



JAXA's Engineering Digital Innovation Center



*JAXA's Engineering
Digital Innovation Center*

Japan Aerospace Exploration Agency



Greeting from the Center's Director

Director of JAXA's Engineering Digital Innovation Center

Eiji Shima

JAXA's Engineering Digital Innovation (JEDI) Center was established on October 1, 2005. Major role of the Center is to improve JAXA's enterprise efficiency and reliability of its spacecraft designs and productions by means of digital engineering that comprises leading-edge information technology and computational engineering as typically referred to numerical simulations. JAXA was established on October 1, 2003, by merging three independent institutions with the hope of performing their activities more efficiently in the aerospace field as one organization. Digital engineering has cross-sectional nature across the whole directorates of JAXA, and therefore, JEDI Center holds an advantage in promoting the merging effect. The center will contribute not only to JAXA organization itself but also to world-wide space development by consolidating its synergy effect of high-quality technological and human resources inherited from old institutions.

Fortunately a favorable evaluation was given to JEDI Center for its activities in the first period of JAXA mid-term plan, which ended in March 2008. Many of the JEDI activities, however, are still in progress. During the second period, it is expanding its activities in more concrete way based on the outcomes and experiences of the past several years. The project of introducing IT technology into the development process for particular satellites in the first-stage is becoming a formal standard for all JAXA's satellite development processes and will be generalized. Furthermore, as a new technical prospect, an IT-based satellite operation enhancement system is being developed. Experience of applying IT technology for satellite development is being transferred to similar activity for rocket engines development process under the collaboration with Space

Transportation Mission Directorate (STMD), which will result in reliability enhancement of future rocket engines. Supercomputer facilities in the three former institutions were replaced by a single supercomputer system, and started general operations in April 2009. This new supercomputer system directly supports highly sophisticated numerical simulations available at only JAXA. Such simulations are introducing digital innovation by reforming the entire JAXA activities as well as directly supporting success of wide variety of JAXA projects. Possible candidates for such innovation are (1) Research of establishing model-based design, and (2) Software development for the next-generation platform of numerical simulations. Several international and national joint-research programs have already started. Especially, under the collaboration of JAXA and University of Tokyo (Social Cooperation Program) a Rocket Engine Modeling Laboratory (REML) opened with the purpose of enhancing academic support for numerical simulations of rocket-engine systems in January 2008. International collaboration between JAXA and Iowa State University in the United States has started in 2007 and a few more collaboration with the foreign organizations is under discussion. Such collaboration will help JEDI to keep its best activities under the restricted budget and personnel.

JEDI center will not stay in a narrow discipline but open its eye to wide range of disciplines, and continue a new challenge. As a center director, I hope for the JEDI center to be given a high appreciation and good reputation from the community of aerospace engineers as a professional center with its effort in the field of IT technology and computational mechanics. Be the "FORCE" with us.

Engineering Digital Innovation Center

The Aim of JEDI Center is ;

To renovate JAXA and Japan's activities through its world-class achievement in innovative digital engineering methodology developed and implemented by highly-talented professionals.

MISSION1

Introduction of up-to-date IT technology/systems into spacecraft and aircraft projects

- Establishment of satellite development & an operations support system
- Establishment of a support system for transportation system development
- Improvement of the reliability of the spacecraft on-board software

MISSION2

R&D on numerical simulation technology and its application to spacecraft and aircraft projects

- Advancement of liquid rocket engine design analysis technology
- R&D on prediction of rocket plume acoustics and its application to launch vehicles
- Application of numerical simulation to JAXA projects for problem-solving purposes
- R&D of next generation CFD technology and its application to JAXA's projects
- Collaboration JAXA and the University of Tokyo

MISSION3

Introduction and operation of JAXA's super-computer system, R&D on the application technology

- Improvement of the utilization environment and the stable operation of the new supercomputer system
- Continuous improvement of operational efficiency and the utilization environment of supercomputers



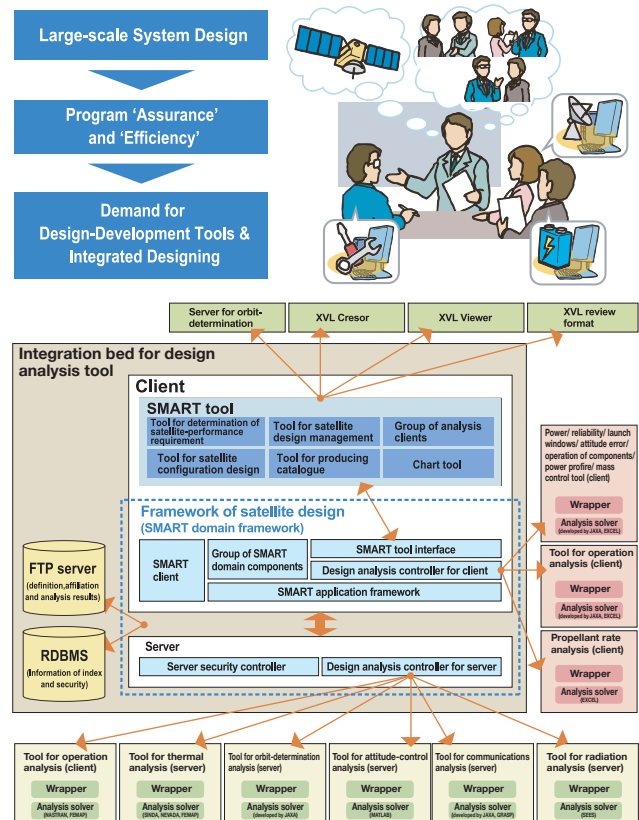
Satellite Project Information System Team

One of the key roles of JEDI is to adapt and promote well-established information technology into the framework of JAXA's satellite projects in order to assure their development processes and actual space operations. The team's efforts are focused on improving various project phases ranging from an early system-designing to manufacture-and-testing activities, as well as on maximizing the satellite performance during operations in order to respond to end-users' needs.

Integrated application tools and support environment for an early system-level designing

Providing a satellite design-aid system (SMART)

Generally, during satellite development, system engineers are responsible to make the entire system meet each requirement by putting together many pieces of information through frequent communication with related engineers and experts about requirements, interfaces, and design results. Such complicated information exchange is time-consuming and may lead to design errors and functional flaws. A satellite design-aid system (SMART) is developed to eliminate these uncertainty and to improve efficiency, especially during an early stage of satellite system-level designing, by integrating well-established design tools, database, and an unique satellite design framework. In addition SMART is also released in a simplified software package 'SMART Lite' which may be installed and executed solely on user client PC.



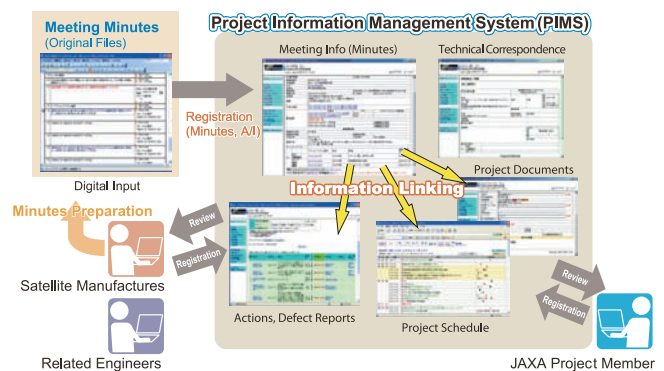
Satellite design-aid system (SMART)

Adaptation and promotion of information systems for satellite manufacture and testing activities

Extending use of 'well-established information technology'

Persuasion of higher reliability, product quality as well as prompt production is essential to JAXA's satellite projects. In order to resolve these challenges by adapting latest information technology among satellite manufacture and testing activities, both WINDS and GOSAT satellites were designated as highly prioritized 'test-bed' projects in focus of program 'assurance' and 'efficiency.' As for practical applications, the team has approached these projects with the concept of 'promotion of information sharing' and 'enhancement of design review.' To improve productivity during the entire project phase, a user-oriented Project Information Management System (PIMS) was designed and applied to the mentioned 'test bed' projects.

The PIMS is capable of systematically managing, transferring and exchanging a variety of and large quantities of project information starting from a single set of meeting minutes, a daily schedule and to various satellite technical specifications which are promptly shared among JAXA as well as related spacecraft manufacturers and institutions.



Information sharing and management scheme

Objectives of Satellite Project Information System Team

Integrated application tools and support environment for an early system-level designing

- Providing a 'satellite design-aid system (SMART)' to assure and improve an early stage of satellite system-level designing.

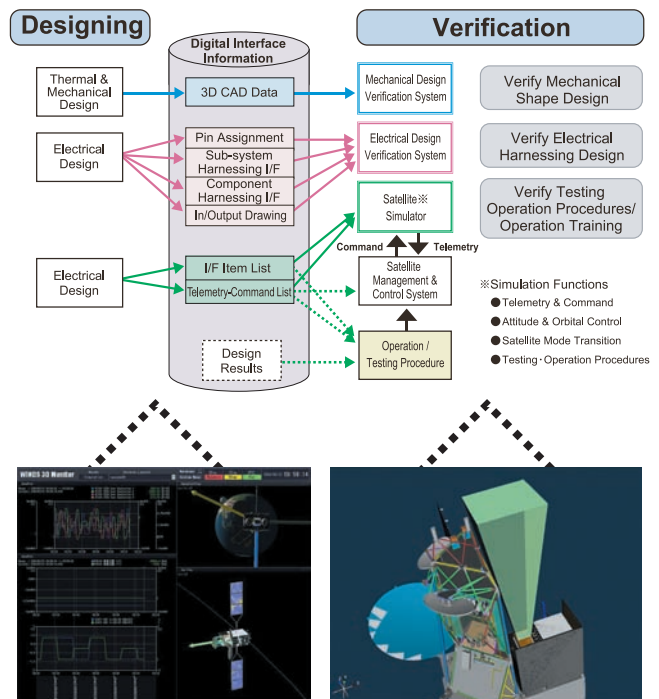
Adaptation and promotion of information systems for satellite manufacturing-and-testing activities

- Extending use of 'well-established information technology' (data management and design-review tools) among on-going and potential satellite projects.

Satellite ground system towards an enhancement of observation capability

- Providing a satellite 'prediction & evaluation' system to maximize its observation duration by predicting potential margins among the satellite's sub-system resources.

Based on engineering interface information, both mechanical and electrical design verification tools were also provided to enhance technical review processes. A dedicated satellite-simulator was also provided to prevent design oversights and to pre-verify satellite operation procedures. These approaches have already demonstrated the effective applications of information technology. Most of the information systems and design-review tools have been standardized and extended its use among on-going and potential projects including earth-observation and science oriented satellites. Moreover, some of these systems and tools are adopted as part of the manufactures' development processes.



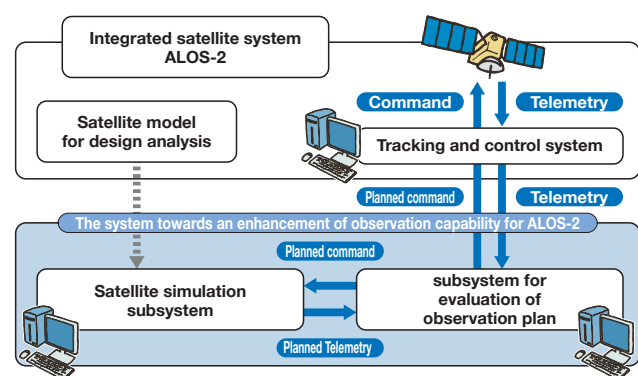
Design review tool & satellite simulator scheme

Satellite ground system towards an enhancement of observation capability

A ground system for Advanced Land Observation Satellite (ALOS-2) and beyond

The remote environment prevents an unmanned spacecraft from any on-site repairing; therefore, they are carefully designed and developed based on worst-case scenarios, standards, and cautious operation rules. On the other hand, during the course of real-time operation, the actual performance of the spacecraft gradually becomes visible along with the surrounding environment. And eventually, by improving the precision of performance estimation, the potential margins among the satellite system resources can be predicted; thus more observation and data utilization opportunities without compromising the overall reliability.

In order to extract this satellite potential and maximize its observation capability, an original satellite resource 'prediction & evaluation' system is under development in support of ground-based satellite operations which targeting the application towards JAXA's Advanced Land Observation Satellite (ALOS-2) and beyond.



Conceptual image of a Satellite Resource 'Prediction & Evaluation' system



Team for Information Systems of Space Transportations

Toward the achievement of highest reliability and international competitiveness of space launch vehicles, JAXA is making comprehensive efforts to establish high-reliability development process which enables to reduce the cost and the duration of launch vehicle development.

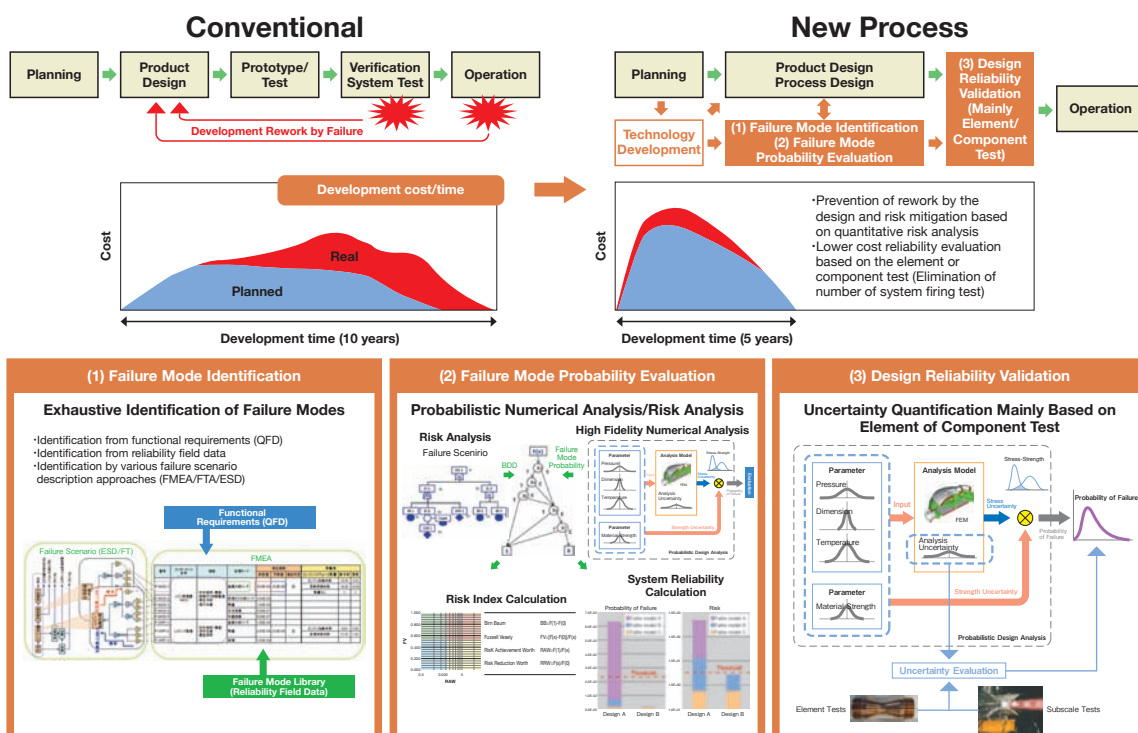
JEDI center is challenging the establishment of an innovative reliable development methodology by proactively using state-of-the-art information technology and system reliability engineering techniques.

New Development Process for High-reliable Space Transportation System

In the development of space launch vehicles, design validation and system reliability evaluation has been carried out based on the conventional test-fail-fix development process. Especially in the rocket engine development, a large amount of expensive firing tests has been required. However, this process has two major drawbacks if it will be applied to human-rated rocket engine development. First, it will be required a unrealistic amount of expensive firing tests for the system reliability evaluation. Second, failures in the later development phase will result in the additional costs and schedule delays such as the redesign and its validation experiments. Accordingly, it is crucial to establish the new front-loading type development method in order to ensure the higher-reliable rocket engine development.

We are currently working with next-generation booster rocket engine (LE-X) research team to establish the high reliable development process as follows:

- In order to prevent development reworks, reliability design consideration should be done from the initial stage of development. Firstly, failure modes are identified comprehensively. For each failure modes, its probability is evaluated based on high-fidelity probabilistic numerical simulations. If needed, design is modified based on the simulation results to meet failure mode probability requirement.
- Engine system reliability is evaluated based on the numerical simulation models. Since these models can be validated based on element tests or/and component tests mainly, number of the expensive firing tests can be reduced.
- Furthermore, quantitative risk analysis is performed continuously from the early development phase. Based on the risk analysis results, risk monitoring and its mitigation are planned. All failure modes are ranked based on the risk analysis, high risk failure mode is prioritized in the risk mitigation plan. Consequently based on this new development method, high reliability should be achieved in the shorter development time and lower cost.



Overview of high reliable development process

Objectives of **Team for Information Systems of Space Transportations****Establishment of highly reliable space transportation system development process**

- We will establish new development process of liquid rocket engine to achieve high-reliability in lower cost and shorter development time. To achieve this goal, JEDI's high-fidelity simulation technology is utilized to the maximum extent possible.
- We will develop information system to implement the new development process certainly.
- We will apply new development process to next-generation launch vehicle development activity.

**Information System to Support
High Reliable Development Process
System of Quantitative Risk Analysis
and Management (SQRAM)**

In the new high reliable development method is highly depending on the quantitative risk analysis and various probabilistic numerical analysis for each failure mode. Since space launch vehicle consists of numerous subsystems and components, there are many contractors to develop each elements. This results in the complicated data handling including failure scenario, reliability field data and input data for numerical analysis.

In order to prevent incorrect data exchange and improve efficiency, development of information system, System of Quantitative Risk Analysis and Management (SQRAM), is in progress at JEDI.

SQRAM consists of two parts.

One is front-end tool (SQRAM-leaf) and the other is database system (SQRAM-ROOT).

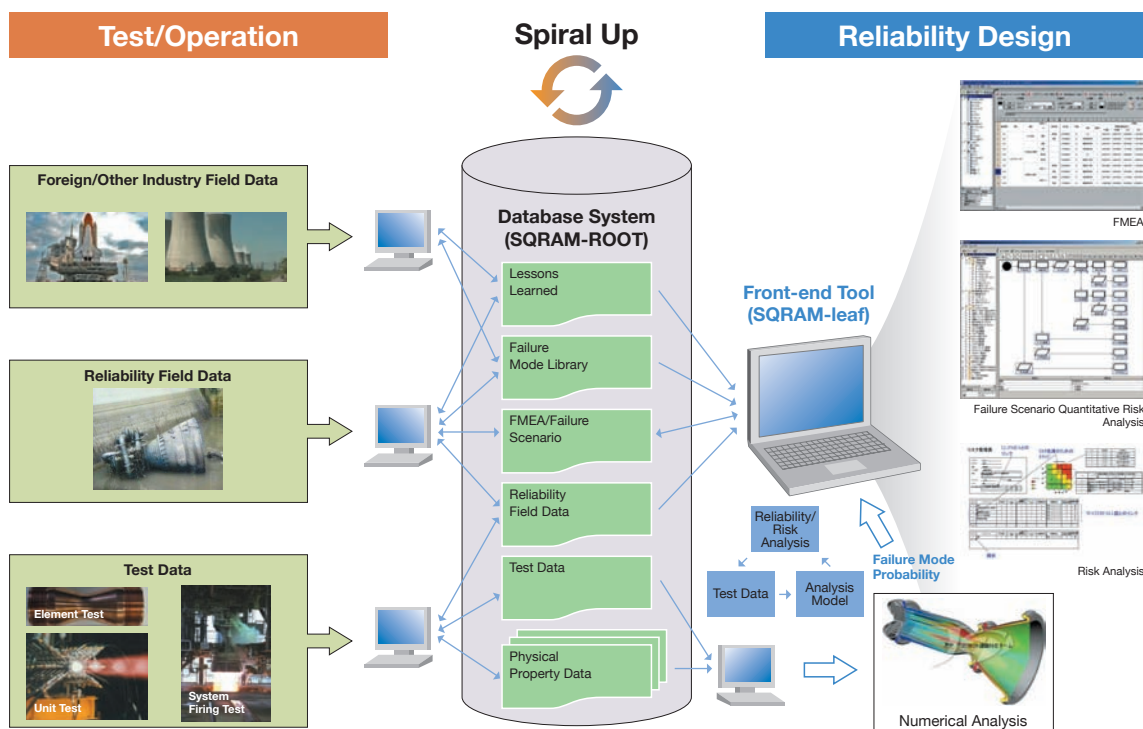
In the new development method, failure scenario is

exhaustively described based on the FMEA (Failure Mode and Effect Analysis) and FTA/ESD (Failure Tree Analysis/ Event Sequence Diagram). Based on the described failure scenario model, quantitative risk analysis is performed by Boolean logic calculation.

By using SQRAM-leaf, failure scenario can be described FMEA, FTA and ESD, minimal cut set/risk index can be calculated, reliability allocation and system reliability calculation can be performed.

Quantitative risk analysis is performed in all development stages. And it is essential to provide valuable heritage knowledge and technical data for the correct design decision. In addition, quality assurance of input data for the numerical analysis is also important for the success of new development method. In order to solve these problems, SQRAM-ROOT provide the platform to support complicated quantitative risk analysis.

SQRAM-leaf and ROOT can communicate to exchange the data such as analyzed failure mode probability.



Overview of System of Quantitative Risk Analysis and Management (SQRAM)



Software Engineering Team

On the electronic equipment for spacecrafts such as space stations, satellites and launch vehicles, various software ranging anywhere from complicated to simple types are installed, including the main controller software for spacecrafts. Our software engineering team is engaged in the research on 'how to produce' and 'how to confirm' accurate and better software, and we are practicing it. We also promote the application of software engineering to electronic equipment in the design phase to optimize design, reduce time spent on designing and improve quality.

Improvement of the reliability of spacecraft on-board software

1. Software Independent Verification and Validation (IV&V)

It is hard to repair spacecrafts such as space stations, satellites and launch vehicles after they go out into space. It is similar for the software installed into such spacecraft and it is not easy to correct or to modify this flight software after launch. However, if a malfunction occurs in the software, it sometimes brings about a fatal failure for the spacecraft. So, the spacecraft on-board software is always required to meet high reliability. As the one of such activity, our software engineering team conducts 'Software Independent Verification and Validation (IV&V).' The purpose of software IV&V is to reduce potential risks by clarifying issues and problems, which are difficult to find at the development section, in the spacecraft on-board software. This activity is carried out by an independent section from the development section in terms of funding and organization, using independent technology and point of view.

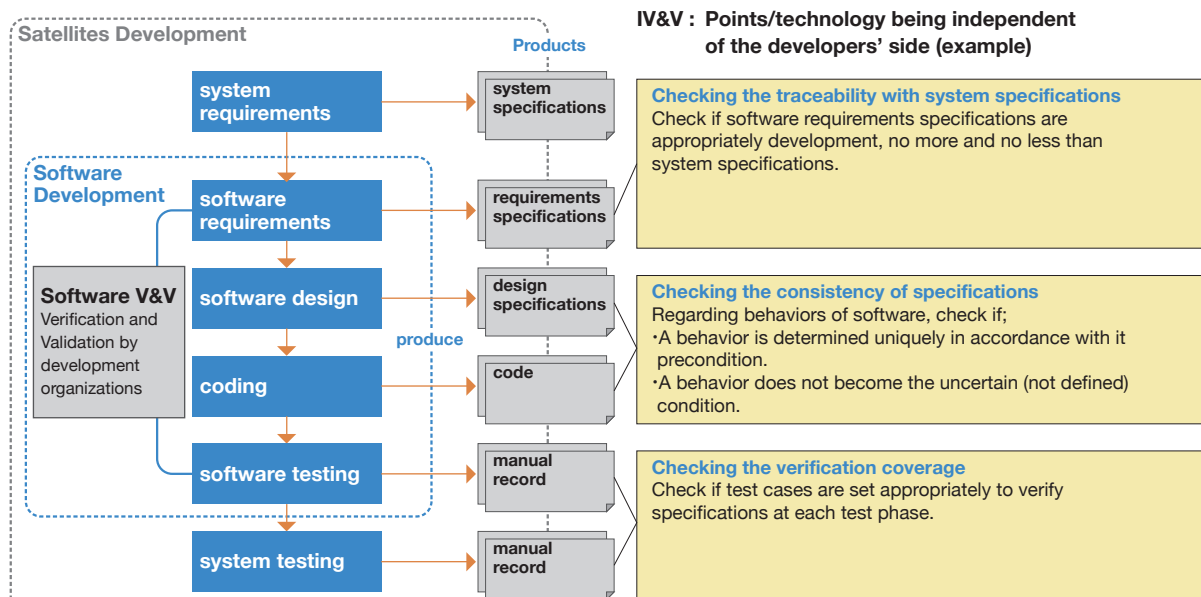
[Substance]

Outcomes including specifications and source codes

provided by the development section are evaluated from various points of view, by using methods such as document review, model checking, analysis, simulation, etc. We confirm whether or not the software meets the condition to realize the mission of the spacecraft and whether or not the contents of designs and tests meet the requirements. When some issue or problems are found in the outcomes during the process of evaluation, the contents would be fed back to the development section on a timely manner. After all evaluations are completed, we will present to the development section an evaluation report on the reliability of the software under target and give proposals about the issues that need to be solved.

[Achievement]

Software IV&V has already been performed on many actual satellites including 'KIZUNA (WINDS),' 'KAGUYA (SELENE)' and 'DAICHI (ALOS),' Japanese Experiment Module 'KIBO' of the International Space Station, and various rocket projects. These achievements show that we are making a contribution on the improvement of spacecraft software reliability.



Software Independent Verification and Validation

Objectives of **Software Engineering Team****Improvement of the reliability of spacecraft on-board software**

- We will establish speedy development process of highly reliable liquid rocket engines and an information system that efficiently supports the process. Furthermore, we will work towards establishing a methodology that halves the engine's development time and cost compared to the past.

Software engineering approach for spacecraft development

- **[technology already developed]** By utilizing software engineering, we provide highly reliable real time OS and development environment. We also support spacecraft development through the design aid system for satellite electronics, ELEGANT.
- **[technology on the research step]** By conducting investigation and research of model base engineering, which enables space craft design in the preliminary development phase by using software, we will estimate its applicability to future spacecraft development.

[Research]

Software IV&V has expanded the application to the actual projects. We maintain the manuals and establish the decision criteria of performance, for the improvement of work efficiency of software IV&V, and we are conducting the optimization and technology improvements of the evaluation model aiming at the upgrading.

In addition, we are conducting the research on new IV&V technology in accordance with the actual project needs. According to the latest outcomes, new safety analysis technology is started to be used, and we verified to identify the matter leading to hazards which are easy to overlook by the conventional methods. We share these outcomes with NASA and ESA, and we aim to establish the international IV&V cooperation system.

2. Software Process Improvement

The meaning of the word 'process' in software process is about how to make software, which includes steps like requirement analysis, designing, coding and testing. Our goal is to construct software development technology with high reliability through the establishment of a process improvement cycle peculiar to spacecraft software development.

The process improvement cycle goes and returns through steps, Plan, Do, Check, and Action. Firstly, at the actual improvement activity, we started from the analysis of the present situation, 'Check'.

[Check]**Analysis of the present situation**

Improvement measures are taken from and examined from problems identified in the processes, and introduced by using the latest technology. These activities are carried out in collaboration with JAXA - related software manufacturer to establish more efficient processes.

[Act]**Standardization of processes**

It is the 'Software development standard (for spacecraft)' which incorporates the improvement measure pointed in 'Check' into the JAXA's standard process, and it has started to apply to the actual software development. This standard is the consolidation of the experience and the knowledge we

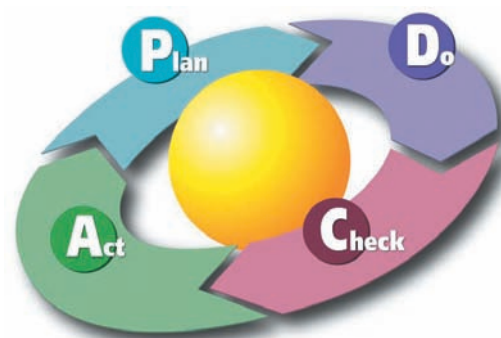
have obtained from past development and it should be one of the guidelines in software development in the future.

[Plan]**Promotion of continuous improvements**

In order to promote this improvement activity we started and the continuous performance, we are planning to research on new technology and to start using it, such as the introduction of the present new process evaluation technology and the research on the technology to visualize processes and to make them easy to use.

[Do]**Promotion of the application of software development standard**

In order for further process optimization and upgrading to be realized, a measurement and evaluation of processes is necessary that takes us back to the 'Check' step. We are testing the activity to check how applied software development standard is performed by using the method of 'Process assessment' and lead to the improvements. In addition, in order to explore the ways of not only qualitative evaluation but also quantitative evaluation, we are testing the method of collecting data which could become an indicator of the process situation.



PDCA Cycle of Process Improvement

Software Engineering Team

Software engineering approach for spacecraft development

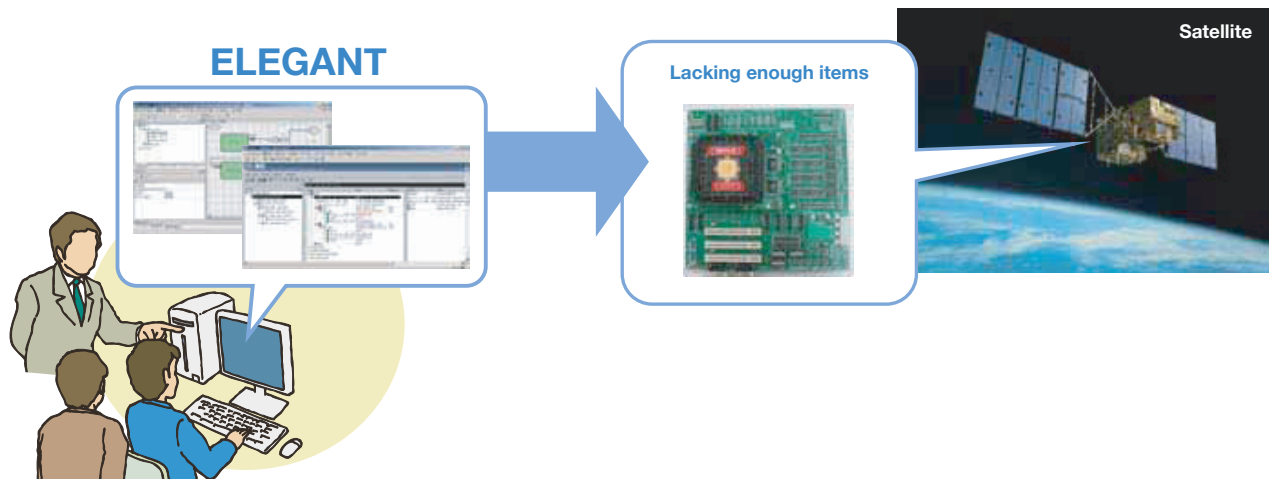
1. Design Aid System for Space Electronics: ELEGANT

Electronic equipment for spacecrafts such as space stations, satellites and rockets have two portions. One is the analog portion composed of capacitors, resistance and others and the other is the digital portion composed of hardware (HW) represented by FPGA and ASIC and software (SW) run on CPU and others.

The HW and SW of the digital portion used to be designed in different environments by different persons. Therefore, some problems occurred like the following: role sharing between HW and SW for processing wasn't suitable; a waiting period before SW testing occurred because SW testing could not be performed until HW designing was completed; and in the combination test of HW and SW, sufficient SW testing was not conducted for fear of the HW crashing.

Therefore, in order to contribute to the reduction of design

period and improving reliability by solving those problems, we developed the 'Design Aid System for Space Electronics: ELEGANT (Electronic Design Guidance Tool for Space Use)'. ELEGANT enables that HW and SW of the digital portion to be designed in the same design environment by the same person. It refines processing in stages and allocates roles to HW and SW. Furthermore, trial and errors may be repeatedly conducted on ELEGANT since simulations can be conducted at various stages, making the optimization of division of roles between HW and SW possible. Also, it enables severe SW testing by use of a simulated HW in ELEGANT rather than using the actual HW which may break down during tests. ELEGANT was completed in fiscal 2007 and has already begun to be used for development of the communication equipment of satellites. It also can be used for the designs of electronic equipment for cars, digital home electronics and other consumer electronics. We are proactively trying to expand its utilization for the designing of such equipment.

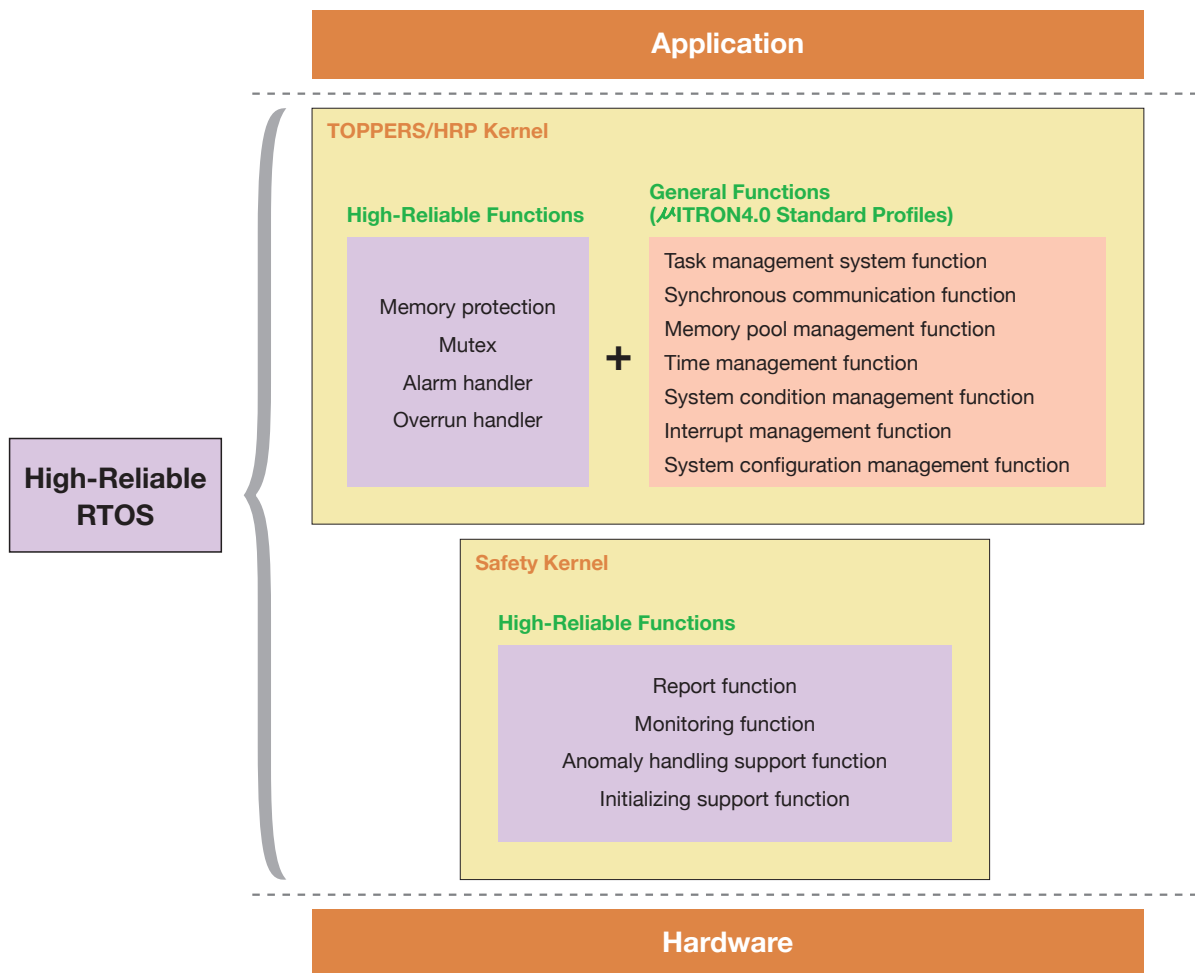


Integrated design tool at the system level, including software that applied to electronic equipment and hardware

[FPGA] Field Programmable Gate Array
[ASIC] Application Specific Integrated Circuit

2. High-reliable Real Time OS, 'TOPPERS/HRP Kernel and Safety Kernel'

Real Time OS (Real Time Operating System: RTOS), which is a basic software, is becoming more important owing to the expanding scale and increasing functionality of software for spacecrafts. Although reliability improvement of RTOS is an urgent problem common to every type of software that requires reliability, not only for spacecrafts, the software industry has not yet tackled the challenge earnestly enough. As part of this challenge, our team conducted research on the verification method for RTOS in advance of the software industry, applied it, and developed the High-reliable RTOS, TOPPERS/HRP Kernel and Safety Kernel. The outcomes of cooperative research with Nagoya university have been used for TOPPERS/HRP kernel.



TOPPERS/HRP Kernel and Safety Kernel

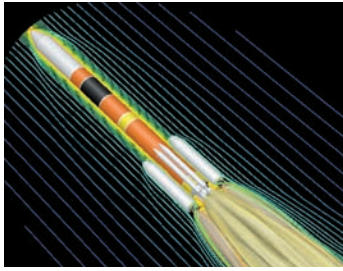
At the research on the verification method, firstly, we have widened the area other than spacecrafts (e.g. aircrafts, railroads, medical equipment, etc.). We are investigating software development standards and guidelines, organizing the types of verification required for software and have compiled verification requirements specific to RTOS. Next, we discussed how to run tests to satisfy such verification requirements and have put together a process that combines a method of validating specifications and functions without fail (exhaustive test) and a method of testing areas that are suspected of causing problems (pinpoint test).

TOPPERS/HRP Kernel and Safety Kernel have the ability to contribute to improving the reliability of the entire space equipment system since it has a function of preventing the failure occurring in one software from affecting the other software. This Japanese RTOS has already decided to be adopted to the on-board computer of H-IIA rocket and H-IIB rocket. (As of September 1st, 2011, they have not had the achievement of flights.)

3. Investigation and Research of the Technology of Model Based Development

In model based development, required abilities and design specifications are expressed by using the model written following specified rules and notations, and not in normal text. Since there is no ambiguity with this model, such as is seen in normal text, it is expected that parts of the task of confirming design will be streamlined by computer processing. Also, a completed model helps streamline the task of development because it can be reused for another system. Although model based development has started to be used for the development of airplanes and spacecrafts abroad, it is still new technology and in Japan, the car industry and others have just started to adopt it.

We are studying the models required at each stage of development, the rules and notations for modeling and the developing process, etc. with the aim of introducing the technology of model based development to satellites.



Aerospace Project Simulation Support Team

In collaboration with experts of numerical simulations within and without JAXA, high-end numerical simulations are carried out to solve technical issues, or to streamline the development process in JAXA projects. Also, JAXA is working for the advancement of liquid rocket engine design analysis technology to help better understand the phenomena occurring inside liquid rocket engines, and to streamline quantitative risk evaluation and design of liquid rocket engine systems.

Application of numerical simulation to JAXA projects for solving technical issues

JAXA's current projects related to, for example, space transportation, human space missions, and science satellites, requires risk mitigation activities at the early stage of the development process to lower cost and shorten development periods. Quick response to technical issues at any stage of development is also very important. For this reason, JEDI has formed a team to apply JAXA's high-end numerical simulation technologies to solve technical issues or to streamline the development process in JAXA projects. In collaboration with experts of numerical simulations within and without JAXA, a

contact has been set to most surely and efficiently support JAXA projects.

Based on our technology developed through liquid rocket engine analysis techniques until today, our support was focused toward space transportation, but hereafter, support for human space missions, earth observation satellites, science satellites, etc. will also be our main goals. Such activities should help promote innovative development processes utilizing high-end numerical simulation techniques, in order to make possible reliable and efficient development of highly reliable spacecraft systems.



Objectives of **Aerospace Project Simulation Support Team****Application of numerical simulation to JAXA projects for problem-solving purposes**

- In collaboration with experts of numerical simulations within and without JAXA, high-end numerical simulations are carried out to solve technical issues or to streamline the development process in JAXA projects.

Advancement of liquid rocket engine design analysis technology

- JAXA is working for the advancement of liquid rocket engine design analysis technology in order to understand the phenomena occurring inside liquid rocket engines, and to streamline quantitative risk evaluation and design of liquid rocket engine systems.

Advancement of liquid rocket engine design analysis technology

Developing a world-class liquid rocket engine system is one of the top goals for JAXA's space transportation program. To achieve this, high-end numerical simulation must be carried out to further advance design analyses of liquid rocket engines. In the next five years, JEDI will develop engine system analysis tools, combustion stability analysis tools, regenerative cooling system analysis tools, thrust chamber life prediction tools, pump and turbine blade optimization design tools, cavitation stability analysis tools, and turbo pump shaft vibration analysis tools. The developed tools will be applied to current and future engine development programs and should prevent failures ahead of time. The

combustion stability analysis tool is developed in collaboration with the TUST team.

Physical phenomena inside liquid rocket engines are occurring under extreme conditions in which cryogenic and super critical properties fuel mixturing, ignition, and high-pressure combustion must be dealt with. To understand fluid dynamics, structure dynamics and chemical kinetics under such extreme conditions and to give feed-back for engine designs, physical or numerical models that describe the physical phenomena are required.

JEDI has installed a rocket engine modeling laboratory at the Collaboration between JAXA and the University of Tokyo (Social Cooperation Program) to develop innovative physical models that can be applied to our numerical simulations.

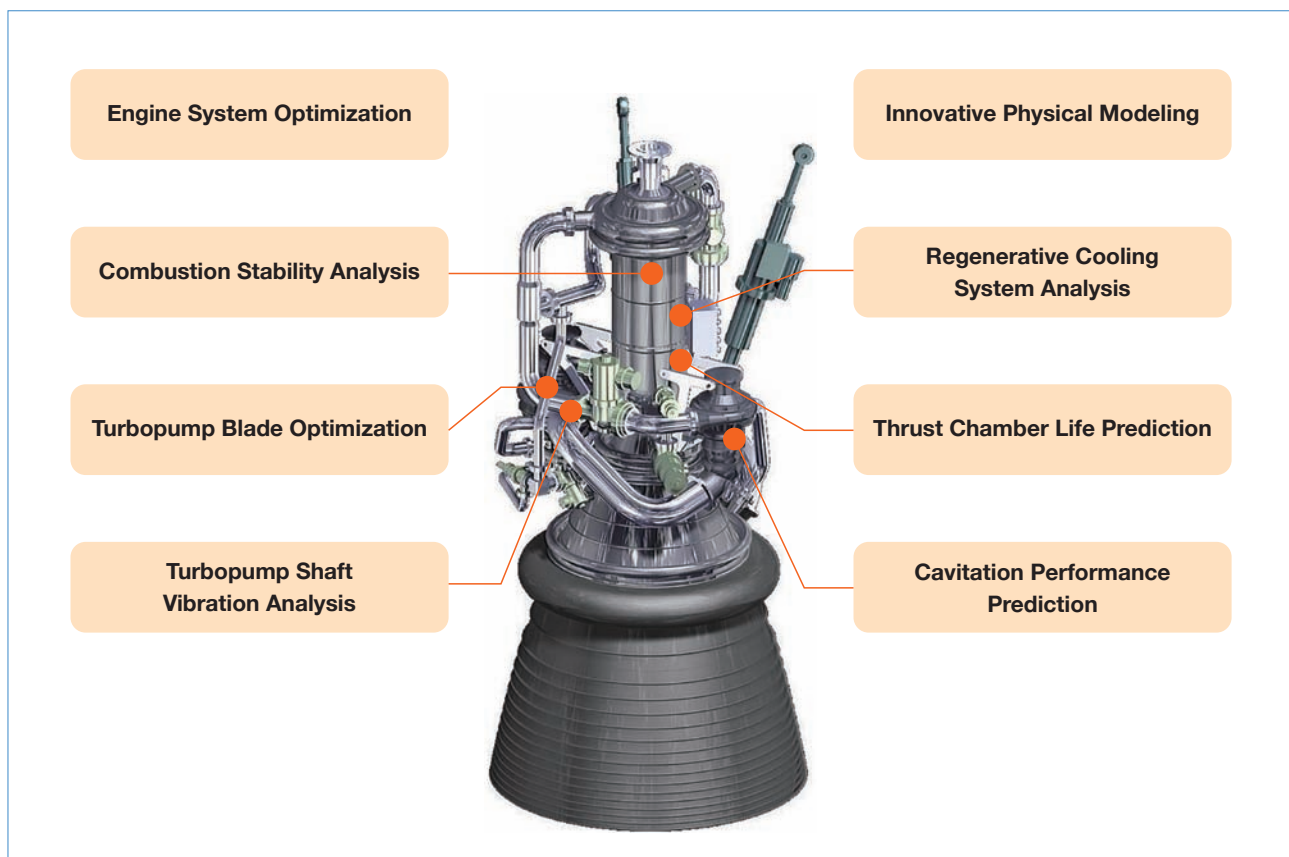
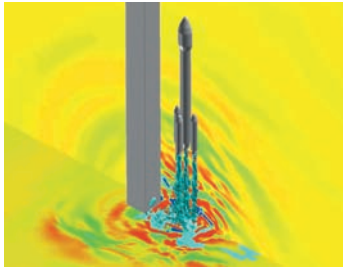


Diagram of liquid rocket engine design analysis

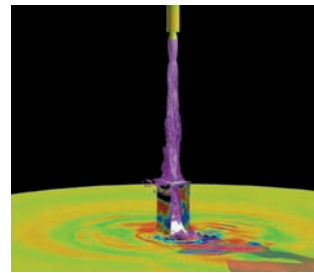


Team for Utilization of Simulation Technology

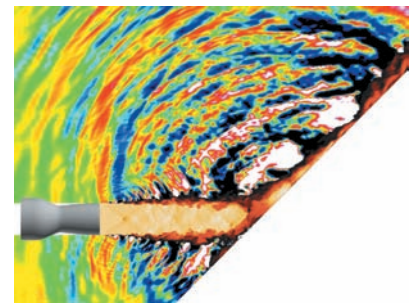
Numerical simulation technology is currently recognized as one of three methods in the field of natural science, while the others are theory and experiment. The objectives of this team are 1) developing innovative methodology for space engineering utilizing numerical simulations for physical phenomena, such as fluid dynamics and 2) applying them to actual projects as well as research and development. We are now working on four selected topics based on impact and reliability.

R&D on prediction of rocket plume acoustics and its application to launch vehicles

The exhaust plume from a rocket engine generates severe acoustic oscillations at lift-off. Since the pressure waves causes acoustic loading on the satellite payload and may even lead to its failure, prediction and reduction of the acoustics level of rocket fairing vibration at lift-off is quite important. NASA SP-8072 has been employed for the acoustic prediction of various launch vehicles but its prediction accuracy is not sufficient. Thus we have applied CFD technology to reveal the generation and propagation of the acoustics in Japanese launch vehicles, such as the H-2A, M-V, and are now studying advanced solid rockets. From these results, the details of acoustic mechanism have become clear. The methodology is now introduced to the designing of launch pads for the designing of H-2B and advanced solid rockets. Our medium-term target is to improve the methodology and make it into a design tool of launch pads.



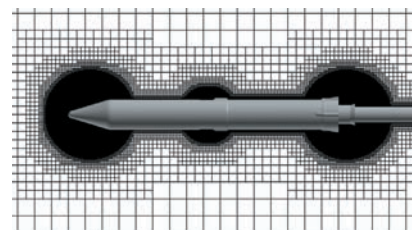
Launch-pad design for the reduction of acoustic loading of Epsilon launch vehicle at lift-off



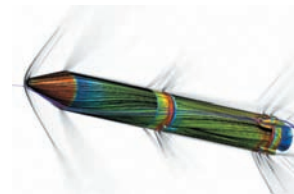
Acoustic radiation from a supersonic jet impinging on a simplified flame deflector

Next generation CFD technology and its application to JAXA's projects

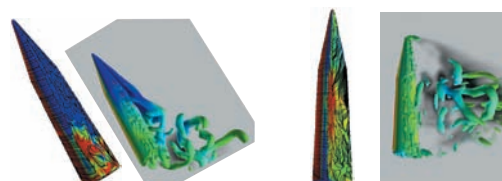
CFD (Computational Fluid Dynamics) is a powerful tool for aerodynamic designs. However, there still remain challenging tasks, such as efficient generation of computational grids (in the preprocessing), accurate prediction of aerodynamic forces created by very small devices, and motion-fluid coupled simulation. Thus, we are developing a new CFD technology having those above features and applicable to the initial stage of space vehicle design. Currently, this technology is actually used for aerodynamic analyses of JAXA's new rockets (Epsilon Launch Vehicle and Reusable Sounding Rocket) at their design stages, and also for aeroacoustic problems in a rocket engine.



Computational Grid around Epsilon Launch Vehicle



Computed Flowfield around Epsilon Launch Vehicle



Computed Flowfield around Reusable Sounding Rocket during Turnover

Objectives of **Team for Utilization of Simulation Technology****Practical application of analysis system on plume acoustics to space transportation system design and its development**

- The exhaust plume from a rocket engine emits strong pressure waves and causes severe acoustic loading onto the payload, etc. at lift-off. We aim to develop a numerical technology which can make an accurate and prompt prediction of the acoustic environment caused by an exhaust plume. This technology will be applied to development of space transportation system.

Next-generation CFD technology and its application to space transportation system design and development

- We aim to develop a new CFD (Computational Fluid Dynamics) technology and apply it to aerodynamic design processes of spacecrafts, etc. We also plan to extend its applicability, for instance, to aeroacoustic simulations in a rocket engine.

Practical application of numerical simulation technology for the plasma around spacecrafts

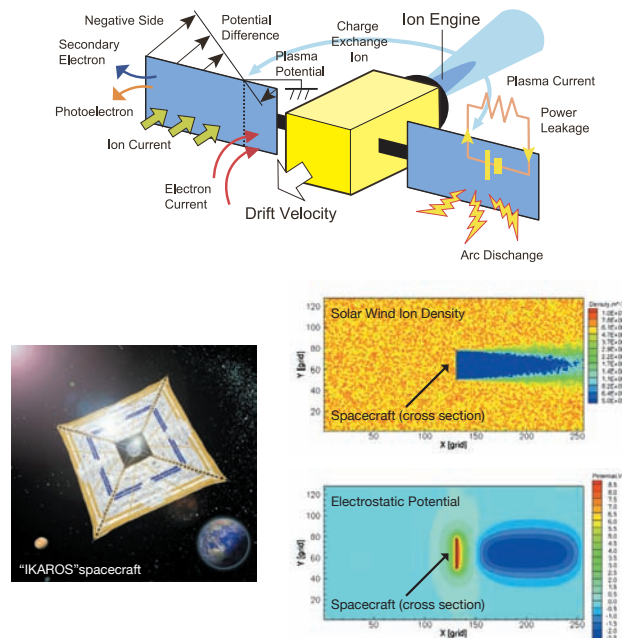
- We aim to develop a numerical technology for analyzing the long-term behavior of plasma which has a great impact on a satellite in orbit. This technology will then be applied to satellite design.

Practical application of numerical technology for combustion stability analysis to rocket engine design

- Combustion oscillation is an important problem. It inflicts catastrophic damage on rocket engines, when it occurs. We aim to develop a combustion stability analysis technology, which can predict combustion oscillation and provide guidelines to avoid its occurrence. This technology will be applied to a rocket engine development.

R&D for plasma analysis technology, and its application to JAXA's projects

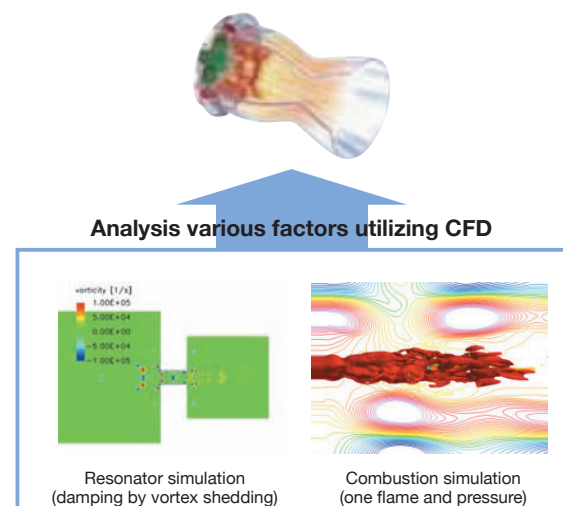
Space is filled with tenuous plasma, and the plasma always affects spacecrafts or satellites. As a result, it causes the spacecraft charging-arc problem, which affects spacecraft life. It is becoming more important to make an estimation of the effects, onto the satellite, of the plasma generated by high-efficiency ion engines such as those mounted onto the Hayabusa spacecraft that probed Asteroid Itokawa. It is also important to estimate the degradation of the internal apparatus of ion engines caused by the plasma. Furthermore, estimation of the plasma is of importance for creating high-precision electric field sensors used for space science. We are conducting research and development of the plasma analysis technology at JEDI center in collaboration with other headquarters of JAXA.



Examples of the Computational Electrostatic Analyses around the IKAROS Spacecraft

R&D of combustion instability analysis

Oscillatory combustion is one of the most high-risk phenomena in a liquid propellant rocket engine, because it may cause a fatal failure such as melting of the combustor. It is necessary to construct countermeasure for oscillatory combustion in the R&D of a new rocket engine. The combustion phenomena in a liquid propellant rocket engine consist of various physical phenomena which complicatedly interact with each other, hence, not only the conventional theoretical and experimental studies but also the numerical simulation bring fruitful understandings. We are performing the simulation of nonpremixed flame to survey the flame structure and the onset of the oscillatory combustion collaborating with other directorates and universities. We are also investigating the resonator to suppress the oscillatory combustion passively. Finally these factors are summed up to estimate the entire instability.





Computing Resource Management Team

To steadily advance JAXA projects such as launch vehicle developments, the application of numerical simulation with a high-performance supercomputer is indispensable. In this team, aiming at cultivating the next generation numerical simulation technologies and building the system and the application environment which brings out the maximum contribution to the JAXA projects, we are working on the installation and operation of the JAXA supercomputer, the continuous development of utilization system, and the enhancement of the utilization technologies.

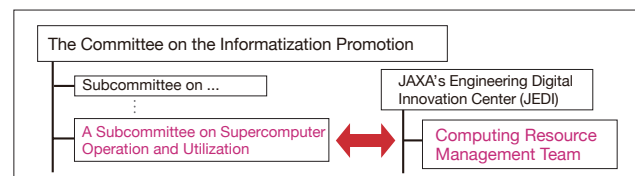
Introduction of the JAXA Supercomputer System (JSS) and realization of integrated operations

JAXA used to separately manage and operate the supercomputers in three decentralized locations, namely Chofu, Kakuda and Sagami-hara. However, with the aim of further contributing the aerospace projects and enhancing service content, we decided to conduct centralized management and operation of the supercomputer. Thus, we establish a system for providing centralized management and operation of the supercomputer at Chofu in fiscal 2007. Furthermore, in order to fulfill the foreseeable dramatic increase in the demand for computing resources from aerospace projects, we made the installation of the JSS in fiscal 2008. It is one of the largest systems in Japan in terms of scale, and we began full-scale operation at the start of fiscal 2009.

[JSS] JAXA Supercomputer System

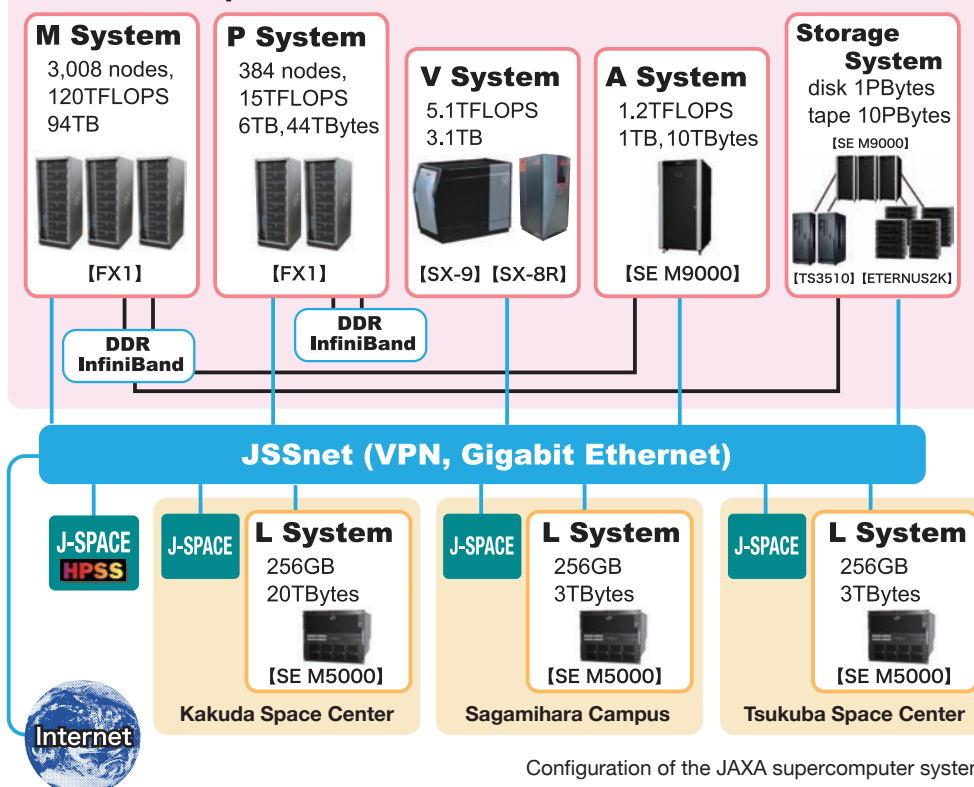
Appropriate allocation of computing resources and creation of a structure for using computing resources that match needs

We will appropriately allocate to users the valuable and limited computing resources and the data storage capabilities of JSS, and will also create and establish a utilization system that can meet the user needs. In order to increase the fairness and transparency of its management and utilization, we have established a subcommittee on supercomputer operation and utilization under the Committee on the Informatization Promotion, which is a decision-making body on promoting the application of information technology.



Steering structure of the supercomputer operation

Chofu Aerospace Center



Configuration of the JAXA supercomputer system

Objectives of **Computing Resource Management Team****Improvement of the utilization environment and the stable operation of the new supercomputer system**

- By striving to keep the stable operation of the new supercomputer and by constantly executing the appropriate and efficient management of the computing resources, we will provide an environment that brings the maximum usage of computing resources.

Continuous improvement of operational efficiency and the utilization environment of supercomputers

- By establishing and maintaining the operational system/utilization environment of supercomputers, we will contribute to the production of research and development enterprises and help solve the technical issues in JAXA projects.

Continuous improvement of operational efficiency and the utilization environment of supercomputers

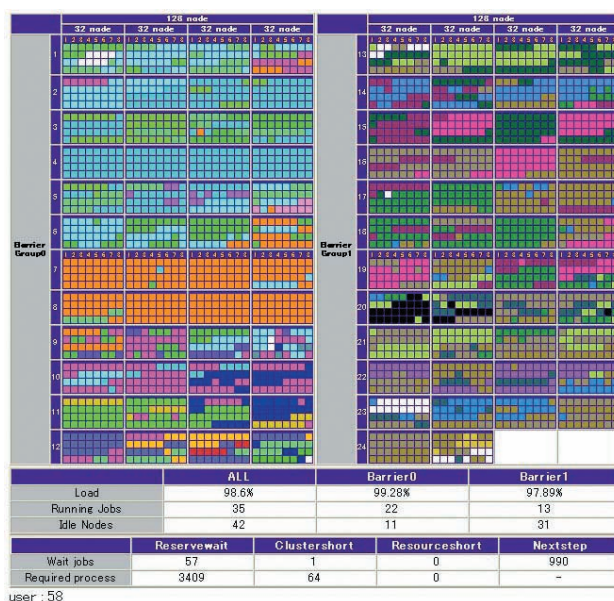
Various efforts are being made to enhance the operational efficiency and to improve the utilization environment of the JSS. For example, we are developing our own job scheduler to aim at conducting a job scheduling suited for the JAXA utilization and operation requirements. Furthermore, we installed the L-systems in three locations, namely Kakuda, Sagami-hara and Tsukuba, which are connected to the M-system in Chofu. By constructing an environment which enables the mutual utilization of the applications between the remote locations, we are continuously improve the utilization environment, including those of the remote locations.

Aiming at the center of excellence of computational science and engineering in aerospace

Engineers and researchers of the field centers are now able to achieve the research results efficiently and productively by using the JSS. This leads to a great contribution to the aerospace projects. JAXA aims to become the Center of Excellence of computational science and engineering in the aerospace field of Japan.

Usage guide of the JSS

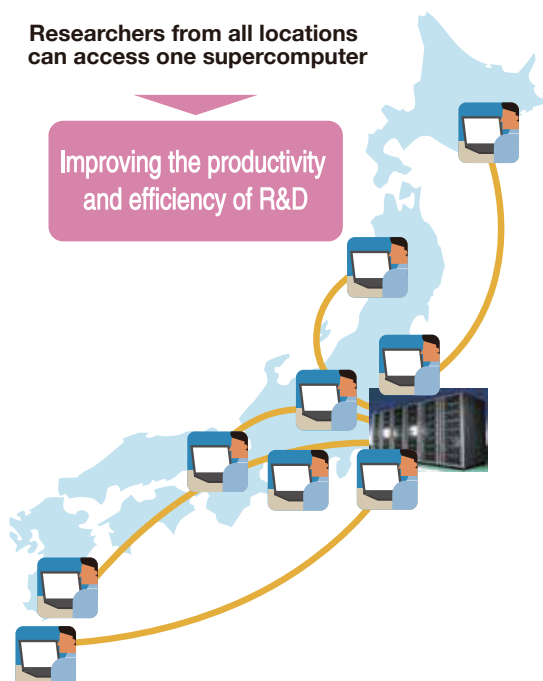
The computing resource management team provides various services related to the JSS. Through the JSS portal, users are able to access the operation information and usage information. Furthermore, we have started a consultation service via telephone and e-mail, etc. and are providing various types of supports, such as how to use the JSS, debug the programs, increasing performance and use applications.



Job allocation monitoring system 'MAPLE'

Researchers from all locations
can access one supercomputer

Improving the productivity
and efficiency of R&D

**JSS Utilization Services**

The JSS Portal Site

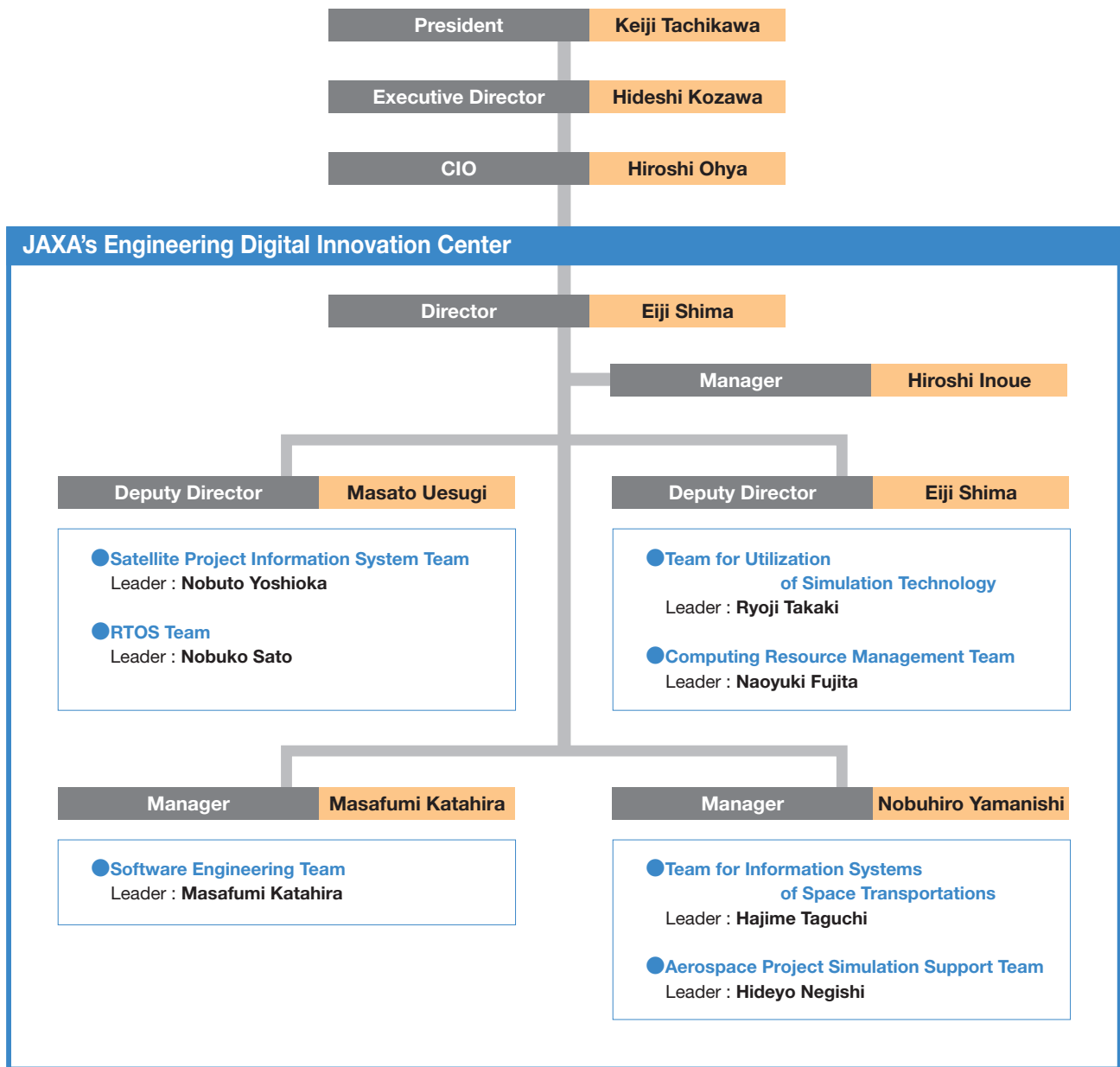
<https://www.jss.jaxa.jp/>



Contact to Consultation Service

050-3362-3333 info@jss.jaxa.jp

JEDI Organization Chart



Regular Staff

Director	1
Business Management	2
Satellite Project Information System Team & RTOS Team	8
Team for Information Systems of Space Transportations & Aerospace Project Simulation Support Team	10
Software Engineering Team	11
Team for Utilization of Simulation Technology	8
Computing Resource Management Team	3
Total	43
Other Department Personnel who are also in charge of JEDI	21
Dispatched Contractors	19

(As of May 1, 2012)

Introduction of the Offices of the JEDI Center

The offices of the JEDI Center are located in several JAXA field centers and campuses including the Sagamihara Campus, Tsukuba Space Center, and Chofu Aerospace Center. In addition, the Rocket Engine Modeling Laboratory (REML) was established in Asano, Hongo Campus of the University of Tokyo through the collaboration between JAXA and the University of Tokyo (Social Cooperation Program) in Japan Fiscal Year 2008.

Sagamihara Campus

JEDI Center's office at Sagamihara Campus is a core research center for pioneering numerical simulation. At the campus, we conduct researches on numerical simulation for rocket plume acoustics and plasma.

【Location】

3-1-1 Yoshinodai, Chuo-ku, Sagamihara-shi, Kanagawa 252-5210

Phone/ 042-751-3911

Main Bldg. 7F :

Team for Utilization of Simulation Technology

Chofu Aerospace Center

JEDI Center's office at Chofu Aerospace Center is a main office which is in charge of operations and utilization of JAXA supercomputer system (JSS). JEDI's Computing Resource Management Team are working on the installation and operation of JSS, the continuous development of utilization system, and the enhancement of the utilization technologies.

【Location】

7-44-1 Jindaiji Higashi-machi, Chofu-shi, Tokyo 182-8522

Phone/ 0422-40-3000

Supercomputer Bldg. :

Computing Resource Management Team

Tsukuba Space Center

JEDI Center's office at Tsukuba Space Center is a center for activities concerning informatization for satellite and space transportation system development, software engineering and support of space development projects by numerical simulation.

【Location】

2-1-1 Sengen, Tsukuba-shi, Ibaraki 305-8505

Phone/ 029-868-5000

Research and Development Bldg. 3F :

Satellite Project Information System Team, Software Engineering Team,

Aerospace Project Simulation Support Team

Main Bldg. 6F :

Team for Information System of Space Transportations

Collaboration between JAXA and the University of Tokyo (Social Cooperation Program)

With the aims of establishing highly advanced analysis technology for rocket engines, and making Japan's rocket engine development technology the world top level, JAXA established the Rocket Engine Modeling Laboratory (REML) in collaboration with the University of Tokyo.

【Location】

2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656

Phone/ 03-5841-0351

Faculty of Engineering Bldg. No. 12 :

Asano, Hongo Campus, the University of Tokyo



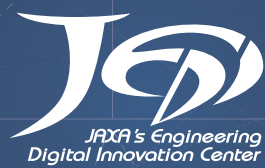
Homepage URL

<http://stage.tksc.jaxa.jp/jedi/>



E-mail Address

prjedi@jaxa.jp



JAXA's Engineering Digital Innovation Center

<http://stage.tksc.jaxa.jp/jedi>

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