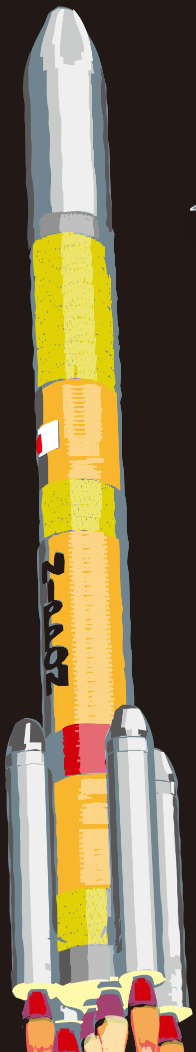
2018~2019

JAXA Explore to Realize



JAXA Supercomputer System Generation 2

JSS2

SORA

J-SPACE

SORA: Supercomputer for earth Observation, Rockets, and Aeronautics

J-SPACE: Jaxa's Storage Platform for Archiving, Computing, and Exploring

SORA

宙

JSS2 is a whole system of supercomputer systems supporting the development of aerospace technology

It consists of 宙: SORA, an advanced supercomputer system, and J-SPACE, a large scale storage system

In April 2016, a new supercomputer system started its operation with more powerful computing performance

JAXA has been conducting the development of cutting-edge aerospace technology focusing on the research fields such as Development and operations of satellites which observes the earth from the space, Research of the rockets which carry satellites to the space securely, and Study of low noise aircraft with environmentally-conscious design.

The numerical simulation by using supercomputer system is one of the important techniques to support these research fields. JAXA previously had three supercomputer systems in different locations (Chofu, Tsukuba and Sagamihara) and developed the numerical simulation technique.

We reviewed the operation of these systems in order to meet the demands for higher computing performance in aerospace projects. In 2009, these three systems were integrated into one as the JAXA Supercomputer System 1 (JSS1) and started its operation.

Subsequently, in October 2014, we started to phase in a new system, JAXA Supercomputer System Generation 2 (JSS2) as the first phase. It consists of a main system, "宙 (SORA)" and an archiver system, "J-SPACE."

The name of the main system "SORA" means "Sky" and "Space," hoping to contribute to research and development of aerospace.

In the second phase from April 2015, a main system, "SORA-MA" started its operation under the condition of 1.31 PFLOPS.

In April 2016, SORA-MA was updated to the peak performance 3.49 PFLOPS and the total memory size 100 TiB. Since then, JSS2 has been fully operational.

JSS2 has an advanced supercomputer system configuration

In addition to SORA-MA, JSS2 consists of advanced systems such as SORA-LM, a large-scale memory system, SORA-PP, a pre-post system, SORA-FS, a file system and J-SPACE, the archiving system.

JSS2 is also designed for energy saving by adoption of a water-cooling system. JSS2 is composed of these well-developed systems and eco-friendly policy.

For utilization of the supercomputer from remote locations via the Internet, JAXA has developed and examined the high-speed transfer technology that is 30 times faster than the conventional system.

System Configuration of JSS2

1 SORA-MA
Main system

The supercomputer with peak performance more than 3 PFLOPS

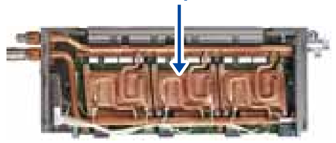
FUJITSU PRIMEHPC FX100
SPARC64 XIfx

Peak Performance: 3.49 PFLOPS
Total Memory: 100 TiB
Total #Nodes: 3,240
Total #Cores: 103,680
(1 CPU, 32 GiB / node)

SORA-MA used as the core machine of JSS2 is a scalar-type parallel computer.

Water-cooling

SORA-MA has adopted a water-cooling system that efficiently removes the massive heat generated by increasing the computational performance.



CMU(CPU Memory Unit)

2 SORA-PP
Prepost system

The computer used in a preprocessing phase for calculation and a post-processing phase for visualization

FUJITSU PRIMERGY RX350 S8
intel Xeon E5-2643v2 (3.5GHz/6core/25MB)

Peak Performance: 75.2 TFLOPS
Total Memory: 12 TiB
Total #Nodes: 200
Total #Cores: 2,400
(2 CPU, 64 GiB / node)

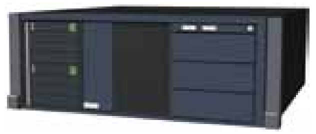
A large amount of data calculated at SORA-MA or SORA-LM is stored in the file system. SORA-PP enables the data to be read directly from SORA-FS for visualization.

3 SORA-LM
Large Memory system

The supercomputer with total memory size more than 1 TiB

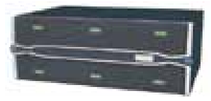
FUJITSU PRIMERGY RX350 S8
intel Xeon E5-2667v2(3.3GHz/8core/25MB)

Peak Performance: 2.11 TFLOPS
Total Memory: 3.5 TiB
Total #Nodes: 5
Total #Cores: 80
(2CPU, 1.0 TiB x 2 nodes)
(2CPU, 0.5 TiB x 3 nodes)



SORA-LM is used for simulation requiring an extremely large amount of memory.

4 SORA-FS
File System

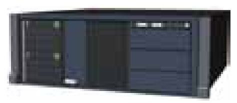


Magnetic Disk: 7 PB

SORA-FS is used for saving large data form SORA-MA.

5 SORA-LI
Login system

Peak Performance : 2.01TFLOPS
Total Memory : 1.56 TiB
Total #Nodes : 6
Total #Cores : 72
(2CPU, 0.37 TiB x 4 nodes)
(2CPU, 0.03 TiB x 2 nodes)



SORA-MA 6.8GB/s×60ports =408.0GB/s
SORA-PP 6.8GB/s×162ports =1101.6GB/s
Storage Area Network (Infini Band FDR)
SORA-FS 6.8GB/s×28ports =190.4GB/s

Ethernet (1G, 10 GEthernet)

Chofu Aerospace Center

▲The Supercomputer Bldg. at the Chofu Aeropace Center

6 J-SPACE
Jaxa's Storage Platform for Archiving, Computing, and Exploring

The archiver system with high-speed I/O

Disk Cache : 0.7 PB
Tape : 40 PB

J-SPACE is a large scale storage system.

Remote System

JSS2 can be connected from every remote office of JAXA in Japan

- Tsukuba Space Center
- Kakud Space Center
- Sagamihara Campus

LAN and SINET5

Visualization

JSS2 has an advanced visualization system

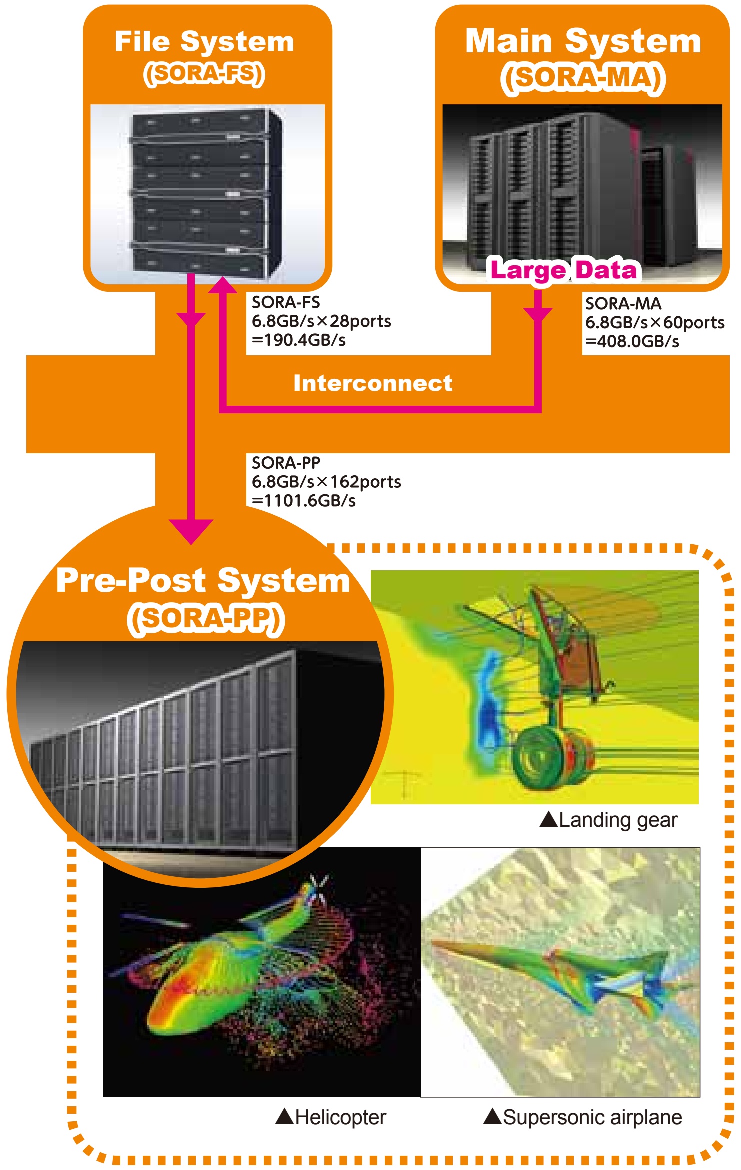
Users can visualize the numerical simulation results directly and faster

Why “Visualization” is important

The data obtained by numerical simulations are processed by supercomputer systems. These results are stored as numbers and they seem to us like a meaningless sequence of numbers. In order to understand these data, they need to be shown on a graph, or displayed as a picture or moving image. We call this process “visualization technology.” This technology is essential to pursue research using supercomputers.

Necessity of a superior visualization system dealing with bigger data

As the processing speed of supercomputers becomes faster, the output of calculation increases. The volume of output will exceed the processing capacity of the existing visualization system. JSS2 has been equipped with a special computer system so as to perform large-scale calculations smoothly. The system named “SORA-PP (Pre-Post System),” which is used for pre-processing for calculations and post-processing for visualization of simulation results. Through the use of SORA-PP, the visualization procedure can be simplified. Namely, users can directly visualize the results stored in a file system, SORA-FS, without transferring the data from SORA-FS to the users’ own computers. JSS2 has adopted various applications for visualization such as Ensight, Fieldview and Paraview, and the visualization can be performed under various conditions like remote desktop function or client server.



▲Landing gear

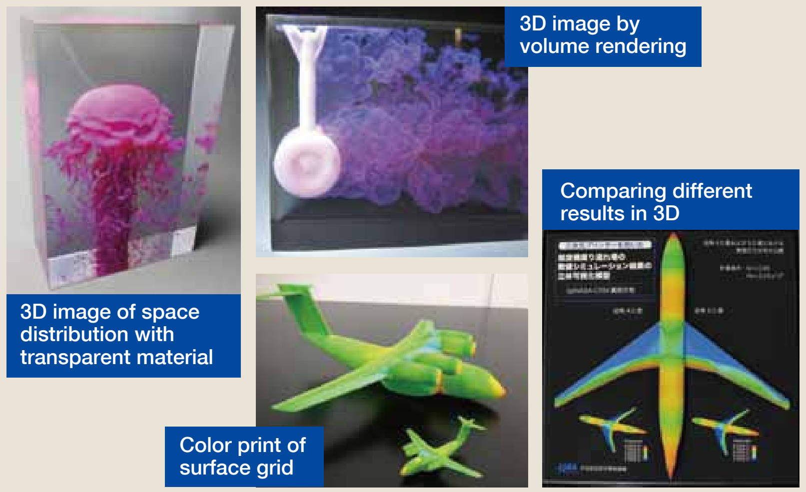
▲Helicopter

▲Supersonic airplane

Visualization technology for next-generation — Challenge to 3D model

Introduction of 3D printer

The visualization technology has been evolved to be more sensory and easily understanding of numerical simulation results. JAXA has introduced a 3D printer in order to visualize the results three dimensionally. The 3D printer creates objects that can be seen from every angle. Viewing the results three dimensionally helps us to comprehend them more deeply and precisely.


3D image of space distribution with transparent material

3D image by volume rendering

Comparing different results in 3D

Color print of surface grid

Technical Challenges

JAXA is tackling technical challenges in operation

Multiple approaches like technological improvement or information disclosure to the solution

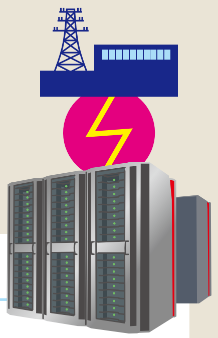
High level of awareness of the technical challenges with supercomputers

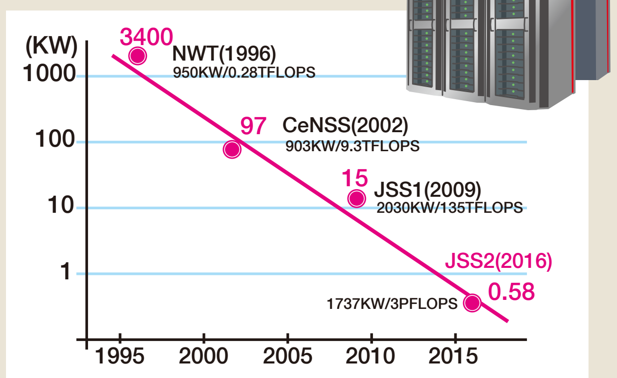
In order to solve the technical challenges in the operation of supercomputers, JAXA has cooperated with the manufactures to apply technical improvements, and provided the information necessary to users to run the programs efficiently.

Challenge Pursuit for Efficiency

Power consumption per FLOPS has been drastically decreased with the progress of semiconductor technology, but it is not enough to satisfy the ever-increasing demand for processing power by the growing scale of the calculation.
We have been making every effort to reduce the power consumption of the whole supercomputer system.

Annual power consumption (Normal rated power x 24h x 360days)	
JSS1	17.5MWh
JSS2	15.0MWh





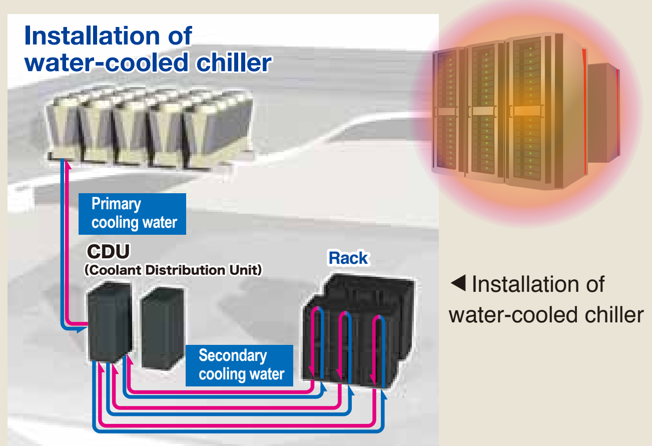
▲KW/TFLOPS


▲ View of job running

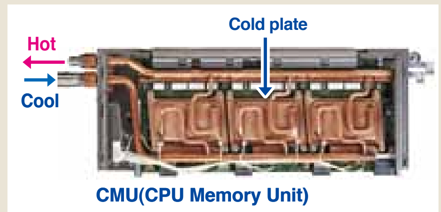
Utilization rate	
JSS1 (JARMan) JAXA’s original scheduler	98%
JSS2 Standard scheduler	85%

Challenge Cooling system

The circuit board in the supercomputer generates more heat as the density increases, but the conventional cooling system cannot handle the huge heat. We have adopted water-cooling system with cold plates which removes more heat efficiently in JSS2.



◀Installation of water-cooled chiller



◀The heat in CPU is removed directly by circulating cold-water in the cold plate.

Challenge Job Scheduling

When multiple users use a parallel supercomputer at the same time, many independent jobs of various amount of resources needed are submitted simultaneously. Job scheduler handles the jobs in efficient and fair fashion.

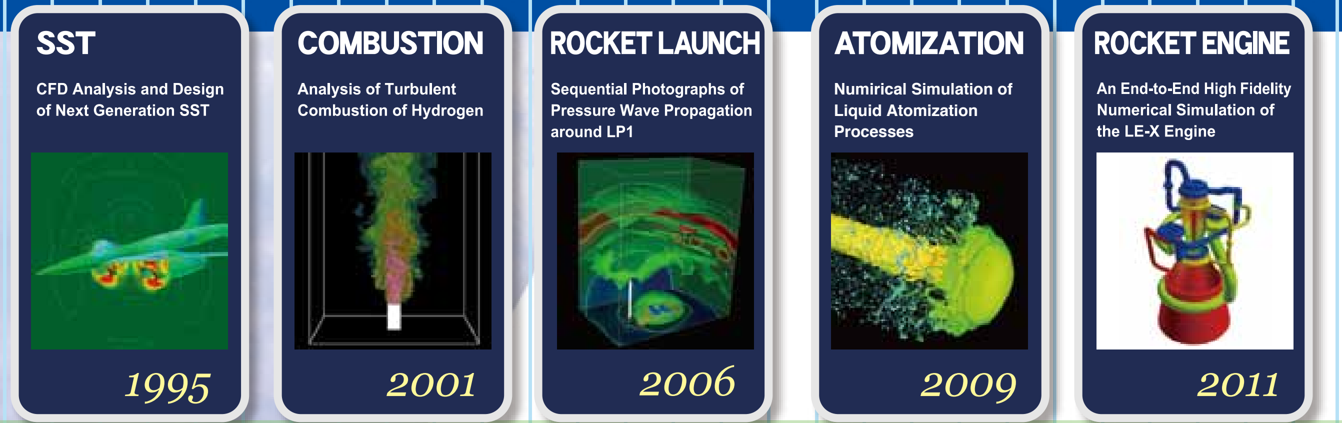
We had developed and used JAXA’s original scheduler “JARMan” until JSS1. It maintained utilization rate of as high as 98%.
Unfortunately “JARMan” cannot be used on JSS2 due to the different inter-connects from JSS1. This dropped the rate to 80% when JSS2 started operation.
Since then, the operation and settings improvements have raised the rate to 85%.
We are researching new technologies for better scheduling of jobs.

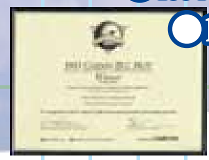
Development History of Computer System and Numerical Simulation in JAXA

Half-century long operation of computer system and research for numerical simulation technology have been contributing to the progress of aerospace fields

1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

JAXA has a long history in research and development of computer system and numerical simulation. It began in 1960 with DATATRON made in U.S. A., which the National Aerospace Laboratory (NAL), a former organization of JAXA introduced as the first computer.
After an introduction of a domestic computer HITAC 5020, NAL and Fujitsu started a joint development, and FACOM 230-75APU was born as the first Japanese supercomputer in 1977.
In 1987, FACOM VP400, a special version of vector processing system for NAL, was developed for 3D CFD simulations based on the time-averaged Navier-Stokes equations. A full configuration simulation around a whole aerospace vehicle was completed within 10-hour CPU time.
The next target was to develop Numerical Wind Tunnel (NWT) having the same capability as the real wind tunnel experiment equipment. A research and development project for NWT began in 1989 and it was installed in February 1993. NWT behaved high performance and had served for national aerospace projects and fundamental research of fluid dynamics. From 1994 to 1996, NWT had won the Gordon Bell Prize for its outstanding achievement for the third consecutive years.
In 2002, NWT was replaced to a new system, Central Numerical Simulation System (CeNSS), which had a Fujitsu-made PRIMEPOWER as a core machine. CeNSS also achieved impressive performance in the development of next-stage numerical simulation technologies.
In 2003, JAXA was established by merging NAL, National Space Development Agency (NASDA) and Institute of Space and Astronautical Science (ISAS). Afterwards, the supercomputers installed in each organization were put together into one system so as to enhance the research efficiency. In 2007, the integrated supercomputers started its operation as JAXA Supercomputer System1 (JSS1).
The performance of JSS1 was updated in phases. In April 2009, the peak performance of both M and P systems for the scalar part became 135 TFLOPS and the total memory size became 100 TB, and since then JSS1 had been fully operational. These advanced capabilities enabled faster and more detailed simulations and parametric studies. JSS1 had contributed greatly to aerospace research.
Subsequently, in October 2014, JAXA started to phase in a new supercomputer system, JSS2, which consists of a main system "宙 (SORA)" and an archiver system, "J-SPACE."
In April 2016, JSS2 was completed its performance update when "SORA-MA" enhanced the capacity of the peak performance to 3.49 PFLOPS and the total memory size over 100 TiB.
JSS2 has been in full operation since then.



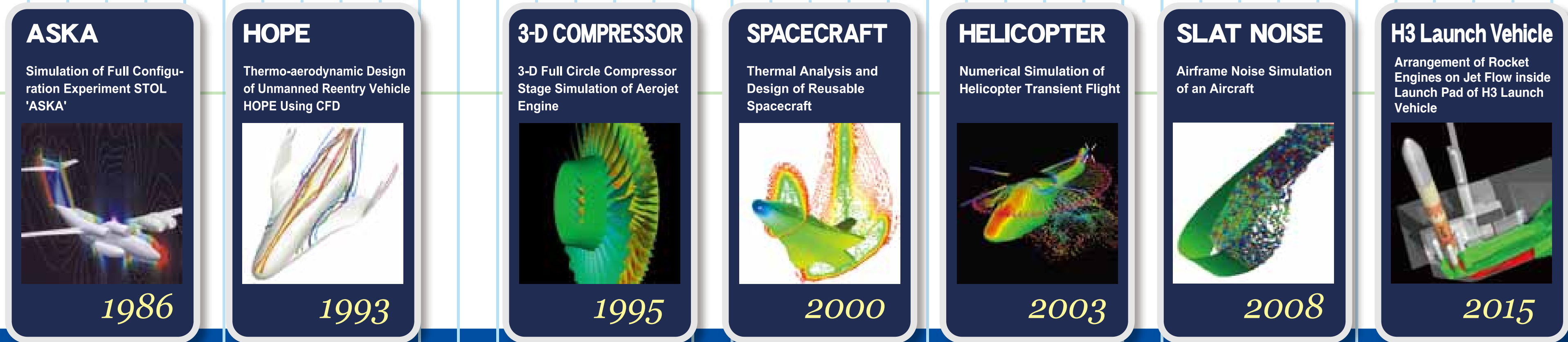


1994 Gordon Bell Prize (Honorable Mention)
1995 Gordon Bell Prize (Performance Winner)
1996 Gordon Bell Prize (Performance Winner)

2015 JSS2/SORA — Phase 3 3.49 PFLOPS
2009 JSS1 120 TFLOPS
2002 CeNSS 9.3 TFLOPS
1993 NWT 140PE
1996 NWT 166PE 280 GFLOPS
2003 JAXA
1990 Fujitsu VP2600
1987 FACOM VP400 1.14 GFLOPS
Fujitsu VP2100
1987 FACOM VP200
1983 FACOM M380 20 MIPS
FACOM M780
1977 FACOM230-75APU 22 MFLOPS
1975 FACOM230-75
1968 HITAC5020F 0.5 MIPS
1967 HITAC5020
1960 DATATRON205

Processor Speed: 1E, 1P, 1T, 1G, 1M, 1K

History of JAXA Supercomputer



1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

DATATRON | HITAC5020F 0.5 MIPS | FACOM230-75APU 22 MFLOPS | FACOM M380 20 MIPS | FACOM VP400 1.14 GFLOPS | Numerical Wind Tunnel 280 GFLOPS | CeNSS: Fujitsu PRIMEPOWER HPC2500 9.3 TFLOPS | JSS1 M System: Fujitsu FX1 120 TFLOPS | JSS2 SORA-MA: Fujitsu FX100 3.49 PFLOPS

Launch Vehicle

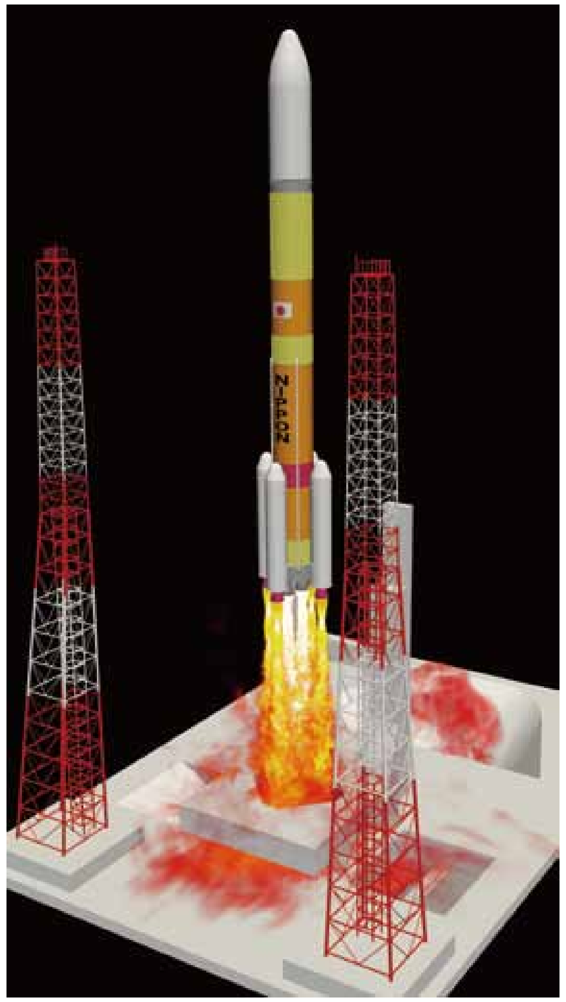
Launch Vehicle

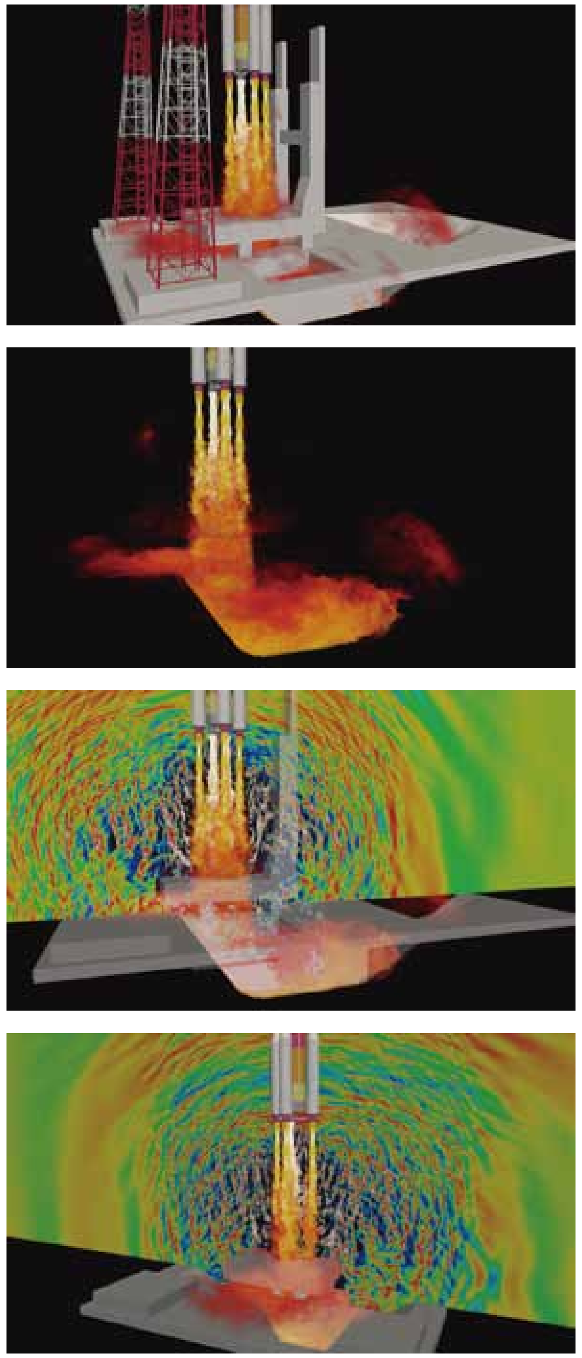
Aiming to Develop Japanese New Flagship Launch Vehicle, H3

Recently, many satellites that are closely related to our lives have been transported to space, thus utilizing space has become part of our daily lives. Under such a progressive society, H3 is aiming to become a launch vehicle that attracts people' s attention not only in Japan but also globally as an easy-to-use space transportation system.
For H3 to succeed, JAXA will modernize the overall launch vehicle based on our experience cultivated through the development and operation of H-IIA. In that sense, we face technological challenges including the development of a new large liquid engine (LE-9) and solid rocket boosters (SRB-3). Technologies developed for H3 will be applied to the Epsilon Launch Vehicle. JAXA and related companies will make active use of Japanese technologies in various fields to develop the new launch vehicle.

H3 Launch Vehicle Image

Aeroacoustic Simulation of H3 Launch Vehicle at Lift-off



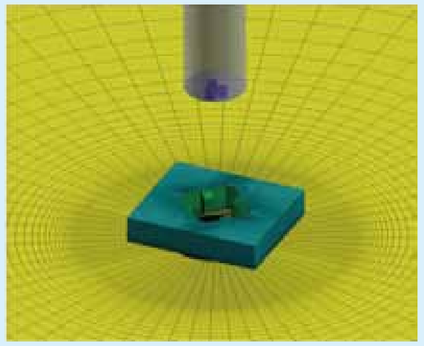


Computational fluid dynamics (CFD) is applied to analyze generation and propagation of acoustic wave generated from Japanese new flagship launch vehicle, H3, at lift-off. Exhaust jets of clustered liquid rocket engines and solid boosters are visualized by volume rendering of the temperature field. Acoustic field is shown by the pressure fluctuation, and it is found that the acoustic wave returns to the launch vehicle.

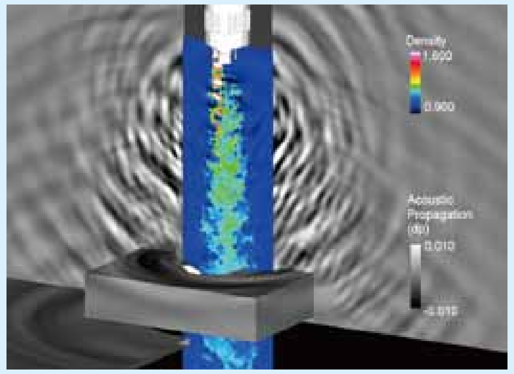
Large-eddy Simulation of Lift-off Plume Acoustics Using High-order Unstructured Flux-reconstruction Method

In order to quantitatively predict the acoustic environment at launch vehicle lift-off, it is necessary to accurately simulate the turbulent flow and the acoustic field around the complex geometry of the launch facility. To satisfy the requirement, we have developed a novel high-order unstructured grid solver based on the flux-reconstruction (FR) method, which has flexibility to complex geometries and superior resolution for multi-scale vortices and broad-band sound waves.

Aiming for understanding the effect of different engine configurations on the lift-off acoustics for the H3 launch vehicle, we conducted large-eddy simulation of the exhaust jet from the clustered first-stage engines and its interaction with the launch pad.
The clustered three-nozzles case is presented here. To predict the maximum acoustic load at lift-off, elevation of the launch vehicle was changed by making use of the overset-grid technique without re-meshing the entire computational domain. Since the data transfer between the grids is minimal (only the face values are needed for the FR method instead of multi-layer fringe points), the present approach is suitable for scalable parallel computation.



Grid of H3 launch pad



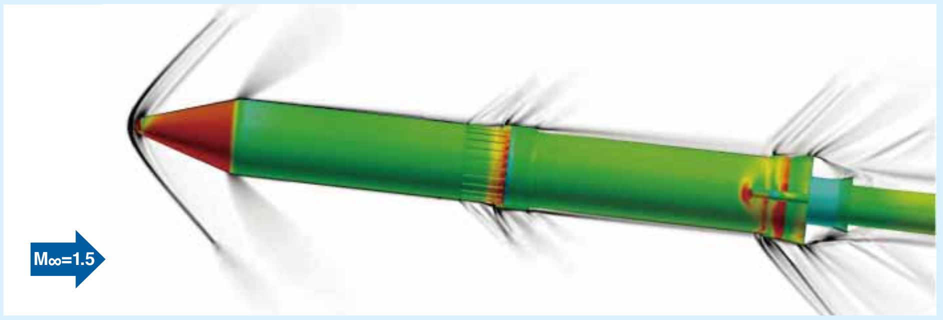
Slice of y =0 density distribution and surface pressure distribution

Iso-surface by density

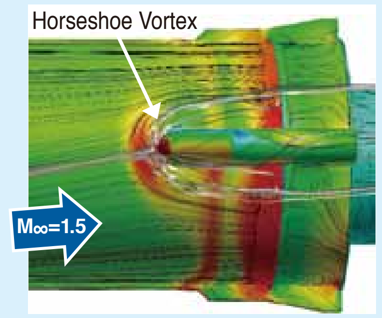
Epsilon Launch Vehicle

Numerical and Experimental Investigations of Epsilon Launch Vehicle Aerodynamics at Mach 1.5

In this study, by conducting both numerical simulations and wind-tunnel tests, the aerodynamic characteristics and associated flow features of the Epsilon launch vehicle are extensively investigated at Mach 1.5. The results provided are axial/normal/side forces, pitching/yawing/rolling moments, detailed three-dimensional flow structure, along with effects of the Reynolds number (between wind-tunnel and flight conditions), skin stringers (small devices on the main body), and the difference from another configuration called "NextGenEpsilon".
This set of data includes unavailable ones at either the experiment stand-alone or the actual flight. Magnitudes of computed aerodynamic coefficients are in good agreement with the experiment and within the design criteria.



Flowfield (Attack angle: 5, Slip angle: 0, Roll angle: 0) computed Cp($-0.3 < Cp < 0.4$) and density gradient magnitude



Computed Cp ($-0.3 < Cp < 0.4$) and flow (SMSJ)

Satellite

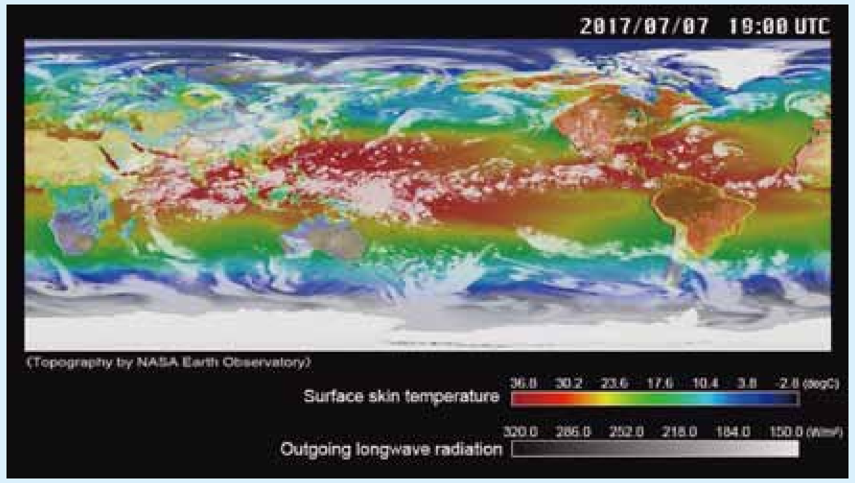
Contributing to Society Through Space-based Earth Observations

EORC: Earth Observation Research Center

EORC was established under the Japan Aerospace Exploration Agency (JAXA) in April 1995 as Japan's core research organization for the scientific studies, analysis, satellite data processing, calibration/validation, and archiving of the Earth observation satellites data. By continuing to carry out these activities using space-based Earth observation technology, we hope to assist humankind in its adaptation to climate change.

ALOS-2: DAICHI- 2

Research for Data Assimilation of Satellite Global Precipitation Map



Surface skin temperature (color: Celsius) and outgoing longwave radiation at the top of the atmosphere (white: W/m2) representative of clouds in the model

This study aims to improve numerical weather prediction (NWP) model forecasts by an effective use of earth-observing satellite data through an advanced data assimilation method. In addition, we also aim to produce a new precipitation product through our global atmospheric data assimilation system.
This study also explores an effective use of satellite data including GPM DPR through an advanced ensemble data assimilation method for improving NWP and pioneering a new precipitation product based on an NWP model and satellite observations.
Ensemble simulation of global cloud-system resolving model with higher (3.5 to 14 km) mesh resolution on JSS2 is conducted to further understand possibility of an extreme phenomena.

GOSAT: IBUKI

GOSAT (IBUKI) was launched on Jan. 23rd, 2009 in order to measure the concentration of greenhouse gases globally. It carries two sensors that is; TANSO-FTS to measure carbon dioxide (CO_2) and methane (CH_4), and TANSO-CAI to measure clouds and aerosol.

SAOC: Satellite Applications and Operations Center

Dramatic Improvement of Re-processing Time of Earth Observation Data by Using JSS2

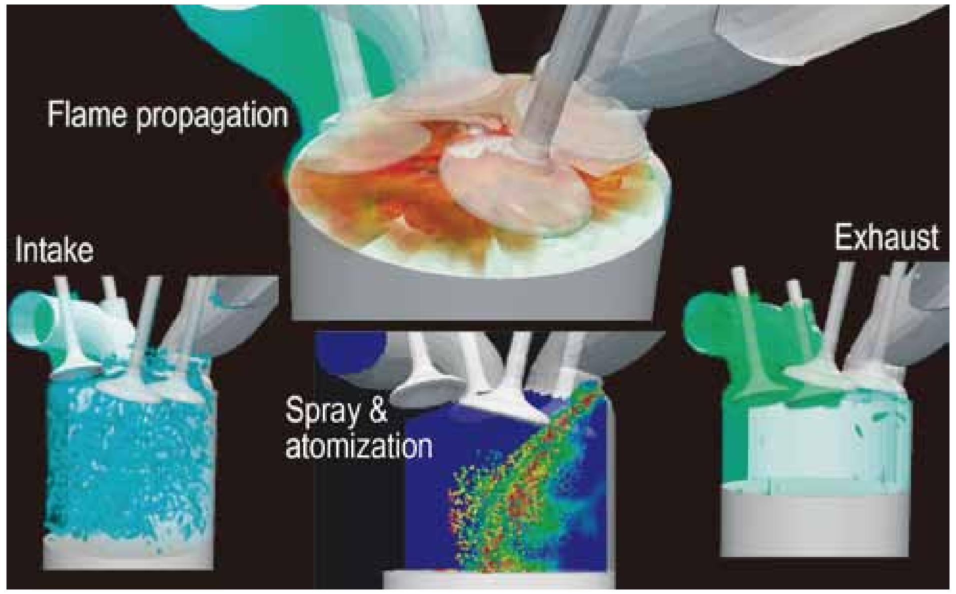
Earth observation by satellites orbiting Earth is an important tool for scientific study of Global Change. Processing of earth observation data includes "routine processing" performed routinely and "re-processing" of several year data performed once a year. The porpuse of re-processing is to correspond with version-up of computing model and algorithm performed periodically.

Input data	**45 TB** (for 6.5 years)
Output data	**20 TB** (200M products)
Computing resouces	**30 nodes** (60 CPUs, 360 cores)
Computing time	**95 kcore hour** (number of cores×time)

JAXA re-processed 6.5 year TANSO-FTS data in Nov. 2015 by utilizing JSS2. It took only 11 days, and we could verify speedup more than 30 times comparing with one year by using conventional computers. We are planning TANSO-FTS level 2 and 3 re-processing and TANSO-CAI perfomance verification in future.

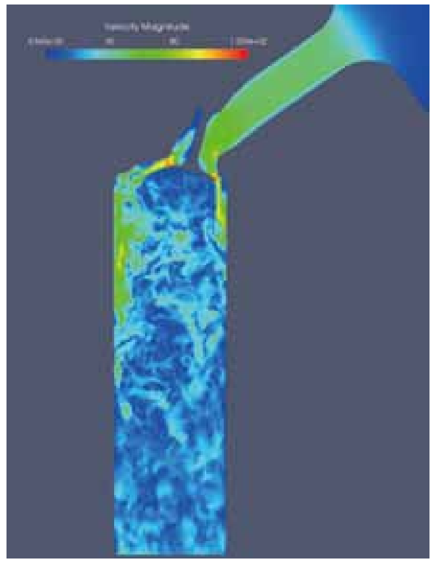
HINOCA

Engine Combustion Simulation Software HINOCA

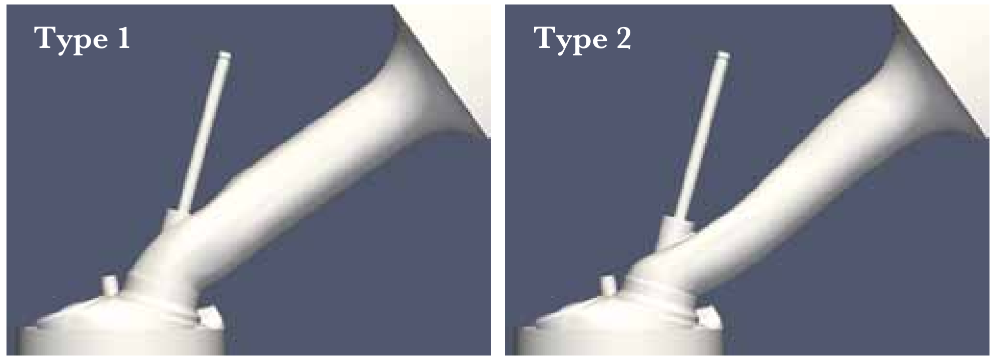


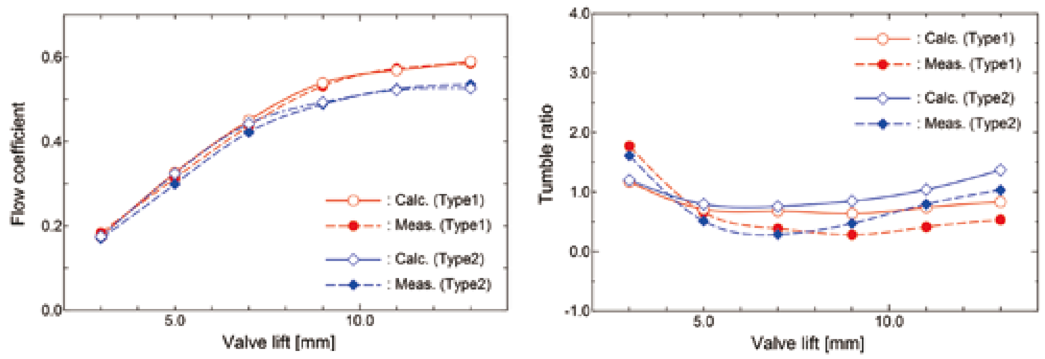
Engine cycle simulation from intake to exhaust

An automotive engine combustion simulation software is now being developed under the support of Council for Science, Technology and Innovation (CSTI), Cross-ministerial Strategic Innovation Promotion Program (SIP), "Innovative Combustion Technology." One of the aims is the enhancement of CAE utilization in automotive engine research by the developed software that is sharable in Japan automotive research community. The software is named "HINOCA." HINOCA is based on fully compressible Navier-Stokes equations which are filtered for LES(Large Eddy Simulation), and employs the uniform Cartesian grid and immersed boundary (IB) methods to reduce the mesh generation cost and labor. The flow solver platform is developed by Japan Aerospace Exploration Agency by utilizing its aerospace CFD (Computational Fluid Dynamics) technology. The sub-models such as spray, ignition, flame propagation and wall heat loss, are built into HINOCA by collaborating research institute and universities: National Maritime Research Institute, Osaka Univ., Waseda Univ., Hiroshima Univ., Tohoku Univ. and Hokkaido Univ. In the newly developed work flow based on the uniform Cartesian grid and IB methods, mesh generation process is reduced to almost zero and flow simulation can be run directly from the engine configuration data defined in STL format. The simulation of steady port flows shows a fairly good agreement with the measurement and reproduces the engine port shape difference effects on flow coefficient and tumble ratio. The engine cycle simulation from intake to exhaust processes dealing with moving valves and a piston is successfully conducted by the employed CFD techniques.



Instantaneous Flowfield (Type 1,Lift=7mm)





Effects of engine port shape difference reproduced by HINOCA. The type 2 is modified from type 1, aiming at augmentation of tumble flow even at the reduction of flow coefficient.

FQUROH Project

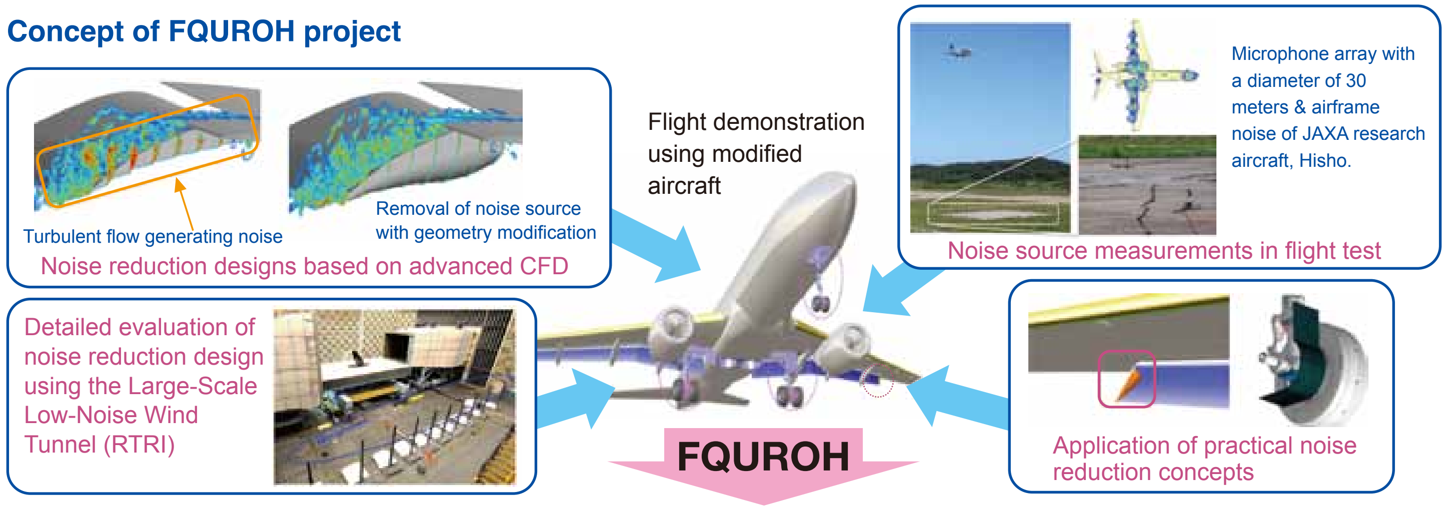
Aircraft

FQUROH: Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations

Even with advanced very high-bypass ratio engines, further efforts to develop quieter aircraft are still necessary because of the prospective increase in the number of takeoffs and landings. The FQUROH project focuses on reducing airframe noise generated mainly by high-lift devices and landing gear, which becomes one of the dominant sources of aircraft noise during approach and landing. The FQUROH project intends to verify design methods based on advanced Computational Fluid Dynamics (CFD) combining with wind tunnel tests and the feasibility of practical noise reduction concepts. Recent computational results can provide information that gives deep insight into detailed noise generation physics, which in turn helps and guides noise reduction design for high-lift devices and landing gear.

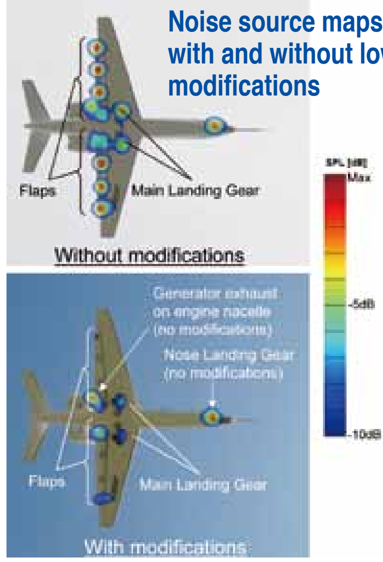
Two flight demonstrations have used JAXA's research aircraft, Hisho, based on a Cessna Model 680 (Citation Sovereign) business jet. The first demonstration was carried out in 2016 to establish the processes for flight testing and to evaluate the preliminary noise reduction designs, followed by the second demonstration in September 2017 to verify the final noise reduction designs. The noise reduction configurations showed obvious noise reductions from the original configuration. Moreover, we observed a good correlation between results from the flight tests, wind tunnel tests and CFD.

Concept of FQUROH project

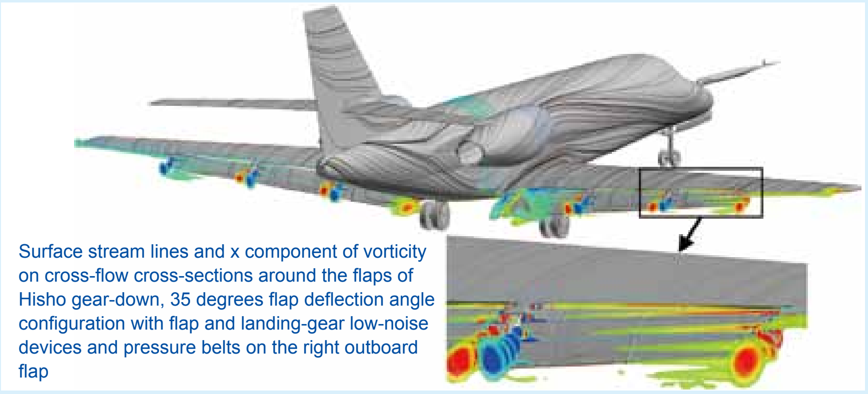


- Acceleration of the development of noise reduction design methods using advanced CFD
- Demonstration of feasibility of the airframe noise reduction concepts

Modified Hisho for the 2nd flight demonstration



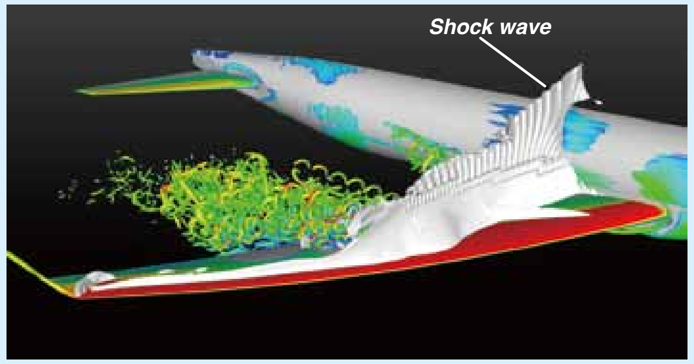
Noise source maps at 1 kHz with and without low-noise modifications

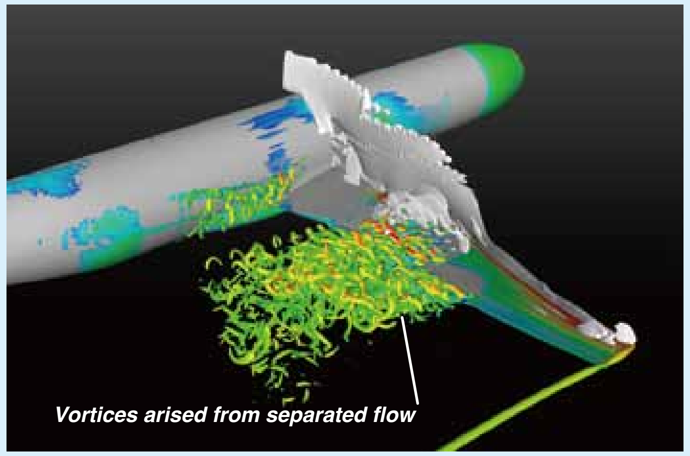


Surface stream lines and x component of vorticity on cross-flow cross-sections around the flaps of Hisho gear-down, 35 degrees flap deflection angle configuration with flap and landing-gear low-noise devices and pressure belts on the right outboard flap

Computational Simulations for Aircraft Modification Design

For the second flight demonstration, a large number of Reynolds-averaged Navier-Stokes (RANS) simulations were also performed to confirm that the flight characteristics, flight performance and structure of JAXA's jet research aircraft, Hisho, were not significantly affected by low-noise devices for the flaps and landing gear and pressure belts on the right outboard flap.





Q criteria and shock wave (color: Mach number)

Unsteady Analysis of High Attack Angle Separated Flow

These simulation results visualize a flow around an aircraft flying at high angle of attack. The shock wave that appears above the wing during high-speed flight and the separated flow behind the shock wave are visualized. We found the shock wave oscillation (transonic buffet) and the fluctuation of separated flow behind the shock wave.

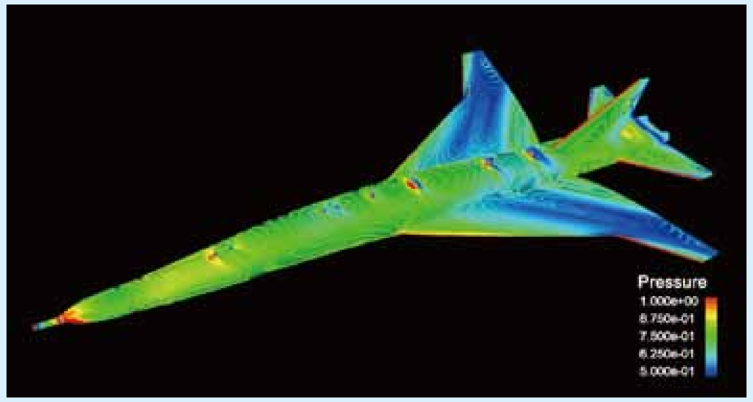
The transonic buffet (aircraft vibration phenomenon due to the shock wave oscillation) occur with increasing the angle of attack. Although there are two kinds of buffet, "low speed buffet" and "high speed buffet," this is the high-speed buffet. The flow is separated behind the shock wave when an aircraft increases the angle of attack at high speeds. Then the shock wave starts to oscillate and the loading on the wing change in time, leading to the aircraft vibration.

By increasing the attack angle more, the aircraft is stalled and possible to crush.

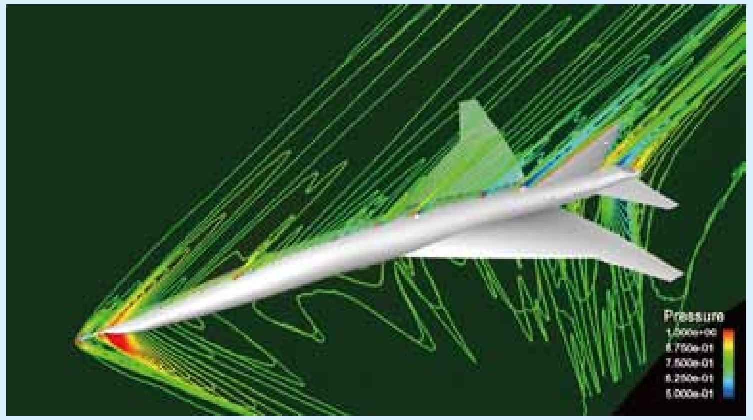
Usually, aircrafts do not fly at such a high angle of attack. But, we have to know the limit of angle of attack (the boundary of flight envelope) in advance when we develop aircrafts. Numerical Simulation Research Unit (NSRU) does research on the prediction of full flight envelope and its boundaries.

Numerical Simulation of D-SEND#2 Airplane

JAXA Aeronautical Technology Directorate is promoting a supersonic transport(SST) research program named "R&D for System integration of Silent SuperSonic(S4) airplane technologies" for low noise SST design technologies. One of the targets of this program is to develop the technologies for reducing sonic-booms to meet an expected future noise standard. Some low sonic-boom design concepts are studied and applied to a 50-passenger aircraft configuration which is defined as a technology reference aircraft and its sonic-boom intensities are compared to those of a conventional Concorde-like SST configuration. In order to demonstrate these low sonic-boom concepts and design technologies, a low-boom demonstration flight using a scaled non-powered experimental airplane named D-SEND#2 was conducted in July, 2015. In the design of the D-SEND#2 airplane, an effective and accurate sonic-boom prediction tool was required and a CFD tool for near-field pressure signature prediction by combining a structured and unstructured CFD codes was developed.



Pressure distribution on the D-SEND#2 airplane surface



Shock waves from the D-SEND#2 airplane simulated for sonic-boom prediction

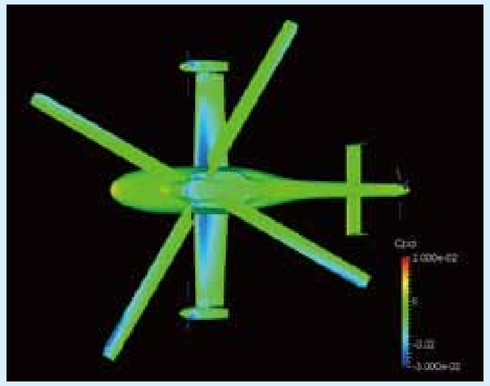
Aircraft

Future Type Rotary-wing Aircraft System Technology

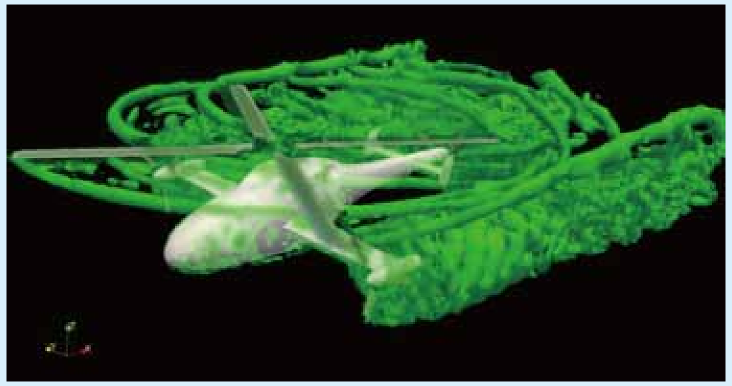
In Japan, rotary-wing aircrafts can be extremely useful for disaster relief, mountain rescue efforts, and for emergency transportation from isolated islands. To present the conceptual design idea of a compound helicopter suited to these needs, we are striving to accumulate basic design technology of future rotary-wing aircrafts and to perform pioneering technical development ahead of domestic manufacturers. Through these efforts, we will play a pioneering role in the development of future rotary-wing aircrafts, eventually transferring the acquired technology to private sector manufacturers.

Compound helicopter model which can fly.

The unsteady flow fields around multiple rotary wings such as for the compound helicopters are solved using a multi-disciplinary CFD/CSD coupling analysis code, rFlow3D, which is developed at JAXA. Based on a moving overlapping grid method, it can generate the aerodynamic data together with the blade elastic motions. The complex geometries of the rotorcraft fuselages are resolved based on unstructured grid solvers, FaSTAR or TAS-code. Besides of the applications to helicopters, rFlow3D has also been used for other rotary wings, such as propellers, drones with multiple rotors, and wind turbines.



Surface Cpa distribution



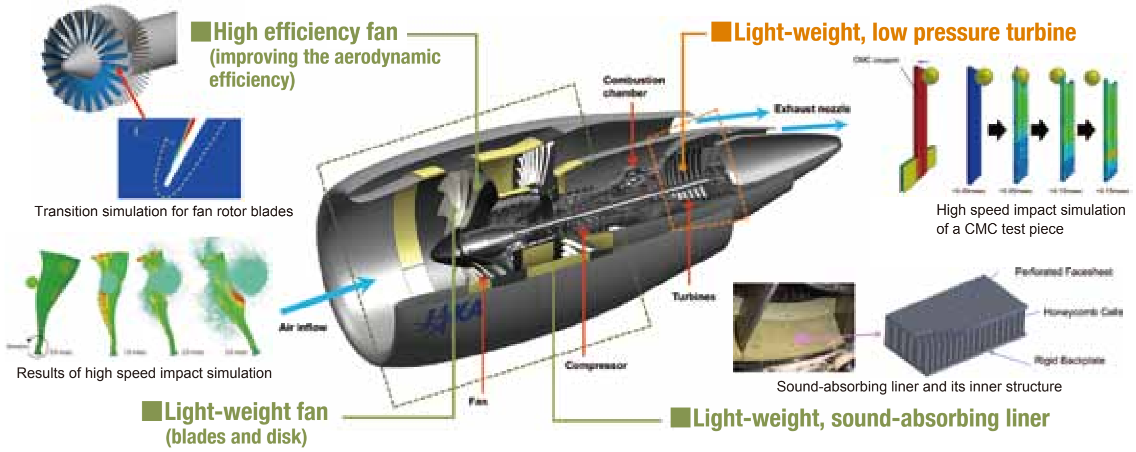
Iso-surface of Cpa around the compound helicopter

aFJR: Advanced Fan Jet Research §

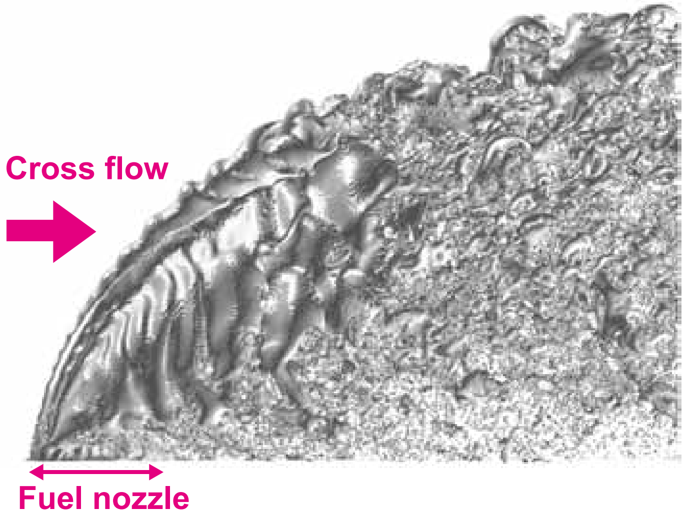
Environmental standards for aircraft engines have become tightened amid global warming, and the world's demand for more green engines with better fuel efficiency and low emissions is growing. JAXA is developing technologies to make lighter fans and low-pressure turbines with higher aerodynamic efficiency for increased engine bypass ratios*, and will evaluate the effectiveness of such advanced technologies by demonstration experiments. JAXA also supports Japanese aero-engine manufacturers to reach a level of technology maturity sufficient to assume a role in the designing of next-generation engines for international projects.

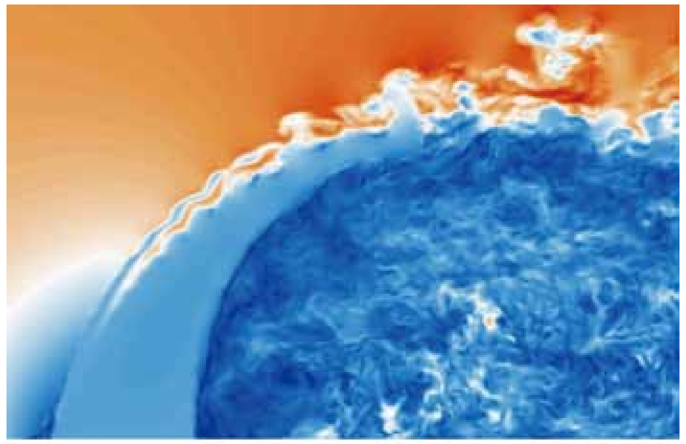
§ Joint research with IHI Corporation, the University of Tokyo, University of Tsukuba, Kanazawa Institute of Technology

** bypass ratios: the ratio of the amount of air flow through the fan only and that through the engine core*



Turbulence





Visualization of liquid phase surface and velocity distribution near the fuel nozzle.

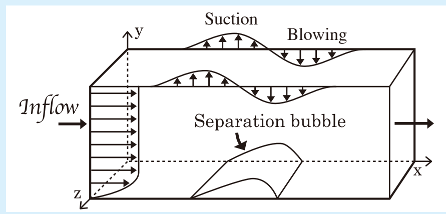
Simulation technology to realize front-loading of combustor design process

We try to model complex flow phenomena in a jet engine combustor using detailed numerical simulations. Our current targets are fuel primary atomization and separated turbulent boundary layer.

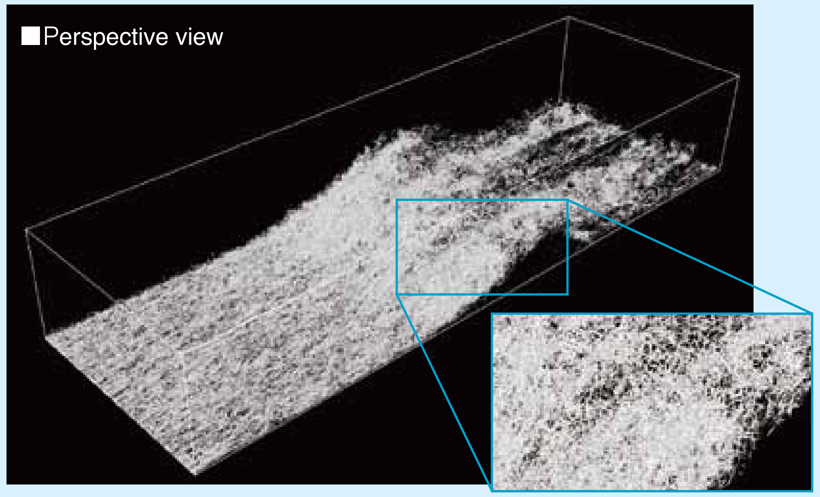
Limit of gas emissions is being more restrictive, and therefore it is necessary to improve the simulation accuracy. Spatial and size distributions of fuel particle are crucial for the gas emission, and therefore the accurate model is needed for the simulation. However, measurement of fuel primary atomization is difficult, and currently, there is no reliable model. It is one of the bottlenecks of combustor simulations.
We try to model the fuel atomization by a detailed numerical simulation which capture both large liquid core and small particle structures. Although the simulation is challenging because its computational cost is very large due to scale gap of these structures, it has been successfully conducted on about 1 billion computational cells using 2048 CPU cores of JSS2.

Direct Numerical Simulation of a Turbulent Boundary Layer with Separation and Reattachment over a Wide Range of Reynolds Numbers

Separation and reattachment of a turbulent boundary layer are crucial issues in aeronautical and engineering applications since they are associated with upper bound of efficiency for the devices. Understanding of the underlying physics and the accurate prediction however may not be still sufficient especially for pressure-induced separated flows. In the present work, we have performed a series of direct numerical simulations (DNSs) for a pressure-induced turbulent separation bubble on a flat plate. A schematic shown here is the current flow configuration. In the present system, suction and blowing are imposed at the upper boundary for producing a separation bubble so that separation and reattached lines (or points) are not fixed in either space or time. The inlet data prescribed are those of a zero-pressure-gradient turbulent boundary layer. The below visualization has been made for the DNS at Re_θ=1500 (Re_θ denotes the Reynolds number based on the inlet momentum thickness), which is the largest simulation ever performed in this configuration. Number of grid points used are 13 billion to resolve the essential vortical motions.



Flow configuration



Isosurfaces of Q (the second invariant of fluctuating velocity tensor) : white, positive values.

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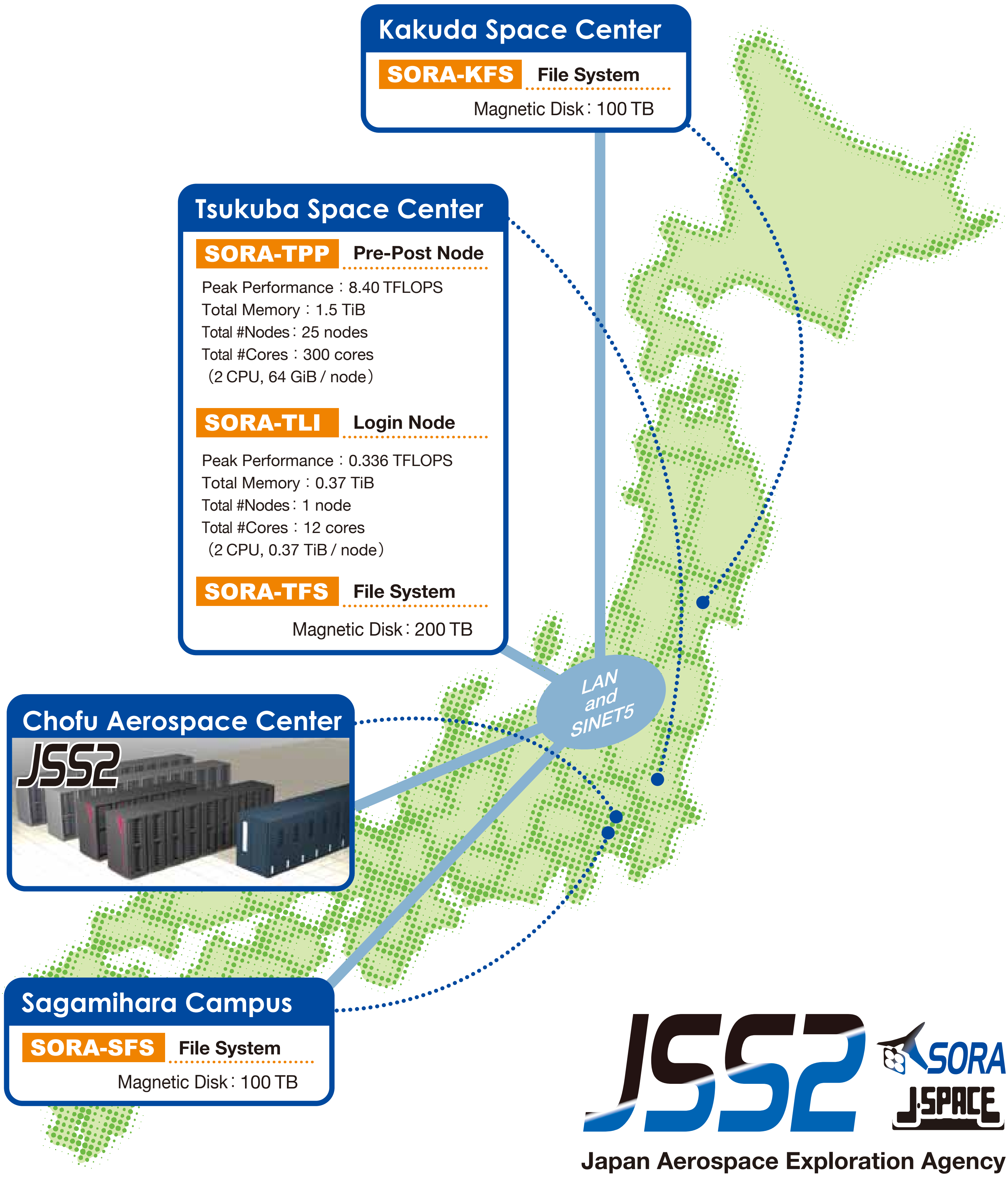

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