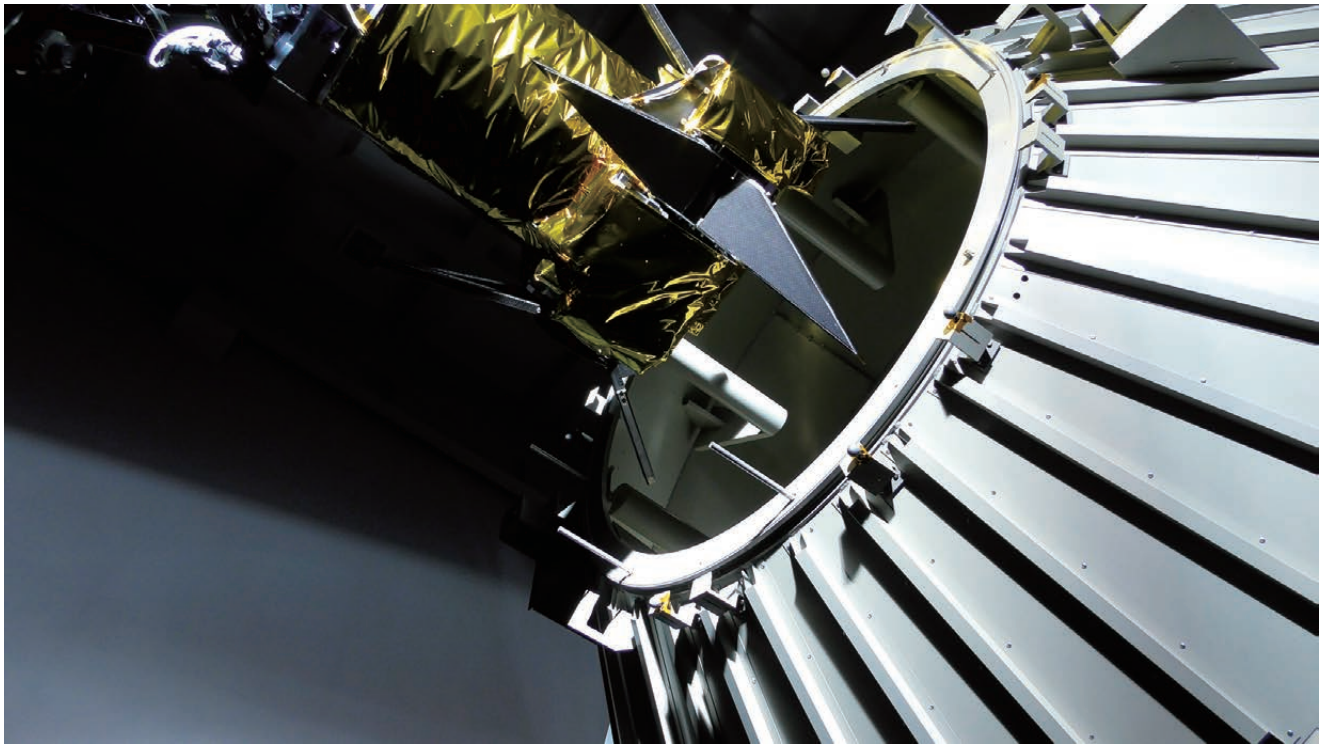
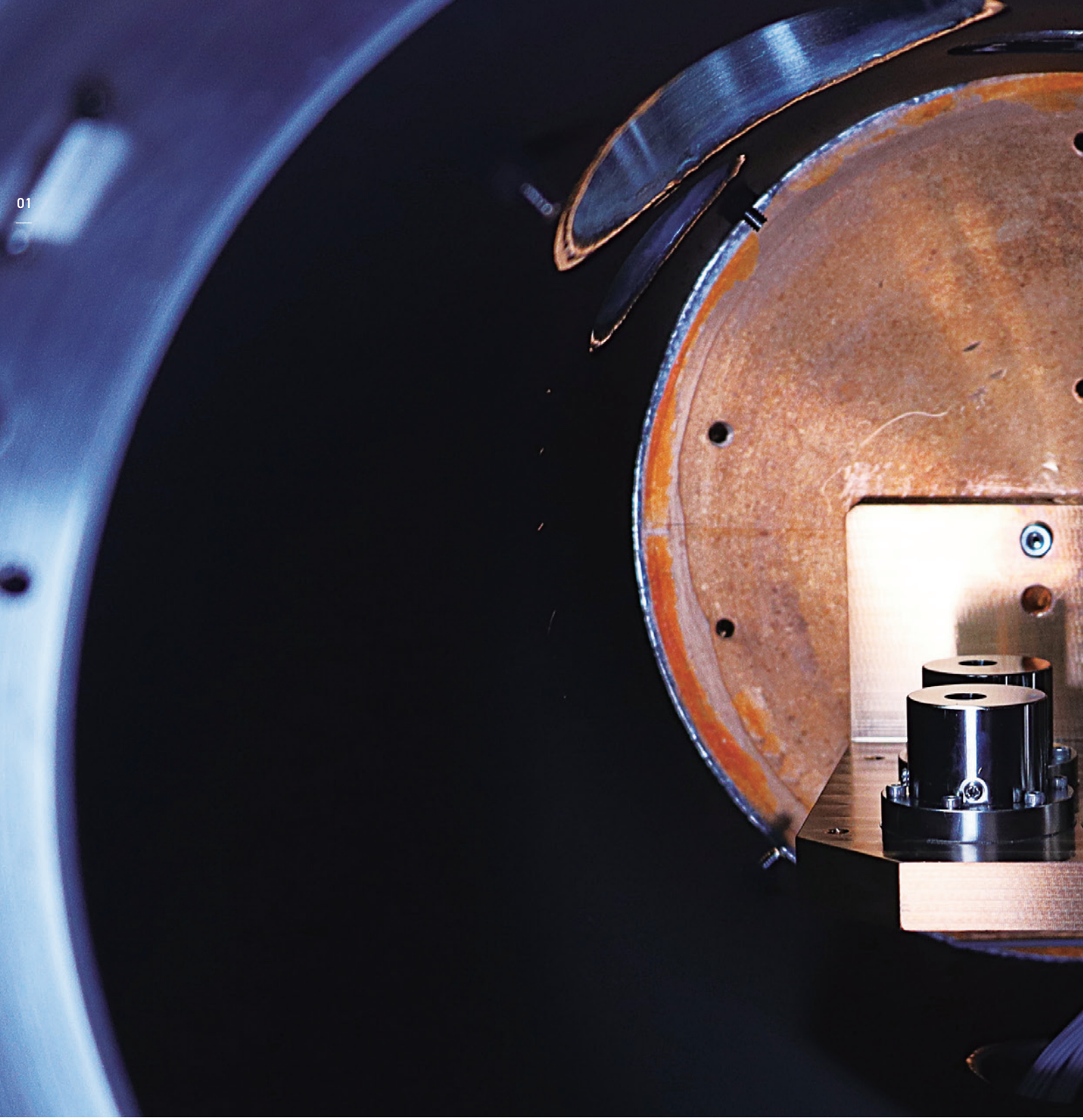
Research and Development Directorate



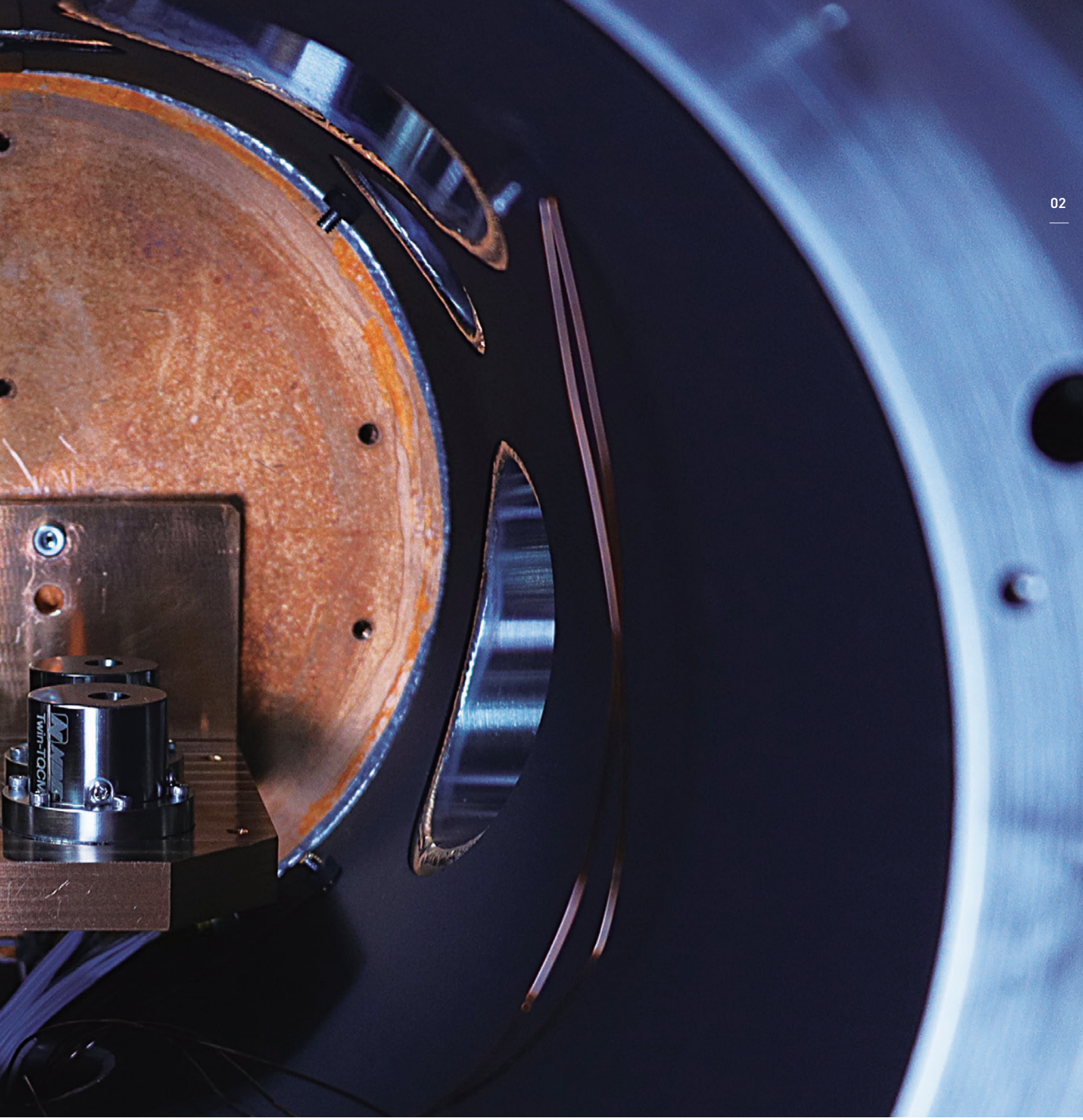


01

The world beyond imagination starts from here

- What JAXA Research and Development Directorate aims for -

JAXA Research and Development Directorate works on creation of innovative “ideas” and highly competitive “technologies” and challenges to realize a rich society by utilizing aerospace.



Creating “Future” - Leading Research -

We promote leading research and development towards realization of advanced aerospace missions and systems that create new value; i.e. we create future from aerospace.

Connecting “now” to “Future” - Research for Secure Development and Success of Missions -

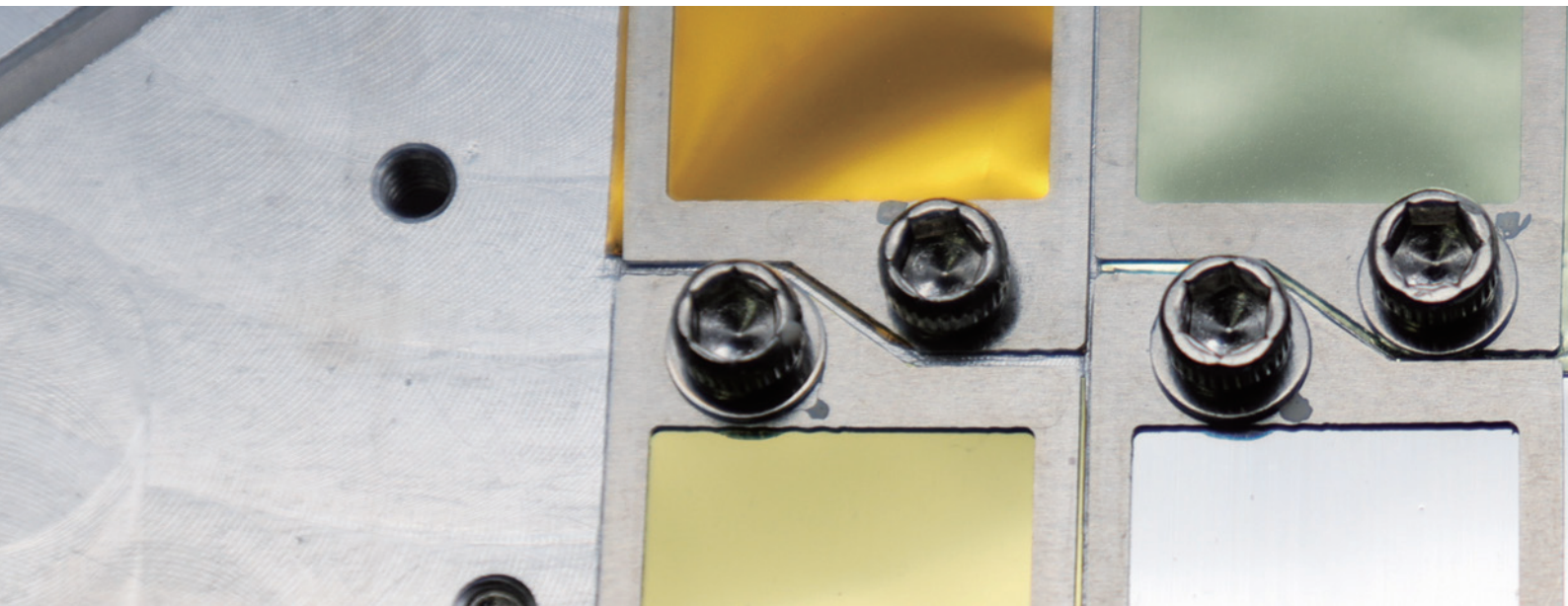
We also support resolving challenges that the aerospace industry and projects face now using our expertise.

Director General
Research and Development Directorate
Japan Aerospace Exploration Agency

INABA Noriyasu

Organization Chart of the Research and Development Directorate

- Director General
  - Research Strategy Department — Intellectual Property Division
  - Management and Integration Department — Kakuda Administration Division
  - Research Unit I — Main research on technologies of electrical systems for trajectory, navigation guidance and control, telecommunications, space power systems, and electronics, space environment, space materials, etc.
  - Research Unit II — Main research on technologies of mechanical systems for thermal systems, structures and mechanism and tribology, propulsion system, space robotics, and environmental control for human space missions, etc.
  - Research Unit III — Main research on technologies for programming, numerical simulation, and informatics, etc.
  - Research Unit IV — Main research on technologies for space transportation systems
  - System Technology Unit
  - Satellite Technology Demonstration Research Unit
  - Sensor System Research Group
  - CALLISTO Project Team
  - MOLI Pre-Project Team
  - CRD2 Phase II Pre-Project Team



Research Policy

As National Research and Development Agency, JAXA, looking at the next decade, will create high-value-added mission and competitive systems by conducting R&D and technology demonstration regarding innovative technologies that dramatically improve the functions/performance of space systems as well as "dual utilization" technologies that are useful for both space development such as space exploration and ground business/social solution, and those efforts will be pursued jointly with industries, including non-space business, in an expanded open innovation approach.
Through these efforts, we will contribute to technological innovation and the promotion of a wide range of industries, as well as promote projects at JAXA, strengthen the competitiveness of private companies, accelerate commercialization, and encourage the entry of different industries, SMEs, and startup companies into the space field. As the major challenges in the 4th mid-term plan, we set the following themes, and we will work on research and development to resolve these challenges by collaborating with each directorate of JAXA as well as related institutions and organizations.

[1] Research and development that contributes to strengthening the comprehensive foundations of Japan's space activities

1 To ensure the continued independence of Japan's space transportation system and to strengthen its competitiveness in the future market, as innovative "R&D on the future space transportation systems" aiming at drastic cost reduction, JAXA as a whole will work together to conduct research and development of innovative technologies such as reusable technology, innovative material technology, innovative propulsion system technology (liquefied natural gas (LNG), airbreathing), innovative manufacturing technology, and reliability and safety technologies for manned transportation, taking into account the upgrading of mainstay rockets.

2 Under the Satellite Development and Demonstration Platform established by National Space Policy Secretariat at the Cabinet Office and the Committee on National Space Policy, JAXA will conduct R&D and demonstration of challenging and innovative satellite technologies that can be utilized by the public and private sectors, key components that Japan should maintain, and new development and manufacturing methods (digitalization, etc.), in cooperation with various government ministries, universities, research institutes, and private businesses including startup companies.

3 Centered around the areas where JAXA has strong points in, such as simulation technology, highly-reliable software technology, mounted equipment and parts with high global competitiveness, advanced rocket engines, we aim to contribute to enhance JAXA's competitiveness in highly advanced space projects and resolve challenges where JAXA strengthens the collaboration among the industry, government, and academia as its core.

4 We also interact and collaborate with areas other than aerospace in order to take in wide knowledge that resides in Japan for enhancing our space technology as well as to utilize space technology to challenges various areas are facing. By doing this, we aim to contribute to maximize and spread the results as the whole country. Furthermore, in the future, depending on the expansion of utilization of aerospace, for the areas that need improvement and enhancement, we will utilize competitive research funds, introduce private funds, and mobilize human resources to promote agile research and development.

[2] Leading research and development that create new value in the aerospace development

1 We will contribute to securing Japan's international competitiveness by taking on the challenge to create a new aerospace market and steadily acquiring debris removal technologies by collaborating with private businesses that aim to operationalize the aerospace debris countermeasures ahead of the world. As the major challenge here, we aim to demonstrate our technologies of the world-first, low-cost debris removal service targeted for large rocket debris. Furthermore, towards its operationalization, we will collaborate with the Japanese government as well as domestic and foreign related organizations to contribute to the early realization of international rules for aerospace debris countermeasures on a stage such as the UN based on the demonstration results of our technologies.

2 We will cooperate with private businesses to perform research and development and develop technologies that foresee the needs of the market, and demonstrate these technologies. By doing so, we aim to create leading services and globally competitive systems ahead of the world.

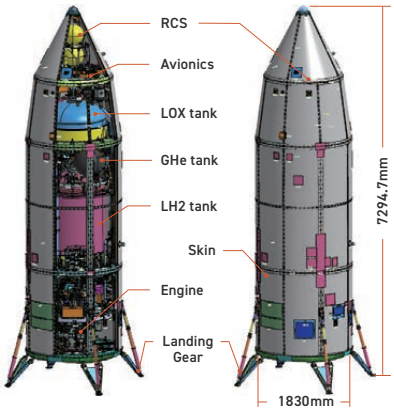
3 In the international space exploration field, which is a new frontier, in order to lead the plan with excellent technologies and designs as an essential international partner, we will perform research and development to polish our own technologies, which have high superiority in exploration and analysis on planets, as well as efficient access to environmental control, life support, radiation protection, gravitational planets, etc.

Reduction in launch costs through the reuse of launch vehicles

Currently, we are conducting research towards the reuse of Japan's flagship launch vehicles in future using Reusable Vehicle eXperiment (RV-X) as part of front-loading research activities for Cooperative Action Leading to Launcher Innovation for Stage Toss-back Operation (CALLISTO), which is being jointly researched by JAXA, CNES and DLR.

Based on considerations brought to attention by the space shuttle, the reusable launch vehicle used in the future must have repeated operation over a short period of time using the same vehicle, and an advanced operation different from that of expendable rockets is required. The plan is for RV-X to demonstrate the vertical take-off and vertical landing (VTVL) capability while reaching to the altitude of hundred meters.

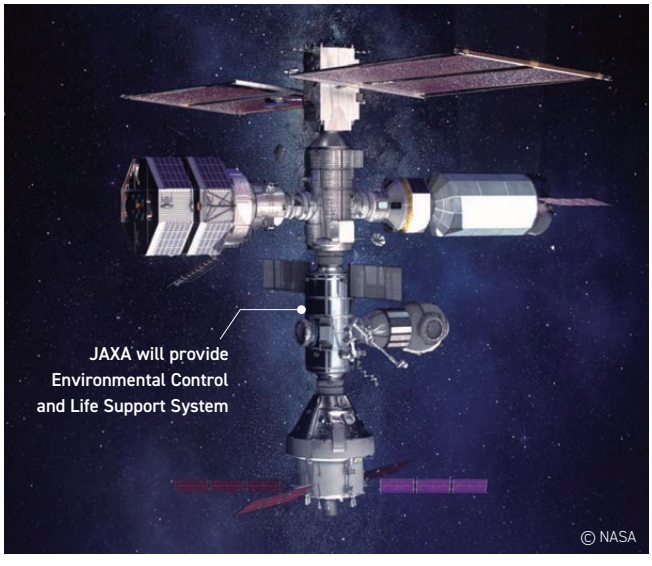
We aim to establish a method of operating the vehicle to be able to execute this series of VTVL sequences at high frequencies and short intervals.



Schematic of the vehicle

Execution of ground firing tests

Research on space exploration for the Artemis Program



Gateway

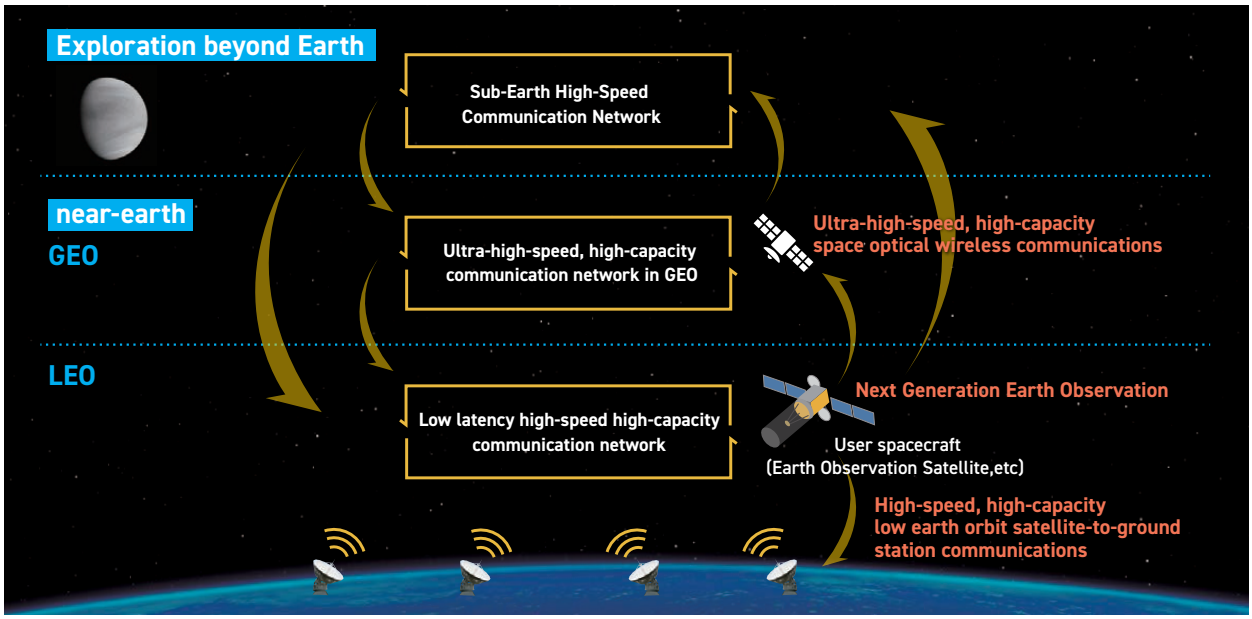
In December 2020, the Japanese government signed a Memorandum of Understanding with the United States regarding Gateway and formally decided to participate in the Artemis mission. In July 2020, MEXT and NASA also issued a joint declaration, agreeing to cooperate in lunar exploration, including joint consideration of a pressurized rover and coordination of lunar exploration opportunities for Japanese nationals. To implement such international commitments, JAXA will continue to promote research and development of (1) gravitational celestial landing technology, (2) gravitational celestial surface exploration technology, (3) human spaceflight technology, and (4) deep space resupply technology.

Specifically, JAXA is promoting research and development of technologies that can leverage Japan's strengths and contribute to international space exploration, in line with the research goals and technology roadmap organized in the "Overall Scenario for Japanese Space Exploration (Draft)" prepared by JAXA's International Space Exploration Center.

Seamless and Autonomous Space Communication System for Society 5.0

For Society5.0, which, is the economic society following on from the hunter-gatherer society, agricultural society, industrial society, and information society, the transmission of information and highly flexible communications are required in broadband environments and in case of large-scale disasters over a wide range of fields of activity, including the sky and sea. The importance of space communication networks that seamlessly connect to terrestrial networks and high-speed communication links for geostationary/non-geostationary commercial communication/earth observation/data relay satellites are increasing.

In this research, for the purpose of achieving a seamless and autonomous space communication system, we conduct over a wide range of device-level to system-level studies.



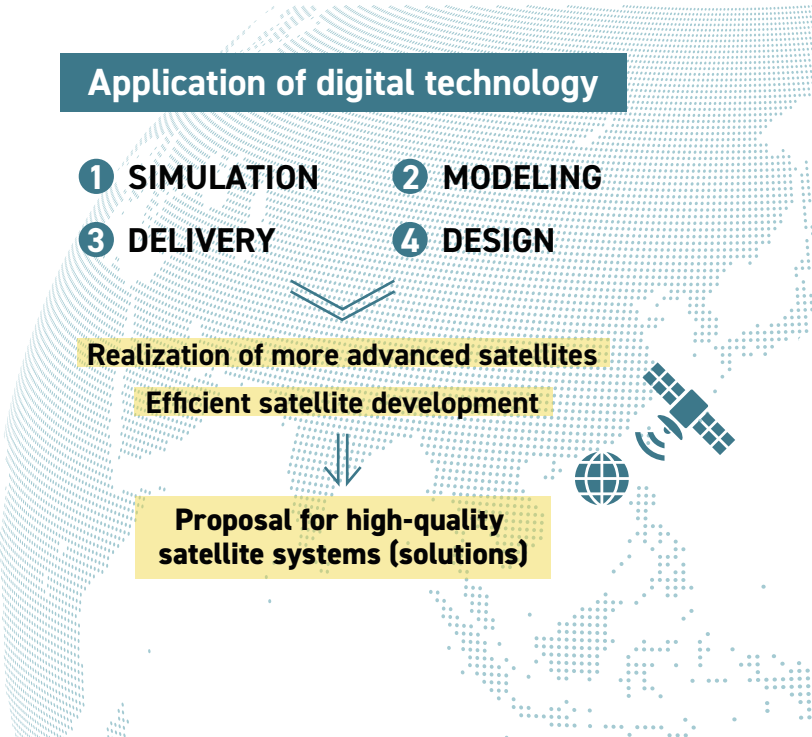
High-speed, high-capacity, and secure optical and radio communication infrastructure connecting terrestrial and space communication networks

Research on the future engineering test satellite that will drive the digital revolution

With overwhelming improvements in computer processing power and digital technologies such as AI, IoT, and ICT, functions and huge amounts of data can be processed quickly, which were impossible with conventional technology. A method that creates added value has appeared in society and propelled remarkable progress.

In this research, we aim to apply these high-potential digital technologies to the entire life cycle of a satellite system, from development to operation.
Also, we are studying the application of these technologies to the functional design of systems to realize functions that can be flexibly modified according to the application and more complex functions.

This research aims to contribute to society by advancing the digital transformation. The research verifies the technologies that will enable these in the future engineering test satellite.



Research on technology for applying hydrogen fuel to aircraft and future space transportation systems

High-Speed Point-to-Point Transportation System

We are developing the technology to apply hydrogen fuel to aircraft and space transportation systems in a carbon-neutral society.

A hydrogen aircraft that does not emit carbon dioxide would have a liquid-hydrogen fuel supply and employ safety management technologies learned in developing the H-IIA and H3 rockets.

We are also investigating hydrogen-fueled air-breathing engines with significantly lower propellant consumption than conventional rockets. We aim to develop a winged space transportation system with air-breathing engines to realize future high-speed point-to-point and high-frequency space transportation.

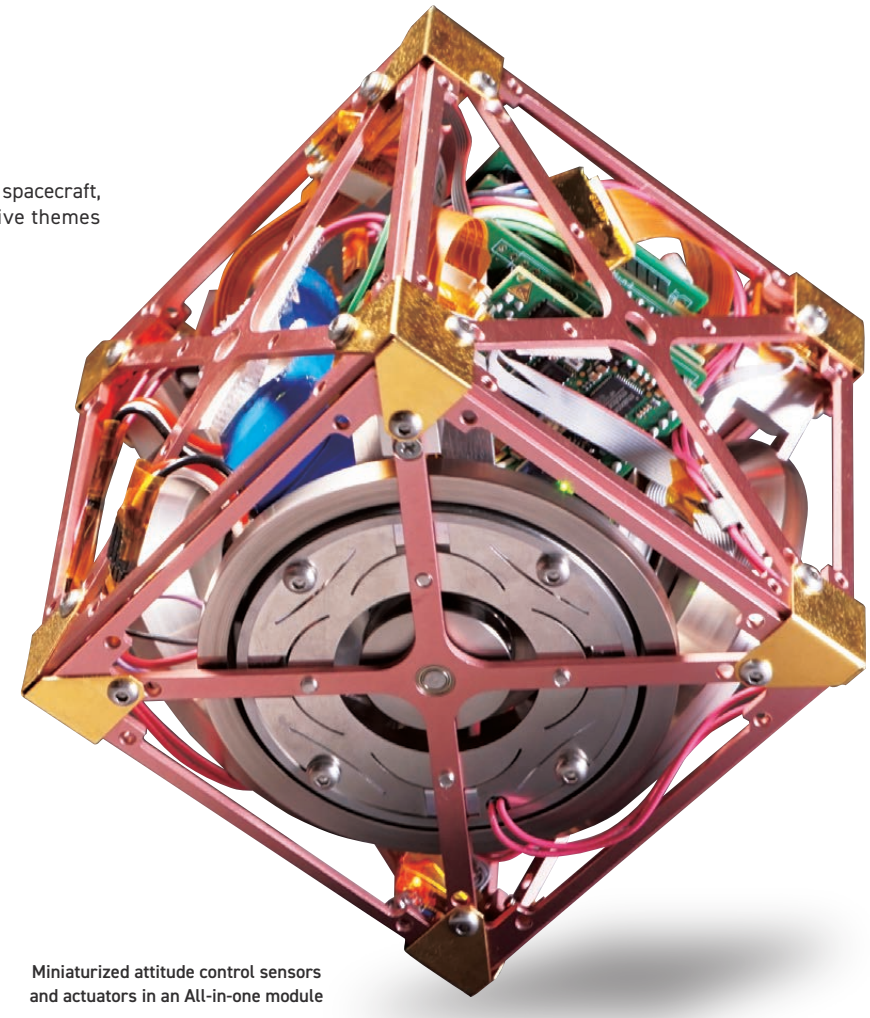
Winged SpaceTransportation System

Inter-disciplinary technology for increasing competitiveness and providing innovation in spacecraft that will create new fields of space use

Aiming to increase the international competitiveness of spacecraft, we are conducting cross-cutting research on innovative themes that lead to technological innovation.

- Wireless technologies
- Research on on-board processing technology for earth observation satellite data
- Automated and autonomous robotics technologies for future human space station operations
- Research on GNSS receiver technology for space applications

Onboard image processor for SAR data
©JAXA/Alouette Technology Inc.



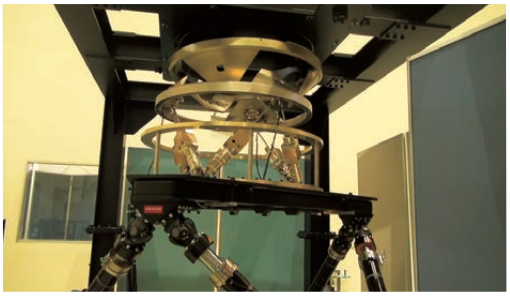
Miniaturized attitude control sensors and actuators in an All-in-one module

Research on software, computational engineering, and V&V technology for space systems

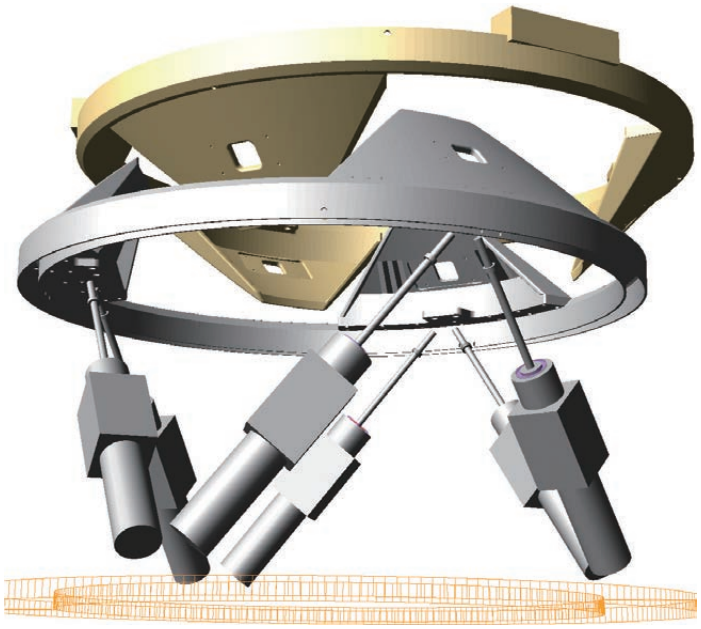
The objective of this research is to establish the systems engineering which balances mission success with reduction of development costs, by researching, development and utilization of the world's top-level information technology and computational engineering.

This will make possible a space mission that currently seems infeasible in terms of development costs and lead time.

As a first step, we will contribute to developing a new H3 rocket in an efficient and reliable manner. In parallel, we will research future satellites and reusable space transportation systems and support space projects with the use of previously developed technologies.



Docking System of Space craft Docking Mechanism
Ground Test

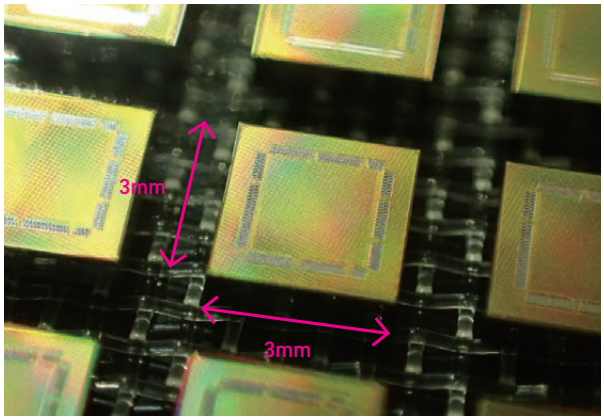


Docking System of Space craft Docking Mechanism
Repeatability Analysis

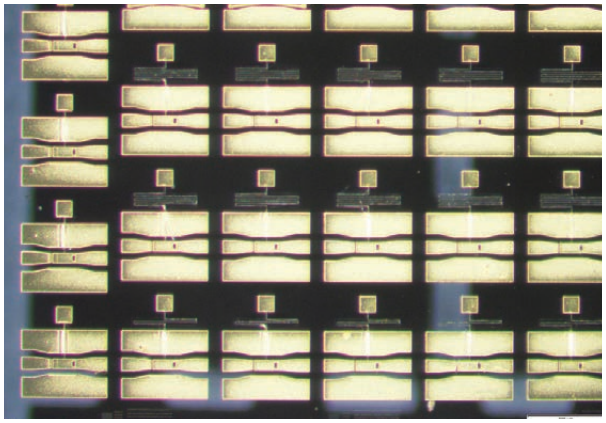
Research on space-qualified parts

Space-qualified parts, which have capability of withstanding the space environment, are indispensable for the reliable operation of a satellite over a long period in space. We have been researching and developing space-qualified parts essential to satellite development with two objectives: maintaining independent space programs and placing Japan's future satellites in a more competitive position.

We take a long perspective approach to R&D on space-qualified parts. Our scientists work with research institutes and private sectors to identify promising domestic technologies and focus our resources on the development of parts that we expect to provide innovative, effective solutions for future satellite systems. We intend to better translate our research into practical outcomes at the earliest stage possible.

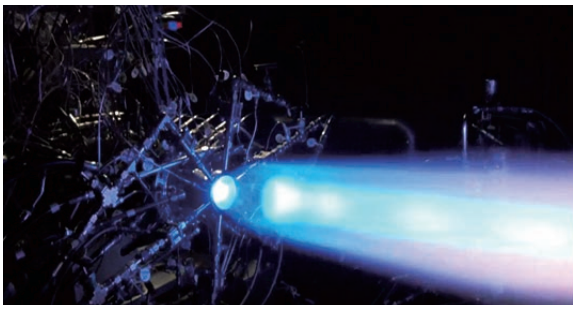


Prototype 16nm FinFET Semiconductor Chip
with Radiation Hardened Circuits



RF-MEMS switches prototyped in Minimal Fab

Research on transportation technology



10kN thrust class metal 3Dmodeling combustor / Methane combustion test

In accordance with the technology roadmap established by JAXA, for the realization of an innovative future space transportation system, this project aims to promote research on improving performance, reliability, and safety. This includes drastic cost reduction of space transportation to expand Japan's independent launch capability and strengthen its launch services' international competitiveness.

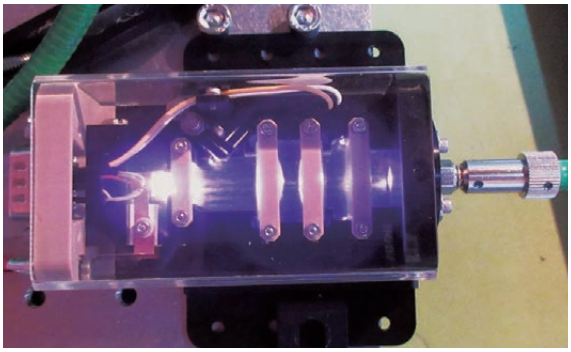
This project will research and develop basic technologies such as Liquefied Natural Gas (LNG) engines and thermal protection technologies to quickly acquire the bottleneck technologies essential to realize an innovative space transportation system.

Research on Earth observation sensor system

There are many types of sensors onboard Earth observation satellites. Spaceborne remote sensing instruments are broadly categorized according to the observation techniques they employ and the electromagnetic spectrums in which they operate (optical or microwave).

Utilizing comprehensive design engineering JAXA has acquired and accumulated for a sensor system, we have been researching key technologies and sensor systems expected to be required in the next decade or two. We have also been working with internal and external organizations to devise space missions that can fully benefit from the remote sensors to be developed in the future.

An ultimate goal is to translate our research findings into Operational Earth observation missions.

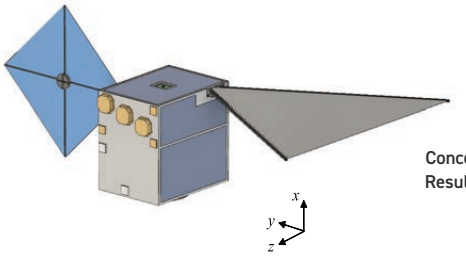


Fiber-coupled LD for pulsed laser excitation for LIDAR

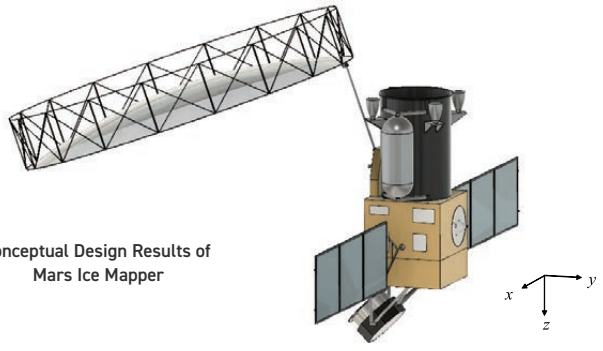
Research on the technology of space systems

A space system is a system of systems, consisting of many elements. It includes not only a launch vehicle and satellites but also ground segments such as the various ground facilities and installations. The mission success relies on the workings of the system as a whole, not on the discrete functions of its elements. In our research we will search for the most appropriate configuration of the elements in order to allocate a space system that will meet requirements for the system.

We will study various concepts of the space system, together with scientific expertise and technological capabilities in cooperation with internal and external bodies. Based on this study, we will propose a project that can pave the way to technologies that enhance Japan's competitiveness, provide solutions to societal challenges, and enable strategies to secure industrial growth in the decades to come.



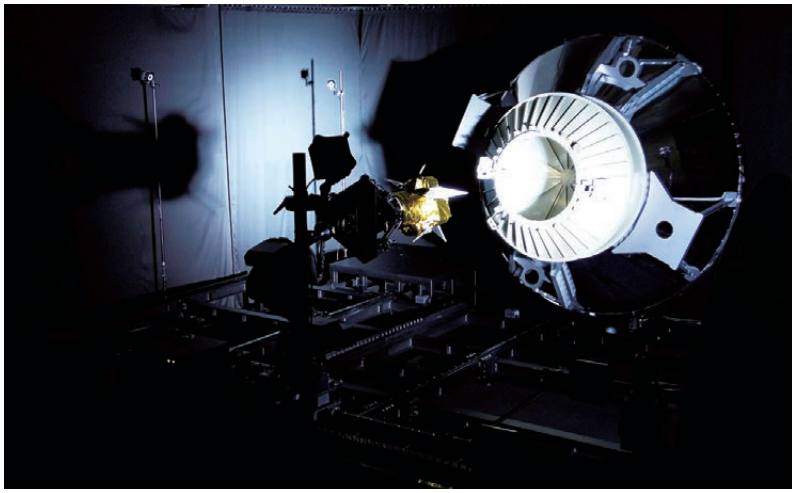
Conceptual Design Results of RAISE-3



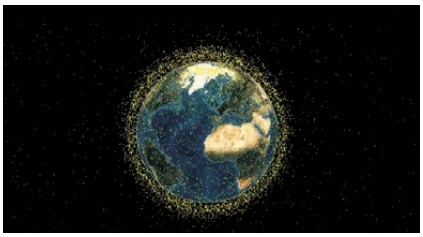
Conceptual Design Results of Mars Ice Mapper

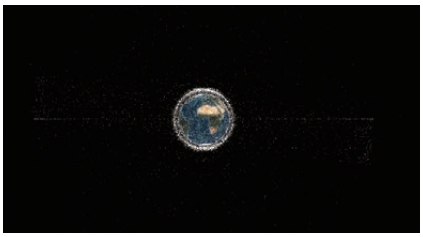
Ensuring the safety of space missions now and in the future

Space debris has been increasing year by year and in the future is expected to interfere with human space activities. To ensure the safety of space activities and promote sustainable space development in the future, JAXA is strengthening its cooperation with the government, as well as with internal and external related organizations, and is engaged in research and development of space debris.



Debris removal and capture mechanism test





Space debris on orbit (image)

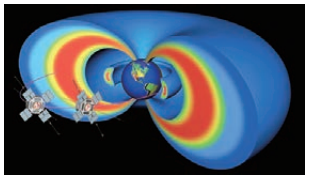
Advancement of basic technologies on mechanisms and materials for expanding space activities

Dust seals

Lithium-ion batteries

To enable more flexible, extensive, and long-term space activities, we aim to establish technologies for accurately measuring and predicting the space environment, as well as basic technologies on materials, mechanisms, and structures that can apply to severe environments and commonly used equipment, such as batteries and attitude control actuators.

Vacuum Combined Environment Testing

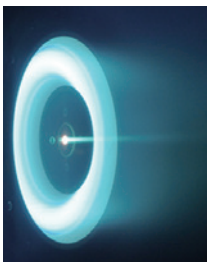


Radiation belt

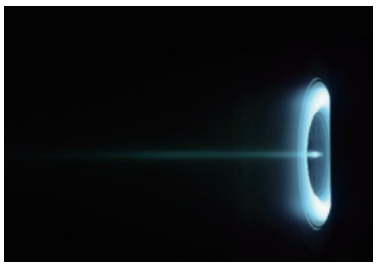
Rolling bearings

The reduction gear

Research to Improve Competitiveness of Hall Thrusters



6kW Hall Thruster



1kW Hall Thruster

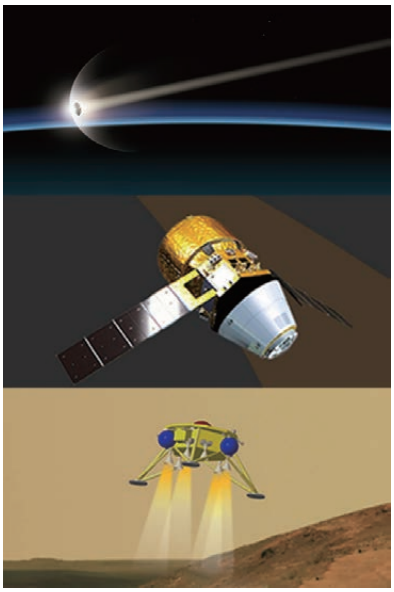
Various propulsion devices control the orbit and attitude of satellites and probes. Some technology uses electric or electromagnetic forces to obtain thrust, called electric propulsion.

There are many types of electric propulsion, and our research focuses on a Hall thruster.
Our research aims to enhance Japan's industrial competitiveness through electric propulsion technology, and the following three themes are the pillars of our current activities.

1. 6kW Hall Thruster
2. 1kW Hall Thruster
3. Innovation on Electric Propulsion

Research on Atmospheric Entry-Descent-Landing and Recovery (EDL&R) Technologies

The purpose of this research is to support the projects currently under development in terms of technologies by organizing a cross-sectoral research team to share knowledge and to provide problem-solving schemes for issues related to the atmospheric entry systems and the take-off and landing systems for lunar and planetary exploration. At the same time, we aim to produce space missions that create new value by strengthening the common fundamental technologies essential for future advanced sample return missions, high frequency and continuous flight demonstrators from LEO, and Mars exploration missions.



[TOP] Sample Return Capsule
[MIDDLE] Manned Return Capsule
[BOTTOM] Mars Pin-Point Landing Demonstrator

Power management that evolves space systems

Research on satellite power systems has so far produced results focusing on the higher efficiency, miniaturization and weight reduction of components such as power control units and battery cells, and realized their implementation in society. On the other hand, as satellite missions diversify with the expansion of space utilization, the issue of how to secure the necessary power has become a challenge.

Lithium-ion cell

In addition to the development of power system components, this research aims to establish power management technology that considers the energy cycle of the entire system, including thermal control, to achieve highly efficient power operation on orbit.

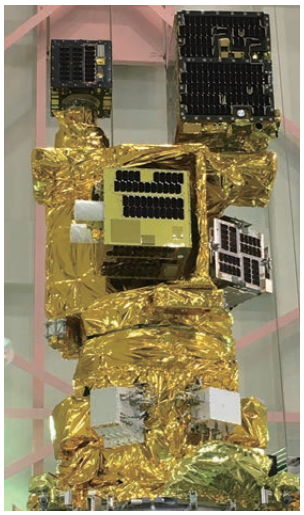
Battery charge regulator "GaN_BCR"

Innovative satellite technology demonstration program

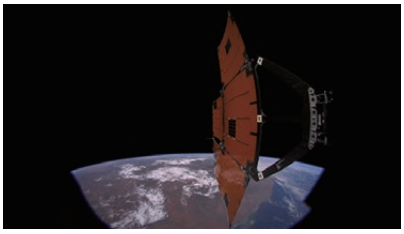
This program is part of the strategic promotion of projects in the satellite development and demonstration platform under the "expansion of satellite development and utilization infrastructure" as indicated in the basic plan for space policy to provide opportunities to demonstrate equipment, parts, microsatellites and CubeSats developed by private companies, universities, research institutions, etc.

JAXA also aims to realize the followings through this program:

1. We will acquire and accumulate new knowledge from the private companies, universities, etc., and connect it to the creation of future missions / projects and the establishment of space demonstration businesses by the private companies.
2. Furthermore, we will lead to achievement of more advance and effective realization of ministries' needs to solve policy issues of Japan reflecting new technologies, and to expansion of market share in the international market etc.



Multi-satellite mount structure
[Innovative Satellite Technology Demonstration-2]



RAPid Innovative payload demonstration Satellite-1 (RAPIS-1) TMSAP deployment

RApid Innovative payload demonstration SatellitE-2 (RAISE-2) flight model

Launch of the Epsilon-5 with Innovative Satellite Technology Demonstration-2 onboard

Commercial Removal of Debris Demonstration (CRD2)

Commercial removal of debris demonstration (CRD2) is the world's first technology demonstration of removing large-scale debris from orbit. This project is launched in collaboration with private sector, aiming to commercialize space debris removal and develop new markets for private business.
We have released Request For Proposal (RFP) concerning Phase I mission on October 2019.
JAXA has contracted with Astroscale for Phase I mission on March 2020.

Check here for the video

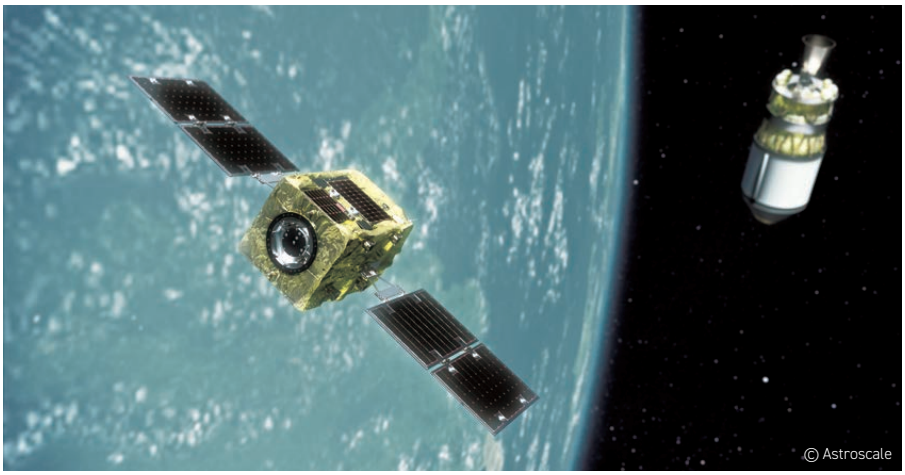
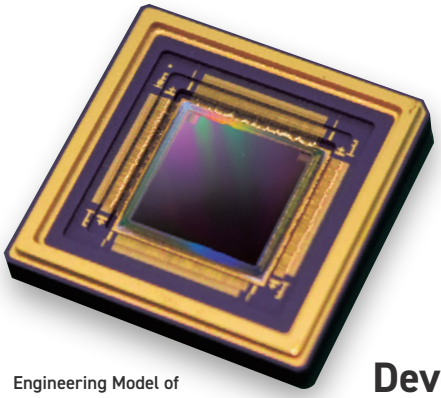


Image of CRD2 Phase-I



Engineering Model of
SOI-SOC MPU
(After assembly without lid)

Development of SOI-SOC MPU

The evolution of information communications technology which realized the autonomous communication between "thing" and "thing" on a global network has enabled the world closely interconnected. It is considered that such a network will further extend into space in the future. Accordingly next-generation spacecrafts will demand even higher functionality and performance from space MPU (Micro processing Unit) which plays a core role of controlling information of the network under the harsh radiation environment of space.

JAXA are developing SOI-SOC MPU as the high-functionality / high-performance next-generation MPU, which adopts the SOI (Silicon on Insulator) semiconductor manufacturing technology and the SOC (System on Chip) design technology. Since the SOI technology is fundamentally superior in radiation tolerance and the SOC technology can load multiple functions on a single chip, SOI-SOC MPU will contribute to diverse and sophisticated space missions.

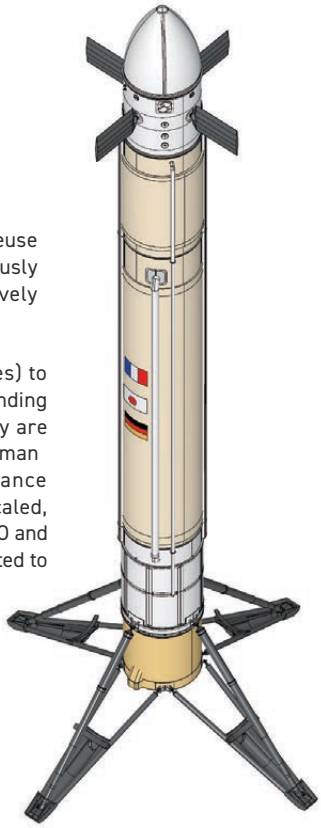
Engineering Model of
SOI-SOC MPU
with test board

Cooperative Action Leading to Launcher Innovation for Stage Toss-back Operation (CALLISTO) project

We are engaged with research that aims to reuse the first stages of launch vehicles that previously have been disposable, as a method to effectively reduce transportation costs to space.

The important technologies (key technologies) to allow a series of operations from launch to landing followed by reuse, have been identified. They are guidance and control technology, propellant man agement technology, and engine maintenance technology. Through the development of a scaled, reusable, experimental vehicle called CALLISTO and flight tests, we will accumulate knowledge related to these technologies.

While taking initiatives in the technologies in which Japan has unique superiority, we also plan to proceed with efficient flight tests, based on international cooperation with French and German space agencies.



Landing configuration of the
CALLISTO experimental vehicle

Research on the Space Solar Power Systems (SSPS)

The Space Solar Power Systems (SSPS) convert energy from solar rays to either microwave or laser energy and transmit it from space to Earth for energy consumers. The system has the potential to solve important challenges facing humanity in areas, such as energy, climate change, and environmental conversion.

JAXA is conducting the following research with a view to realization in the mid-21st century.

- Research on wireless energy transmission technology using microwaves and laser beams
- Research on technologies common to systems such as technology for constructing large space structure and space solar cell technology

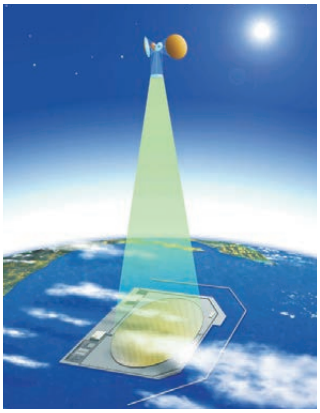
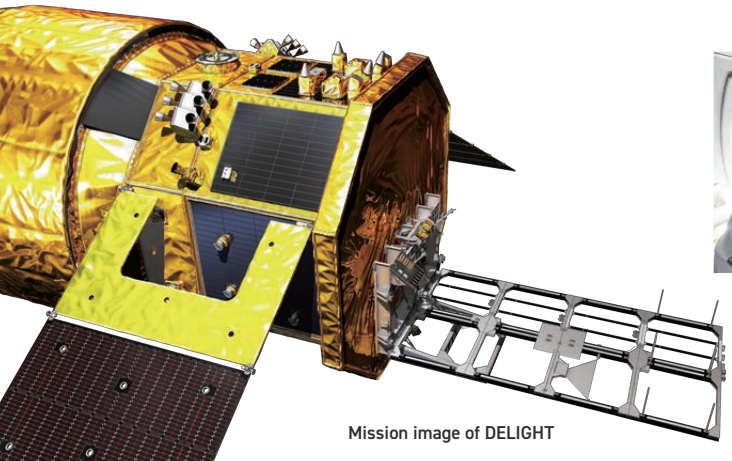


Image of SSPS



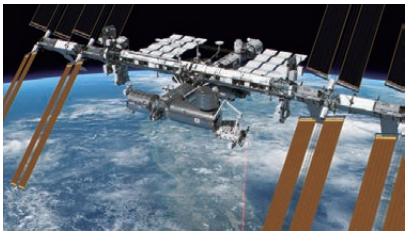
Mission image of DELIGHT

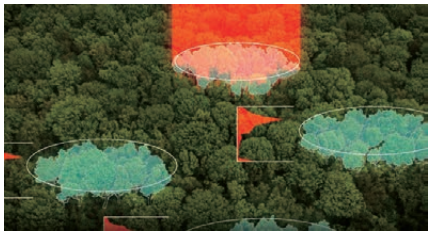
Microgravity Experiments on Deployable Lightweight Panels

MOLI Multi-footprint Observation LIDAR and Imager mission

This is a pre-project to conduct a technical demonstration of LIDAR observation technology on the International Space Station (ISS).
LIDAR is a radar that uses light to detect the object. The distance to the target can be measured with high accuracy.
Since this technology enables observation of vertical distribution, which cannot be observed by ordinary cameras, it is expected to contribute to the understanding of the amount (volume) of forests and the creation of high-precision 3D maps by accurately observing the height of forests and the height of the ground.

Check here for the video

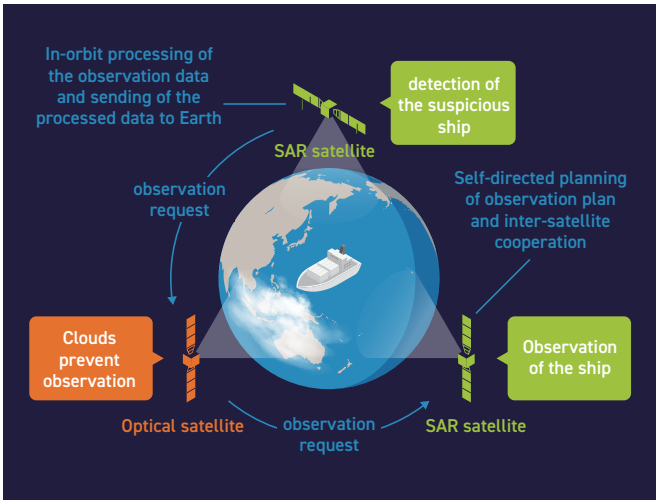




Multi-footprint Observation LIDAR and Imager mission (image)

Agile Research Program for Advanced Technology in Satellite Service and Process

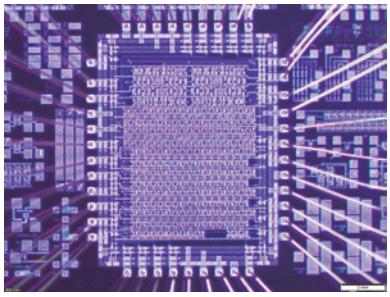
This program aims to realize disruptive satellite technology to enhance Japan's space service capability. In order to achieve our goals, we utilize micro and small satellites as technology demonstration platform, and employs agile process to keep up with rapid technology advancement. This program also focus on digital technology as a key component for competitiveness of Japanese space industry.

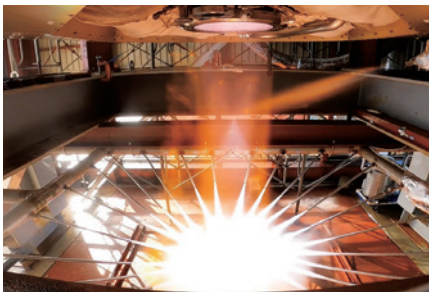


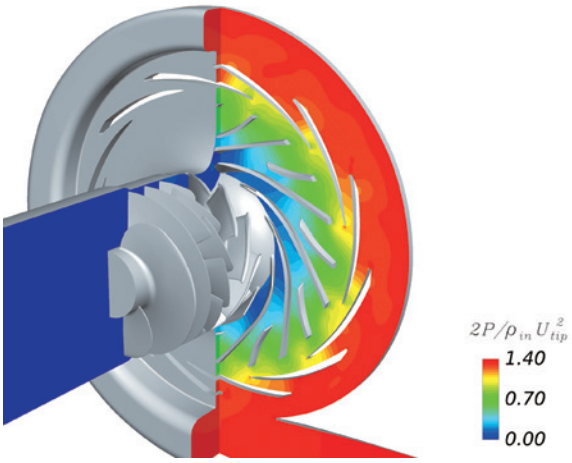
Innovative Space Transportation Programs

We will promote the realization of a "Core Launch Vehicle Development Space Transportation System" aiming at significant cost reduction and a "High Frequency Outbound Flight Space Transportation System" led by the private sector, based on the "Innovative Space Transportation Roadmap" established by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
In addition, we will conduct the following annually based on the trend of technological research to ensure that the plan is properly implemented.

- Research on overseas trends and business feasibility
- Identification of technology issues through system studies and establishment and updating of technology roadmaps.
- Establishment of a co-creation system through open innovation between the space industry and other industries.







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