JAXA Technology Challenge

Japan Aerospace Exploration Agency

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JAXA Technology Challenge

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Aerospace technology has brought humankind great tools such as aircraft, rockets and artificial satellites. These devices have improved our daily lives, increasing our convenience, safety and comfort. In order to maximize the benefits derived from aerospace technology, basic research and development projects in aerospace technology must be pursued energetically and continuously. JAXA has articulated its long-term vision for the next 20 years with the aim of ensuring the success of aerospace activities over the coming two decades. Also, JAXA is constantly driven to challenge the cutting edge of aerospace science and technology. Our long-term vision says; "to build a secure and prosperous society through the utilization of aerospace technology", "to unveil the mysteries of the universe and to utilize lunar resources", "to explore the origins of the Earth and humankind", "to implement world-class space transportation and foster Japan's own space activities", "to promote the aerospace industry through the development of its domestic commercial aircraft", and "to realize a high-speed aerial transportation vehicle".

The Aerospace Research and Development Directorate (ARD) is playing the key role in this JAXA technical challenge, especially in the provision of services and solutions for highly reliable and advanced aerospace systems. One of our recent major achievements in space technology is the 200 MIPS (million instructions per second) radiation-resistant 64-bit microprocessor for satellites, at this moment boasting the world's best specifications. Another unique accomplishment is the satellite, SDS-1 (Small Demonstration Satellite), a largely in-house project which is helping JAXA's young engineers to build up a reservoir of advanced design and evaluation skills. This satellite will be launched in January of 2009. In other fields, we have established highly sophisticated wind tunnel measuring technology such as pressure sensitive paint (PSP) and particle image velocimetry (PIV) which have been useful in the wind tunnel tests of Japan's new commercial aircraft, the MRJ (Mitsubishi Regional Jet). Also, some of our staff have made great progress in predicting the transition process in high Reynolds number flow with their interpretation of the growth of the boundary layer from T-S wave to turbulent flow using a large scale numerical simulation derived by the LES technique.

The Aviation Program Group is growing to become a core component of Japan's aviation community by working toward realization of the above-mentioned new commercial jet aircraft, the MRJ, future supersonic aircraft, new operational safety systems, and other innovative technologies. Among the supporting efforts for the MRJ, JAXA's low-cost composite structure technology called VARTM (vacuum assisted resin transfer molding) has made great progress in recent years and leads the world in this field. Also, JAXA's CFD (computational fluid dynamics) team has developed a prediction method for the aerodynamic noise created by airframes, particularly high lift devices. This method is supporting the design of the MRJ main wings. In the supersonic technology area, JAXA proposed the silent supersonic technology demonstrator concept in which the sonic boom inherent to supersonic flight will be drastically decreased by CFD design. In the area of future air traffic control systems, JAXA is planning the DREAMS (distributed and revolutionary efficient air-safety management system) project. DREAMS involves the development of total systems based on new data link technology, route definition systems and high performance avionics.

This brochure, outlining JAXA's wide range of research and development activities, is aimed to be both a "guide" for our overseas colleagues who are actively involved in aerospace and related fields of technology, and an "instrument" to encourage more intensive communications between researchers. We would like to promote more meaningful discussions with our colleagues worldwide and to expand our contribution to today's and tomorrow's challenges in aerospace technology.

Takashi Ishikawa
Executive Director

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Aerospace Technology

Chapter 1

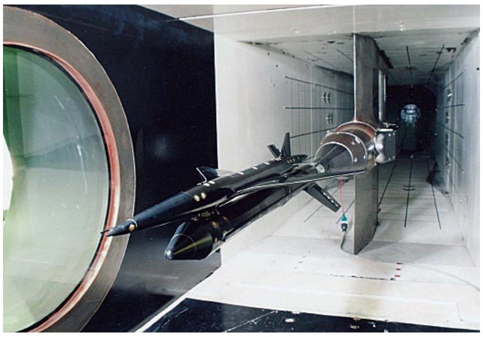
Aerospace Technology

Wind Tunnel Technology Center

A wind tunnel is one of the most important aeronautical ground test facilities, reproducing fluid flow around vehicles made to fly, including aircraft and spacecraft. Wind tunnels make it possible for us to gather data on the interaction between the vehicles and the flows. The Wind Tunnel Technology Center (WINTEC) operates and manages eleven wind tunnels of various sizes and types, ranging from low-speed to hypersonic, and including a high-enthalpy type. These wind tunnels are not restricted to JAXA's use only, but are open to researchers and designers from outside JAXA. Since the establishment of this facility, these tunnels have been used for development tests on almost all aircraft produced in Japan, as well as many Japanese rockets. WINTEC also conducts research on advanced testing technologies, developing them so that they can be utilized in the wind tunnels. Some of these new measuring technologies are world leaders. In all forms of testing, WINTEC endeavors to satisfy its users, ensuring that they receive the full benefit of its accumulated experience and technology. New testing technologies to meet the advanced and diverse needs of the day are always being developed.

(a)

(b)



(c)

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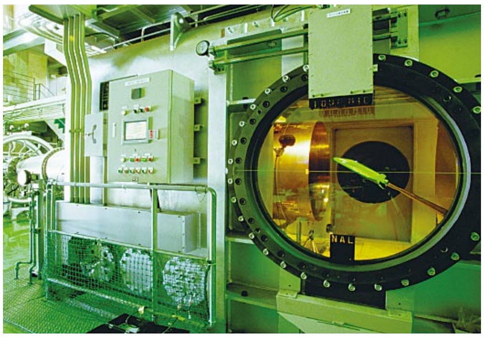
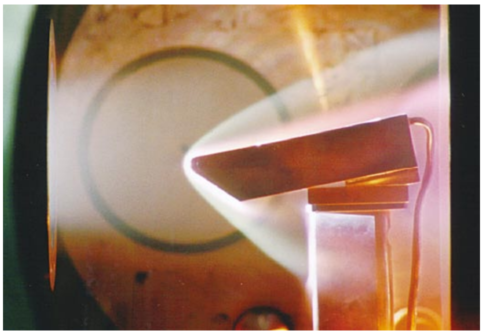




(e)

Fig.1 Main wind tunnels in WINTEC

WINTEC Wind Tunnels

6.5m x 5.5m low-speed wind tunnel.......Fig.1(a)
2m x 2m low-speed wind tunnel
2m x 2m transonic wind tunnel..............Fig.1(b)
0.8m x 0.45m high-Reynolds-number transonic wind tunnel
1m x 1m supersonic wind tunnel............Fig.1(c)
0.2m x 0.2m supersonic wind tunnel
0.5m hypersonic wind tunnel
1.27m hypersonic wind tunnel..............Fig.1(d)
0.44m hypersonic shock tunnel
750kW arc-heated wind tunnel.............Fig.1(e)
110kW ICP-heated wind tunnel

Goals

The Wind Tunnel Technology Center undertakes two major missions: 1) maintenance, operation and management of wind tunnels. 2) research and development of advanced technologies that can be used in large wind tunnels to support aircraft development. The center conducts an average of more than 100 wind tunnel tests in a year. As an executive body bearing the responsibility for such a large number of tests, the center has established a quality management policy that applies to all wind tunnels in the center. This policy ensures that the maintenance, operation and general management of all of the wind tunnels is carried out safely and efficiently. The sphere of the first mission includes not only the passive operation of wind tunnels, but also the performance an active research program intended to improve the reliability and productivity of wind tunnels. What the center aims at through all these activities is to enhance user satisfaction and to attract more users to take advantage of the benefits of WINTEC's wind tunnels.

Among all the activities included in the second mission, the center focuses strongly on the technologies of model surface pressure measurement (pressure sensitive paint (PSP)), velocity field measurement (particle image velocimetry (PIV)), and aircraft airframe noise measurement. These three technologies are currently in the spotlight worldwide, and most of the major aerodynamic research and test organizations in the world strive to become the front-runner in their development. This center is in the competition, and has established its own technologies step by step. The center aims to be the leader in all three of the target fields.

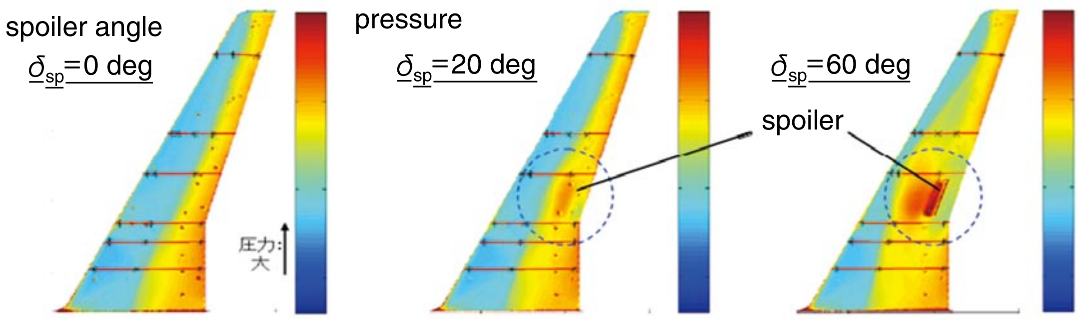


Fig.2 Surface pressures on wings with different spoiler angles

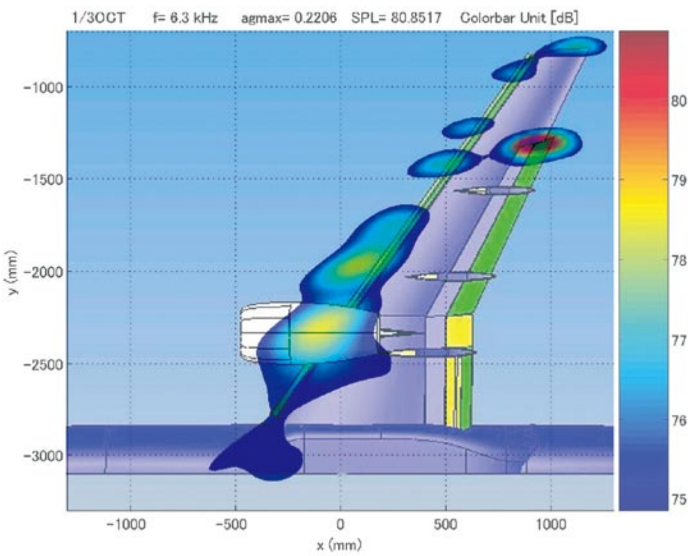


Fig.3 Contour of noise emitted from various positions on a wing

Research Objectives

In the development of PSP technology, we have pioneered the simultaneous use of PSP and TSP (temperature sensitive paint) to compensate for the effect of temperature on the PSP response. Many PSP tests have been conducted with this method, and the data supplied by them have proven to be indispensable in the design of, for example, the Mitsubishi Regional Jet (MRJ)(see Figure 2). As the next stage, we have already developed "two-color paint", a combination of PSP and TSP that can produce information on pressure and temperature at the same time. The development of PSP for low-speed wind tunnel tests and for unsteady phenomena is also one of our current targets for research.
The development of PIV technology has attained the stage where the space velocity field around an airplane model can be measured from nose to tail in the 2 m x 2 m transonic wind tunnel, with the building and dismantling of the seeding systems accomplished within 4 days. A study has been initiated to calculate lift and drag forces on a model in the wind tunnel, from the velocity distribution in its wake as measured by PIV. Along with data on noise emitted from the aircraft airframe, measured by the microphone array planted in the wind tunnel wall (Figure 3), flow visualization at the critical position of the wing-nacelle combination as measured by PIV (Figure 4) is supplied to the designer of MRJ, together making a significant contribution to its design.

The center undertakes many kinds of research that may not always make headlines but that are indispensable to its mission of maintaining and improving the quality of wind-tunnel testing. Included in this category are studies to elucidate the flow characteristics of individual tunnels, to improve measurement accuracy, and to increase data productivity. A typical example can been seen at the transonic wind tunnel, which accepts the largest number of tests among other tunnels. A recent investigation aimed at improving the accuracy of drag force measurement in this tunnel led to a very significant improvement. Studies aimed at improving measurement accuracy include correction for tunnel wall interference, reduction of starting and stopping loads, and others.

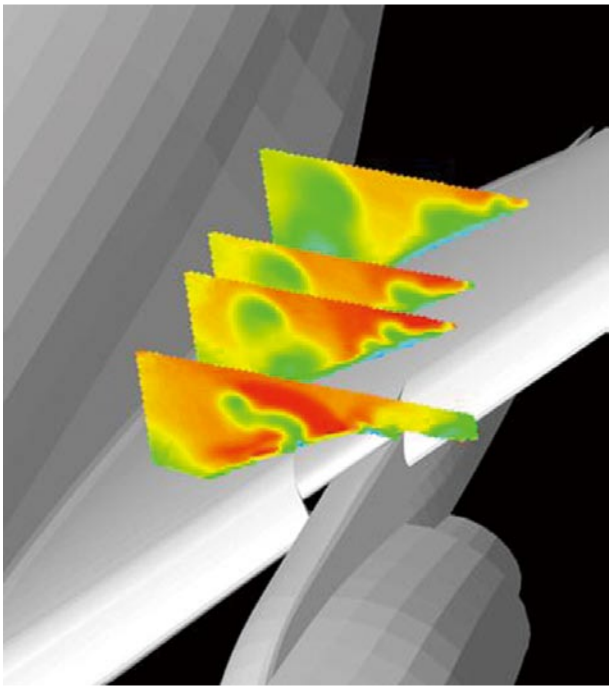


Fig.4 Vortices on wing behind nacelle

Aerodynamics Research Group

The Aerodynamics Research Group elucidates the phenomena involved in the flow of air around aircraft, space planes, and other entities flying in air or in dilute gases. We also research and develop advanced technologies for measurement, evaluation, and prediction. In an ambitious project underway since 2004, we have been studying advanced and innovative aerodynamic technologies for future-oriented aircraft.

Goals

The group will research the following topics, aiming to produce technology with real-world applications. The first topic is high-subsonic support technology. The group will measure six component forces on an aircraft model, and drag measurements on a rocket shape at dynamic pressures over 20 kPa and speeds around Mach 0.7 with the use of a magnetic suspension and balance system. A database of the aerodynamic characteristics of basic shapes such as disk, sphere, cylinder and so on will be prepared. The second topic is molecular sensor technology. The group will enhance the performance of what is already the world's quickest-responding pressure-sensitive paint, improve measurement accuracy of the rate of aerodynamic heating in high-velocity flow, eliminate the temperature-dependence of pressure-sensitive paint by copolymerizing molecular probes onto polymers, and promote the transfer of technology.

The third topic is the numerical analysis of turbulent flow and aeroacoustics. The group has developed an innovative LES (large eddy simulation) technology for flows involving separation, transition, and acoustic radiation, applicable at high Reynolds numbers where numerical calculations with sufficient accuracy have been considered impossible, and also a technology to enable the study of complicated shapes such as multistage flaps or a three dimensional wing.

The last topic is gas dynamics in extreme environments. The group will improve numerical prediction technologies of aerothermodynamic environments around hypersonic planes, reentry vehicles, and planetary entry probes in extremely-high-enthalpy flows and rarefied flows. The group will also perform leading-edge research on innovative thermal protection technologies for reentry vehicles as well as improving ground test facilities and testing techniques.

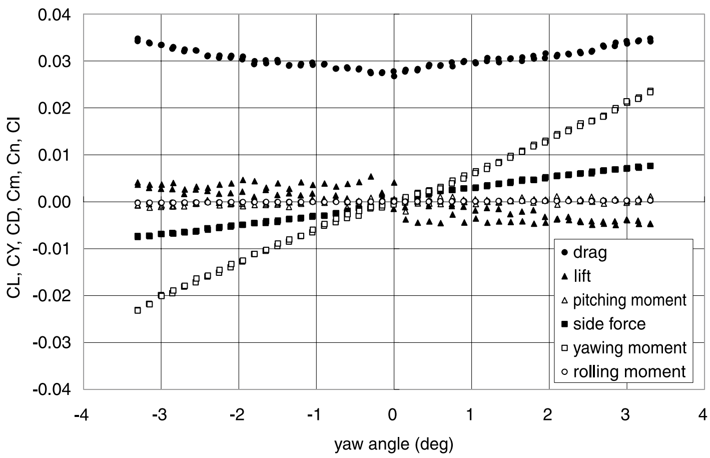


Fig.1(a) Measured all static aerodynamic coefficients of a winged model during its yaw angle change at 30 m/s in flow speed.

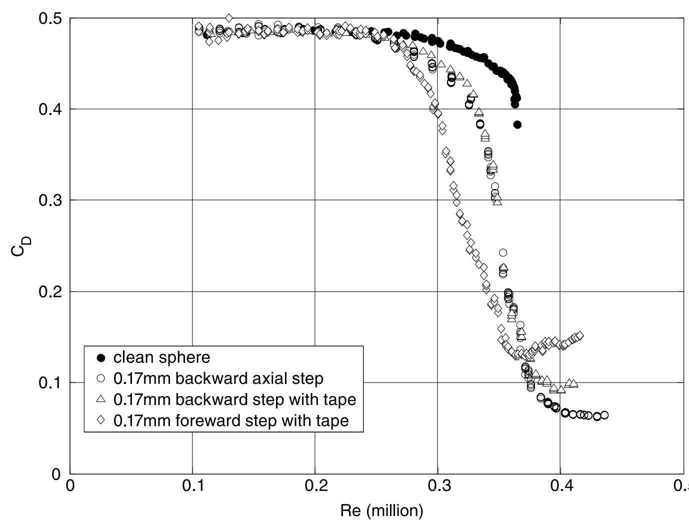


Fig.1(b) The Reynolds number effect on spheres with varying roughness.

Research objectives

For high-subsonic aerodynamic force measurements on axial bodies, our group has redesigned a magnetic suspension and balance system (MSBS), which now uses about 4 times as great a magnetic force as the original system. We have also measured aerodynamic forces on a winged model under six-axis control with the use of the JAXA 60 cm MSBS (Fig.1(a)). This system was also used to examine the Reynolds number effect on drag on a spherical body with several types of surface roughness. (Fig.1(b)). It was found that the drag coefficient of a sphere with the smallest roughness tested became about 0.063 beyond the so-called critical Reynolds number. The system was also used to investigate the aerodynamic properties of ultra-slender bodies similar to an arrow, with a fineness ratio of 75 (Fig.1(c)).

In the field of molecular sensing technology, the group has focused on global pressure/ temperature measurement in an unsteady flow field, which requires both sensor and system improvements. The group has been developing a fast-response pressure-sensitive paint combined with a new temperature-cancellation method, because the temperature dependency of this type of sensor is a major source of error. This method uses an intermediate wavelength between two luminescent peaks, whose response is not temperature sensitive (Fig. 2 (a)). For an unsteady pressure measurement, a new method was developed with the use of a fast frame rate camera as a pixel-based frequency analyzer. Figure 2(b) shows unsteady pressure distributions over a cylinder in various frequency ranges at a uniform velocity of 33 m/s. As an innovative technical challenge, a molecular sensing technology for flow control is also being worked on.

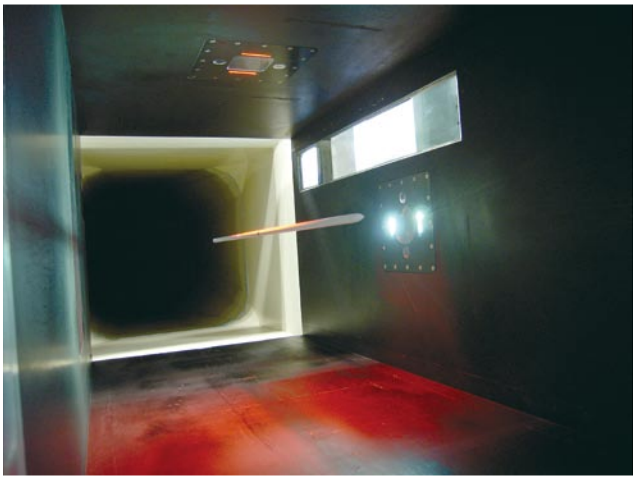


Fig.1(c) A magnetically suspended cylindrical model (10 mm diameter, 750 mm long) in the JAXA 60 cm magnetic suspension and balance system.

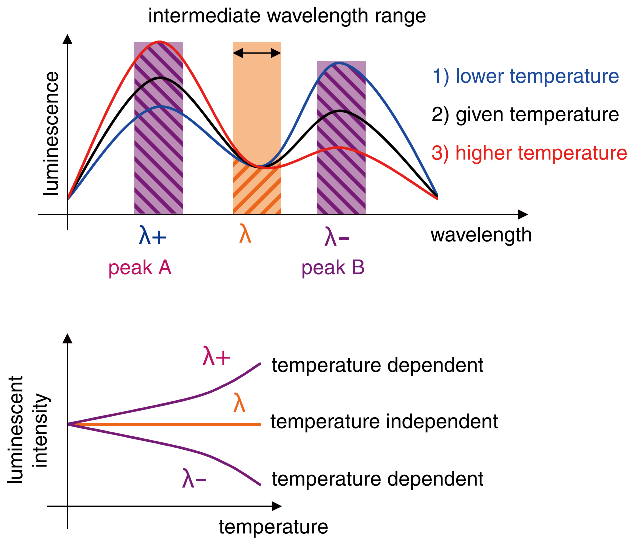


Fig.2(a) Temperature-cancellation method using two luminescent peaks.

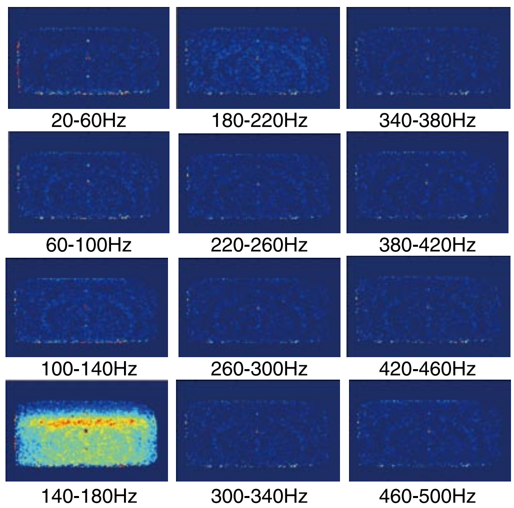


Fig.2(b) Unsteady pressure distribution over a cylinder in various frequency ranges.

The group is developing a high-accuracy numerical analysis technology based on a multi-block method and LES, as well as an advanced analysis method that combines these, as the result of our research on the numerical analysis of turbulent flow and aeroacoustics. These methods will be applied to future challenges in aerospace such as analyses of turbulent flow noise and stall characteristics in high-Reynolds-number regimes. Fig.3(a) shows the sound waves radiating from the trailing edge of the 2-D wing, as captured by the numerical simulation. Comparison of the frequency/velocity relation with the corresponding experimental results shows quantitatively good agreement, as shown in Fig.3(b). Figure 3(c) shows the details of flow structure around the trailing edge region and figure 3(d) is an example of the multi-block calculation around a wing with a flap. Several transition points are captured without any explicit numerical modeling.

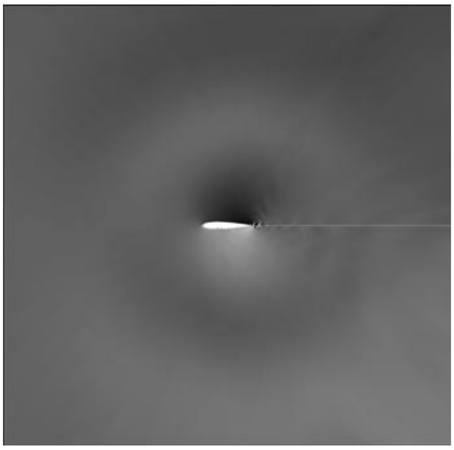


Fig.3(a) Instantaneous pressure fluctuation around NACA0015 wing profile at mid-span (Re=4x10^5, a=-5°, U=14.5 m/s) .

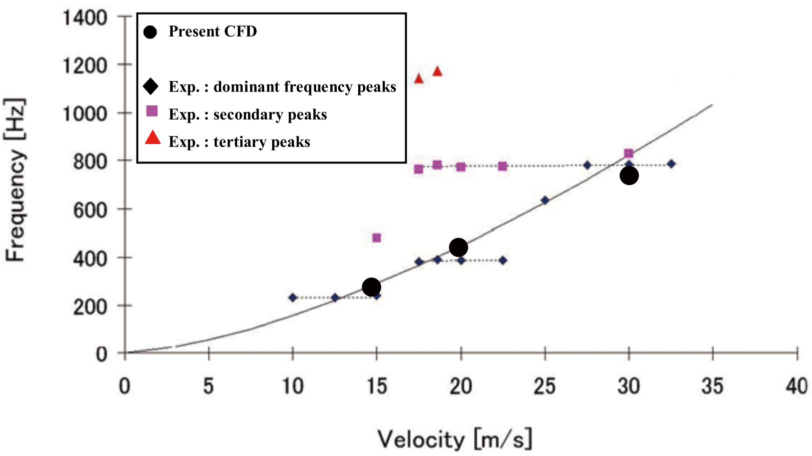


Fig.3(b) Velocity vs. frequency dependency: experimental results.

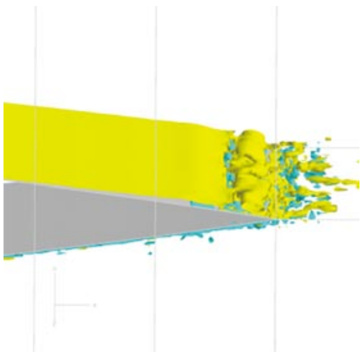


Fig.3(c) Vorticity distribution around the trailing edge on the pressure side

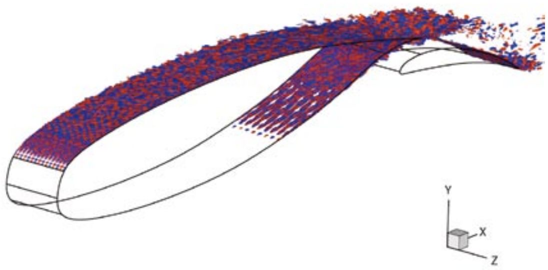


Fig.3(d) Vorticity distribution around an NLR7301 wing with flap (Re=2.51x10^6, a=13.1°, M=0.185) .

Finally, for research on gas dynamics under the most extreme conditions, the group is developing advanced numerical analysis tools for the assessment of aerothermodynamic and radiative environments, as well as the thermochemical behavior of thermal protection systems for atmospheric entry vehicles. Figure. 4(a) shows a typical computational result for the radiation-coupled flow field around a HAYABUSA-type capsule with ablation of the CFRP ablator involved. To improve accuracy in prediction of the aerodynamic heating rate, analytical models for gas-surface interactions such as catalytic recombination and oxidation are being developed. Figure. 4(b) shows the heating test of graphite in a plasma wind-tunnel, from which the world's first accurate model for the temperature-dependent nitridation rate of a carbon surface was obtained.

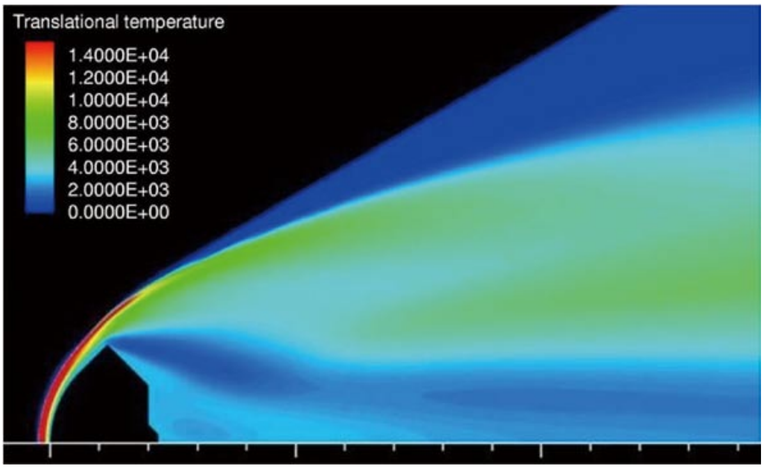


Fig.4(a) Distribution of translational temperature around HAYABUSA-type capsule in continuum flow (V = 11.4 km/s, alt.= 64 km).

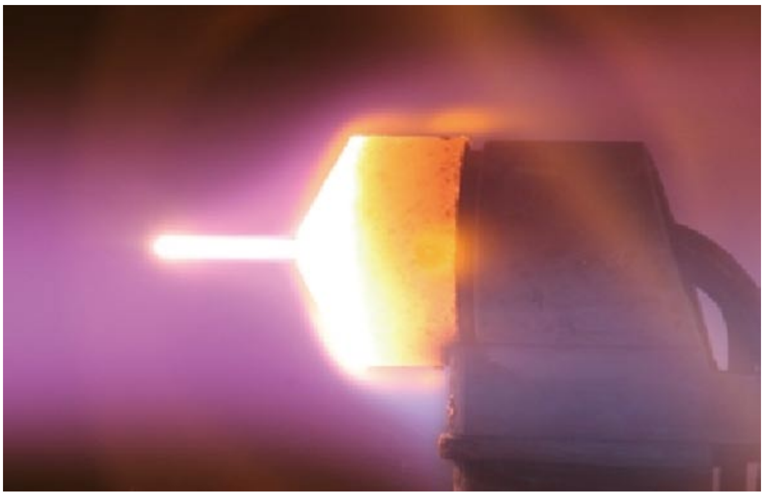


Fig.4(b) Heating test of a graphite test piece in a plasma wind tunnel with nitrogen as the working gas.

Structure Technology Center

The Structure Technology Center investigates advanced fundamental technology for lightweight and heat-resistant high-performance structures capable of meeting the high reliability and safety requirements of aerospace applications. The center focuses closely on optimum structures and functional structures incorporating new materials, research on the structural vibrations inevitable in flight and their control, structural heating analysis technology, and structure simulation technology.

Goals

The center aims to establish high-precision, high-efficiency structural analysis technology and structural design methods based on two lines of research closely connected with each other: the establishment of evaluation technology and the collection of experimental data focused on the key components that underpin the reliability of whole structures (micro research), and numerical structural analysis for estimating the behavior of entire structures (macro research).

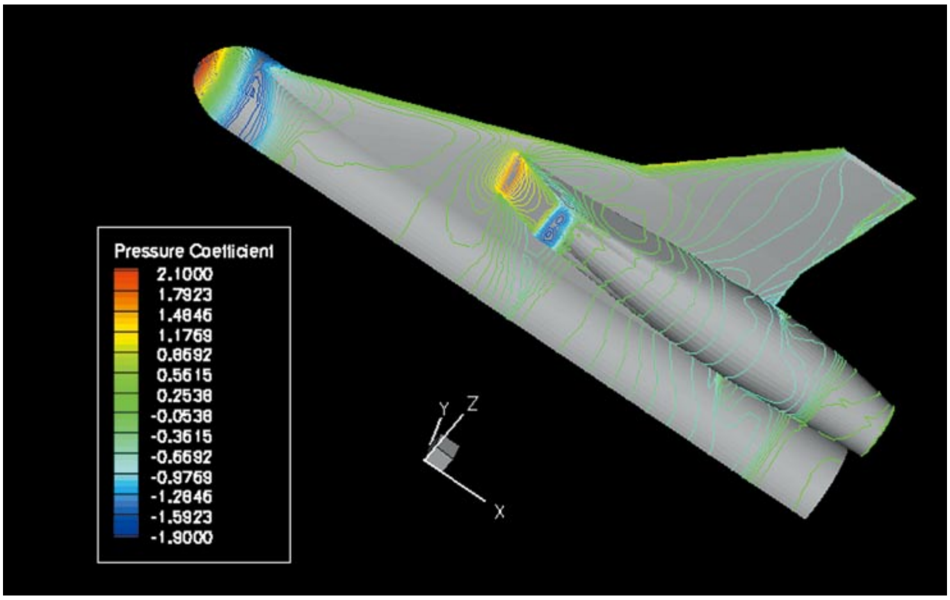


Fig.1 Transonic flutter analysis and test facility

Research Objectives

●Structure and Strength of New Materials

The center is investigating the strength and durability of the three-dimensional composite materials and the titanium hybrid composites expected to realize the heat-resistant lightweight structures required for the next-generation supersonic aircraft and similar structures. We are also analyzing leak behavior in a liquid hydrogen-oxygen environment in order to incorporate composite materials in the structure of a propellant tank exposed to cryogenic conditions. Other research topics include the use of Smart Bolts to monitor and warn of initial damage in structural connections important for maintaining structural integrity, evaluations of strength against fatigue and corrosion damage to structures, and the ongoing advancement of safety-assurance technologies.

●Structural Vibration

As spacecraft have grown in size, it has become more difficult to carry out ground-based whole-system vibration tests. The center is developing a safe, efficient and practical technique to identify the dynamics of a system from online data provided by an in-service satellite or other remote source.

We are also developing a new strain measurement system with a long gauge fiber Bragg grating (FBG) sensor based on optical frequency domain reflectometry (OFDR), which enables us to measure fully distributed strain at especially high spatial resolution for monitoring strain distribution in a structure. This measurement system has the potential to be used for health monitoring of aerospace structures and measurement of structural vibrations.

Fig.2 Fiber optic sensor system applied to full scale composite wing structure testing

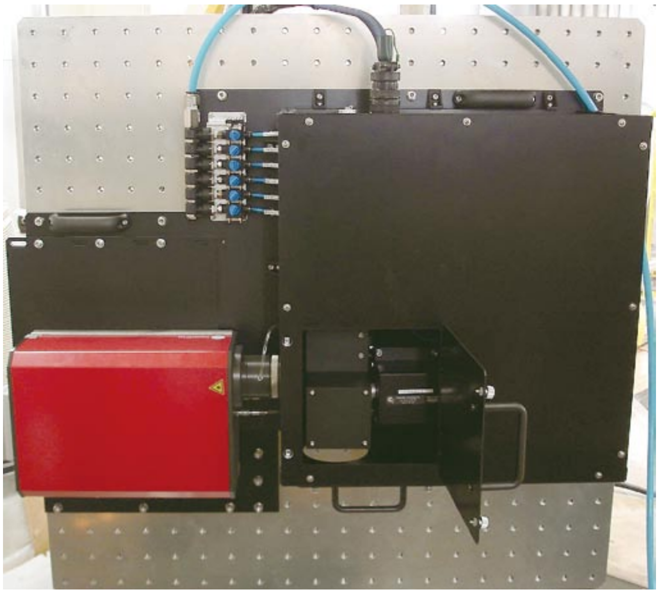


Fig.3 High-power laser-diode heating system with bi-axial galvano scanner

●Heat-Resistant Structure

The center will develop an evaluation method for thermal shock resistance by heating a specific area with a high-power laser with systematic control of positioning and timing. In parallel, we will be improving our technologies for thermal stress and damage analysis of inhomogeneous materials with special microscopic structures. We are aiming to develop and establish experimental and numerical evaluation technologies focused mainly on the composite materials used in nozzle throats.

An infrared lamp heating system has been constructed to aid in the development of thermal protection systems. A control system has recently been installed so that heating rate and environmental pressure are controlled automatically to model time-varying re-entry conditions for items undergoing testing.

●Aeroelasticity

Both deep understanding and accurate evaluation of aeroelastic phenomena are required to achieve high reliability and flight safety for a faster and lighter airplane. The center is working toward an understanding of the behavior of unsteady airflow on ailerons in the transonic speed range, the establishment of a design technique for active control systems using control surfaces, and the development of a flutter analysis tool and its verification in our transonic flutter wind tunnel facility for supersonic aircraft with complicated configurations.

●Structural Integrity

Research on the structural integrity of aircraft is indispensable for enhancing structural safety and preventing accidents caused by structural failure. The center is studying the following: (1) Structural elements and sub-components are evaluated for their damage tolerance. Crack growth behavior and residual strength evaluation, as well as total fatigue life of the structure and its failure mechanisms are evaluated both by testing and numerical calculations. (2) Load testing of structure components with fastener joints is conducted to evaluate the detailed mechanism of load transfer. (3) Fatigue testing of aircraft structural materials and actual structural parts is conducted in a corrosive environment to evaluate the effect of environment on structural integrity. The location of damage and its progress, and deterioration due to fatigue are evaluated.

Advanced Composite Technology Center

Welcome to the Advanced Composite Technology Center (ACTec) Technology Challenge 2008. In order to facilitate the practical application of advanced composite materials (ACMs) in lightweight and reliable aerospace structures, the ACTec deals with a broad variety of activities on ACMs, including fundamental and applied research, industrial support, and collaborative research and education. ACTec's research portfolio continues to be very strong, reflecting the high quality of research staff and facilities. The ACTec also remains the largest domestic ACM research facility.

Goals

ACTec is performing round-robin tests on evaluation methods for ACMs in collaboration with outside research institutes. On the basis of the tests, suitable test methods will be proposed for inclusion in future Japanese Industrial Standards (JIS) and International Standards Organization (ISO) standards. A pubic database of ACM properties has been established and opened to users from industry, government and academia. Publication of a textbook on ACM theory and practice is also being promoted. New types of composite materials, e.g. multifunctional materials and nanocomposites, are being developed and explored. Innovative application technology research is focused on low-cost processing methods and state-of-the-art evaluation techniques.

Research Objectives

The following sections contain details of all current and recently completed research projects in the ACTec in the field of composite materials.

●Advanced composite database construction

There are over 1200 users of the ACTec's database of the mechanical properties of ACMs. Fundamental data on high-strength type ACMs mainly used in the aircraft industry are available in the database (registration-based free database: JAXA-ACDB, http://www.jaxa-acdb.com/). Unlike most other databases, a full set of properties, including environmental conditions such as so-called Hot/Wet and Cold/Dry, are given whenever possible. Figure 1 is the top page of the JAXA-ACDB website. New data on high-modulus type ACMs useful in space structures are now being prepared. Furthermore, in order to meet industry demands, the basic composite handbook will be published as a comprehensive reference that treats both fundamentals and applications.

Fig.1 JAXA-ACDB website

●Development of composite evaluation technology and standardization

Various testing methods useful for the thermomechanical evaluation of carbon fiber-reinforced plastics and continuous fiber-reinforced ceramics have been proposed to JIS. Several of our results have already been accepted as JIS standards, including JIS R1644, JIS R1659, and JIS R1663. Parts of these proposals have been translated into English and submitted for discussion in ISO/TC61 (for polymer matrix composites) and ISO/TC207 (for ceramic matrix composites). Figure 2 illustrates one of the testing methods that ACTec proposed for JIS.

●Multifunctional materials and nanocomposites

The aim of this research is to design a material that satisfies multiple performance objectives in a single system, such as high-temperature/heat-resistant, self healing, flame retardancy, sensing and actuating, and electrical capabilities. Applications for a range of heat-resistant materials are under development at ACTec. The materials now under investigation include carbon/carbon composites that can be used at temperatures up to 2000°C, ceramic-based heat-resistant composites for up to 1200°C, and heat-resistant polymer-based composites for up to 300°C. The highlight topic of this category of research at ACTec is a newly developed polyimide resin, which can be used as the matrix in ACMs. As illustrated in Figure 3, this resin has a higher temperature capability and is more easily fabricated into composite materials than existing heat resistant polymers.
New functional materials, various types of nanofillers (nanotubes, etc.) dispersed composites and nano-polymer functional materials are under evaluation from various viewpoints.

●Innovative application technology research

A fabrication technology based on advanced vacuum-assisted resin-transfer molding (VaRTM) has been developed. Since the VaRTM process does not require an expensive autoclave system, this technology has the potential to reduce fabrication cost. The main target of this processing technology is the fabrication of wing structures for civil transport aircraft. The special focus of this activity is the establishment of a method that can qualify for aircraft-type certification, since the VaRTM method has never been used for a primary aircraft structural part such as a wing. Many tests have been performed on scale models of elements and sub-components of full-scale structures to evaluate the consistency of the process in producing adequately strong parts. Finally, a full-scale test of a 6 m long wingbox structure (Figure 4) was completed in March 2008, and the strength of the VaRTM wing was verified. Research on the fatigue and damage tolerance properties of this VaRTM structure and on techniques for the numerical analysis of various types of damage in composites is also ongoing.

Fig.2 Proposed test fixture for the open hole compression (OHC) test - This test fixture allows the use of a much smaller test specimen than the conventional test configuration.

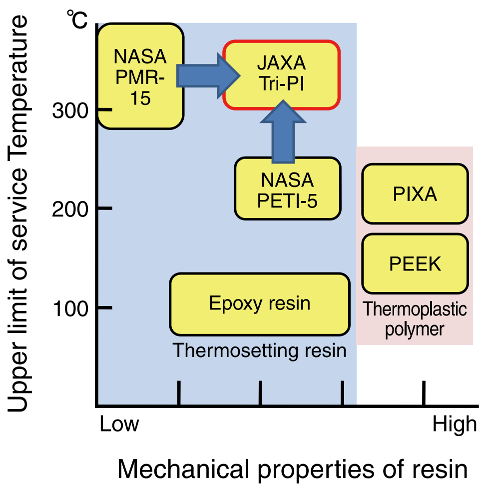


Fig.3 Newly developed polyimide resin has an 80K higher temperature capability and superior mechanical properties, with triple the strength and 10 times the tensile failure strain compared to existing heat resistant materials

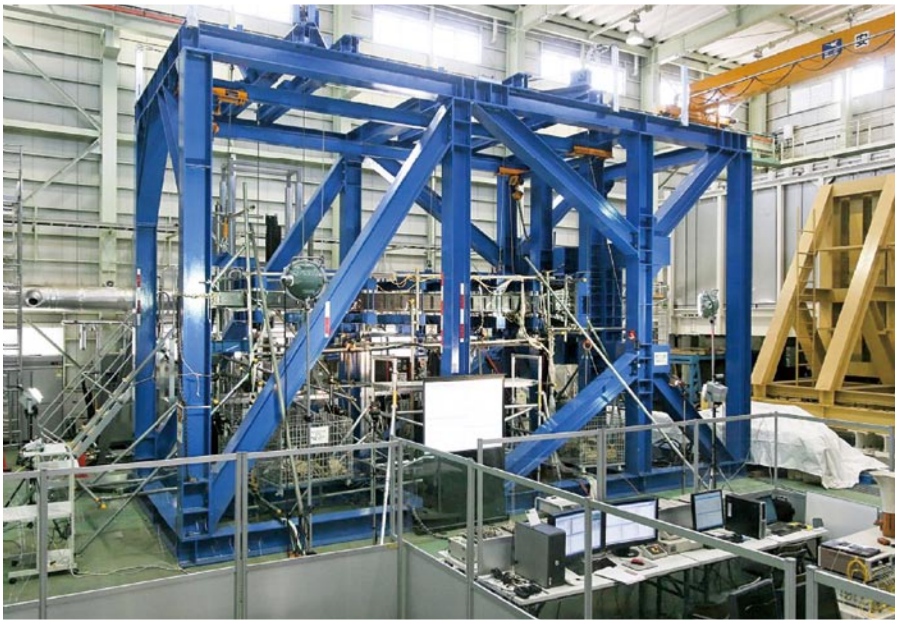


Fig.4 Full-scale test of VaRTM wing structure

●Evaluation of the space environment and its effect on materials

The aim of this research is to determine the durability of space materials. Evaluation technologies have been established and maintained in ACTec for space materials under the impact of the space environment, including hard radiation, ultraviolet rays (UV), atomic oxygen (AO) and electron beams (EB). Figure 5 shows the special test facilities that can simulate the combined space effects of UV, EB and AO. The material data obtained in these studies is also available on the website of JAXA's Material DataBase; http://matdb.jaxa.jp/main_e.html.

●Other efforts (collaborative projects, etc.)

Collaborative research efforts with various JAXA divisions and outside research organizations and universities are ongoing. This category of research topics includes:

- Enhancement of the reliability of composite structures for rockets and satellites
- R & D on composite material structures (main structures, rocket propellant tanks, thermal protection systems, etc.) for future space systems
- Research on a high-efficiency non-destructive inspection and repair technology for aircraft at field maintenance sites
- Miscellaneous research projects underwritten by outside competitive funds

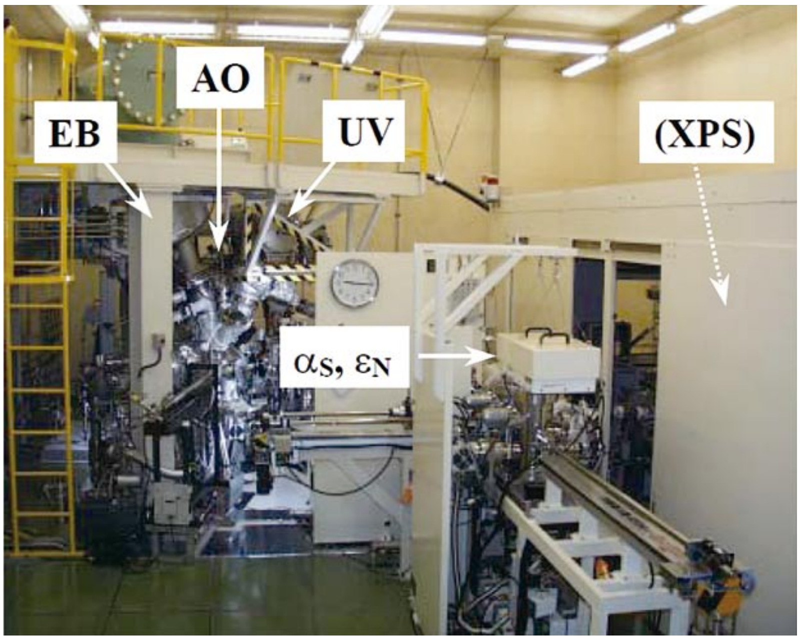


Fig.5 Combined space environment test machine

Aeroengine Technology Center

The objective of the Aeroengine Technology Center (ATC) is to provide advanced technologies and to open large-scale test facilities to the public, thereby enhancing the technological potential of the Japanese aeroengine manufacturing industry. ATC's research primarily deals with environmental technologies for subsonic and supersonic civil aircraft engines. ATC also proposes and demonstrates innovative engine concepts for future propulsion devices.

Goals

Two programs have been initiated with the goal of producing Japan-made, environmentally-friendly aeroengines: the "TechCLEAN" project by JAXA and the "Eco-Engine" project by NEDO, which is a Japanese government agency. To support these projects and to strengthen the world-market competitiveness of Japanese aeroengine industries, the ATC strives to demonstrate advanced technologies. One hardware example is equipment to make simultaneous measurements of the flow velocity distribution and fuel-air mixture distribution in a combustion chamber, which will foster the development of very low NOx combustors with enhanced stability. A software example is a program to predict fan noise, based on large-scale, highly-accurate numerical simulations needed to design commercial aeroengines that are less noisy.

ATC also constructs and operates large-scale test facilities for our own advanced research work, facilities that are also essential for aeroengine development but difficult for the private sector to set up. Therefore they are available for performance tests connected with other national projects.

With a view to the more distant future, we also investigate entirely new concepts for aeroengine propulsion systems. Key technologies have been demonstrated for a hypersonic turbojet engine for flight up to Mach five. An electrically driven alternative aeroengine with extremely low noise and emission has been proposed and its great potential performance has been demonstrated.

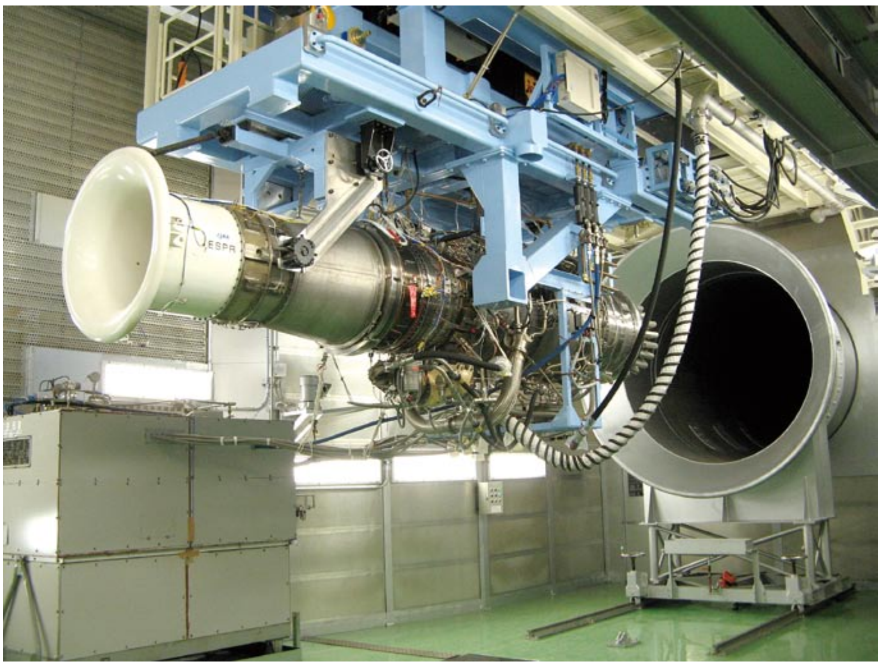


Fig.1 ESPR engine installed in engine test cell

Research Objectives

●Fan Noise Analysis by CFD (Fig. 2)

Fan noise is caused by a combination of three types of physical phenomena involving pressure fluctuation: noise generated by the interaction between rotor blade wakes and stator blades (rotor-stator interaction noise), noise propagated inside the fan duct, and noise radiated from the nacelle. ATC has developed a high-accuracy prediction method for noise generation and propagation by using three-dimensional unsteady CFD (computational fluid dynamics) technology.

Rotor-stator interaction noise is generated at a specific frequency, called the BPF (blade passing frequency), and its harmonics. Figure 1 shows, in the case where twice the BPF (2BPF) is the dominant noise frequency, the 2BPF component of the calculated pressure fluctuation around the stator vanes at mid-height, entry and exit. The solid lines indicate the 2BPF wave fronts. Three-dimensional waves are observed propagating and rotating around the fan.

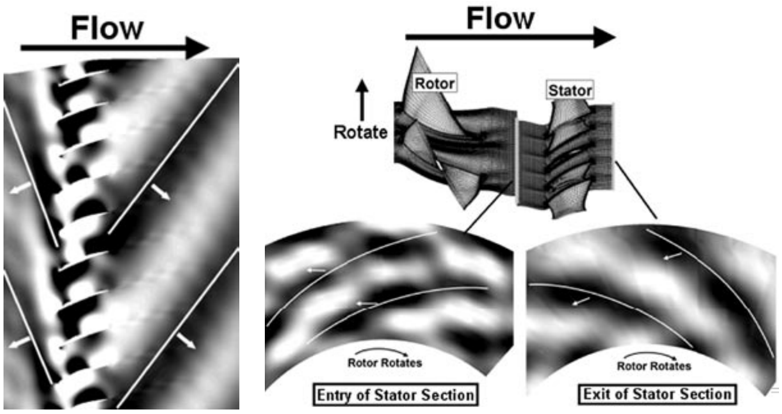


Fig.2 Pressure fluctuation contours around stator vanes showing mid-height, entry and exit.

●Reducing NOx emission from a combustor with an enhanced measurement technique (Fig. 3)

The spatial distribution of fuel, combustion products and flow speed in a combustor can be measured accurately with lasers and the results displayed graphically. A new combustion system for a low-emission engine is being studied to enhance our understanding of combustion phenomena, using detailed data. Fig.3 shows examples of the use of laser-induced plasma spectroscopy (LIPS) in visualizing concentration distribution measurements.

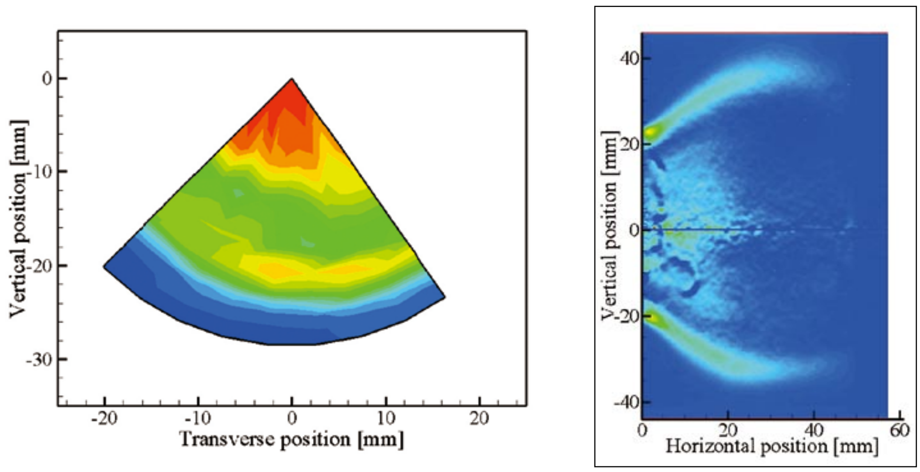


Fig. 3 Laser measurement and visualization of a high-pressure combustion test

Fuel Concentration distribution (LIPS) OH* emission

●Electrical Aircraft Propulsion System (Fig. 4)

ATC has proposed a toroidal outer-shell drive electromagnetic fan as the key element of an innovative aircraft propulsion system designed for enhanced environmental friendliness. Compared with fans in conventional turbofan engines, the newly proposed fan has flexible thrust vector control ability and such distinct advantages as lighter weight and improved energy efficiency that would encourage the introduction of fuel cells as the primary or partial power source. A primary model of the electromagnetic fan has been constructed, and the operational principle of a fan rotor with a rotation coil on its outer circumference casing driven by an excitation coil has been proven.

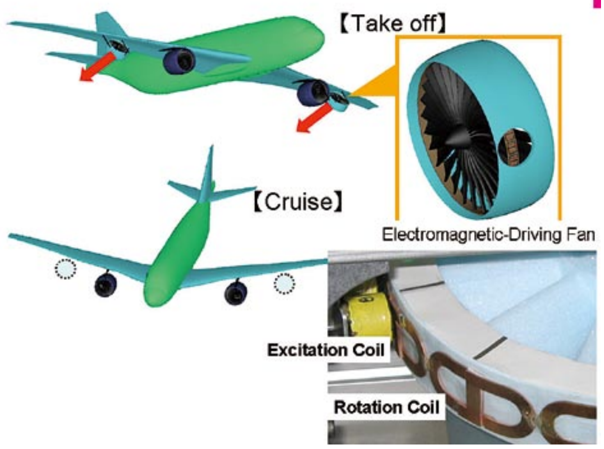
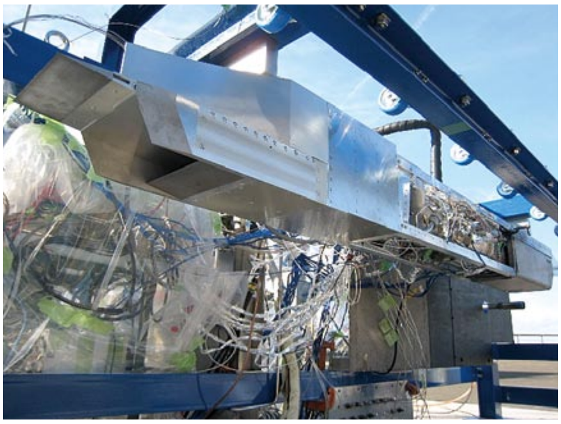


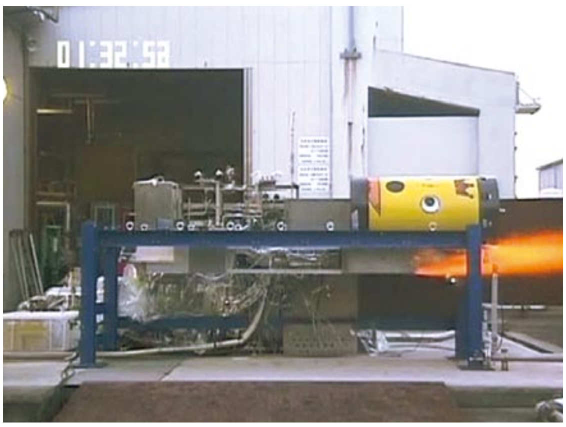
Fig.4 Conceptual diagram of an electric fan engine system and proof-of-principle model

●Research on Hypersonic Turbojet Engine (Fig. 5)

A Mach 5 class hypersonic turbojet engine has been fabricated and tested. The engine has a pre-cooler to reduce the air temperature at hypersonic speed. The starting sequence of the engine to accelerate the rotation speed and initiate pre-cooling has been established. The technology to cool the incoming hot air has been demonstrated using cryogenic liquid hydrogen. Moreover, research on hydrogen fuel control technology has brought closer the practical use of a hydrogen-fuel jet engine, which will have less impact on the global environment.



Hypersonic Turbojet



Firing Test at Sea Level Condition

Fig.5 Hypersonic Turbojet (Sub-scale Demonstrator Engine)

Aeroengine Technology Center facilities

The Center possesses the following testing facilities and makes them available for public use.

A) high-pressure combustion test facility,

B) general-purpose air source facility,

C) sea-level engine test cell,

D) high-altitude engine test facility,

E) annular combustor test facility.

Flight Systems Technology Center

Flight testing and flight demonstration are essential for developing aerospace technology. The Flight Systems Technology Center operates flight test facilities required for research on, and development of, guidance, navigation, and control technologies for aircraft and spacecraft, and flight safety technology. These facilities include experimental aircraft, flight test fields, and flight simulators. The center operates two “flying laboratory” aircraft, called MuPAL (Multi-Purpose Aviation Laboratory), which have been developed to support in-flight evaluations and the development of advanced aerospace technologies. One of them is a fixed-wing aircraft (MuPAL-α), and the other is a helicopter (MuPAL-ε). In addition, the center operates a Queen Air for observation flights. While JAXA’s research aircraft are usually based at Chofu aerodrome in Tokyo, major flight tests are conducted at Taiki Aerospace Research Field in Hokkaido. JAXA’s flight simulators are based in the FSCAT (Flight Simulation Complex for Advanced Technology) facility. JAXA has two simulators, one an airplane simulator (FSCAT-A) and the other a helicopter simulator (FSCAT-R).

In this way the Center participates in JAXA projects and promotes flight system research in collaboration with external organizations. The Center is also carrying out fundamental research on flight systems.

Goals

●Needs-Oriented Research

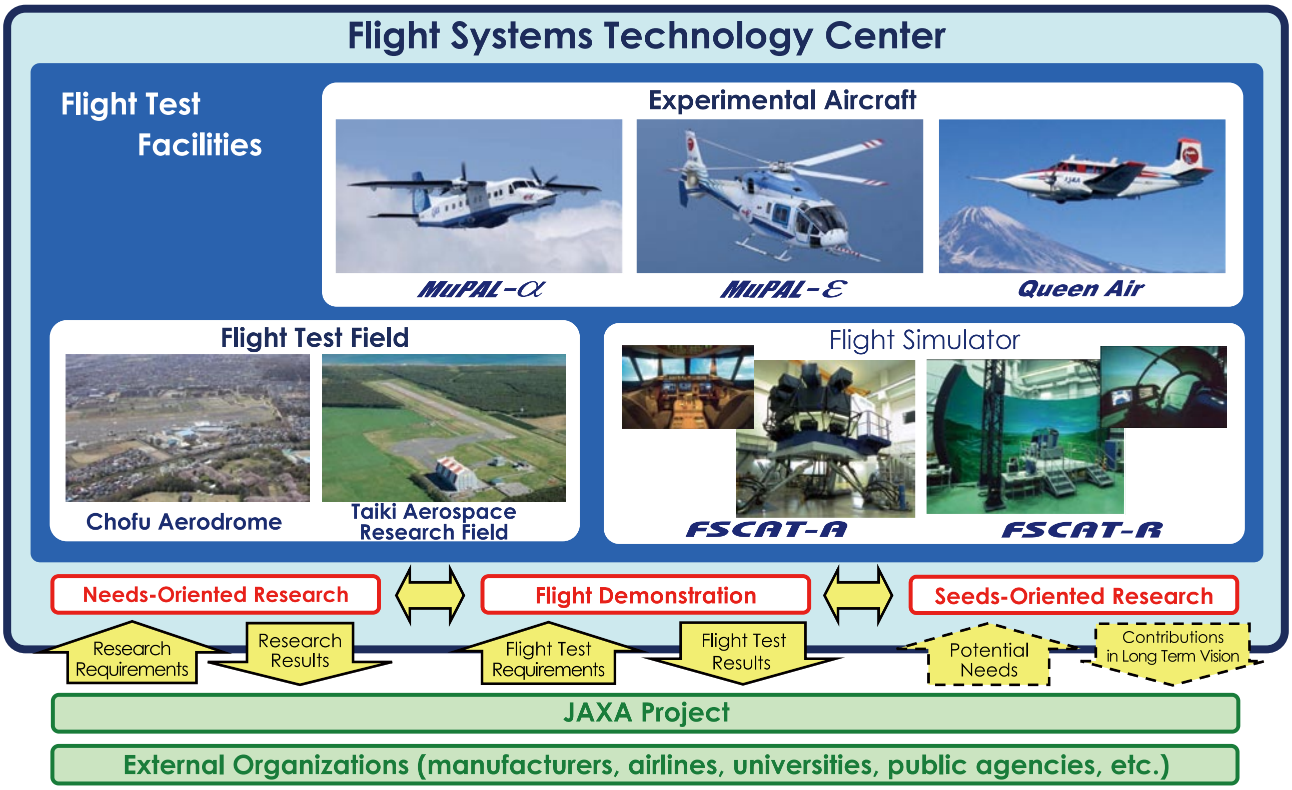
The center promotes research and development in response to needs from both inside and outside JAXA by conducting applied research with the use of fundamental technologies for flight systems, such as flight control technology.

●Seeds-Oriented Research

The center conducts preliminary research on flight systems technologies on an ongoing basis to respond to the long-term needs of society.

●Flight Demonstrations

The Center carries out flight demonstrations to respond to public requests, using its flight test facilities. The center also maintains or improves the flight test facilities to meet the demands of research programs.



Total image of Flight Research Center’s activity

Research Objectives

●Noise abatement flight support system

Noise pollution is one of the major issues that prevent the wider use of helicopters. Especially in Japan, heliports have restricted operations, even though they are critical for responding to social needs such as emergency medical support to/from hospitals. This research is aimed at developing a system to support noise abatement flight in order to relax the restrictions.

Figure 1 shows the results of a first-validated optimal noise abatement system. This onboard system includes a model to predict ground noise in real-time by estimating helicopter source noise as a function of airspeed and the descent angle. Atmospheric conditions are then taken into consideration to estimate propagation effects and ground noise contours. The system automatically computes a low-noise trajectory that minimizes ground noise annoyance using a metric based on the average of noise levels at multiple evaluation points. This trajectory is then provided to the pilot via the "Tunnel-in-the-Sky" display. Effectiveness of the system during terminal operations in an urban area is enhanced by applying a weighting factor for the noise sensitivity of particular areas and facilities, for example, schools and hospitals, to further reduce noise annoyance.

Another use of this system is for news helicopters that fly/hover over a specific area for a long time. High levels of accumulated noise impact can become a major problem. Figure 2 shows an onboard display to inform the pilot of the cumulative noise impact introduced by his own aircraft as a footprint imposed on a map. The pilot will be encouraged to change the flight path, when predicted noise impact levels are about to exceed the prescribed acceptable limits, as determined by the land use.

The feasibility and effectiveness of first-generation systems have been demonstrated in several flight tests. JAXA will continue research to improve accuracy of the noise prediction model, and to develop a practical system retrofittable to general aviation aircraft.

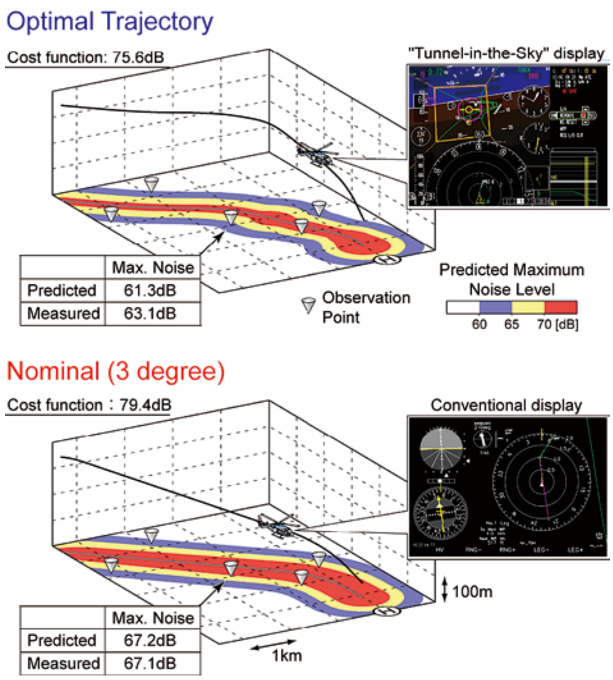


Fig.1 Optimal noise abatement system. The results show a 4dB reduction in the average of the noise levels at 5 observation points.

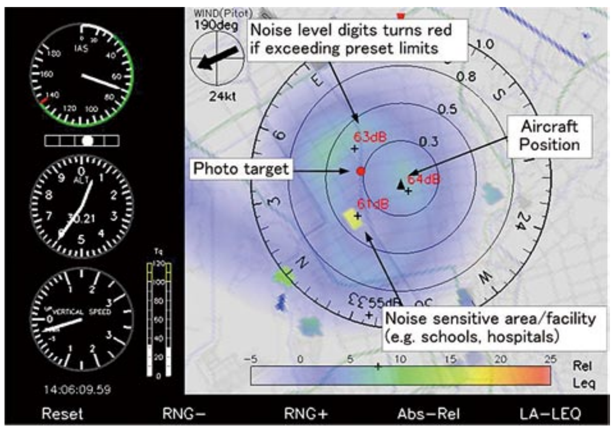


Fig.2 Onboard display of cumulative and instantaneous noise. Pilots can easily avoid causing excess noise where quiet is required, even in unfamiliar areas.

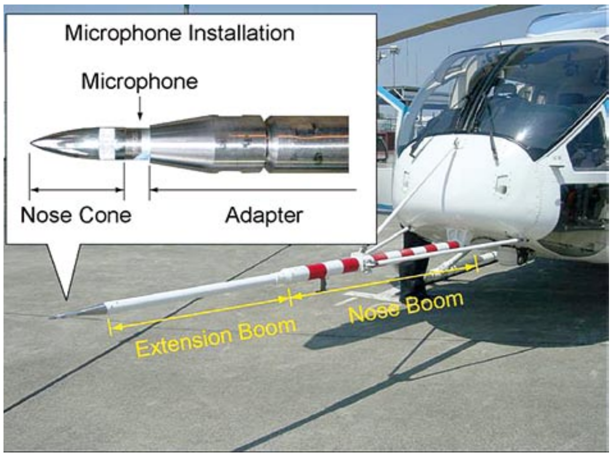
●In-flight measurement of helicopter source noise and atmospheric propagation characteristics

To support the development of this noise abatement flight support system with an accurate ground noise prediction model, precise data are needed on source noise and atmospheric propagation. Since acoustic measurement using ground microphones is affected by the reflection and refraction by the surrounding environment and terrain, JAXA has been conducting flight tests to measure those influences separately and precisely.

One approach is to make use of an onboard microphone (Fig. 3) to acquire "near-field" acoustic data that can be correlated with "far-field" ground noise levels. The body-fixed microphone enables accurate source noise measurement during climb, descent, and turns. Figure 4 shows the source noise levels in terms of airspeed and vertical speed.

Figure 5 shows a flight experiment designed to study noise propagation effects. Microphones were positioned 200 m above the ground using two tethered balloons. The effects of ground reflection/absorption, and refraction due to a wind boundary layer at high altitude were identified with this setup. The results show that the vertical wind profile significantly affects the way sound propagates.

These findings will be incorporated in the future development of noise abatement systems to improve ground noise predictions by taking propagation effects into account.



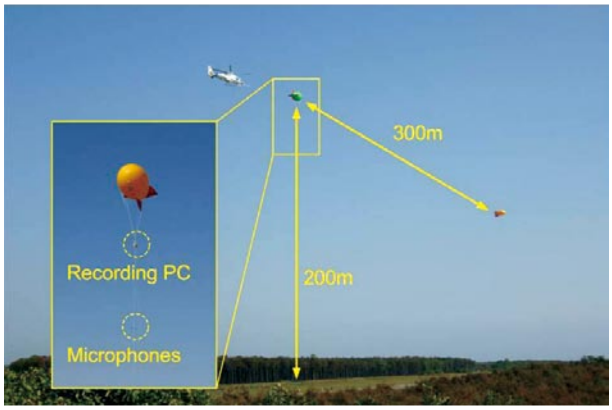


Fig.3 The onboard external microphone. The nose boom was originally used for air data sensors.

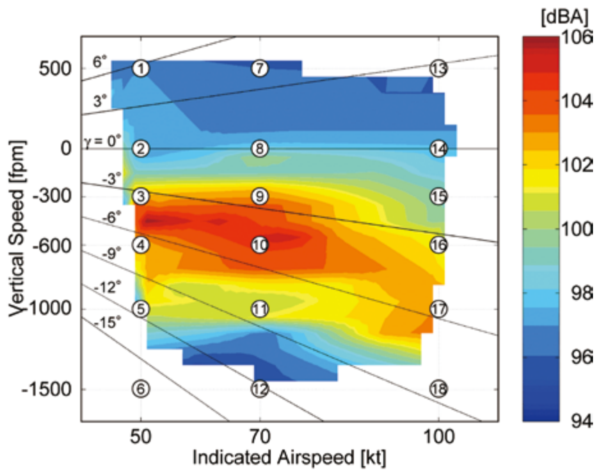


Fig.4 Noise levels obtained by the onboard external microphone. The loudest noise was observed in the normal approach flight condition (airspeed of 70 kt and descent rate of 600 fpm).

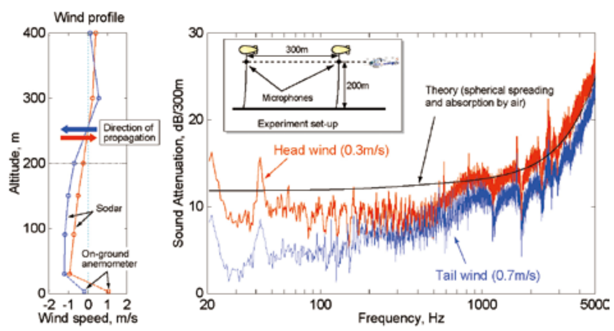


Fig.5 (top) Overview of the acoustic measurement using balloons.
(bottom) Propagation effect of vertical wind profile.

Computational Science Research Group

The Computational Science Research Group is one of the cutting-edge research groups for applied engineering at the Aerospace Research and Development Directorate. Major missions of the group focus on research and development of advanced numerical simulation technologies using high-end computing systems, and their application to JAXA's space and aeronautics programs. To this end, the group is conducting research on simulation technologies and tools for combustion and turbulence, sound and vibration, cross-discipline research including the deep understanding of the fundamental physics involved, and also working on the next-generation computing and networking infrastructure.

Goal

With respect to sound and vibration, we are aiming to construct prediction methods for the acoustic vibrations of a satellite at rocket launch to establish a design methodology for noise reduction. Other research objectives in this field are to understand the mechanism of the noise reduction achieved by sprinkling water on the rocket launch pad, and to construct analysis methods for transonic buffeting and sound propagation at launch. With respect to combustion and turbulence, we aim to simulate the multiple unsteady elements of the combustion injector, and eventually the subscale combustor, by developing combustion models both for super-critical combustion and spray combustion. As for the next-generation computing and networking infrastructure, we are working to develop fast data transfer and file sharing technologies between remote places, and to enhance the efficiency of computation and data manipulation by using built-in hardware features. Finally, in order to make numerical simulations more credible, we plan to establish standards for validation and verification of the simulated results.

Research Objectives

●Research on Simulation of Unsteady Flow/Sound and Vibration

Prediction methods for the acoustic vibrations of a satellite have been developed to improve the reliability of launch mission. One of these is the Wave Based Method, which is a breakthrough method applicable to the mid-frequency range (Fig. 1). Design tools for low-noise high-performance helicopter blade have also been devised to reduce the noise impact on residents in densely populated areas. Combining a generic algorithm and computational fluid dynamics enables us to obtain an optimized blade shape (Fig. 2).

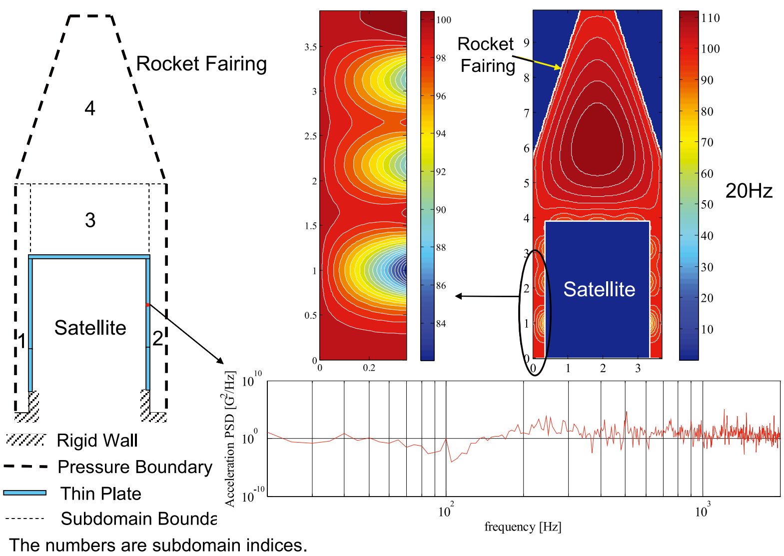
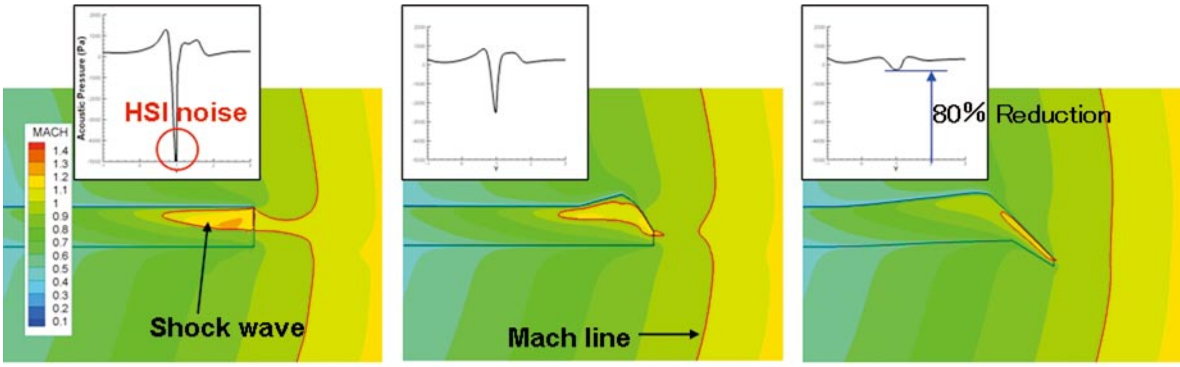


Fig.1 Acoustic environment within the rocket fairing and vibration of the satellite surface.



(a) rectangular tip (b) tip shape developed by NAL (c) optimized tip

Fig.2 Mach contour and sound wave form of conventional and improved blade tip shapes.

●Research on Simulation of Combustion and Turbulence

In order to understand and model combustion-related phenomena in aerospace propulsion systems, fundamental numerical simulations have been carried out. The breakup of fuel droplets has been numerically simulated to improve the understanding of this key mechanism at the first stage of combustion. Figure 3 shows the droplet breakup from a fuel ligament, where propagative capillary waves from the ligament tip pinches off a droplet. The propagative capillary waves are generated at every breakup event and sustain successive self-initiated droplet formation.

Combustion stability is one of the most important issues in combustor design. The three-dimensional combustion field around a super-critical and cryogenic co-axial rocket combustor injector has been simulated to examine the unsteady behavior of the flame, where the detailed chemistry is replaced by a look-up table to reduce the computational cost. Figure 4 shows the instantaneous flame structure in the vicinity of the injector exit.

Detailed flame simulations under atmospheric conditions have also been conducted to elucidate the complicated structure of turbulent flames. Numerical research on turbulence modeling based on the direct numerical simulation (DNS) database is ongoing.

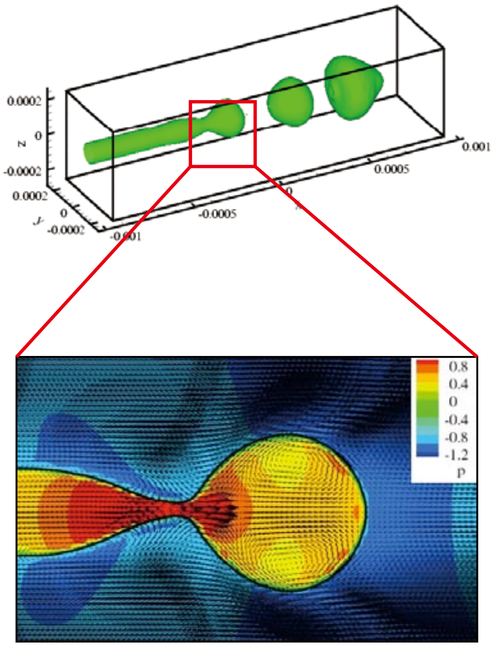


Fig.3 Droplet break-up by a propagative capillary wave.

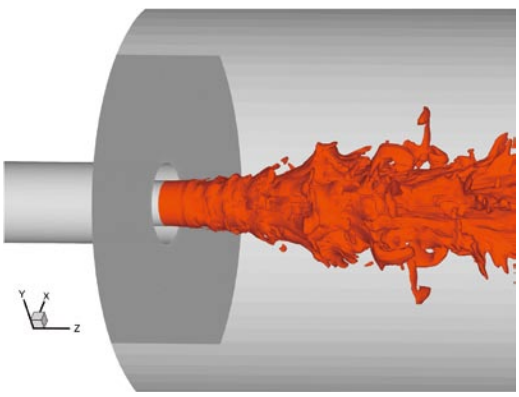


Fig.4 Instantaneous flame structure in the vicinity of a super-critical and cryogenic co-axial injector.

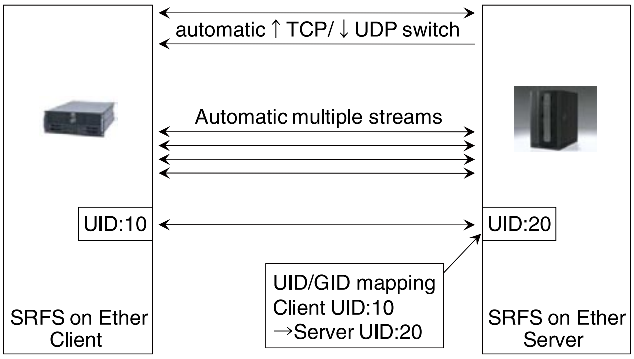


Fig.5 "SRFS on Ether" features

File Transfer Rates:
NFS :0.5MB/s
SRFS on Ether:16MB/s
Visualized AVS data
which is at Japan from
client at U.S.

Fig.6 "SRFS on Ether" vs. "NFS" on AVS

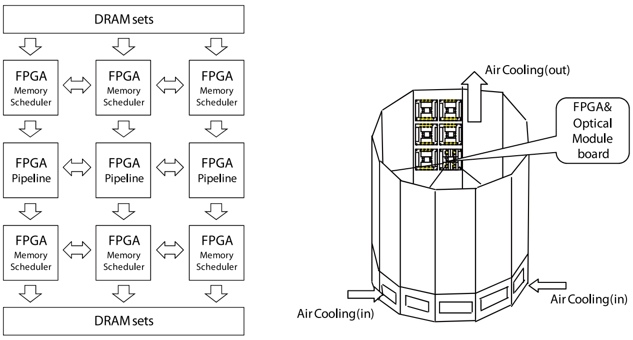


Fig.7 Custom computer research

●Research on High Performance Computing System and Networking

For numerical simulation, it is important to make the most of a high performance computing (HPC) system's capabilities. To improve that capability, the file system, processing elements and networking capacity have been studied.

Since 2002, we have been developing our network file system, named "SRFS on Ether" that permits the use of our HPC-system file space over the Internet. It includes several features to enable fast file accessibility and security: automatic TCP/UDP switch on data transfer, automatic multiple streams generation, and UID/GID mapping (Fig. 5). At SC07, we demonstrated its speed, which was over 30x faster than "NFS" (Fig. 6).

In recent years, the HPC-system has become very highly parallel, so it is difficult to increase its speed and to do efficient parallel programming. Given this situation, we started studying the elements of processing on a custom computer. One clock pipeline and memory scheduling module are being developed (Fig. 7).

Also, in order to use the HPC-system on the Internet, which is not a secure environment, we are working on network security, in particular on IDS: Intrusion Detection System. Fig. 8 shows "CABOX" which has a hardware-accelerated intrusion detection engine and incorporates patented JAXA technology.

Fig.8 IDS system: "CABOX"

●Research on Validation and Verification of Numerical Simulations

Any numerical simulation of practical value is a complex combination of several different models that include equations describing the physics or other machinery of targeted phenomena and their discretizations to be coded into the numerical simulation. Verification and validation are essential to improve the credibility of a simulation, and their scope extends over numerous academic subjects or research fields. To improve our simulation's credibility, we have been conducting research to verify or improve the model equations and discretizations. We intend to extend this research activity to establish a comprehensive framework for credibility so that the overall quality of our numerical simulation is validated as adequate for practical use in engineering.

Spacecraft Guidance, Control and Dynamics Engineering Group

Guidance, navigation and control (GNC) are fundamental and essential technologies for all spacecraft including artificial satellites, deep space probes, and rockets. The Spacecraft Guidance, Control and Dynamics Engineering Group promotes the development of the enabling technologies to control the attitude and orbit of spacecraft for current and future JAXA space missions.

Goals

The group has three goals. The first is the development of sensors and actuators for attitude/orbit control of spacecraft. Our policy is to use domestic GNC products as much as possible to secure the autonomy of national space activities in Japan. The second is to provide solutions to technical problems relating to GNC that ongoing JAXA missions are routinely faced with. We contribute to the missions with numerical analysis and/or performance tests of GNC hardware. The third is to contribute to mission analysis and design of JAXA's new space missions as the GNC technology expert group. GNC usually plays a key role in the conceptual design of new missions, so we are performing analysis, survey and research to provide the basis for GNC systems that can make new concepts into reality.

Research Objectives

●High-performance Autonomous Star Tracker

Recent technological advances in computers enable second generation star trackers that can autonomously identify stars and estimate attitudes without any a priori information. Based on the expected requirements of future satellite programs and observation of technological trends, we have been working on the next generation star tracker. It can perform autonomous attitude determination with high accuracy. The research model has been completed and its performance evaluated.

Fig.1 High-performance autonomous star tracker research model real sky test

Fig.2 High-performance reaction wheel long-term operation test

●High-performance Fiber Optical Gyro

All satellites developed by JAXA have until now used a mechanical tuned dry gyro (TDG) to determine attitude. For future missions we are looking into a fiber optical gyro (FOG) as the next standard for Japanese satellites because it has fewer mechanical and moving parts and creates less disturbance. It can be engineered for very low noise emission, stable bias and stable scale factor. Our primary target is the best angular random walk performance in the world. An engineering model is currently being performance tested.

●High-performance Global Positioning System (GPS) Receiver

In recent years an on-board GPS receiver (GPSR) has performed many important functions on spacecraft and rockets. Moreover, with GPS modernization new civil codes on the L2 and L5 frequency bands will be added and performance will be upgraded. To comply with the emerging technical need for space-borne GPS receivers in Japanese space missions, JAXA has been studying a next-generation multi-frequency small space-borne GPS receiver that can track the new GPS signals, including L2C and the new code on L5. The key technologies for the downsizing are now under investigation, including the direct sampling method and CMOS SOI device.

●High-performance Reaction Wheel

A reaction wheel is an essential component of spacecraft attitude control. Malfunction of the reaction wheel will lead to loss of the proper attitude, so its reliability is paramount. Based on lessons learned from past failures in orbit, we have been working to improve reliability with research on tribology. We have developed an advanced reaction wheel with highly reliable ball bearings, which is now undergoing long-term operation testing.

●Rendezvous, Docking and Formation Flying

JAXA has accumulated a large body of knowledge and experience with respect to spacecraft rendezvous and docking technologies. The autonomous rendezvous and docking experiment "ETS-VII" was successfully completed in 1997. The Japanese autonomous rendezvous bringing cargo to the International Space Station "HTV" is scheduled and under development. As an extension of these technologies, we are studying relative navigation technologies for spacecraft formation flying. Advanced image navigation sensor development and theoretical analysis of relative navigation and control have been carried out for future multi-spacecraft missions.

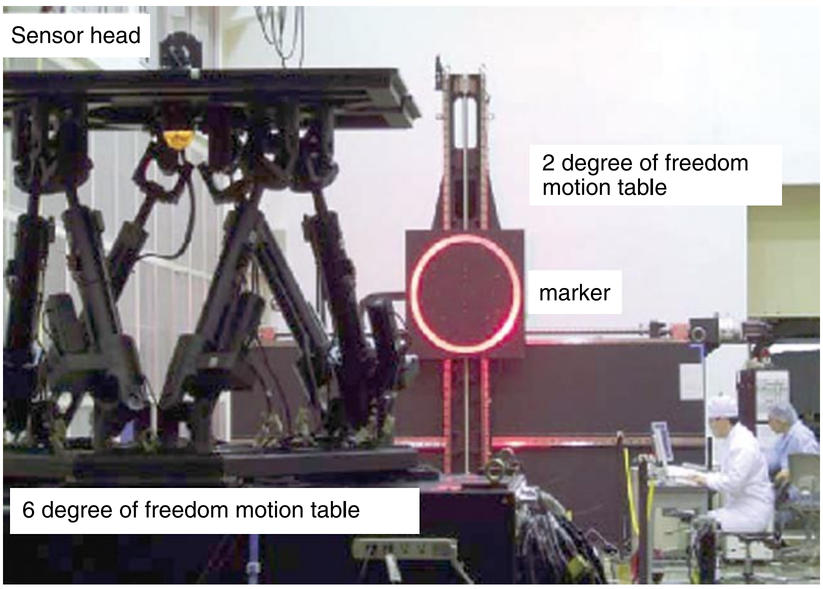


Fig.3 Test of the image navigation sensor

Space Power Engineering Group

Image of a satellite

The Space Power Engineering Group offers practical solutions to enhance the reliability and performance of electric power systems and power generating solar paddles for space applications by reducing their size and weight. The main research themes are as follows.

1. Research on the technology of electric power systems and batteries for spacecraft
2. Research on solar cells and solar paddle systems

Goals

The group aims to realize comprehensive electric power systems, including solar paddles, to secure success in current and future space missions. Such systems must be developed to make spacecraft lighter as well as to provide flexibility for a wide variety of space missions.

●Production of electric power systems with reduced-weight, higher-reliability, higher-performance power control components—as well as lightweight, high-performance secondary battery cells.

●Production of small-area, lightweight, low-cost and durable solar panels/paddles—utilizing high-efficiency, radiation-hardened solar cells and also a lightweight solar paddle structure optimized for flexible thin-film solar cells.

Research Objectives

●Development of highly reliable, small and lightweight electric power systems

We are pursuing not only the realization of high-reliability and lightweight systems (twice the specific power as that of conventional EPSs), but also bus-architecture improvement, mounting-technique modification and bus-voltage optimization. This is in response to the specific requirements of space missions. Also, we are optimizing power-control component design, by means of fabrication and performance evaluation of prototypes.

●Life cycle testing of lithium-ion batteries simulating operation in space

For practical use, we are evaluating high energy density lithium-ion batteries (twice that of conventional alkaline batteries such as Ni-Cd, Ni-MH and Ni-H_2), mainly in terms of a cycle-life performance test.

Fig.1 Lithium-ion battery assembly

A lithium ion battery with 10 cells (100 Ah) connected in series is shown in fig.1. The energy density of a cell is 135 Wh/kg, and that of the battery assembly is 80 Wh/kg.

We have more than 50 pieces of battery test equipment, and evaluate batteries under a variety of operational conditions simulating in-orbit performance. Evaluations of charge (sunshine mode) / discharge (shading mode) cycles are performed with real-time operations, that is, the cycle time is the same as that in actual low Earth orbit (LEO) or geostationary Earth orbit (GEO). In 2007, we have confirmed a cycle-life test corresponding to 7 years (40,000 cycles) in LEO, or 20 years (1,800 cycles in eclipse mode) in GEO. The experimental data are shown in Figs. 2, 3, respectively. The test of LEO simulation is still underway.

Qualification Tests were performed and completed for large capacity lithium ion cells manufactured by GS Yuasa Technology Ltd.

We are also studying improved cells with higher energy density and longer cycle life.

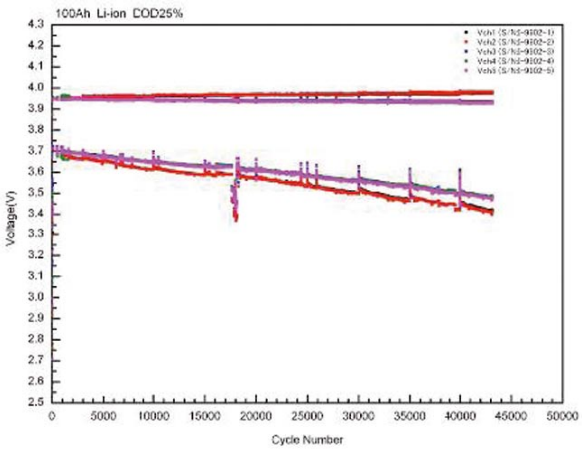


Fig.2 LEO simulation test.
5 cells (100 Ah) connected in series.

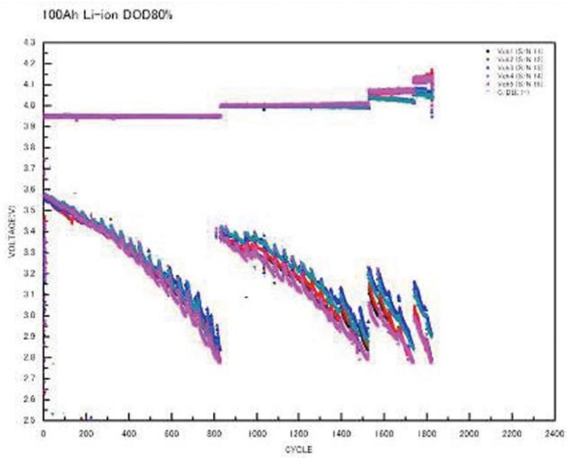


Fig.3 GEO simulation test.
5 cells (100 Ah) connected in series.

●Development of a Thin Film Solar Cell for space

To meet the needs of lightweight and high-power spacecraft, solar paddles have to shrink in weight and stowage volume. To meet this need, we are currently developing thin-film solar cells for use in space. We aim to produce thin film solar cells that are highly efficient, radiation-hard, lightweight and flexible, using III-V compound solar cells, specifically InGaP and GaAs, as component sub-cells in a dual-junction tandem structure. As another option, a $CuInGaSe_2$ thin-film cell is being investigated. This cell has been developed for terrestrial use, but we discovered that the $CuInGaSe_2$ cell has super-high radiation resistance. Several in-space demonstrations of the cells are underway. In addition, we are studying the radiation degradation behavior of the solar cells.

We are also studying high specific-power solar paddles, which take advantage of the properties of the thin-film solar cells described above.

●Evaluation of charge/discharge phenomena occurring in solar paddles

We are trying to clarify charge/discharge phenomena occurring on solar paddles in the space environment to enhance paddle durability by reducing damage due to discharge.

We have developed a plasma chamber for charge/discharge tests specifically to verify the durability of LEO satellites' solar panels against electrostatic discharge. We are trying to measure the material properties important to engineering design optimization and charging on spacecraft.

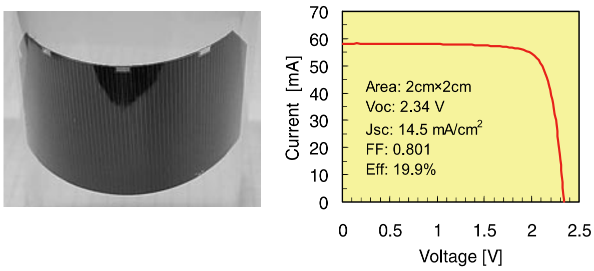


Fig.4 A prototype InGaP/GaAs dual-junction thin film solar cell and its current-voltage output characteristics.

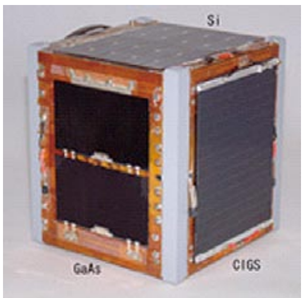


Fig.5 The micro-satellite "Cubesat XI-V" developed by the University of Tokyo. One mission of the satellite is to demonstrate the super-high radiation resistance of a $CuInGaSe_2$ solar cell.

Fig.6 Plasma chamber

Spacecraft Propulsion Engineering Group

The most significant duty of the Spacecraft Propulsion Engineering Group (SPEG) is to build reliable and high-performance propulsion subsystems for spacecraft. In pursuit of this goal, SPEG supports the development of propulsion subsystems by the project teams responsible for JAXA's current space missions such as GOSAT, Greenhouse Gases Observing Satellite, and HTV, H-II Transfer Vehicle.
Other areas of responsibility for SPEG include the construction of robust and durable propulsion components and propulsion subsystems, and providing them to spacecraft projects.

Goals

For almost all spacecraft, any malfunction in propulsion subsystems could preclude the success of the mission. Thus the ultimate duty for SPEG is to provide high-reliability propulsion subsystems for spacecraft. SPEG activities currently focus on:
(1) The development of propulsion subsystems and components for JAXA spacecraft, and,
(2) The development of technologies necessary to improve the reliability of such subsystems and components

To achieve these goals, SPEG provides high-reliability propulsion subsystems by evaluating the engineering process of each spacecraft, and implementing research activities to improve their reliability, based on our daily evaluation activities. Components for which we are responsible include tanks, valves, mono- and bi-propellant thrusters, apogee kick engines, ion engines and various sensors. We are involved with internal project teams from the earliest phases of a mission, through design meetings, propulsion subsystem integration testing, system-level environment testing, launch site system checks, propellant loading, and pressurizing the spacecraft.
SPEG is also developing advanced propulsion components such as a next-generation ion engine. It is expected to bring the higher power and longer operating life required for a next-generation high-performance propulsion system, that will be used in heavy geostationary satellites and deep-space probes.

SELENE

WINDS

Fig.1 Project support at the Tanegashima Launch Site

Research objectives

● The High Reliability Monopropellant Thruster Valve

A 20N-class monopropellant thruster valve has been developed by SPEG under the Japanese space components supply restructuring program.

We aim for this valve to have high reliability and a robust design. The GD³, which is the TOYOTA motor company qualification control method, has been applied to the design and development process of this valve on trial.

The valve features:

1) Solenoid type operation: This thruster valve is a solenoid type valve.

2) Suspended armature configuration: The armature (plunger) is suspended by an "S-Spring", which is a kind of leaf spring, not with a coil spring. There is no friction surface between armature and casing. This design contributes to long life performance and reduces the generation of contaminants.

The qualification and marginal performance tests have been successfully completed. A 1,000,000-actuation test has shown no performance degradation.

Fig.2 High reliability monopropellant thruster valve

Table Typical specification

Property	Spec value
Compatible fluid	N_2H_4, MMH, GHe, GN_2, H_2O, IPA
Pressure	
operation	0 to 2.8 MPa
proof	7.0 MPa
Flow rate	12.7g/s with N_2H_4
Pressure drop	0.17 MPa
Internal leakage	< 1×10^{-6} Pa・m^3/s
Operating voltage	23.5 to 32 VDC
Power consumption	35W @32 VDC
Response time	Open: <15 ms Close: <10 ms
Temparature	5 to 121 degrees C
Cycle life	Wet: 1,000,000 cycles Dry: 50,000 cycles
Weight	< 300 g
Delivery date	6 months

● The Next-Generation High-performance Ion Engine

This engine has already demonstrated a remarkably high thrust-to-power ratio, which is convenient to compensate for air drag on satellites in ultra-low earth orbits. One of our tasks is extending the long thruster's life to 30,000 hours and we have developed graphite hollow cathodes to accomplish this. An endurance test of the cathode has continued since March 2006 and the accumulated operating time exceeded 16,000 hours in May 2008. An endurance test of a thruster is in preparation.

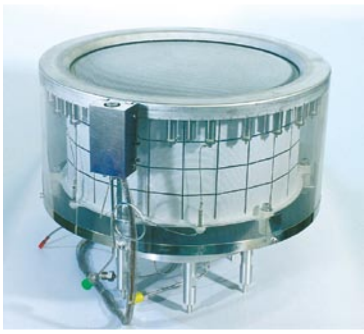


Fig.3 Next-generation ion engine

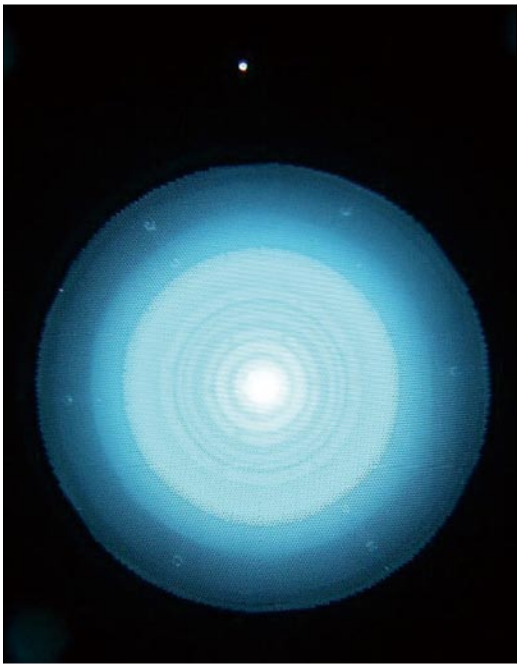


Fig.4 Luminescence of thruster in operation

Electronic, Mechanical Components and Materials Engineering Group

The mission of the Electronic, Mechanical Components and Materials Engineering Group is to establish fundamental technologies and enhance the reliability and the performance of space electronic parts, materials, mechanical elements and space equipment — the lifeline items for space exploration. This involves extensive research and development of the components required for Japanese space exploration programs. We also maintain databases of existing space parts and materials and keep them continuously updated using data from demonstration satellites and ground tests. Other research topics include space demonstration tests of materials and mechanical elements, and cooperative evaluation of mechanical elements and materials used in individual projects. In addition, the group also deals with the safety of space materials and equipment for manned space travel, and safety demonstration experiments.

Goal

For future space activities, certain electronic parts and mechanical components have been identified as key elements that should be domestically available. An extensive range of such parts/components is being developed by the group to establish a self-supporting infrastructure for Japanese space programs.

Fundamental parts technologies include design technology, manufacturing technology and mounting technology. In the design technology area, the group is studying radiation hardening technology and reliability assurance technology for electronic parts. In particular, a series of radiation-hardened advanced semiconductor devices developed by the group will serve as key components for future space activities. In the manufacturing technology area, the group is researching the efficient and low-cost manufacturing of various parts by small-lot production, and technology for making full use of commercially available parts. In the mounting technology area, the group is researching equipment assembly in efforts to reduce size, weight, power consumption and cost, while enhancing functionality.

Mechanical components such as ball bearings and slip rings sometimes cause significant failures of satellites in space. The basic phenomena of lubrication comprise one of the most important areas where improved understanding can enhance mechanical reliability. Some life testing is conducted in a vacuum environment to evaluate the design parameters of mechanical components.

To improve the efficiency of our research on these fundamental technologies, we are working strategically in collaboration with industry, academia and the government.

Requirements for space materials will become more varied as the range of space activities becomes broader. The group continues to promote R&D in advanced materials to meet such new requirements. Ground-based evaluation techniques for materials for space use is an important requirement both for these R&D activities and individual projects. Improvement of such evaluation technique is also our mission.

Fig.1 Parts developed for space (Left: 36 Mbit synchronous burst SRAM, Right: power MOSFET)

Research Objectives

●Development of Electronic Parts

The group mainly develops electronic parts of highly strategic significance and evaluates their quality (Fig. 1).

In JFY2007, the main projects of the group were the following:

Firstly, 36 Mbit synchronous burst SRAM was developed and fully qualified as meeting JAXA's QML standards. It realizes 100 MHz synchronous operation for use with a high-performance 64 bit MPU. The address decoders and the cell blocks are separated to prevent multi-bit SEUs in one word. All errors are correctable by the EDAC on the MPU.

Secondly, the development of N-channel MOSFETs was completed. These radiation hardened MOSFETs achieved the lowest $R_{DS(ON)}$ and are used for power supply modules with rated voltages of 100,130,200,250 and 500 V. The family includes the package types TO-254 and SMD.

Also, SOI[1] ASIC based on 0.15 μm commercial SOI technology is under development, and will be used for the GEO bus for the next generation.

[1]SOI: Silicon On Insulator

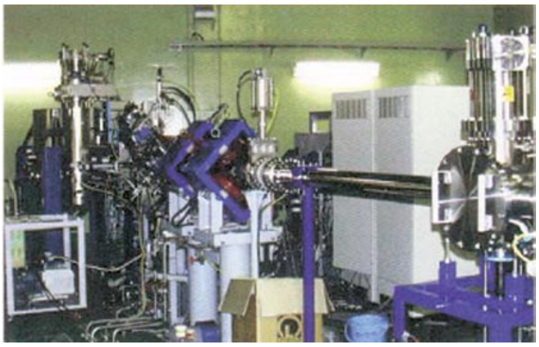


Fig.2 Irradiation equipment for single-event evaluation(At the Takasaki Research Institute of the Japan Atomic Energy Agency)

●Radiation-Hardening Technology for Electronic Parts

The radiation in space strongly affects electronic parts. Robust radiation-hardening technology is therefore essential for electronic parts for rockets and artificial satellites. Smaller parts with improved functions and lighter weight are also increasingly required, as is cost optimization for spacecraft in general. Unfortunately, smaller parts are usually more sensitive to radiation. As tolerance for radiation is a space-specific requirement, the group is now studying radiation-hardening technology for advanced parts to be used in spacecraft (Fig. 2).

●Research on the Applicability of Commercial Electronic Parts to Space Use

The group is investigating the usability of commercial electronic parts and mounting technology. We also study testing methods, the key factors to evaluate, and flight demonstrations in space. Efforts are also underway to refine various elementary technologies, to reduce the size and to enhance the functionality of space electronic equipment.

The group has started the study and development of MEMS[2] for downsizing and multifunctional spacecraft. MEMS integrate electrical functions and mechanical structures at the micro scale. COTS MEMS, such as acceleration sensors and RF switches, are under evaluation for space application.

Three dimensional (3-D) integration technology and packaging technology are also under development for further miniaturization of electronic components, especially for CPU boards. So far, chip stacking technology has been applied to the 36 Mbit burst SRAM, which includes four chips formed of two units, each unit consisting of a vertically-stacked structure of two chips (Fig.3).

[2] MEMS : Micro Electro Mechanical Systems

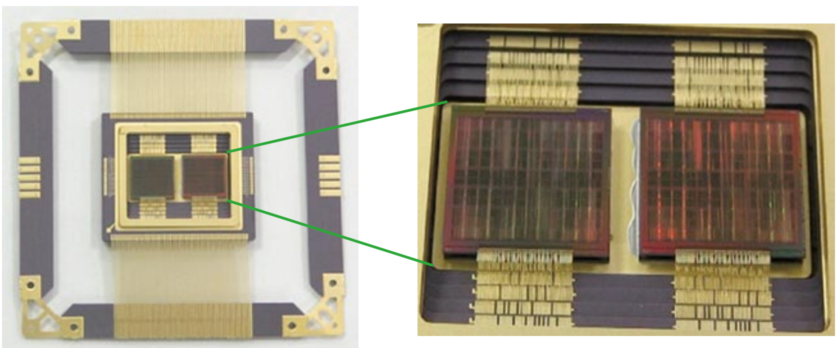


Fig.3 Stacked structure of 36 Mbit synchronous burst SRAM (Top view)

●Space Demonstration Experiment

JEM[3)]/SEDA-A[4)]/ EDEE[5)]

EDEE is planned to be equipped with SEDA-AP, one of the experiment payloads connected to JEM's external experiment platform, and to observe single event phenomena due to charged particles that significantly affect electronic parts (Fig.4). The evaluated parts are frequently used for JEM and may encounter such phenomena. The EDEE measurement helps us in identifying causes of trouble with JEM. The result also gives us a calibration for the radiation test on the ground, enhancing the accuracy of the test. EDEE and SEDA-AP will be delivered during the STS-127 Mission (2J/A) in JFY 2008.

3)JEM: Japanese Experiment Module, Kibo

4)SEDA-AP: Space Environment Data Acquisition equipment- Attached Payload

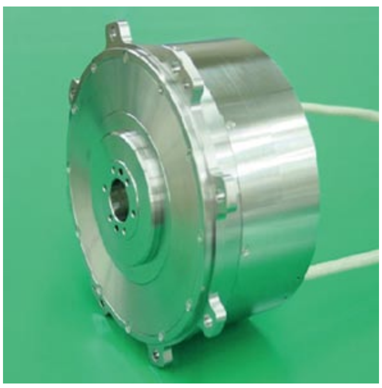
5)EDEE: Electronic Device Evaluation Equipment

Fig.4 Electronic Device Evaluation Equipment (EDEE)

●Research on Mechanical Elements for use in Space

In its ongoing work to develop mechanical elements that operate reliably in severe space environments, the group is evaluating the properties of mechanical elements under simulated space and rocket-launch environments. This includes evaluation techniques and research on fundamental technologies such as vacuum tribology. The group is also finding ways to improve the performance of mechanical elements commonly used for important mechanical functions in satellites, such as harmonic drive gear and resolvers. (Fig.5).

Harmonic drive gear



Resolver

Fig.5 Harmonic drive gear and resolver for space use

Fig.6 Combined space effects test facility
(electron beam, ultraviolet ray, and atomic oxygen irradiation facility)

●Research on Space Materials

The group is investigating the effects of elements of the space environment such as radiation, ultraviolet rays, atomic oxygen, and other phenomena on materials, utilizing ground simulation facilities (Fig.6). We are also researching and developing state-of-the-art materials such as shape-memory polymers, and a resin resistant to atomic oxygen.

●Space Demonstration Experiment on Materials and Research on Contamination

The group conducts materials exposure experiments utilizing the International Space Station (ISS) to evaluate the degradation behavior of materials by exposing them to space (Fig.7).

Through comparison between results in the space experiments and that in the ground simulation tests, we improve the ground simulation techniques. In addition, the space experiments add to our knowledge of contamination phenomena in orbit. The group has developed a contamination analysis tool "J-SPICE" to estimate the contamination level for individual projects.

Fig.7 The latest space materials exposure experiment on the ISS

Space Structures Engineering Group

Various pieces of equipment mounted on the inside of a satellite can disturb the microgravity environment and vibrate during operation in orbit. Such vibration may have a very low amplitude and broad frequency range, and this internal disturbance is often called microvibration. Reaction wheels, inertial reference units, control-moment gyros, pumps for coolers, solar paddle drive mechanisms and antenna pointing mechanisms are typical sources of microvibration. Satellites usually mount several optical instruments that require very high pointing accuracy and stability. Microvibration during their operation causes blurring of images that must be corrected by the instruments or that generate error signals.

Another type of disturbance in orbit is thermal load, which can influence the performance of sensors and antenna subsystems. Temperature changes can cause deformation of antenna reflectors and support structures, and then this may degrade gain as well as corrupt their pointing direction to an extent unacceptable for the mission. The larger the coefficient of thermal expansion (CTE), the larger the thermal strain. When a structure is composed of different materials, mismatched CTE causes large deformations called bimetallic effects.

The Space Structures Engineering Group has been studying control technology for microvibration and developing composite structures with minimal thermal-change distortion to produce high-reliability designs for satellite systems.

Goals

Internal disturbance has been controlled as a special task for each satellite project individually, but a unified strategy is preferable. In some cases, the fatal effects of internal disturbances cannot be detected earlier than at system integration. Therefore, measurement and control methods for microvibration must be established for design not only at the system level but also the subsystem level.

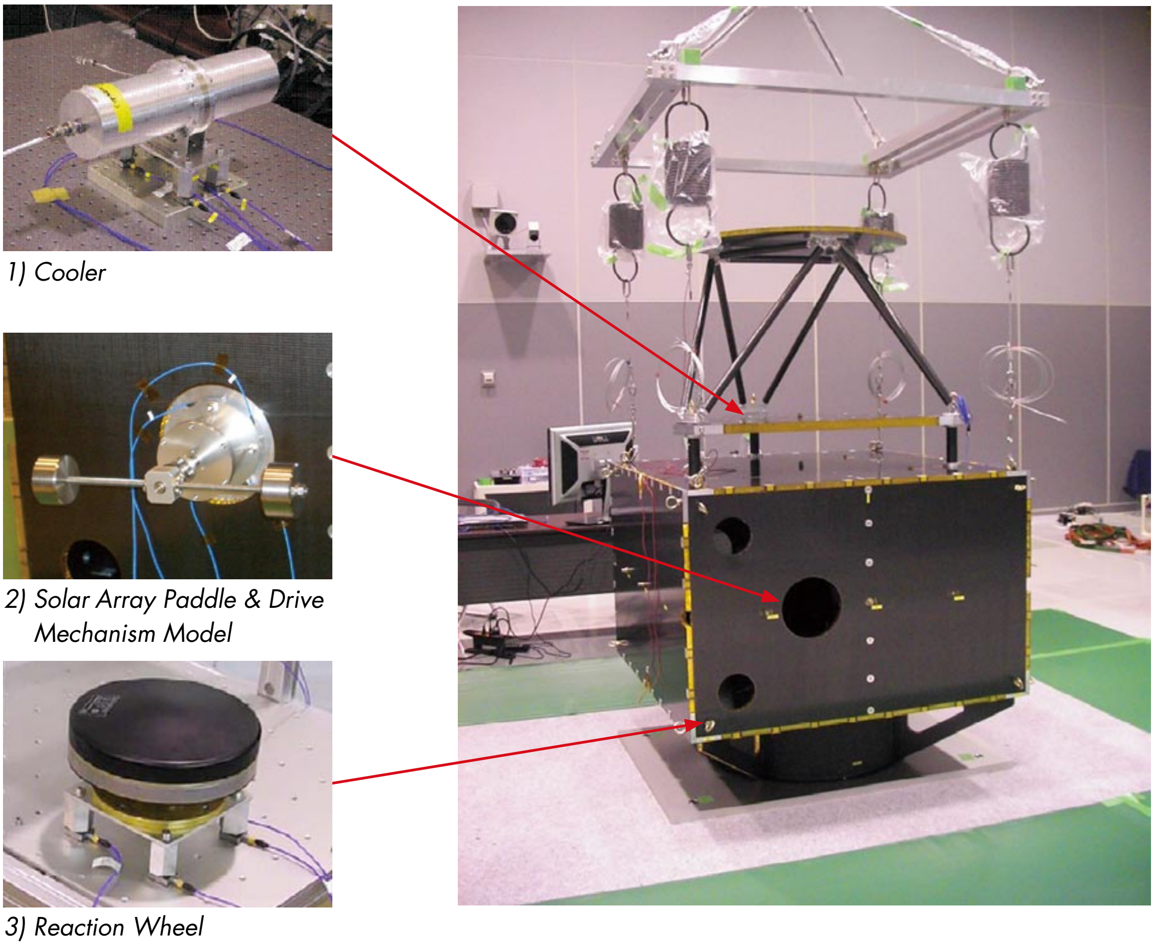
In contrast, thermal distortion should be controlled in the early design phase. The higher the frequency used for communication, the more severe the requirement for surface accuracy of antenna reflectors. Therefore, it is important to investigate the mechanism of thermal deformation and establish modeling methods for analysis and design when very high frequencies are used.

The Space Structures Engineering Group has been studying prediction and control methods for microvibration and thermal distortion not only analytically but also experimentally. Hardware is also investigated in order to suppress internal disturbance at the source. Moreover, lightweight carbon composite structures with minimal CTE are being investigated as antenna or telescope structures. The outcome of these studies will contribute to the more advanced missions scheduled for the future, whose requirements for observation and communication will be extremely demanding.

Fig.1 Laboratory-Scale Specimen with a Reaction Wheel for Microvibration Transmission Measurement

Research Objectives

Microvibration is transmitted from disturbance sources to mission components via the satellite's main body, and influences the performance of sensors. In order to control the internal disturbance, the transfer function has to be obtained to evaluate the transmissivity of the structure for the microvibration. For the first step of the study, a laboratory-scale structure was manufactured as shown in Fig.1, and the transmissivity was evaluated. Ultra-sensitive accelerometers, jitter sensors, and 3-component force sensors were utilized to measure the transfer function. Moreover, the disturbance forces and torques from a reaction wheel and a cooler were measured by 3-component force sensors, and spectrum data have been stored in a database. If the transfer function from a disturbance source to mission components, and the spectrum of the disturbance, are known, their influence on mission components can be evaluated analytically before system integration. Finally, the disturbance sources were mounted on a carbon composite satellite model as shown in Fig.2 and the transfer functions were measured and analyzed.



1) Cooler

2) Solar Array Paddle & Drive Mechanism Model

3) Reaction Wheel

Fig.2 Satellite Structure Model Suspended in Midair by Springs for Microvibration Transmission Measurement

A carbon fiber reinforced plastic (CFRP) structure with CTE as low as 1×10^{-7}m/m/K has been designed and demonstrated as a thermally stable reflector (Fig. 3). The reflector surface accuracy was investigated in relationship to the composite structure and manufacturing conditions.

In addition, the Space Structures Engineering Group supports satellite projects for developing components and systems. The most recent activity was the microvibration testing of the thermal and near-infrared sensor for carbon observation (TANSO) - a Fourier transform spectrometer (FTS) for the Greenhouse gases Observation Satellite (GOSAT). In order to establish a testing method for the engineering model, a breadboard model (BBM) was used to investigate the feasibility of the test. The schematic configuration of the test is shown in Fig.4 The BBM was mounted on a vibration-isolated workstation, and milli-g level acceleration was induced by a small electrodynamic shaker located behind the workstation bench and measured by ultra-sensitive accelerometers to evaluate the transmissivity from the base mounted on the workstation bench to components on the optical bench. The input acceleration was increased gradually until error signals appeared, and the sensor's tolerance for microvibration was evaluated.

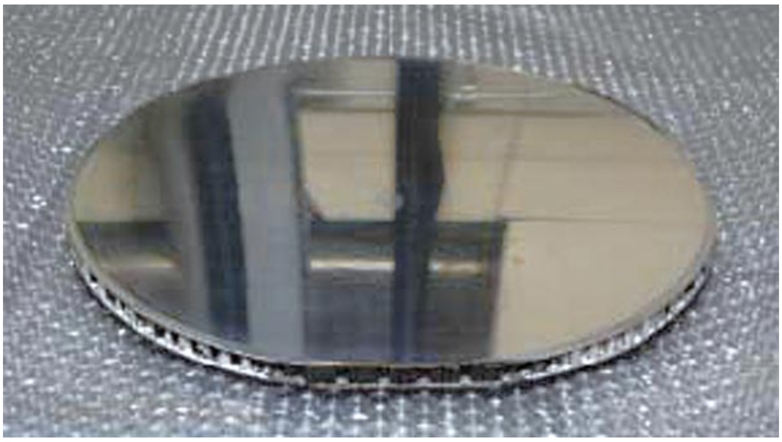


Fig.3 High Precision Mirror of CFRP / CFRP Honeycomb Core Sandwich Structure

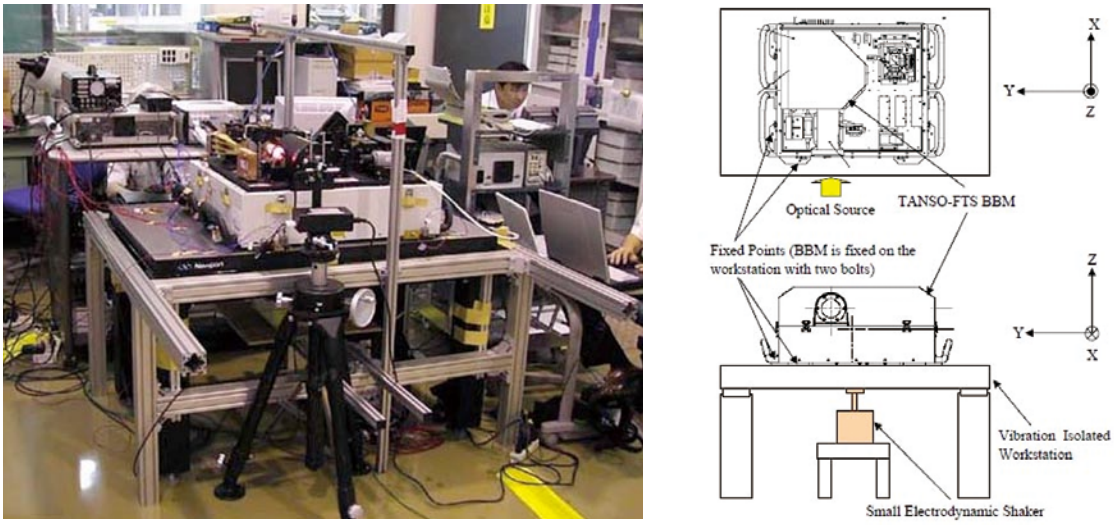


Fig.4 GOSAT TANSO-FTS BBM Microvibration Test Setup

Spacecraft Thermal Engineering Group

Thermal control technologies are generally used to maintain spacecraft component temperatures within the desired range while in orbit. The Spacecraft Thermal Engineering Group studies thermal control systems (TCS) with high performance and high reliability to meet the design requirements of advanced spacecraft missions. Space cryogenics are also studied to cool down optical detectors and telescopes on next-generation astronomical observation satellites with unprecedented levels of sensitivity and resolution. In addition, we provide technical assistance to JAXA spacecraft projects through design reviews, thermal analyses or thermal evaluation tests.

Goals

●TCS components and materials

Spacecraft thermal control technologies can be categorized as active thermal control (ATC) or passive thermal control (PTC). We have been developing innovative heat pipes such as a loop heat pipe and a flat-type heat pipe, and also space cryocoolers with high efficiency and high reliability in order to make available advanced ATC technologies for flexible thermal management of future spacecraft. Even conventional PTC requires high durability and high reliability for the entire mission life. Thus, the characteristics of thermal control materials must be investigated in detail and must be well understood for accurate thermal design and adequate design margins, because thermophysical property data often involve some uncertainty in installation conditions concerning sizes, attachment methods, temperatures and the environments they are exposed to..

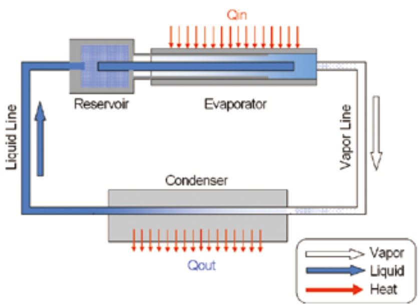
●TCS designs

We review and validate the TCS design of ongoing JAXA projects in order to contribute to the steady development of spacecraft and their mission success. For future space missions, we investigate the feasibility and reliability of the required TCS in the conceptual study with thermal analyses or preliminary experiments.

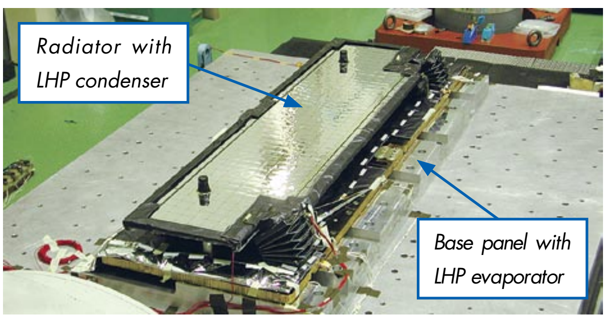
Research Objectives

●Loop heat pipe (LHP)

An LHP is one of the promising two-phase heat transfer devices for spacecraft coping with high heat dissipation loads or requiring precise temperature control. A conceptual schematic drawing of an LHP is presented in Fig. 1(a). The reservoir-embedded type of LHP with ammonia as its working fluid was installed on the deployable radiator (DPR) of "KIKU No.8 (Engineering Test Satellite Ⅷ)" launched on December 2006 as shown in Fig. 1(b). We carried out flight experiments on the DPR to investigate its thermal performance and characteristics under the microgravity environment in GEO (Geostationary Earth Orbit) for a period of over 1 year. These showed that the DPR could obtain experimental data on the start-up process and steady-state operation in various thermal environments that were in good agreement with analytical results. Long-term performance testing of the DPR is planned to evaluate its reliability and the non-condensable gas effect on its performance for the entire mission period.



(a) Principle of loop heat pipe



(b) Deployable Radiator (DPR) with LHP onboard ETS-Ⅷ

Fig.1 Loop heat pipe

Furthermore, we have studied a practical LHP with enhanced functions in order to use it in the TCS of future spacecraft such as astronomy satellites, broadcasting satellites or lunar exploration rovers, which demand accurate temperature controllability, layout flexibility and efficient thermal transport. We designed and produced a breadboard model with the reservoir outside of the evaporator in order to provide temperature controllability and a shutdown function. Results of the evaluation test showed excellent heat transfer characteristics as expected. Further work is planned to confirm the temperature controllability and the shutdown function.

●Mechanical cryocoolers

Based on cryogenic requirements from new missions such as the next radio astronomy mission "ASTRO-G"(2012), the next X-ray astronomy mission "ASTRO-H"(2013) and the next infrared astronomy mission "SPICA (Space Infrared Telescope for Cosmology and Astrophysics) "(2017), we have developed 1K-class, 4K-class, and 20K-class cryocoolers with high efficiency, high reliability and low vibration in cooperation with the Institute of Space and Astronautical Science of JAXA. In the SPICA mission, mechanical cryocoolers, without using a massive and consumable cryogen like superfluid helium, allow unprecedented fine observations during a long period of over 5 years by cooling the large primary mirror (3.5 m diameter) and the optical bench down to 4.5 K. The 20K-class cryocooler was upgraded by modifying the coldhead of the two-stage Stirling cooler with low-outgas materials and flexure springs, based on the Stirling cooler onboard the AKARI(2006). The engineering model of the upgraded 20K-class cryocooler was designed and fabricated with higher cooling capacity at 20 K and high reliability for the over-5-year operation mission requirement as shown in Fig. 2. The 4K-class cryocooler, consisting of a two-stage Stirling cryocooler for 20 K and a Joule-Thomson (JT) circuit with helium gas for 4.5 K, must be drastically improved in both cooling capacity and reliability over the one developed for the ISS (International Space Station)/JEM (Japanese Experiment Module)/SMILES (Superconducting SubMillimeter-wave Limb-Emission Sounder) mission(2009). It was experimentally confirmed that the cooling capacity at the 4.5 K stage could be increased from 30 mW to 50 mW with an input of 160 W AC. For the lowest temperature requirement, which is 1.7 K of for the far-infrared detector onboard the SPICA, a new 3He-JT cryocooler breadboard model could successfully demonstrate the cooling capacity of 16 mW at 1.7 K for the target of 10 mW with compact and efficient JT compressors. The upgraded two-stage Stirling cryocooler and the 1K-JT cooler are planned to be adopted and to be demonstrated in the cooling system (Fig.3) of the X-ray astronomy mission "Spectrum-RG/SXC(Spectrum-RG X-ray Calorimeter)"(2011) as a precursor mission of ASTRO-H/SXS(Soft X-ray Spectrometer).

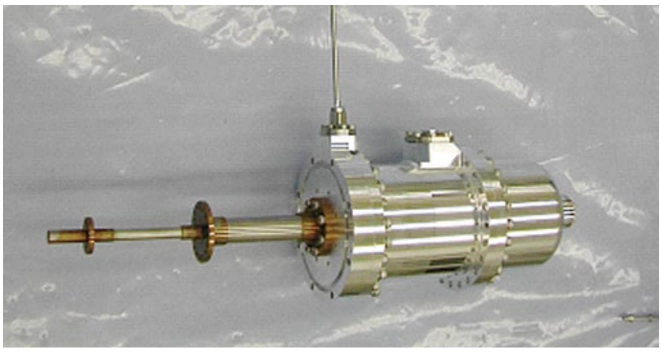


Fig.2 Modified coldhead of 20 K-class two-stage Stirling cooler

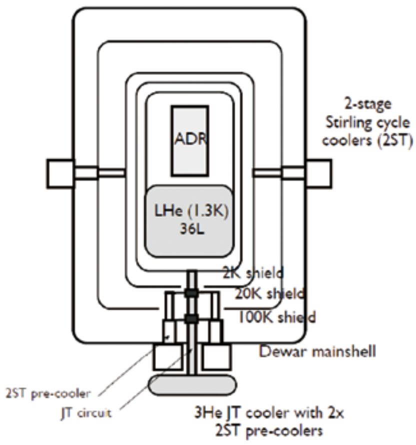


Fig.3 Cooling system design for ASTRO-H/SXS

●TCS designs

We reviewed and verified the thermal design of almost all ongoing spacecraft projects in JAXA such as the HTV (H-II Transfer Vehicle)(2009), the WINDS (Wideband InterNetworking engineering test and Demonstration Satellite)(2008), the GPM(Global Precipitation Measurement)/DPR(Dual-frequency Precipitation Radar), the GCOM-W1(Global Change Observation Mission)"(2011), the ASTRO-G, the Mercury exploration mission "BepiColombo"(2013), etc.

In addition, we have been involved in the conceptual study or the phase-A study of challenging missions such as the ASTRO-H/SXS, the SPICA" (Fig. 4), the next lunar exploration mission "SELENE-2", the REXJ(Robot Experiment on JEM)(2011), the astrometry observation mission "JASMINE", etc and we investigated feasible thermal-control systems and/or cooling systems for these missions through preliminary design activities.

We have been in charge of the TCS development of small satellites such as the SDS (Small Demonstration Satellite) series (Fig. 5) as well. We carried out thermal design analyses and thermal vacuum tests through all development phases in cooperation with the Space Technology Demonstration Research Center.

Experimental equipment

- *Thermal fluid laboratory (Ammonia injection and discharge equipment)*
- *Cryogenics laboratory*

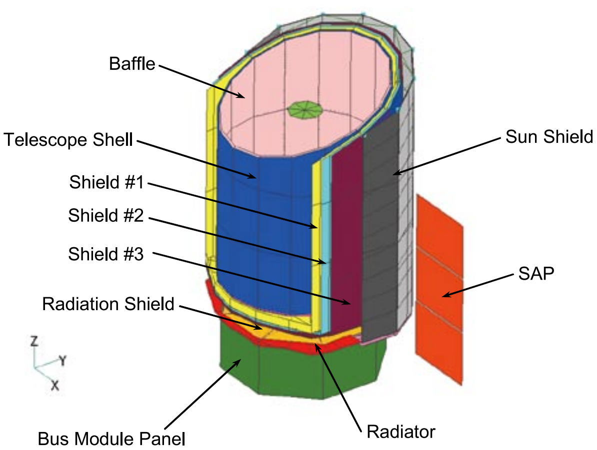


Fig.4 Baseline configuration of a SPICA spacecraft

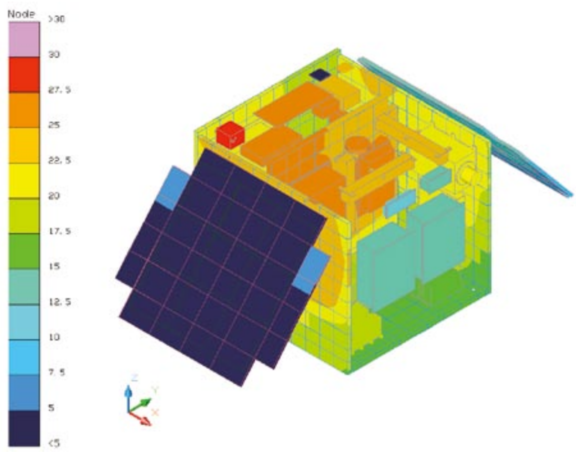


Fig.5 Thermal design analyses of SDS-1

Telecommunications and Data Handling Engineering Group

The Telecommunications and Data-Handling Engineering Group has studied ways to enhance the performance of satellite telecommunication systems, especially on-board telecommunication components such as transponders and antennas, and on-board data-handling components such as data-recorders, processors, and remote terminals. We have also studied error control codes, data compression, and an on-board data bus as fundamental technologies for communications and data handling.

Goals

The services provided by spacecraft are already indispensable in our daily life. The use of data from broadcasting satellites, communications satellites, earth observation satellites, etc., will steadily increase in quantity and will serve new applications. These satellites require wide-band telecommunication systems, high-speed data processing systems, and large mass data storage systems. Reducing the size, mass, and power consumption of spacecraft is a never-ending need.

Spacecraft collect various types of telemetry data in orbit. Secure and efficient communication between spacecraft and the ground stations is crucial for telemetry and command links.

For those reasons, we are now working on the following:

- An S-band multi-mode integrated transponder (MTP) as a higher-information rate and larger-capacity telemetry/command communication system
- An active phased array antenna (APAA) for small, lightweight and more capable on-board antennas and communication equipment
- A solid-state recorder (SSR) as a compact and high data-rate on-board data handling device
- Study of error correction and data compression algorithms for data handling technologies.

Research Objectives

- S-band multi-mode integrated transponder (MTP)

An S-band multi-mode transponder (MTP) is being developed to handle telemetry/command links for various kinds of future satellite systems. An MTP performs four types of modulation, PSK(phase shift keying)/PM(phase modulation), QPSK(quadrature phase shift keying), CDMA(code division multiple access), and UQPSK(unbalanced staggered QPSK) in one unit. JAXA plans to make this the standard transponder.

To realize a more sophisticated communication system capable of meeting the anticipated diverse communication requirements of future satellite systems, it will be necessary to improve information rates and quality. The group is working in this direction by studying a satellite communication system using the adaptive modulation technology employed in third-generation cell phones. (ref."Concept of communication system using adaptive modulation technology")

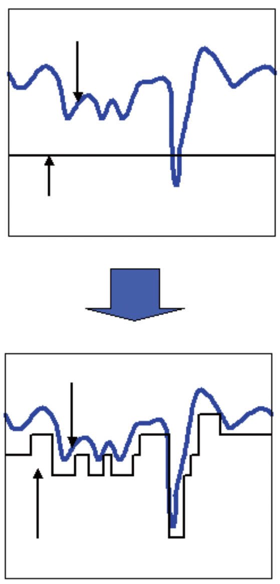


Fig. 1 Concept of communication system using adaptive modulation

●Active phased array antenna (APAA) (ref."APAA installed on WINDS")

Since two spacecraft in communication are generally moving relative to each other, their antenna aim must be changed continuously, especially if the antennas are strongly directional.The phased array antenna (PAA) has attracted attention for use as a scanning spot beam antenna that can potentially be used as an electronically controllable on-board satellite antenna. We have developed an active phased array antenna (APAA) composed of many antenna elements with power amplifiers in each. The key goals for the APAA are a minimal number of elements, and the development of RF components, MMIC (monolithic microwave integrated circuit) devices, and high-density packages with extreme miniaturization and light weight. Figure.2 illustrates the configuration of the APAA for the Wideband Internetworking engineering test and Demonstration Satellite (WINDS).

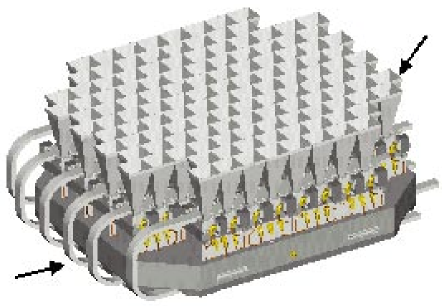


Fig.2 APAA installed on WINDS

●Solid-state recorder (SSR) (ref."Solid state recorder")

We are developing a high-speed, high-capacity and low-power consumption solid state recorder (SSR) for space use. The aim was to develop an SSR for installation on Earth observation (EO) satellites that could store and process large amounts of data. An engineering model of the SSR was completed in the spring of 2005. The main features of this SSR are 200 GByte capacity, total 2.5 Gbps (four channels) data transmission speed, low weight (25 kg) and low power consumption (120 W). A 512 Mbit synchronous dynamic random access memory (SDRAM) with an on-board multi-bit error detection and correction (EDAC) mechanism, as well as a Compact-PCI bus for fast data exchange, all improve the efficiency of data collection and storage. Currently, mainstream commercial DRAMs are Double Data Rate 2 SDRAM (DDR2), so we are replacing the SDRAM by the DDR2. We are also studying a non-volatile data recorder using flash memory.

Fig.3 Solid state recorder

●Error correction (ref."Prototype of error control circuit") and Data compression

An SSR for space use usually uses commercial DRAMs as the recording medium, due to their recording capacity, record replay speed, power consumption, and cost. However, SEU (single event upset) mitigation is required in order to use DRAMs in the space environment. Therefore, the SSR uses extended Hamming codes (single error correction - double error detection codes) to correct single-bit errors, or the extended Reed-Solomon codes (double bytes error correction codes) to correct multi-bit errors. The extended Reed-Solomon codes are very powerful codes but require long check sums. We are studying Spotty-byte codes instead.

Data compression is an effective way to reduce the volume of on-board data. To integrate data compression systems into data storage units, the computation for compression must be done in real time. We are providing a new lossless compression algorithm, 20 times faster and with the same compression ratio as JPEG2000, in a rad-hard FPGA.
A high performance lossy algorithm is necessary to compress image data, for example movie data from monitor cameras. However, new standards, MPEG2, H.264, etc., require heavy computation for encoding, and it is very costly to design a custom ASIC for space-based processing. Therefore we are studying an original compression method with a simple encoding algorithm by using low density parity check (LDPC) code to easily implement a realtime encoder with space-qualified FPGA or software.

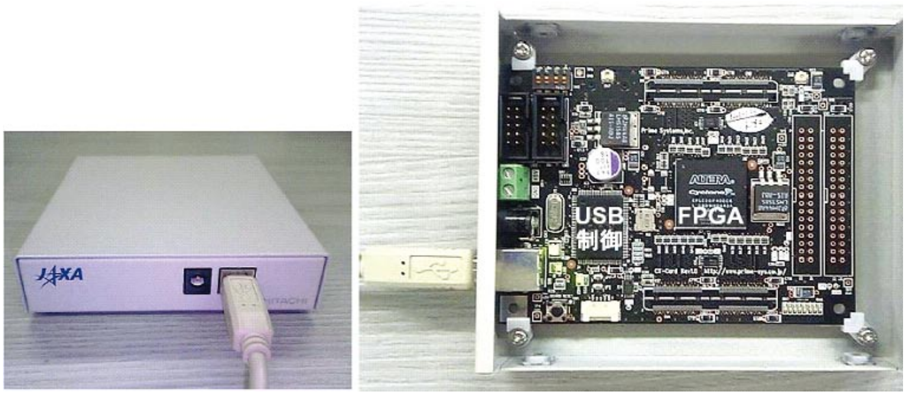


Fig.4 Prototype of error control circuit

●Data handling architecture

Next-generation onboard data handling system (DH) architecture has been studied with a view to ensuring the survivability of spacecraft, shortening the development period, and maintaining and improving the level of product quality. The new architecture incorporates a networked and modularized onboard subsystem, along with standardized spacecraft monitoring and control (SM&C) to reinforce onboard SM&C, to provide functional independence of the subsystems, and to promote the reusability of design and products.

Space Environment Measurement Group

The Space Environment Measurement Group conducts research on space environment measurement technologies, develops on-board equipment based on the results of the research, evaluates space environment models based on actual space experience, and creates other technologies essential to its goal of supporting satellite projects, including all stages from design to operation. Topics include the high-accuracy prediction of space environmental conditions, space environment analyses of orbital anomalies and anomaly prevention (space weather forecasts and space environment warnings), and other topics important to satellite design.

Goals

The group engages in the following tasks in its ongoing efforts to build space environment models based on actual measurements. The main goal is to assist satellite projects at every stage from design to operation, using technologies for the high-accuracy prediction of conditions in space, analysis of orbital anomalies in the space environment and anomaly prevention (space weather forecasts and space environment warnings), and other important topics important to satellite design.

●Research on space environment measurement technology
●Development of a satellite-borne space environment monitor
●Establishment of a satellite measurement network with space environment monitors
●Opening measurement data to the public

Research Objectives

●Development of Technical Data Acquisition Equipment (TEDA) for GOSAT and JASON-2

We are developing Technical Data Acquisition Equipment (TEDA) for GOSAT. GOSAT (Greenhouse gases Observing Satellite) will be launched in mid-2008 into a sun synchronous sub-recurrent orbit with an altitude of 666 km, an inclination of 98°, and a nominal lifetime of 5 years.

The objective of GOSAT TEDA is to provide comprehensive measurements of the space radiation environment as it impacts spacecraft operations. GOSAT TEDA consists of five instruments, a data processing unit (TEDA-E), four light particle telescopes (LPT) and a heavy ion telescope (HIT). LPTs measure the energy spectra of light particles, for example electrons in the energy range from 30 keV to 20 MeV, protons in the energy range from 0.4 MeV to 500 MeV, alpha particle in the energy range from 0.8 MeV/n to 500 MeV/n, etc. The HIT measures the energy spectra of heavy ions from He to Fe in the energy range from 7 MeV/n for He to 210 MeV/n for Fe.

The instruments for GOSAT TEDA are developed based on the breadboard model of a compact and high-performance radiation detector that JAXA developed from 2001 to 2004. We have taken advantage of this sensor's compactness and high performance to design TEDA to obtain a greater range of measurements of the space radiation environment, and with greater accuracy than heretofore.

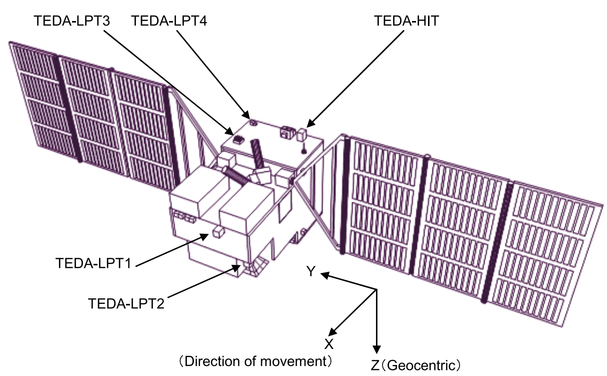


Fig.1 Outline figure of GOSAT

We developed an LPT for the JASON-2 satellite, which is the ocean observation satellite developed by the CNES (Centre National D'etudes Spatiales, French space agency). Based on the CNES/JAXA cooperation, CNES and JAXA agreed that the radiation particle monitor, LPT, would be accommodated in the JASON-2. This satellite was launched in June, 2008 into a 1336 km high orbit with an inclination of 66°.

The design of the LPT for the JASON-2 is almost the same as the one for the GOSAT. The LPT will measure the energy spectra of light particles, such as electrons, protons, deuterons, tritons, ^{3}He and ^{4}He.

The data which will be taken by the LPT will be used not only to obtain more varied and accurate knowledge of the space radiation environment, but also to calibrate the sensitivity of another sensor that will be aboard the JASON-2 to monitor the sea surface and which seems to be sensitive to space radiation. So, because the data will be shared between JAXA and CNES and will be analyzed and used by both, cooperation will be enhanced between JAXA and CNES in the field of space radiation research.

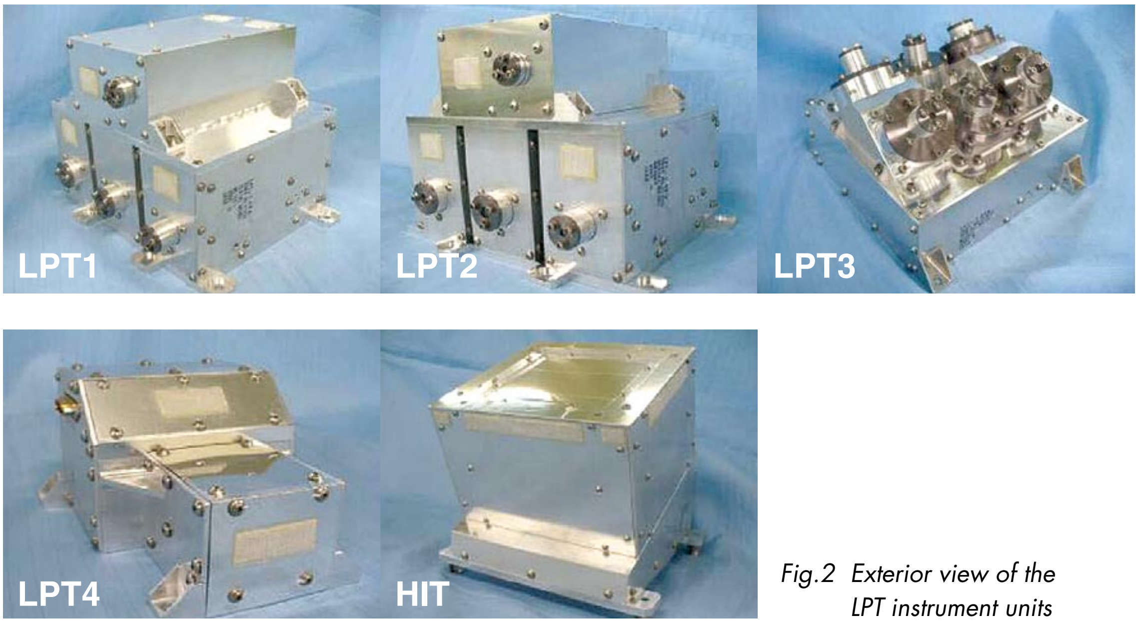


Fig.2 Exterior view of the LPT instrument units

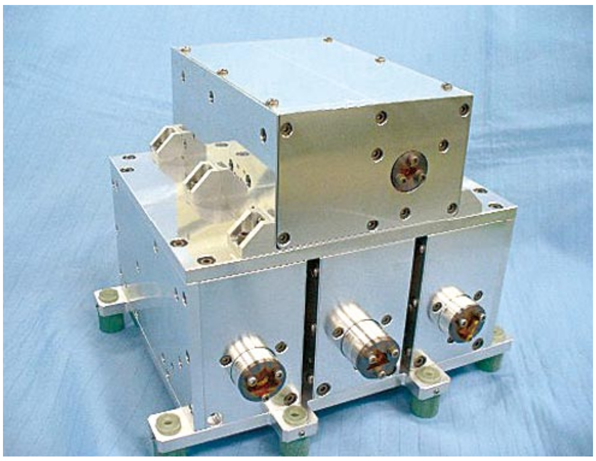


Fig.3 Photograph of JASON-2 LPT sensors

Space Technology Demonstration Research Center

The Small Demonstration Satellite (SDS) program is one of several JAXA activities to improve the reliability of practical artificial satellites by demonstrating a range of new technologies for space with equipment that ranges from single components to complete systems.

The Space Technology Demonstration Research Center of the JAXA Aerospace Research and Development Directorate (ARD) is studying ways to develop small satellites (50- to 100-kg class) and nano-satellites (20-kg class) at low cost in a short time. To obtain frequent launch opportunities, these satellites are launched as piggy-back payloads. Short periods and low-cost development are achieved not only by the small size of the satellites and the use of commercial off-the-shelf (COTS) equipment, but also because of the in-house activity of a small development team of JAXA researchers, with its flexible and efficient management. From the viewpoint of human resource development, small satellite programs also contribute to the training of young engineers through in-house work, taking advantage of the short development cycle from conceptual design to launch and operation.

Goals

In order to demonstrate the new technology's low cost and the team's quick response,we are studying and developing the bus and also the entire system of demonstration satellites such as the small satellite (100-kg class) and nano-satellite (20-kg class), which are collectively called the SDS series.

The 100-kg class demonstration satellite SDS-1 is undergoing system testing of a flight model, and SDS-2 is in the concept design phase.

A feasibility study of SDS-3, a nano-satellite in the 20-kg class, is under way to obtain possible solution for required demonstration misson.

During the development of these satellites, we are working on establishing a general bus system for small satellites and also nano-satellites. (Fig.1)

The characteristics of these bus systems are (1) cost lowered by using COTS parts and equipment, (2) cost reduced by in-house system assembly, integration and testing carried by young engineers, (3) rapid development by a small team with efficient management.

As many pieces of equipment for SDS are manufactured in small companies, the process of their production and development provides the companies with training in space technology. Also, we provide support to a consortium for developing micro-satellites in the 50-kg class, called SOHLA-1, which implements technology transfer to small companies interested in space development.

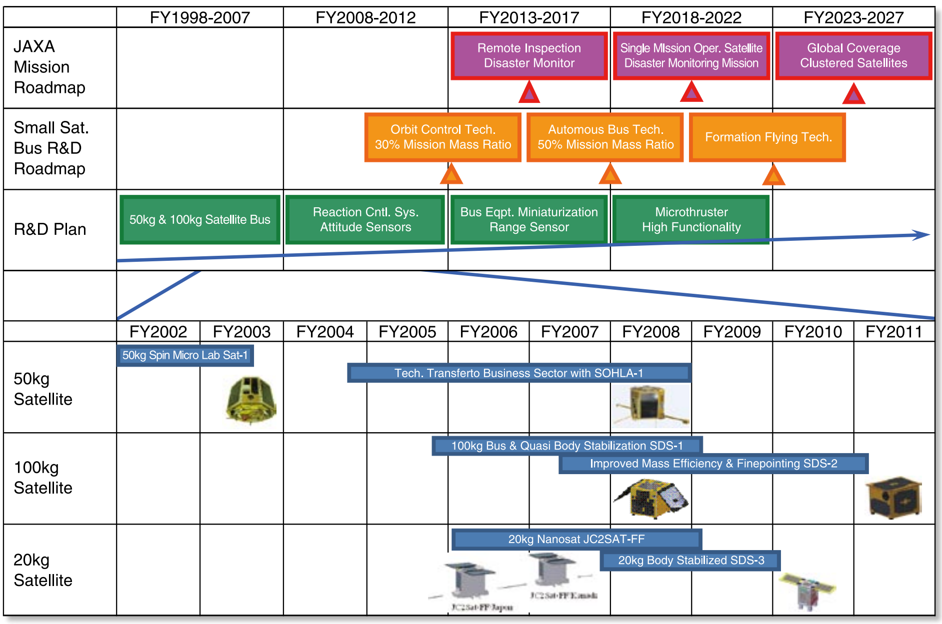


Fig.1 Development roadmap of SDS series

Research Objectives

●Series of Small Demonstration Satellites (SDS).

The concept of developing small demonstration satellites quickly and cheaply was first implemented on MicroLabsat-1, launched on 2002. Two classes of satellites are under development as our in-house activity. The 100-kg class of satellites is SDS-1 and SDS-2, the other class is 20-kg nano-satellites named SDS-3.

・SDS-1 and SDS-2

The Small Demonstration Satellite 1 (SDS-1), the first satellite in the SDS program, has been under development since FY2006, and will be launched in FY2008 (Fig.2). The satellite has a spin-stabilized bus, and will carry the three major missions and experimental bus equipments described below.

– Multi-mode integrated transponder (MTP) to improve operational availability in next generation satellite tracking, telemetry and command subsystems.
– Space-wire demonstration module (SWIM) to prove the concept of a next-generation data handling subsystem based on the space-wire standard that will be used in future JAXA science satellites.
– Advanced micro processing in-orbit experiment equipment (AMI) to demonstrate key devices for power supply and data handling systems for future applications.
– Thin film solar cell (TFC) demonstration of two types of thin-film solar cells, which are candidates for next-generation space solar cells.
– Experiments with bus equipment for future small satellites such as Small GPS Receiver, Small Sun Sensor and Advanced Monitor Camera (Fig.3)

Fig.2 In-orbit configuration of SDS-1

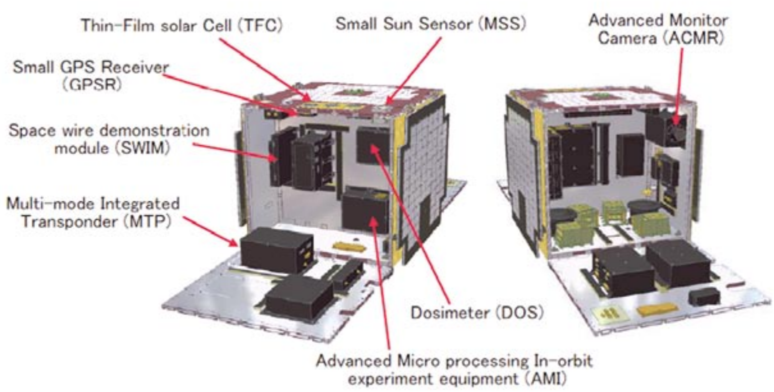


Fig.3 Mission equipment of SDS-1

Currently, system testing of flight models is carried out by JAXA young engineers as an in-house activity to assure flight quality. (Fig.4)

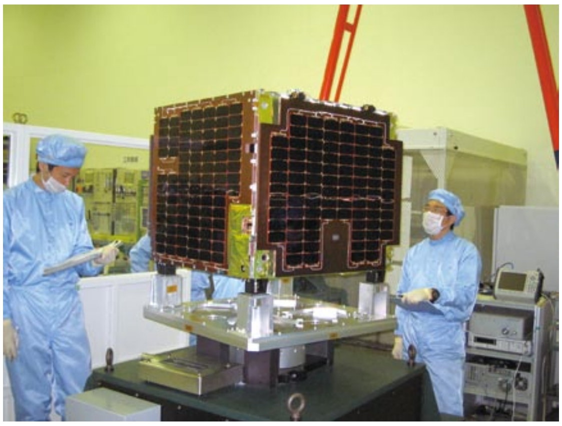


Fig.4 Mass balance test of SDS-1 flight model

With the goal of providing in-orbit demonstrations and experimental opportunities in early FY2010, and to seek higher performance of the satellite bus, a feasibility study of the next-generation 100kg Small Demonstration Satellite-2 (SDS-2) is currently under way.
The major features of SDS-2 are (1) full body stabilization using zero momentum attitude control, (2) precision earth or other target pointing using a star tracker, and (3) improved mass efficiency to increase mission capacity from the 20% mission mass ratio of SDS-1 to 30% (Fig.5). Currently scheduled missions of SDS-2 include the in-orbit demonstration of an advanced star tracker developed by JAXA, and a disaster monitoring experiment using a non-cryogenic thermal infrared imager.

Fig.5 In-orbit configuration of SDS-2

・SDS-3
A feasibility study of the Small Demonstration Satellite-3 (SDS-3), which is a 20kg-class nano-satellite, was started in late FY2007 (Fig.6). The volume available in the fairing for piggyback satellites is very small in such missions as the 4-ton class large satellites or H-II Transfer Vehicle. In those cases, the available volume for sub-payloads is sometimes as small as 20cm x 20cm x 40cm. Smaller satellites that fit into this limited sub-payload volume have a better chance of getting into space.
Although mission support capability is very limited in this class of satellite, with a mission weight of a few kilograms and available power of a few watts, they can still accommodate a single mission with miniaturized equipment. For the case of SDS-3, a disaster monitoring experiment with a non-cryogenic thermal infrared imager is one of the candidate missions.

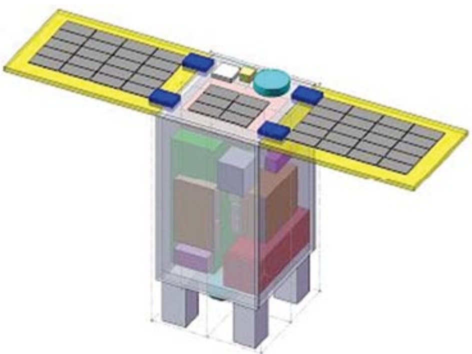


Fig.6 SDS-3 satellite

●Other small satellites

・SOHLA-1

SOHLA-1 is a 50kg-class spin-stabilized satellite based on MicroLabSat-1. (Fig.7 and 8) Its mission is to transfer the technology development of a 50kg micro satellite to the business and academic sectors, as well as providing a flight opportunity for various experiments. With the technical assistance of JAXA and in collaboration with universities, the satellite is being developed by a business sector SOHLA (Space Oriented Higashiosaka Leading Association).

What is unique to SOHLA-1 is that some components of the satellite are being developed by universities and enterprises joining SOHLA. SOHLA-1 carries eight experimental components including a newly developed miniature GPS receiver and a corner cube reflector. SOHLA-1 is now undergoing system tests of a flight model and is expected to be launched in late FY2008 as a sub-payload to GOSAT along with SDS-1 and other piggyback payloads.

Fig.7 In-house integration of SOHLA-1 flight model

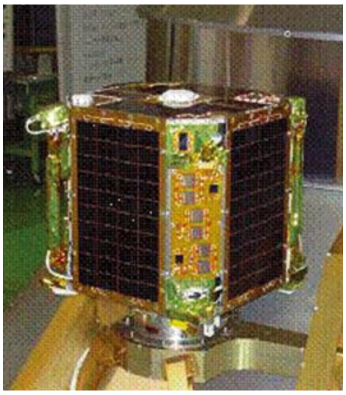


Fig.8 SOHLA-1 flight model

・JC2Sat-FF

The Japan-Canada Joint Collaboration Satellite-Formation Flight (JC2Sat-FF) is a joint effort between the Canadian Space Agency (CSA) and JAXA to develop two nano satellites. Its primary mission is to demonstrate spacecraft formation flight technology using aerodynamic drag control by varying the cross-sectional area of the spacecraft, and GPS-based relative navigation. The secondary mission is to demonstrate the novel non-cryogenic micro-bolometer technology (MIRAD), developed by CSA.

JC2Sat-FF consists of two nearly identical 20kg class nano-satellites that are stacked during launch and then separate from each other after their separation from the launch vehicle. (Fig9) The two JC2Sats were designed and built by a team of JAXA and CSA engineers and researchers in a period of less than two years. Since both agencies have their own body of experience in developing small satellites with different technology and methodology, the technical exchange stimulates both and generates a synergistic effect.

Fig.9 JC2Sat

●Development of small components for future small satellites.

In the future, high performance small demonstration satellites will be required with, for example, high attitude control accuracy and orbital maneuvering capability. Our center is developing these features, and working on the following low-cost equipment for future SDSs, such as a small GPS receiver (GPSR) modified from a car navigation system (Fig.10), a micro sun sensor (MSS) using CMOS APS based COTS (Fig.11), and a propulsion system for small satellites (Fig.12).

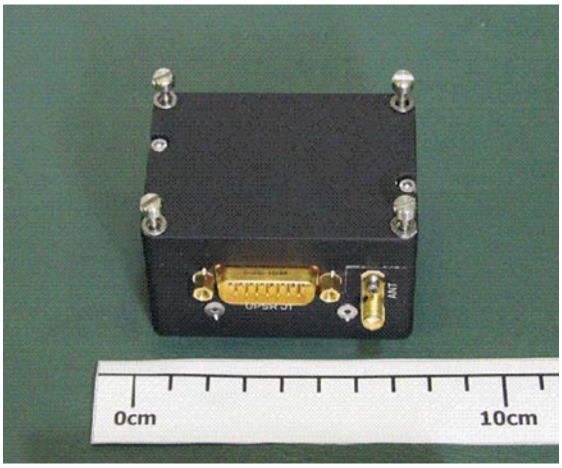


Fig.10 Small GPS Receiver

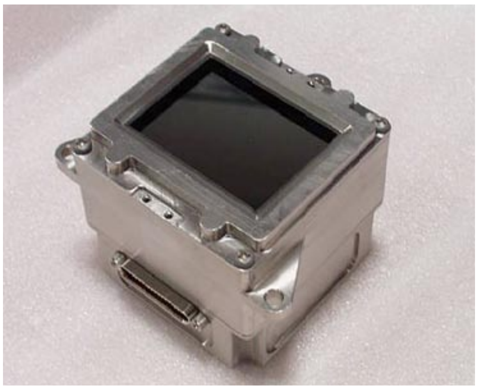


Fig.11 Micro Sun Sensor

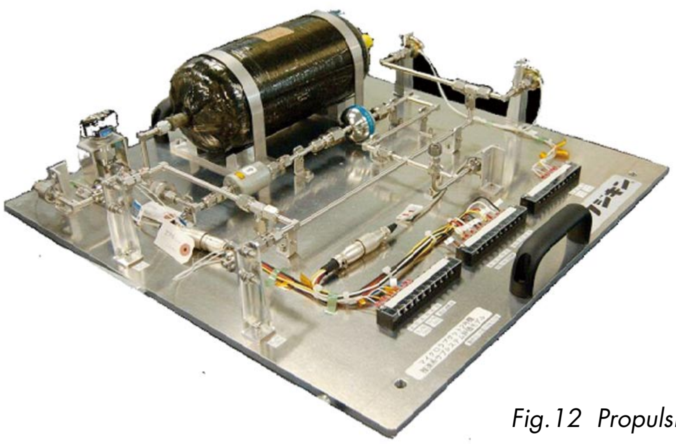


Fig.12 Propulsion system

Advanced Mission Research Center

Space solar power systems (SSPS) are designed to convert collected solar energy into microwaves or laser beams, either for use in space or for transmission to movable bodies or fixed points on the ground. The Advanced Mission Research Center is coordinating overall system research on SSPS, the ground energy transmission experiment, related component prototype tests, etc.

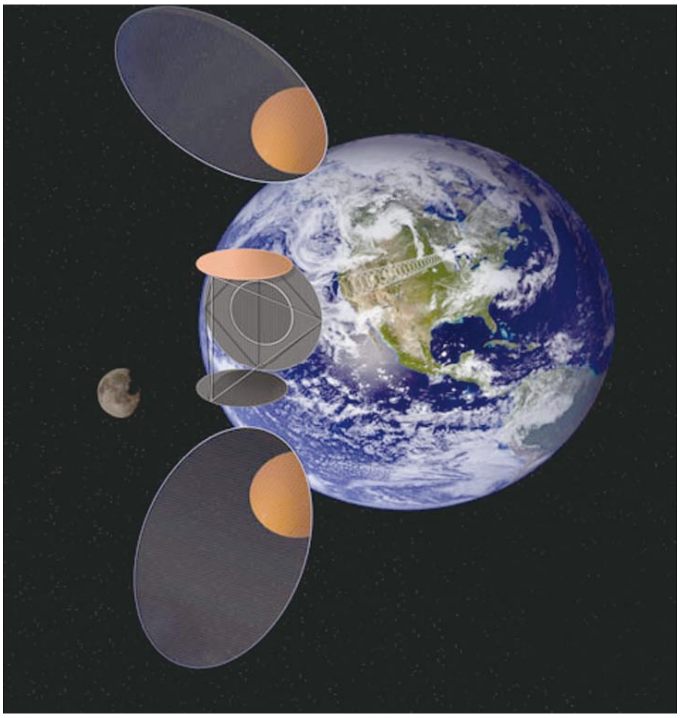


Fig.1 M-SSPS Image

Goals

The Center's SSPS research is focused on the realization of a commercial system capable of providing a stable supply of electric power/ hydrogen at a cost low enough to compete with other sources of energy. We aim at the realization 1-GW-class (power of one commercial nuclear power plant) microwave-based SSPS (M-SSPS) and laser-based SSPS (L-SSPS). To reach this goal, important technologies like transmitting energy must be demonstrated on a step-by-step basis.

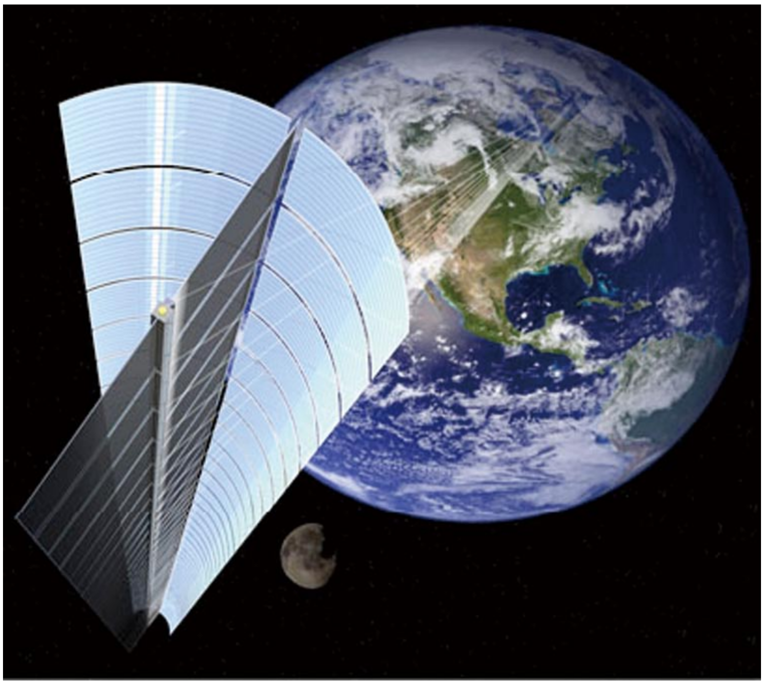


Fig.2 L-SSPS Image

Research Objectives

●Research on space solar power systems

Research on both microwave-based and laser-based commercial systems for SSPS has been demonstrated in parallel with studies of the missions and systems.

In the SSPS concepts and architectures study, the major focus is on identifying system concepts, architectures, and key technologies that may ultimately produce a practical and economical energy source.

With the primary objective of demonstrating wireless energy transmission technology, a ground-based long-distance and high-power transmission experiment was planned. A laser energy transmission experiment was carried out in FY2007. In this experiment the laser output power was designed to be about 0.8 kW and the transmission distance to be about 500 m. This experiment showed that high-power and long-distance laser power transmission is possible, and clarified the major challenges to setting up such a system.

The center is also carrying out partial prototype experiments and examining technologies required for important subsystems and elements of SSPSs, including technologies for light concentration, photocatalytic hydrogen generation using laser beams, robot assembly, power generation, high electric power transmission, direct solar pumping of a solid-state laser, and prototype devices of gallium nitride.

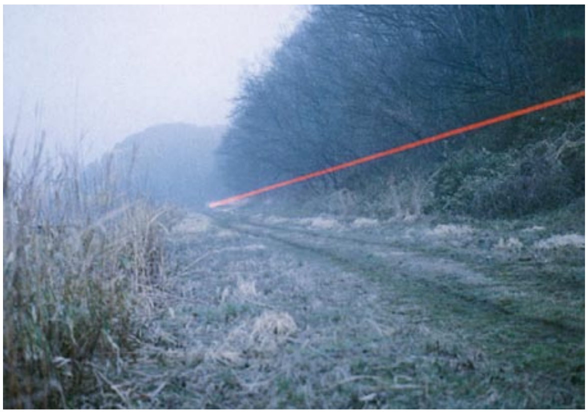


Fig.3 This image is preliminary experiment of laser energy transmission in Kakuda Space Center. Now a higher power experiment of about 0.8 kW is being carried out at this facility.

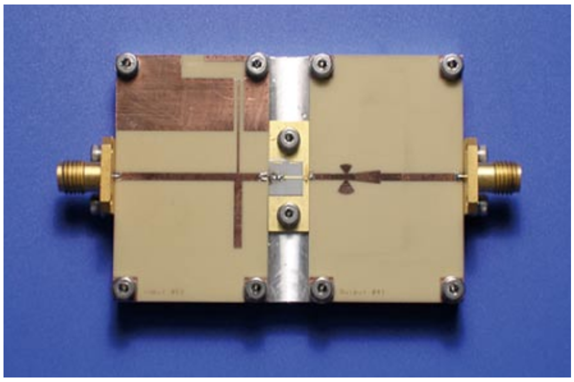


Fig.4 Trial model of an F class amplifier in the 5.8 GHz band that is used as the transmitting antenna for M-SSPS.

Fig.5 Trial model of an inflatable expandable structure that is a candidate for the large structure of an SSPS.

Advanced Space Technology Research Group

To advance Japan's present and future space programs, we must always strive to pioneer technologies that are ahead of the times. The Advanced Space Technology Research Group follows this principle in its research on advanced missions for future projects. The basic and fundamental technologies necessary for future missions are an important part of our research and development activities. Thus we are working on space debris problems as mission-oriented research objectives, and space robotics, manned space technology, and space tribology as basic and fundamental research objectives. We also provide technical assistance when ongoing projects face challenges in fields related to these.

Goals

JAXA's projects are expected to succeed, no matter how challenging the task. To play our part in this, our goal is to provide ready-to-use technologies in our special fields even before the projects that will use these technologies begin. Our research on basic and fundamental technologies will be the key to proposing realistically feasible future space missions and projects.

Fig.1 Optical observation facility at Nyukasa-yama mountain in Nagano prefecture

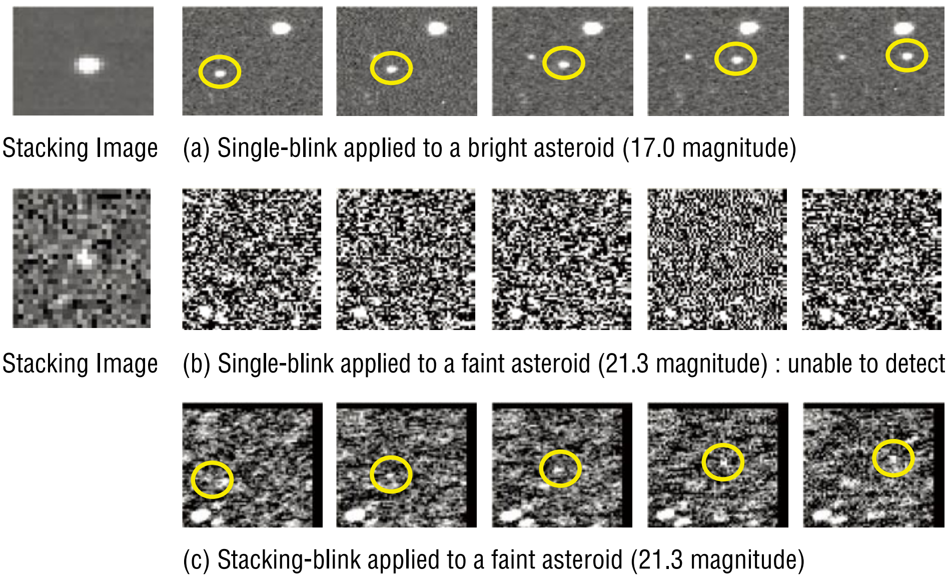


Fig.2 Asteroid detection improved by the stacking-blink technique

Research Objectives

● Technologies to deal with Space Debris Problems

Significant amounts of space debris from artificial satellites and rockets still orbit the Earth. The growing amount of debris compromises our space exploration programs. The group is researching technologies for finding debris (observation), modeling, protecting against debris (protection), and capture and removal of space debris (mitigation).

In 2006, an optical observation facility was constructed at Nyukasa-yama mountain in Nagano prefecture for the detection and orbit determination of space debris and asteroids.

A stacking method to detect moving objects (space debris and asteroids) is under development. The stacking blink method has been applied to asteroid detection software to improve the detection capability for faint asteroids, and a noticeable improvement has been confirmed.

Two studies are being carried out on protection technology. One is the development of a shaped charge system for simulating collisions at speeds of above 10 km/sec, which is a possible impact velocity. The other is the collection of hyper-velocity impact data on carbon fiber reinforced composites, which are a major component of space structures. A design technique for protecting space structures from impact damage will be established by these studies.

The active removal of large space debris, that is, defunct or malfunctioning satellites and rockets, is one of the most proactive strategies for solving the space debris problem. Electrodynamic tethers (EDT) are very promising as an orbital transfer system, since they are able to generate a thrust without the need for much propellant - by utilizing interactions with the Earth's magnetic field. In parallel with the conceptual study of the debris removal system, some key components are under development such as a robot arm for capturing a debris, and a small EDT package that consists of a bare conductive tether and field emitter cathodes (FECs) that utilize carbon nano-tubes.

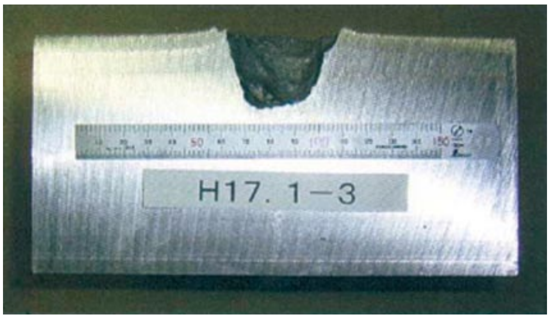


Fig.3 Collision of 1g bullet with thick aluminum plate at 7 km/s (cross section)

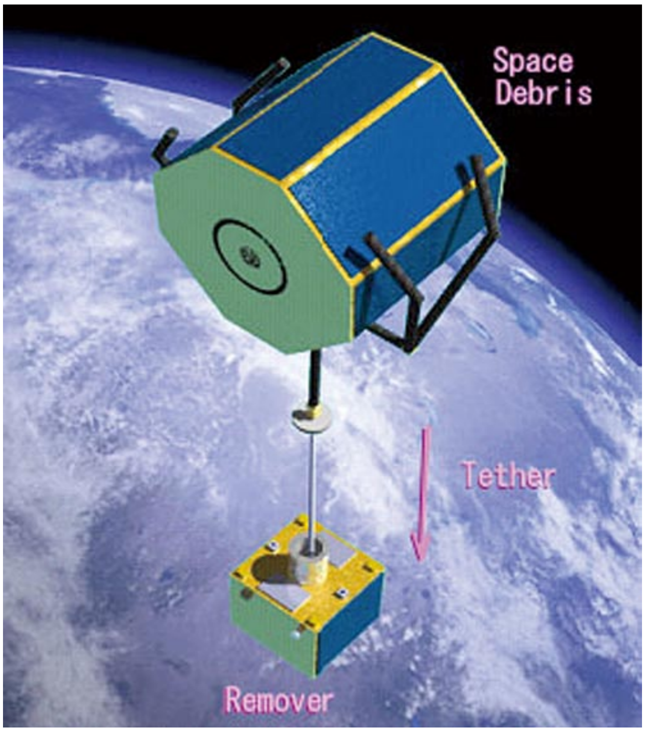


Fig.4 Space debris removal using an electrodynamic tether

●Space Robot Technology

Our group is conducting research and development of two kinds of space robots, orbital robots used on spacecraft and crew support robots working with astronauts.

JAXA, including the former NASDA (National Space Development Agency), developed the world's first satellite-mounted robot system that was tele-operated from the ground, the ETS (Engineering Test Satellite)-VII robot arm, as well as the remote manipulator system of the International Space Station (ISS), Japanese Experiment Module (JEMRMS). The ETS-VII robot arm demonstrated the possibility of in-orbit satellite servicing. JEMRMS will be used on a JEM named KIBO ('hope' in Japanese). Based on this experience and technological foundation, research is being conducted at the Chofu Aerospace Center on using space robots to assemble large space facilities or satellites, and an experimental system to demonstrate the potential of the crew support robot on KIBO is being developed at the Tsukuba Space Center. The demonstration mission named REX-J (Robot Experiment on JEM) is scheduled in 2012. The unique feature of the robot system in REX-J is an ability to move along the surface of large space structures using tethers and an extensible robot arm.

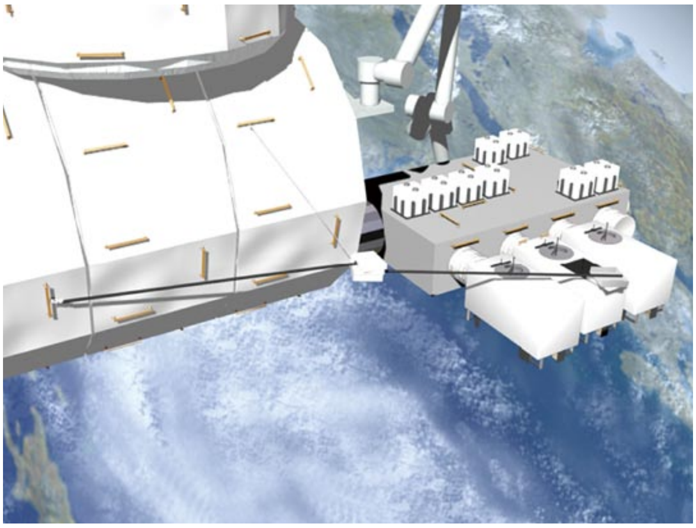


Fig.5 An artist's image of the robot system in REX-J moving along the surface of KIBO using tethers

●Manned Space Technology

All of the materials crucial for human life in the ISS, water, air, food, and so on, must be transported from the Earth. Therefore, our group is conducting research on the essential technologies to completely recycle the wastes into the resources such as breathable air, drinkable water, and nutrients. Having spinoffs from our technologies applied to the solution of on-the-ground problems is also important for space applications.

A:Water purifier using a reverse-osmosis membrane (manufactured by New Medican Tech Corporation)

B:Cosmic water

Fig.6 Water purifier developed through technology transfer

Fig.7 Air revitalization system with Sabatier reactor and water electrolysis for microgravity conditions

●Frontier Technology

In addition, various advanced technologies (e.g., nanotechnology) and their application in space are studied by this group.

Our group has designed and fabricated the Regenerative Fuel Cell (RFC) system for the demonstration and verification of the feasibility of a small, lightweight system for aerospace use. The RFC system consists of an electrolyzer (EC), fuel cell (FC), gas/water separation and circulation pumps, connecting pipes, valves, and tanks (GH2, GO2, H2O), and measures 500 mm x 500 mm x 300 mm.

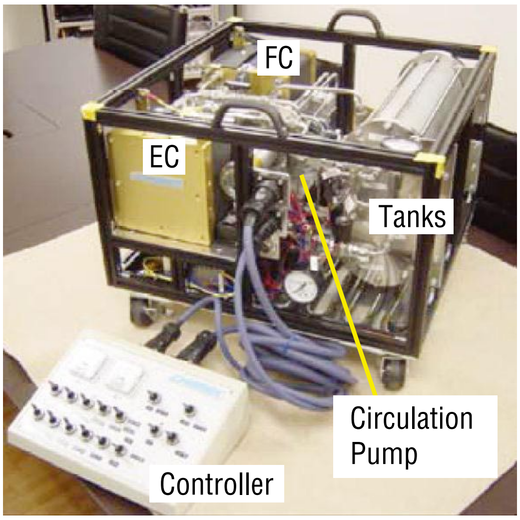


Fig.8 Breadboard model (BBM) of regenerative fuel cell system

●Space Tribology

Our group is evaluating the performance of lubricants in simulated space environments. A solid lubricant coating exposed to the ISS (International Space Station) environment has been evaluated. The influence of the lunar dust environment on friction and wear behavior is being examined. New types of lubricants for space applications are being tested, including ionic liquids. A dynamic simulation program for minimally lubricated ball bearings for space applications is also being developed. The aim of the group's research activities is to improve the performance and reliability of any moving mechanical components of devices used in space.

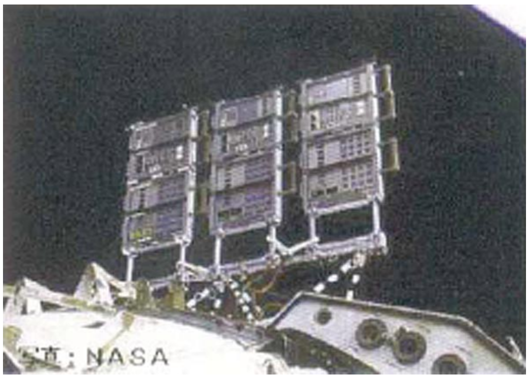


Fig.9 ISS low earth orbit space environment exposure experiment

Chapter II

Aviation Program

Chapter II

Aviation Program

Civil Transport Team

The Civil Transport Team is responsible for the development of advanced aeronautical technologies for the design of civil transport. The team consists of two management offices and five technical sections. We are conducting a wide variety of research, covering materials, structures, aerodynamics (including acoustics), and flight control. We provide aircraft manufacturers not only with the advanced technologies developed at JAXA but also with the large-scale test facilities of JAXA for the design of civil transport.

Goals

Since 2003, we have been taking part in a project to develop a high-performance, environment-friendly small aircraft with seating capacity of 70 to 90 passengers. Mitsubishi Heavy Industries, Ltd. (MHI) is running the effort with support from the New Energy and Industrial Technology Development Organization (NEDO). Mitsubishi Aircraft Corporation, a new company established in April 2008 by MHI, is conducting the MRJ business and accelerating the MRJ's development. Our goals are to develop and transfer the technologies for the design of competitive aircraft in the world market and to provide technical assistance in the project.

Project Details

●Our country seeks to bring to market a regional jet, for which global demand is expected to grow. Manufacturers in Canada and Brazil have already established track records, and Russia and China are carrying out their own R&D to enter the market as newcomers. Against this background, JAXA has been supporting MHI in order to have the MRJ stay ahead of the game with so many competitors for these five years.

Technical transfer from JAXA has almost been completed. In March 2008, the decision to launch the project on a commercial scale was made by MHI, accepting a considerable number of orders from airlines for the new aircraft, the MRJ. In the next phase, we will concentrate on the validation and confirmation of the performance of the MRJ, which was designed with our transferred technologies, through structure ground tests and flight tests. We will also assist in obtaining a Type Certificate for the MRJ from the JCAB, the FAA, and other relevant agencies.

The present article briefly introduces two areas of our technical activities in the project: one is aero-acoustic design for noise reduction and another is hydrodynamic analysis of horizontal water impact tests for ditching certification.

●Reducing noise from high-lift devices

The traffic volume of civil aviation aircraft is increasing steadily, and it is thought that this trend will continue for some time into the future. Thus their noise impact on the environment becomes problematic, making it important to design and manufacture quiet aircraft and bring them into wide use.

Sources of noise from aircraft generally fall into two categories. The first is engine noise, which has been a large concern since jet planes made their debut, and continues to be a problem. Also, though, noise generated from areas other than engines has become problematic. When an aircraft prepares for landing and approaches an airport, a device designed to increase the aircraft's lift force (high-lift device: Fig. 1) and its landing gear are deployed, which greatly increases noise generation.

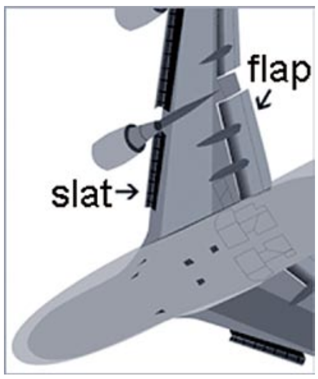


Fig.1 Example of typical high-lift device

At present, we are pursuing research to reduce noise generation from "high-lift devices". In order to realize low noise without impairing the essential characteristics (lift force and safety performance) of conventional high-lift devices, it is necessary to understand the mechanism by which noise is generated. Therefore, in order to understand the mechanism of noise generation from a high-lift device, we made a simplified high-lift device model as shown in Fig. 2 and conducted wind tunnel tests. In order to examine what kind of noise is generated from which portions of a high-lift device, a measurement method called the "Phased Array Method" was used. Fig. 3 shows an example of the result. It can be seen from this figure that strong noise is generated from red portions. In addition, it has become possible, as shown in Fig. 4, to perform computation of the detailed flow physics that generates noise by using the Large-Eddy Simulation (LES) technique.

Information obtained from these wind tunnel test results and calculations is being utilized in the development of the MRJ. Based on our results, we are developing a quiet HLD, using such devices as modified slats and flap-tips.

Fig.2 Model for high-lift device noise measurement (OTOMO)

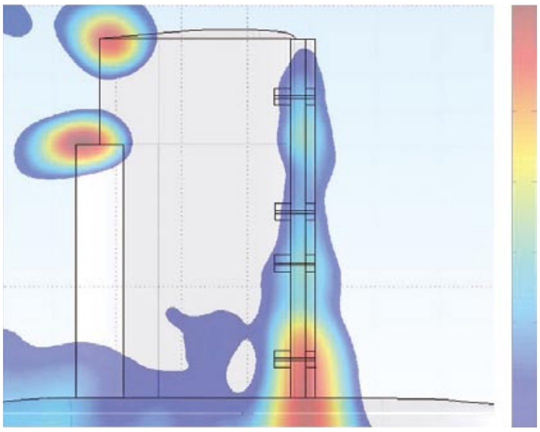


Fig.3 Indication of noise generation positions by source location.

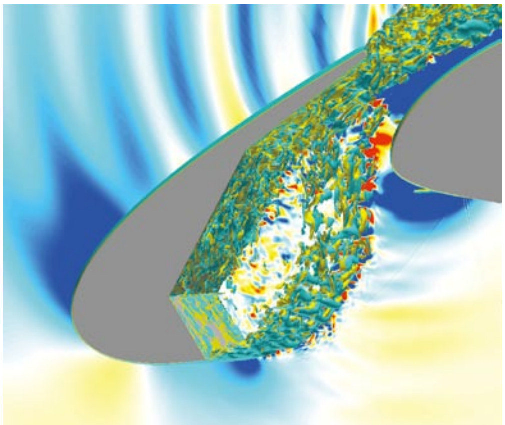


Fig.4 Analysis of noise around leading edge of high-lift slats

●Hydrodynamic analysis of horizontal water impact tests

Ditching is a controlled emergency descent onto the water. If an airplane flies over oceans, it needs to be certified appropriately for ditching according to these criteria:

- Each practicable design measure, compatible with the general characteristics of the airplane, must be taken to minimize the probability that in an emergency landing on water, the behavior of the airplane would cause immediate injury to the occupants or would make it impossible for them to escape.
- The probable behavior of the airplane in a water landing must be investigated by model tests or by comparison with airplanes of similar configuration for which the ditching characteristics are known. Scoops, flaps, projections, and any other factor likely to affect the hydrodynamic characteristics of the airplane, must be considered.

In the certification process, hydrodynamic analysis plays a very important role. Precise analysis will be able to reduce the number of cases that must be considered for ditching tests, and to reduce the risk of needing to redesign the airplane structure to comply with the ditching provisions.

In this article, we introduce hydrodynamics analysis results for horizontal water impact tests being conducted at the Ocean Wave Reappearance Towing Tank at Yokohama National University with a scaled model which had the simulated aft-fuselage outer configuration. These are basic efforts to acquire the analytical techniques required for ditching certification. Fig. 5 shows the model set up for the horizontal water impact test. Fig.6 shows the analytical model with the ALE (Arbitrary Lagrangian-Eulerian) method of LS-DYNA, which is a general-purpose finite element code for analyzing the large-deformation dynamic response of structures including structures coupled with fluids. Fig.7 shows both test and analytical results for acceleration in a case with 6.3 m/s of horizontal impact velocity, 1.02 m/s of vertical impact velocity, and 9.83 degrees of pitch. Fig.8 shows both test and analytical results for hydrodynamic pressure on the outer skin in the same case. In these figures, we show the successful simulation of acceleration and water-impact hydrodynamic peak pressure. Therefore, these analytical techniques will be used in verification of the structural design of the newly developed airplane.

Fig.5 Horizontal water impact test model set-up

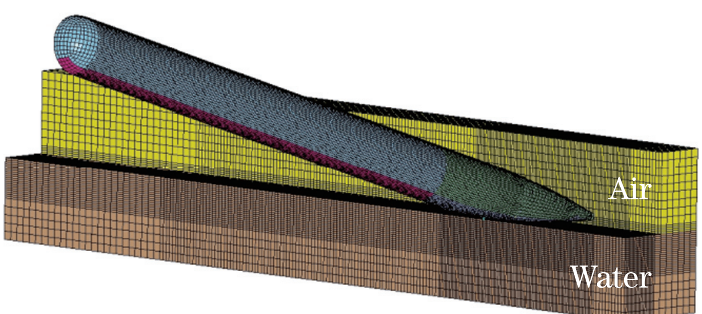


Fig.6 Analytical model

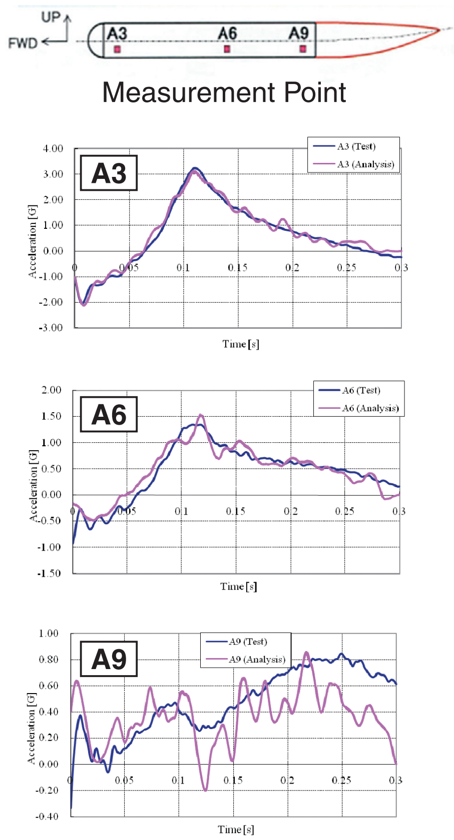


Fig.7 Accelerations in a horizontal-impact test case

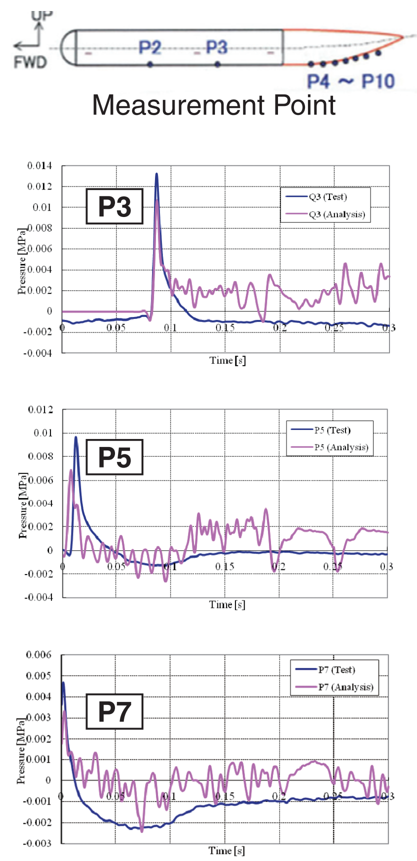


Fig.8 Pressures in a horizontal impact test case

Clean Engine Team

The impacts of aviation on the environment near airports and even on the global atmosphere are of great concern since air traffic is steadily increasing. Environmentally friendly aeroengines that do not produce excessive noise and air pollution will help permit the continuing growth of the world economy. This team is promoting the Technology Development for Clean Engine (TechCLEAN) project for the development of aeroengine technologies to reduce noise and emissions of nitric oxides (NOx) and CO2. The team is also conducting tests and evaluation of advanced materials for aeroengines in simulated operational conditions.

Goals

The major objective of the TechCLEAN project is to develop engine component technologies, numerical simulation technologies, test and measurement technologies, advanced materials, and structure technologies, with the aim of realizing environmentally friendly aeroengines. This includes contributing to the development of a demonstrator engine of 50-kN class thrust in the Eco-Engine Project, sponsored by the New Energy and Industrial Technology Development Organization (NEDO), and fuel injectors for next-generation high-pressure ratio aeroengines. Some of the advanced environmental technologies will be validated by on-engine testing in the later stages of the project.

Fig.1 Anechoic Room

Project Details

●Noise reduction

Research and development on turbofan engine noise reduction involve scale model tests and engine tests. In scale model tests, mechanical nozzles for better mixing and less thrust loss are investigated under subsonic or supersonic conditions in an anechoic facility. Engine tests are ongoing, using a turbojet demonstrator. A nozzle-with-tabs configuration, a variable cross-section configuration, and a water injector were tested for their influence on jet noise. Measurement technologies are also studied to improve experimental quality. These technologies include a microphone array system for source location of flyable model planes and a remote-controlled vehicle for mobile measurement around a jet engine.

Fig.2 Engine Test Site

Fig.3 Flight Test by Model Plane

●NOx Emission Reduction

Three companies collaborating on a NEDO project (Eco-engine) are developing different types of combustors with the goal of reducing nitrogen oxide (NOx) emission below 50% of the aero-engine exhaust gas standard (ICAO CAEP4). JAXA is supporting these developments based on a joint research contract with each company and conducting performance-evaluation tests of these combustors and development of its own original combustor. The original combustor achieved a 62% NOx reduction below the ICAO CAEP4 standard. JAXA is also researching an advanced combustion technology for reducing NOx emission drastically. Advanced laser spray diagnostics and CFD (computational fluid dynamics) techniques are being developed for the optimal design of fuel injectors and combustion chamber configurations. An annular combustor test facility was set up to evaluate combustor performance, featuring a maximum pressure of 2.5 MPa, maximum air temperature of 750K and maximum air flow rate of 25 kg/s. Annular combustors for small aircraft can be tested in realistic conditions. It has a 360° rotational traverse system for gas temperature measurement and gas sampling in the combustor exit plane, and a VIDEO system for observation of the situation in the combustor.

Fig.4 Low NOx combustor for small engine

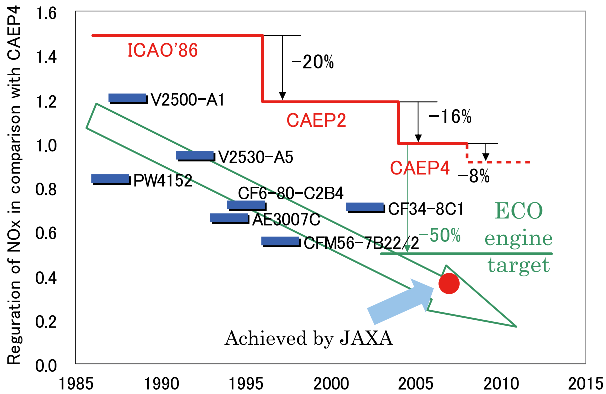


Fig.5 Achieved NOx emission vs. ICAO CAEP4 standard

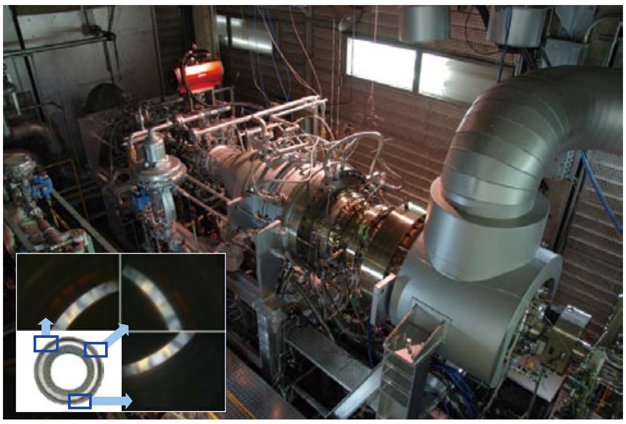


Fig.6 Test section of annular combustor test facility (Flame in combustor at the lower left)

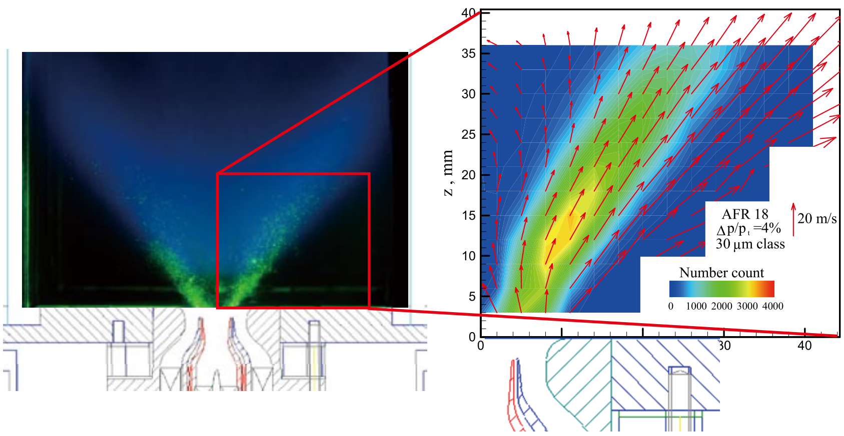


Fig.7 Number of droplets and velocity distribution of droplets from air-blast fuel nozzle (by stereo interferometric laser imaging technique)

●CO_2 Emission Reduction

In order to reduce CO_2 emission from aero-engines, we are developing various new technologies such as turbine blade cooling structures and high-temperature superalloys for higher thermal efficiency, small but high-performance compressors, fans with better propulsive efficiency, and intelligent engine control methods. New turbine cooling structures which permit the cooling air flow rate to be reduced to half are experimentally investigated while conjugate heat transfer simulation codes which predict the precise temperature distribution on turbine metals are being developed. For high-temperature superalloys, our research target is to make a test facility that can simulate the actual turbine blade environment, including high-temperature gases and centrifugal forces, then evaluate the strength of newly developed superalloys that are candidates for the Eco-engine.

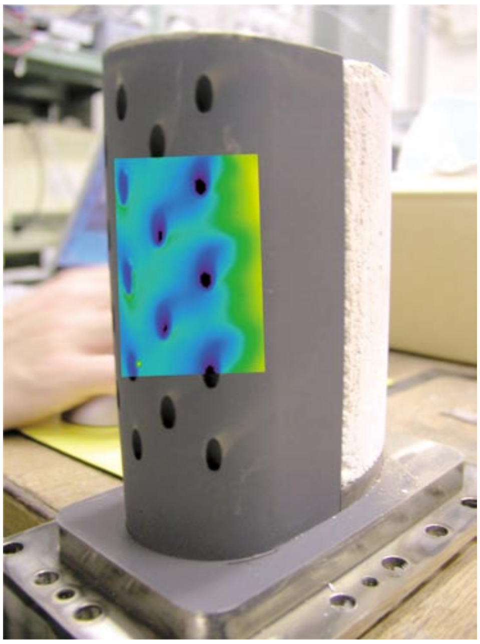


Fig.8 Cooling structure test piece and temperature distribution (montage)

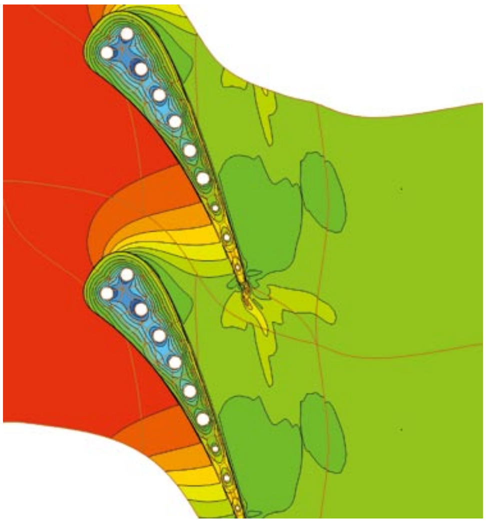


Fig.9 Conjugate flow and heat transfer simulation of turbine cross section

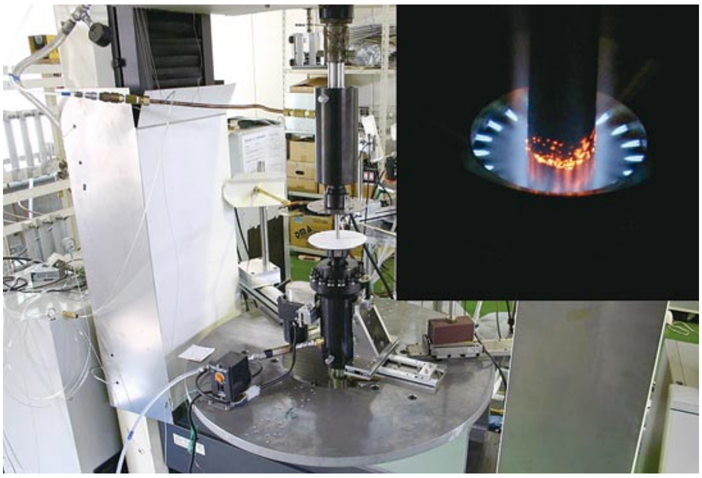


Fig.10 Burner test rig for superalloy evaluation

Supersonic Transport Team

Our team is pursuing R&D on silent supersonic technology to establish essential advanced technology for realizing a supersonic civil aircraft. This quiet, economically-viable and environmentally-friendly aircraft will make traveling times dramatically shorter, and bring a revolutionary change to the air transportation business. Our R&D is not only on an innovative airframe concept and advanced component technologies, but also on the development and flight testing of the demonstration aircraft as a part of its technology demonstration.
Moreover, a Mach 5-class hypersonic transport that could cross the Pacific Ocean in two hours is now being studied conceptually, and a flight demonstration with a hypersonic propulsion system is expected within the next 15 years.

Goals

In another decade, the team will have created world-leading super/hyper-sonic civil aircraft technologies.
Specifically, the team aims to verify the feasibility of our advanced supersonic transport concept, which could halve the sonic boom produced during supersonic flight. This will be accomplished by the development and flight testing of our silent supersonic technology and subsequent flight demonstration of hyper supersonic engine technology.

Project Details

●R&D on Silent Supersonic Technology

– Concept study of next generation supersonic civil aircraft

In order to promote advanced technological study, the team has been conducting research on a concept for the next generation supersonic civil aircraft's system: this is the technological goal the team has set out to achieve.

Fig.1 Concept image of quiet small supersonic transport

●R&D on Component Technologies

– Computational analysis and design technology

The team promotes the study of computational technologies for high-fidelity analysis and works to promote an interdisciplinary integration resulting in a multi-purpose optimum design method. These technologies are considered essential for the development of the next-generation supersonic civil aircraft, and an analysis/design tool based on the technologies is now being developed by the team.

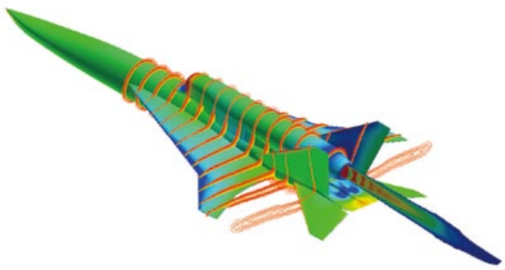


Fig.2 High fidelity CFD

– Aerodynamic Technology

To achieve both aerodynamic performance and environmental compatibility in the next-generation supersonic civil aircraft, the following advanced aerodynamic studies are being carried out by numerical simulations and/or wind tunnel tests.

– Technology to design a low drag and boom airframe
– Technology to improve take-off/landing performance
– Technology to reduce frictional drag

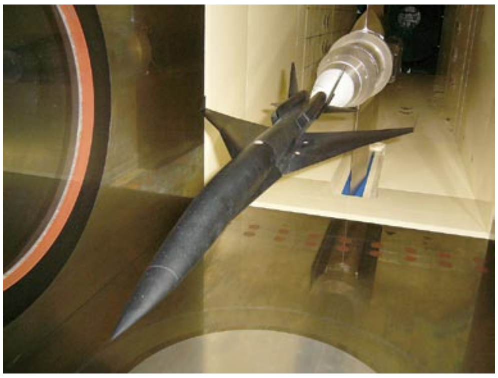


Fig.3 Supersonic wind tunnel test of quiet small supersonic transport concept

Fig.4 Composite material structure wing demonstrator

– Structure Technology

The team has been accumulating basic data on the long-term durability and mechanical characteristics of heat-resistant composite materials, while promoting R&D on the manufacturing technology of low-cost high-precision composite structure materials for the next-generation supersonic civil aircraft, which will be light in weight, designed for safety, and produced at low cost. Furthermore, R&D on prediction/assessment technology of aeroelastic characteristics such as flutter of supersonic aircraft and its testing technology has been pursued as well.

– Propulsion Technology

The team is promoting R&D on next-generation supersonic civil aircraft propulsion system technology. Ground engine tests and wind tunnel tests have been carried out to study a low-noise nozzle and highly efficient intake for a quiet takeoff and landing.

Fig.5 Low-noise nozzle noise test

– Sonic boom measurement and assessment technology

To help establish international environmental standards for sonic booms, the team is promoting a study on the assessment of how people perceive it and buildings are affected by it. Our study also includes an analysis of its airborne propagation.

Fig.6 Sonic boom simulator

●R&D and flight test on Silent Supersonic Technology Demonstrator

The team is working on a detailed study using our own silent supersonic technology demonstrator to verify our advanced airframe concept, which could reduce the sonic boom by half. This noise reduction is the most significant challenge for realizing a supersonic civil aircraft.

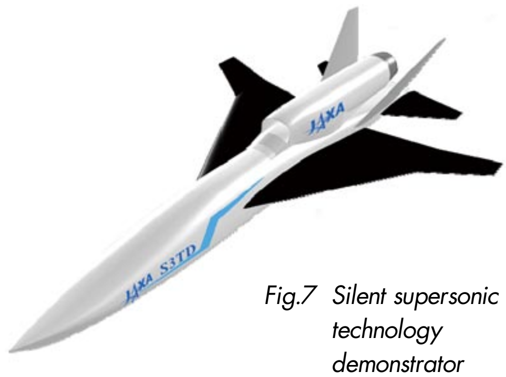


Fig.7 Silent supersonic technology demonstrator

●R&D of Hypersonic Aircraft Technology

The team is performing advanced research on a Mach-5 class hypersonic transport system concept, its flight test and related component technology such as propulsion technology. At the same time, the framework of a small hypersonic technology demonstrator is now being considered with the main aim to verify our Mach-5 hyper propulsion system technology.

Fig.8 Concept image of Mach 5 hypersonic aircraft

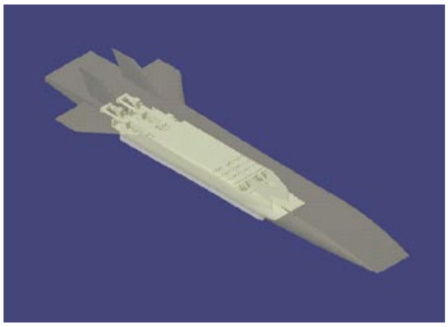
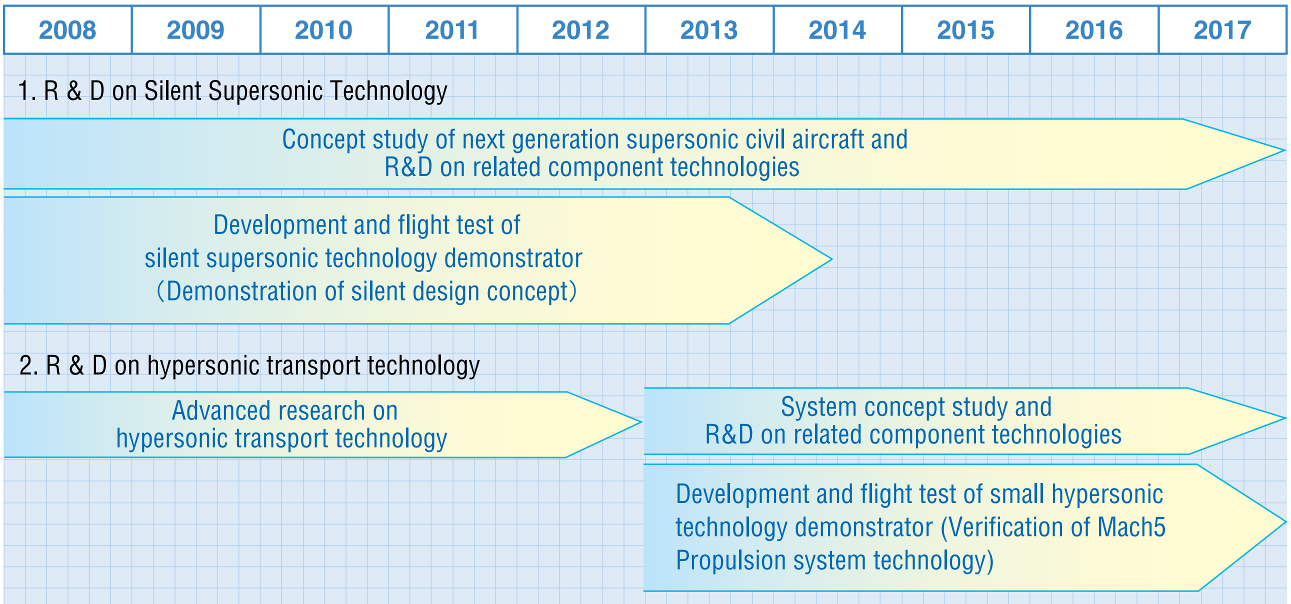


Fig.9 Small hypersonic technology demonstrator (example)

Project Plan



Operation and Safety Technology Team

The density of air traffic is going to be very significant in the near future. We are tasked to find the best way to promote efficiency and increased safety for air traffic. The Operation and Safety Technology Team strives to apply advanced technologies to high-precision navigation, human factor analysis and laser radar techniques to ensure a safe air transportation system. Protecting the environment is also our major concern, so we are developing technology to reduce the impact of aviation noise. The team will make next-generation aviation more efficient, safer and environment-friendly.

Goals

●Research on Technology to Prevent Human Error

Reduce the number of accidents caused by human error by improving human factors training methods and developing human factor performance models for use in cockpit design and safety analysis.

●Research on an Air Turbulence Detection System

Develop an air turbulence detection system (LIDAR) for measuring winds 5 NM (9 km) ahead by remote sensing and thereby prevent accidents due to air turbulence, including cabin accidents.

●Research on Next-Generation Operation System

Develop advanced operational technologies using a satellite, data link, etc. to permit all-weather operations and high-density operations and thereby enhance the safety and convenience of air transport.

●Research on Technology for Helicopter Noise Reduction

Reduce by 5 to 6 dB the noise generated by BVI (blade-vortex interaction) that is generated during a helicopter's landing approach descent, by using active devices and thereby establish a new noise-reduction technology applicable in next-generation helicopter development.

Project details

●Technology to Prevent Human Error

More than 50% of fatal aircraft accidents are related to human error, and the primary causal factor is insufficient CRM (Crew Resource Management) skills. CRM is defined as an approach to preventing aircraft accidents by using available resources such as hardware, software and information in the most effective manner and CRM skills is defined as the ability to carry out CRM.

Flight crew CRM training was first recognized as important in the United States in the 1980s, and the first CRM training programs were started by airlines there. It is considered that concrete behavioral indicators are necessary for effective CRM training, so with the support of major airlines in Japan JAXA has been developing CRM skill behavioral markers that take into account the particular behavioral and psychological characteristics of Japanese crew members.

In order to make the CRM training more efficient, it is important to assess the extent of CRM skills acquisition and to provide feedback to the training program to remedy possible training inadequacies. Therefore, we have developed a CRM skills measurement method that utilizes a subject rating technique based upon JAXA CRM skills behavioral markers and can identify how far CRM skills have been learned.

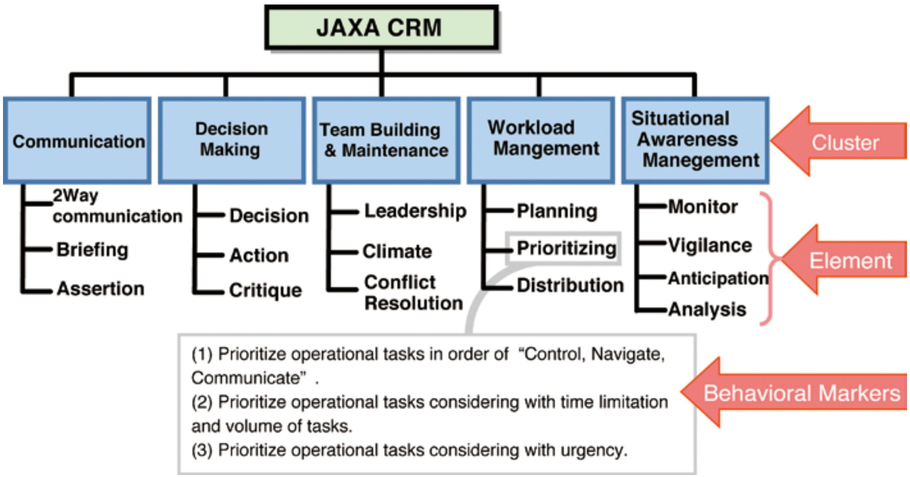


Fig.1 CRM skills proposed by JAXA

Fig. 1 shows the CRM skills proposed by JAXA. CRM skills are classified into five clusters with 3-4 skill elements in each. Each skill element is associated with two or more CRM skills behavioral markers. For example, the "Prioritizing" CRM skill element has the three behavioral markers: (1) Prioritize operational tasks according to "control, navigate, communicate", (2) Prioritize operational tasks considering time limitations and task magnitudes, (3) Prioritize operational tasks considering urgency. Fig. 2 shows a CRM skills rating sheet that we have proposed. With support from airlines, a series of experiments was conducted using simulated Line-Oriented Flight Training (LOFT) to evaluate the effectiveness and usability of the method (Fig. 3). Fig. 4 is a sample of the evaluation result. The results obtained from the experiment indicate that rater's point of view and the scores coincide to some extent and discussion between raters is effective, but there is still some variance in scores. This suggests that there is room for improvement in the rating sheet, in inter-rater reliability, and design of the LOFT scenario. The importance of making these improvements is clear, and targeted research is underway.

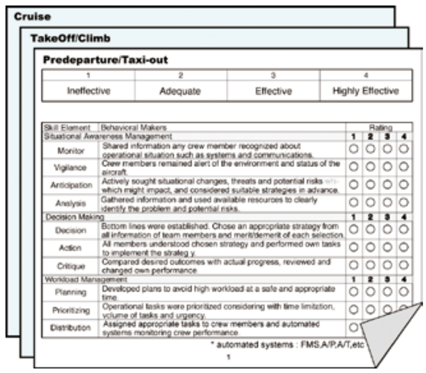


Fig.2 CRM skills rating sheet

Fig.3 Simulated line-oriented flight training

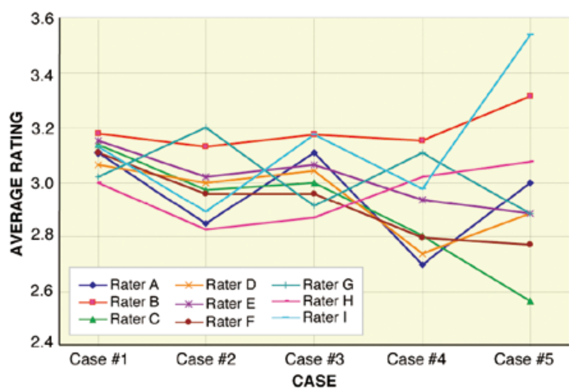


Fig.4 Sample result

● Air Turbulence Detection System

Air turbulence has become a major cause of aircraft accidents, including crew and passenger injuries. Timely warning of turbulence ahead of an aircraft may allow the pilot to take action to minimize any damage. This project aims to develop a practical onboard Doppler LIDAR (light detection and ranging) that can detect wind turbulence even in clear air at a distance of 5 nautical miles (9 kilometers) at cruising altitude.

The overall concept of onboard wind measurement LIDAR is shown in Fig. 5. Doppler LIDAR is installed on an aircraft to measure air turbulence ahead of the aircraft during flight. Pulsed laser light emitted forward from the aircraft is scattered by aerosol particles in the atmosphere and some of the backscattered radiation is received back at the LIDAR. The aerosol particles travel with the wind, so the wavelength of the scattered laser light is shifted in proportion to the velocity of the particles due to the Doppler Effect, enabling measurement of the wind speed.

Fig. 6 shows in-flight measured data from the LIDAR when our airplane flew into a wind shear. Each vertical column indicates the measured wind speed, which can be acquired at one-second intervals, and a row of the lines shows the time history of the wind speed 6 km ahead of the aircraft. In this case, it is easy to recognize that there is a wind shear, and it is possible to predict the airstream 40 to 50 seconds in advance.

Fig. 7 shows the predicted intensity of the turbulence, which is given an Fh-factor value as proposed by JAXA. Each color in the upper figure shows an absolute value of the Fh-factor. The Fh-factor is an index representing the intensity of the turbulence and the rate of change of the horizontal wind. In the experiments we conducted in July 2007, we were only able to make measurements up to about 2 kilometers ahead due to unfavorable air conditions. However, we could predict the possibility of severe turbulence a full 20 seconds before the aircraft started to shake up and down (shown by the lower graph of Fig.7).

The upgraded 10 km range model was developed in 2007. We have already demonstrated measuring the wind speed up to 10 km away in a ground test. This model will be installed in our experimental aircraft and its performance tested in the sky.

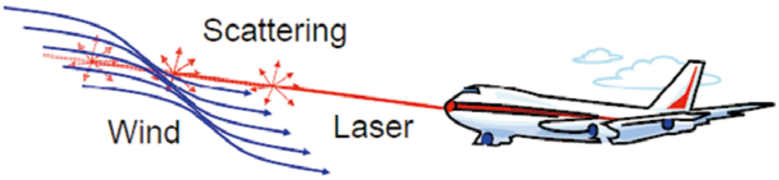


Fig.5 Concept of onboard doppler LIDAR

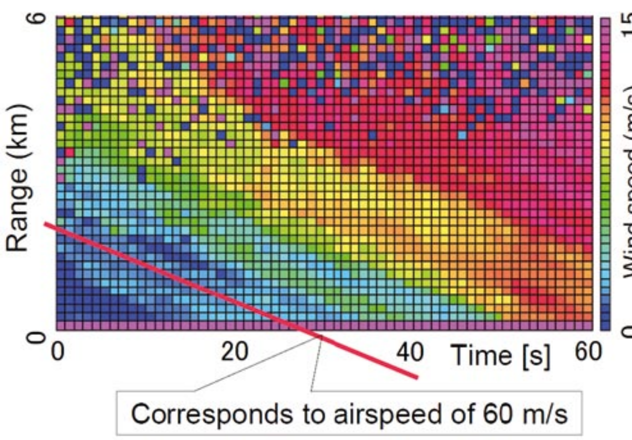


Fig.6 Wind speed measured by LIDAR

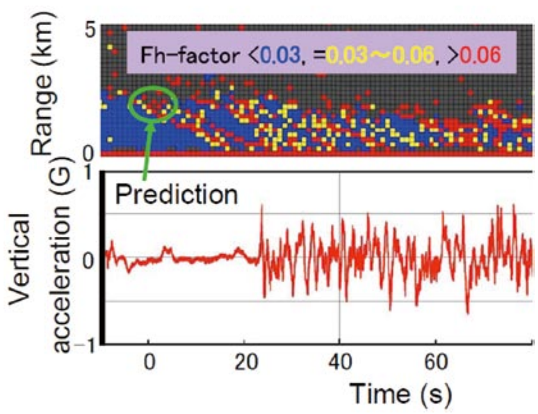


Fig.7 Intensity prediction for possible severe turbulence

Unmanned and Innovative Aircraft Team

JAXA has accumulated Unmanned Aerial Vehicle (UAV) technologies through R&D on various experimental vehicles. The team will research and develop advanced UAV systems for disaster monitoring that can contribute to the security and safety of society. We will also do research on environmentally friendly, innovative aircraft.

Goals

●Research and Development of UAV System for Disaster Monitoring

The team will develop a disaster information gathering system using UAV technology to reach disaster-stricken areas. JAXA will operate the system experimentally in cooperation with local governments to demonstrate the usefulness of the technology.

●Research on Future Oriented Aircraft

As a long-term measure to cope with the problems of future global environment and depletion of fossil-fuel resources, we will develop an electric propulsion system applicable to an ultra light plane (ULP), and demonstrate the performance of the system.

Project Details

●Development of Disaster Monitoring UAV System

– A disaster monitoring UAV system that meets actual needs

In a large-scale earthquake or the extensive disasters caused by storms and floods, a UAV system is expected to be useful for disaster monitoring from the sky. Based on several investigations into opinions or suggestions by local governments, fire departments and related organizations, and also on the UAV technologies owned by JAXA, we propose a disaster monitoring UAV system composed of a small fixed-wing electric plane and a small unmanned airship (LTA: Lighter Than Air).

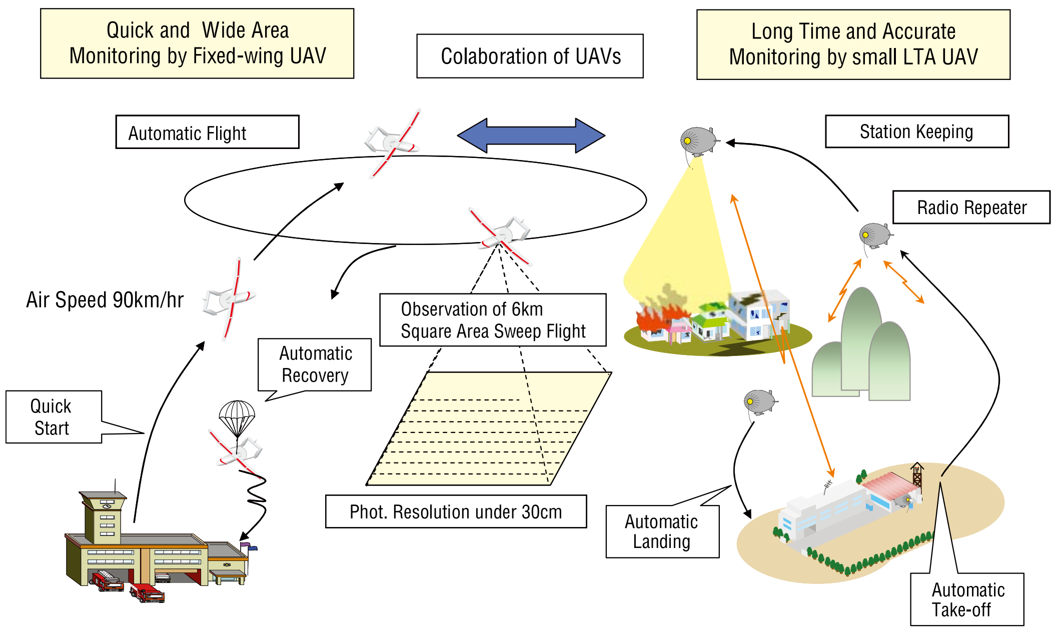


Fig. 1 Disaster Monitoring UAV System by Coordinated Fixed-wing UAV and LTA UAV

● Research on the operational problems of UAVs

To make disaster monitoring with a UAV system as convenient as possible requires full automation both for in-flight monitoring and for takeoff and landing operations. Autonomous flight along pre-specified waypoints and automatic takeoff and landing technology have been investigated in flight tests using test vehicles.

Fig.2 Small Unmanned Airship (14m long)

Fig.3 Electric Powered Fixed-wing UAV (2m span)

● Research on the safety of UAVs

To carry out disaster monitoring above a stricken area, the UAVs will need to fly over inhabited areas. So any damage from the collision of our UAVs with other aircraft or with objects, including people on the ground, must absolutely be avoided. We have investigated obstacle detection and avoidance technology, and collision-safe structures and material to reduce the potential for harm.

● Research on disaster monitoring and long range data transmission

In aerial photography for disaster monitoring, image resolution is important. We have investigated the quality of aerial photos and real-time long-range image transmission to disaster control headquarters. Flight tests for technology demonstration are underway.

Fig.4 Test pattern on the ground for image resolution evaluation

Fig.5 Long-range moving image transmission (15km)

●Research on Future-Oriented Aircraft

Aiming to equip future aircraft with technology that will reduce the use of fossil fuel, we have carried out experimental research on an electrically driven, wheel-assisted, short takeoff and landing (STOL) system. Flight tests have been conducted using a model plane.

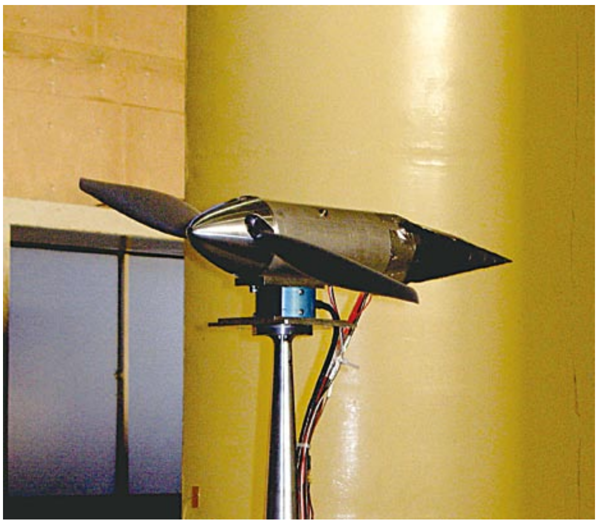
Basic research on electric power plants has also been conducted.

Model Plane (19% Scale)

(Takeoff Distance 50%)

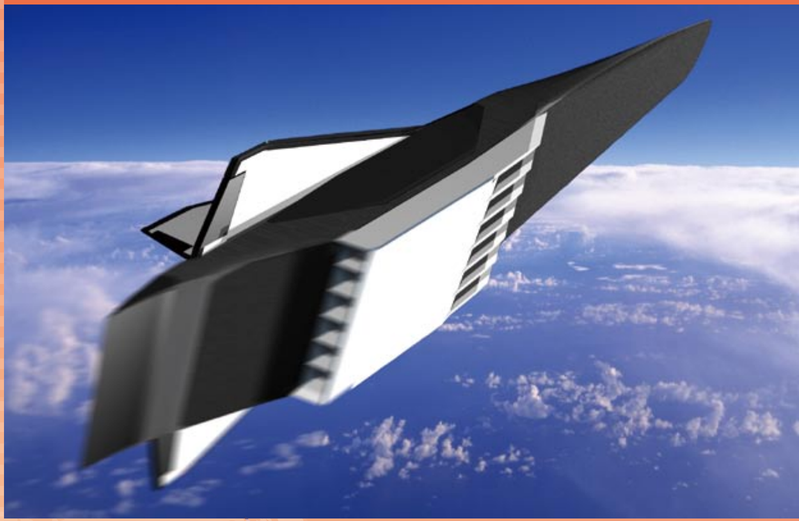
Vehicle in the Test Field

Fig.6 Flight test of a model plane with electrically driven wheels.



Electric Propulsion System

Chapter III



R&D on Space Transportation Technology

JAXA is now working to improve the technologies required for safer, more economical and stress-free space transportation and to create next-generation systems. We are accumulating technologies for dependable space transportation and enhanced system reliability. In the meantime, we are also taking up the challenge to develop a new transportation system. Some of our recent R&D efforts to improve space transportation are introduced in the following pages. These activities are conducted mainly in the R&D Centers of the Space Transportation Mission Directorate.

Chapter III

R&D on Space Transportation Technology

New Development Approach for the LE-X Engine

●The LE-X is a new cryogenic booster engine with the high reliability required for man-rated missions, low cost to beat the competition, and high performance for the next flagship Japanese launch vehicle. It combines the high-pressure component technology of the LE-7A, the first-stage engine of the H-IIA launch vehicle, and the expander bleed cycle system of the LE-5B, the current second-stage engine. It will be the first booster engine in the world with an expander cycle. (Fig. 1)

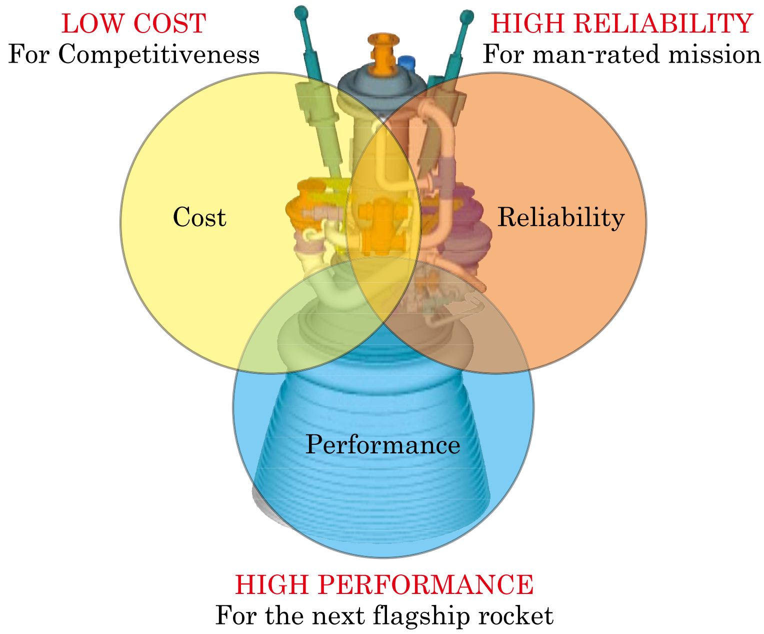
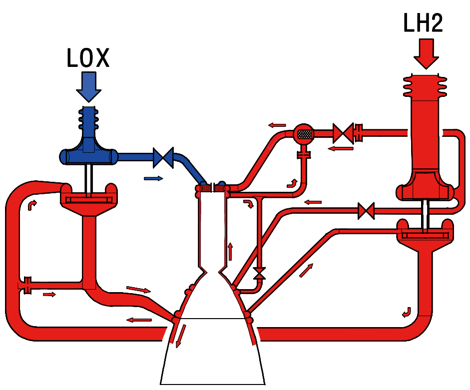


Fig. 1 LE-X engine

LE-X engine research involves an innovative rocket engine design process to ensure higher reliability and performance with lower cost.

Previously, the development process from design to engine test was a so-called "one loop" investigation process. A less-than-well-thought-out design can cause severe problems in the engine testing phase, and can have a major impact on development costs and schedules. The LE-X design approach requires deep investigation in the early design phase. Risks are identified and estimated using various methods such as fault tree analysis (FTA), event tree analysis (ETA), an event sequence diagram (ESD), elementary experiments, and numerical simulation. The identified risks are summarized in a fault mode effect analysis (FMEA). Risk identification and assessment lead to the LE-X engine specification and development plan, and these are reviewed by means of "multi loop" consideration in each design phase. This approach ensures that engine development proceeds as planned and produces a balanced engine with the intended reliability, performance and cost.

The early-stage feasibility study, the engine system analysis and fundamental studies on the LE-X components were completed by 2006. In 2007, the engine baseline configuration with balanced reliability, performance and cost was determined (Fig. 2).



LE-X Engine Characteristics	
Engine Cycle	Chamber Expander Bleed
Thrust (Vacuum)	1410[kN]
Thrust (Sea-level)	1190 [kN]
Chamber Pressure	11.8 [MPa]
MixtureRatio(O/F)	5.9
Nozzle Area Ratio	37:1
Specific Impulse (Vacuum)	430 [sec]
Weight	2250 [kg]
Length	3740[mm]
Rotational Speed (Fuel Turbopump)	40200 [rpm]
Rotational Speed (Oxidizer Turbopump)	15800 [rpm]

Fig.2 LE-X engine system configuration

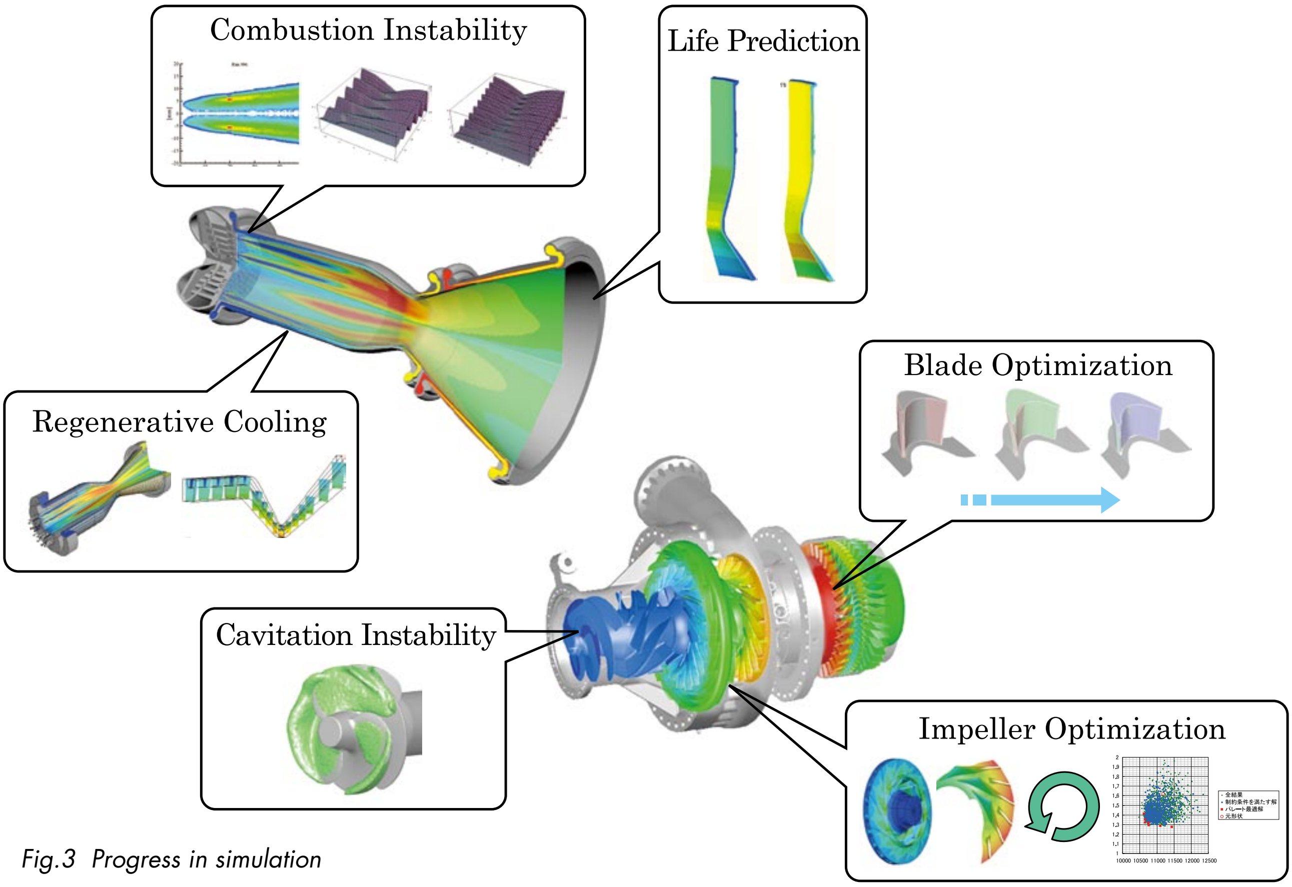


Fig.3 Progress in simulation

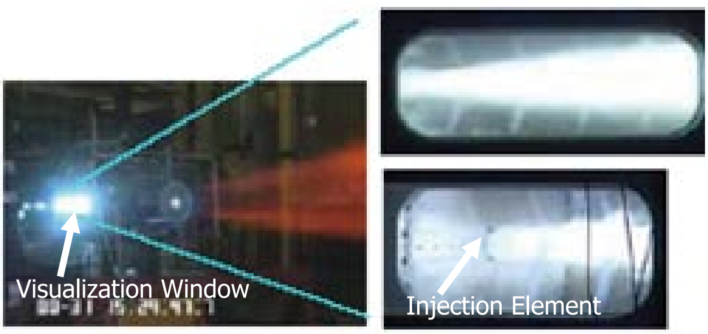


Fig.4 Propellant injection element test

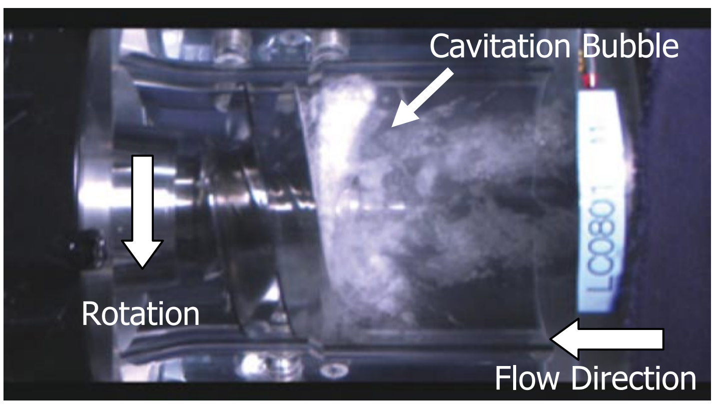


Fig.5 Turbopump inducer cavitation test

Progress in numerical simulation is essential for the LE-X design approach. Aside from risk identification, LE-X development simulation technology includes several areas such as combustion instability prediction, regenerative cooling analysis, combustion chamber life prediction, turbine blade and impeller shape optimization for turbopumps, and cavitation instability (Fig. 3). Simulations are verified by experiments, such as the combustion chamber propellant injection element test (Fig. 4) for combustion instability, and the turbopump inducer cavitation test (Fig. 5) for cavitation instability.

Combustion chamber life prediction is one of the most important technical issues. The combustion chamber of a rocket engine is exposed to high-temperature combustion gas and low-temperature hydrogen coolant, and it sustains the huge thrust of the booster engine. There are no other components that must withstand such extremely severe environments, so life prediction for the combustion chamber amounts to prediction for the entire rocket engine.

Combustion and regenerative cooling analysis, chamber inelastic analysis and combustion chamber life prediction interact with each other (Fig. 6). Combustion and regenerative cooling analysis inputs are the combustion chamber structure, the combustion conditions, and cooling from the engine system, and the combustion and regenerative cooling analysis outputs are chamber heat flux and distribution of pressure and temperature. Chamber inelastic analysis uses the combustion and regenerative cooling analysis outputs, and estimates the history of combustion chamber stress and strain, which are fundamental for life prediction. The estimated combustion chamber life is used for the estimation of engine system design. These coupled analyses will improve the combustion chamber design process.

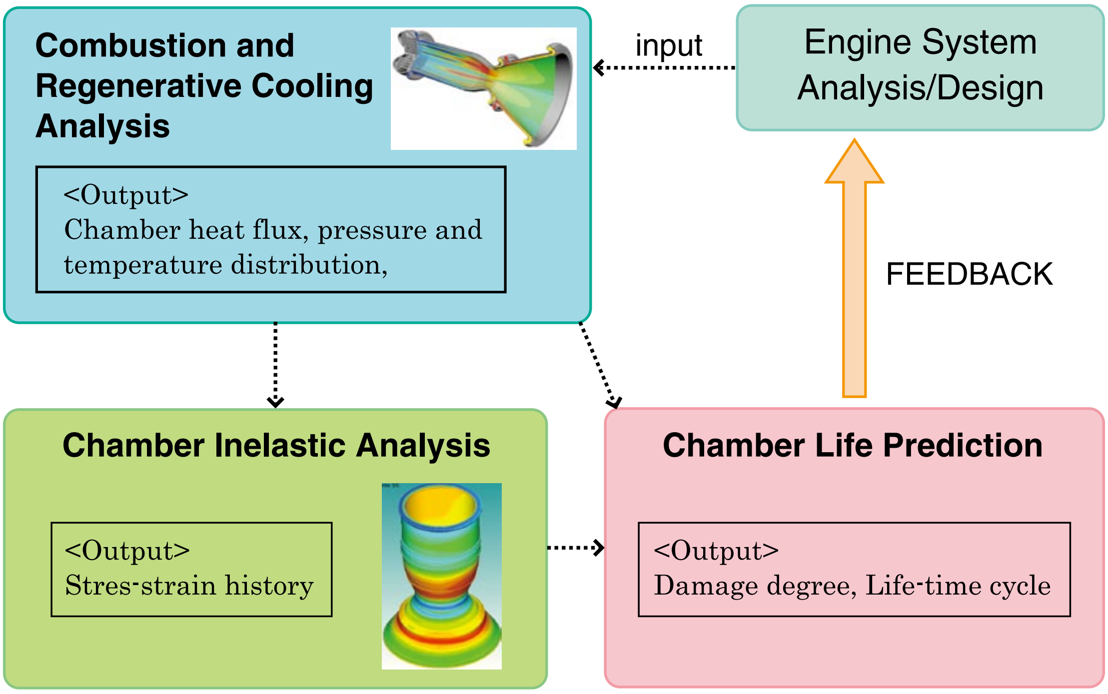


Fig.6 Combustion chamber coupled analyses

The combustion chamber material becomes hot during engine operation, and creep damage to chamber material becomes significant. Therefore, estimation of the mutual effects of creep and fatigue is important for the prediction of combustion chamber life. In addition, the combustion chamber shape may include a convergent and divergent nozzle with a regenerative coolant path, and the stress and strain have a three-dimensional distribution. Three-dimensional stress and strain affect the material life. Therefore, the precise estimation of material life must consider the impacts on the combustion chamber.

Creep and fatigue tests were conducted to aid simulation of the nozzle and coolant path (Fig. 7). Quantitative data were obtained on creep/fatigue in three dimensions and compared with simulations. These data are used for the combustion chamber life prediction analysis.

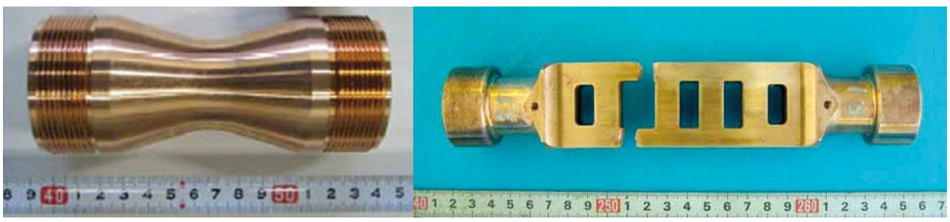


Fig.7 Combustion chamber material test

Thermodynamic Effects on Rotating Cavitation in an Inducer

A turbopump inducer, which is actually a high-precision, high-speed, sophisticated rotating impeller, is one of the key components of a liquid-propellant rocket engine. Cavitation in the liquid can be a problem, but in cryogenic fluids the thermodynamic effects on cavitation act in our favor. Cavity growth is suppressed because the temperature inside the bubble falls due to the heat required for evaporation, and thus the vapor pressure within the bubble is less than that in the liquid. Therefore, cavitation performance of the inducer is improved in cryogenic fluids.

The relationship between the thermodynamic effect and rotating cavitation was investigated with a focus on the cavity length. Experiments were conducted with liquid nitrogen at different temperatures (74 K and 83 K) in order to confirm the dependence of these thermodynamic effects on the temperature. Experiments were conducted in the Cryogenic Inducer Test Facility (CITF) at the Kakuda Space Center (KSC) in Fig.1.

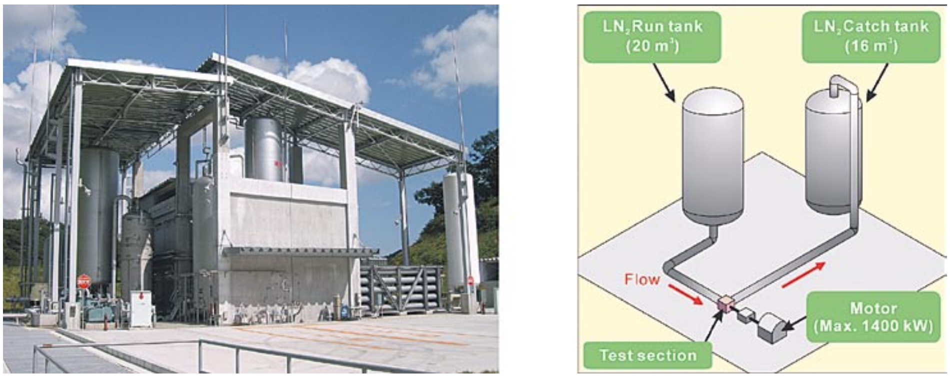


Fig.1 Cryogenic Inducer Test Facility (CITF) at Kakuda Space Center (KSC)

Rotating cavitation can be divided into two patterns based on the aspect of cavity fluctuations. Figure 2 (a) shows typical super-synchronous rotating cavitation, and Fig. 2 (b) shows typical synchronous rotating cavitation. Unevenness of the cavity length is observed in both figures. The longer/shorter cavity propagates from blade to blade in sequence in the super-synchronous rotating cavitation in Fig. 2 (a). In contrast, the cavity length on each blade is uneven but not unsteady in synchronous rotating cavitation in Fig. 2 (b). It is steady with no propagation during the sequence of rotation.

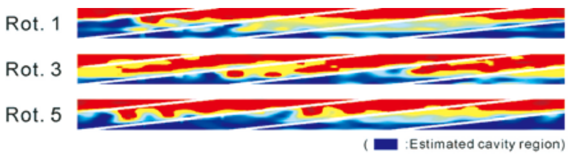


Fig.2(a) Super-synchronous rotating cavitation

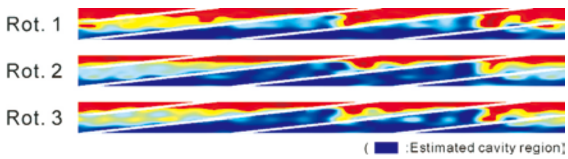


Fig.2(b) Synchronous rotating cavitation

Figure 3 shows a non-dimensional inducer head (□/□0) with varying non-dimensional cavity lengths (Lc/h, Lc: cavity length along the blade, h: blade spacing). This figure shows behavior at two temperatures, 74 K (blue) and 83 K (red), with the symbols ∇ and Δ showing the maximum and minimum fluctuating cavity lengths in super-synchronous rotating cavitation.

Cavity growth is distinctly suppressed as liquid temperature rises, in particular, at lower cavitation numbers. It was found that the thermodynamic effect appears when the liquid temperature is higher and the cavity length is longer. The differences in the behavior of the cavity fluctuation and oscillating frequency in super-synchronous rotating cavitation were not prominent at any temperature. However, the unevenness of the cavity length under synchronous rotating cavitation was greatly affected by the thermodynamic effect. Thus, the favorable thermodynamic effect on cavitation instability becomes greater when the cavity length extends over the throat (Lc/h>1.0) at lower cavitation numbers.

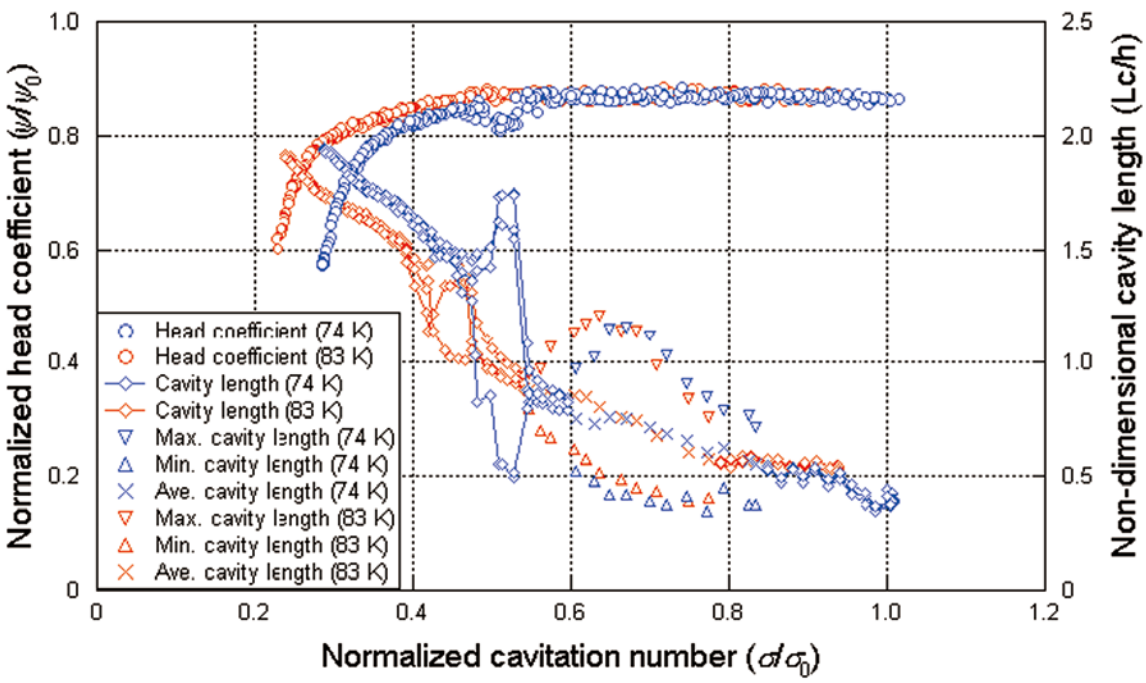


Fig.3 Cavitation performance and cavity length at 74 K and 83 K

Experiments on the Combined Cycle Engine in Mach 4 Flight Condition

Resource limitations on Earth loom as a barrier to the prosperity of mankind, making the more active development of the space environment a realistic topic of study. For more frequent and safer space transportation, the concept of a reusable launch vehicle (RLV) was introduced, and has been studied for decades. One key requirement for the success of the RLV is a reliable and economical reusable engine that can accelerate the vehicle from launch to earth orbit. Rockets can produce an enormous thrust in any environment from ground level to the vacuum of space. However, they must carry a heavy load of oxidizer to burn their fuel. In contrast, jet engines are economical in atmospheric flight, since they use the oxygen in the air to burn their fuel. Jets are useless in air that is too lean. To get the benefits of both systems, a hybrid system has been investigated, and one of the solutions is a rocket-based combined cycle engine.

Figure 1 shows the concept of the combined cycle engine. The engine is mounted on the ventral surface of the airframe. At the core of the engine are rockets with throttling capability. Below the rocket housing, is a flow passage for jet operation. The combined cycle engine operates in several different modes, each of which is suitable for a specific flight speed regime.

In the low-speed regime, the rockets produce most of the thrust, augmented by the combustion of a second fuel in the induced air flow (ejector-jet). In supersonic flight, the rockets are reduced to minimal operation and primarily serve as an igniter for the combustion of a ramjet, a high speed jet that uses shockwave compression and a subsonic combustion process. In the hypersonic speed regime, the engine switches to scramjet or rocket mode.

Fig.1 Conceptual image of combined cycle engine

In the Kakuda Space Center, the combined cycle engine has been under study, and the very first experimental model, a 3-m-long combined cycle engine (Fig.2) was constructed and has been undergoing tests since December 2006. The engine has a pair of rockets, and secondary fuel injection ports at several locations (designated "DIV1" to "DWNC" in Fig. 2). The air comes in through a double-staged inlet and goes into the combustor section. The bottom side of the engine is covered by a cowl with a "droop" leading edge, which ensures good starting capability and helps the flow rate. A series of tests will be conducted on this experimental model at various Mach numbers, and the engine design will be improved. Ultimately, this will lead to the construction of an actual flight engine.

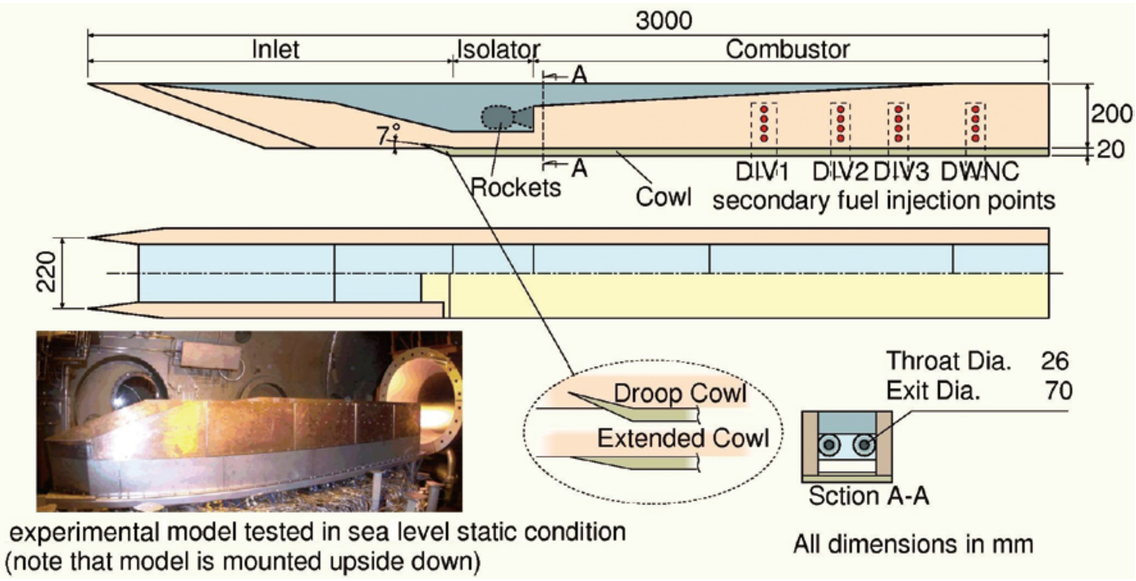


Fig.2 Schematic view of the combined cycle engine experimental model

Following the static ejector-jet experiments at sea-level in 2006, in April and November 2007, experiments at Mach 4 condition were carried out. At Mach 4, the combined cycle engine is scheduled to operate in ramjet mode. All experiments were conducted in the Ramjet Engine Test Facility (RJTF) at the Kakuda Space Center.

The basic characteristics of the air stream, such as the pressure distribution and thrust, were obtained at a total pressure of 0.86 MPa and total temperature of 870 K. Note that the actual Mach number at the entrance of the model was 3.4 since the flow is assumed to be compressed by the ventral surface of the vehicle.

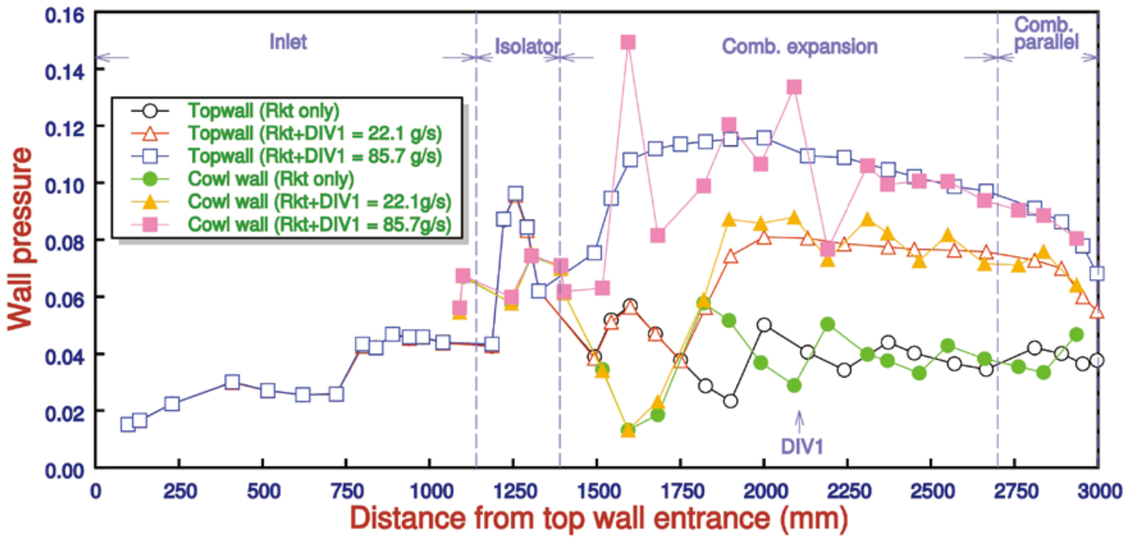


Fig.3 Wall pressure distribution in ramjet mode

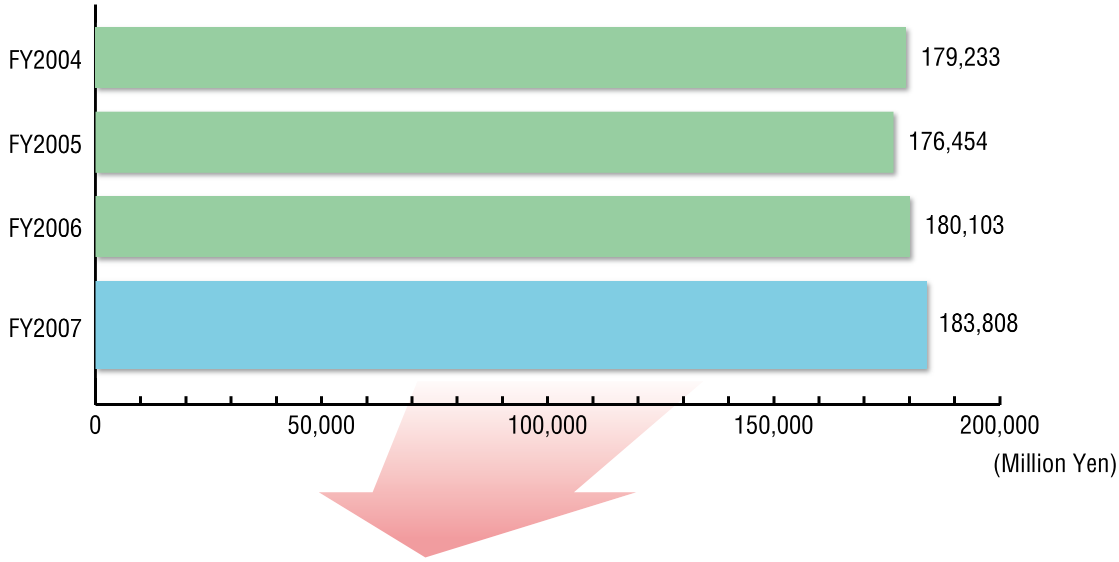
In the ramjet mode experiments, the rocket chamber pressure, Pc, was reduced to 0.6 MPa from its nominal state of 3 MPa. Figure 3 shows the typical pressure distribution on the top wall and cowl surface obtained along the center line. The pressure is normalized by the total pressure of the free stream. The incoming air was first compressed by the oblique shock waves that were generated at the kink points of the ramp of the inlet. Inside the isolator, the flow was further compressed by the shock wave emanating from the leading edge of the cowl. Without fuel injection, the pressure inside the combustor section showed a rather low and uneven distribution. However, with even a small amount of fuel, a high pressure region appeared from upstream of the injection point (DIV1, in this case). With more fuel, the pressure in the entire combustor section increased. A steep pressure rise started near the combustor entrance, and the pressure became gradually higher until it reached a maximum around the fuel injection point. Downstream of the injection point, the pressure decreased towards the exit of the model. This pattern corresponds to the typical pressure distribution of the ramjet cycle. This result indicates that the current model is capable of establishing ramjet mode, as well as the ejector-jet mode that was confirmed in previous experiments. The current experiments also prove that the high pressure inside the combustor section did not affect the flow field in the inlet, assuring good starting capability for the model at Mach 4 condition.

During all the experiments, the thrust was measured directly by a mechanical force measuring system. It was confirmed that the thrust was roughly proportional to the fuel quantity. In the current ramjet mode experiments, a positive net thrust that is about 90% of the predicted design value was achieved when a sufficient amount of fuel was injected.

In the upcoming 2008 season, ramjet operation will be further explored at a higher Mach number condition. Examination of the scramjet mode will follow in the near future. All these data will be vital to improve the design of the rocket-based combined cycle engine.

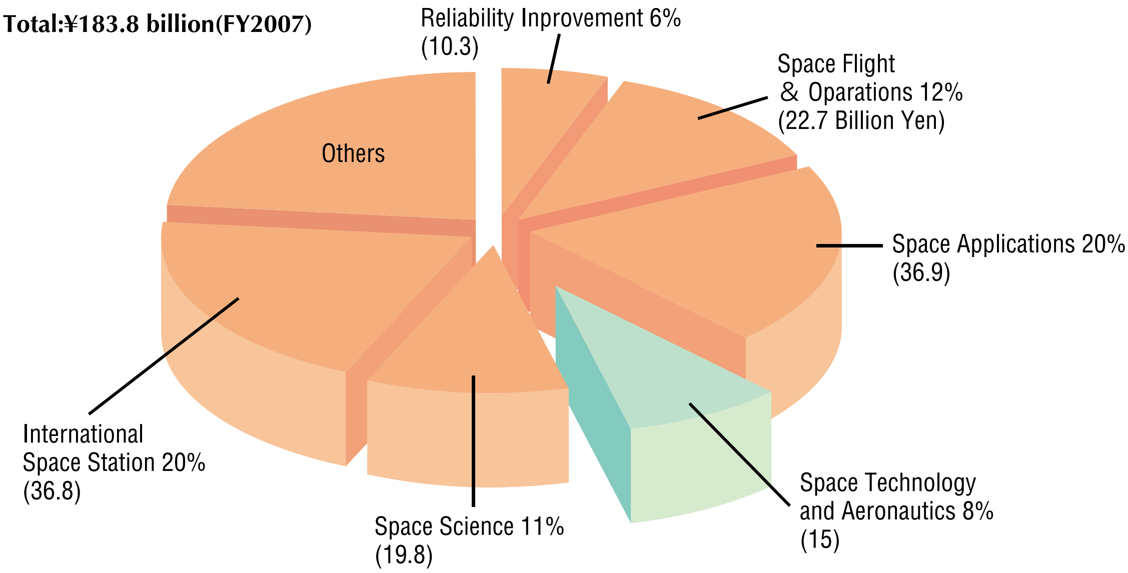
Trend of Budget

JAXA Total Budget from the Government of Japan

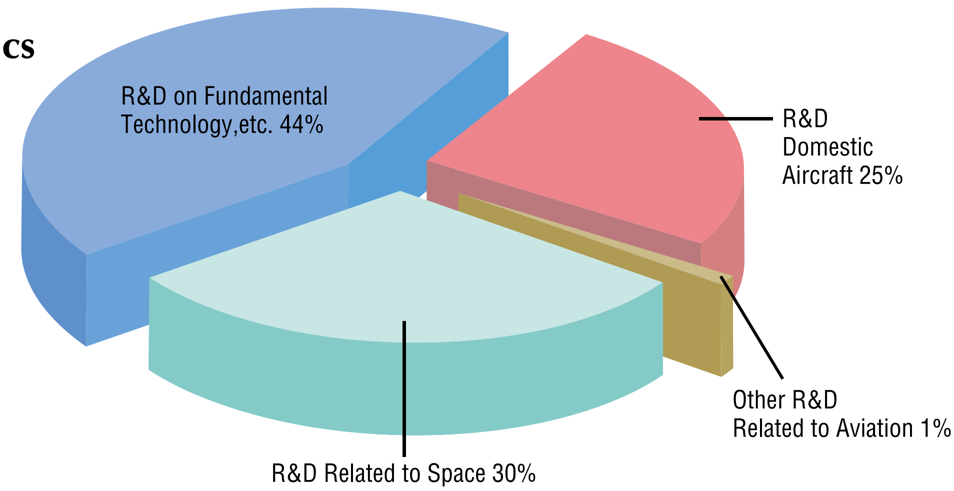


Ratio for Each Field of Program in JAXA Budget

JAXA Total:¥183.8 billion(FY2007)



Space Technology and Aeronautics



Organizational Structure

President

Vice-President

Policy Coordination
- Strategic Planning & Management
- Industrial Collaboration
- International Relations

Administrative Management
- General Affairs
- Public Affairs
- Human Resources
- Finance
- Contract
- Aseesment & Audit
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- Security Administration

Technical Management
- System Engineering
- JAXA's Engineering Digital Innovation
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- Information Systems
- Ground Facilities
- Spectrum Management

Office of Space Flight & Operations
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Office of Space Applications
- Earth Observation Program
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Institute of Aerospace Technology(IAT)(299)
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- Safety & Quality Assurance Office
- Centers & Groups for Aerospace Technology (134)
- Centers & Groups for Space Technology (110)

Institute of Space & Astronautical Science(ISAS)
- Space Science Research & Graduate Education
- Space Science Program

Aviation Program Group (APG)(70)
- Program Office
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- Safety & Quality Assurance Office
- Teams for Quality Assurance Office
- Teams for Aviation Program (65)

IGS Group

JAXA Total Personnels
1,752

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