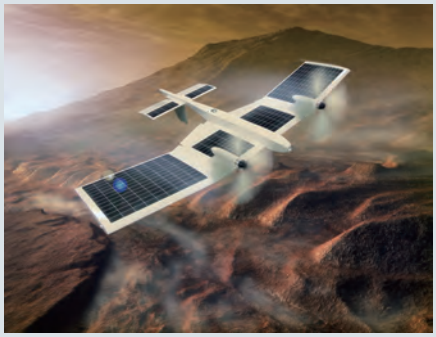
Research and Development of Next-generation Actuators

Project title | Develop the world's best-performing actuators (large/small)

Institutions：ShinMaywa Industries, Ltd., et al. ／ EXTCOM Inc. ／ YASKAWA Electric Corporation ／ MEIJI RUBBER & CHEMICAL CO.,LTD., et al. ／ Adamant Namiki Precision Jewel Co.,Ltd.

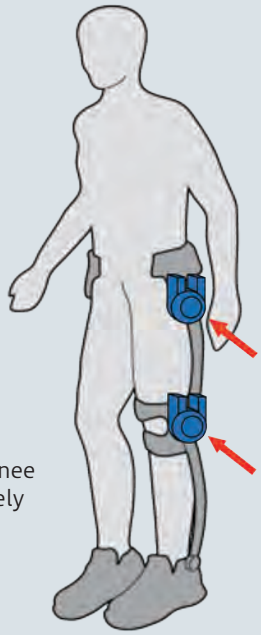
Selected topics

1) Develop the world's best-performing electromagnetic motor
   ▶Develop a high power density/ high-efficiency compact motor (50 w/25 g)
   ▶Develop a waterproof and dustproof (1 kw/400 g) high-output motor
   ▶Develop a high-torque (110 Nm/1 kg) actuator system
2) Develop space-resistant sensor systems
   ▶Develop a small and high resolution resolver (ϕ 20 mm resolution 524288)
3) Develop a smart fluidic actuator system
   ▶Contraction force more than three times that of the McKibben artificial muscle



Aerospace application
1. Mars aircraft, drone
2. Mars rover
3. Casting device
4. Two-axis gimbal

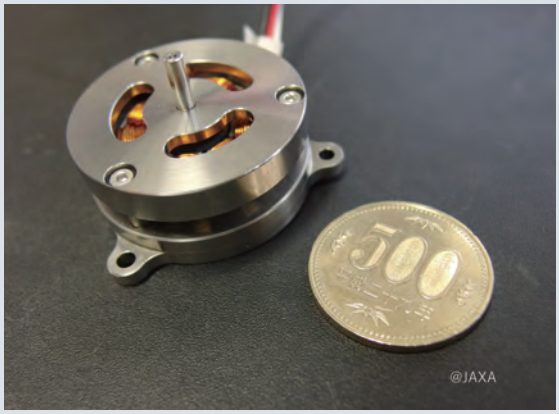
Terrestrial application
1. Wind generators / Hydro generators
2. Drones and robots
3. Nursing care products such as power suits and wheelchairs



The torque of the knee joint is approximately 100 N-m

Ultra-small sensor for absolute angles
Outer dimensions of product :
Squair 20 mm and thickness 7.5 mm
Resolution 1048576

Primary prototype of IP56 clear dustproof and waterproof motor



high power density/ high-efficiency compact motor (85 w/25 g)

April 2016 to March 2017

Project title | Toy Technology Robotics（Small size, Low energy, Low cost）

Institutions：TOMY Company,Ltd.

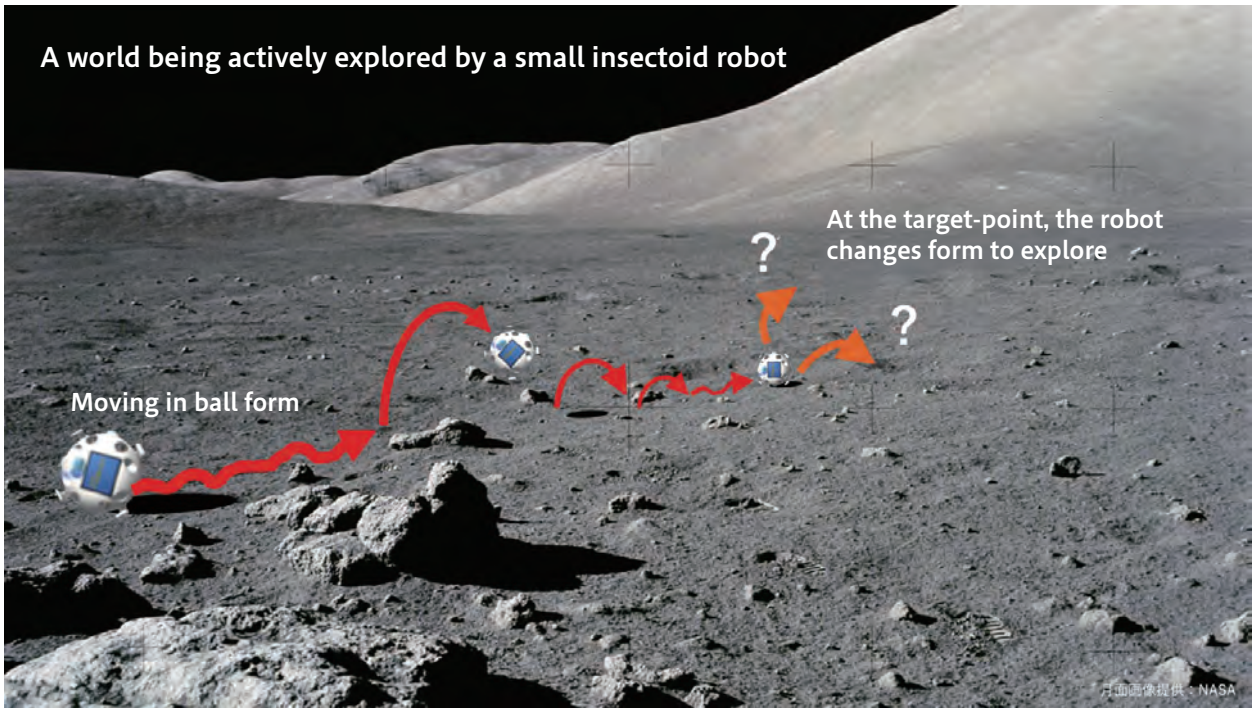
Project outline

Objective

The objective is to develop a low-cost insectoid robot capable of activity both on Earth and on the Moon or Mars.
We are aiming to bring both the insectoid robot itself and the underlying technologies to market, starting with technologies that have already been developed with features such as ease of communication, conservation of power, extended operating life, and miniaturization.

Contents

We applied these mechanisms and expertise used in toys to develop a mobile robot with a diameter of 100 mm and weight of 300 g. The robot is small, roughly the same size as a softball. The initial shape is a perfect sphere. When a command is sent from an external controller via Wi-Fi, the robot transforms from spherical mode to extended travel mode, capable of moving forward and turning right. Because it is a spherical shape, it moves/rolls faster down an inclined surface, consuming less power.
In addition, while in travel mode, it moves stably by releasing wheels on either side of the sphere and a rear support wheel. At present, it has succeeded in ascending a10° slope in a test environment simulating a lunar surface.



November 2018 to November 2019

Project title

Conceptual system design of a deployable inflatable structure

Institutions：Shimizu Corporation, Taiyo Kogyo Corpolation, Setsunan University

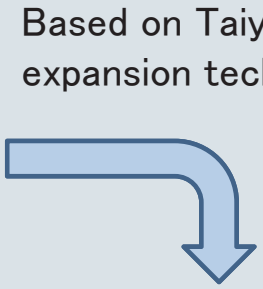
Project outline

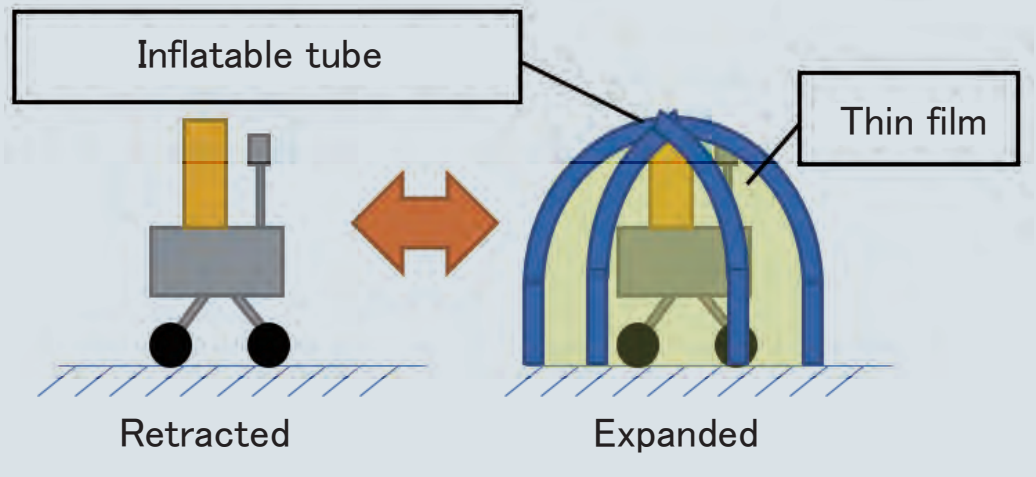
Objective

In order to realize an overnight shelter in which a rover running on the lunar surface can be carried over the night, a method of deploying and storing a structure which can stand on its own even under a gravitational environment by using inflatable material of a cylinder as a frame structure is established.

Contents

1. Automatic deployment and storage of structures
   - Demonstrate the feasibility of automatic construction of large-scale structures
   - Experimental study of automatic deployment by partial prototyping
2. Develop specifications for overnight shelter
   - Determine specifications based on the size of lunar rover overnight shelter, the shape of rover entrance, the method of opening and closing the shelter, thermal conditions, interface with the lunar regolith, membrane material, additional power generation and communication, and relationship with the lander
3. Examination of measuring inflated structures
   - Propose a measurement method that can monitor the deployment of inflatable structures
   - Obtain measurement data by experimentally inflated prototype model
4. Examination of methods for joining and expanding structures Investigate a mechanism for joining inflatable structures after deployment or storage to expand space





Research on the unmanned construction system of a manned lunar outpost

Project title | **Development and evaluation of the innovative remote construction system by cooperation of remote control and automatic control**

Institutions：Kajima Corporation, Shibaura Institute of Technology,
Kyoto University and The University of Electro-Communications

Project outline

Objective

It will be difficult for humans to stay and conduct all the construction work on the moon and Mars. Similarly, on Earth, remotely-controlled or automated construction technologies are required to cope with the shortages of workers and to improve productivity and safety under strenuous environmental conditions.
Among existing technologies, there is reliable unmanned construction technologies on the ground. It can be combined with the automated construction technologies or the time-delay compensation methods that are the research subjects of this project. If these technologies are realized, we will achieve remote construction system on the lunar surface, which can prepare several tens of square meters of land to place and shield the structures. Furthermore, the same new construction system can be applied on Earth to provide better productivity and safety.

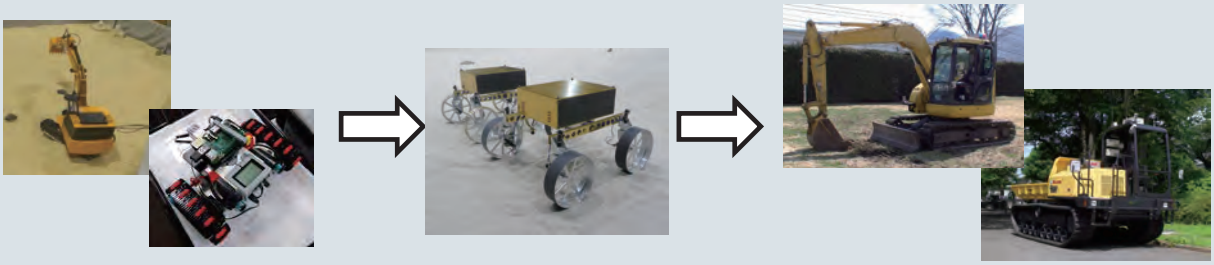
Contents

In addition to the basic automation functionalities of construction machines developed on the ground, the following functions will be developed to achieve a remote construction system by “coordinating between remote and automated control”.

- Functionality to support operation with time delay compensation. Even when there is a large communication delay of 3-8 seconds, the support function enables remote operations based on the work plan, without impairing the operability and stability of the remotely-operated construction machine.
- Functionality to automatically determine motion based on the surrounding environment. A function that autonomously selects an action (motion) corresponding to the task at the current position by detecting topographical changes that is difficult to assess in advance due to time delay constraints.
- Functionality for coordinated work between multiple construction machines. A function that autonomously changes operations, such as measures for collision avoidance, when there are malfunctions, such as interference, in the instructions to multiple remote construction machines.

Remote construction on Earth and space

Detailed examination of construction methods on the lunar base



Construction machinery model/test model→testing platform vehicle→gradual testing with construction machinery

November 2017 to October 2020

Project title Development and field verification of remote operation of excavators and lightweight construction system capable of automatically mounting and removing attachments

Institutions：Taguchi Industries, Tokyo University of Agriculture and Technology

Project outline

Objective

In recent years, there has been an increasing demand for interior demolition of high-rise buildings concomitant with urban development as well as for employment in disaster sites. However, there are some challenges for constructions on the ground such as the weight reduction, remotization, and automation of construction machinery.
On the other hand, the machinery used in the space for the construction of a lunar base must be capable of remote and automated operation of large lightweight and unmanned equipment to reduce the cost of transportation from the Earth.
Therefore, in this study, we have used materials different from conventional ones to design and prototype lightweight components of the construction machine while maintaining the size, performance, and functions of the machinery. In addition, we have designed and prototyped new systems such as remote control, electrification, and function automation of the construction machinery, with a view to commercialize it in the future.

Contents

① Design and prototype the body frame of a 1 ton class hydraulic excavator and its running parts with lightweight materials, carry out the evaluation, test operability, and reduce the weight of excavator.
② Design and prototype a 1 ton class hydraulic excavator with remote operation, electrified driving, automated attachment, and detachment system for construction machinery, and carry out performance-evaluation tests.
③ Design and prototype the bucket of a hydraulic excavator with lightweight material, perform evaluation test, and reduce the weight of the excavators.

[Research Overview] Each part of the 1-ton class hydraulic excavator is designed and prototyped using the composite material (CFRP) to reduce its weight.

Overall weight of the construction machine reduced by more than 200 kg

Further improvement of the performance of the hydraulic excavators through weight reduction

October 2017 to September 2020

Project title | Construction of a sustainable new housing system

Institutions：Misawa Homes Co., Ltd., Misawa Homes Institute of Research and Development Co., Ltd., National Institute of Polar Research

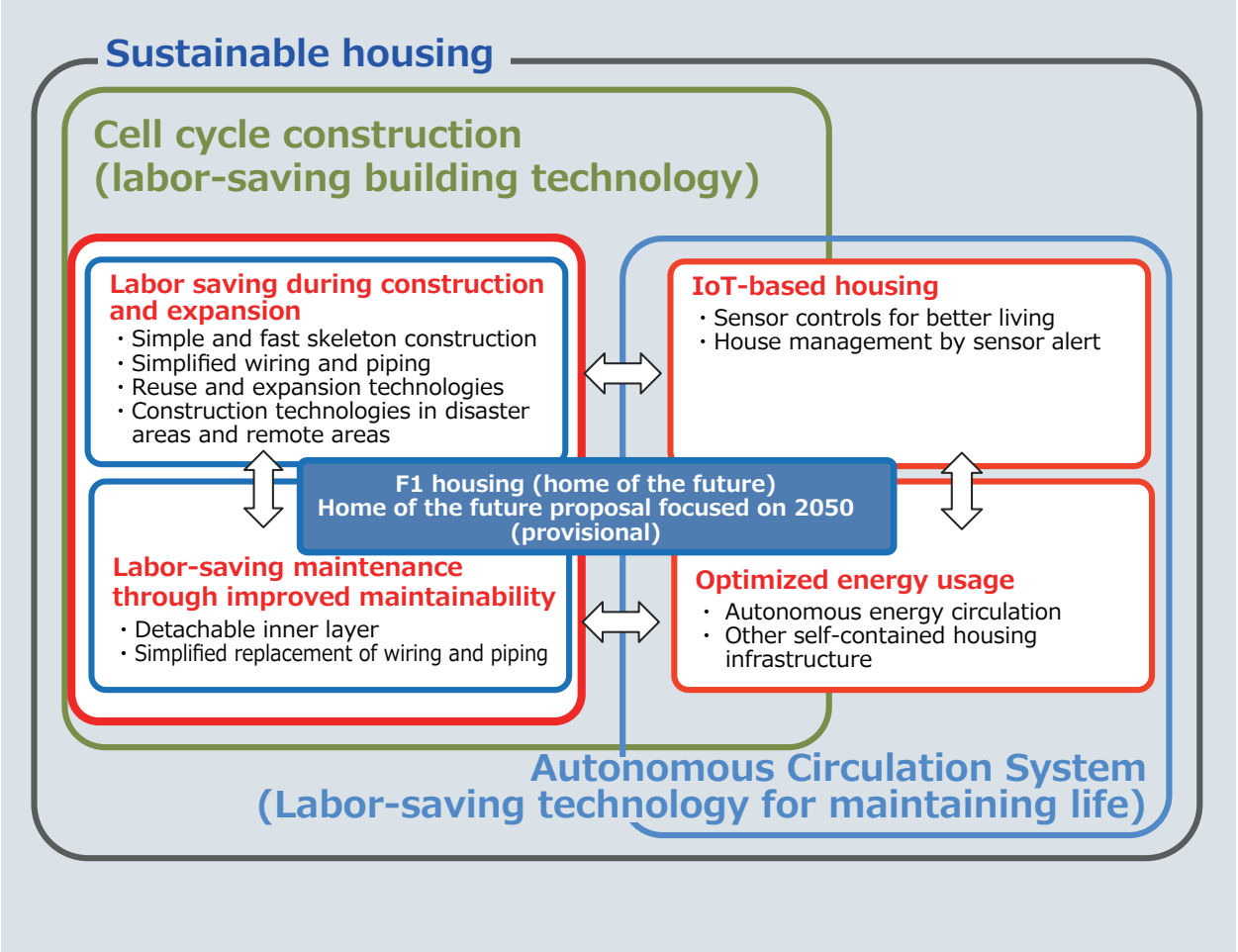
Project outline

Objective

We are developing construction technologies for the flexible up- and downsizing of structures and new housing systems that are easier for non-specialists to construct and for residents to maintain.
Structures: We are developing a new building method (the cell cycle method) that allows structures to be easily expanded, reduced, and rearranged.
Systems: We are developing systems for self supporting energy with the goal of achieving autonomous circulation and infrastructure-free deployment as well as autonomous energy utilization and maintenance systems that can ensure continuous safety and comfort by using sensors and other devices to monitor various types of information necessary to maintain life and the state of the structure.
Space-related applications: We are identifying the design conditions of construction in space by classifying them into environmental factors, transport factors, infrastructure factors, etc.

Contents

1. Study on the home of the future: We are creating the home of the future concept and investigating applicable technologies to develop and deploy technologies related to the new sustainable housing system.
2. Cell cycle method: We are pursuing research and development of the “interjoint” method for the construction and mass production of trial buildings.
3. Autonomous energy use and maintenance: We are developing housing systems that use IoT for maintenance and investigating autonomous energy systems for the construction and mass production of trial buildings.
4. Identification of design conditions: We are investigating the external conditions and various requirements and performance standards to prepare draft standards for the design of facilities.



November 2018 to October 2019

Project title | # The Control method study using AI, IoT technology to realize autonomous motion of excavating machine（Road Header）

Institutions：Mitsui Miike Machinery Co., Ltd.

Project outline

Objective

In a partial face machine (road header), which is used for excavating bedrock and similar materials in dangerous confined work sites such as tunnels, the rotation of the cutting head and the hydraulic cylinder mechanism are under the control of an operator. During excavation, every time a new geological section that is harder or softer than predicted by the geological survey appears, the condition of the excavation gravel also changes, requiring the operator to change the excavation strategy to fit the new situation.
On the surface of the moon, where there is no prior information on the terrain and where remote operation introduces a time lag, the survey excavators and similar equipment need to be controlled autonomously and continuously in accordance with the surrounding conditions.
This study investigates the modeling of autonomous action planning and control methods for road headers based on the measurement and recognition of the surrounding environment and situation, including the prototyping of the component systems that use AI and IoT technology.

Contents

1. Prototyping and verification of systems that recognize the surrounding environment:
   - Deep-learning AI models for object detection and region identification in images from various cameras
   - Combining multiple LiDAR sensors for the measurement of distances to the environment at simulated tunnel test site and similar tasks
2. Prototyping and verification of systems for collecting and analyzing operation log data:
   - Collection and visualization of operation log data (electric current, oil pressure, vibration, etc.) and anomaly detection by AI machine learning in the cloud
3. Investigation of AI learning models required for the autonomous operation of road headers:
   - Examination and evaluation of AI reinforcement learning models to plan construction (excavation) patterns based on the recognition of the environment and road header conditions
4. Prototyping and verification of AI hydraulic control systems:
   - Implementation and verification of AI control models for road headers

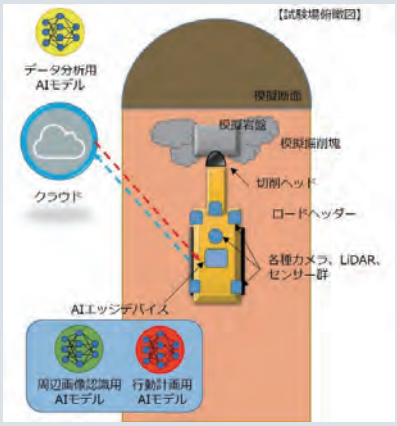


Fig. 1. AI road header system / overhead view of test site

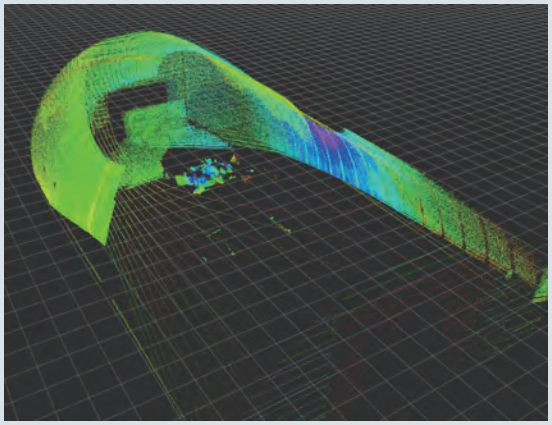


Fig. 2. Example of 3-D underground scan combining multiple LiDAR sensors

Fig. 3. Excavation verification at simulated tunnel test site

Fig. 4. Examples of image recognition using AI deep learning
Left: Original image (during simulated rock excavation)
Right: Region identification
(yellow: excavated gravel, green: tunnel cross-section)

Research on sensor technology for water ice detection

Project title | Study on ice/water sensing technology by development of the small Imaging Spectrometer

Institutions：Sentencia Corporation and Osaka University

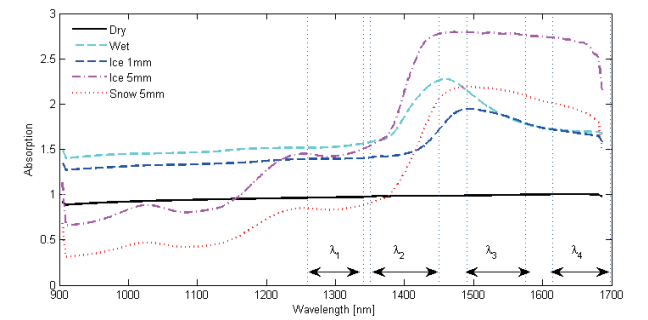
Project outline

Objective

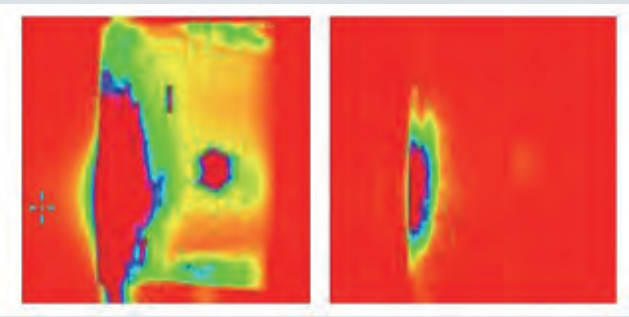
Various types of two-dimensional imaging spectrometers with different methodology exist ; however, each has limitations in the reduction of weight and size. A major objective for this study is to develop a hardware model with a considerably reduced size and weight using a method with less restrictive conditions. In FY2016, we optimized the optical system for this purpose, examined the driver system, surveyed the detector, and optimally designed and prototyped a portion of the optical components.

Contents

1) Optical system design and size optimization, and frame and structure of the entire system. We conducted surveys and selected a detector. We optimized the equipment arrangement and optical path using optical design, and examined the frame size. We targeted a size/shape of ~200 mm square, with final target dimensions of 90 × 150 × 100 mm. The system has built-in optical components (e.g., diffraction grating), detectors, and drive mechanisms, which are not motorized and driven manually.
2) Study and prototyping of optical components. We optimized the design and prototype of the diffraction grating. Based on the optical design, we conducted an examination and an optimization study of the diffraction grating, and then created a prototype. We verified the spectral performances and incorporated them into the BBM optical system, the primary prototype.
3) Examination of the spectroscopic functionality and performance required in lunar and planetary exploration. We prototyped a cooling stage to examine the required functionality and performance for lunar and planetary exploration, and then simulated and observed the ice formation on lunar and planetary surfaces.

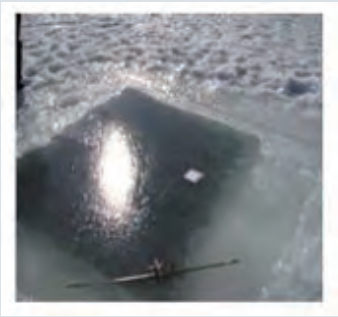


Patrik Jonsson, et al., 2014, Road Condition Imagimg-Model Development



1290nm 1370nm

Reflectance images of water and ice surface at different wavelengths



An instance involving the use of two-dimensional spectroscopy to distinguish between surfaces covered in water, ice, and snow (here, measured by Sentencia).

November 2018 to November 2019

Project title | # Development of a small scale and efficient protein production platform utilizing edible microalga, Spirulina

Institutions : Chitose Laboratory Corporation, Taberumo, IHI Aerospace Co., Ltd., Fujimori Kogyo Co., Ltd.

Project outline

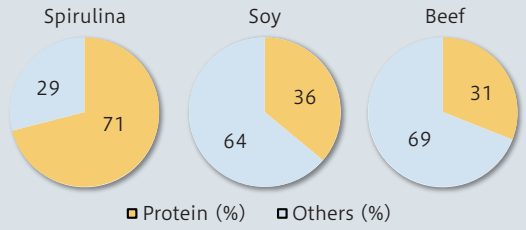
Objective

This project aims to develop a space-saving and highly efficient device that is capable of producing Spirulina (Arthrospira platensis; earlier classified under genus Spirulina) and apply it to the greenhouse agricultural system on earth as well as to self-supplied protein production during stay on the moon. Among other nutrients, Spirulina has especially high protein content accounting for approximately 70% of its dry weight. As a result, the annual protein productivity per unit area of Spirulina is overwhelming, and over 15 times greater than that of soy. Another feature of Spirulina is that it allows for resource-saving production. Using these features of Spirulina, we propose to develop a protein self-supplied device for astronauts during their stay on the moon. This technology is applicable on earth too, and we will seek to expand it to greenhouse agriculture in future.

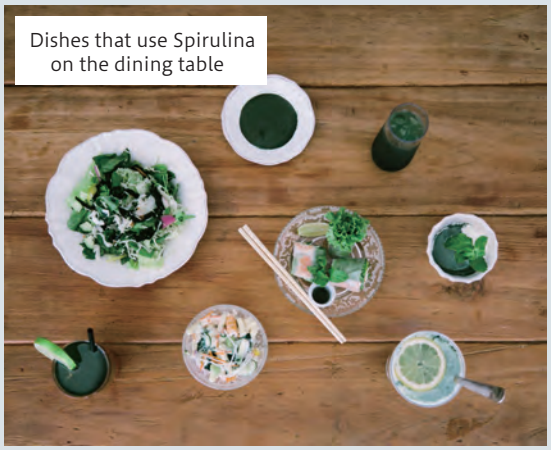
Contents

In this study, we will address the following:

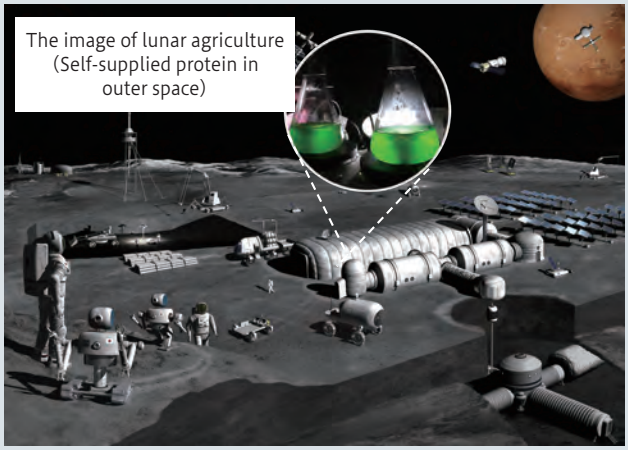
(1) Optimization of culture conditions for the cultivation of Spirulina using artificial light and standard medium. We will assess the adequacy of materials with various characteristics as the supporting material, on which algal cells are attached and immobilized, using primarily materials that were used for alga culture in the past.
(2) Manufacture and testing of several small-sized demonstrators equipped with LED light sources. Using the supporting material selected in (1), we will conduct a culture assay using small-sized demonstrators.
(3) Production of a liquid fertilizer from non-edible plant remnants using nitrification bacteria.
We will use greens as a model of non-edible plant remnants and artificial urine to perform fermentation via nitrification bacteria that are adequate for fermenting the model case.
(4) Culture Spirulina using the liquid fertilizer obtained from non-edible plant remnants and artificial urine (see point 3).
(5) Discuss a system that can be used in outer space.
We will design a concept of a system that assumes use in outer space, by examining items necessary for culture in outer space environments, including low gravity environment, and by considering the maximization of culture efficiency.



Percentage of protein contained in Spirulina, Soy, and Beef
Compared to that in soy and beef, Spirulina has approximately twice the protein content, and is expected to serve as an abundant source of protein supply.



Spirulina has been appreciated from old times as an invaluable dietary source due to its high nutrient value. Today, it is appreciated in various forms, such as smoothies, salads and yogurts, and has become increasingly recognized as a new ingredient.



In outer space, Spirulina can be cultured as a nutrient-rich raw diet with high protein content in the International Space Station and on the moon, by using a resource-saving and space-saving device that can culture Spirulina. Thus, even during a long-term mission, astronauts are expected to be able to keep in good shape by eating Spirulina on a daily basis.

March 2016 to March 2019

Project title

Development of all-solid-state lithium-ion secondary batteries

Institutions：Hitachi Zosen Corporation

Project outline

Objective

All-solid-state lithium-ion secondary batteries possess advantageous characteristics, such as high energy density, wide operating temperature range, low risk, and long lifetime. They are expected to solve challenges faced by conventional lithium-ion batteries with liquid electrolyte. There are high expectations for their successful application in space, particularly for use in extreme temperatures unachievable with conventional batteries. The objective of this study is to achieve increased tolerance to extreme environments, larger size, and higher capacity through prototyping and evaluating all-solid-state lithium-ion secondary batteries. Ultimately, we hope to attain innovative battery technologies to apply to future missions in planetary exploration.

Contents

The aim of this study is to develop technology with spacecraft applications. We have made the following developments to achieve performance surpassing prior models:

1) Study and prototype an all-solid-state lithium-ion secondary battery that can operate stably under extreme environments. Specifically, we studied and prototyped a battery that can withstand extreme temperature fluctuations, exceeding 100 °C, while maintaining stable operation during the required period.
2) Study and prototype a larger, higher capacity secondary battery. Specifically, we studied and prototyped battery structures and packaging to achieve a size and capacity that greatly exceed past achievements.
3) Various evaluations of prototype batteries. We evaluated the prototyped batteries under severe environments, such as extreme high and low temperatures and vibrations, to assess their performance characteristics.

Battery Characteristics and Research Objectives

As the battery uses inorganic solid-state electrolytes, it has the following features

● High safety

The battery does not produce flammable gases.

● High energy density

As cells can be layered in a single battery package, high voltage and high capacity are possible.

● Broad range of usable temperatures

In contrast to lithium-ion batteries with liquid electrolyte, as the electrolytes do not freeze or evaporate, the battery is operable in both cold and hot conditions.

● Long operating lifetime

Side reactions are suppressed because only lithium ions are transported, allowing for stable operation with less degradation.

Research at the JAXA Space Exploration Innovation Hub Center aims to implement capabilities that extend beyond current accomplishments (Temperature range: -40℃ -+100℃, capacity: several ampere hours) in capacity and environmental tolerance to extreme temperature range.

Application Areas, Commercialization Plans

Going forward, we are in the process of examining the application of batteries to three different fields in which growth is expected

【Storage batteries for use in the power grid】

To stabilize the output of unstable renewable energy, such as wind power generation and solar power generation, a storage battery is installed as a system linkage.

【Stationary storage batteries】

For reducing the load on the power grid, stationary storage batteries are installed in homes or small-scale commercial facilities in order to store electricity generated by solar panels, and nighttime power.

【On-board batteries】

As an indispensable part of many next-generation vehicles, such as electric and fuel-cell vehicles.

In addition, we are considering potential uses in space.

【Storage batteries for use in space】

As equipment on missions to extreme environments where it would be difficult to operate conventional batteries.

March 2016 to March 2018

Project title

Fundamental and feasibility studies on long-distance communication system with free-space laser link technologies

Institutions：Sony Corporation

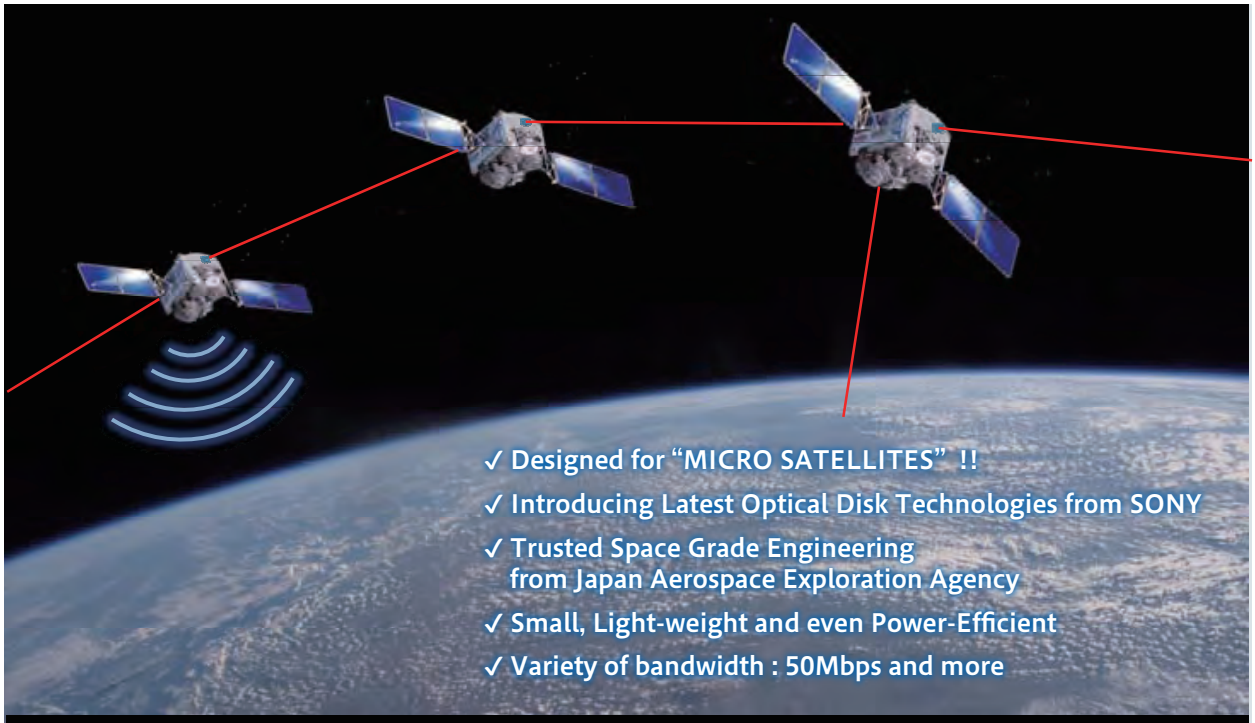
Project outline

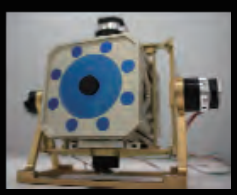
Objective Contents Research outline

In recent years, low Earth orbits have been increasingly utilized due to technological innovations primarily in advances in ultra-small satellite, also known as micro and nano satellite technology and reus-able rocket technology. However, low Earth orbit is not always connected to the Internet.

The purpose of this study is to develop a fundamental technology for optical communication device that can be operated in ultra-small to small satellites, with the objective of allowing for constant connectivity between low Earth orbit and the Internet communication network. Therefore, it is important to produce compact, light-weight, and highly-power efficient optical communication devices for satellites. In this study, we will develop a fundamental technology by applying the following our own technologies with well experienced.: compact, light-weight, and highly-efficient optical systems and optical discs with control systems.

We believe this technology will contribute continuous connectivity to the terrestrial Internet communication network with inter-satellite optical communication that employs ultra-small satellites, and keep connecting to the internet during operations accompanying satellite missions. To this end, we plan to connect a ~4,500 km communication distance at a control angle range of ± ~500 mrad and accuracy of ~10 (μrad). To achieve this goal, we will incorporate laser and optical technology using optical discs, integrated optics technology, and control technology to meet the weight of the optical communication system below about 1.5kg. Rest of works include managing radiation, heat, vibrations, and shock as required in a space environment; we will try to convert optical disc technology as a “ground” technology into one that can be utilized in outer space at an early stage.





optical inter-satellite system (mockup)

transmitting optics (working prototype)

Target Specification

weight (kg)	~1.5
band width (Mbps)	50~
inter-satellite distance (km)	~4500
laser out (W)	1.5
power consumptioin (W)	15
tracking accuracy (urad)	~10

November 2018 toOctober 2019

Project title | Development of multipoint high sensitive photon sensor for simultaneous ranging

Institutions：Hamamatsu Photonics Co., Ltd.

Project outline

Objective

The technology for accurate recognition of the terrain surrounding any surface activity on the Moon and Mars is indispensable for automatic and autonomous controls, such as determining the self-location and travel paths with few obstacles. In addition, it is essential for ground-based self driven vehicles, such as automatic construction machines and drones, to have a grasp of the shape and position of the ground features (road, ground surface, obstacle). Therefore, our research aims to develop an exceptional three-dimensional imagesensor) that accurately recognizes the surrounding terrain and the shape of the human made objects. This sensor will have broad applications in several industries, including self driven vehicles, automatic construction machines, and drones.

The aim of this study is to develop the Flash LIDAR, which is an ultra-compact, lightweight, and ultra-sensitive two-dimensional simultaneous distance measurement sensor. The distance measurement sensors are arranged in parallel as an array, and they can simultaneously measure the distance with a single-light pulse.

Contents

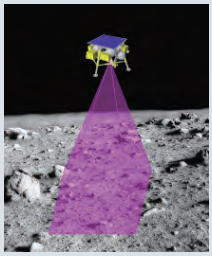
The image sensor developed in this study can capture a three-dimensional distanceimage with a dedicated device in which pixels are integrated with an optical sensor and a circuit (ROIC: Read Out IC), that measures the time-of-flight (TOF) of light, are arranged in an array. A high-sensitivity avalanche photodiode (APD) that can detect individual photons, is arranged in an array in the optical sensor. Moreover, an ROIC made of integrated circuits is joined vertically below the APD. The number of pixels is 128 x 128, and the distance resolution in the line-of-sight direction is less than 10 cm.

Ranging systems using this sensor may be used in a wide range of applications from self driven vehicles on the ground to space probes. These systems have the following features:

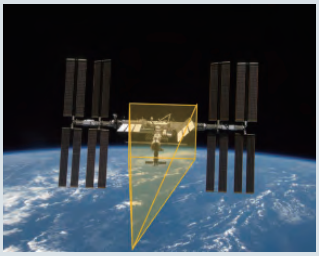
- Ultra-high sensitivity that imposes very little burden on the required light quantity and optical system
- It can be applied to flying objects and traveling vehicles with a high degree of time synchronization.
- Simple structure, small size, and light weight

Applications of 3D image sensorsensor

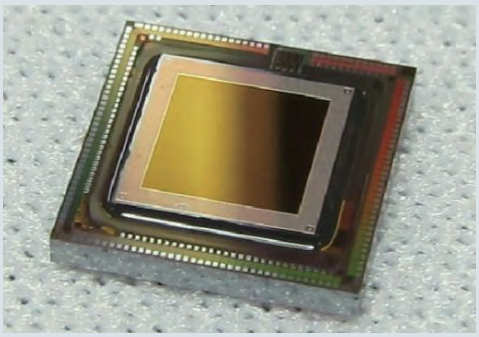
On board LIDAR for self-driven cars



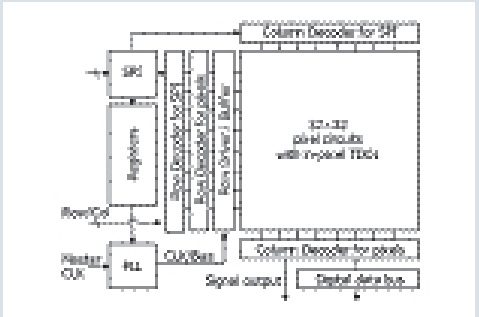
Obstacle detection sensor for lunar and planetary explorer



On-orbit rendezvous docking sensor



Prototype of 3D image sensor with 32 × 32 pixels



Ranging circuit configuration of prototype 3D image sensor

October 2017 to September 2020

Project title

Durability enhancement of high efficiency, low cost, and lightweight perovskite thin film solar cells

Institutions：Toin University of Yokohama, Hyogo University, Kishu Giken Kogyo Co., Ltd., Peccell Technologies Co., Ltd., Ricoh Co., Ltd.

Project outline

Objective

The perovskite solar cell developed by the authors is a next-generation solar cell, attracting worldwide attention due to its excellent features such as low cost, high conversion efficiency of over 20%, high efficiency even under low illumination, and flexibility. However, some drawbacks, such as low durability against temperature, humidity, and light, prevents its usage in practical applications.
This study aims to develop lightweight and thin-film perovskite solar cell modules with high conversion efficiency and high durability in the case of low illuminance light. The main application of these devices is in the power supply for sensing devices in IoT.

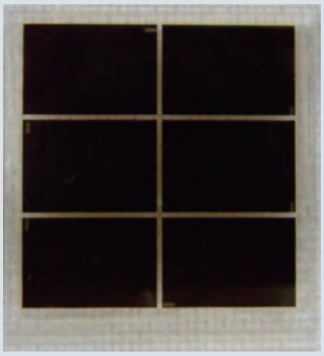
Contents

① High efficiency of perovskite solar cells
The aim is to improve the efficiency under indoor lighting and sunlight by optimizing materials and interfaces.
② Improvement of moisture resistance, high-temperature resistance, and life characteristics of perovskite solar cells
The aim is to improve the durability using the results of various durability evaluations in solar cell fabrication.
③ Development of perovskite solar cell module
The aim is to develop solar cell modules that reflect the high-efficiency and high-durability studies, as mentioned above.
④Improvement of radiation durability of perovskite solar cells
The aim is to develop solar cells with enough radiation durability for space applications.

[Features of perovskite solar cells]
Low cost (simple manufacturing method, inexpensive material)
・High conversion efficiency of over 20%
・High conversion efficiency maintained even under low illumination Flexibility

[Problems of perovskite solar cells]
・Low durability against temperature, humidity, and light

Aiming for improvement through durability testing and evaluation technology in the demanding environments of JAXA



6 series modules under development

<Step 1>

High efficiency / High durability / Modularization

↓

Development of highly efficient and durable perovskite solar cell modules

↓

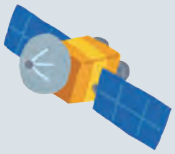
Commercialization as power supply of IoT devices

<Step 2>

Development of high radiation durability

↓

Extension to space applications



October 2018 to September 2021

Project title | **Development of High-performance Marine Radar**

Institutions：Koden Electronics Co., Ltd.

Project outline

Objective

Ship-mounted marine radar antennas, which consist of multiple antenna elements arranged horizontally to form a narrow directional beam, are rotated by a motor to gather data in all directions to avoid collisions. Therefore, current antennas must be installed in locations that ensure a sufficient radius of rotation. In recent years, there have been calls to expand the scope of use of marine radar systems further by supplementing their radar capabilities with communication capabilities, for example, to share individual ship information.

The goal of this study is to transform the way marine radar is used by introducing phased array technology and new communication capabilities to create a high-performance ship-mounted marine radar system.

Contents

The phased array antenna is constructed by integrating various types of high-frequency circuits such as semiconductor amplifiers and phase shifters into the antenna in a multilayer structure. In current marine radar systems, the antenna aperture (the sharpness and gain of the beam) varies depending on the ship on which it is mounted. In practice, by using sub-arrays as the elemental building blocks of the antenna, the antenna' s performance and transmission power can be selected relatively freely depending on how many sub-arrays are deployed. The objective is to make the circuits smaller and thinner using the bare-chip-based design and manufacturing technology developed for the 1st RFP problem-solving theme, "Development of Solid-state Marine Radar" and then integrate them into a transceiver system for the solid-state radar, which is the end product.