Research on the Future Transportation Technology (Integrated Design of Airframe and Engine)

Report Number：R17EG3103
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4436/

Responsible Representative

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Susumu Hasegawa

Abstract

The establishment of technologies for airframe/engine integration of the spaceplane for the realization of future space transportation technology.

Reasons for using of JSS2

The comparison between the experimental data obtained by wind tunnel tests and the numerical results were conducted and verified. After the verifications of numerical results, various aerodynamic data which are difficult to obtain by experiments are computed and analyzed by CFD for the realization of the spaceplane.

Achievements of the Year

Correspondent numerical calculations of spaceplane performed by wind tunnel experiment were carried out. Comparing the experimental results with the numerical calculation results, computational results obtained by CFD are in good agreement with experimental results. Furthermore, in order to improve the spaceplane configuration, the configuration where flow separation was likely to occur was identified in each flight Mach number. We changed the spaceplane configuration of the second phase spaceplane and conducted the wind tunnel tests in December, 2017. Moreover, the analysis of ejector experiments was carried out using CFD.

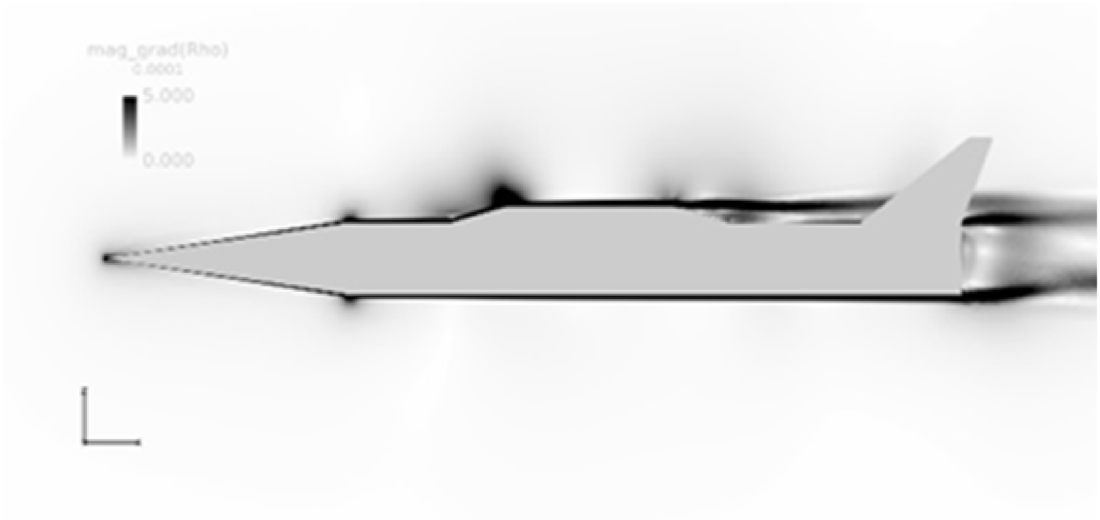

Fig.1 Numerical Schlieren around the splaceplane for the flight condition of Mach 0.7

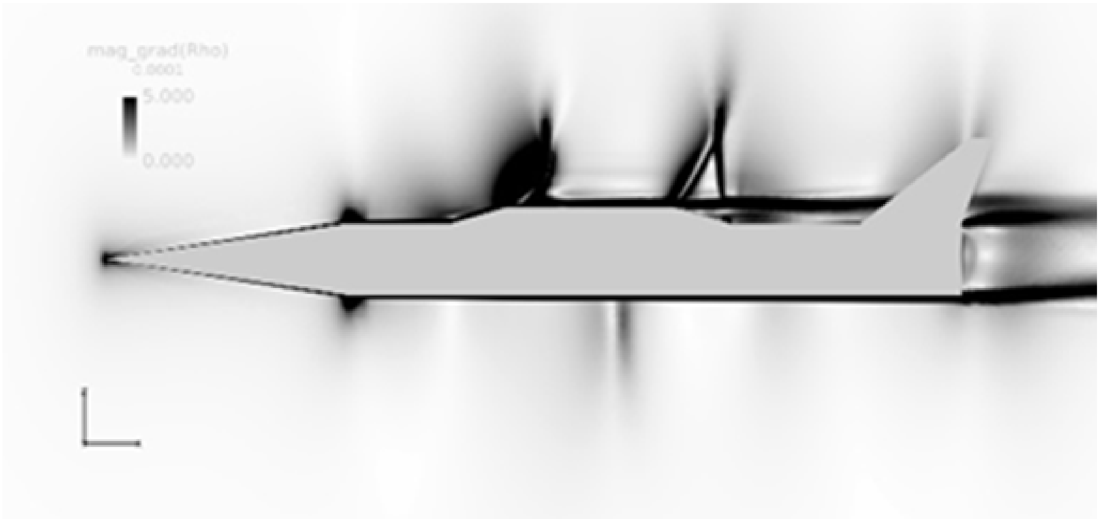

Fig.2 Numerical Schlieren around the splaceplane for the flight condition of Mach 0.9

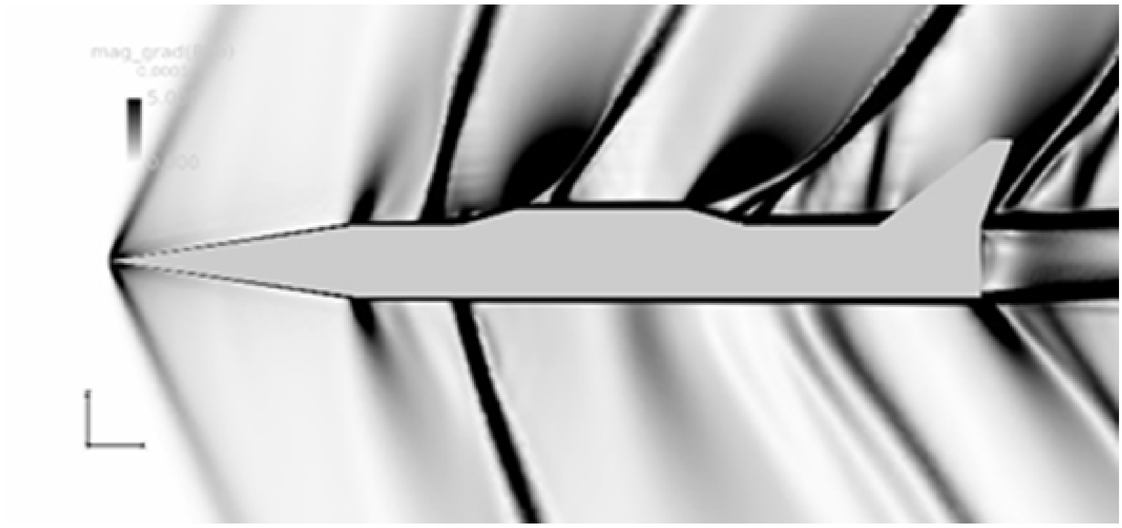

Fig.3 Numerical Schlieren around the splaceplane for the flight condition of Mach 1.1

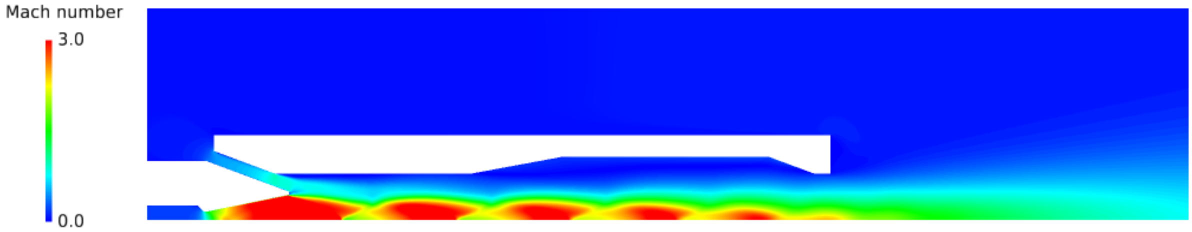

Fig.4 Mach number distribution around the ejector (The chamber pressure was 3.0MPa)

Publications

- Peer-reviewed papers

1) Susumu Hasegawa, Takeshi Kanda: "Preliminary Numerical Simulation of Flow around Spaceplane for Airframe Engine Integration", Transactions of JSASS, Aerospace Technology Japan.

- Non peer-reviewed papers

1) Kanenori Kato, Kouichi Takasaki, Kouichiro Tani, Susumu Hasegawa, Kazuhide Mizobata, and Takeshi Kanda, "Coupled Aerodynamic Characteristics of Airframe and Engine of Space Plane", 31st ISTS, 2017-a-41, Matsuyama, Ehime, Japan. Jun. 2017.
2) Susumu Hasegawa, Kanda Takeshi : Numerical analysis of the flowfield around the spaceplane tested in the transonic wind tunnel, JSASS Northern Branch 2018 Annual Meeting, Sendai, May. 2018.

- Presentations

1) Susumu Hasegawa, Takeshi Kanda: "Preliminary Numerical Simulation of Flow around Spaceplane for Airframe Engine Integration ", 31st ISTS, 2017-a-40, Matsuyama, Ehime, Japan. Jun. 2017.
2) Kanenori Kato, , Kouichi Takasaki, Kouichiro Tani, Susumu Hasegawa, Kazuhide Mizobata, and Takeshi Kanda, "Coupled Aerodynamic Characteristics of Airframe and Engine of Space Plane", 31st ISTS, 2017-a-41, Matsuyama, Ehime, Japan. Jun. 2017.
3) Susumu Hasegawa, Kanda Takeshi : Numerical analysis of the flowfield around the spaceplane tested in the transonic wind tunnel, JSASS Northern Branch 2018 Annual Meeting, Sendai, May. 2018.

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	32 - 256
Elapsed Time per Case	3.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.04

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	279,219.58	0.04
SORA-PP	105.87	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	004.45	0.00
/data	4,231.77	0.08
/ltmp	651.04	0.05

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.57	0.02

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Research for Future Transportation System (Research for Scramjet Engine Flow Path)

Report Number：R17EG3104
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4437/

Responsible Representative

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Members

Shigeru Sato, Toshihiko Munakata, Masaaki Fukui, Masaharu Takahashi

Abstract

The purpose is to investigate the influence of the internal flow path on the engine performance by help of CFD in the viewpoint of aerodynamics about a scramjet engine which is a main mode of combined cycle propulsion engine as a reusable space propulsion engine, and to contribute to designing a combined cycle propulsion engine.

In other words it is to compare the engine results with CFD in order to extract effective factors on improvement of the engine performance from a lot of experimental results of engine tests stored in Kakuda Space Center, and to make CFD simulation about a trial engine configuration which is proposed for engine performance improvement.

Reasons for using of JSS2

In Kakuda Space Center, scramjet engine is being investigated as a main mode of combined cycle propulsion engine, and a lot of engine performance tests have been made by using Ramjet Engine Test Facility (RJTF). It has been found in the tests that the difference of engine inner configuration produces large difference of thrust performance in the flight condition of Mach 6. CFD simulations are being carried out based on the plenty of engine test data stored in Kakuda Space Center about how the difference of engine inner configuration of main elements of the engine, inlet, isolator, strut and others influent on the engine performance, and CFD simulations on trial engine configuration not yet tested are also carried out.

Aerodynamic effects of engine inner configuration are investigated by using CFD, compared with the engine tests, and systematized to prepare basis for decision for designing of combined cycle engine.

Achievements of the Year

In order to compare to the result of engine configuration already tested in RJTF (Ramjet Engine Test Facility) located in Kakuda Space Center, a virtual engine test is being carried out about an improved engine configuration. The configuration has a boat-tail strut of which the tail is shortened and sharpened in order to improve the engine thrust performance, though it has the same basic dimension to the tested engine. Figure 1 shows the tested engine outline and the both configurations. The difference of engine inner quantity is compared between the both engine configurations.

A commercial code ANSYS Fluent is applied to this calculation, and structured grid system is used. The minimum grid size is set by 0.1mm near the cowl leading edge. The calculation is done in the half of the engine model assuming mirror condition in the engine symmetric center plane. The number of grids at the maximum is 5.03×10^6. The limiter is the second order accuracy, space integral is AUSM+, time integral is explicit method, and turbulence model is k-ω model.

For the combustion calculation, a model used here is the model of Fluent including Hydrogen-Oxygen reaction equation based on the Peterson and Hanson. [*)] This time Finite Rate Chemistry Model is employed for the combustion calculation, and the reaction consists of 9 species and 20 elementary reactions.

Engine air flow condition for calculation is set Mach 5.3 at engine entrance, and total temperature is set at 1500K. RJTF nozzle exit boundary layer (57.9mm thickness / 99.9% of main stream velocity) is also set in the flows into the engine, which corresponds to the boundary layer on the air frame bottom surface.

The calculation is performed mainly on JAXA's present Supercomputer System the 2nd Generation,JSS2. It is used remotely from Kakuda research center.

Figure 3 gives the cowl shock wave in air flow. Fig.3a shows the 5/5-Height strut configuration, and Fig.3b shows the Boat-tail strut configuration. In the both configurations it is found that the shock wave caused at the cowl leading edge clearly expand and reach the top wall. In the comparison between the both, the shock wave image in the Boat-tail configuration is much clear whose tail part is shortened and narrowed.

Figure 4 gives the cowl shock wave in combustion oppositely to the above. Fig.4a shows the 5/5-Height strut configuration, and Fig.4b shows the Boat-tail strut configuration. In the both configurations the oblique shock waves caused at the leading edges are seen, and it is found that the shock wave angles increase. Additionally the oblique shocks do not reach the top wall clearly to become smeared on the way. It seems that the shock wave limit cannot be exactly defined.

It is natural that the pressure and the temperature increase if we have transition to the combustion, so that sound of speed increases and Mach number decreases. Therefore the angle of oblique shock wave increase. In addition to that, the present combustion calculation indicated that the shock wave reach points are smeared. The flow field changes very much in the area where the shock waves are smeared. It is needed to research the changed flow field minutely and to fine origins of thrust product. Finding the origins will make it possible to build methods to create the engine performance.

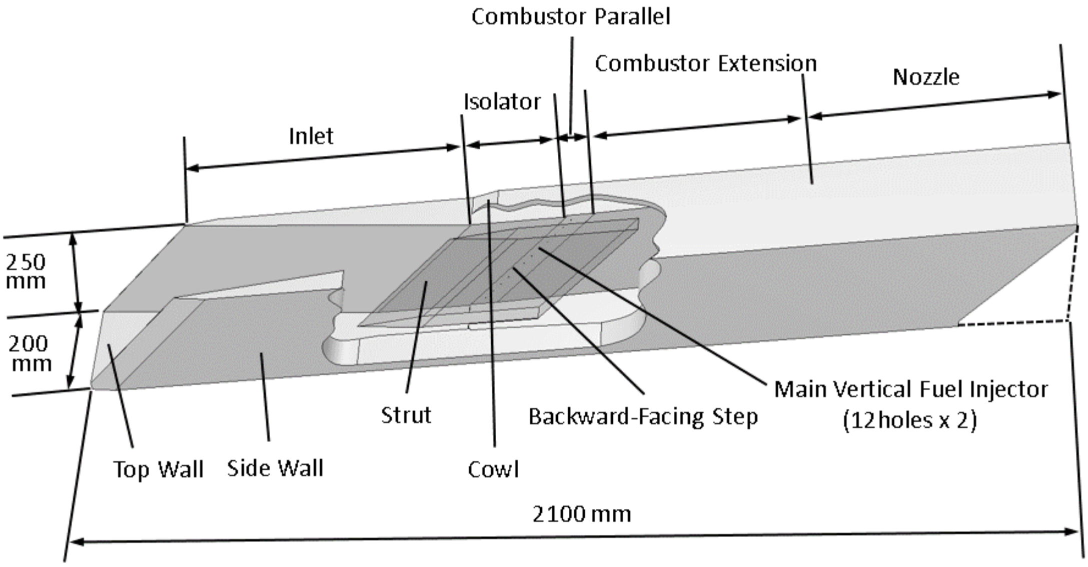

Fig.1 Outline of a scramjet engine tested

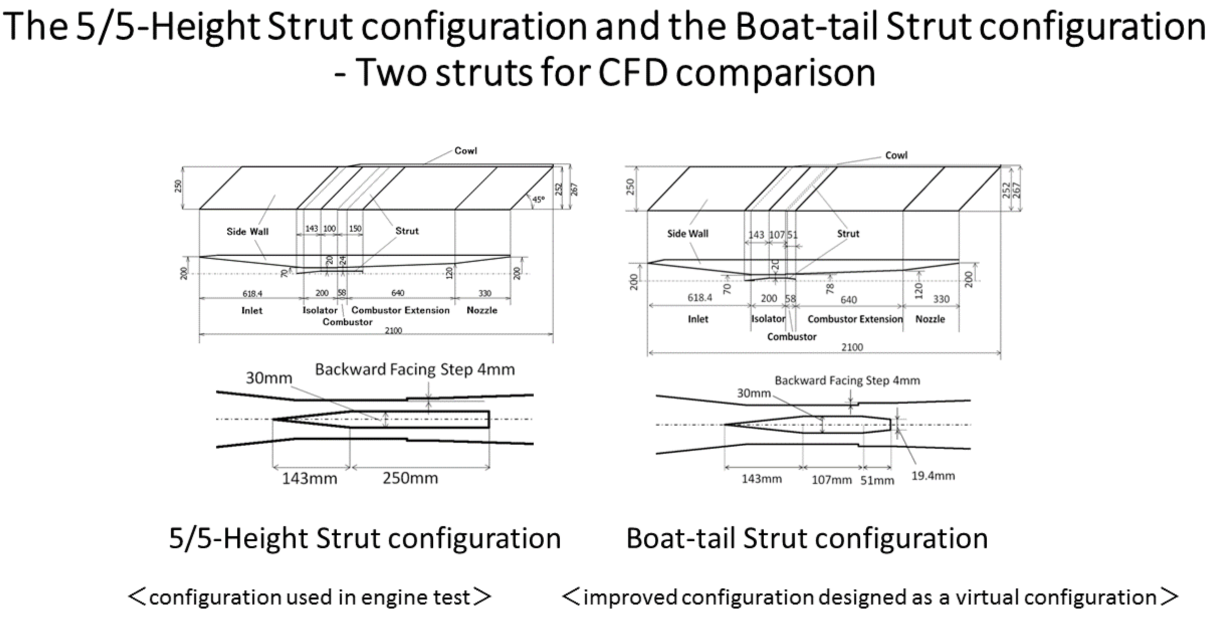

Fig.2 The 5/5-Height Strut configuration and the Boat-tail Strut configuration

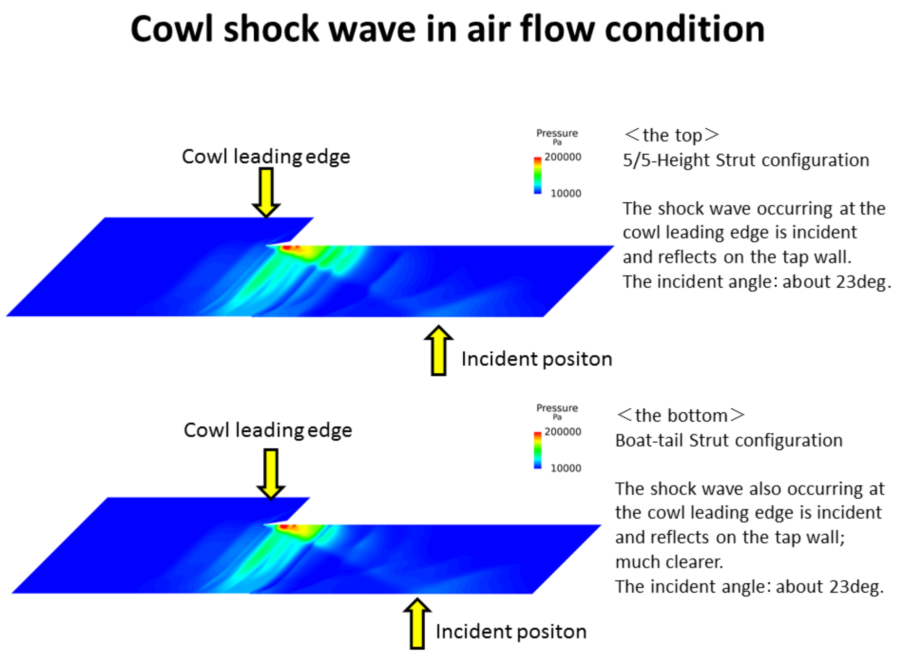

Fig.3 Cowl shock wave in air flow

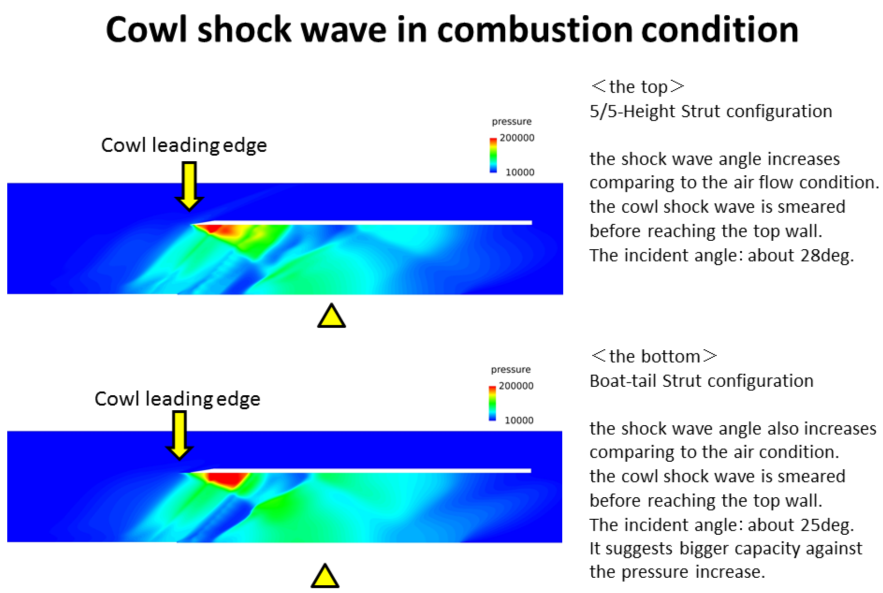

Fig.4 Cowl shock wave in combustion

Publications

- Presentations

1) Shigeru Sato, Masaaki Fukui, Takahiro Watanabe, Masaharu Takahashiand Toshihiko Munakata,Trial for Improvement in Scramjet Engine Performance, AIAA-2018-0889, Kissimmee, 2018.

Usage of JSS2

Computational Information

Parallelization Methods	It depends on FLUENT
Thread Parallelization Methods	It depends on FLUENT
Number of Processes	2 - 32
Elapsed Time per Case	720.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.03

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.00	0.00
SORA-PP	43,179.91	0.54
SORA-LM	48.40	0.02
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	039.07	0.03
/data	397.05	0.01
/ltmp	2,115.89	0.16

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.58	0.02

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Future Projection by orbital debris evolutionary model

Report Number：R17EG3105
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4438/

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Members

Takayuki Hirai, Satomi Kawamoto, Masumi Higashide, Yasuhiro Kitagawa, Shuji Abe, Toshiya Hanada

Abstract

Increase of space debris is a problem for reliability of future space activity. JAXA has researched for space debris removal technology. JAXA and Kyushu university developed an orbital debris evolutionary model named NEODEEM to predict numbers of future space objects. Analysis results from NEODEEM lead which object should be removed.

http://www.kenkai.jaxa.jp/eng/research/debris/debris.html

Reasons for using of JSS2

NEODEEM predicts numbers of long-term future space objects by using Monte-Carlo method. We expect reduction of computation time.

Achievements of the Year

In this year, preliminary tests for the NEODEEM computation were performed with SORA_PP. An example of the computation results is shown in Fig. 1. NEODEEM was updated for parallel computing with OpenMPI. However, the updated model was not employed for this research because repeatability of computation results are not assured. Total analysis time was reduced by assigning Monte-Calro run numbers to multiple cores. We will start NEODEEM computation for future orbital environment analysis from next year.

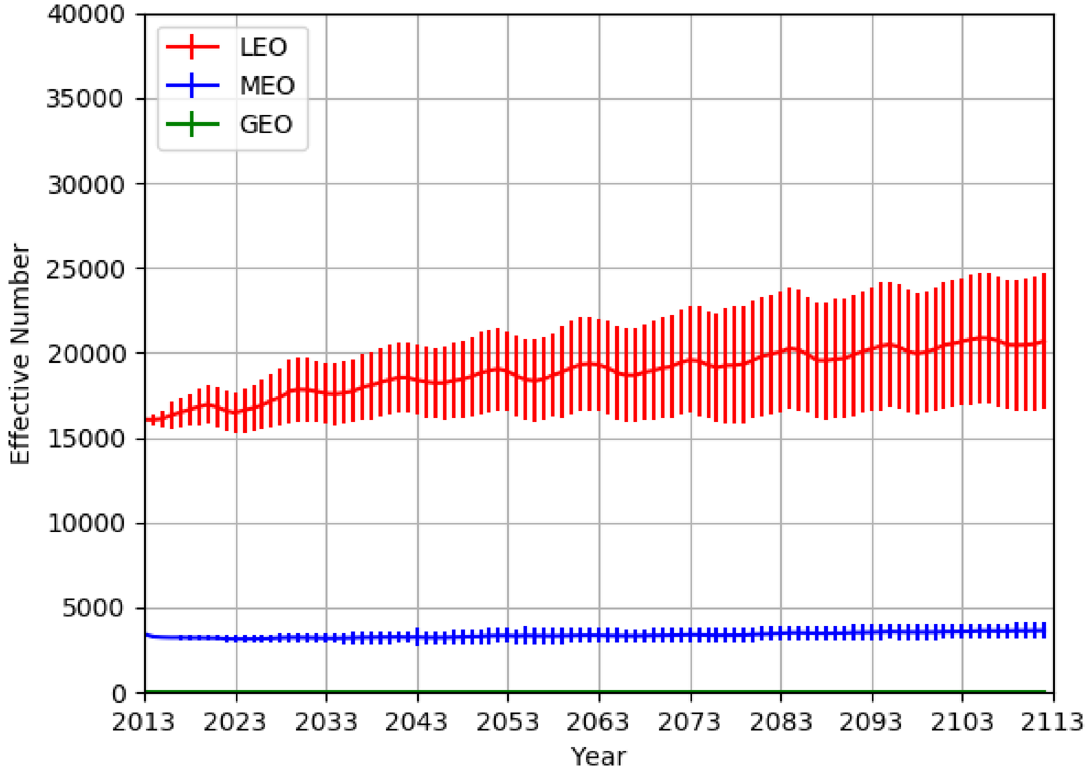

Fig.1 Prediction example of space object number for 100 years

Publications

N/A

Usage of JSS2

- **Computational Information**

Parallelization Methods	Assigning Monte-Calro run numbers to multiple cores
Thread Parallelization Methods	N/A
Number of Processes	2 - 10
Elapsed Time per Case	60.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 0.01

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.00	0.00
SORA-PP	7,260.68	0.09
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	023.84	0.02
/data	238.42	0.00
/ltmp	4,882.81	0.37

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Launch Cost Reduction by Reusing Launch Vehicles

Report Number：R17EG3106
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4439/

Responsible Representative

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Members

Yoshiki Takama, Yoshihisa Aoki

Abstract

This research conducts the study of key technologies applied to future reusable launch vehicles including long-life rocket engines, lightweight structures, landing guidance, and small experimental vehicles to validate the technologies.

Reasons for using of JSS2

JSS2 is nessesary for the estimation of aerodynamic performance　for a small experimental vehicle.

Achievements of the Year

CFD in the rocket launch phase was conducted as follows:

1) the inside of the rocket nozzle was not calculated.
2) the static pressure, static temperature, and velocity at the nozzle exit were given as the boundary condition.

The calculation started from the first-order accuracy with the pressure at the nozzle exit one third of the nominal value. The calculation was gradually accelerated, and successfully converged at the second-order accuracy with the pressure of the nozzle exit the nominal value.

The axial velocity distribution in the vicinity of the nozzle exit is shown in (Fig. 1). Mach number is 0.1. The angle of attack is 0 deg.

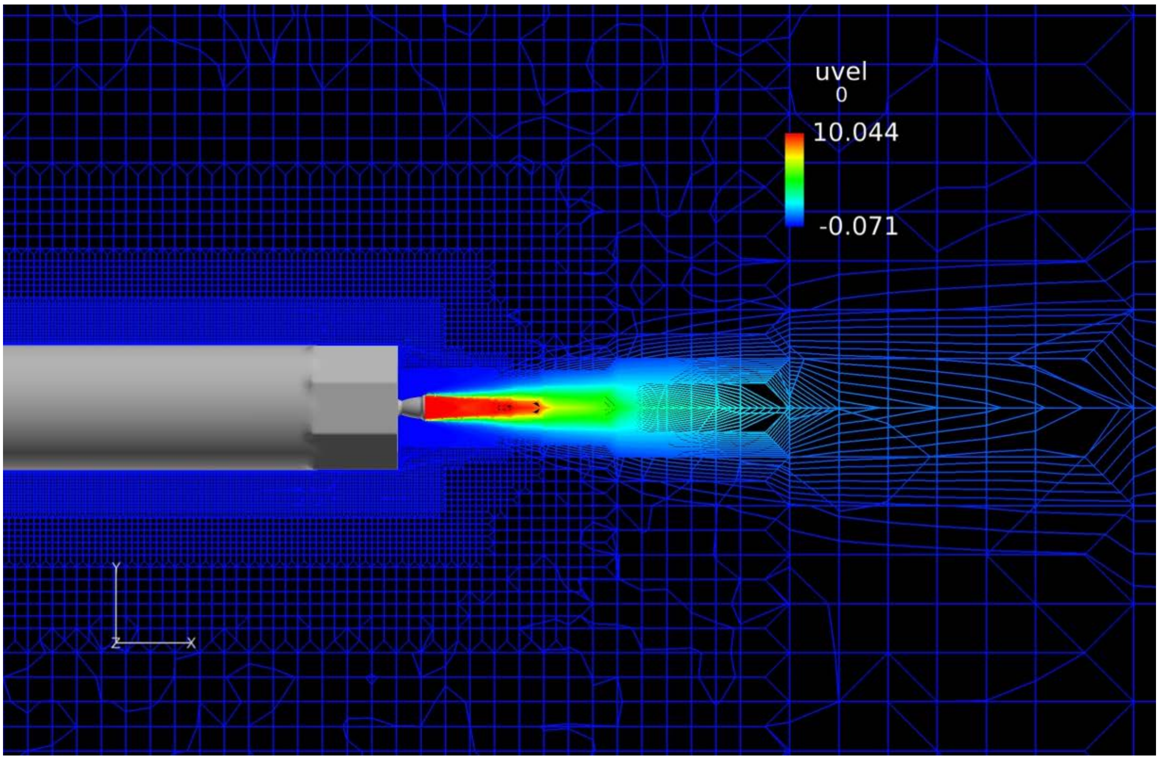

Fig.1 Axial velocity distribution at the lift-off (M=0.1, AOA=0deg)

Publications

N/A

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	96
Elapsed Time per Case	300.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.23

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	1,895,520.26	0.25
SORA-PP	113.88	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	037.71	0.03
/data	889.02	0.02
/ltmp	634.77	0.05

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Research for Innovation of Rocket Propulsion Engine

Report Number：R17EG3204
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4440/

Responsible Representative

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Members

Susumu Hasegawa, Toshiya Kimura, Kosei Goto, Atsushi Osada, Masaaki Fukui,
Toshihiko Munakata, Masaharu Takahashi, Kenji

Abstract

Reusable rockets are attracting attention as spacecraft, but their engines are required to have high performance at a wide range of environmental pressures. In this research, the performance of the aerospike nozzles was investigated by using large-scale numerical fluid dynamics.

Reasons for using of JSS2

The number of experiments is limited, and the data obtained are limited. Therefore, after verification of numerical results, data which are difficult to obtain by wind tunnel test can be obtained. By using higher-performance computer, more reliable data can be obtained and the development of nozzle technology are accelerated.

Achievements of the Year

We began to do research on the aerospike nozzles by using the numerical fluid dynamics. Since it was necessary to verify the numerical results with the experimental data obtained, numerical analysis was conducted the liner aerospike nozzles of 40% and 60% in addition to the 80% linear aerospike nozzle. Computations were performed and numerical results were obtained when the nozzle pressure ratio (NPR) were 10, 40, 100. Details of the flow analysis are under consideration.

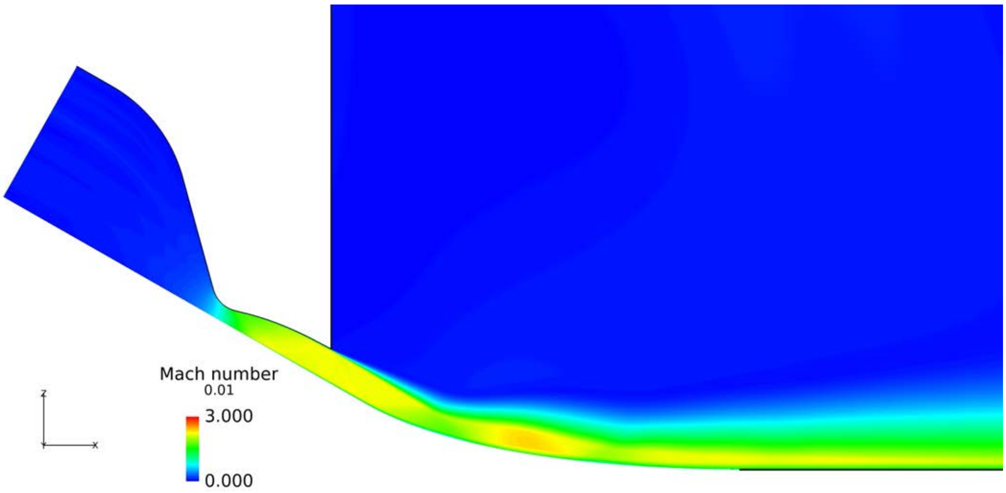

Fig.1 Mach number distribution around the 80% linear aerospike nozzle, NPR=10

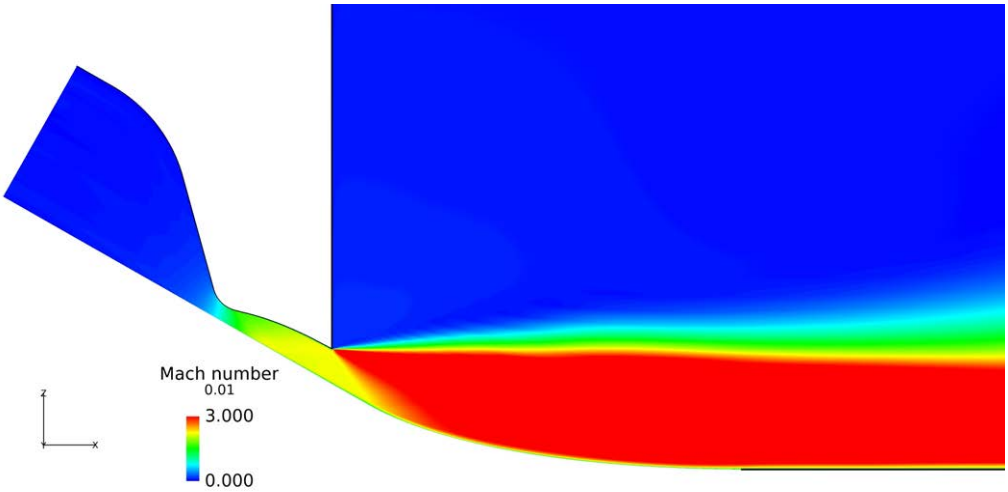

Fig.2 Mach number distribution around the 80% linear aerospike nozzle, NPR=100

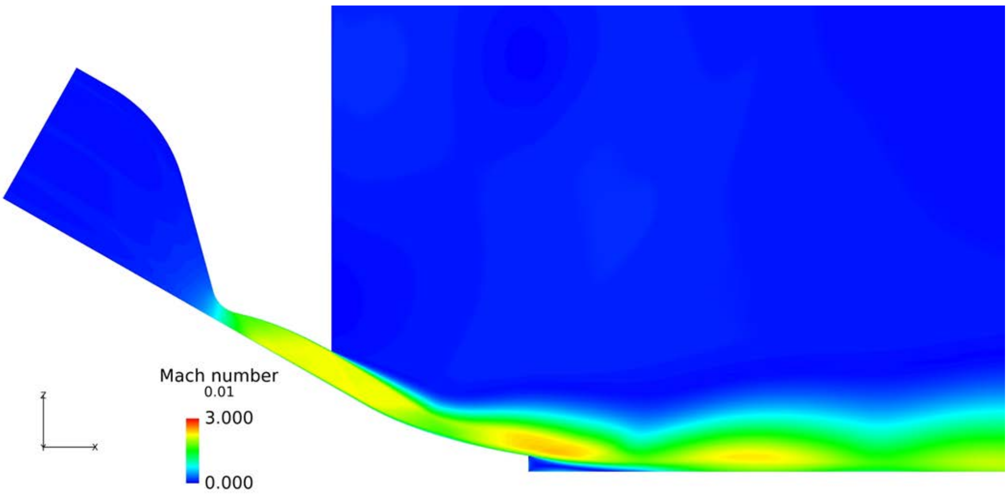

Fig.3 Mach number distribution around the 60% linear aerospike nozzle, NPR=10

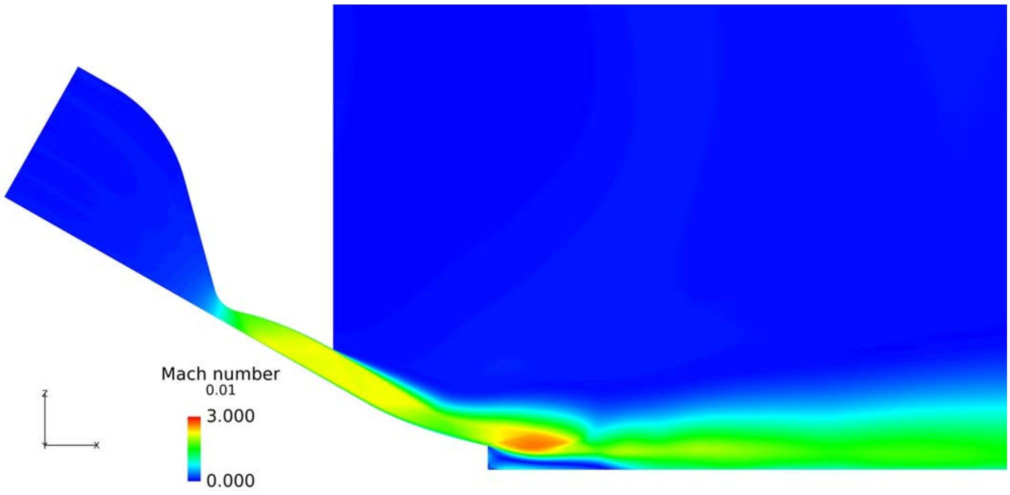

Fig.4 Mach number distribution around the 40% linear aerospike nozzle, NPR=10

Publications

N/A

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	32 - 256
Elapsed Time per Case	3.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 0.01

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	6,423.68	0.00
SORA-PP	9.49	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	100.89	0.07
/data	5,034.13	0.09
/ltmp	11,067.71	0.83

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	1.15	0.05

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Study on Future Space Transportation System using Air-breathing Engines

Report Number：R17EG3205
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4441/

Responsible Representative

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Members

Masahiro Takahashi, Masatoshi Kodera, Masaaki Fukui, Toshihiko Munakata,
Masaharu Takahashi, Sadatake Tomioka, Akihiro Shimuta, Takuto Miyaura

Abstract

Recently, reusable rockets have been being studied to reduce the cost of space transportation systems significantly. However, in order to extend the structural lifetime, it is necessary to operate them with relatively low engine power, leading to a decrease in launch capability. Therefore, air-breathing engines such as scramjets and rocket/scram combined cycle engines are promising to compensate the drawback. By using air in the atmosphere as an oxidizer, the engine becomes highly efficient, and can be expected to maintain and improve the launch capability even if reused. In this project, we will research and develop key technology for practical application of the engine.

Reasons for using of JSS2

The following points are raised as problems of engine design by ground experiments. 1) There are limits to reproducing various airflow conditions from takeoff to hypervelocity ranges. 2) Measured values are limited and complicated three-dimensional flow structures inside the engine can not be well identified. 3) Since the time and cost are limited, it is not easy to change the engine flow path configuration. Therefore, it is indispensable to utilize 3D CFD as a design tool, and a supercomputer is required for performing numerous CFD works efficiently.

Achievements of the Year

Subject 1: We continued to conduct a collaborative research with Tohoku University on construction of simple reaction mechanisms for high molecular hydrocarbon pyrolysis fuel from last year. In this fiscal year, we applied simple reaction mechanisms for methane / ethylene fuel mixture, which mimics a cracked jet fuel, to combustion CFD calculations including supersonic combustor flows. The results were compared to those obtained from a detailed reaction mechanism to validate the prediction accuracy and robustness (Fig. 1).

Subject 2: The validation of the combustion CFD using a LS-FLOW solver, which JAXA-JEDI has been developing, was conducted by comparing with the experimental results of the scramjet combustor model with gaseous ethelyne as a fuel. Some issures with the current RANS CFD have been clarified (Fig. 2, 3). The CFD was also applied to the simulation for undergoing combustion experiments with other scramjet combustor models to help understanding of the experimental results and those to evaluate combustor performance with modified flow-path design in advance.

Subject 3: RANS CFD on iso-thermal n-octane fuel flow within a tube to evaluate cooling capacity including thermal decomposition effects, was carried out with turbulence model and reduced chemistry and the results were compared to experimental results (Fig. 4). The deviation implied deficiencies in the reduced chemistry and the coking problem in the experiment.

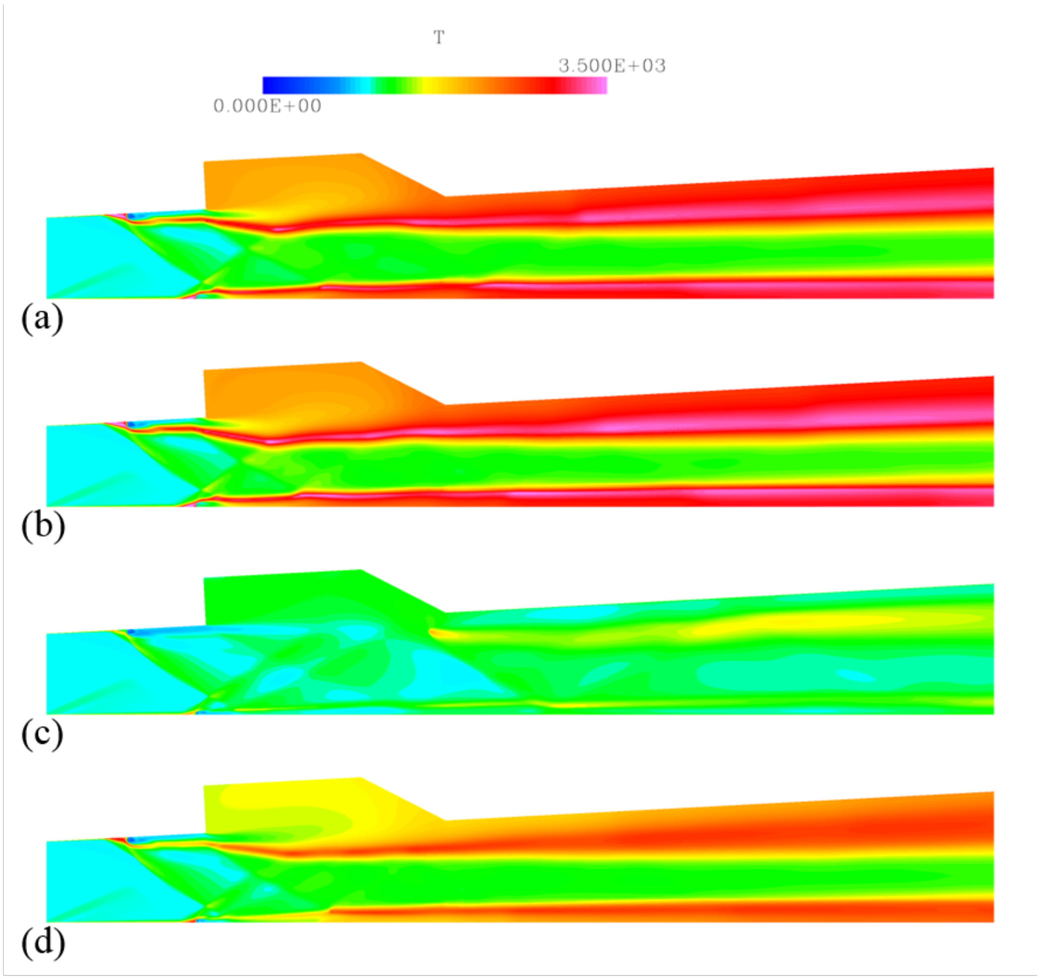

Fig.1 Comparison of CFD results (temperature distributions in supersonic combustor) obtained from simple and detailed reaction mechanisms ((a)-(c) simple mechanisms, (d) detailed mechanism)

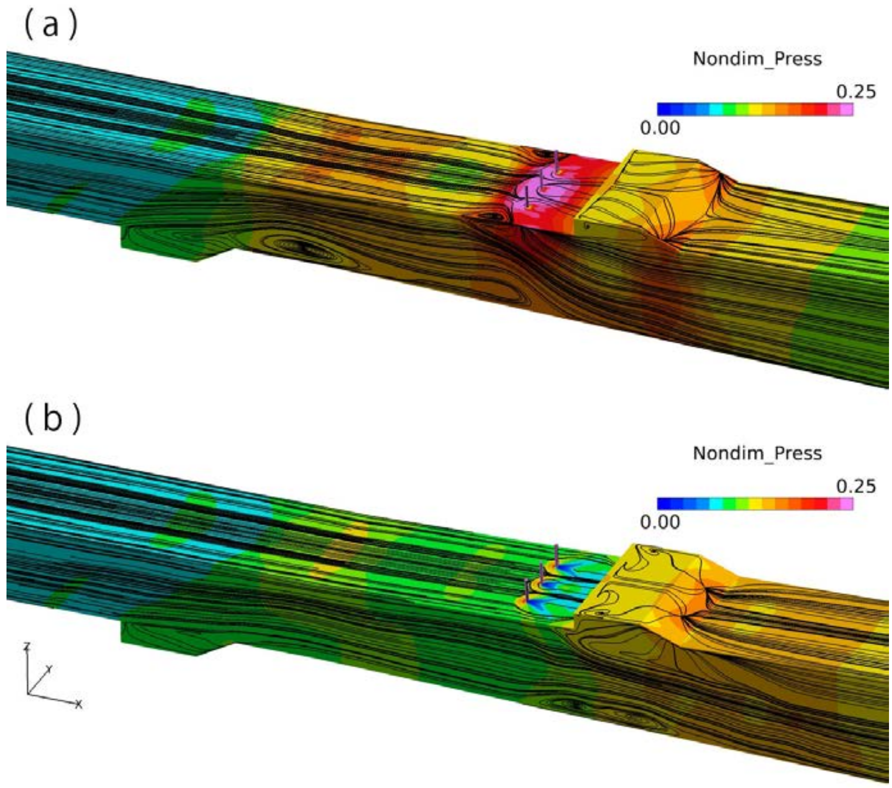

Fig.2 Comparison of the normalized wall pressure distributions and the surface streamlines on the ethelene-fueled scramjet combustor model obtained by RANS CFD with different turbulent Schmidt numbers (a) Sct = 0.3 (b) Sct = 0.89

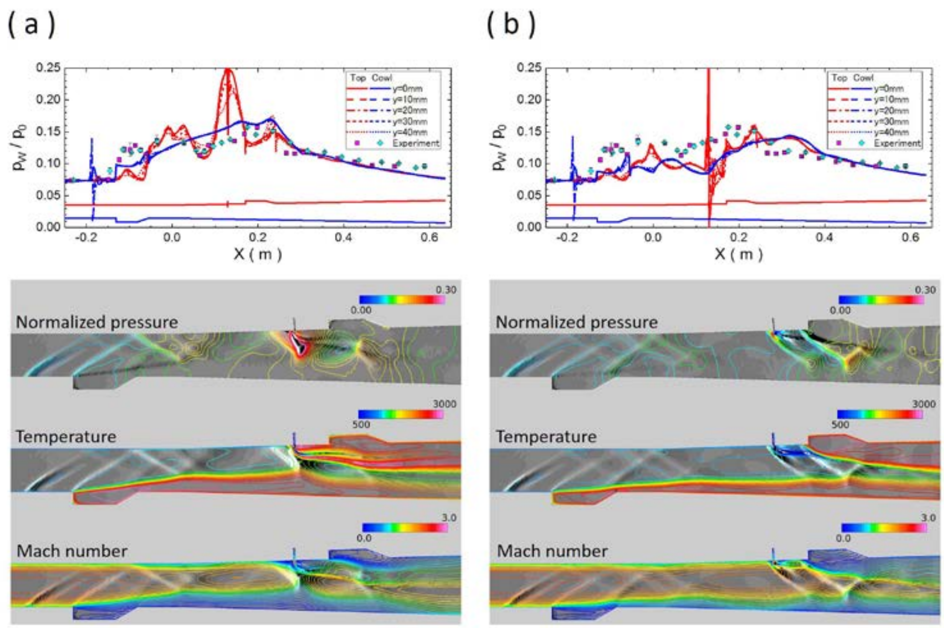

Fig.3 Comparison of the normalized wall pressure distributions and the cross-section profiles of the normalized pressure, temperature and Mach number obtained by RANS CFD with different turbulent Schmidt numbers (a) Sct = 0.3 (b) Sct = 0.89

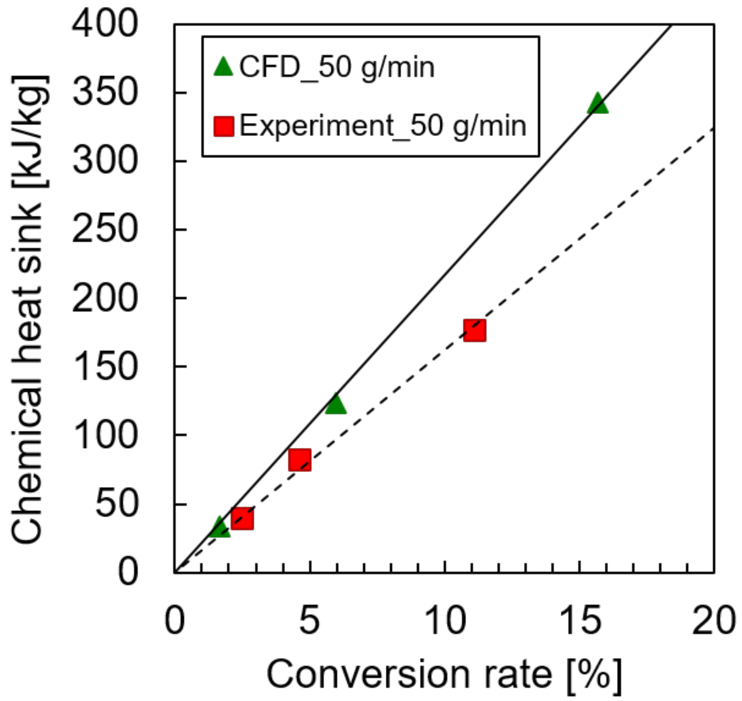

Fig.4 Comparison between CFD and experiments on endothermic heat capacity and decomposition rate

Publications

- Non peer-reviewed papers

1) Kodera, M., Tomioka, S., Sasaki, Y., Nakamura, H., and Maruta, K., "Application of Simple Reaction Mechanisms for CH_4/C_2H_4 Fuel Mixture to Supersonic Combustor Flow Computations," Proceedings of the 2018 Annual Meeting, Northern Branch of the Japan Society for Aeronautical and Space Sciences, 2018.

2) Takahashi, M., Nojima, K., Shimizu, T., Aono, J., and Munakata, T., "Numerical Simulation of Hydrocarbon-fueled Scramjet Combustor Flows by Using LS-FLOW Solver," Proceedings of the 31st Symposium on Computational Fluid Dynamics, 2017.

3) Shimuta, A., "Research on Endothermic Heat Capacity of Liquid Hydrocarbon Fuel at Supercritical Condition," Master Thesis, Tohoku University, 2018.

- Presentations

1) Kodera, M., Tomioka, S., Sasaki, Y., Nakamura, H., and Maruta, K., "Application of Simple Reaction Mechanisms for CH_4/C_2H_4 Fuel Mixture to Supersonic Combustor Flow Computations," The 2018 Annual Meeting, Northern Branch of the Japan Society for Aeronautical and Space Sciences, 2018.

2) Takahashi, M., Nojima, K., Shimizu, T., Aono, J., and Munakata, T., "Numerical Simulation of Hydrocarbon-fueled Scramjet Combustor Flows by Using LS-FLOW Solver," The 31th Symposium on Computational Fluid Dynamics, 2017.

3) Takahashi, M., Nojima, K., Shimizu, T., Aono, J., and Munakata, T., "Characteristics of Scramjet Combustor Flows with Ethelyne Fuel," FY29 Space Transportation Symposium, 2018.

4) Miyaura, T., Shimuta, A., Daimon, Y., Tomioka, S., "Research on Endothermic Heat Capacity of Hydrocarbon Fuel at Supercritical Condition," The 2018 Annual Meeting, Northern Branch of the Japan Society for Aeronautical and Space Sciences, 2018.

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	32 - 1280
Elapsed Time per Case	72.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 1.10

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	9,220,531.74	1.22
SORA-PP	1,197.46	0.01
SORA-LM	69.74	0.04
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	260.80	0.18
/data	6,000.80	0.11
/ltmp	9,765.63	0.74

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	2.88	0.12

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Protection from Space Environment for Expanding Future Space Activities

Report Number：R17EG3210
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4442/

Responsible Representative

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Abstract

Our goal is to obtain the technology and knowledge to protect spacecraft and astronauts from harsh space environment for expanding future space activities. Long-term-stay under safer environment is especially required in the future manned-mission. We, therefore, address the radiation shielding technology in terms of materials for supporting the safe and long-period manned space activity.

Reasons for using of JSS2

We use JSS2 for PHITS (Particle and Heavy Ion Transport code System) Monte Carlo simulations to estimate shielding effects of materials against space radiations. PHITS Monte Carlo simulations take a large amount of time when the computational system is large and complex, such as the system simulated manned-spaceship structure. Such simulations enable to be run at high speed with statistical accuracy by using JSS2.

Achievements of the Year

In FY2017, we focused on the galactic cosmic rays (GCR) to be protected in the Beyond Low Earth Orbit (BLEO) where a manned exploration mission will be conducted in the future, and investigated optimal shielding design against GCR by conducting calculations for using PHITS (Particle and Heavy Ion Transport Code System) code.

GCR is high energy particles that flow constantly from outside the solar system, and consists of protons (~ 85%), He nuclei (~ 14%), electrons (~ 1%), and heavy nuclei ranging from lithium to uranium. One method of reducing the exposure dose is an installation of shielding materials on the spacecraft. In terms of the limitation of transportation weight, a material having high shielding effect per mass is required as a shielding material for manned mission. It is known that low atomic number elements have high

shielding effect per mass against GCR, and hydrogen (^{1}H) is the most effective. In this study, we investigated optimal shielding thickness of polyethylene (PE, $(CH_2)_n$) which is an existing shielding material containing a large amount of hydrogen (hydrogen weight%: 14 wt%). The optimal shielding thickness of PE is different from the shielding thickness of the spacecraft (mainly composed of Al alloy) and the dose measurement position (astronauts staying position). In order to investigate the optimal thickness of PE according to the shielding thickness of the spacecraft, dose calculations were performed with a simple spherical shell geometry consisting of two layers of Al and PE.

The calculation geometry is shown in Fig. 1. A water sphere (a virtual dosimeter imitating a human body) with 30 cm diameter was installed at the center of an Al/PE two layers spherical shell with an inner diameter of 400 cm. The Al/PE spherical shell was installed so that outside was Al shell. The thickness of Al was 0 - 50 g/cm^2, the thickness of PE was 0 - 60 g/cm^2. The interior of the spherical shell (excluding the water region) was void. The GCR spectra were calculated using the CREME 96 model and are shown in Fig. 2. The solar activity was set as solar minimum (no flare condition), and the position of the spacecraft was set as near-earth interplanetary (no trapped particles, no geomagnetic field). The dose equivalent in the water sphere, when the GCR radiation source (proton - Ni) was isotropically irradiated to the Al/PE sphere shell geometry, was calculated by Monte Carlo calculation.

The calculation results are shown in Fig. 3. Because of the installation of PE, the dose equivalent in the water sphere was reduced by 40% at the maximum (compared with the condition without shielding material). Regardless of the shielding thickness of Al, the dose equivalent was reduced by about 34 - 40% by adding PE with about 30 g/cm^{2}thickness. Even if adding PE with over 30 g/cm^2 thickness, shielding effect on dose equivalent nearly unchanged (shielding thickness - dose equivalent curve is almost plateau at the range of > 30 g/cm^2). From this result, the addition of the shielding material with 30 g/cm^2 or more thickness in the BLEO mission is useless in terms of GCR shielding. And, the addition of about 30 g/cm^2 PE can be minimized the exposure dose (the achievable minimum value by passive shielding of realistic thickness) inside the spacecraft.

The future work is to reflect these results in the shielding guidelines for actual missions. We think that the addition of extra shielding materials is not necessarily needed depending on the solar activity, the mission duration / place. In the future, we plan to obtain the quantitative data that will contribute to shielding-design optimization guidelines according to the solar activity, the mission duration, and the design of the spacecraft.

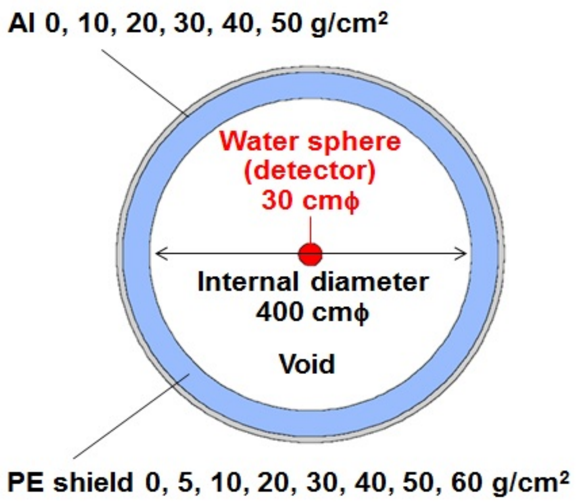

Fig.1 Geometry for calculation of effective dose on water sphere under irradiation of GCR source

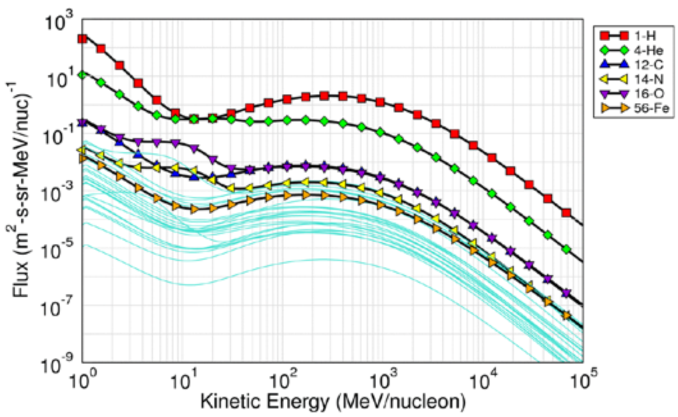

Fig.2 GCR spectra (CREME96 model; solar minimum (no flare), near-earth interplanetary, H-Ni)

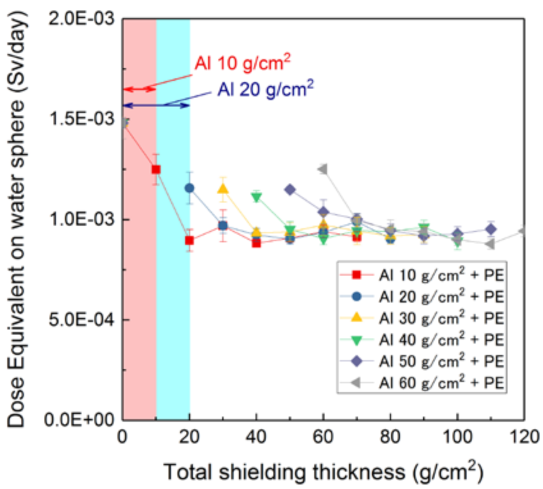

Fig.3 Dependence of dose equivalent in water sphere on shielding thickness (under irradiation of GCR)

Publications

N/A

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	5 - 24
Elapsed Time per Case	30,000.00 seconds

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.04

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.00	0.00
SORA-PP	58,110.50	0.73
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	014.31	0.01
/data	4,978.18	0.09
/ltmp	2,929.69	0.22

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Project support using numerical simulation

Report Number：R17EG3211
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4443/

Responsible Representative

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Abstract

Utilize the simulation technology of Reserch Unit III to deal with the technical problem solving in current JAXA project, and respond to the request for the project concerning issue. In addition, it realizes "added value (efficiency improvement, high reliability, cost / period reduction, ripple effect, etc.)" unique to numerical simulation technology.

http://www.kenkai.jaxa.jp/eng/research/software/software.html

Reasons for using of JSS2

In order to respond timely to project requirements, it is necessary to simulate complex geometries of actual spacecraft and to analyze a large number of conditions in a short period.

Achievements of the Year

With regard to H3, SLIM, HTV-X projects, evaluation of design and risks as well as studies for improvement were carried out by making full use of the simulation technology of Reserch Unit III and JSS2.

Publications

- URLs for the Research Results on the Web

1) http://www.kenkai.jaxa.jp/eng/research/software/software.html

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	16 - 32
Elapsed Time per Case	30.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 1.17

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	5,738,372.24	0.75
SORA-PP	141,174.57	1.77
SORA-LM	0.00	0.00
SORA-TPP	1,035,782.58	30.77

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	6,790.95	4.70
/data	111,422.26	2.06
/ltmp	21,380.23	1.61

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	111.76	4.81

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Internal flow, combustion, and rotating machinery

Report Number：R17EG3212
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4444/

Responsible Representative

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Abstract

To capture the unsteady phenomena in the liquid rocket engine, combustion large eddy simulations (LES) are carried out, and this evaluation tool is validated by comparing with a sub-scale test. For thrusters, we build analysis code that can simulate spray combustion mode, first aim at prediction of steady state performance.

http://www.kenkai.jaxa.jp/eng/research/software/software.html

Reasons for using of JSS2

Since the flow and combustion in rocket chambers are in a turbulent state and have nonstationary characteristics, LES analysis is essential. Even in this verification target, analysis calculation of about several million steps is required for grid of tens of millions of cells, so it is impossible to achieve the target without using supercomputer.

Achievements of the Year

1. In order to develop and validate numerical analysis code for spray combustion, LES of an ethanol

spray combustion burner have been conducted. The diameter of target burner is 10.5 mm, and the number of cells of the 3D numerical model is about 15 million. The space has been discretized by finite volume method. Detailed chemical reaction mechanism constructed with 50 species and 258 reactions has been solved to simulate combustion of ethanol, then ERENA method has been use for temporal integration of reactions. Figure 1 and 2 show temperature distribution and axial velocity distribution respectively. As shown in the figures, it is confirmed that the numerical code can reproduce spray combustion qualitatively.

2. Accurate prediction of wall heat flux in combustion chambers using numerical simulations is required for engine designs to prevent the serious damage on the chamber wall due to high heat load. Towards the wall heat flux prediction using LES, wall-modeled LES (WMLES) of turbulent channel flows with heat transfer was performed (Fig. 3). WMLES well predicted velocity and temperature fields in a wide range of Reynolds numbers up to 100,000 in spite of using a coarser grid resolution compared with conventional LES.

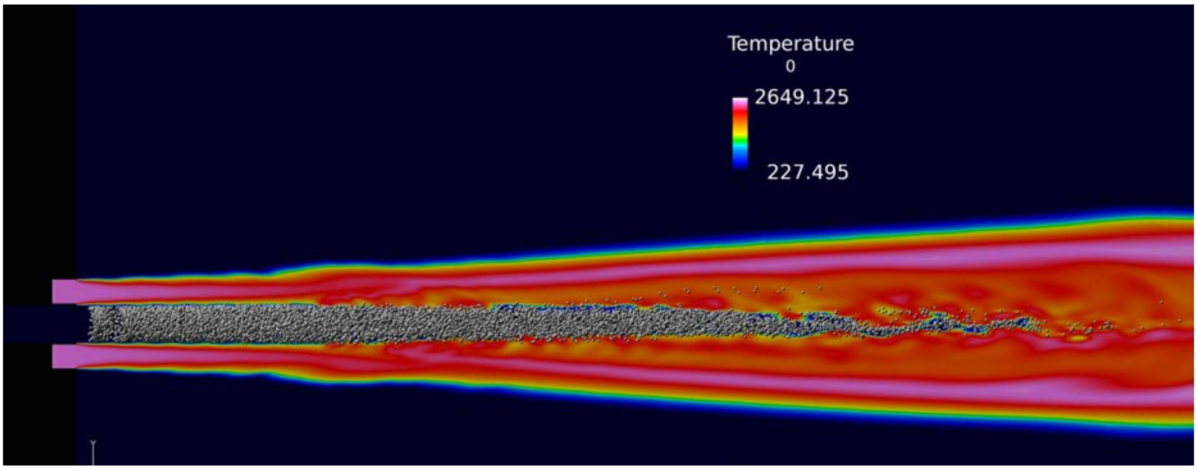

Fig.1 LES of spray combution, temperature distribution

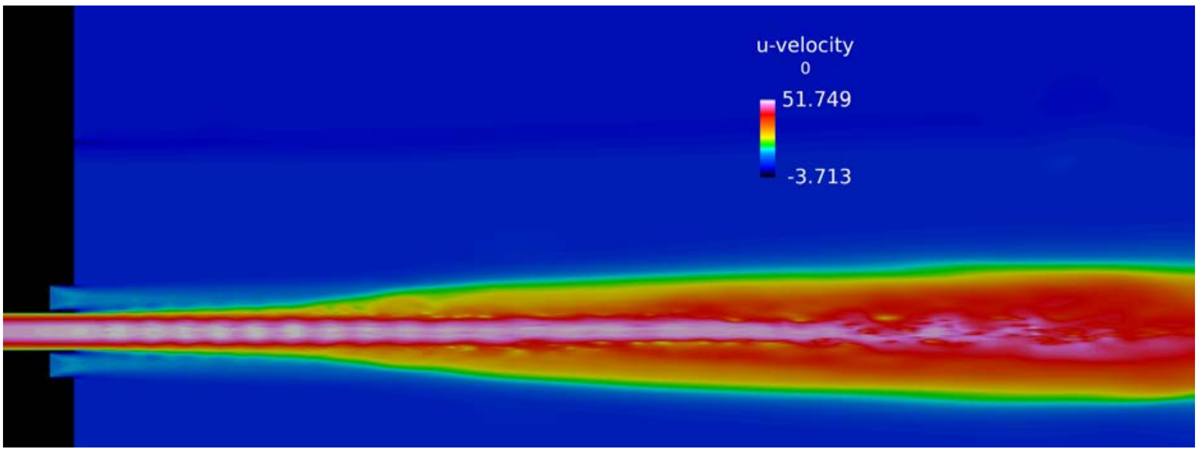

Fig.2 LES of spray combution, axial velocity distribution

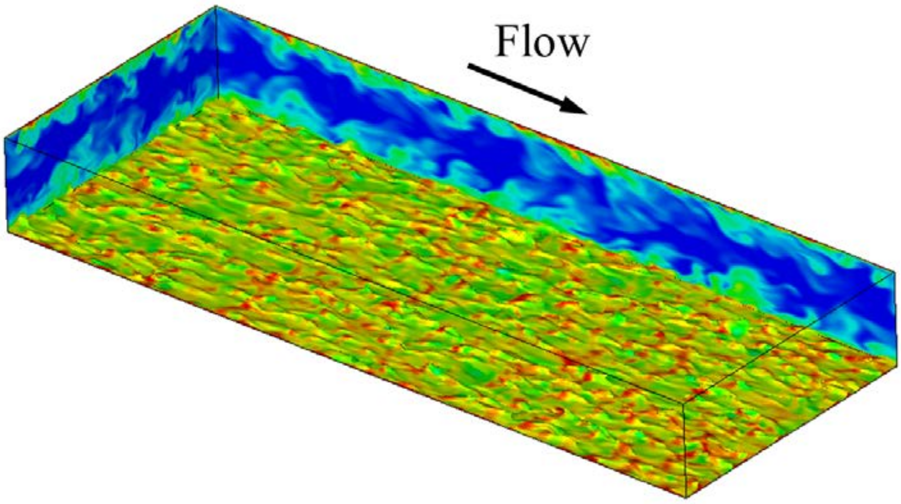

Fig.3 WMLES of turbulent channel flow with heat transfer. Iso-surface of velocity colored by temperature is shown.

Publications

- Presentations

1) Motoe, M., "Combustion Simulation for Coaxial Spray Burner Using Detailed Chemical Reaction Mechanism", The Japan Society of Fluid Mechanics Annual Meeting 2017 (in Japanese).
2) Muto, D., et al., "Preliminary Study on Wall-modeled Large Eddy Simulation of Turbulent Heat Transfer for Liquid Rocket Engines", 7th European Conference for Aeronautics and Space Sciences, 649, Jul., 2017.
3) Negishi, H., et al., "Numerical Anaylsis of Unshrouded Impeller Flowfield in the LE-X Liquid Hydrogen Pump", 53rd AIAA/SAE/ASEE Joint Propulsion Conference, AIAA paper 2017-4930, 2017.
4) Amakawa, H., et al., "Preliminary Study of Numerical Simulation of Macro-Scale Grease Flow Using Moving Particle Simulation -Validation between Experiment and CFD for Grease Dam Break -", Tribology Comference 2018 Autumn, 2017 (in Japanese).
5) Negishi, H., et al., "Future Perspectives for Grease Flow Simulation in Ball Bearings to enhance Spacecraft Lifetime", 31st CFD Symposium, E10-3, 2017 (in Japanese).
6) Daimon, Y., et al., "Heat Flux Estimation on a Chamber Wall of GH2/GOX and GCH4/GOX Single Element Rocket Combustors", 31st International Symposium on Space Technology and Science, 2017.
7) Daimon, Y., et al., "Numerical Investigation on Effects of Recess Variation upon a GCH4/GOX Shear Coaxial Combustion Chamber", 31st International Symposium on Space Technology and Science, 2017.

8) Daimon, Y., et al., "Film Cooling Performance Analysis of a Full-scale Liquid Rocket Engine Combustion Chamber based on a Coupled Combustion and Heat Transfer Simulation", AIAA Paper, 2017-4919, 2017.
9) Daimon, Y., et al., "Combustion Modeling Study for a GOX-GCH4 Multi-element Combustion Chamber", Proceedings of the 2017 Summer Program, SFB TRR40, 2017.
10) Shimizu, T., et al., "Evaluation of the Characteristics of Liquid Hydrogen Mixer using LES", 31st CFD Symposium, E10-2, 2017 (in Japanese).

- Invited lecture

1) Negishi, H., "Numerical Modeling of Liquid Rocket Turbopumps", The National DFG SFB TRR40 project, Graduate Program on Launchers and Propulsion, University of Stuttgart, 2018.
2) Daimon, Y., "Numerical and Experimental Study on Small Thruster", The National DFG SFB TRR40 project, Graduate Program on Launchers and Propulsion, University of Stuttgart, 2018.
3) Daimon, Y., "GCH4/GO2 Rocket Combustor Simulation -Methane vs Hydrogen, Single vs Multi Element-", DLR Institute of Combustion Technology Seminar, 2018.

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	1280 - 2560
Elapsed Time per Case	500.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 6.10

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	49,901,475.03	6.57
SORA-PP	88,645.47	1.11
SORA-LM	709.56	0.37
SORA-TPP	85,997.68	9.60

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	6,431.26	4.46
/data	107,461.81	1.99
/ltmp	18,249.37	1.38

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	122.73	5.28

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Research and Development of Predicting Launch Vehicle Acoustics

Report Number：R17EG3213
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4445/

Responsible Representative

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Abstract

Prediction and reduction of the acoustic environment level caused by aeroacoustics of exhaust jet at lift-off and transonic buffet are required for the development of the next flagship launch vehicle (H3). Therefore, improve the acoustic analysis tool at the lift-off constructed up to the previous phase, and expand the range of application, predict the acoustic environment throughout the flight of the launcher / spacecraft, contribute to the design of low noise launch pad and silent launch vehicle.

Reasons for using of JSS2

It is necessary to carry out LES analysis on the scale of billions of points, and to achieve the targeted frequency resolution it is essential to havesupercomputer.

Achievements of the Year

Through the subscale model test conducted for the acoustic design of H3 launch vehicle, it was observed that acoustic level was reduced by shielding the air intake attached to flame duct. Numerical study was conducted to investigate the flowfield of air intake and its effect on the acoustic environment around the launch vehicle.　In the subscale model test, clustered liquid rocket engines (LE-9s) located at the core of the vehicle were modeled as a single engine. Numerical study was also utilized to evaluate the difference of acoustic environment between subscale and full-scale acoustic environment. Figure 1 shows the results of the subscale test configuration of the H3-30 having three liquid rockets (LE - 9) without solid rocket boosters.

In the development of H3 launch vehicle, it is considered to cluster the first-stage main engines. A small cold flow test has been carried out so far and observation of Mach wave reduction of free jet by clustering is observed, but the clustering effect under the condition that interacts with the launch pad is unconfirmed. In the subscale test conducted this fiscal year, acoustic measurements simulating a new launch pad geometry were performed, but due to constraints of the feed line system, cluster nozzles were modeled as a single nozzle of the same exhaust power, and the clustering effect was not evaluated. The purpose of this numerical analysis is to clarify the clustering effect on the interaction between the exhaust jet and the launch table (Fig. 2), and the sound pressure level in the vicinity of the launcher for each clustered and single nozzle configuration is compared using the lift amount as a parameter.As a result of the analysis, the lift amount that becomes the maximum sound pressure can be parameterized with a dimensionless lift amount at each nozzle diameter D (in this case it becomes maximum at 17 D). In addition, it was found that the sound pressure (OASPL) of the cluster nozzle is smaller than that of the single nozzle when comparing with the same dimensionless lift amount.

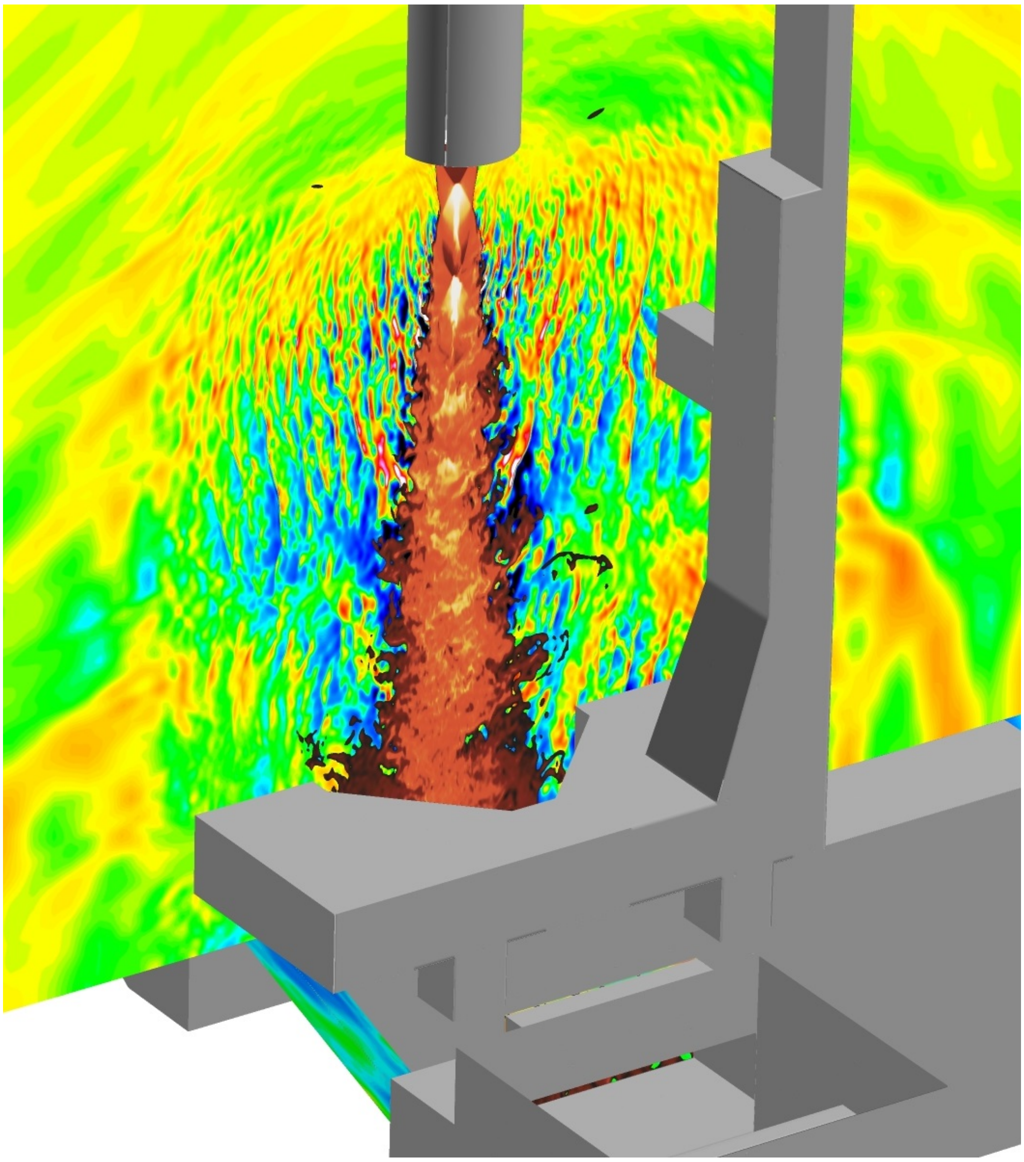

Fig.1 Result of subscale configuration of H3-30. (Acoustic field: static pressure, Hydrodynamics of jet: temperature)

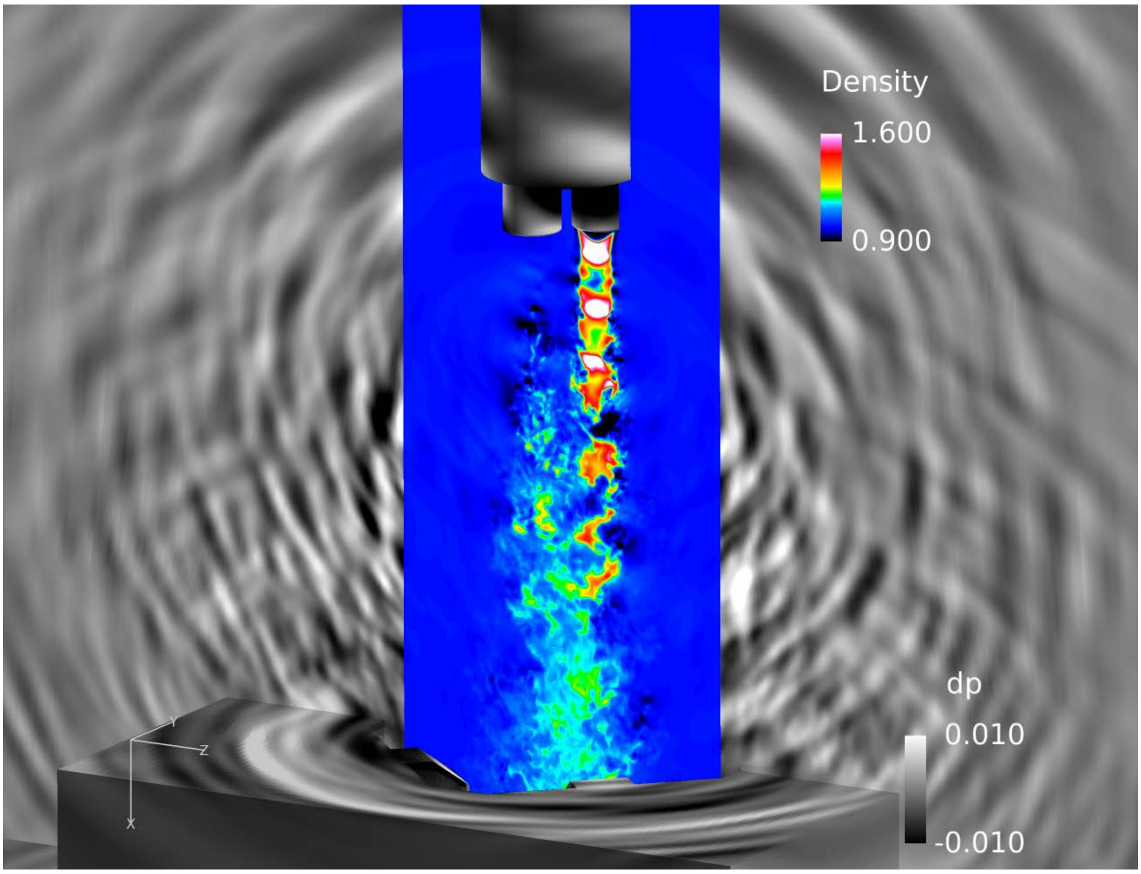

Fig.2 Interaction between cold cluster jet and launch pad (instantaneous field of density and pressure).

Publications

N/A

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	64 - 119
Elapsed Time per Case	1,440.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 5.03

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	41,901,509.38	5.49
SORA-PP	135,532.99	1.70
SORA-LM	880.09	0.45
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	5,591.15	3.87
/data	33,975.56	0.63
/ltmp	5,913.99	0.45

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	111.51	4.80

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

DSMC analysis of the rarefied gas flows

Report Number：R17EG3214
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4446/

Responsible Representative

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Abstract

To understand the rearfield gas flow phenomenon in high altitude and outer space, which is difficult to conduct ground test, and to predict the aerodynamic / thermal environment for reentry and the thermal load of gas plume from a thruster, we aim to develop a practical tool that can deal with actual shape and short analysis period.

http://www.kenkai.jaxa.jp/eng/research/software/software.html

Reasons for using of JSS2

In order to respond timely to project requirements, it is necessary to simulate complex geometries of actual spacecraft and to analyze a large number of conditions in a short period.

Achievements of the Year

We evaluated the risk of abnormally high temperature due to the interaction between the thruster plume and the loading of the HTV-X by using the rarefield gas flow analysis tool developed at Research Unit III. It predicted the plume interaction and the heat load with the loading. We contributed to changing the RCS thruster attachment position and angle. Figure 1 shows the simulation result of HTV-X.

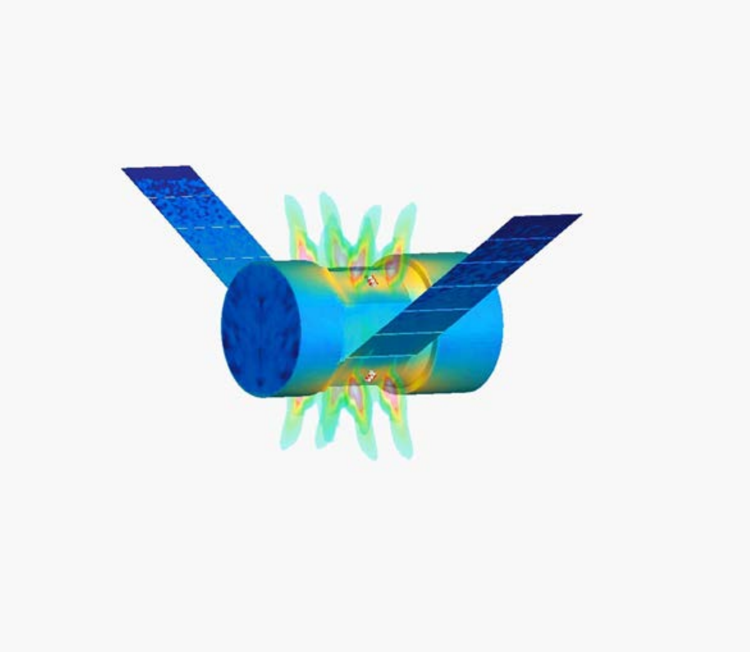

Fig.1 Plume simulation for HTV-X, number of density distribution

Publications

- URLs for the Research Results on the Web

1) http://www.kenkai.jaxa.jp/eng/research/software/software.html

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	300 - 625
Elapsed Time per Case	50.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.99

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	8,234,867.05	1.08
SORA-PP	1,337.81	0.02
SORA-LM	4.64	0.00
SORA-TPP	11.25	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	509.62	0.35
/data	25,306.17	0.47
/ltmp	16,404.39	1.24

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.24	0.01

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Numerical Simulation of Propellant Management for Rockets and Spacecrafts

Report Number：R17EG3215
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4447/

Responsible Representative

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Abstract

In order to improve the payload capacity of spacecraft, it is necessary to optimally design the propellant amount on board under the uncertainty of cryogenic propellant evaporation and low gravity environment. This project has been conducting numerical simulation development for the cryogenic propellant thermal flow analysis. By understanding the internal heat flow of the propellant tank and the feed line, it is linked to the change of propellant system design and operation.

Reasons for using of JSS2

In the thermal flow analysis inside upper stage propellant tanks, the calculation lattice is as small as several millimeters in order to consider a evaporation on the liquid surface, and it is necessary to solve operation time of 500 seconds or more. The calculation load of this tank thermal flow analysis is so large that it requires the supercomputer's performance.

Achievements of the Year

The flow in the upper propellant tank during flight operation is changing every moment due to the difference in fluid density and rocket's acceleration.

From improving the evaluation of the heat transferred to the liquid surface by implementing a physical model that takes into consideration the effects of evaporation and component mixing such as helium, the upper stage of the H-IIA rocket Simulation from engine start to inertial flight after engine stop was realized.

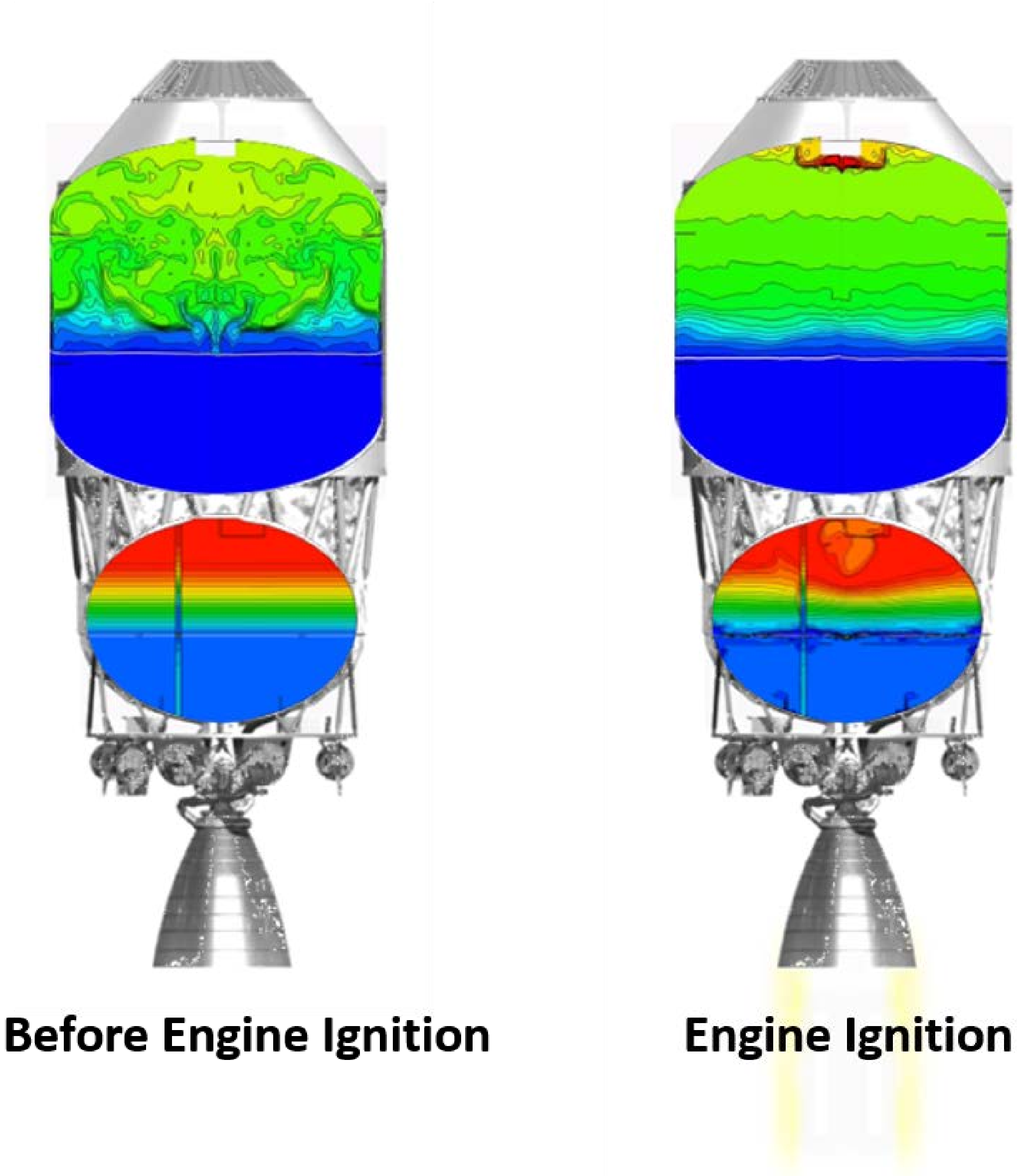

Fig.1 The thermal flow behavior inside the upper stage propellant tank

Publications

- Non peer-reviewed papers

1) Liquid Nitrogen Chill-down Process Prediction by Direct Interface Tracking Approach, Yutaka UMEMURA, Takehiro HIMENO, Osamu KAWANAMI, Wataru SARAE, Kiyoshi KINEFUCHI, Hiroaki KOBAYASHI, Osamu FUKASAWA, Propulsion & Energy 2017

2) Visualization for Liquid Behavior under Low Acceleration Attitude Control, Yutaka UMEMURA, Takehiro HIMENO, Daichi HABA, Osamu FUKASAWA, Mayu MATSUMOTO, Yasuhiro SAITO

3) Study on Simulation Technology for Improving the Cryogenic Propellant Management in the Space Transfer Vehicle, Yutaka UMEMURA, Takehiro HIMENO, Daichi HABA, Osamu KAWANAMI, Osamu FUKASAWA

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	3 - 4
Elapsed Time per Case	104.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 0.92

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	4,481,020.35	0.59
SORA-PP	537,755.45	6.73
SORA-LM	81.10	0.04
SORA-TPP	8,021.22	0.89

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	646.24	0.45
/data	22,964.06	0.42
/ltmp	15,688.24	1.18

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.24	0.01

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Development of Quantitative Safety Analysis Method by High-fidelity Simulations

Report Number：R17EG3216
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4448/

Responsible Representative

Eiji Shima, Reseach and Development Directorate, Reseach Unit III

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Members

Keiichiro Fujimoto, Takayuki Itoh, Shota Suto, Tetsufumi Ohmaru, Akimitsu Terunuma

Abstract

In order to perform detailed destructive re-entry safety analysis and to obtain the validation data for the empirical models, the aerodynamic and heat flux analysis under the wide range of flow conditions based on the developed rapid turn-around CFD method is carried out. In addition, by using the developed tools, the aerodynamic and heat flux design analysis are conducted in order to support the research and development activities for the small re-entry capsule installed in HTV and the fly-back re-usable rocket.

Reasons for using of JSS2

Accurate high-fidelity numerical simulations for the complicated physics under the wide range of conditions is essential for the quantitative safety analysis. In addition, the analysis methods and its results are high-level confidential information. Therefore, high-performance own supercomputer system is essential.

Achievements of the Year

In the conventional re-entry safety analysis, the aerodynamic and heat flux models with conservative assumptions are used, and the system shape is treated as the combination of the simple geometries such as the sphere and the cylinders. Due to these conservative assumptions, the predicted risk is generally resulting in the conservative risk which includes the various margins. To meet the challenging safety requirement in the near-future by the design for safety at the early design stages, an establishment of the new destructive re-entry safety analysis method based on the high-fidelity numerical simulations is essential.

Therefore, in order to establish new re-entry safety analysis method, the detailed CFD analysis is carried out to obtain surface heat-flux distributions for the comparison with that by empirical heat-flux model employed for safety analysis. Computed heat flux distributions obtained by CFD is compared with that by the empirical correlation model for simplified upper stage in Fig1.Results obtained by empirical model are generally agreed well with that by CFD including small curvature area where larger heat flux is observed. Research and development activities to realize next generation space transportation and re-entry systems such as the small re-entry capsule installed in HTV and the re-usable fly-back booster are under the way at JAXA.

In the aerodynamic design studies for such vehicles, large-scale parametric CFD analysis under the wide range of flow conditions is essential. Aerodynamic analysis is the most time-consuming process which is the bottle-neck for the conceptual design and the probabilistic analysis. In this study, rapid turn-around time CFD tool (LS-FLOW) is employed for such parametric studies. For the development of small re-entry capsule installed in HTV, the aeroacoustics CFD is carried out to predict the pressure fluctuation level from the hypersonic through the subsonic conditions to decide the acoustics level for the enviormental resistance tests (Fig 2), aerodynamic CFD for 6 degree-of-freedom trajectory analysis is carried out to decide the side wind requirement for the high-altitude drop tests (Fig 3).

Parametric CFD studies for wide range of flow conditions are carried out for both studies. For the aerodynamic design of the fly-back booster demonstrator, large scale parametric CFD study of various configuration under the wide range of flow conditions is conducted. By the application of the developed CFD tool, large scale parametric CFD analysis becomes available, which is the key for the success of the next generation space transportation and the re-entry vehicles.

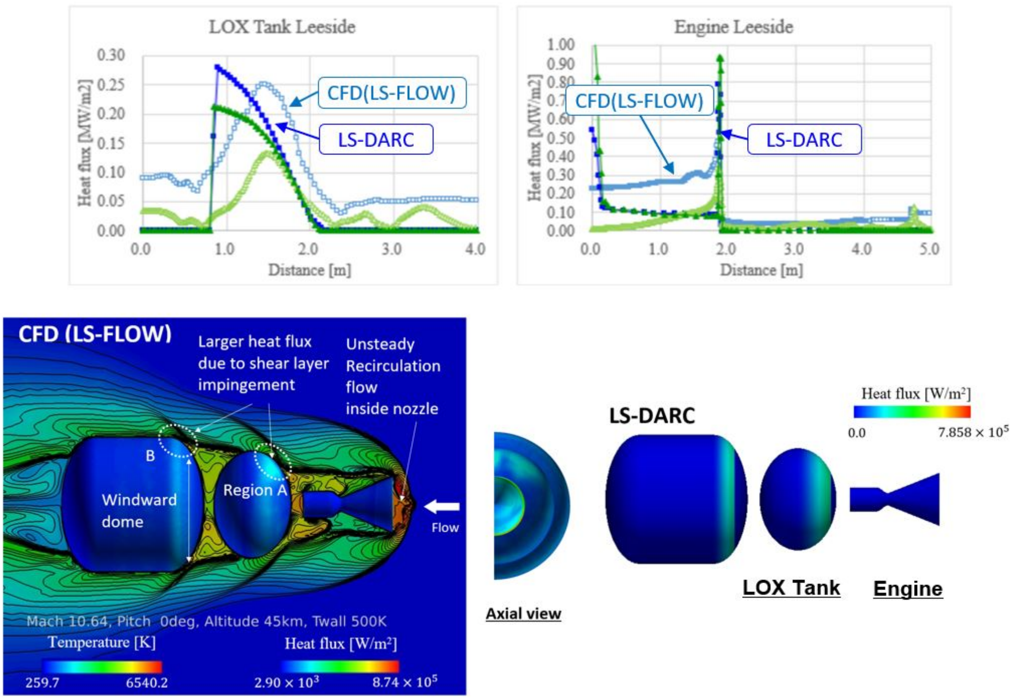

Fig.1 Comparison of surface heat-flux distributions obtained by CFD and the empirical model for rocket upper stage

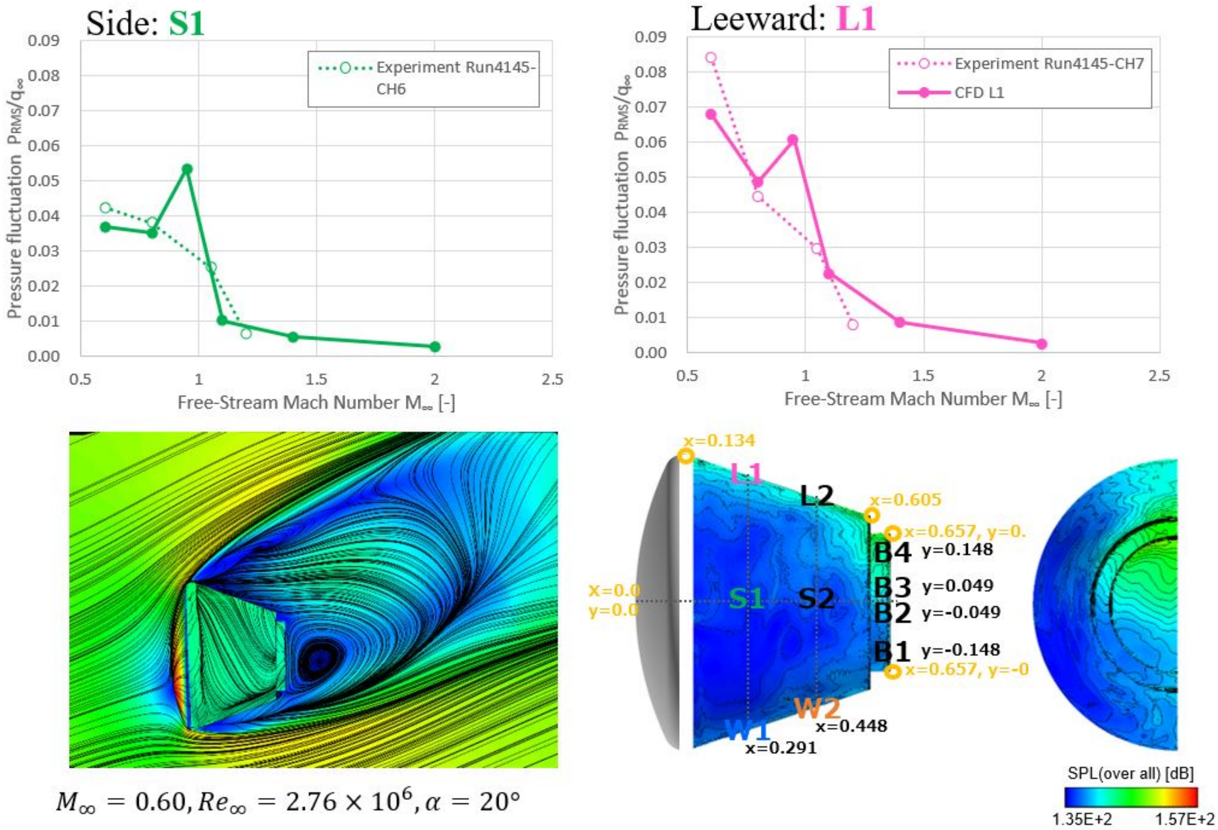

Fig.2 Aeroacoustics CFD for the small re-entry capsule installed in HTV

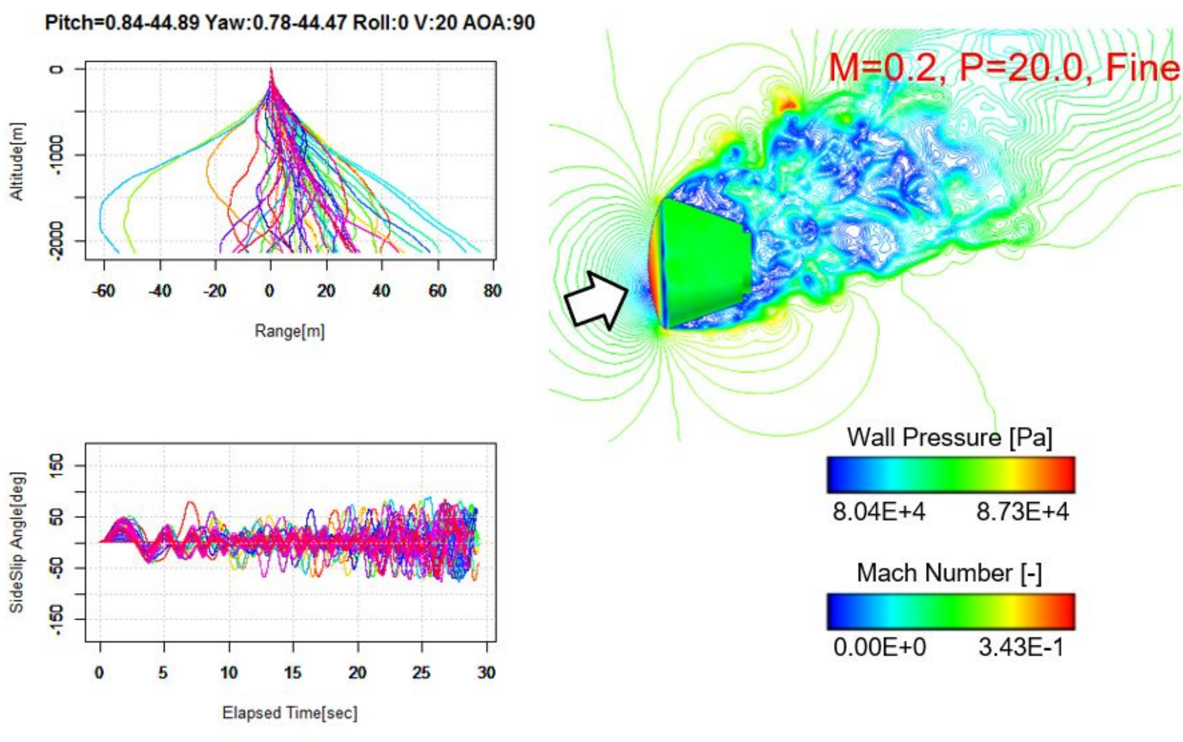

Fig.3 6 DoF trajectory analysis for drop test of the small re-entry capsule installed in HTV

Publications

- Peer-reviewed papers

1) Ryuta Hatakenaka et al., "Thermal Design of Small Sample-Return Capsule Integrated into HTV," ICES 2017, 2017.

- Non peer-reviewed papers

1) K. Fujimoto, H. Tani, H. Negishi, Y. Saito, N. Iizuka, and K. Okita, "High-fidelity Numerical Simulations for Destructive Re-entry of Upper Stages," in 7th European Conference on Space Debris, 2017.
2) F. Keiichiro, N. Hideyo, S. Yasuhiro, M. Spel, and G. Prigent, "BENCHMARK OF JAXA AND CNES RE-ENTRY SAFETY ANALYSIS TOOLS FOR ACCURATE HEAT-FLUX PREDICTION," in IAASS 2017, 2017.
3) F. Keiichiro, N. Hideyo, N. Ryoh, and N. Kazuyuki, "Aero-Acoustics CFD Prediction for Re-entry Capsule at Subsonic to Supersonic Regine," in AIAA Scitech 2018, 2018.
4) F. Keiichiro, N. Hideyo, S. Yasuhiro, N. Iizuka, and K. Okita, "Aerodynamic Characteristics and Heat Flux Model Development for Reentry Safety Analysis of Rocket Upper Stages", 31st CFD Symposium, E09-4, 2017.

- Other

1) F. Keiichiro et al., "Uncertainty Quantification for Destructive Re-Entry Risk Analysis", Stardust Final Conference Advances in Asteroids and Space Debris Engineering and Science, Springer, 2018.

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	64 - 512
Elapsed Time per Case	72.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.56

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	4,493,003.30	0.60
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	421.40	0.29
/data	25,614.73	0.47
/ltmp	14,990.70	1.13

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.24	0.01

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Numerical analysis on high-temperature Hypersonic flow

Report Number：R17EG3217
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4449/

Responsible Representative

Koichi Okita, Research and Development directrate, Research unit IV

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Members

Junpei Yamamoto

Abstract

Numerical simulation on high-temperature shock tunnel HIEST

Reasons for using of JSS2

Requirement for huge numerical simulation.

Achievements of the Year

Three component aerodynamic coeffcients of Hyflex lifting body model were obtained.

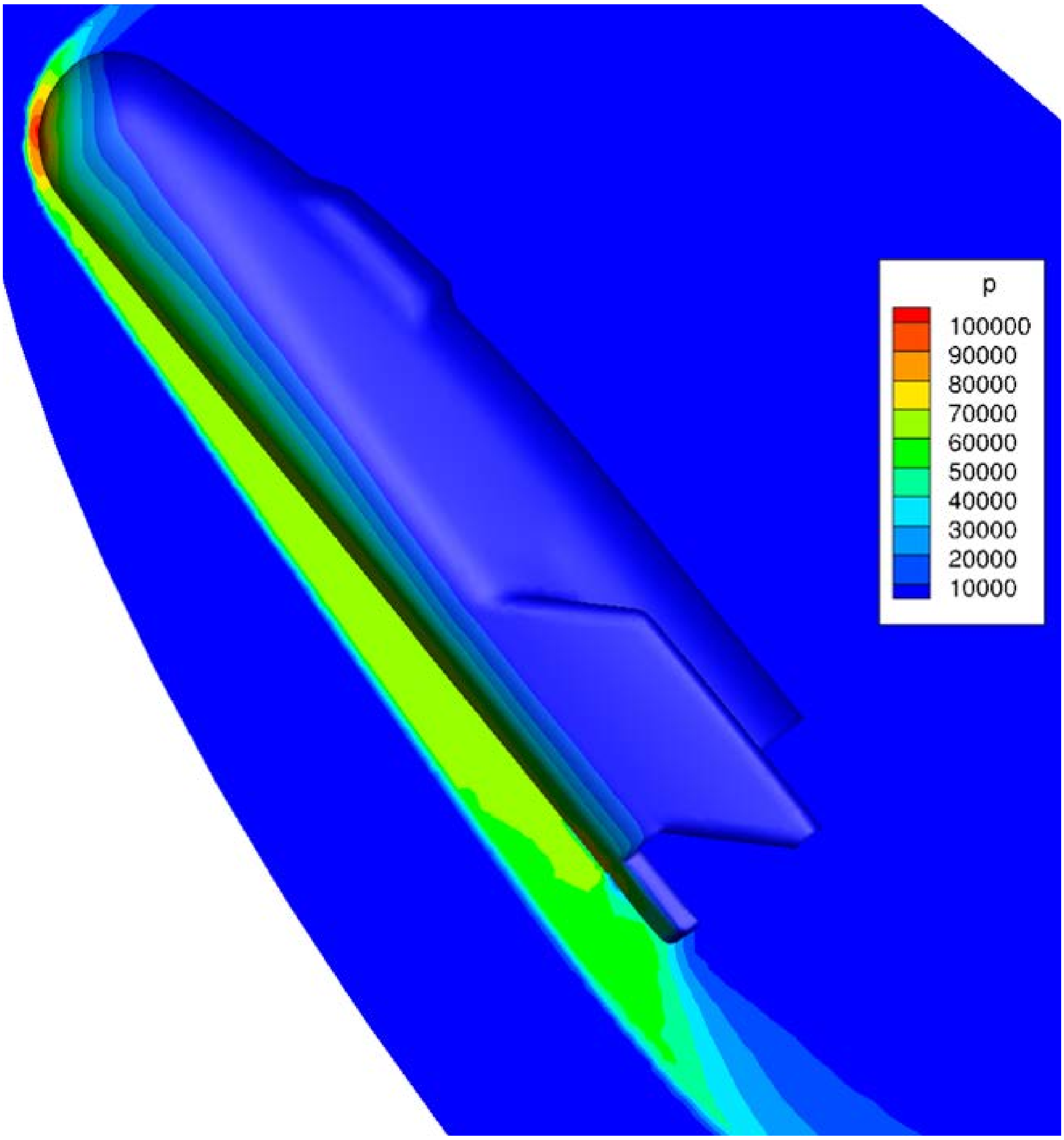

Fig.1 Pressure contour around Hyflex reentry vehicle (V=3km/s)

Publications

- Peer-reviewed papers

1) Master thesis, "Numerical analysis of hypersonic flow around lifting body vehicle model", Tohoku Univ. 2018

Usage of JSS2

- **Computational Information**

Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelizatio
Number of Processes	2 - 100
Elapsed Time per Case	100.00 hours

- **Resources Used**

Fraction of Usage in Total Resources*1 (%): 0.11

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	880,584.26	0.12
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	476.84	0.33
/data	9,765.63	0.18
/ltmp	1,953.13	0.15

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Uncertainty quantification on satellite thermal design

Report Number：R17EG3288
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4450/

Responsible Representative

Eiji Shima, Research and Development Directorate, Research Unit

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Members

Hiroshi Kato

Abstract

Our purpose is to improving the satellite thermal design process by developing a key technology of "satellite thermal environment uncertainty quantification".

Reasons for using of JSS2

There is no environment to perform the satellite thermal analyses of numerous samples under realistic time.

Achievements of the Year

We developed an method to create emulator for satellite thermal simulator using the Gauss process regression. The method was applied to actual satellite thermal problems, and the effectiveness was shown. JSS 2 was employed to study the speedup of calculation of the Gaussian process regression.

Publications

- Peer-reviewed papers

1) Hiroshi Kato, Makiko Ando, and Yasuhiro Fukuzoe, "Toward Uncertainty Quantification in Satellite Thermal Design," Transactions, 2017. (Accepted)

- Presentations

1) Hiroshi Kato, Makiko Ando, and Yasuhiro Fukuzoe, "Toward Uncertainty Quantification in Satellite Thermal Design," 31st International Symposium on Space Technology and Science, June 9, 2017, Matsuyama, Japan.

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	64
Elapsed Time per Case	0.00 seconds

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.00

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.36	0.00
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	011.92	0.01
/data	2,384.19	0.04
/ltmp	488.28	0.04

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year

Fundamental Studies of Methane RCS

Report Number：R17EG3500
Subject Category：Research and Development
URL：https://www.jss.jaxa.jp/ar/e2017/4451/

Responsible Representative

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Members

Daiki Terakado

Abstract

The present RCS of hydrazine used for controling rockets has a weak point on its toxicity. The present project focuses on the non-toxic property of methane and develops safer RCS system for the future rockets.

Reasons for using of JSS2

The present computation needs more than 10 species reactive computation, so that the computational cost is very large. In addition, a massive parametric study will be conduted to find the optimal way of injection. Thus, using supercomputer is necessary.

Achievements of the Year

N/A

Publications

N/A

Usage of JSS2

Computational Information

Parallelization Methods	N/A
Thread Parallelization Methods	N/A
Number of Processes	1
Elapsed Time per Case	24.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.00

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.00	0.00
SORA-PP	26.64	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage assigned(GiB)	Fraction of Usage*2 (%)
/home	158.95	0.11
/data	3,255.21	0.06
/ltmp	651.04	0.05

Archiver Resources		
Archiver System Name	Storage used(TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1 Fraction of Usage in Total Resources: Weighted average of three resource types (computing, file system, and archiver)

*2 Fraction of Usage: Percentage of usage relative to each resource used in one year