Silent Supersonic Technology Demonstrator Project

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1. Introduction

Japan Aerospace Exploration Agency (JAXA) has promoted the "Next Generation Supersonic Aircraft Technology Research Program" 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 year 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]. JAXA has also performed the research on silent supersonic technologies such as low-boom/low-drag configuration design methodology and low noise technology as a part of this program. In JFY2006, JAXA started the "Silent Supersonic Technology Demonstration Program" focused on such technologies as a post-program of the "Next Generation Supersonic Aircraft Technology Research Program"(Fig.1). 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 in order to validate the multi-disciplinary optimization design tool for supersonic aircraft and to demonstrate
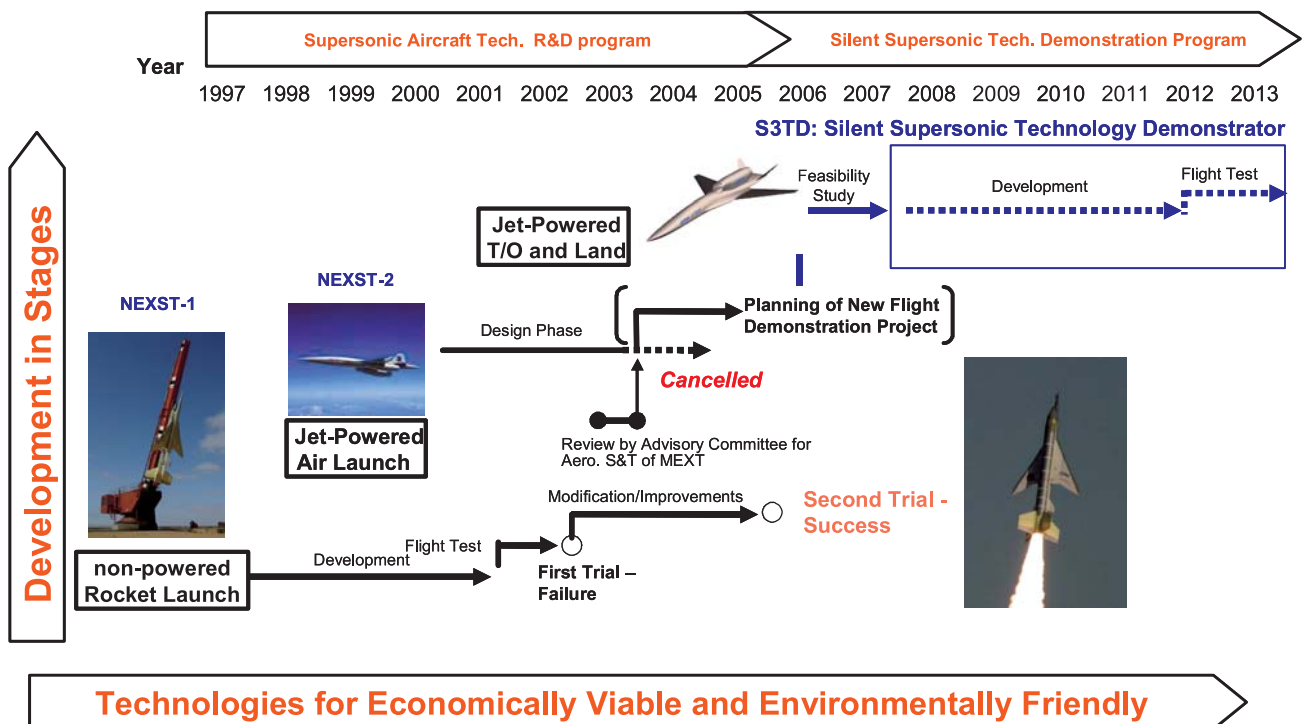

Fig.1 Supersonic research and development project in JAXA

the silent supersonic aircraft concept.   This paper describes the summary of S3TD project and the current status of the flight demonstrator design.

2. Silent Supersonic Technology Demonstration Program

The S3TD Project is the core project of the "Silent Supersonic Technology Demonstration Program".   The objective of this program is to achieve technology level to realize economically-viable,   environmentally-friendly small supersonic transport, as a technological step for larger supersonic transport.   The program targets are shown in Table.1.   The total budget is estimated at the present time to be about 20billion Japanese Yen.   This program is 8 year program(Fig.2), and has three activities as the followings;

(1)Flight Demonstration ("S3TD" Project)

Development and flight experiments of S3TD to demonstrate low-boom design concept

(2)R&D on Computational Design Technology

R&D on High fidelity Computational Fluid Dynamics(CFD) and Computational Aero-Acoustics(CAA), Multi-disciplinary Design Optimization(MDO), etc.

(3)R&D on Silent Supersonic Vehicle Technology

Basic research for aerodynamics ,structure, propulsion technologies, and ground testing.

Table 1 Program Targets

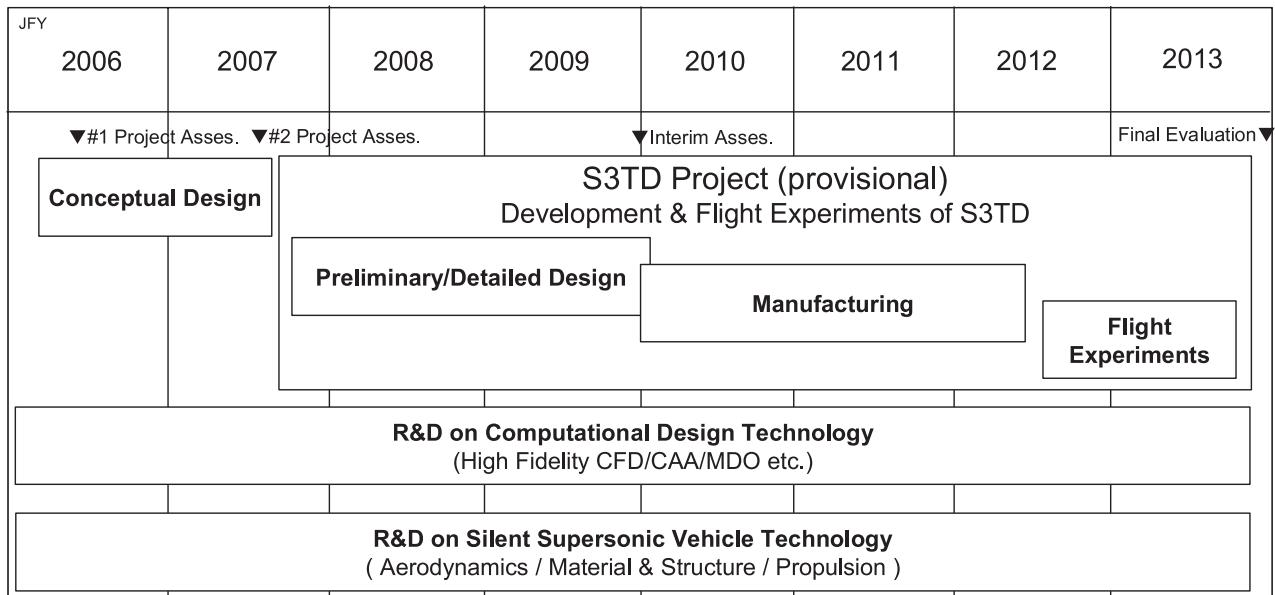| Reference Aircraft	small supersonic transport (30-50pax.) Mach 1.6 – 2.0 Range >3,500nm MTOW 65 - 70ton
Sonic Boom Reduction	50% (<0.5psf for small SST)
Lift to Drag Ratio	more than 8.0 (M2.0 cruise) for small SST
Weight Reduction	12% (provisional) ref. to Concorde tech.
Noise Reduction	3dB by Noise Shielding (meet to Chap.4 with margin)

JFY 2006	2007	2008	2009	2010	2011	2012	2013

▼#1 Project Asses. ▼#2 Project Asses.   ▼Interim Asses.   Final Evaluation▼

Conceptual Design

S3TD Project (provisional)
Development & Flight Experiments of S3TD

Preliminary/Detailed Design

Manufacturing

Flight Experiments

R&D on Computational Design Technology
(High Fidelity CFD/CAA/MDO etc.)

R&D on Silent Supersonic Vehicle Technology
(Aerodynamics / Material & Structure / Propulsion)

Fig.2 Schedule of Silent Supersonic Technology Demonstration Program

3. "S3TD" Project

3.1 Project Targets

The S3TD project 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 project are the followings;

3.1.1 Reduce Sonic-boom Intensity by 50%

Sonic-boom is one of the biggest environmental problems for supersonic overland flight. Fig.3 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 project 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 project, 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 multi-objective optimization(MOO) and MDO design methodologies.

3.1.2 Reduce Landing and Takeoff noise 3dB by Airframe Shielding

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 project, 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 project target is to reduce LTO noise 3dB by shielding the engine noise, especially fan-noise. During the design of the S3TD, we will apply both high fidelity CFD and 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.

3.1.3 Demonstrate System Integration Technology

One of the objectives of this project 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.
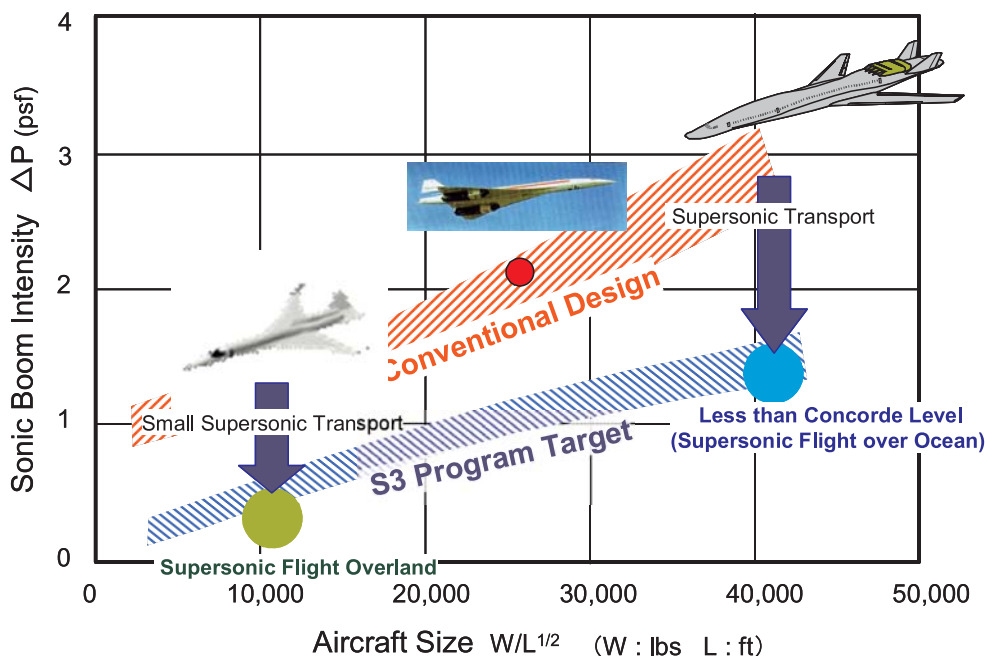

Fig.3 Estimated shock overpressure[2]

3.2 Schedule

The "S3TD" project is in conceptual design phase, the schedule after JFY2007 in Fig.2 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 2 shows design requirements of the S3TD in the first conceptual design study.   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 2 Design requirements

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

Wo   3,200kg
L   13.0m
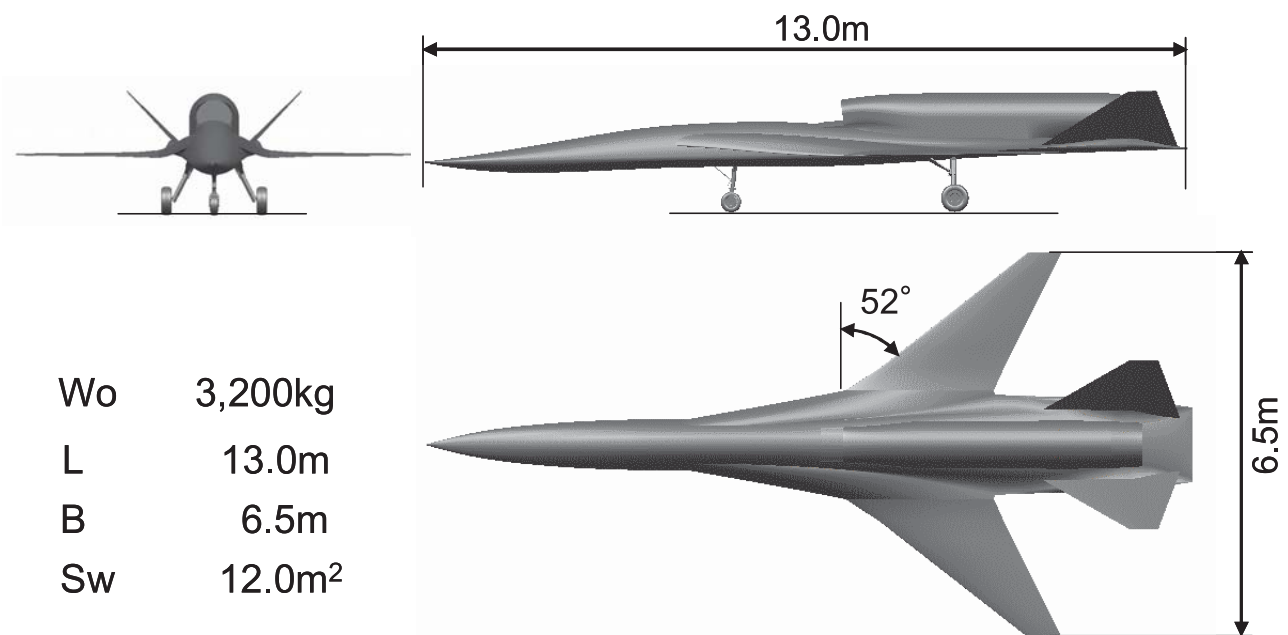B   6.5m
Sw   12.0m²

Fig.4 S3TD base-line configuration

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 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 investigated because the rear shock boom signature is so sensitive to flight condition.   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.
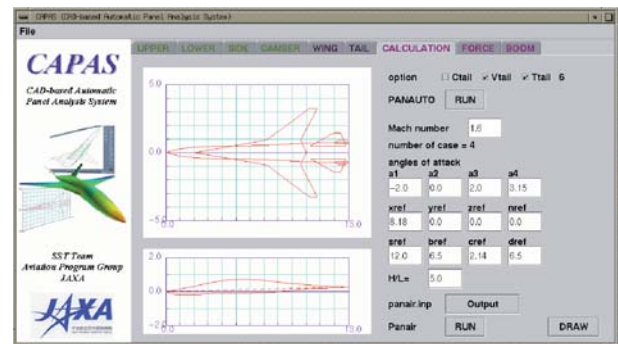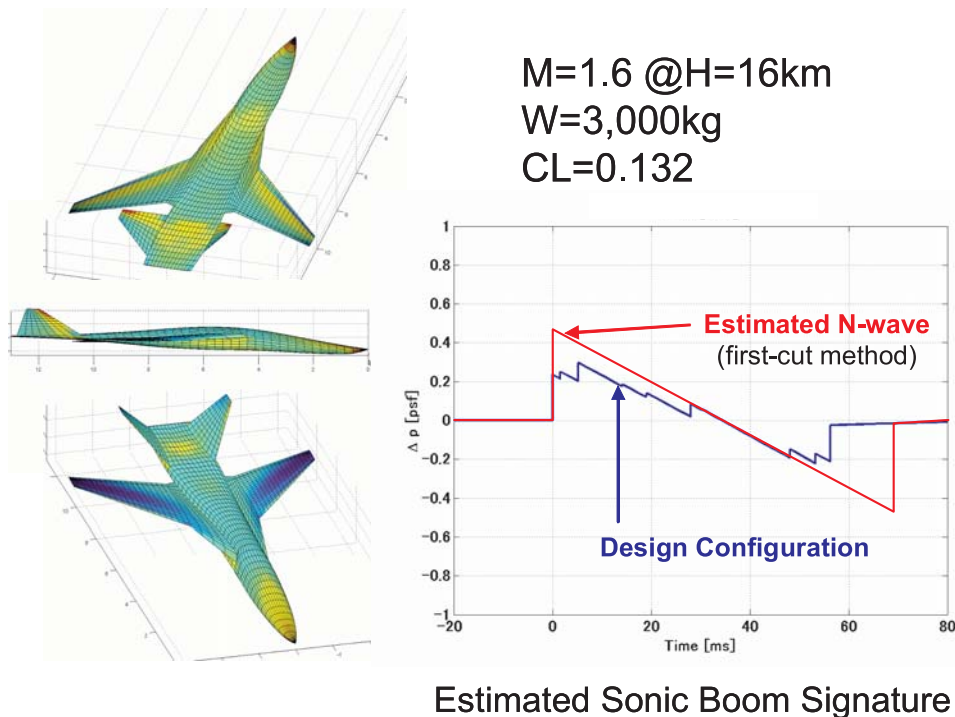

Fig.5 CAPAS
(CAD based Automatic Panel Analysis System)

M=1.6 @H=16km
W=3,000kg
CL=0.132

Estimated Sonic Boom Signature

Fig.6   Low-boom design by CAPAS

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].   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 effective tail configuration for jet-noise shielding.
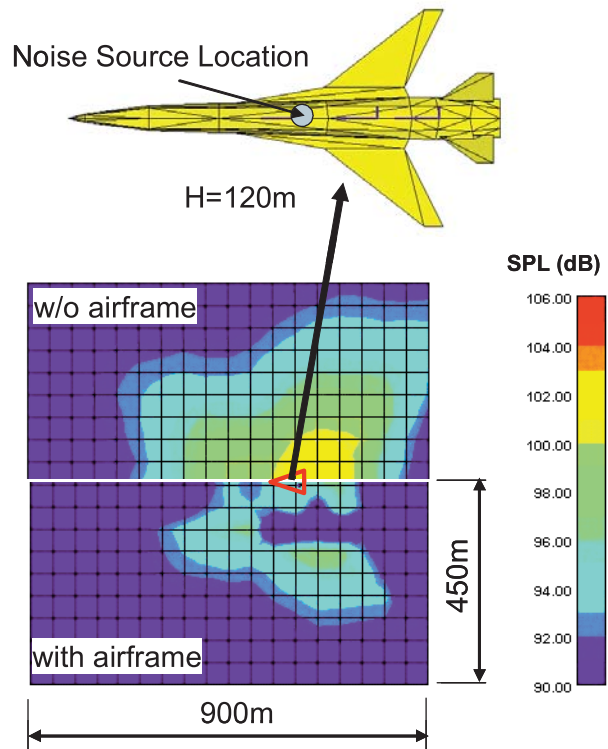

Fig.7 Effect of fan-noise shielding[5]

4.3 Flight Experiments

Fig.8 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 project targets are, 1)to reduce sonic boom by 50% with multi-disciplinary optimization design, 2)to reduce landing & takeoff noise 3dB by noise shielding with highly propulsion-airframe integrated design, and 3)to demonstrate advanced system integration technology such as advanced flight control system.   The first phase conceptual design study of has been just completed using the low-fidelity design tools, and in the next phase we will refine the base-line configuration using the high-fidelity tools identify the design requirements for the preliminary design phase in the next fiscal year.

References

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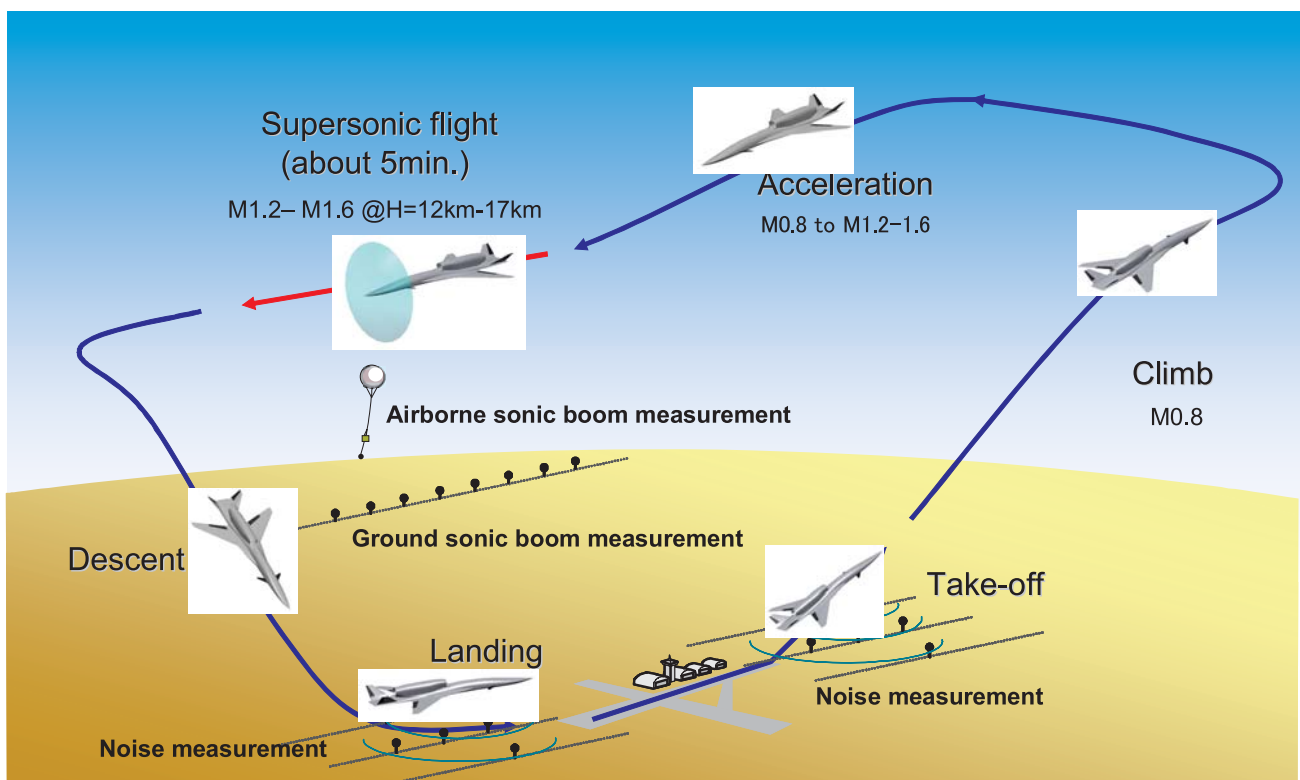
Fig.8 Schematic image of flight experiment