JAXA Supercomputer System Generation 3

JSS3/TOKI

2023~2024

Security and Information Systems Department, Supercomputer Division

JSS3 is a whole system of supercomputer systems supporting the development of aerospace technology.

【Computing Infrastructure】 TOKI:TOkyo and ibaraKI

Chofu Aerospace Center

1 TOKI-SORA HPC System

SORA: Supercomputer for earth Observation, Rockets, and Aeronautics

FUJITSU PRIMEHPC FX1000
FUJITSU Processor A64FX

Peak Performance: 19.4 PFLOPS
Total Memory: 180 TiB (32GiB / node)
Total #Nodes: 5,760 (15 racks)

The HPC System (TOKI-SORA) is the core computer of JSS3, which carries on the name "SORA" from JSS2. It is a scalar-type parallel computer with the peak performance of 19.4 PFLOPS.

Operation Management System

High-speed Ethernet Backbone

InfiniBand

2 TOKI-RURI General System

RURI: all-RoUnd Role Infrastructure

The General System (TOKI-RURI) consists of ST node, GP node, XM node and LM node in order to meet the various computing needs of users.

Peak Performance: 1.24 PFLOPS
Total Memory: 104 TiB

ST: STandard
PRIMERGY RX2540 M5
1,121 TFLOPS = 2.99 TFLOPS / node x 375 nodes
70 TiB =192 GiB / node x 375 nodes, Quadro x 1

GP: GPgpu *Water-Cooling System
PRIMERGY CX2570 M5
95.6 TFLOPS = 2.99 TFLOPS / node x 32 nodes
12.0 TiB = 384 GiB / node x 32 nodes, Tesla V100 x 4

XM: eXtra large Memory
PRIMERGY RX2540 M5
5.98 TFLOPS = 2.99 TFLOPS / node x 2 nodes
12.0 TiB = DCPMM 6.00 TiB / node x 2 nodes, Quadro x 1

LM: Large Memory
PRIMERGY RX2540 M5
20.9 TFLOPS = 2.99 TFLOPS / node x 7 nodes
10.5 TiB = DCPMM 1.50 TiB / node x 7 nodes, Quadro x 1

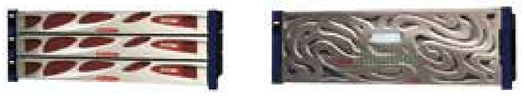
3 TOKI-LI Login System

LI: LogIn system

PRIMERGY RX2540 M5 x 4nodes
41.8 TFLOPS = 2.99 TFLOPS / node x 14 nodes
5.37 TiB = 384 GiB /node x 14 nodes, Quadro x 1

4 TOKI-FS File System

FS: File System

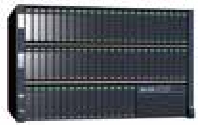


File System: FEFS
All-Fash NVMe Storage: 10 PB
Hard Disk Drive Storage: 40 PB

Tsukuba Space Center

TOKI-TRURI Tsukuba General System

TRURI: Tsukuba all-RoUnd Role Infrastructure



Peak Performance: 145 TFLOPS
Total Memory: 10.8 TiB
Total #Nodes: 49

TST PRIMERGY RX2540 M5
137 TFLOPS = 2.99 TFLOPS / node x 46 nodes
8.62 TiB =192 GiB / node x 46 nodes, Quadro x 1

TGP PRIMERGY CX2570 M5 *Water-Cooling System
5.98 TFLOPS = 2.99 TFLOPS / node x 2 nodes
768 GiB = 384 GiB / node x 2 nodes, Tesla V100 x 4

TLM PRIMERGY RX2540 M5
2.99 TFLOPS = 2.99 TFLOPS / node x 1 node
1.50 TiB = 1.50 TiB / node x 1 node, Quadro x 1

TOKI-TLI Tsukuba Login System

TLI: Tsukuba LogIn system

PRIMERGY RX2540 M5 x 2 nodes
5.98 TFLOPS = 2.99 TFLOPS/ node x 2 nodes
768 GiB = 384 GiB / node x 32 node, Tesla V100 x 1

TOKI-TFS Tsukuba File System

TFS: Tsukuba File System
File System: FEFS
Total Memory: 0.4 PB

Tsukuba Operation Management System

InfiniBand

Water-cooling

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

CMU (CPU Memory Unit)

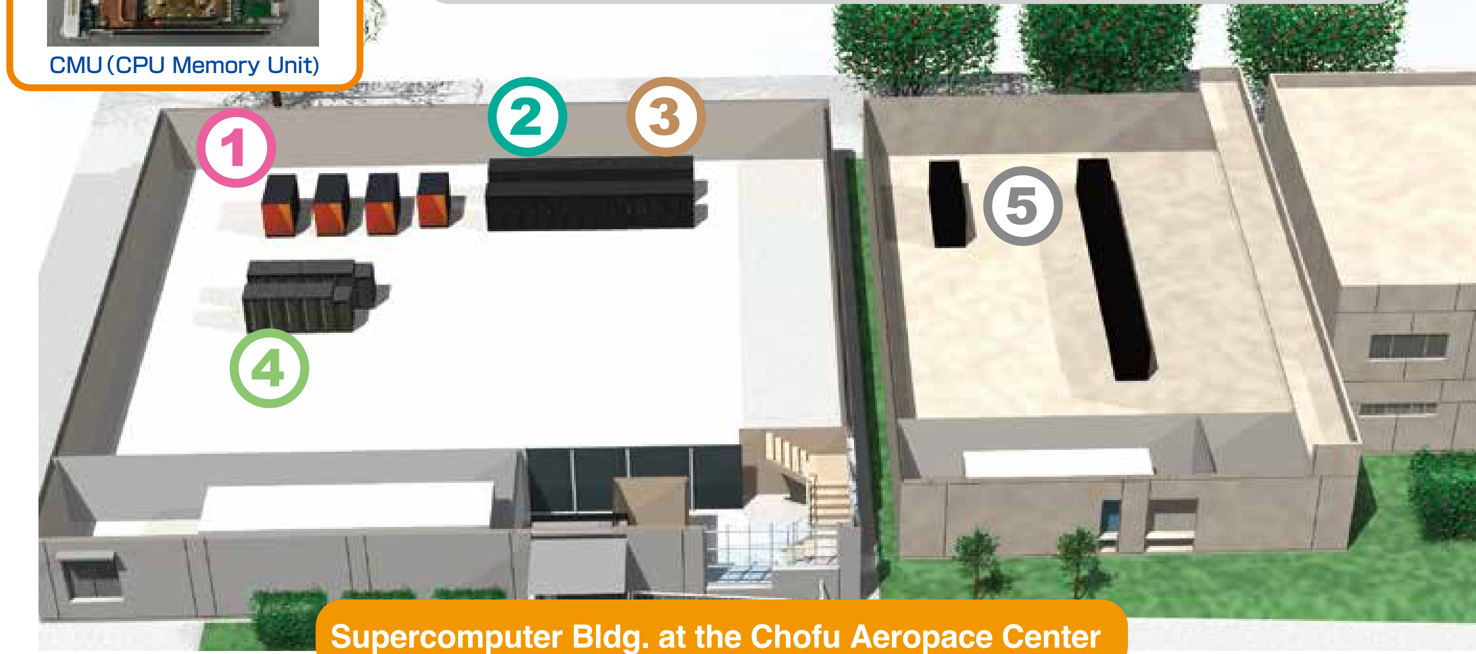
【Archiving Infrastructure】 J-SPACE

5 J-SPACE

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

Disk Cache: 3 PB
Tape: 70 PB

Powered by HPSS



Supercomputer Bldg. at the Chofu Aeropace Center

Start of JSS3 operation

▲HPC System（TOKI-SORA)

JSS3 is the successor to JSS2.

Even if we install one of the most powerful supercomputer systems in the world today, its performance will be degraded in just a few years. As Japan's most advanced aerospace research organization, JAXA always needs a supercomputer system with the fastest computing power.

Supercomputer Division, Security and Information Systems Department has been operating JSS3 (JAXA Supercomputer System Generation 3), the successor supercomputer system to JSS2, since December 2020. The name TOKI comes from the name of Japanese bird toki (crested ibis (Nipponia nippon)), Japanese expression of "time and space" and "solution". TOKI also expresses "TOkyo and ibaraKI", where JSS3 is located.

HPC System (TOKI-SORA) is the mainframe of JSS3

Supercomputer for further development of space and aircraft technology

The HPC system (TOKI-SORA), the main computer of JSS3, is a computational system for large-scale numerical simulations, with 5,760 nodes of the PRIMEHPC FX1000 developed by Fujitsu. This supercomputer has a peak performance of 19.4 PFLOPS and a total memory of 180 TiB.It will play a role as a high-performance computing (HPC) platform to contribute to the enhancement of international competitiveness in the aerospace field.

▲Fujitsu Processer A64FX

General System (TOKI-RURI) with a choice of node types

A computer composed of four types of nodes

The programs that users calculate can be small or quite large, depending on their research. The General System (TOKI-RURI) consists of four different types of nodes, so the user can choose the most efficient node for the program to be calculated.

Equipped with TOKI-RURI GP node for AI (artificial intelligence) calculations

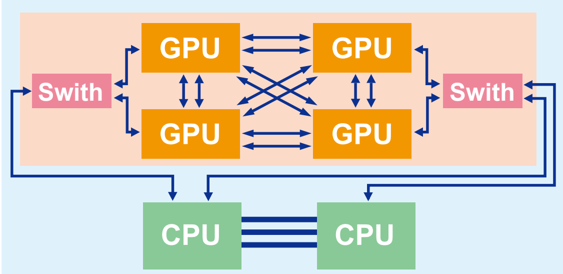
The General System of JSS3 is equipped with the GP node, a GPGPU system that can be used for machine learning purposes. GPGPU is a technology that uses the GPU (graphics board) for numerical calculations. It is suitable for calculations that repeat the same calculation many times.

Each GPnode has four NVIDIA Tesla V100 GPUs. TOKI-RURI at the Chofu Aerospace Center has 32 nodes, and TOKI-TRURI at the Tsukuba Space Center has 2 nodes.

Various nodes of TOKI-RURI

STnode	Standard	375 nodes
	Normal program calculations	
GPnode	GPgpu	32 nodes
	Machine learning	
XMnode	eXtra large Memory	2 nodes
	Program calculations with extra large memory	
LMnode	Large Memory	7 nodes
	Program calculations with large memory	

TOKI-RURI　GPnode



JAXA is tackling technical issues in operation

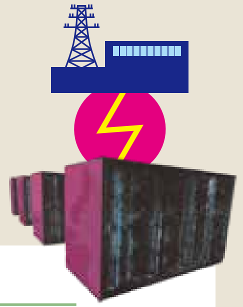
High level of awareness of the technical challenges with supercomputers

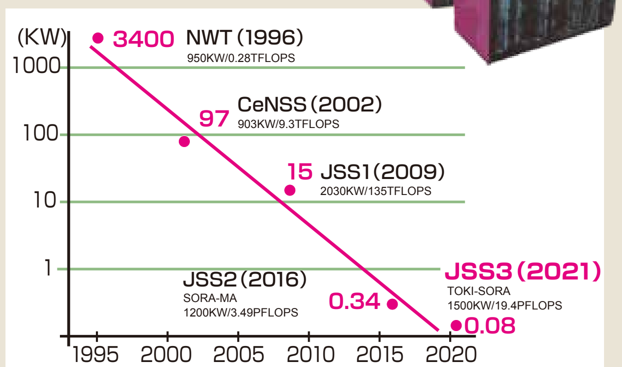
In order to solve the technical issues in the operation of supercomputers, JAXA has cooperated with the manufactures to apply technical improvements, and provided the information necessary to users to run the programs efficiently.

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.

Power per 1 TFLOPS (Electricity per hour÷Peak Performance)	
JSS2	0.34 KW
JSS3	0.08 KW

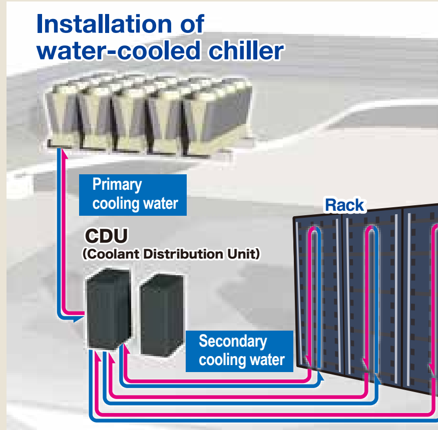




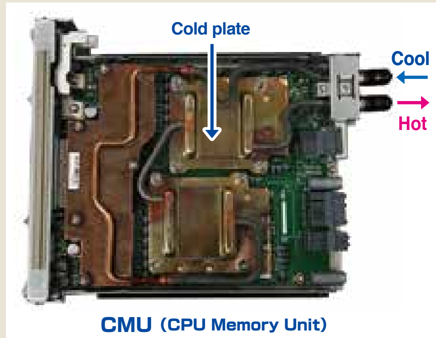
▲Power per 1 TFLOPS of successive generations of computers

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 JSS3.



◀Installation of water-cooled chiller



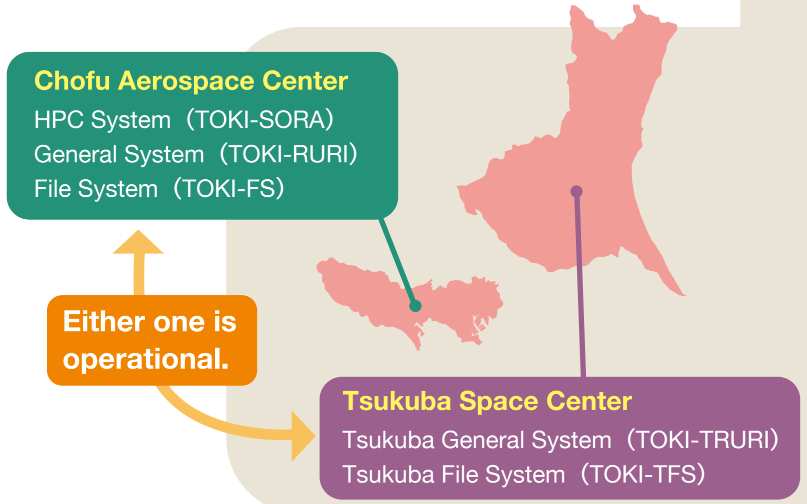
◀The heat in CPU is removed directly by circulating cold-water in the cold plate.

Challenge　Uninterrupted Operation Service

A system that can be used 365 days

For researchers who use supercomputers for research throughout the year, the ideal system is one that does not stop for maintenance during the year.

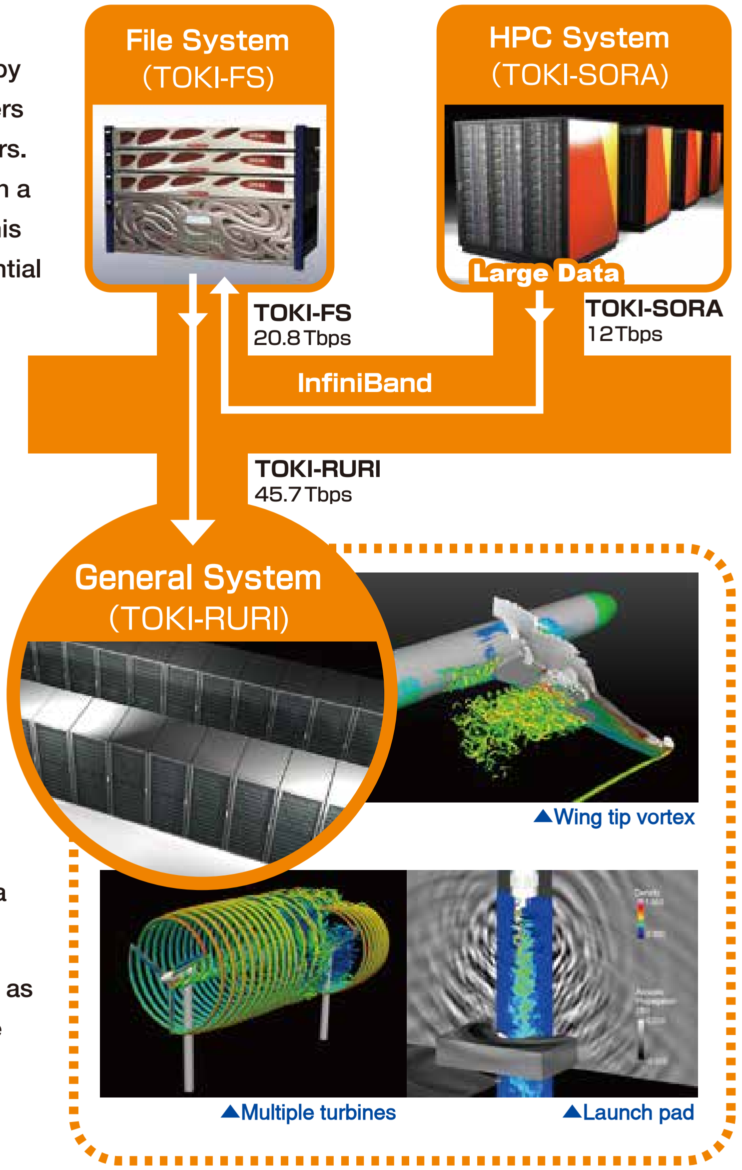
JSS3 has the General System and the File System at each of its bases in Tokyo and Tsukuba. Therefore, researchers can continue their research even if one of the systems shuts down its operation.



JSS3 has an advanced visualization system

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.



▲Wing tip vortex
▲Multiple turbines
▲Launch pad

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. JSS3 has been equipped with a special computer system so as to perform large-scale calculations smoothly. The system named "TOKI-RURI (General System)," which is used for pre-processing for calculations and post-processing for visualization of simulation results. Through the use of TOKI-RURI, the visualization procedure can be simplified. Namely, users can directly visualize the results stored in a file system, TOKI-FS, without transferring the data from TOKI-FS to the users' own computers.

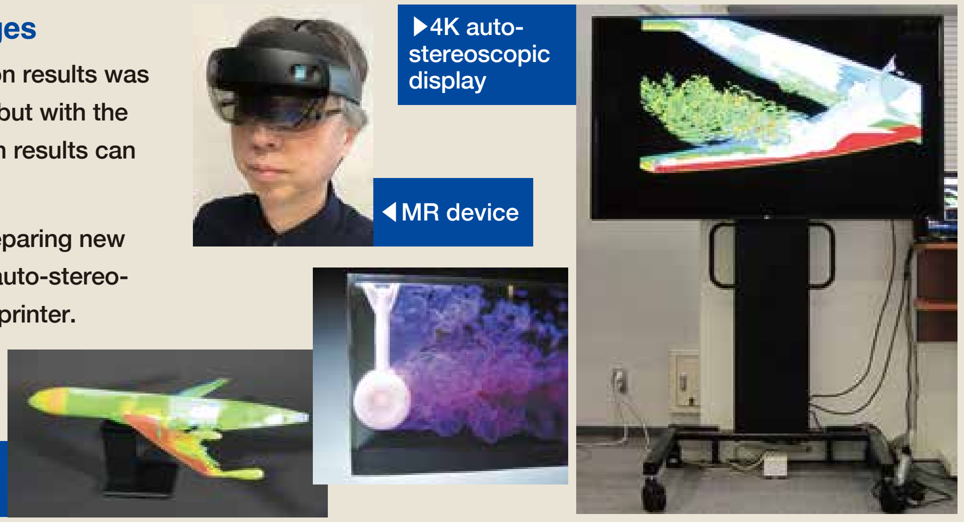
JSS3 has adopted various applications for visualization such as Ensight, Fieldview and Paraview, and the visualization can be performed under various conditions like remote desktop function or client server.

Diversified 3D Visualization Devices

From 2D images to 3D images

Visualization of numerical simulation results was mainly displayed on a 2D monitor, but with the evolution of 3D devices, calculation results can now be confirmed in 3D.

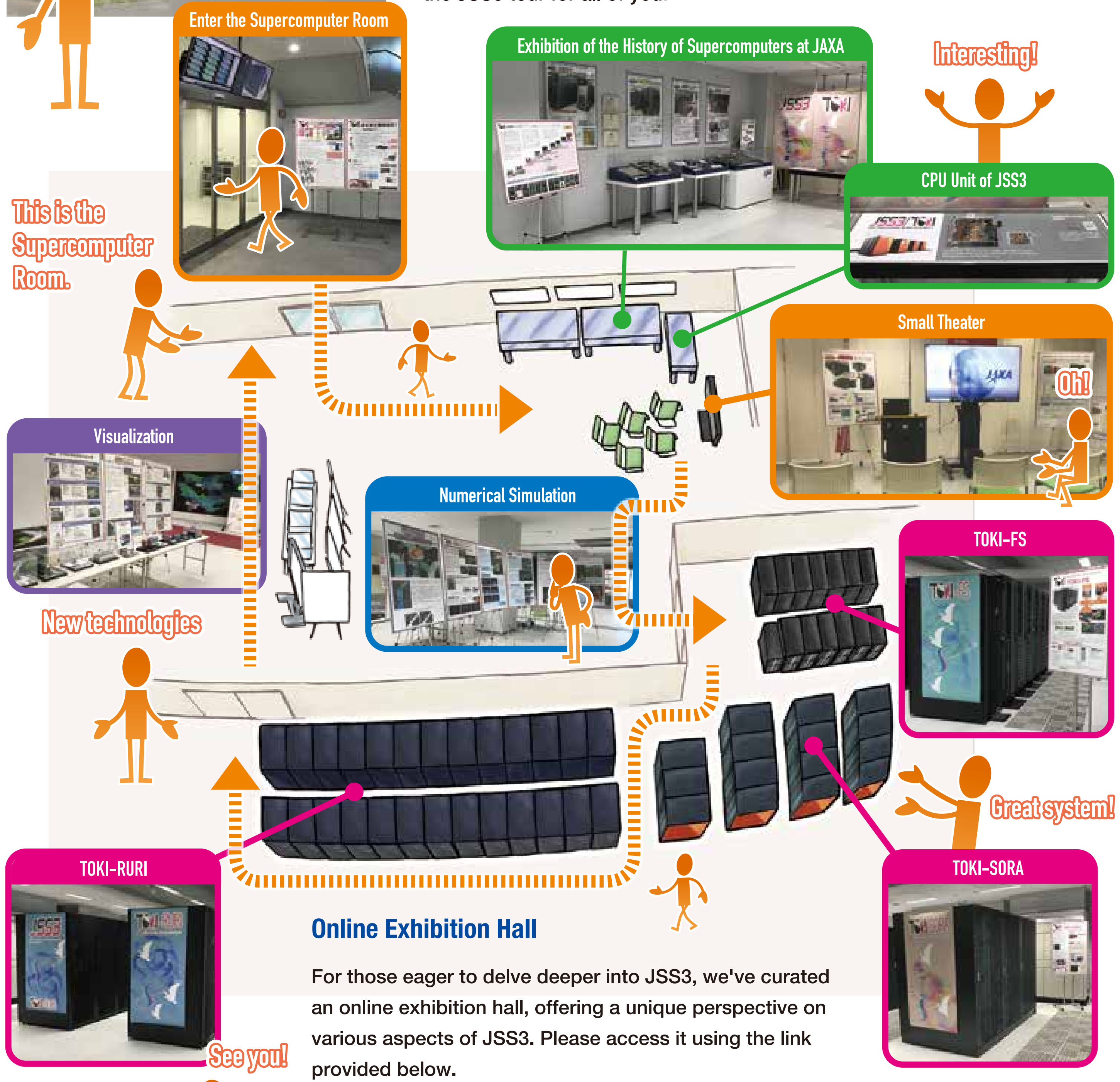
The JSS3 Visualization Team is preparing new visualization technology using 4K auto-stereoscopic display, MR device and 3D printer.


▶4K auto-stereoscopic display
◀MR device
▶3D models made by using 3D printers

Welcome to the JSS facility!

Supercomputer Observation Tours

We have consistently offered Supercomputer Observation Tours to provide an opportunity for individuals interested in understanding the supercomputer system to explore JSS3. Our tours feature a variety of exhibits, including historical CPUs, posters showcasing numerical simulation results computed using supercomputers, and various visualization items. However, for those residing outside of Japan or at a considerable distance, participating in these tours may not be feasible. As a result, we present a concise experience of the JSS3 tour for all of you.



Online Exhibition Hall

For those eager to delve deeper into JSS3, we've curated an online exhibition hall, offering a unique perspective on various aspects of JSS3. Please access it using the link provided below.

https://www.jss.jaxa.jp/en/online-exhibit/

Development History of Computer System and Numerical Simulation in JAXA

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.

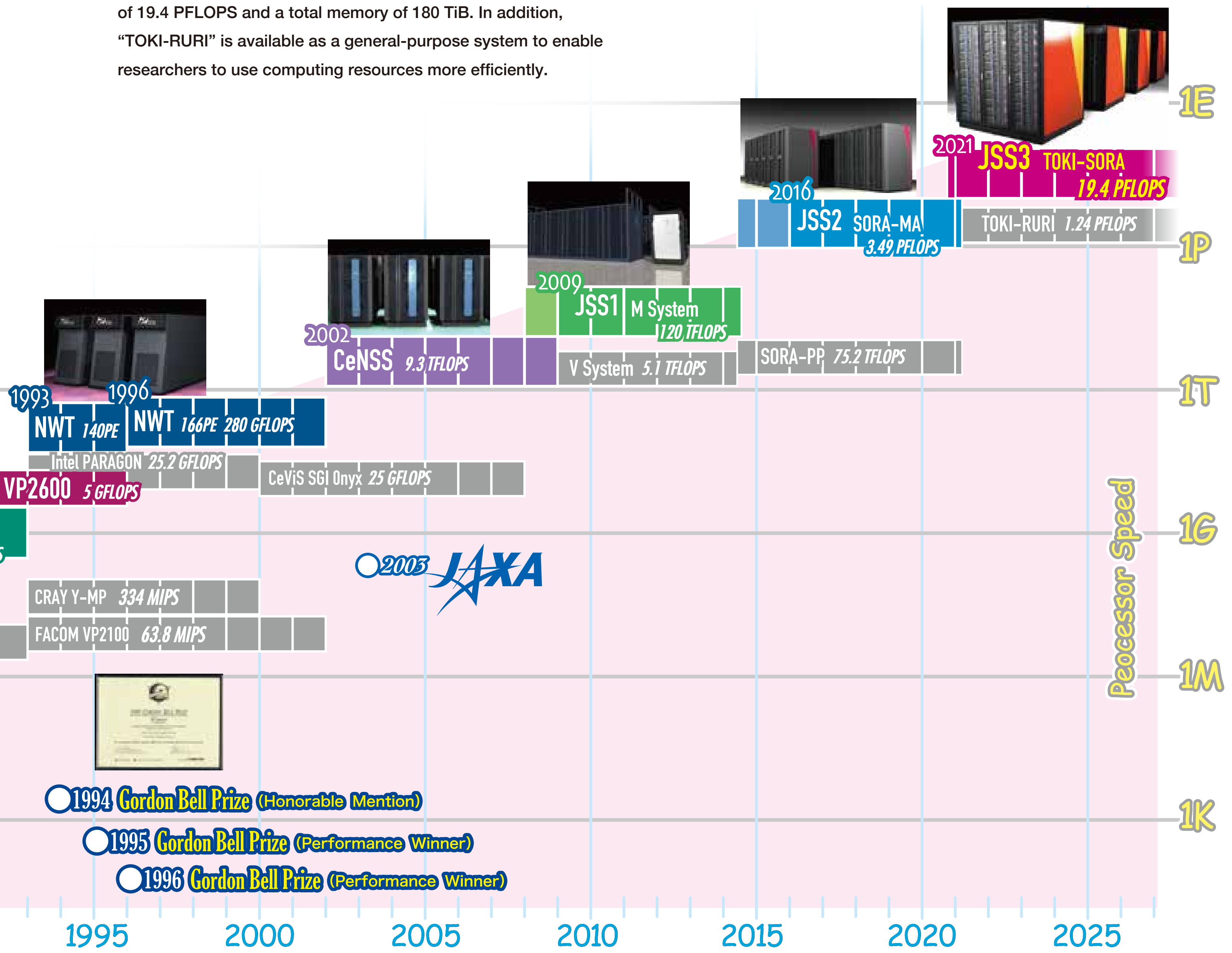
In 2002, NWT was replaced to a new system, Central Numerical Simulation System (CeNSS), which had a Fujitsu-made PRIMEPOWER as a core machine. CeNSS also achieved impressive performance in the development of next-stage numerical simulation technologies.

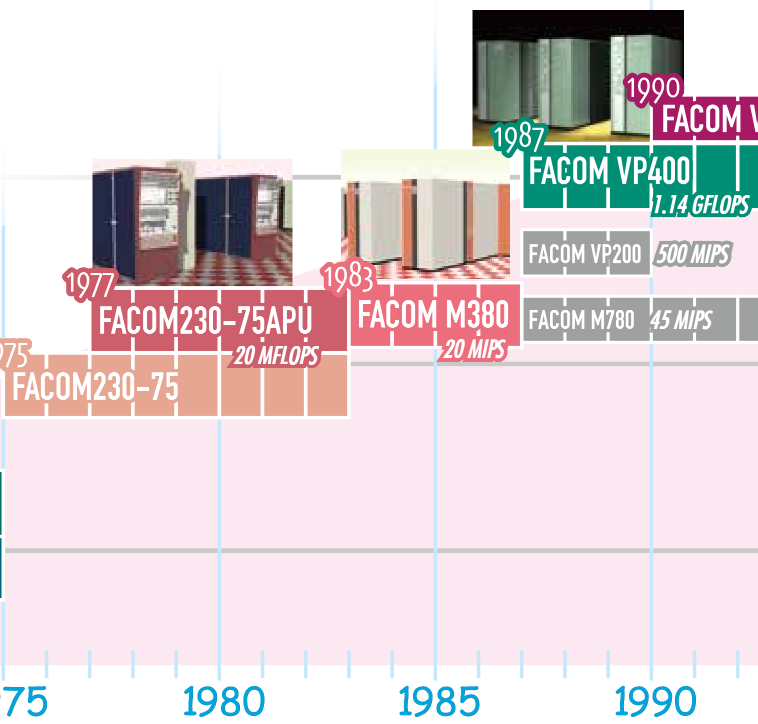
In 2003, JAXA was established by merging NAL, National Space Development Agency (NASDA) and Institute of Space and Astronautical Science (ISAS). Afterwards, the supercomputers installed in each organization were put together into one system so as to enhance the research efficiency. In 2007, the integrated supercomputers started its operation as JAXA Supercomputer System1 (JSS1).

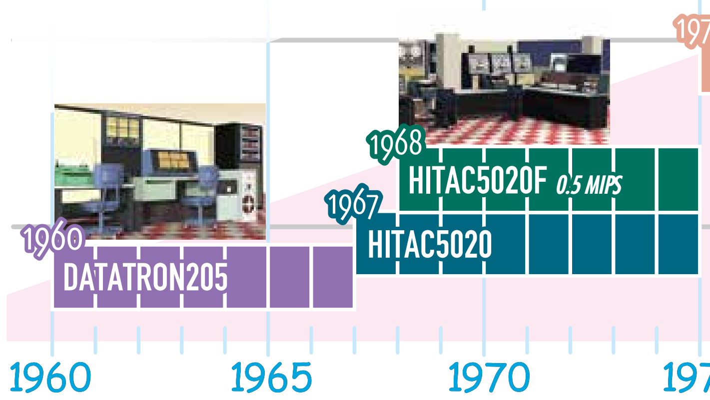
The performance of JSS1 was updated in phases. In April 2009, the peak performance of both M and P systems for the scalar part became 135 TFLOPS and the total memory size became 100 TB, and since then JSS1 had been fully operational.

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.

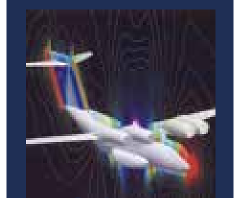
The installation of JSS3 as a new supercomputer system started in mid-2020, and it has been in operation since December. The new system is called "TOKI", and "TOKI-SORA", which is configured as the main computer, has a theoretical computing performance of 19.4 PFLOPS and a total memory of 180 TiB. In addition, "TOKI-RURI" is available as a general-purpose system to enable researchers to use computing resources more efficiently.

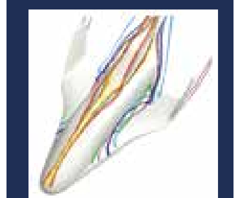






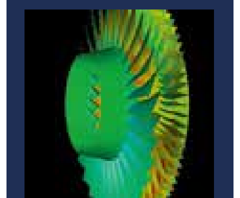
Pioneering | Technology Development | Verification | Practical use

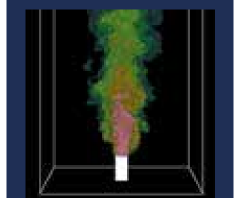
ASKA
Simulation of Full Configuration Experiment STOL 'ASKA'

1986

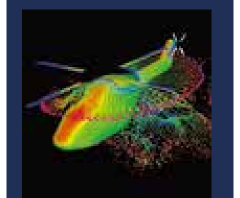
HOPE
Themo-aerodynamic Design of Unmanned Reentry Vehicle HOPE using GFD

1993

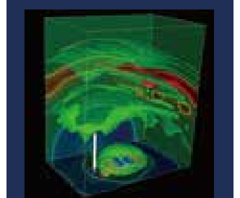
SST
CFD Analysis and Design of Next Generation SST

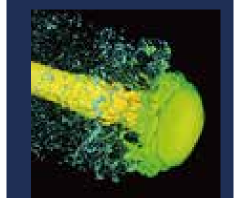
1995

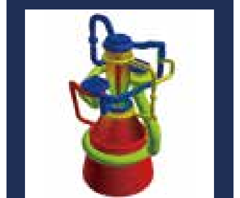
3-D Compressor
3-D Full Circle Compressor Stage Simulation of Aerojet Engine

1995

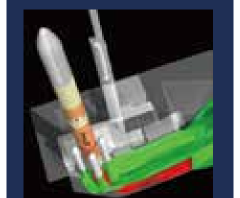
Combustion
Analysis of Turbulent Combustion of Hydrogen

2001

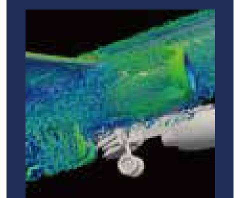
Helicopter
Numerial Simulation of Helicopter Transient Flight

2003

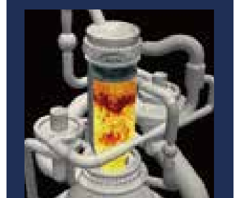
Rocket Launch
Sequential Photographs of Pressure Wave Propagation around LP1

2006

Atomization
Numerical Simulation of Liquid Atomization Processes

2009

Rocket Engine
An End-to-end High Fidelity Numerical Simulation of the LE-X Engine

2011

H3 Launch Vehicle
Arrangement of Rocket Engines on Jet Flow inside Launch Pad of H3 Launch Vehicle

2015

Aircraft
Core Technology to Innovate Aircraft Design and Operation

2018

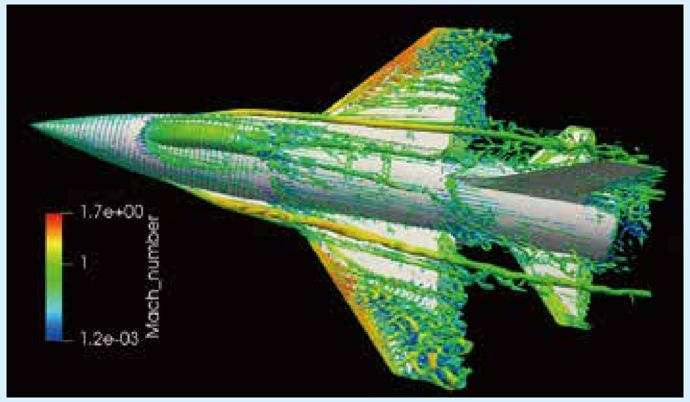
Rocket Engine
Large-eddy Simulation of a Full-scale Liquid Rocket Engine Combustor

2022

Numerical Simulation of **Aircraft**

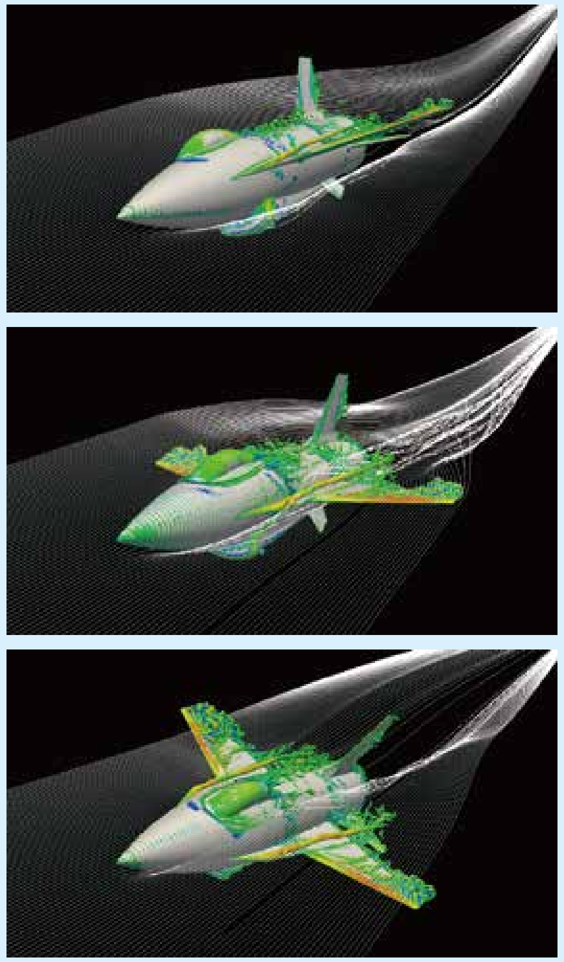
Research on Dynamic Stability Analysis

Aircraft dynamic stability is crucial for designing aircraft maneuver control systems and avoiding unstable flight motion, which prediction with textbook-based data or wind tunnel tests sometimes prove challenging due to their limited information on detailed unsteady flow fields. In this research, we have developed FaSTAR (Fast Aerodynamics Routines), a high-speed compressible flow solver that excels in providing both highly accurate predictions of aircraft stability and substantial data productivity.

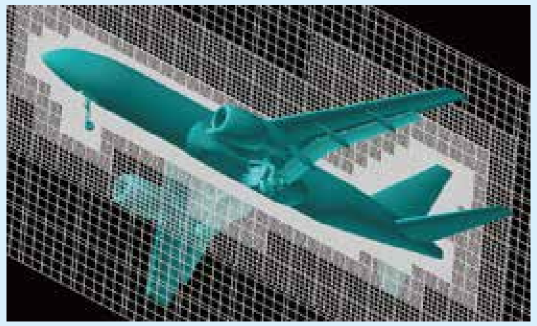
The figures presented here illustrate instances of unsteady flow over a Standard Dynamics Model (SDM) undergoing oscillations in roll direction. To simulate the turbulent flow, we employed the Spalart-Allmaras-based Delayed Detached Eddy Simulation (SA-DDES) method. The visualization of turbulent eddies allowed us to capture the periodic separation occurring over the airfoil tip. We conducted quantitative comparisons between the numerical and experimental results and confirmed that our numerical method provides accurate predictions for aircraft's dynamic stability.



Iso-surface of Q criteria (color: Mach number)


Streamlines around the rotating aircraft

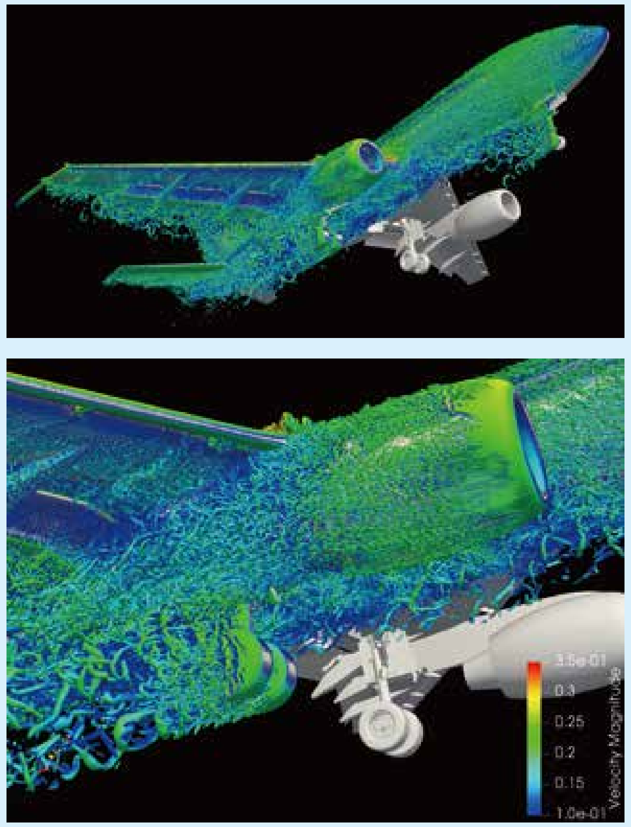
Research and Development of Core Technology to Innovate Aircraft Design and Operation


Computational grid around the aircraft

The development of new aircraft requires a high-speed and precise computational program which enables to reproduce the actual environment. To this end, we have proceeded with the development of high-speed compressible flow solver with geometric wall models and LES wall models based on the high-resolution hierarchical , orthogonal and equally spaced structured grids.

The computational grids near the aircraft body is finer than the outside. So we can calculate with high accuracy around the high lift devices and landing gears.

The left images show the flow around the aircraft in flight at a seven-degree attact angleI. We can see that the flow varies in complexities depending on the shape of the aircraft.


Iso-surface of the vorticity (color: Velocity magnitude)

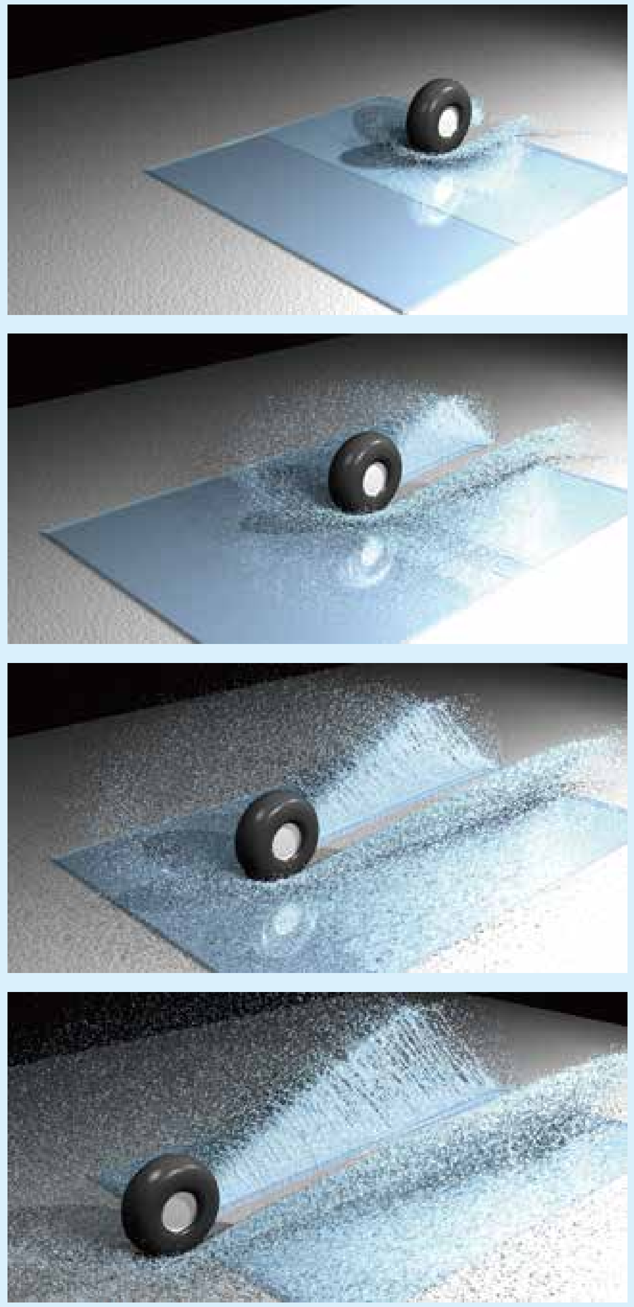
Research on Prediction Technology of Water Spray Generated from Aircraft Tire

When obtaining a type certification for an aircraft, it is necessary to ensure that the engine does not ingest a large amount of water spray generated from the tires running on flooded runway. To predict the distribution of the water spray, a particle simulation tool using MPS (Moving Particle Simulation) method has been developed in JAXA. The tool is parallelized via MPI technique, and the load balance is kept uniform using dynamic domain decomposition method.

Experimental efforts to obtain in-house data are also being made to validate the simulation. The left figure is the photo of the quasi-full-scale test, where the aircraft tire was attached to the end of the beams extending from a dolly running on a rail.

The right figures are the simulation results of the test, where the metaball and ray tracing techniques were utilized to render the result of the particle simulation. The angle of the water spray viewed from the front side against the ground was evaluated, and was confirmed to be consistent with the test results.

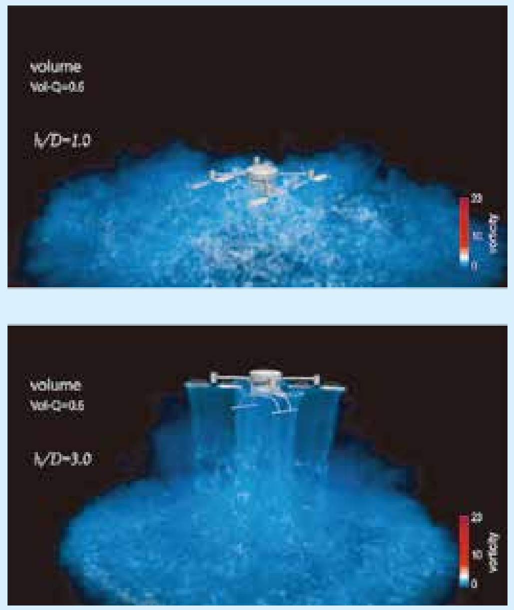

Photo of the quasi-full-scale test of the water spray


Particle simulation result rendered with meatball and ray tracing techniques

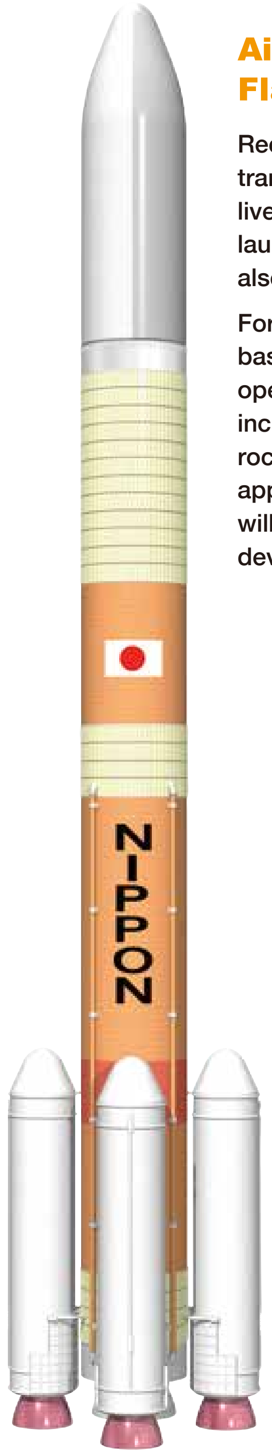
Aerodynamic Investigation of a Multiple-Rotor Drone in Ground Effect

Larger and heavier drones are being developed along with new trials to built multiple-rotor type eVTOLs which can carry several people. However, the flowfields around multiple rotors where the neighboring rotors are rotating in different directions are very complex and not well understood. Especially when the multicopters are hovering near the ground, the so-called ground-effect is considered different with the conventional single rotor helicopters.

Computational model based on a prototype variable-pitch controlled quad-rotor drone is created. Flowfields and the drone performance are investigated for the drone hovering at several different height from the ground. It is found that the flowfields for the quad-rotor drone are much complex compared to those of a single rotor.


Distribution of vortices around a multiple-rotor drone (volume rendering)

Numerical Simulation of **Spacecraft**



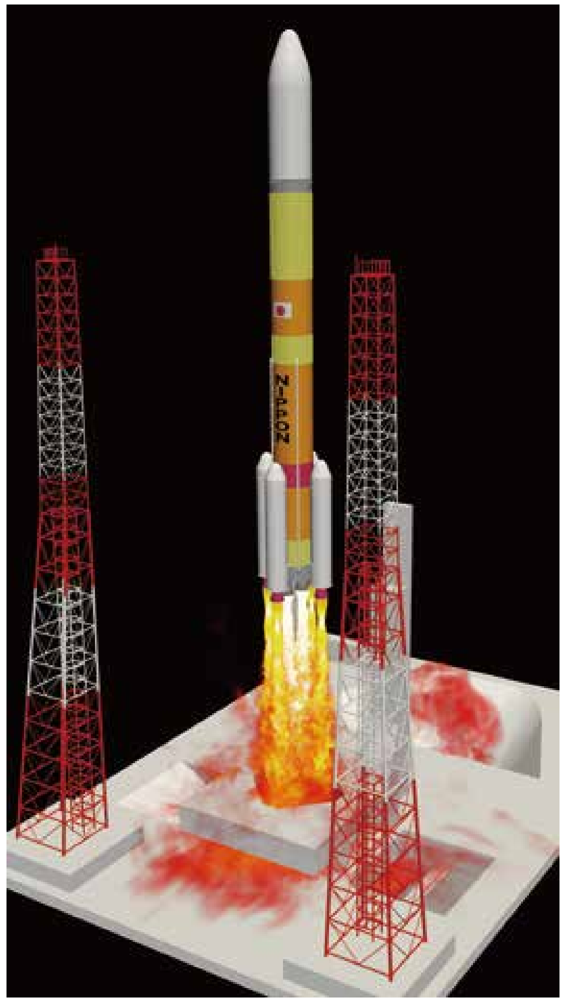
Aiming to Develop Japanese New Flagship Launch Vehicle, H3

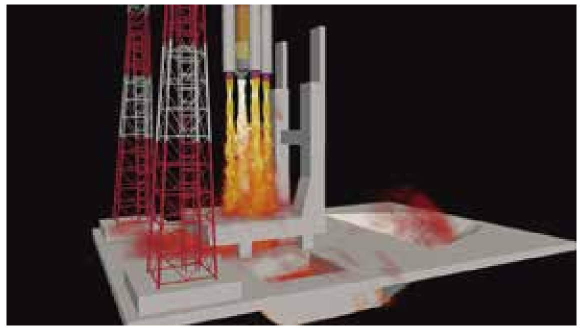
Recently, many satellites that are closely related to our lives have been transported to space, thus utilizing space has become part of our daily lives. Under such a progressive society, H3 is aiming to become a launch vehicle that attracts people' s attention not only in Japan but also globally as an easy-to-use space transportation system.

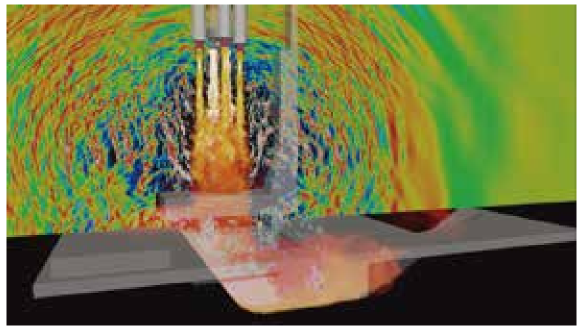
For H3 to succeed, JAXA will modernize the overall launch vehicle based on our experience cultivated through the development and operation of H-IIA. In that sense, we face technological challenges including the development of a new large liquid engine (LE-9) and solid rocket boosters (SRB-3). Technologies 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.

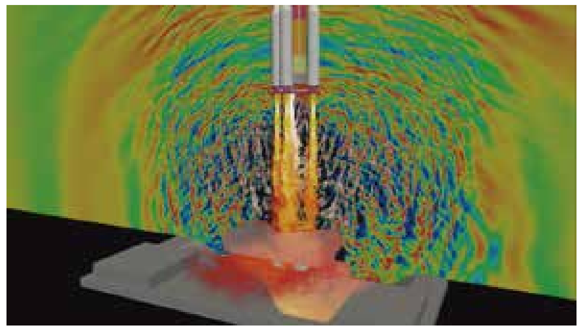
H3 Launch Vehicle Image

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.

Liquid rocket engine combustor of LE-X engine

Large-eddy simulation of a full-scale liquid rocket engine combustor

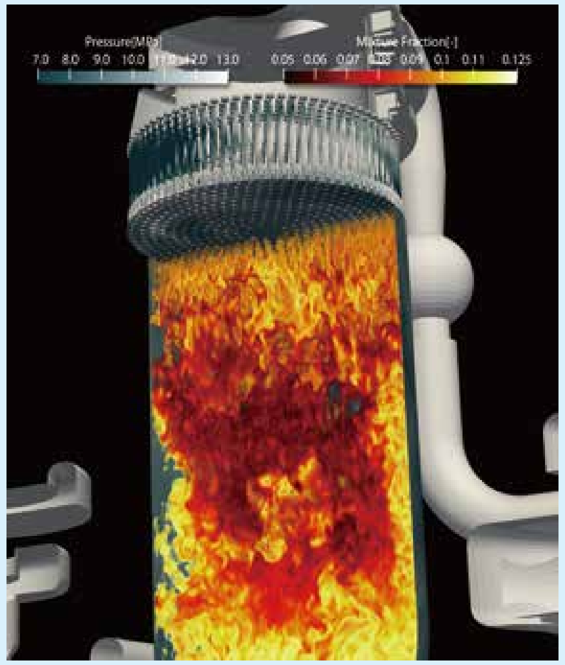
In the development of a liquid rocket engine combustor, the risks of particular concern are the oscillating combustion and erosion of the inner walls due to excessive local heat load. These combustion anomalies are often observed only after full-scale tests, and it is difficult to understand the phenomena through measurement and visualization due to the high temperature and pressure environment. In order to reproduce and predict these unsteady combustion phenomena, a compressible LES (Large Eddy Simulation) solver, LS-FLOW-HO, has been developed.

To perform large-scale parallel computations on the order of 10 billion points, LS-FLOW-HO employs the high-order Flux-Reconstruction method and the low-cost Flamelet model. Compared to the conventional in-house solver, the computational cost of the LES of a combustor is dramatically reduced to less than 1/20. The overset grid approach is used to deal with more than 500 injectors on the full-scale combustor.

The analysis conditions are combustion pressure of 8.2 MPa and mixture ratio of LOX to GH2 of 6.4 (O/F) for the LE-X engine : a technology demonstration engine for the development of the new LE-9. The total number of calculation points is about 2.6 billion. We used 960 nodes (48 cores/node) of JSS3 TOKI-SORA (Fujitsu FX1000, 5760 nodes, 19.4 PFLOPS) . It took two weeks to simulate 4.3 [msec] of physical time.

The instantaneous field during the transient (T~2.5 ms) of the flowfield development is shown in the figures. The pressure distribution is shown on the injector and face-plate walls. Flame shapes are visualized by colored isosurfaces of mixture fraction.
The coaxial flow of LOX and GH2 jetting from the injector forms turbulent shear layer due to the large velocity ratio, and mixing and combustion occur. The flame surface was observed to be shaken by the interference with neighboring jets and acoustic waves in the chamber.

Such thermoacoustic coupling between the acoustic modes specific to the full-scale geometry and the turbulent diffusion flame formed by each injector, is a phenomenon that can be reproduced only by full-scale simulation, and is expected to be a means of predicting combustion oscillations.



Pressure fluctuations and flame deformation developed in the combustor

Enlarged image of flame near injector

Earth Observation Research Using **Satellite** Data

Contributing to Society Through Space-based Earth Observations

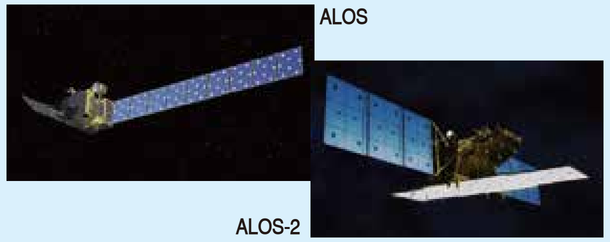
Global Land-Cover Classification by ALOS-2/PALSAR-2 etc.

■Purposes

Land-Use and Land-Cover (LULC) is one of the oldest remote sensing applications and is essential as basic information for various applications. There is an urgent need to develop algorithms that can cope with the **diversity**, **high-resolution**, and **high-frequency** of recent satellite data.

■Use Cases and Significance

Examples of LULC use are summarized in the table on the bottom. Direct and indirect **contributions to many SDGs as fundamental information**.



ALOS-2(DAICHI-2): The Advanced Land Observing Satellite-2 (ALOS-2, "DAICHI-2") is a follow-on mission from the ALOS "Daichi". ALOS has contributed to cartography, regional observation, disaster monitoring, and resource surveys, since its launch in 2006. ALOS-2 succeeds this mission with enhanced capabilities.

■Analysis Methods and Results

1. We conducted a study to extend the CNN-based classification method that has been developed for the Japanese region to a global region using JSS. This time, we focused on the **Asian region**.
2. JAXA satellite products such as **ALOS-2/PALSAR-2**, **GCOM-C/SGLI**, **GSMaP**, and **AW3D** were used as input data. Wide-area maps of LULC are developed by utilizing the characteristics of each satellite.
3. The output data consists of 16 categories, and we obtained a total of 36,000 pieces of reference data.
4. The final product was confirmed to have an overall accuracy of **86 %** (Figure 1).

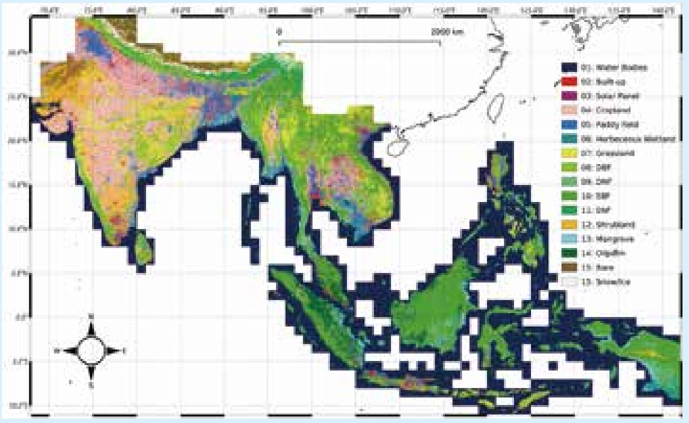


Figure 1: Final Product
Overall accuracy: 86%,
Number of categories: 16
Spatial resolution: 25 m
Time: June 2021 ~ May 2022

■Effects of JSS3 Utilization

In this study, classification processing, which took approximately 215 hours on the existing Linux server, was **six times faster on JSS3** at 36 hours.
In the future, when expanding worldwide, JSS3 is expected to be able to process data in about one month, whereas it is expected to take about six months with the existing servers.

Input data	2TB
Output data	100GB
Computation time	35.8 hours
Computing resources	10 nodes

Table: The computing resources.

JAXA LULC Map Application Examples

Energy	Radio propagation calculation Stream flow calculation for hydropower dams Solar **power plant** siting location review
Disaster Prevention	Simulation of river flooding Survey of **disaster** damage and land-use change Sediment runoff analysis
Urban Planning	**Urban planning** status survey, flood control planning Land utilization, the current status of landscaping Confirmation of embankment topography
Environment/ Biodiversity	Conservation of “SATOYAMA” forests **Environmental** impact assessment survey Understanding the location of bamboo groves Extraction of **forest** change transition, logging sites, etc. Landscape analysis and **biodiversity** analysis in ecology Wildlife habitat mapping Study of the relationship between bird communities Habitat suitability assessment for **endangered species**
Agriculture/ Public Health	Prediction of crop pests and diseases Creation of **farmland maps** Risk mapping of **sanitary pests**
Climate Change	**Climate Change** Impact Assessment Input data for hydrologic and meteorological models
Education	Exhibits at museums, photo galleries, etc. Used for quiz shows, broadcast, and news coverage, **university lectures**, etc.

Development of an EnKF-based ocean data assimilation system

■Purposes

JAXA and RIKEN developed an ensemble Kalman filter-based regional ocean data assimilation system with satellite and in-situ observations at a 1-day interval and created ensemble ocean analysis products in the western North Pacific and Maritime Continent regions (LORA: LETKF-based Ocean Research Analysis, Ohishi et al. 2022a, b, 2023). Here, we used a high-performance computing infrastructure of the JAXA Supercomputer System 3 (JSS3) because the huge amount of computation resource is required to integrate the system.

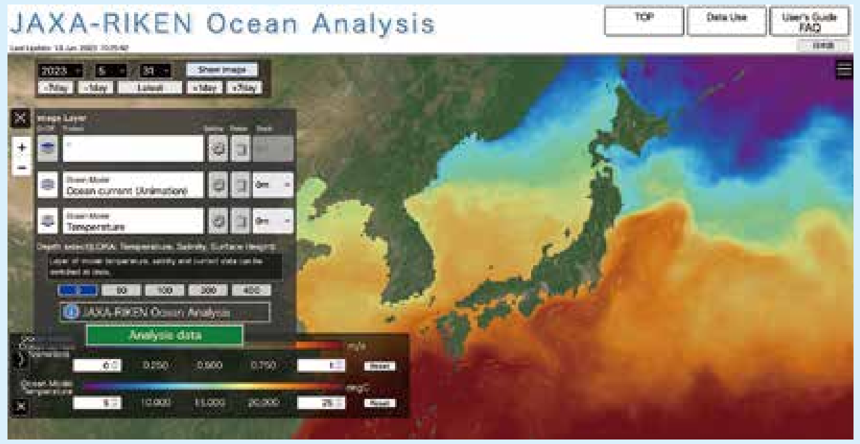


Figure 1: Sea-surface temperature (Color) and horizontal velocity (vector) from LORA (LETKF-based Ocean Research Analysis) on 31st May 2023, showing southward large meandering south of Japan and northward Kuroshio overshooting along eastern coast of Japan.

This data assimilation system is unique in using frequent observations by Japanese geostationary satellites Himawari-8 and -9. Compared with other existing datasets, LORA provides sufficiently accurate analyses for geoscience research and various applications such as fisheries and marine transport with particular strength for Kuroshio and Kuroshio Extension in the mid-latitude regions with large spatiotemporal variations. LORA is available online at JAXA-RIKEN Ocean Analysis webpage (https://www.eorc.jaxa.jp/ptree/LORA/index.html, Fig. 1) for the following variables (cf. Table 1):

1. **Analysis ensemble mean and spread (3D)**
2. **All 128-member ensemble analyses at the sea surface (2D)**
3. **Analytical ocean mixed-layer heat and salinity budget terms (2D)**

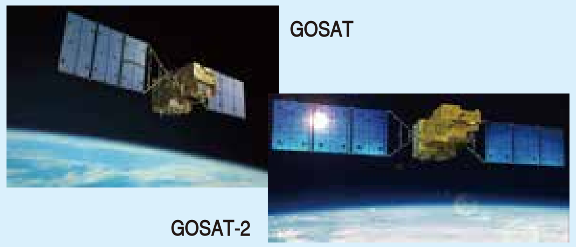
The second can be used for atmospheric boundary conditions and particle tracking, and the third is helpful for investigating spatiotemporal temperature and salinity variations.

References:
Ohishi, Shun, Tsutomu Hihara, Hidenori Aiki, Joji Ishizaka, Yasumasa Miyazawa, Misako Kachi, and Takemasa Miyoshi, 2022: An ensemble Kalman filter system with the Stony Brook Parallel Ocean Model v1.0, Geosci. Model Dev., 15, 8395–8410, doi:10.5194/gmd-15-8395-2022
Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 2022: An ensemble Kalman filter-based ocean data assimilation system improved by adaptive observation error inflation (AOEI), Geosci. Model Dev., 15, 9057–9073, doi:10.5194/gmd-15-9057-2022
Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 2023: LORA: A local ensemble transform Kalman filter-based ocean research analysis, Ocn. Dyn., 73, 117-143, doi:10.1007/s10236-023-01541-3

Period	After August 2015 (About 8 years)
Resolution	0.1°x50 σ-layers
Region	western North Pacific [108°E-180°、12°-50°N] Maritime Continent [95°-136°E、18°S-30°N]
Open data	- Ensemble mean and spread - All 128-member analysis at the sea surface - Analytical heat and salinity budget terms
Open data volume	260 GB/year
Number of CPU cores	512
Computation time	20 mins. for 1-day assimilation cycle

Table 1: Overview of system setting, open data, and computation.

GOSAT 12 years observation data has been processed by JSS3 every time algorithm upgrade



The Greenhouse gases Observing SATellite "IBUKI" (GOSAT) is designed to measure the concentration of major greenhouse gases from space.
GOSAT Project is a joint effort promoted by the Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE).

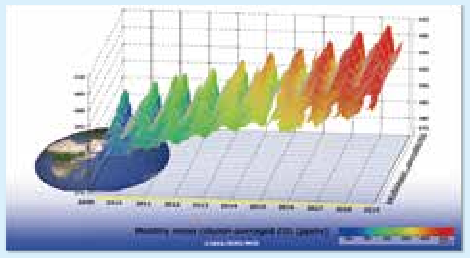


Figure 1: Zonal mean CO_2 density observed by GOSAT between 2009 and 2019. A decade-long global GOSAT data shows annual increase of CO_2 density that exceeded 400 ppm. Larger seasonal variations in the northern hemisphere indicate larger CO_2 emission and stronger plant photosynthesis in summer.

Figure 2: GOSAT Methane products
Partial column difference
(lower - upper troposphere)
(2019,California)

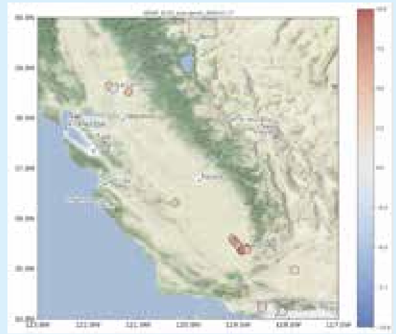


Figure 3: GOSAT CO_2 products
Partial column difference
(lower - upper troposphere)
(2019,California)

Input data	83TB (for 12 years)
Output data	35TB (3.5M products)
Computing resources	30nodes (360cores)
Computing time	30 days

Table 1 : The computing resources.

Red and blue dots show positive and negative enhancements, respectively.Positive enhancement suggests large local emissions from the surface.

More information about JSS3

You can get more information about JSS3 via this website.

We publish more information about JSS3. Please visit the website to touch our supercomputer system!

You can see the configuration, history, outcomes, and some publications about JSS. In addition to them, you can also learn how to use JSS3.

https://www.jss.jaxa.jp/en/

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