". They came from 4 Universities within the UK and 4 within Japan among which was Tohoku University. The school consisted of lectures, group work and site visits at one of the Sendai municipal incineration plants, the Toyota factory and Higashi-Matsushima. RENKEI stands for Research and Education Network for Knowledge Economy Initiatives. It is a Japan-UK scheme aimed to encourage knowledge transfer and expand university and industry ties in the fields of science and technology.

Upcoming Events in Sendai

2014 Asia-Pacific Microwave Conference (APMC 2014)

The 2014 Asia-Pacific Microwave Conference (APMC 2014) will be held at the Sendai International Center, Sendai, Japan, on November 4-7, 2014. Pre-Registration (Early Bird & Advanced) is available on the APMC 2014 website from August 8 to October 24, 2014. Please check details about the conference at the APMC 2014 official website.
http://apmc2014.org/index.html

The Third UN World Conference on Disaster Risk Reduction (WCDRR), Sendai, Japan, 2015

The Third UN World Conference on Disaster Risk Reduction (WCDRR) will be held at the Sendai International Center from March 14-18, 2015 in Sendai, Miyagi, Japan. Please check details about the conference at the official website.
http://www.wcdrr.org/home

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