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Aerospace Applications in JAXA's Supercomputer and Personal Perspectives of Next-Generation Supercomputing in Japan

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OUTLINE

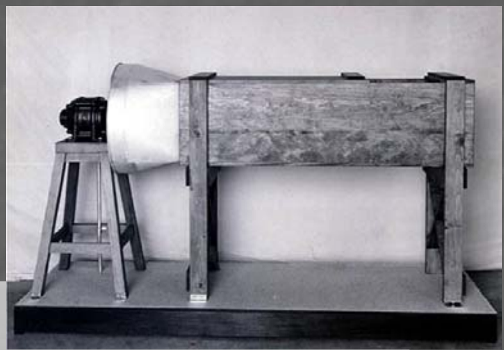
- Back to the Future (background discussion)

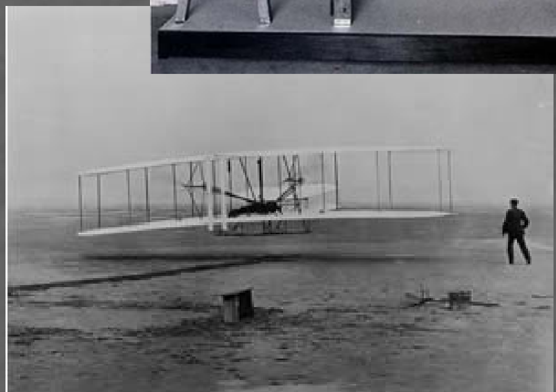
  Aerospace requires still faster supercomputers

- JAXA supercomputer and JEDI strategy
- Next-generation supercomputer project
- Personal ideas beyond current use
- Summary

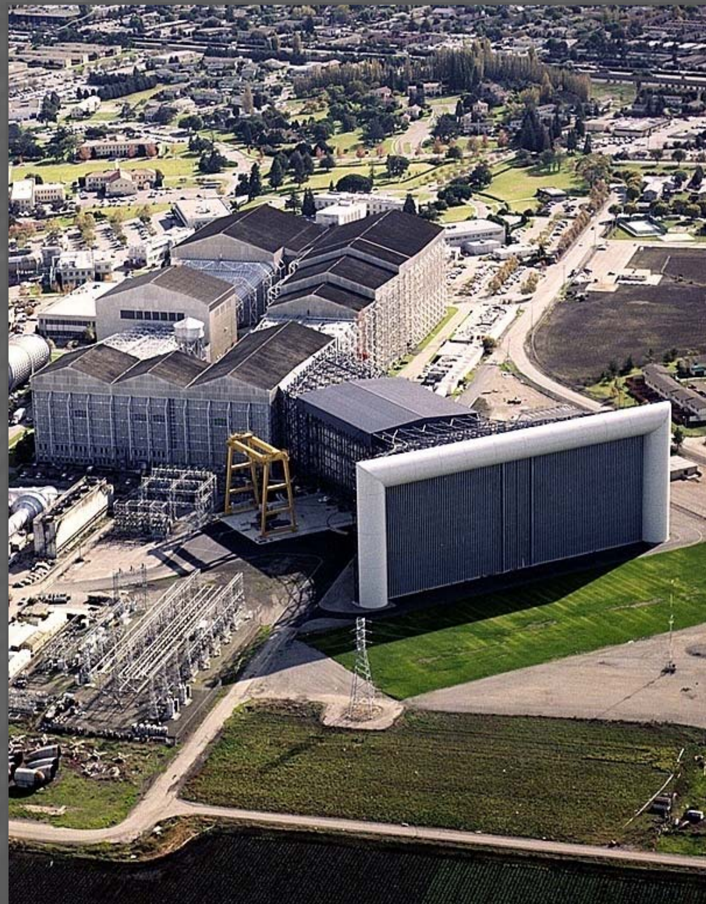
Wind Tunnels for Aircraft Development

Wind tunnel used by Write Brothers



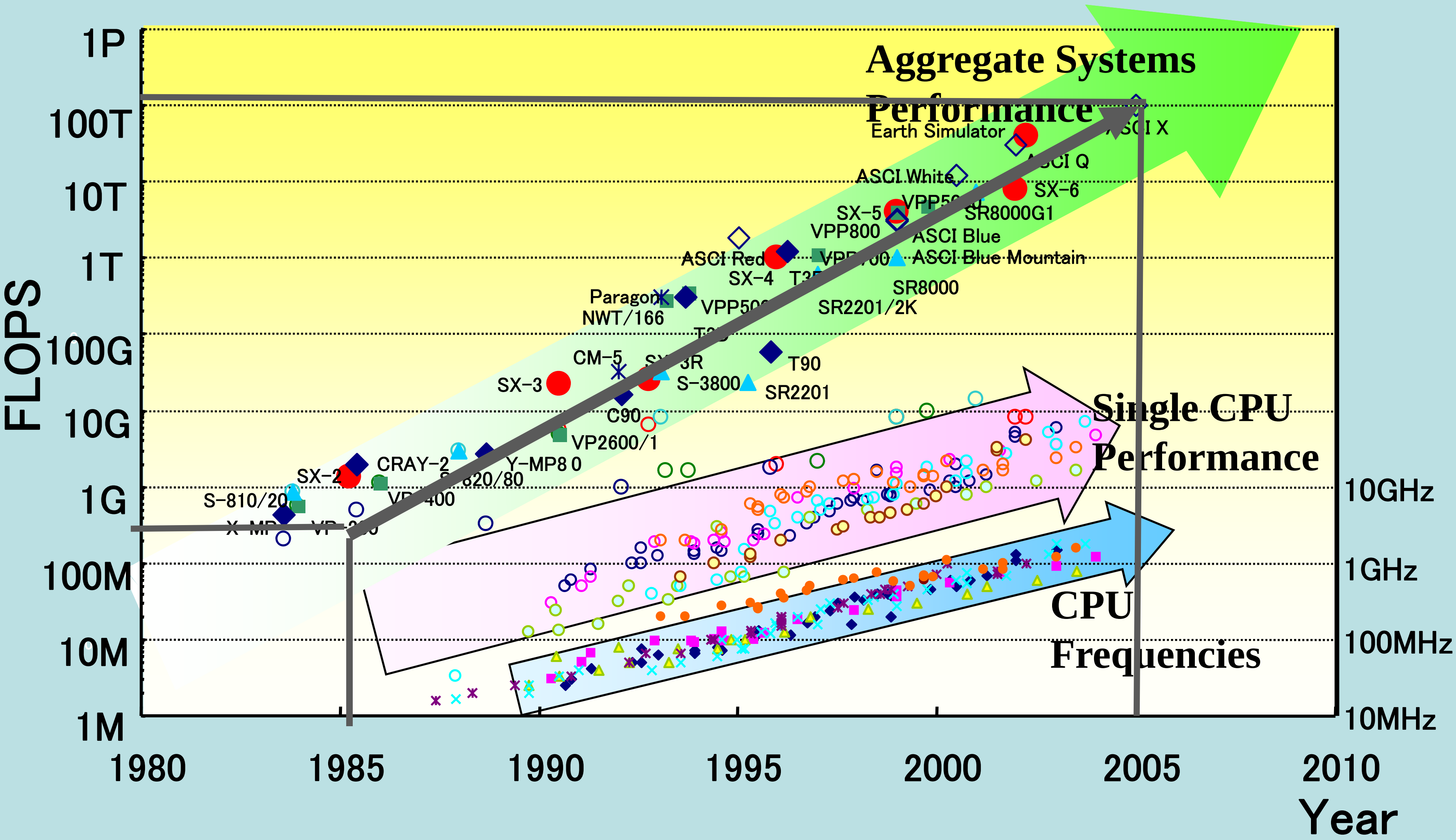


Huge wind tunnel at NASA Ames R. C.



Scale effect is critical for aircraft design

Development of Leading-edge Supercomputers



Courtesy of Dr. Tadashi Watanabe, former HPC manager of NEC Corporation

Achievement of CFD - Current status

- Simulations with order of million grid points are now feasible even on single PC's.
- Good software products are available for grid generation, flow simulation and visualization.
- Parametric study of steady flows reveals flow domains and their structures.

Only the replacement of wind tunnel

Achievements of CFD -As a tool

- **Improved understanding fluid physics**
  (mainly under Euler and RANS)
  - a lot of information in space
- **Supplyed a new tool for aerodynamic design**
  - large-scale simulations as a tool

Mostly, steady state or limited number of unsteady RANS simulations due to limited computer resource.

→ Consider difference between CFD simulations in 1985 and 2008?

Message by Dean Chapman in 1977

Workshop "Computer Requirements for Computational Aerodynamics" held at NASA Ames R. C. in 1977.

Prof. Dean Chapman at Stanford Univ. said,

" There are two major motivations behind CFD .

(1) providing an important new technology capability
(2) economics

It would not change in coming decades."

There are many restrictions in the wind-tunnel experiment such as **scale effects**, wall and support interference, aerodynamic distortion, and else. The restriction of CFD comes from the speed and storage, but the technical trend shows that such limitations are rapidly decreasing.

Three elements to push CFD into next stage

(1) Computer power still increases

- Parametric study for understanding fluid physics
- Detailed analysis with more sophisticated methods

(2) New sophisticated Methods become daily tools

- LES/RANS hybrid methods
- LES methods

(3) New approach makes such study feasible

- Spectral-like high-order schemes

Fujii, K., “Progress and Future Prospects of CFD in Aerospace-Wind Tunnel and Beyond”, Review Journal, Progress in Aerospace Sciences, Vol. 41, pp. 455-470, 2005

LES Computer time with spectral-like high-order schemes

	Lower than Re=10^5 MAV, UAV, Mars Aircraft	Re=10^6 Wind tunnel level	Higher than Re=10^7 Civil transports
No. Grid points (required memory size)	1.25×10^9 (1 TB)	1.250×10^{11} (100 TB)	1.250×10^{13} (10 PB)
Computer time on SX-6 one node	120 hours (5 days)	12,000 hours (17 months)	1,200,000hours (137 years)
Computer time on **1 TFLOPS**	10-50 hours (1-2 days)	1,000-5000 hours (1-6 months)	100,000 -500,000 hours
Computer time on **1 PFLOPS**	0.1-0.5 hours	1-5 hours	100-500 hours (5-20 days)

* Assuming perfect scalability

* Personal prediction based on the performance of the ISAS supercomputer

Key Words in future HPC in Aerospace

▷ Data exploration

As a tool to evaluate scale effect

From space-oriented data analysis to time-space data analysis

New ideas required for post processing

Reconsideration of time integration schemes

▷ Design exploration

As a tool for design innovation

Acquisition of variety of information and consideration of how to use them

Multi-objective robust optimization

Only the replacement of wind tunnel. CFD can do more.

HPC in JAXA (former NAL, ISAS and NASDA)

- 1977 FACOM230-75AP (prototype of supercomputer)
- 1987 VP400 (Numerical Simulator I) 1GFLOPS
- 1993 NWT (Numerical Wind Tunnel) 120 → 170GFLOPS
- 2002 NWT III (CenSS) 10 TFLOPS


昭和60年(1985年)1月8日 (火曜日) (日刊)

日本経済新聞

スーパーコンピューター 富士通が世界最高速

一秒に十億回

演算実現、近く発売

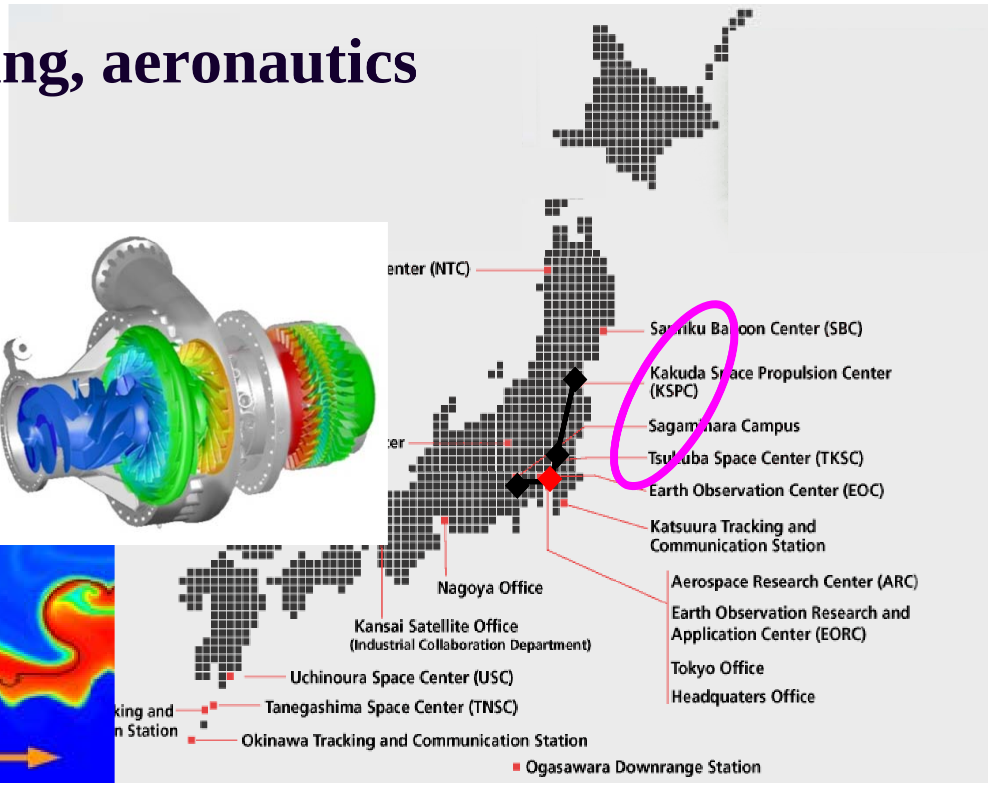
航空機設計などに威力

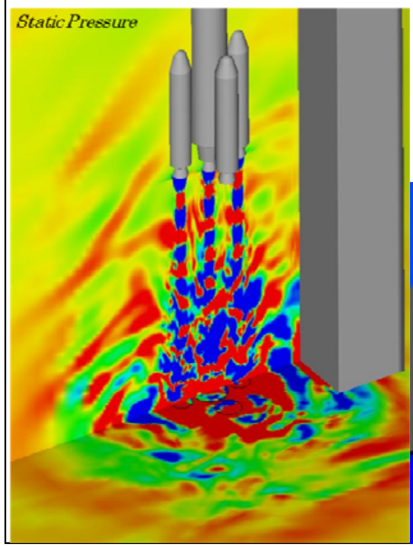
謹賀新年

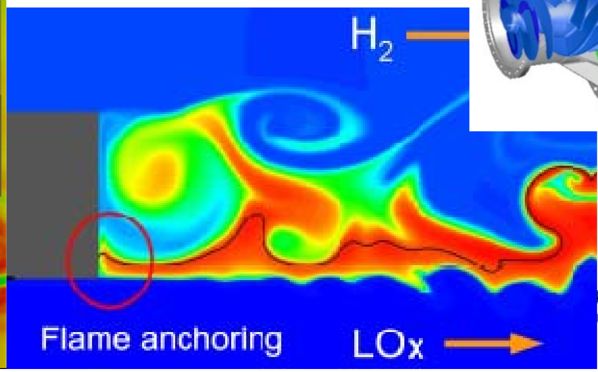
西日本銀行 コミュニケーションバンク

JAXA Supercomputer System
for Engineering Digital Innovation

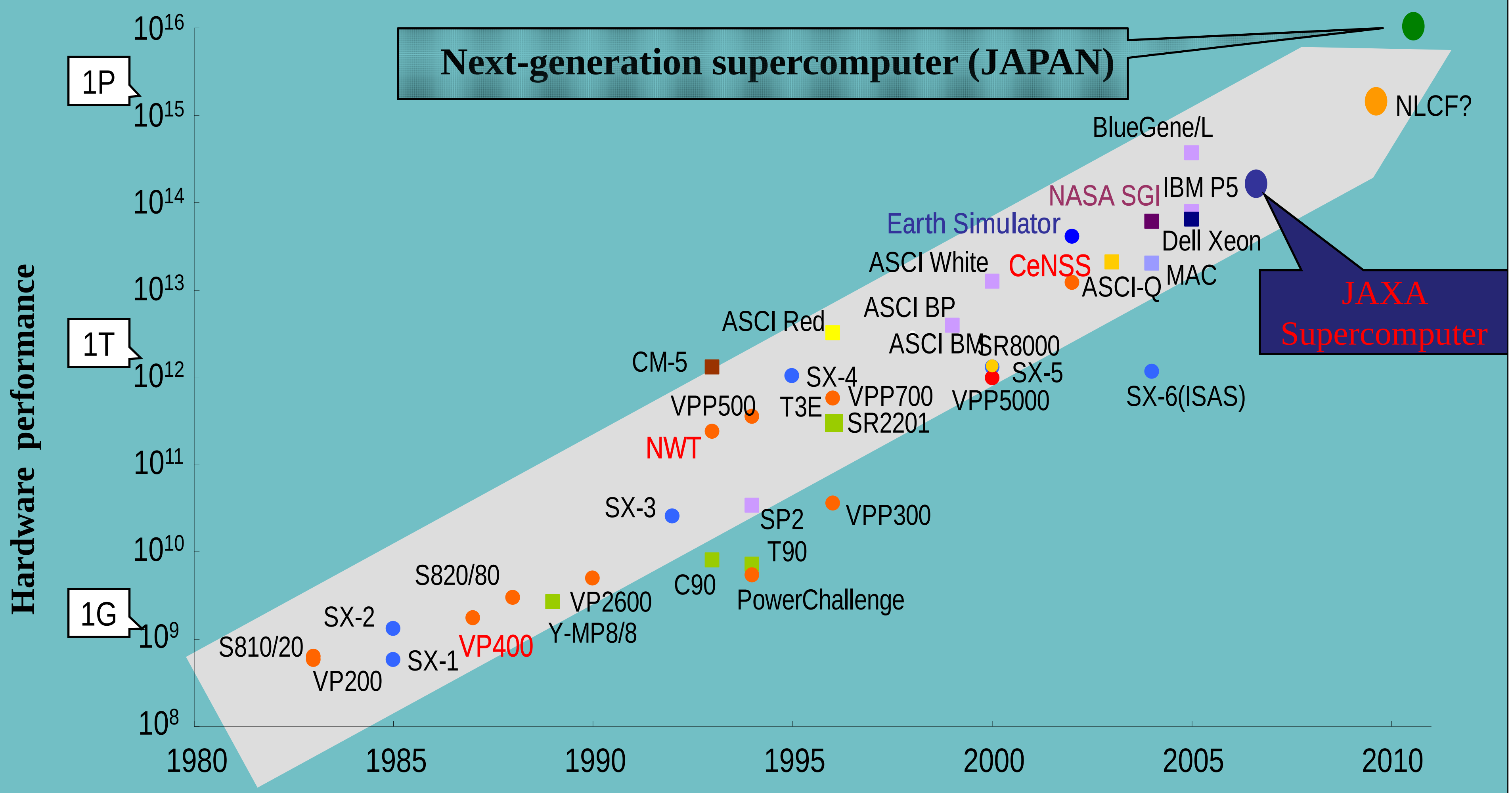
- **High performance135TFLOPS, Scalar MPP**
- **High availability 100TB memory, 1PB disk**
- **With vector(5TF, 3TB)**
- **Large-scale facility**
- **High-speed network and local stations**
- **Space science and engineering, aeronautics**







Hardware Performance of Next JAXA Supercomputer



JEDI Supercomputing Strategy -1

It is not easy to insist the necessity of expensive supercomputers

BACKGROUND

- ➢ We believe that HPC simulations will make remarkable contribution in space development.
- ➢ Current space development in Japan does not make good use of it and strategic plan is necessary.

ACTIVITY FOCUS (in the present mid-term plan period)

- ➢ With a clear definition of why we need simulations, tackle urgent problems where simulations can directly contribute, but can ultimately change the design and development process.

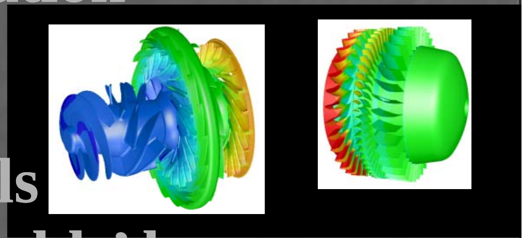
Improve reliability and efficiency

Shorten development period

JEDI Supercomputing Strategy -2

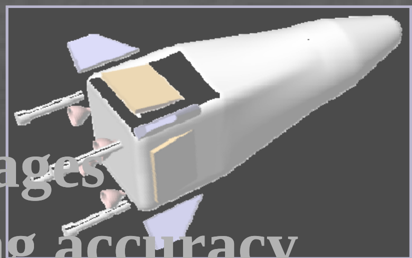
Four target applications

- **Plume acoustics**
  - → Establish a new standard that improves NASA SP8072
  - → Find a new idea to reduce acoustic vibration



- **HIIA, HIIB rocket engines**
  - → Reduce the number of engine test models
  - → Aim JAXA's rockets to be one of the worlds' best

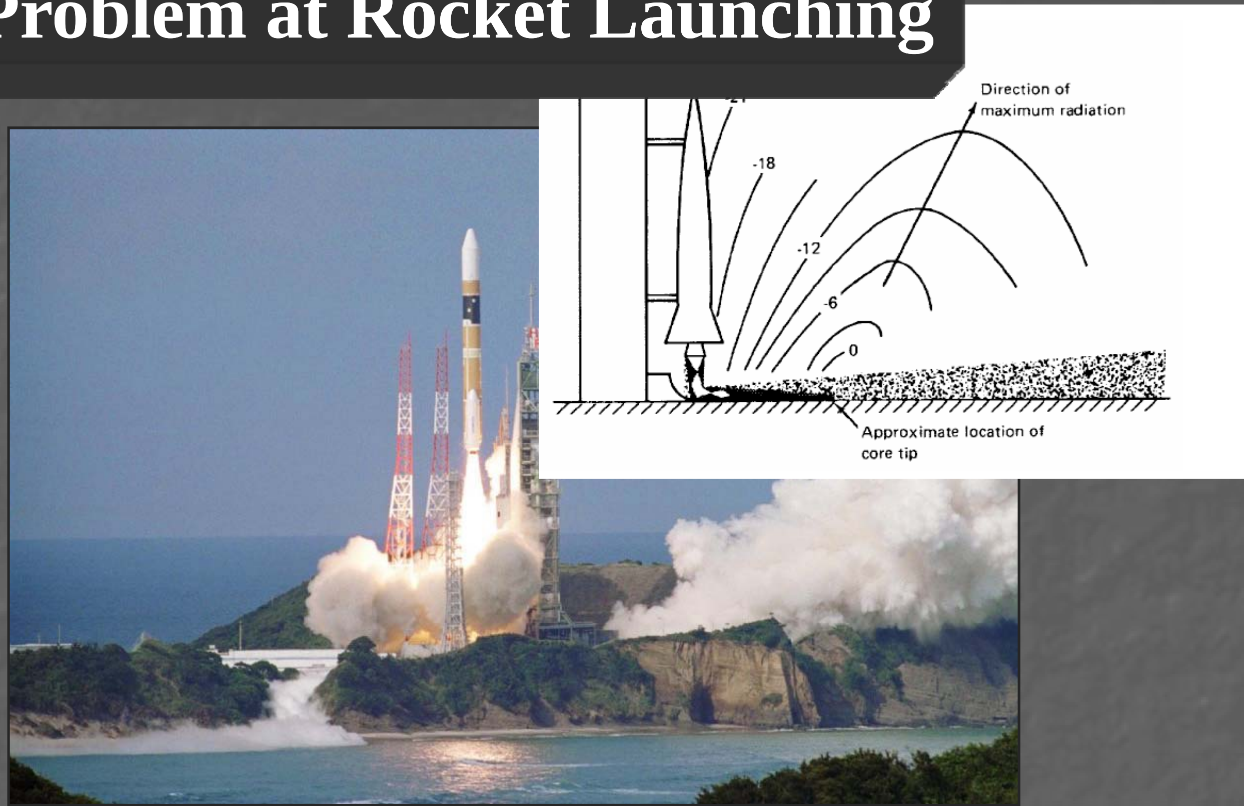
- **Plasma physics for satellites and other areas**
  - → Ion engine, Plasma magnetic sail, Plasma actuator,...



- **Techniques to optimize simulation process**
  - → Establish a new-age CFD software base
  - → Prepare to use in the conceptual design stages under limited time period but with keeping accuracy

Acoustic Problem at Rocket Launching

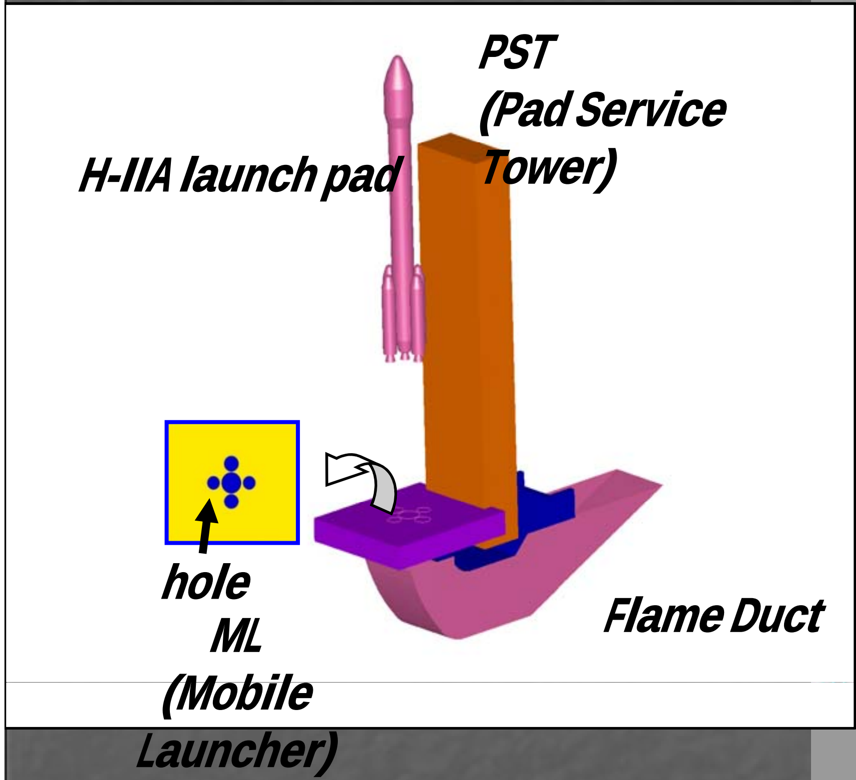
H-IIA : Lw=200dB

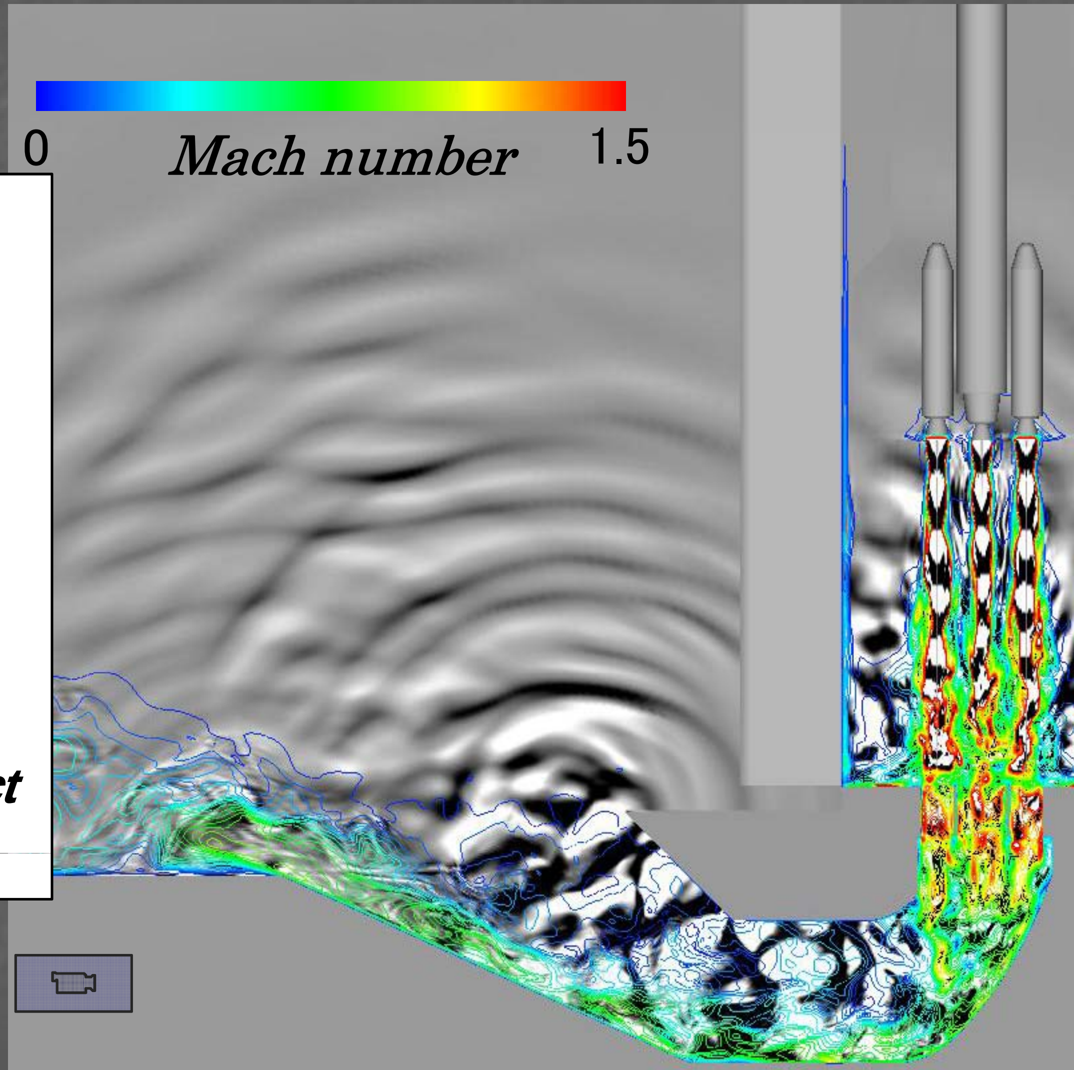


- **Satellite development requires expensive and time-consuming acoustic and vibration tests.**
- **Estimation of strength and frequencies of plume acoustics at vehicle lift-off relies on semi-empirical method in NASA SP-8072.**

Background of computer speed and recent effort in CFD

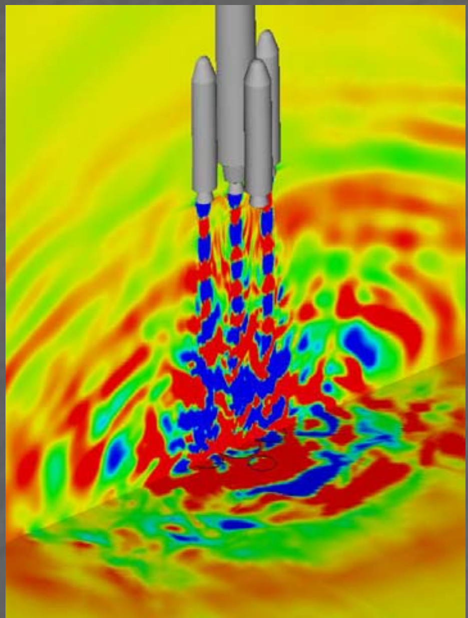
Acoustics from Rocket Plume

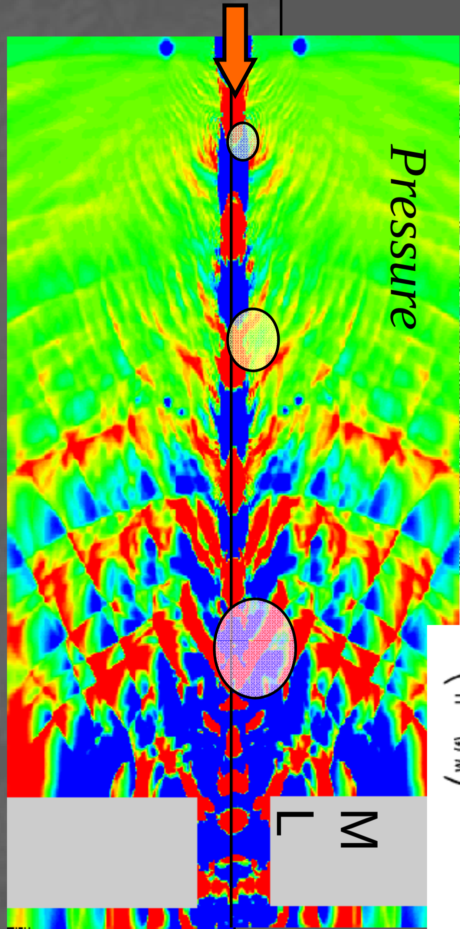




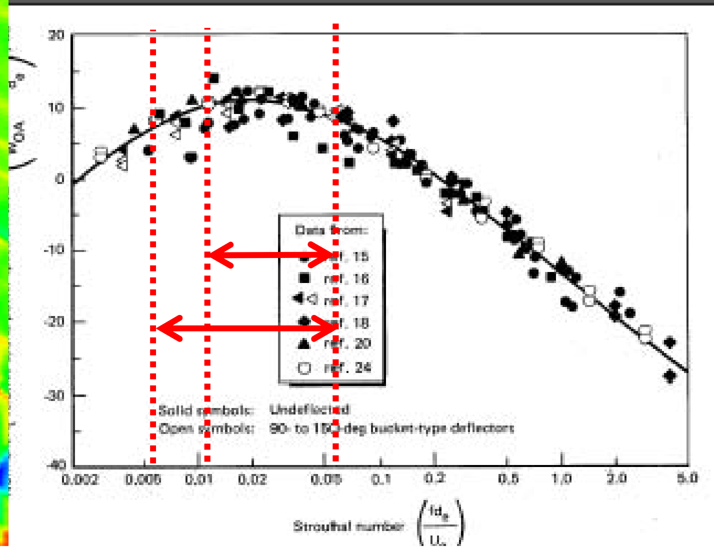
Tsutsumi, et al. AIAA Paper 2008-0390

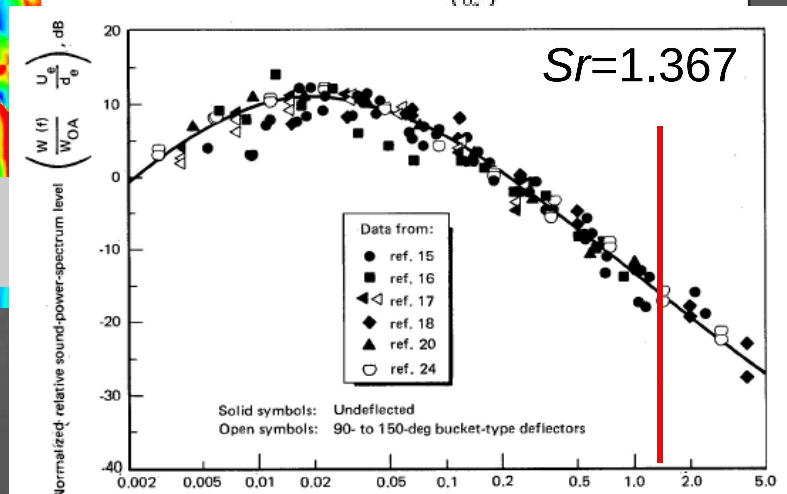
Effect of Spectral-like FD scheme



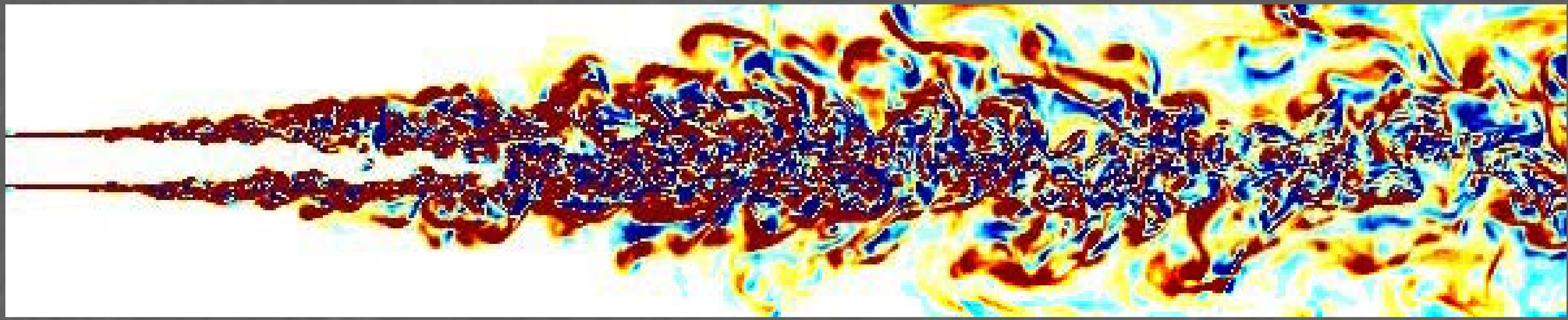


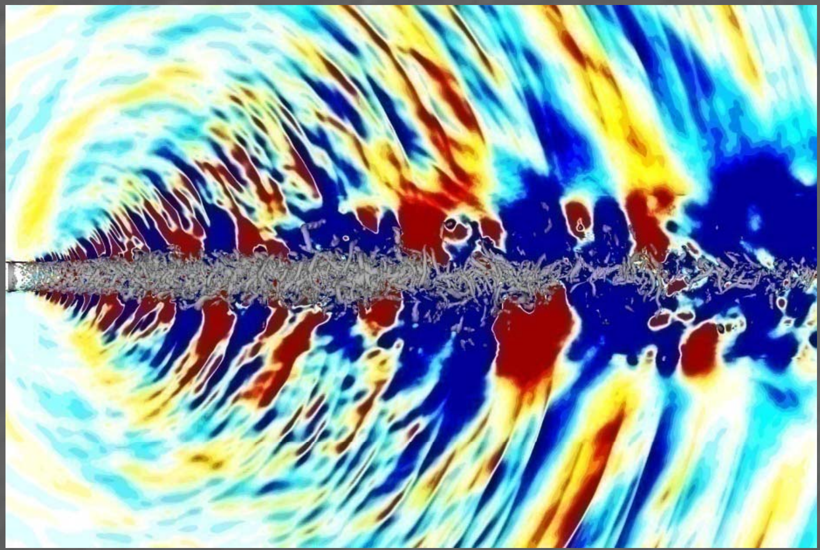
From NASA SP-8072





DNS of acoustics from high-speed jets





Nonomura and Fujii, ASME/JSME FEDSM-2007-37539, San Diego, July-August 2 2007

JEDI Supercomputing Strategy -3

Discussion underway for the next mid-term plan period (April 2008 – March 2013)

- Continue the research chosen in the current mid-term plan.
- Enhance our capability by the collaboration with universities, other organizations and industries under the clearly-defined objectives
- New areas to be discussed
  - Multi-objective robust optimization for satellite development
  - Destruction and fragmentation analysis
  - Fluid-Structure interaction analysis for rockets
  - Construct DB and use data exploration methods
  - Conceptual Design Method

The Next Generation Supercomputer Project in Japan -1

The Next-Generation Supercomputer will be an essential foundation for Japanese science, technology and industry. The government's Council for Science and Technology Policy has therefore designated it a "key technology of national importance".

(1) Design, build, and set up the Next-Generation Supercomputer, the world's fastest and most advanced computer, with a speed of 10 petaflops

(2) Develop and distribute large-scale software applications (Grand Challenge software) to make full use of the supercomputer

(3) Connect the supercomputer to Cyber Science Infrastructure

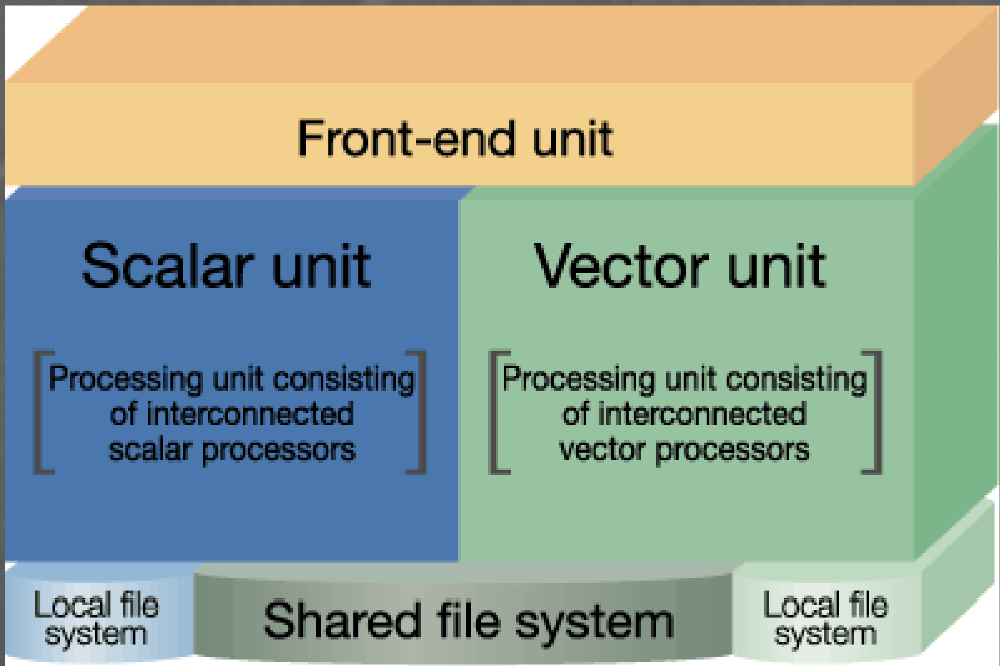
(4) Set up a center to run the supercomputer, to be the world's top center of excellence in the field of supercomputing

From http://www.nsc.riken.jp/p4-eng.html

The Next Generation Supercomputer Project in Japan -2

The Next-Generation Supercomputer project is being carried out by RIKEN, with partners in industry, universities, and the government, under an initiative by MEXT (the Ministry of Education, Culture, Sports, Science and Technology).

Hardware architecture (concept)



The Next Generation Supercomputer Project in Japan -3

Hardware features

- Electricity consumption and space occupation are key issues.
- Expansion of the same (similar) architecture to smaller models are considered to be important.
- Speed on the real application is focused.

Software features

- 21 application software were selected and 10 of them are given first priority. Aero application is one of them.

- Nano and Bio were chosen to be the Grand Challenge Application Software and the groups to promote these have already started. That does not mean aero is out of the focus.

CFD can do more than replacement of wind tunnel

As a tool to evaluate scale effect

- Data exploration

As a tool for design innovation

- Design exploration

And beyond

（supercomputer on spacecraft ）

- Real-time simulations
  - —Visual computing
  - —Transaction use of supercomputers
- Super real-time simulations
  - —Faster than what will happen

Another Small Step to Real-time Simulations

Rough and optimistic estimation from current performance

（Ex. １）Plume acoustic simulations for rockets

1TFLOPS machine

One time step: Computer 2.4×10^{-1} sec = Physical 6.1×10^{-6} sec

40 PFLOPS machine

One time step: Computer 6.0×10^{-6} sec = Physical 6.1×10^{-6} sec

（supercomputer on spacecraft ）

New Life with Supercomputers

Nobody notices that there work supercomputers behind his/her life.

No aircraft cra

Best choice of golf club

Atmosphere information
Geometry information
Biometric information
……

Summary

- CFD is still one of the key players in HPC
- Realization of “Scale effect” and “Conceptual Design” is the key for HPC in aero .
- JAXA strategically plans focus topics with these in mind, .
- Some features of Japanese Peta project is presented.
- Batch-job type of numerical simulations is not the only area for supercomputer use.   That will avoid zero-sum game of supercomputers.