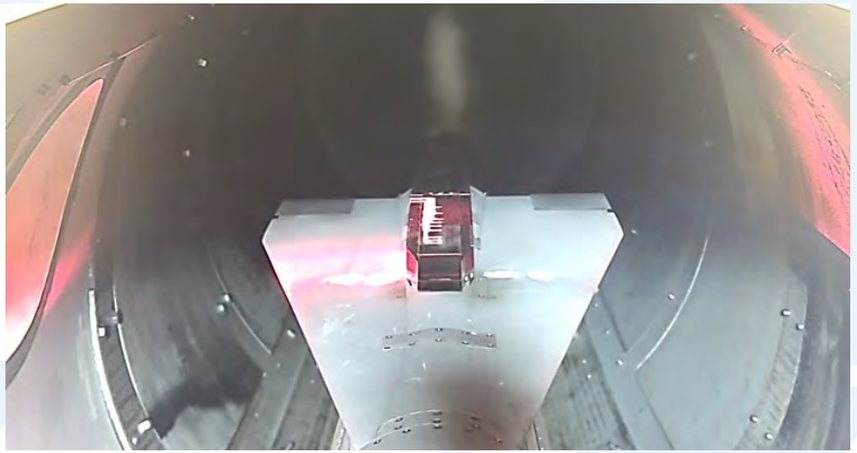
Design Analyses and Demonstration Tests of High-Mach Integrated Control Experiment Aircraft (HIMICO)







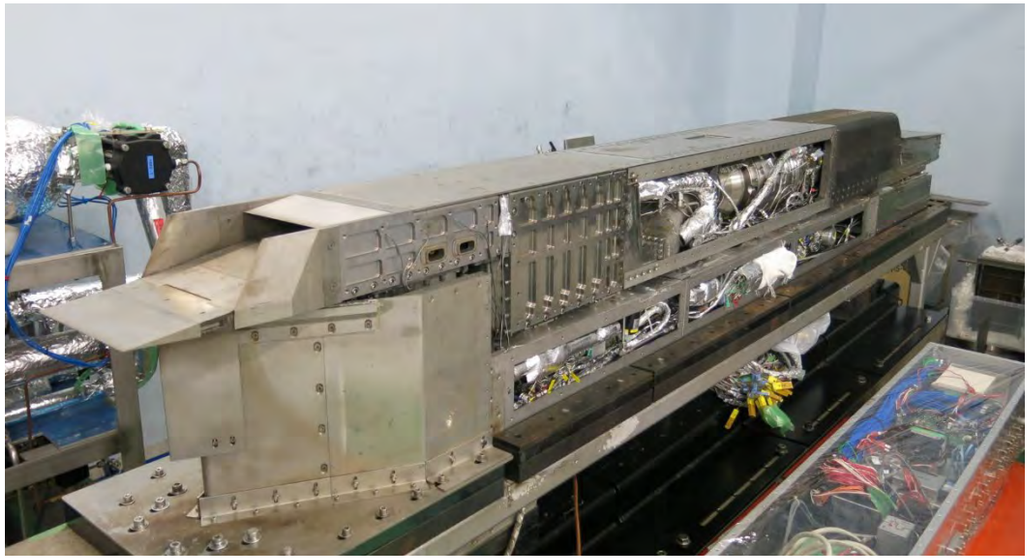
Hideyuki Taguchi (Tokyo University of Science)
Tetsuya Sato, Asei Tezuka, Chiro Fujio (Waseda University)
Mitsuhiro Tsue, Takeshi Tsuchiya, Shinji Nakaya, Kengo Takizawa (The University of Tokyo)
Akiko Matsuo (Keio University)
Tomonari Hirotani, Hidemi Takahashi, Motoyuki Hongoh,Masaru Koga, Tatsushi Isono
(Japan Aerospace Exploration Agency)



Hydrogen Jet Engine Research for Hypersonic Aircraft

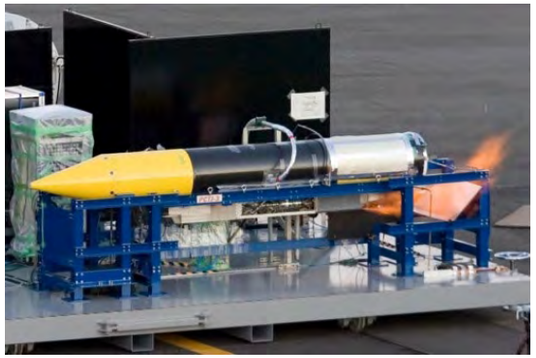


Hypersonic Aircraft

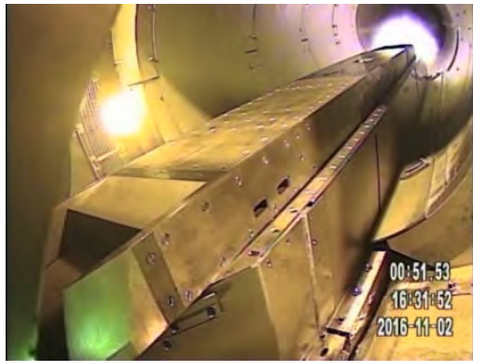


Hydrogen Pre-Cooled Turbojet Engine

- Hydrogen pre-cooled turbojet engine has been developed aiming at Mach 5 class hypersonic aircraft.
- Stable hydrogen combustor has been demonstrated by LH2 fuel supply system with supercritical condition.
- Next step will be a flight demonstration of this technology integrated with aircraft in a real flight environment.



Ground Level Test

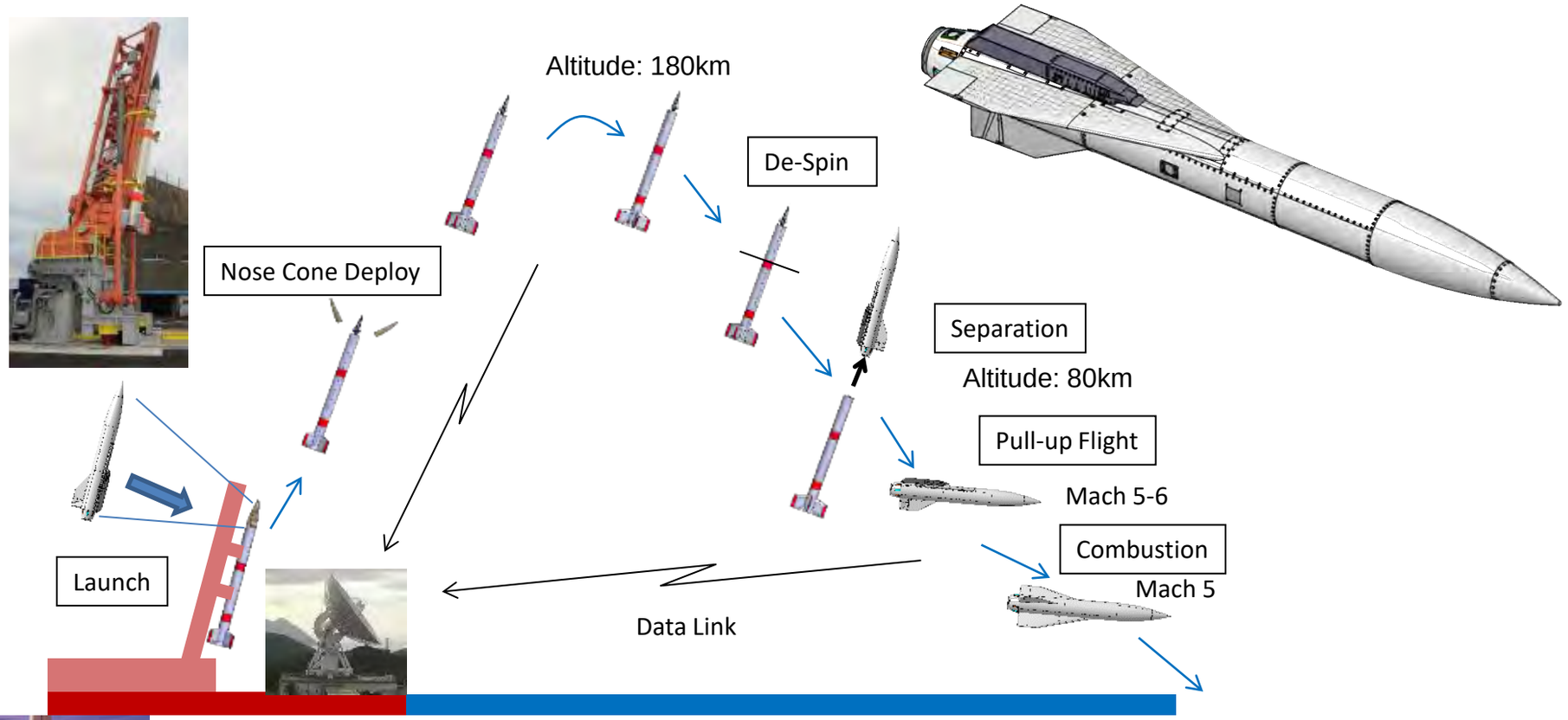


Mach 4-5 Wind Tunnel Tests



Mach 5 Flight Experiment of HIMICO

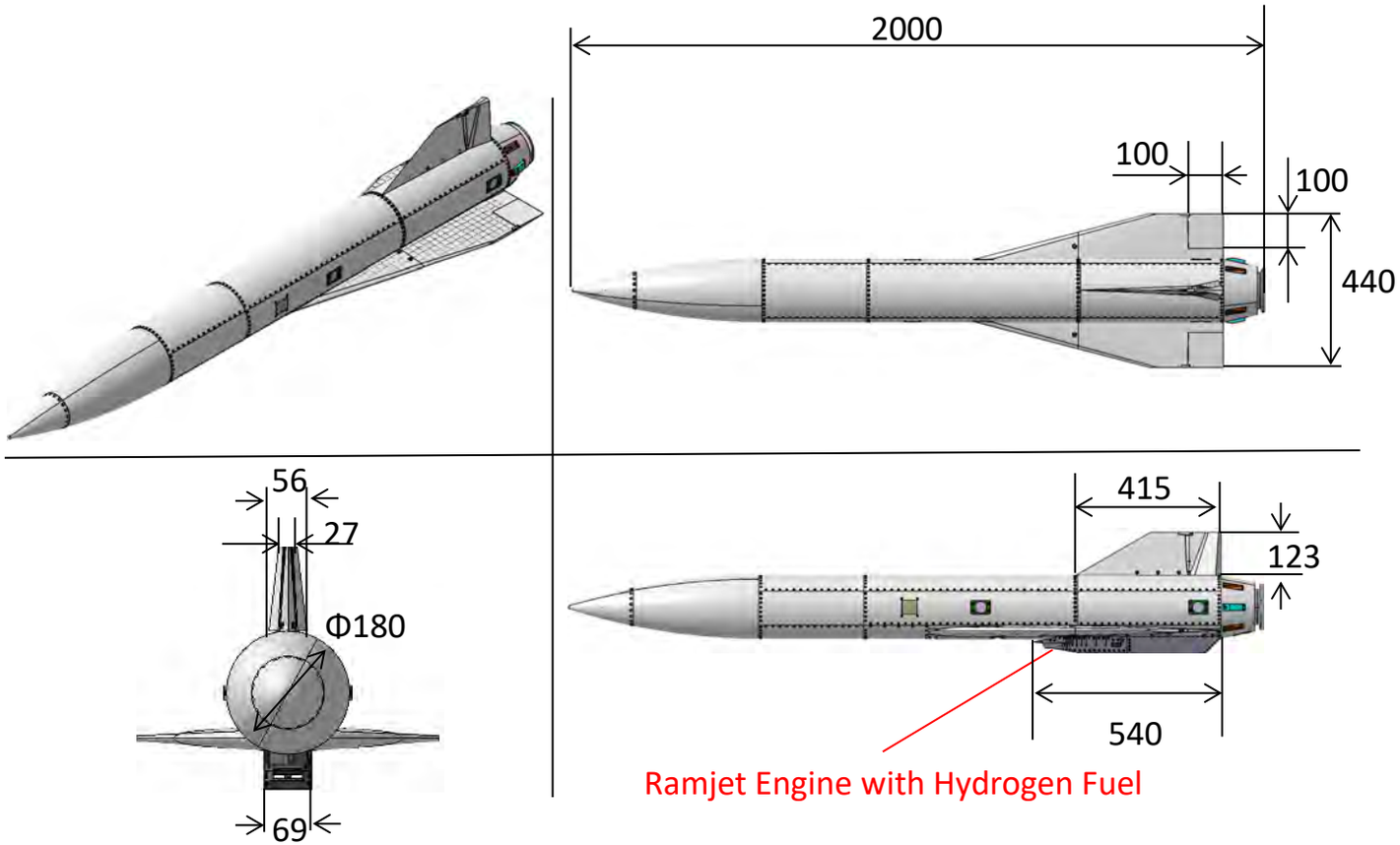
- The experimental aircraft is planned to demonstrate airframe / propulsion integrated control method in a real flight environment.
- The aircraft will fly with very high angle of attack to attain horizontal trajectory with the constant dynamic pressure after the ballistic trajectory.
- The hypersonic ramjet engine, simulating the PCTJ engine, will be operated under Mach 5 flight environment to acquire the propulsive performance.

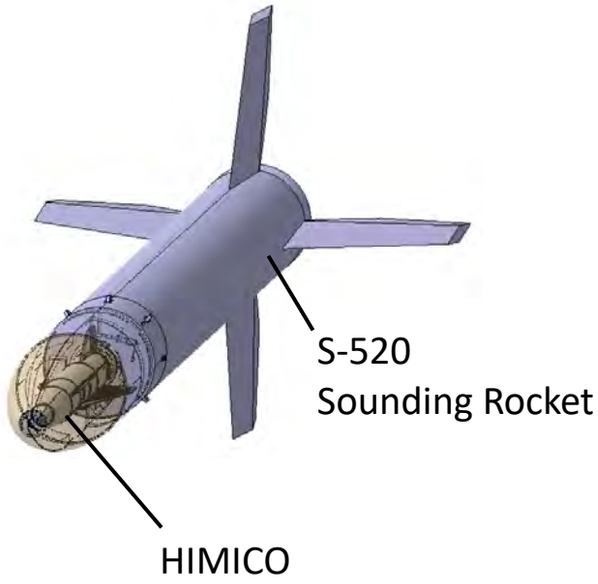


Flight Profile of HIMICO (Waseda University, Keio University, The University of Tokyo, Tokyo University of Science)

HIMICO aircraft shape

- The wing and elevon areas were set to achieve the flight with high angle of attack to attain constant dynamic pressure trajectory.
- The wall angle of the rear vertical stabilizer was set to ensure directional stability.
- The fuselage length was extended to add a flight termination unit.

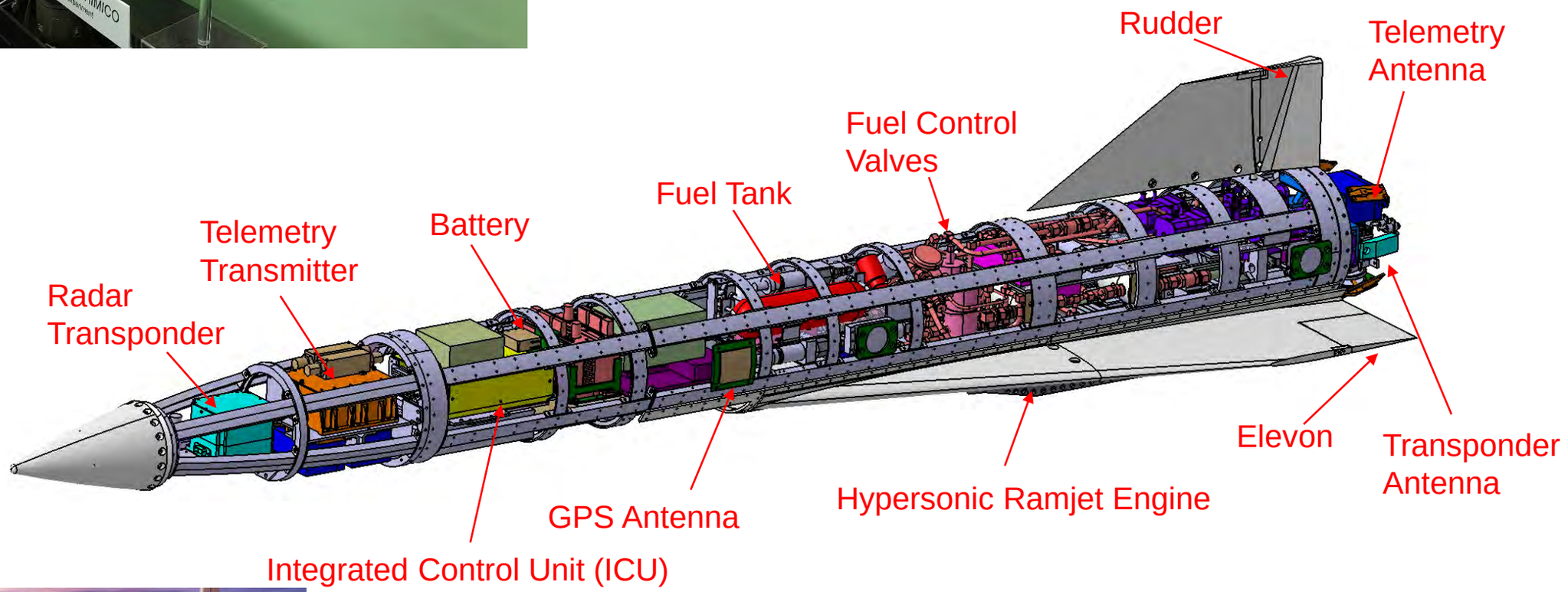




HIMICO Flight Control and Communication System



- A radar transponder and a telemetry transmitter are installed inside of the aircraft.
- Elevons on the main wing is used for the pitch and roll control.
- A rudder on the vertical tail wing is used for yaw control.
- The integrated control unit (ICU) is under development to measure the position and attitude of the aircraft.

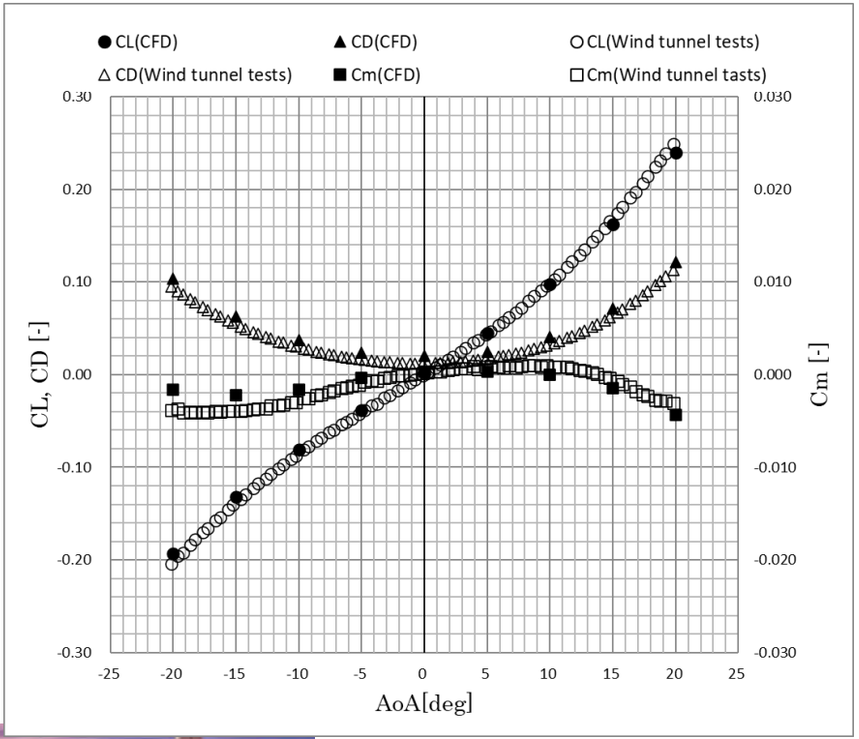


Hypersonic Wind Tunnel Tests / Aerodynamic Analysis

- Mach 5 Wind Tunnel Experiment has been conducted at hypersonic wind tunnel facility (HWT) in JAXA.
- The model has a flow through duct simulating the hypersonic ramjet engine without combustion.

Test Condition (JAXA-HWT1)

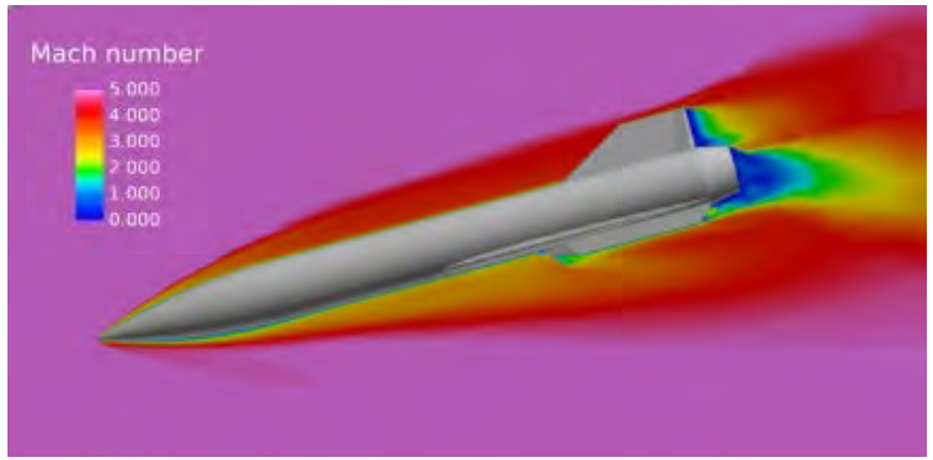
Mach	5	
Total Pressure	1.0	MPa
Total Temperature	700	K
Angle of Attack (AoA)	-20 - 20	deg



Comparison of aerodynamic coefficients (Mach 5)



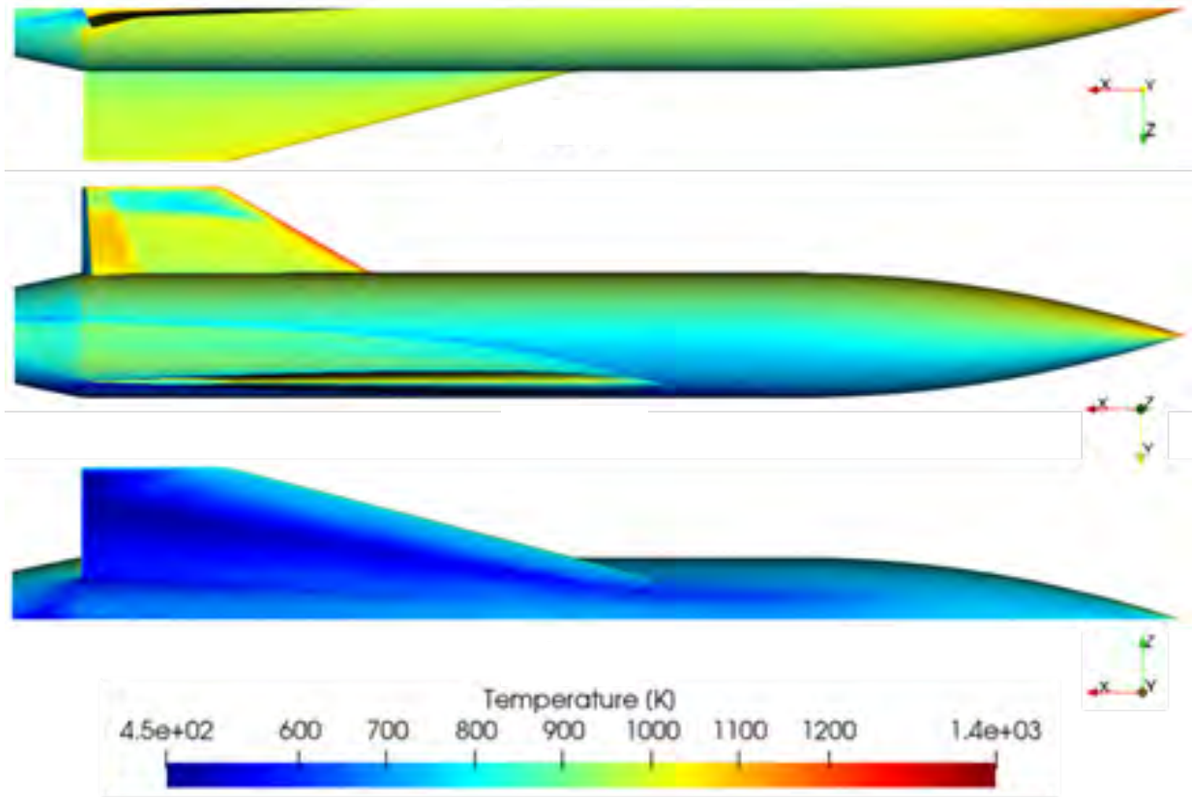
Wind tunnel testing Mach 5, α=-15deg



CFD analysis Mach 5, α=-15deg

HIMICO Aerodynamic Heating Analysis

- The heat flux distribution during high-angle-of-attack flight was estimated.
- The aircraft surface temperature under radiation equilibrium condition was estimated
- The strength of the aircraft structure was evaluated based on the result.



Heat flux distribution (Keio Univ.)

Hypersonic Intake Wind Tunnel Test

- Wind tunnel test of the hypersonic intake was conducted at the hypersonic wind tunnel in JAXA Chofu Aerospace Center.
- The starting range under Mach 5 flight conditions and performance maps for mass flow capture ratio and total pressure recovery rate was obtained.
- Shock wave position control tests was conducted to prevent unstarting driven by the change of downstream condition.

Air velocity:	Mach 5
Total temperature:	650 K
Total pressure:	1 MPa
Heating type:	Storage Heating



Hydrogen Ramjet Engine Installation



a) Starting state (supercritical)



b) Starting state (Critical point)



c) Unstarting state



d) Buzz state

Schlieren image of the flow around the intake



Hypersonic Intake Control Experiment

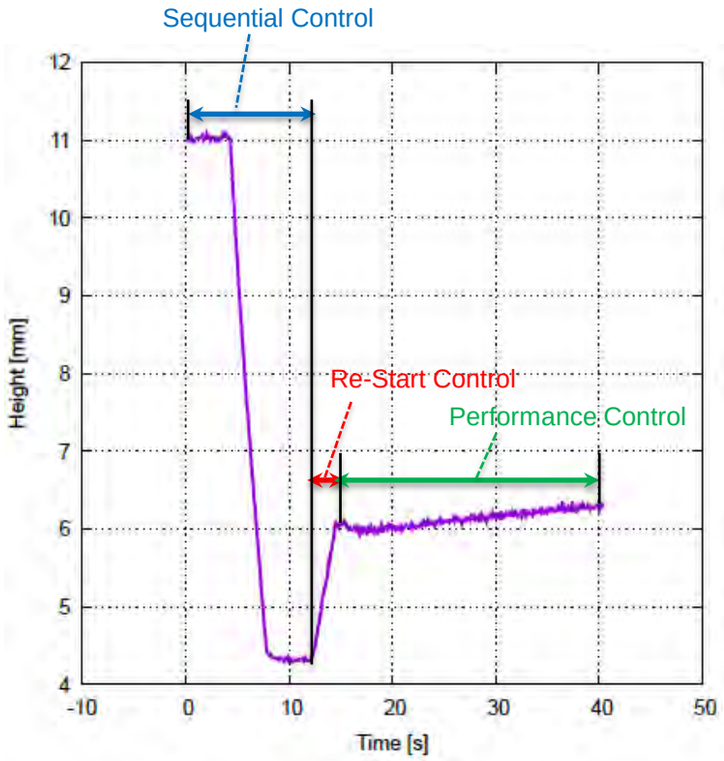
Stage 1: Sequence control (0–12 s); nozzle throat height changes from 11 mm to 4.5 mm

Total pressure recovery ratio: Peak (0.09) → Intake unstart (0.076)

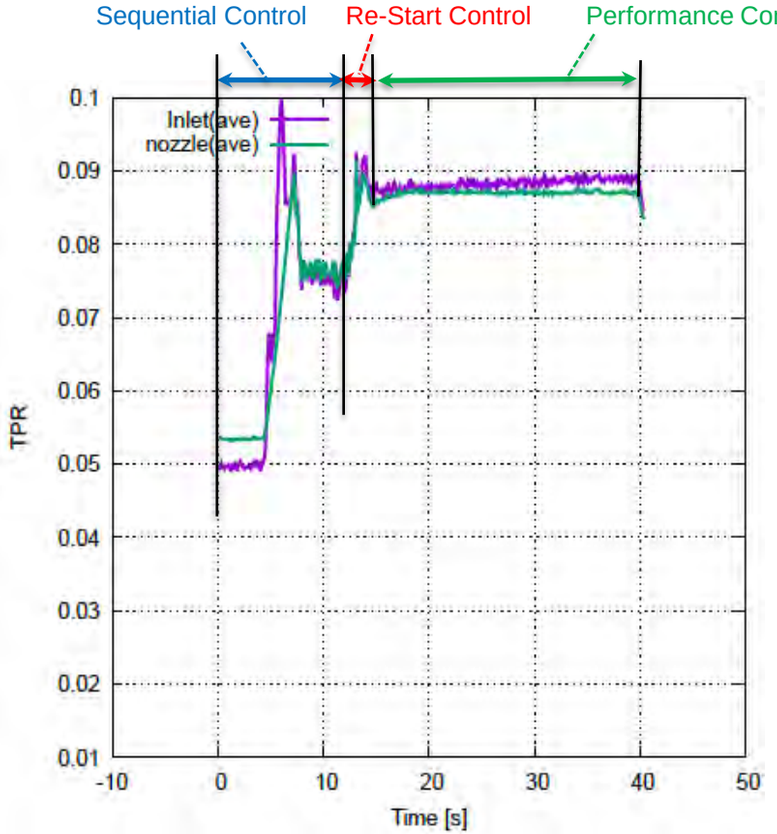
Stage 2: Restart control (12–15 s); nozzle throat height changes from 4.5 mm to 6 mm

Total pressure recovery ratio: Reaches peak during restart control; drops slightly after restart

Stage 3: Performance optimization control; maintain target total pressure recovery ratio by controlling nozzle throat height



Nozzle Throat Height

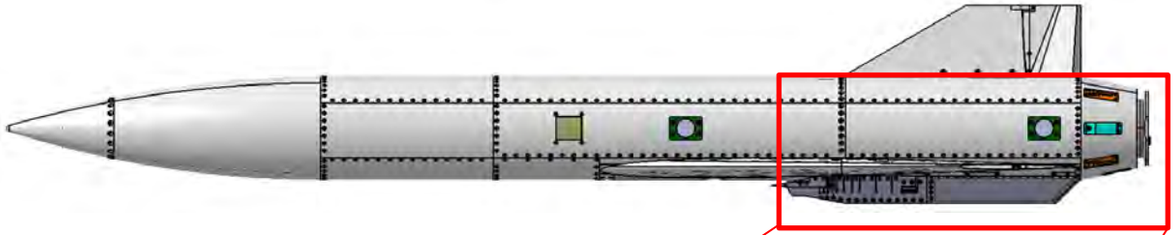


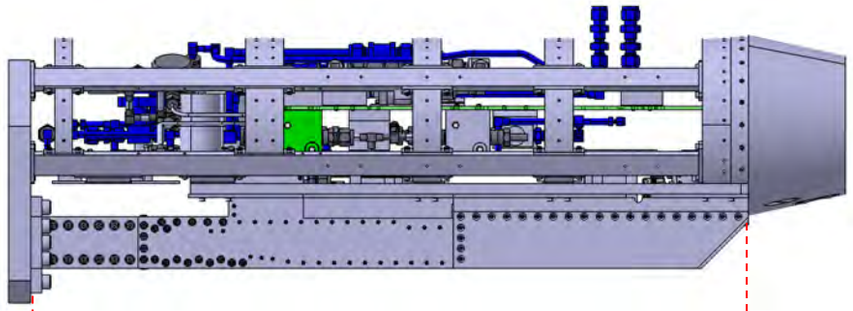
Total Pressure Recovery

Combustion Temperature Control Test of Hydrogen Ramjet Engine

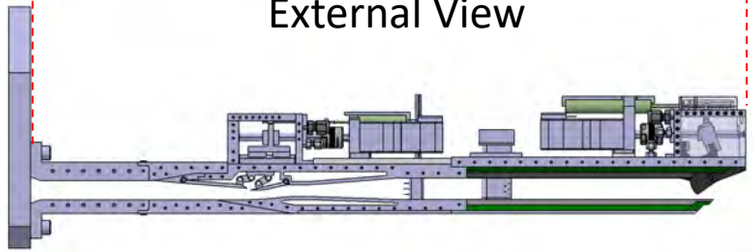
- The airflow rate into the engine varies depending on flight speed and aircraft attitude, so the fuel flow rate must be controlled autonomously.
- Tests to control combustion temperature were conducted at hypersonic high-enthalpy wind tunnel at the University of Tokyo.
- Several tests were conducted with different control gains to converge combustion temperature.

Total temperature:	900 K (equivalent to Mach 4)
Total pressure:	200 kPa (simulated intake outlet)
Heating type:	Storage Heating





External View



Cross Section



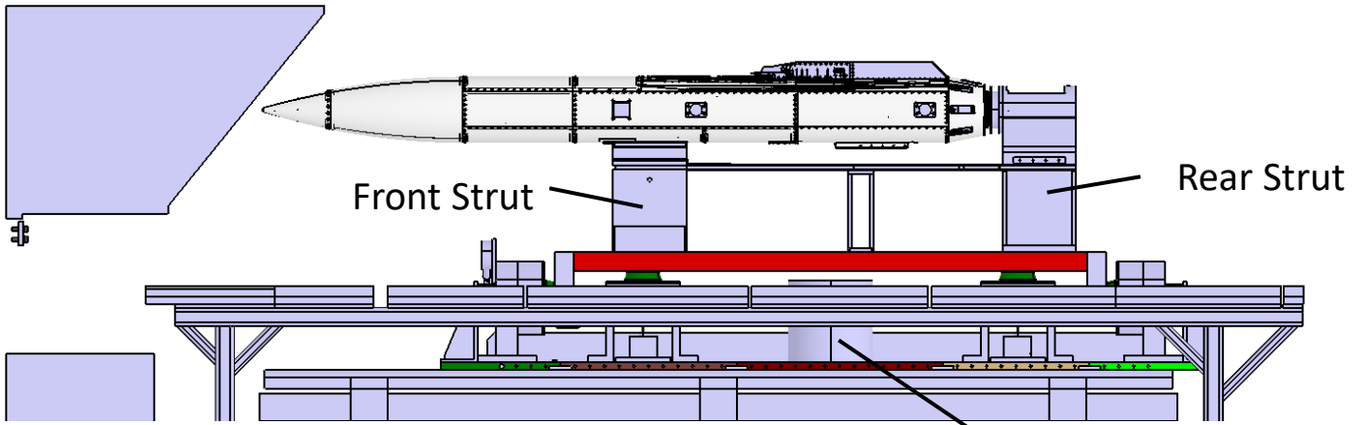
Hydrogen ramjet combustion test equipment

Mach 5 Propulsion Wind Tunnel Experiment of HIMICO

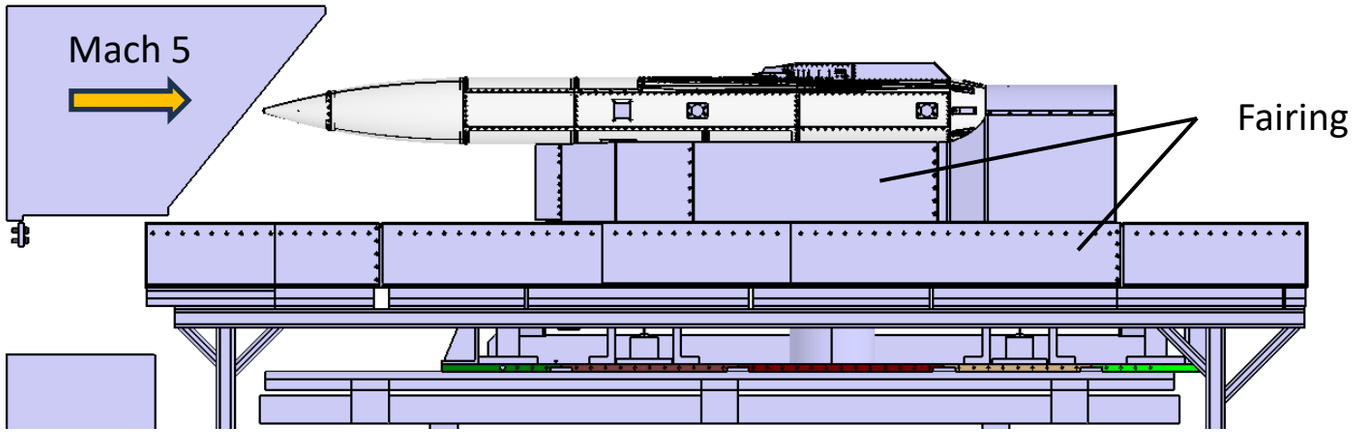
- The experiment was conduced in March,2026 at the Ramjet Engine Test Facility in JAXA Kakuda Space Center.
- The vehicle was supported by struts at the front and rear of fuselage to ensure the strength.
- The support structure and three-component balance were protected by a fairing.



Air Stream：	Mach 5
Total Temperature：	1320 K
Total Pressure：	1.34 MPa
Heating Type：	Combustion Heating



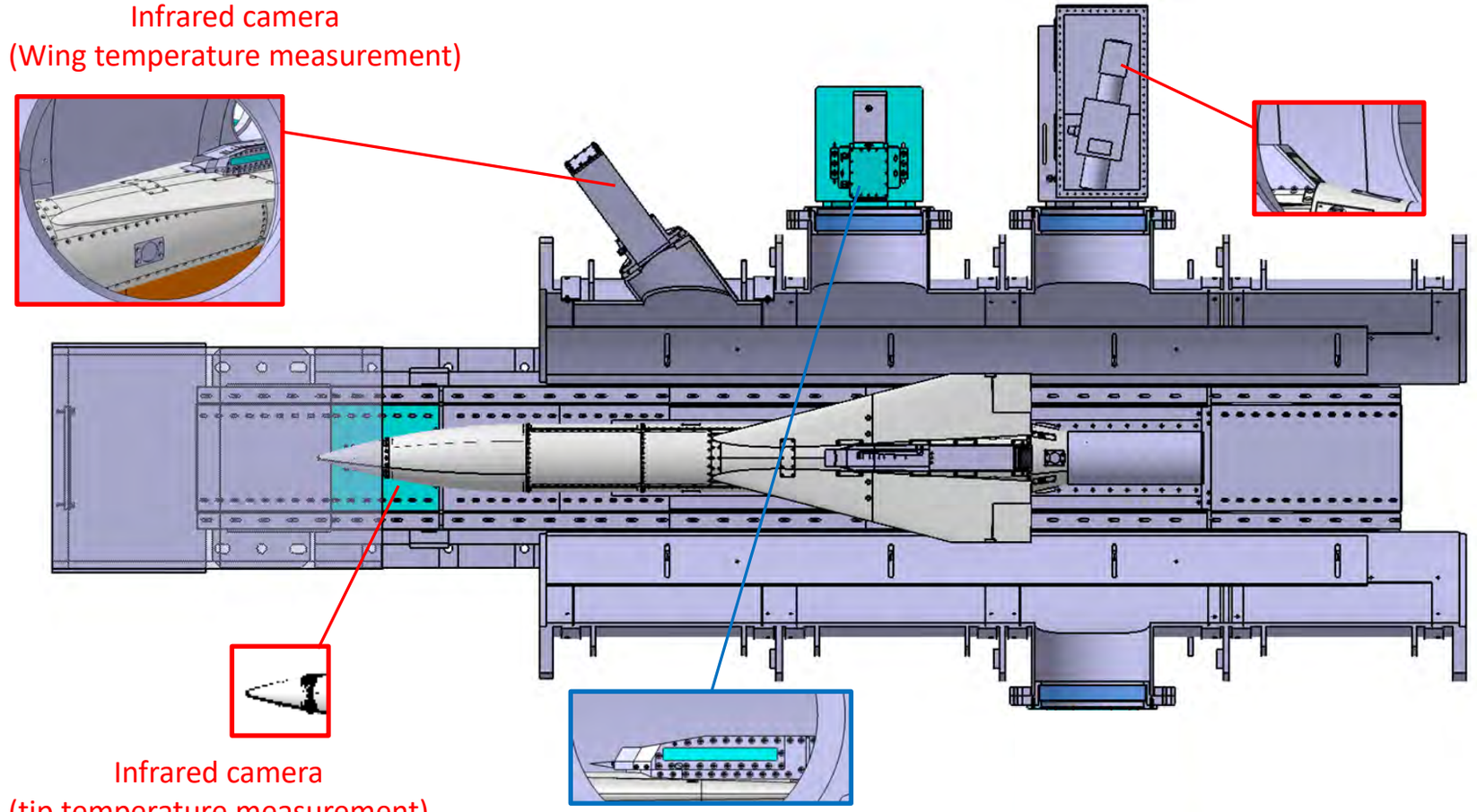
a) Strut installation status



b) Fairing installation status

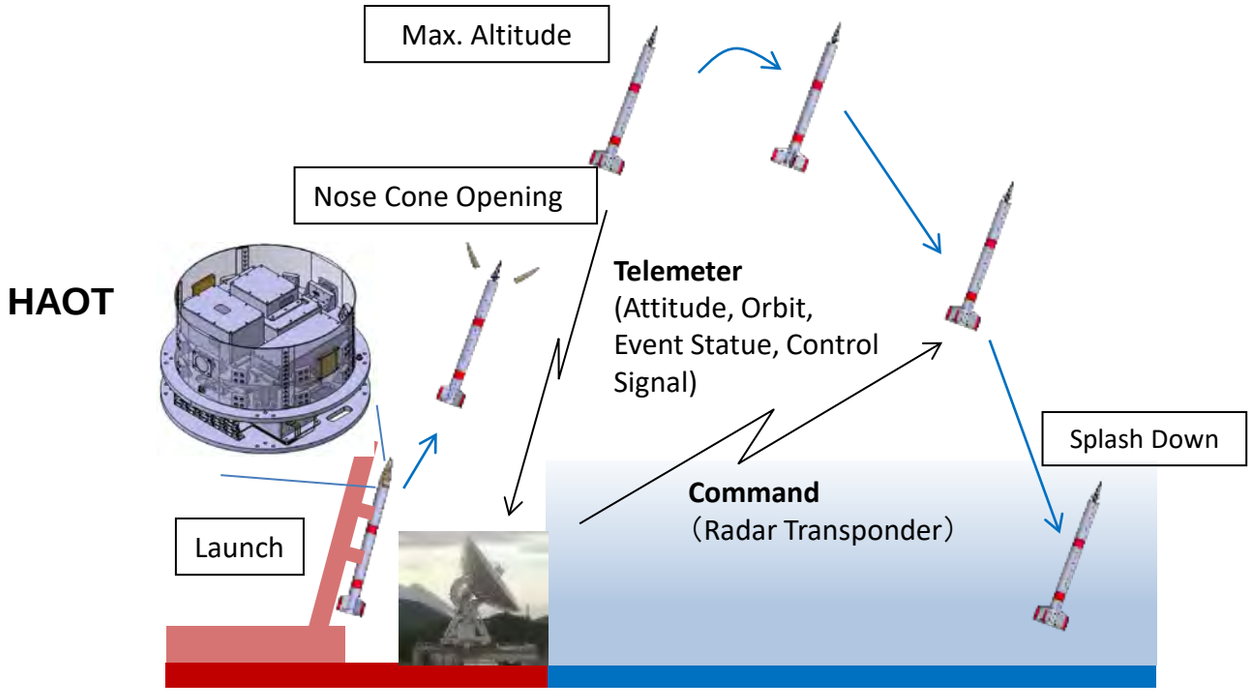
Flow Visualization around HIMICO Experimental Aircraft

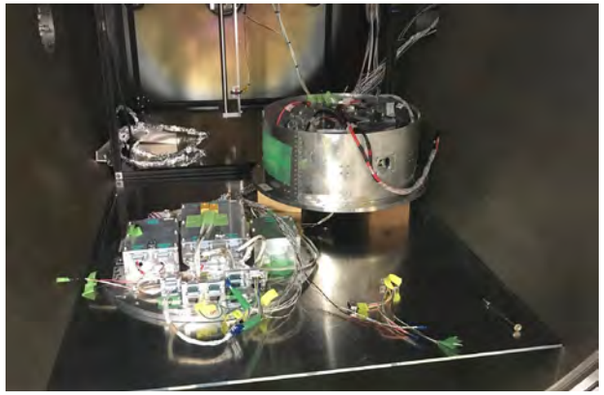
- Infrared camera: Tip temperature measurement, wing temperature measurement
- Near-infrared two-color camera: Exhaust temperature field measurement to predict the NOx generation
- Background Oriented Schlieren (BOS) camera: Intake internal flow



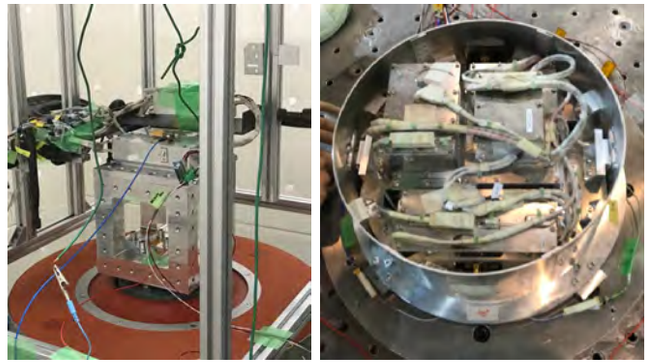
HIMICO Attitude and Orbit control Test (HAOT)

- In parallel with preparations for HIMICO propulsion wind tunnel test, preparations are also underway for the preliminary flight demonstration of the HIMICO Orbit and Attitude control Test (HAOT).
- HAOT is planned to demonstrate the equipment required for attitude and orbit control during the HIMICO flight experiment.
- The operational integrity of the Integrated Control Unit (ICU), Navigation Computing Unit (NCU), and Flight Abort Unit (FAU) is being verified.





Vacuum Environment Test



Mechanical Environment Test

Conclusions

Design analysis and verification tests of the hypersonic integrated control experimental aircraft (HIMICO) were conducted. The following findings were observed.

- The aerodynamic shape of the HIMICO experimental vehicle was designed, and aerodynamic coefficients were determined through wind tunnel testing and CFD analyses.
- A structural analysis of the HIMICO experimental vehicle was conducted, confirming that the onboard equipment could be protected from aerodynamic heating at Mach 5.
- The control law for the variable intake was verified in hypersonic wind tunnel test.
- The control law for the hydrogen ramjet combustor was verified in a combustion wind tunnel test.
- The HIMICO aircraft with a ramjet engine was tested in the Ramjet engine test facility with Mach 5 condition.
- Environmental tests of HIMICO Attitude and Orbit control Test (HAOT) was conducted to confirm the integrity of the onboard equipment under sounding rocket conditions.









