SILENT SUPERSONIC TECHNOLOGY DEMONSTRATION PROGRAM

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Abstract

Japan Aerospace Exploration Agency has promoted supersonic technology research including flight demonstration since 1997, and NEXST-1 flight trial had been successfully completed in 2005. As a post-project of NEXST-1 the "Silent Supersonic Technology Demonstration" program started in 2006. In this program, JAXA is now planning the new flight demonstration project to validate the design tool and to demonstrate the silent supersonic technology. This paper describes the summary of this flight demonstration project and the current status of the flight demonstrator design.

1 Introduction

Japan Aerospace Exploration Agency (JAXA) has promoted supersonic technology research including flight demonstration since 1997, in order to establish the fundamental technologies on next generation supersonic transport. In this program, JAXA has developed a scaled supersonic experimental airplane ("NEXST-1" project) and had made a flight trial at South Australia the last October to validate the computational design methodology that is the inverse design method combined with computational fluid dynamics (CFD) and to demonstrate the unique natural laminar flow wing[1]. On the other hand, JAXA has also performed the research on silent supersonic technologies such as low-boom/low-drag configuration design methodology and low noise nozzle technology. In 2006, JAXA started the research and development program on the silent supersonic technology. In this program, JAXA is now planning a new flight demonstration project, the Silent Supersonic Technology Demonstrator "S3TD" project as a post-project of the "NEXST-1" project (Fig.1) in order to validate the multi-disciplinary optimization design tool for supersonic aircraft and to demonstrate the silent supersonic aircraft concept. This paper describes the summary of this flight demonstration project and the current status of the flight demonstrator design.

2 Program Target

This R&D program, the Silent Supersonic Technology Demonstration Program aims at validating the multi-disciplinary optimization design tool that JAXA has developed and demonstrating the silent supersonic aircraft configuration concept. The targets of this program are the followings;

(1)Reduce Sonic-boom Intensity by 50%
Demonstration of the new low-boom/low-drag configuration concept designed by multi-objective optimization (MOO) / multi-disciplinary optimization (MDO).

(2)Reduce Landing and Takeoff noise by 50%
Demonstration of Airframe-Propulsion highly integrated configuration concept for shielding engine noise.

(3)Demonstrate System Integration Technology
Demonstration of advanced flight control system and composite material structure (provisional).

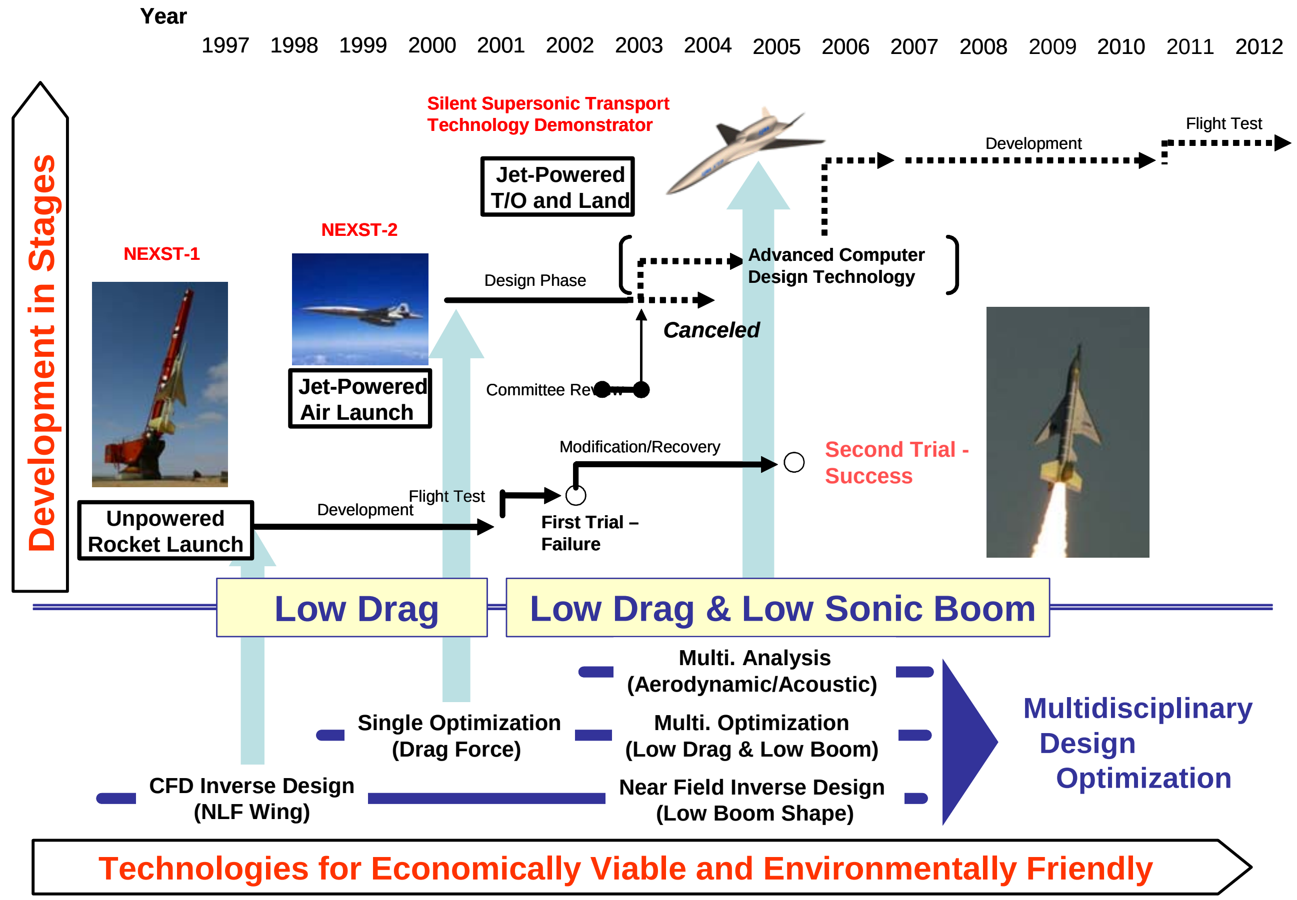

Fig.1 Supersonic research and development project in JAXA

2.1 Reduce Sonic-boom Intensity by 50%

Sonic-boom is one of the biggest environmental problems for supersonic overland flight. Fig.2 shows estimated shock overpressure (sonic-boom intensity) against airplane size, for high-L/D and low-boom configurations, respectively. Generally speaking, the configuration to reduce the sonic-boom intensity causes relatively large drag and various problems related to vehicle structure and flight stability. The target of this program is not only to reduce sonic-boom intensity by 50% as compared with high-L/D designed configuration but also to maintain low drag equivalent to high-L/D designed configuration. In this program, we plan the development and flight experiments of a new experimental vehicle, the Silent Supersonic Technology Demonstrator "S3TD" to validate the low-boom/low-drag airframe concept and the design technologies such as MOO and MDO design methodologies.

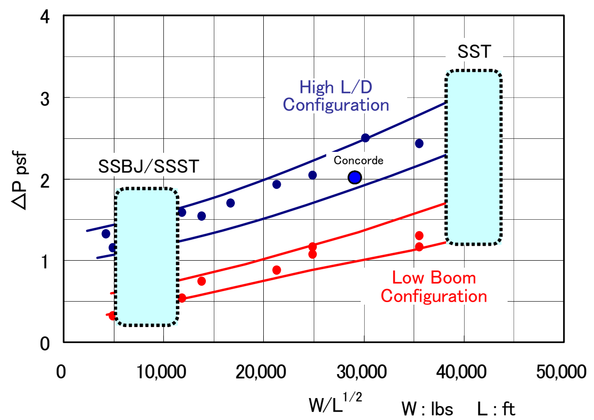

Fig.2 Estimated shock overpressure[2]

2.2 Reduce LTO Noise by 50%

Noise during landing and takeoff (LTO) is also one of the biggest problems for the supersonic transport. Upper mounted engine configuration to shield engine noise with airframe is considered as one of the LTO noise reduction concepts and/or technologies. In this program, such concept is applied to the demonstrator "S3TD" by airframe-propulsion highly integrated design, and the effectiveness will be validated by flight experiments (provisional). The program target is to reduce LTO noise by 50%, exactly, -3dB by shielding the engine noise, especially fan-noise. During the design of the S3TD, we will apply both high fidelity Computational Fluid Dynamics (CFD) and Computational Aero-acoustics (CAA) that we have developed. Acquisition of validation data for such CFD and CAA is also one of the objectives of the flight experiments. Not only noise shielding airframe concept but also other LTO noise reduction concepts and technologies will be studied in this program such as thrust vectoring technology for low noise and engine nozzle technology.

2.3 Demonstrate System Integration Technology

One of the objectives of this program is to strengthen the system integration technology basis through the development and flight of the S3TD. For example, advanced flight control system that we have developed in the previous flight demonstration projects such as "NEXST-1" project and High Speed Flight Demonstrator "HSFD" project will be applied to the S3TD which is an unmanned vehicle capable of autonomous flight from takeoff and landing to supersonic cruise. Also, composite materials including heat resistant composite materials will be applied to the wing and/or the fuselage of the S3TD (provisional). In the S3TD project, such technologies will be also demonstrated.

3. R&D Schedule

Fig.3 shows the schedule of this program. This program started in 2006. In this program, the R&D on computational design technology such as MDO tool and the silent supersonic vehicle technologies is promoted as well as the "Silent Supersonic Technology Demonstrator"

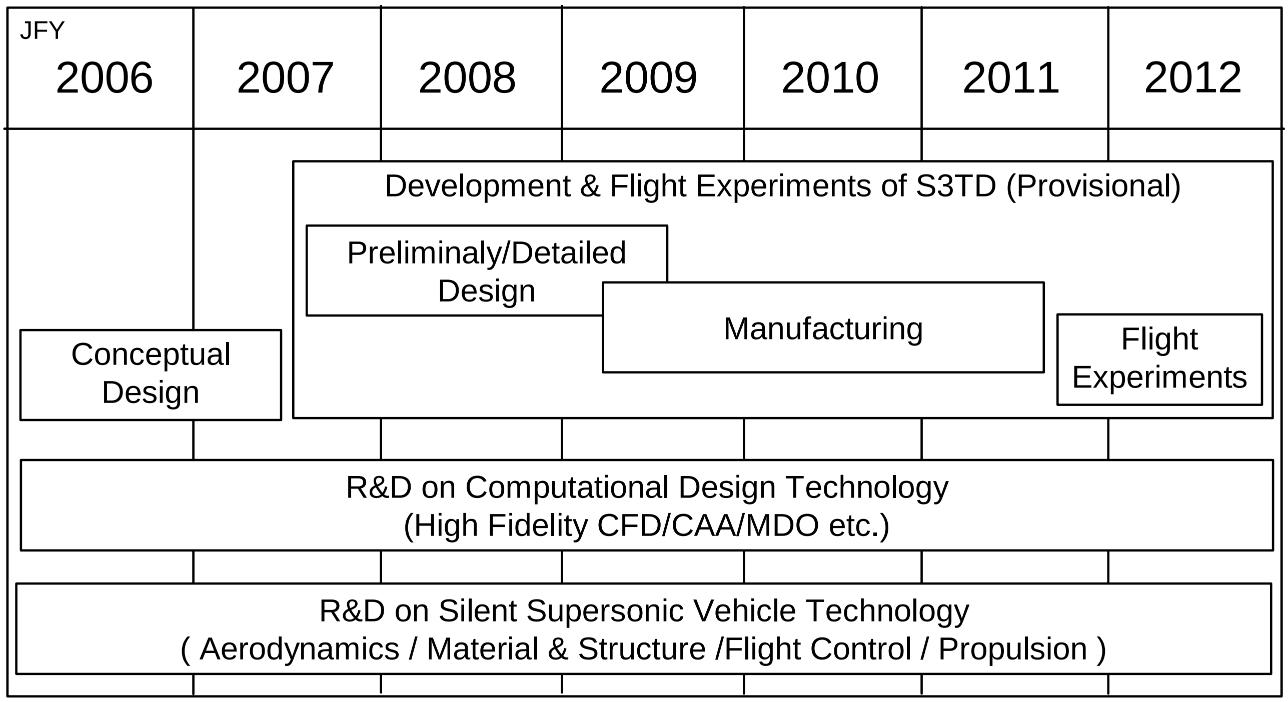

Fig.3 Schedule of Silent Supersonic Technology Demonstration Program

project (S3TD project). The S3TD project is in conceptual design phase, the schedule after JFY2007 is provisional. The development of the S3TD will start in JFY2007 if it is authorized by the Japanese government, and will be completed by JFY2011 and the flight experiments will start in JFY2012.

4 Silent Supersonic Technology Demonstrator

As mentioned in the above, the S3TD project is now in the conceptual design phase. Current status of the S3TD conceptual design is shown in the following.

4.1 Conceptual Design

Table 1 shows design requirements of the S3TD. The S3TD is an unmanned jet aircraft capable of supersonic cruise at Mach number of more than 1.4. The size (weight) is determined to be a minimum for ground sonic boom measurement with necessary accuracy. Fig.4 shows the base-line configuration of S3TD which is about 3,200kg in max. takeoff weight, 13m in length and 6.5m in span. The reference wing area is about 12m^2 and the aspect ratio is about 3.5. The existent jet-engine of approximately 6,000lbs thrust (dry) at sea level static is assumed at present.

Table 1 Design requirements

Type	unmanned jet aircraft
Cruise speed	>Mach1.4 @12-17km
Flight time	>1min. @cruise speed
Weight	≅3,000kg @cruise
Runway	<1,200m (dry asphalt)
Flight control	Full Autonomous

4.2 Configuration Design

4.2.1 Low boom design

The target of low boom design is to reduce sonic boom intensity by 50% as compared with conventional configuration, and to modify sonic boom signature for not only front shock boom but also rear shock one. We are now designing the base-line configuration, using the CAD based Automatic Panel Analysis System, "CAPAS" that we have developed (Fig.5). Fig.6 shows the estimated ground sonic boom signature of S3TD base-line configuration

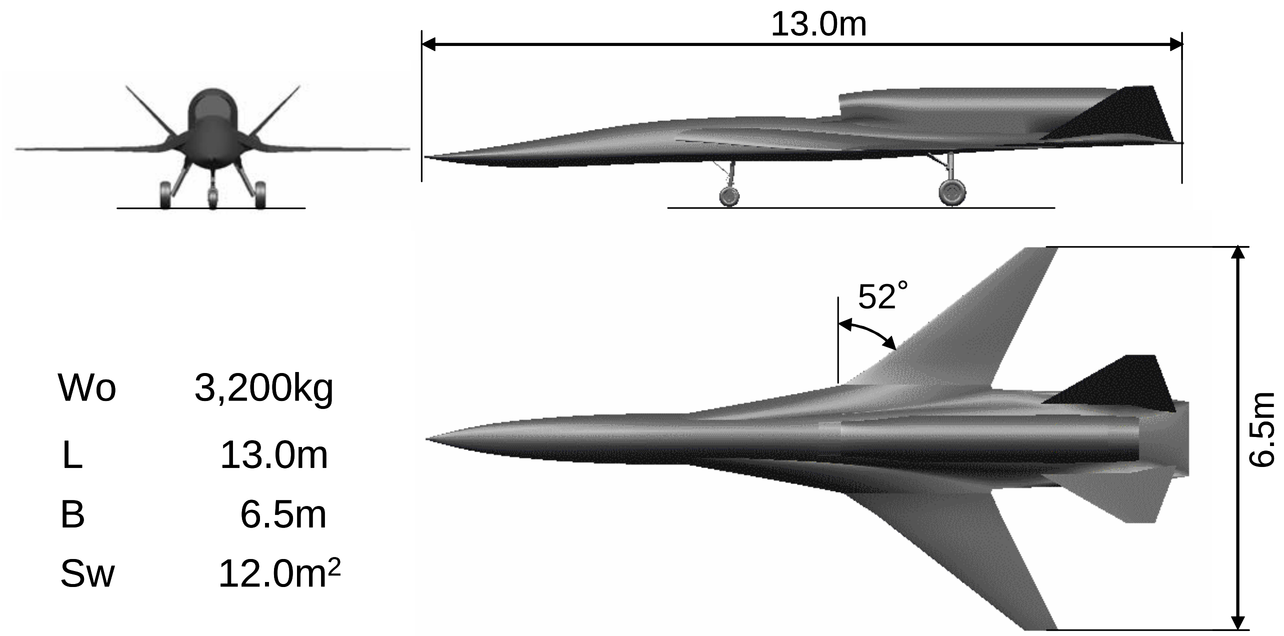

Fig.4 S3TD base-line configuration

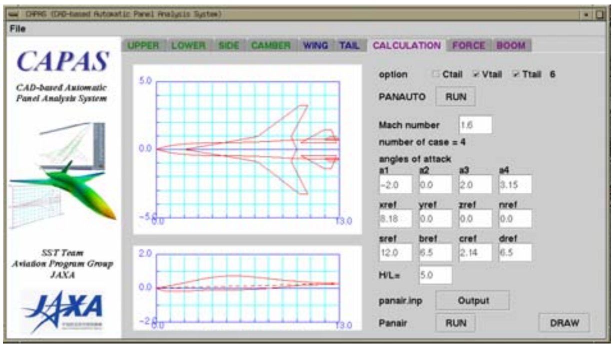

Fig.5 CAPAS
(CAD based Automatic Panel Analysis System)

at Mach1.6 level flight condition at the altitude of 16km. The shock overpressure is estimated to be about 0.23psf for front shock and 0.21psf for rear shock, corresponding to about 50% intensity as compared with those of N-wave signature estimated by the first-cut method. Robustness of low boom signature is also considered. The rear shock boom signature is so sensitive to flight condition that some small device is installed around the aft-deck (not shown in Fig.4). In the next phase of conceptual design, we will apply MOO using genetic algorithm[3] and near-field inverse design using adjoint method[4], and then based on those results, we will apply MDO design combined high fidelity CFD with Computational Structural Dynamics.

4.2.2 Noise Shielding effect

Fig.7 shows one of the estimated results of fan-noise shielding[5] for S3TD configuration at an altitude of 120m by the ray tracing method. It indicates that fan-noise from the engine is effectively shielded by the airframe. The reduction of ground noise at the above condition is approximately 4dB to 8dB. On the other hand, jet-noise shielding is not so easy. The reduction of observed jet-noise on the ground is not more than 1.2-3.0dB which strongly depends on jet velocity[5](Fig.8). We will apply high fidelity CFD/CAA[6] in the next phase to improve the prediction accuracy. Also, we will try MOO[7] for the design of S3TD to explore

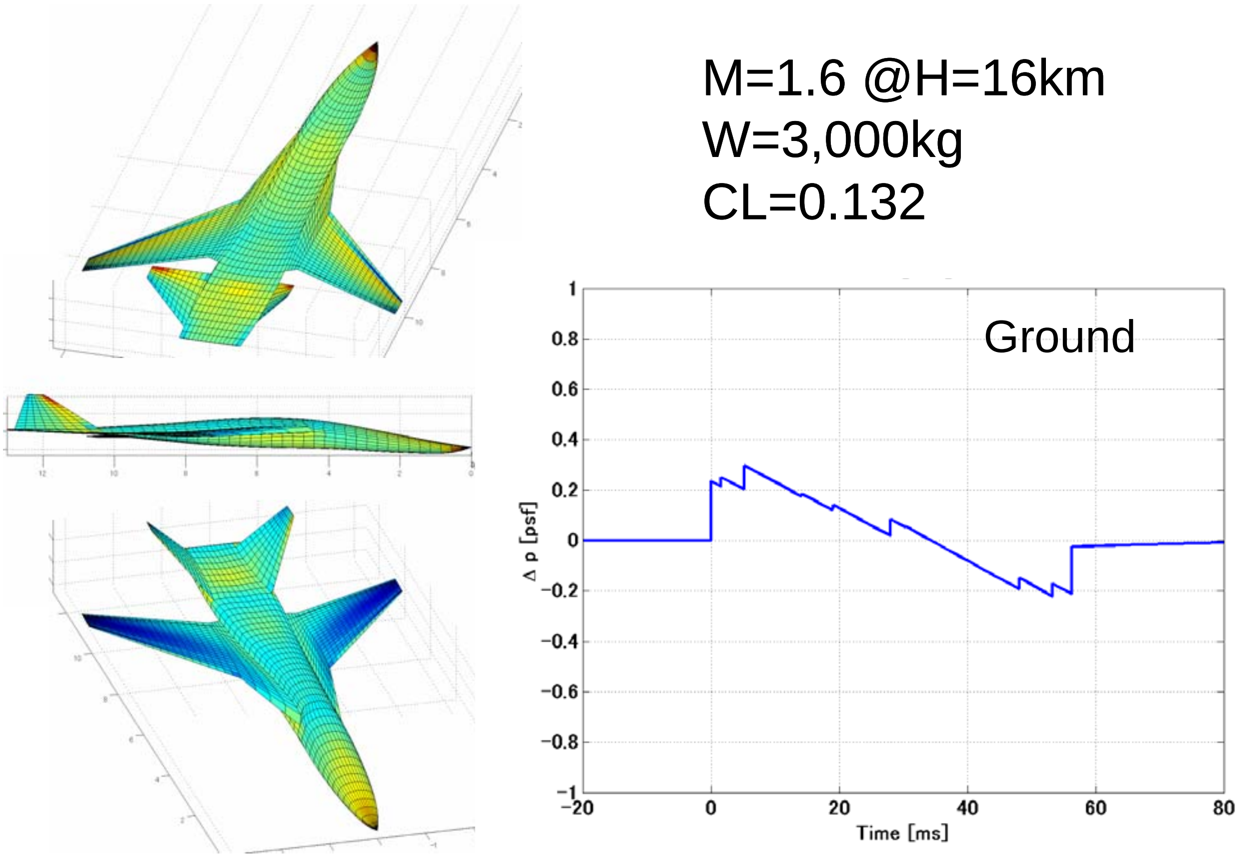

Fig.6 Low-boom design by CAPAS

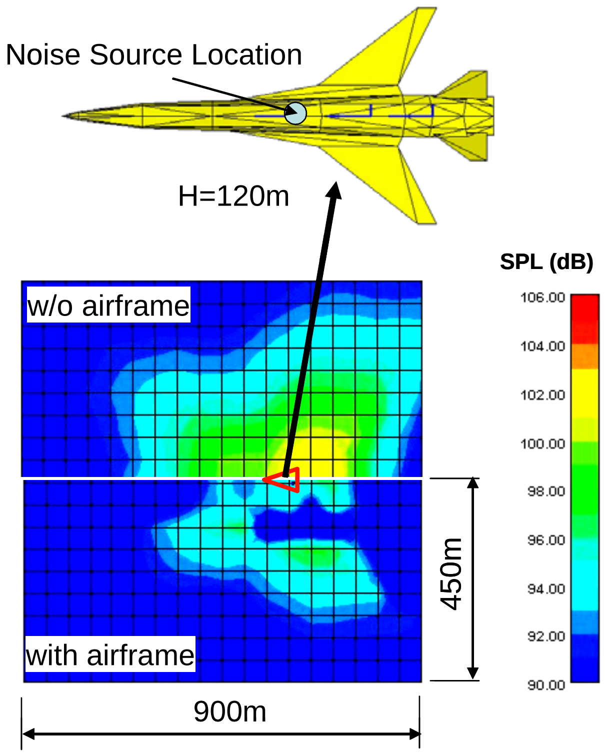

Fig.7 Effect of fan-noise shielding[5]

effective tail configuration for jet-noise shielding. Fig.9 shows a sample result for V-tail design.

4.3 Flight Experiments

Fig.10 shows the schematic of the flight experiment. The demonstrator takes off and climbs up to about 12-16km at M0.8. After accelerating to M1.2-1.6, supersonic flight at a variety of flight conditions is made for about 5 minutes to measure the sonic-boom on the ground and in the air. The noise measurements are also made at takeoff and landing. Flight time is approximately about 17minutes. We plan 20-30 flight trials for supersonic flight experiment, 10-15 trials for subsonic, especially for takeoff and landing noise measurement.

5.Conclusion

This paper presents the summary and current status of the Silent Supersonic Technology Demonstrator Project (S3TD project) in the Silent Supersonic Technology Demonstration Program at JAXA. The program targets are, 1)to reduce sonic boom by 50% with multi-disciplinary optimization design, 2)to reduce landing & takeoff noise by 50%(-3dB) with highly propulsion-airframe integrated design, and 3)to demonstrate advanced system integration technology such as advanced flight control system. In the S3TD project, we will develop the technology demonstrator which is an unmanned jet aircraft capable of supersonic cruise at Mach number of more than 1.4. The purpose of flight demonstration is to demonstrate 1) low-boom/low-drag concept obtained, 2) propulsion-airframe highly integrated design concept for low noise, and 3) advanced flight control system technology and composite material structure (provisional).

References

[1] Ohnuki T, Hirako K and Sakata K. National Experimental Transport Project. *ICAS 2006*, Hamburg, ICAS 2006-1.4.1, 2006.

[2] Horinouchi S. Conceptual Design of a Low Boom SSBJ. *43rd AIAA Aerospace Sciences Meeting and Exhibit*, Reno, Nevada, AIAA-2005-1018, 2005.

[3] Makino Y. Low-drag/low-sonic-boom design for supersonic airplane. *UK-Japan Bilateral Workshop on the Environmental Impact of Aircraft Emissions & Noise and Impact Reduction*, Tokyo, 2006.

[4] Makino Y. Near-Field Inverse Design Using Gradient-Based Optimization with Continuous Adjoint Sensitivity Analysis. *Computational Fluid Dynamics JOURNAL*, Oct. 2003, pp.509-515, 2003.

[5] Kawasaki Heavy Industries LTD., Conceptual Design Study for Silent Supersonic Technology Demonstrator (Part-1). *JAXA Contract Report*, 2006. (in Japanese)

[6] Imamura T, Amemiya K, Enomoto S and Yamamoto K. Development of Linearized Euler Equation Code and Its Application to Complicated Configuration. *Journal of the Japan Society for Aeronautical and Space Sciences*, Vol.53, No.621, pp. 452-460, 2005 (In Japanese)

[7] Chiba K, Imamura T, Amemiya K, Jeong S, and Yamamoto K. Design Exploration of Shielding Effect for Aircraft Engine Noise. *Transactions of the Japan Society for Aeronautical and Space Sciences*. (to be published)

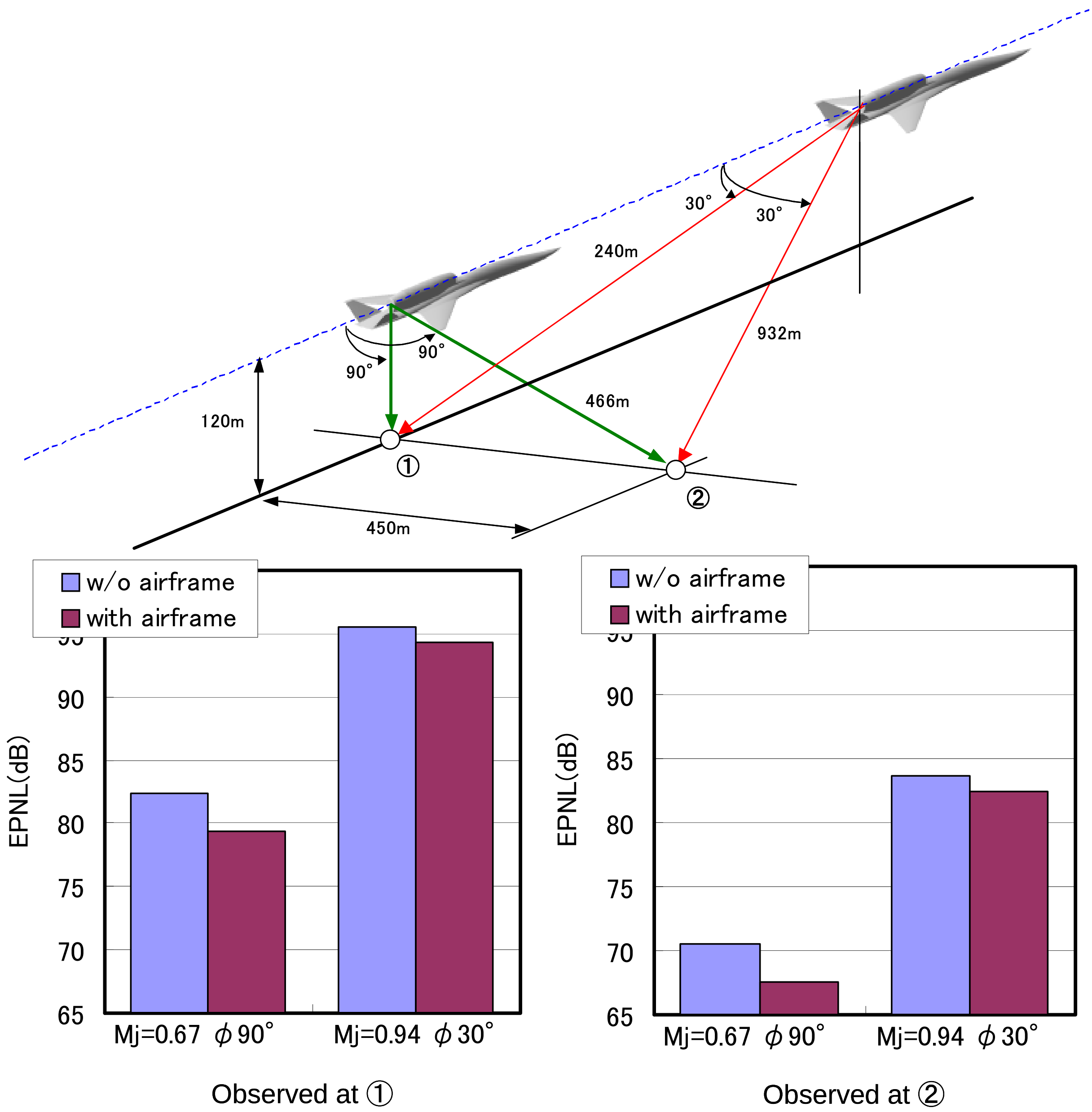

Fig.8 Effect of jet-noise shielding by airframe[5]

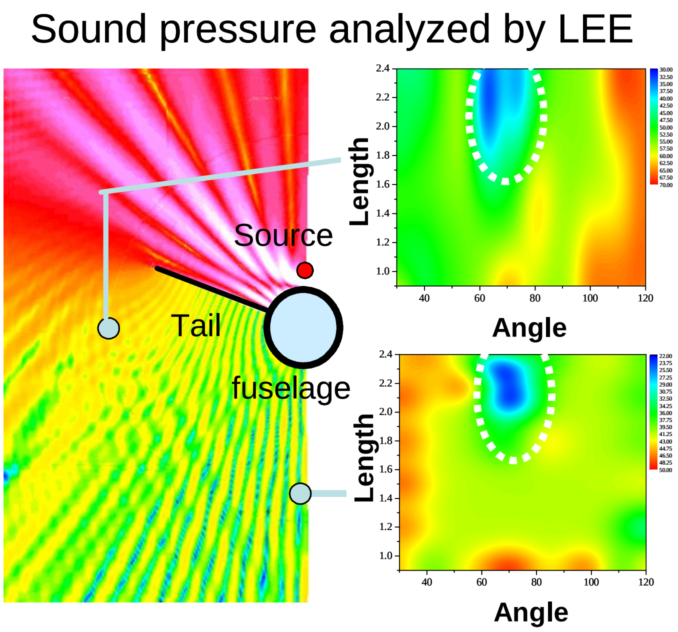

Fig.9 Sample result of V-tail design for jet-noise shielding

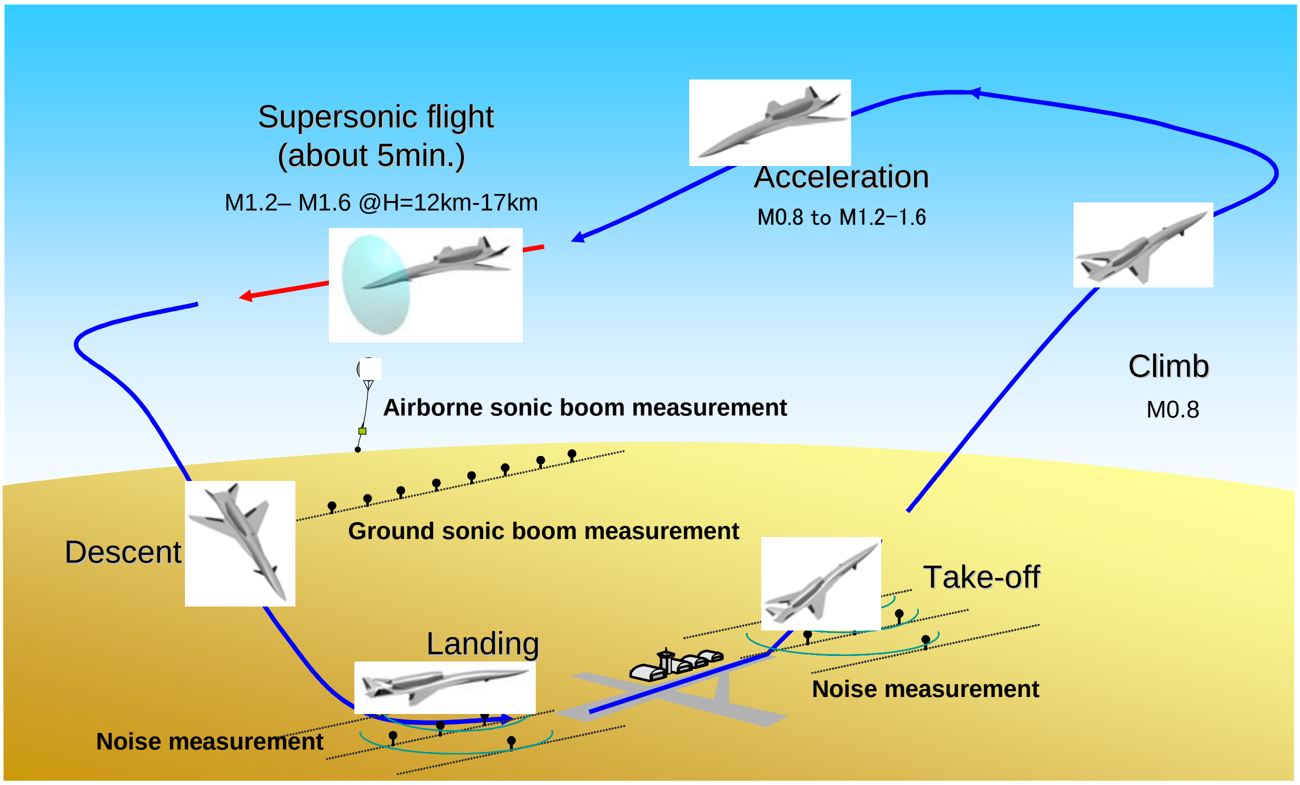

Fig.10 Schematic image of flight experiment