

Aeroheating test of entry capsule models in high-enthalpy and high-pressure flow

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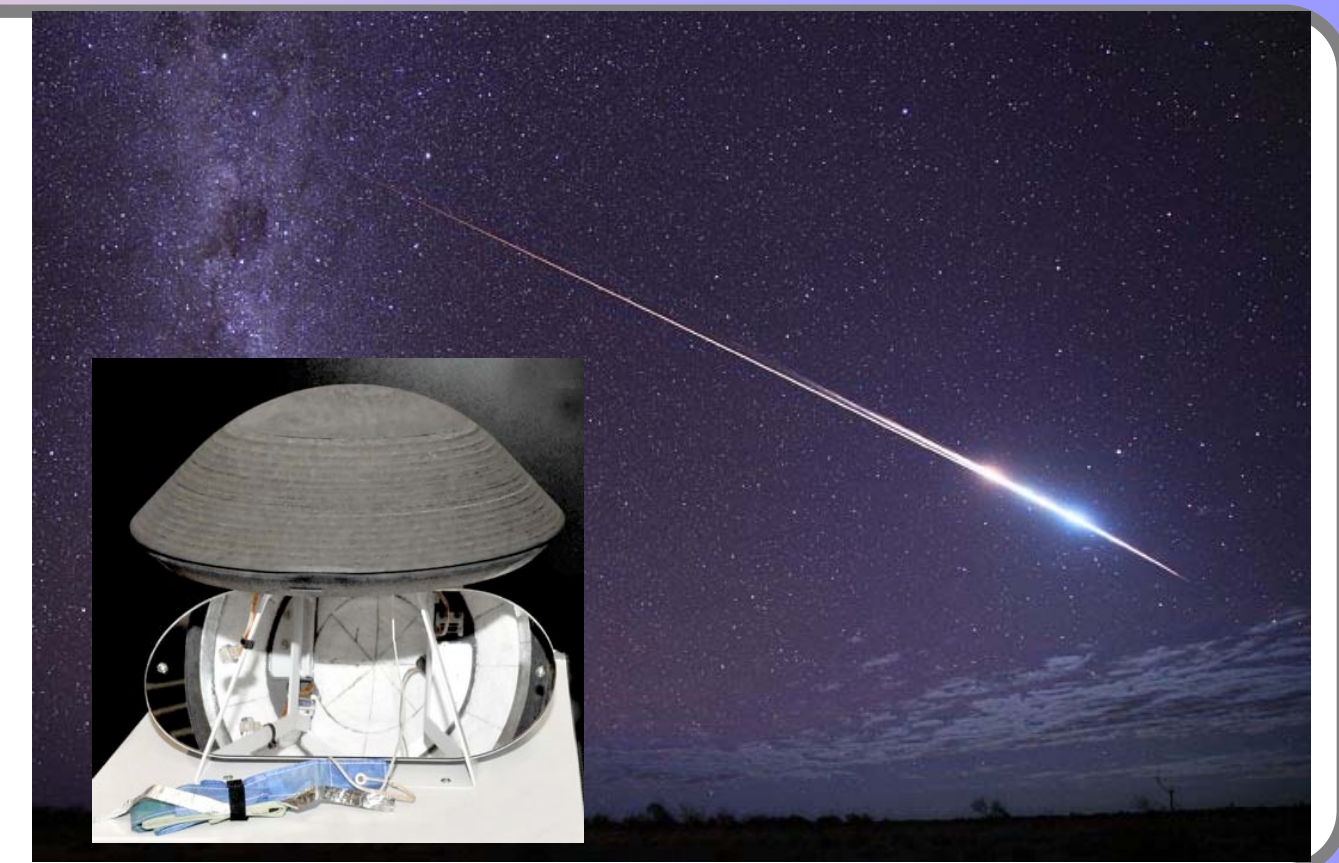
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Introduction

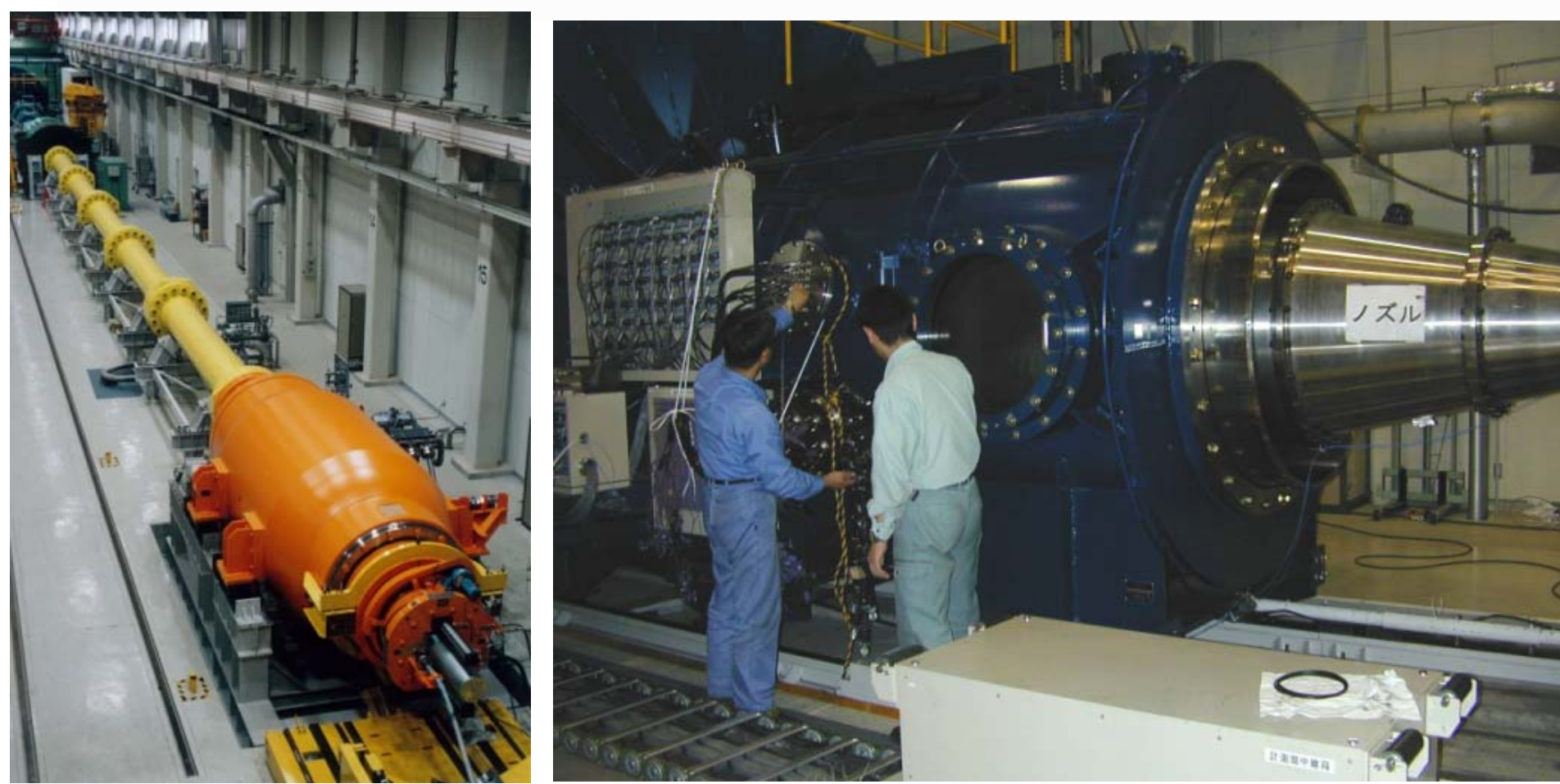
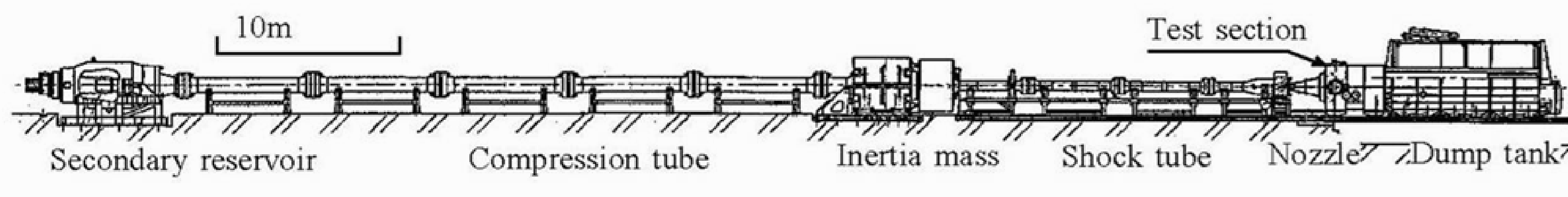
➤ **Object:** Aeroheating characteristics of Hayabusa capsule under real gas condition in the impulsive facility Hiest.

The model has thirty-two fast-response coaxial thermocouples on the windward to measure the heat flux distribution. Twelve thermocouples and eight Piezo-resistive pressure transducers were also mounted on the aft of the model and were used to determine flow establishment around the model. Stagnation enthalpy and stagnation pressure were varied from $H_0=3\text{MJ/kg}$ to 22MJ/kg , and from $P_0=14\text{MPa}$ to 50MPa , respectively. The unit Reynolds number under the condition was 0.9 million/m to 3 million/m.



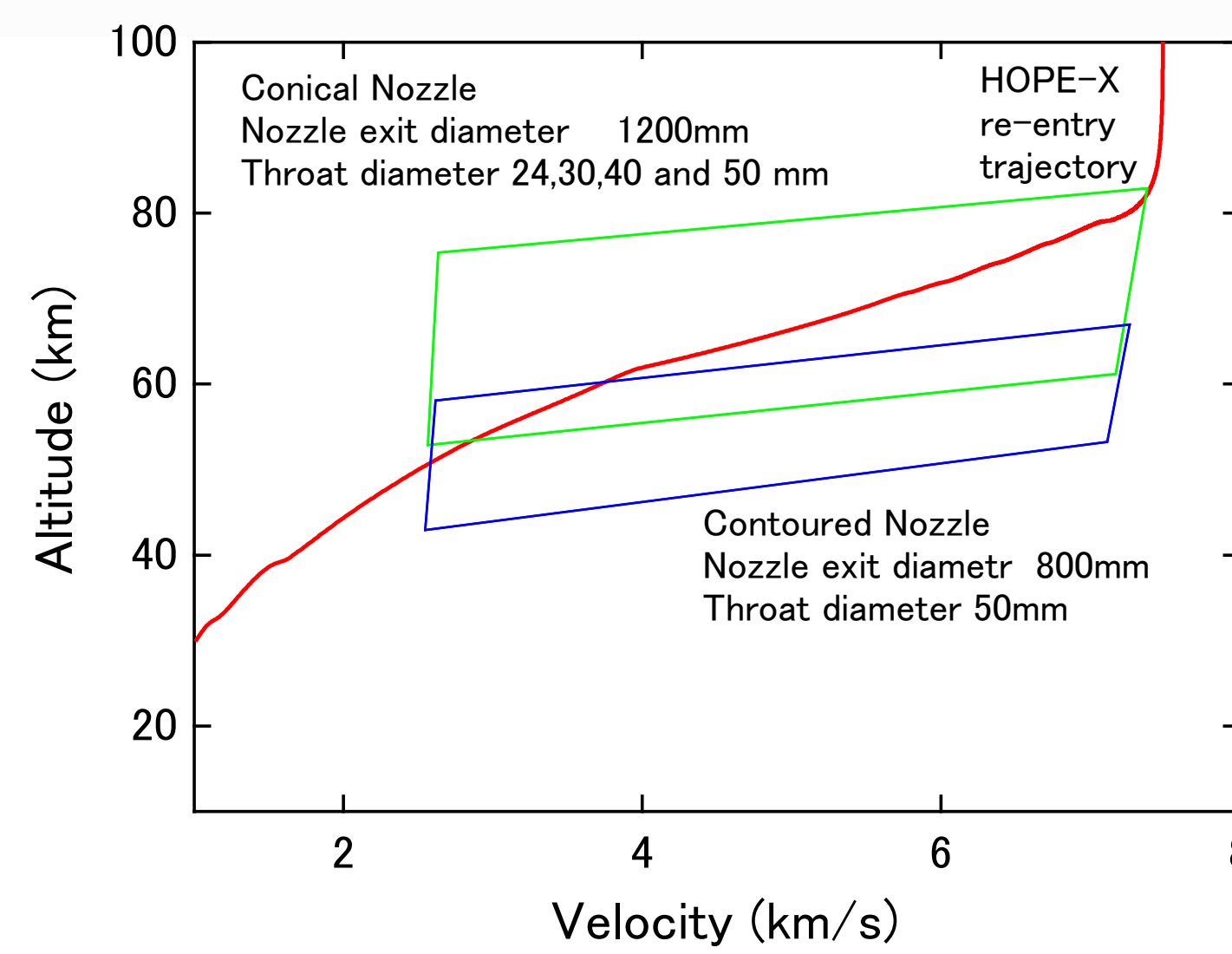
Experiments

Aeroheating test in the free-piston shock tunnel Hiest



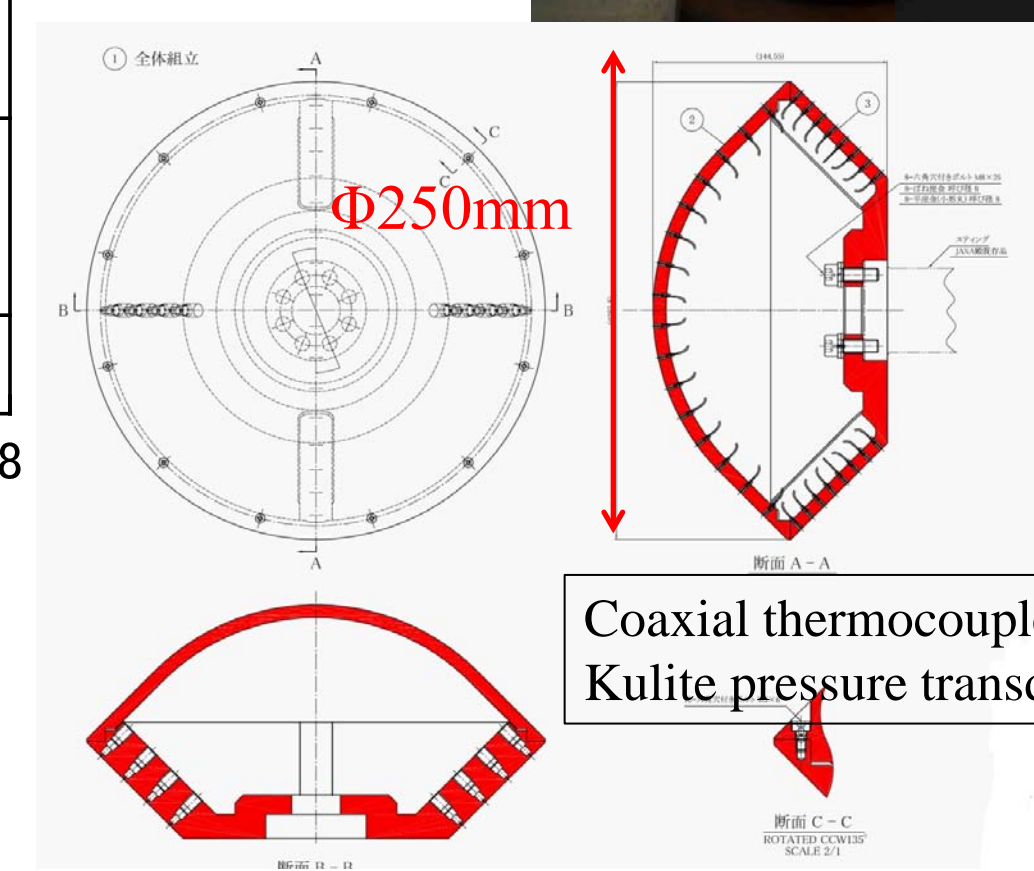
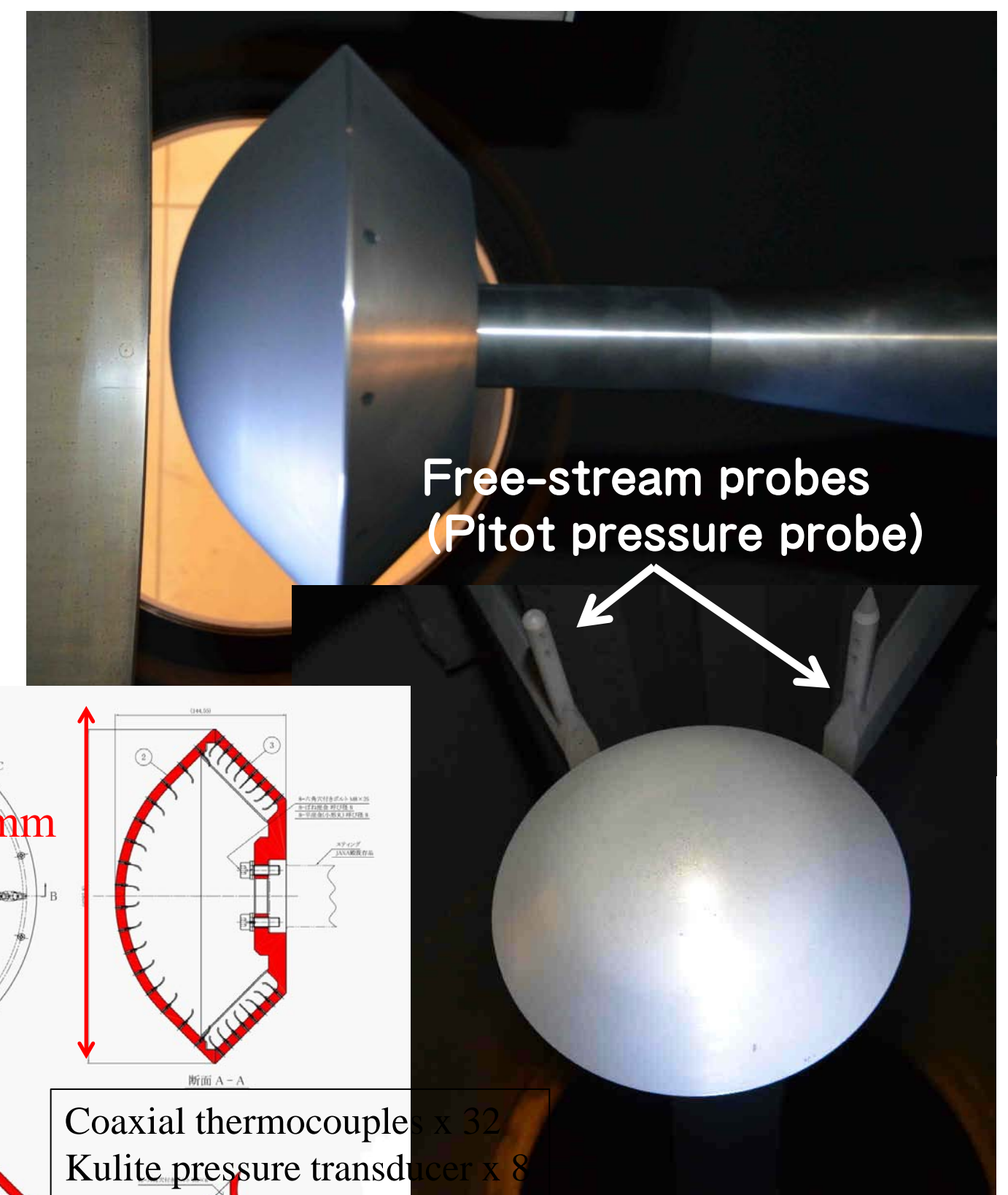
Hiest Specifications
 Compression tube Bore: $\phi 600\text{ mm}$, Length: 42 m
 Shock tube Bore: $\phi 180\text{ mm}$, Length: 17 m
 Piston 220 to 780 kg
 Conical Nozzle: exit diameter 1.2 m
 Contoured Nozzle: exit diameter 0.8 m

Stagnation enthalpy: 3 to 25 MJ/kg
 Stagnation pressure: 120 to 1500 bar
 Test time: 2 ms or longer



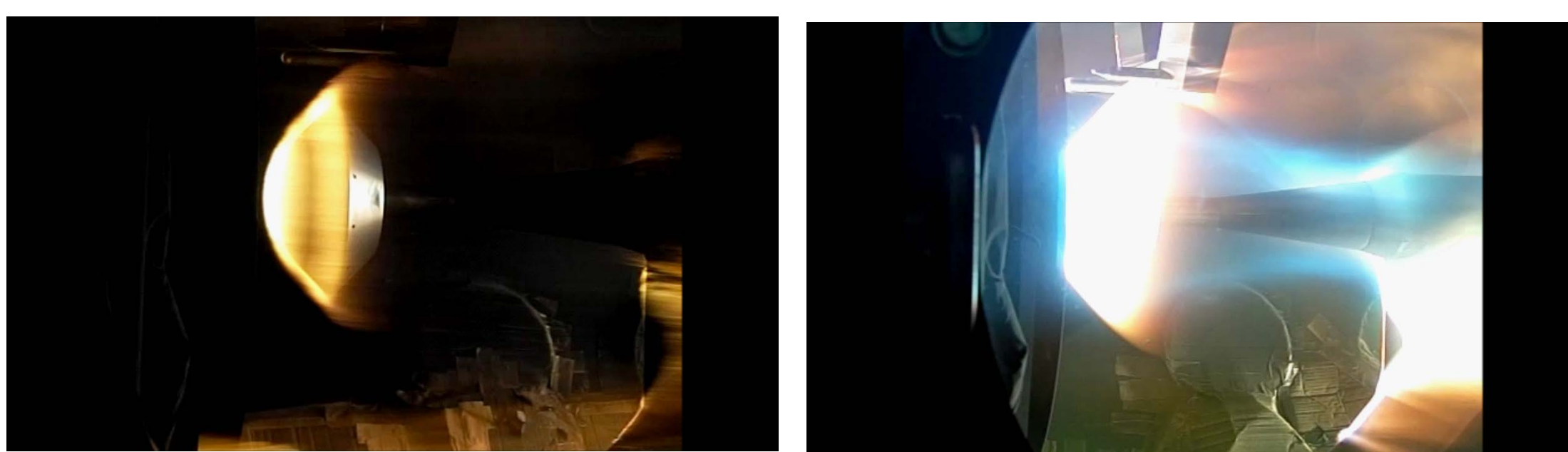
Hiest operation envelope

Hayabusa capsule installed in the Hiest test section



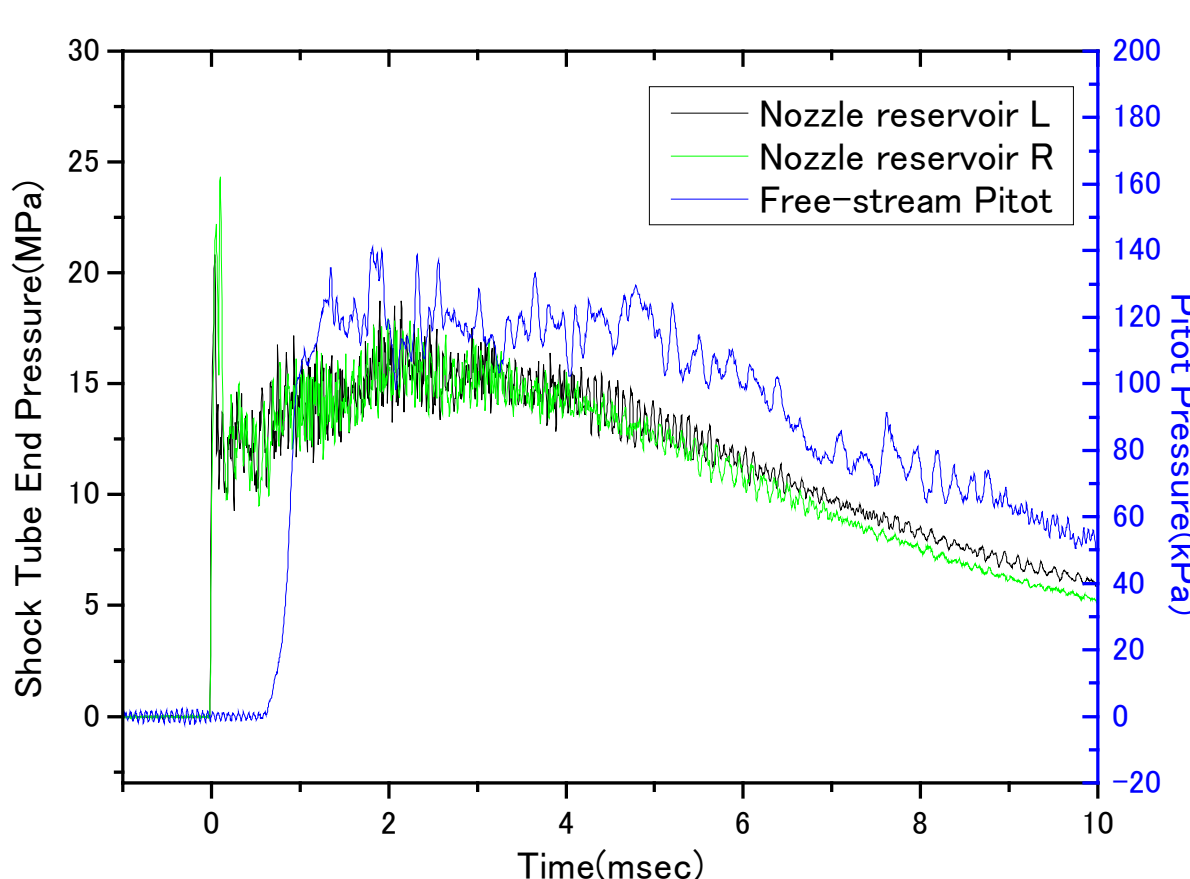
Hayabusa capsule 70% model

Results 1 (Optical and pressure measurement)

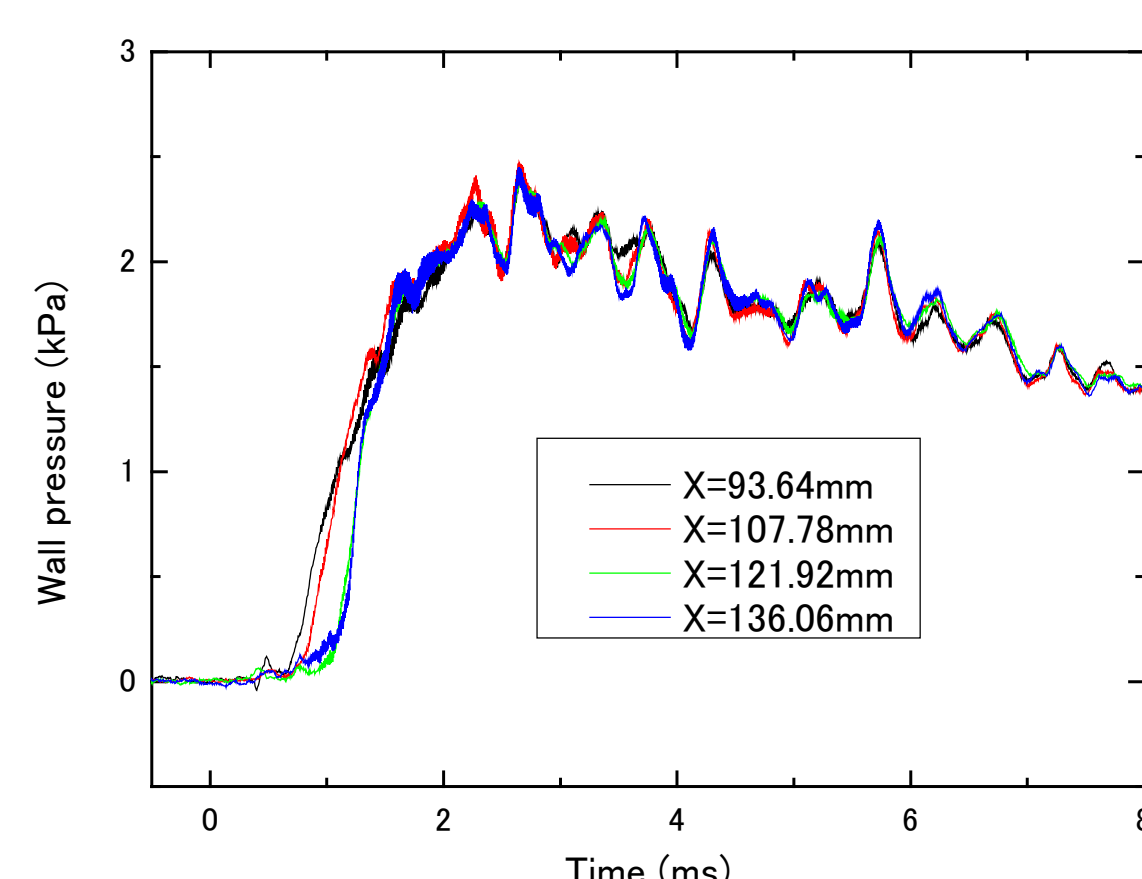


$H_0=20\text{MJ/kg}$ with Air

$H_0=20\text{MJ/kg}$ with CO_2



Nozzle reservoir pressure and Free-stream Pitot pressure at $H_0=20\text{MJ/kg}$ and $P_0=20\text{MPa}$



Surface pressure at the aft of the model at $H_0=20\text{MJ/kg}$ and $P_0=20\text{MPa}$

Results 2 (Heat flux around the model)

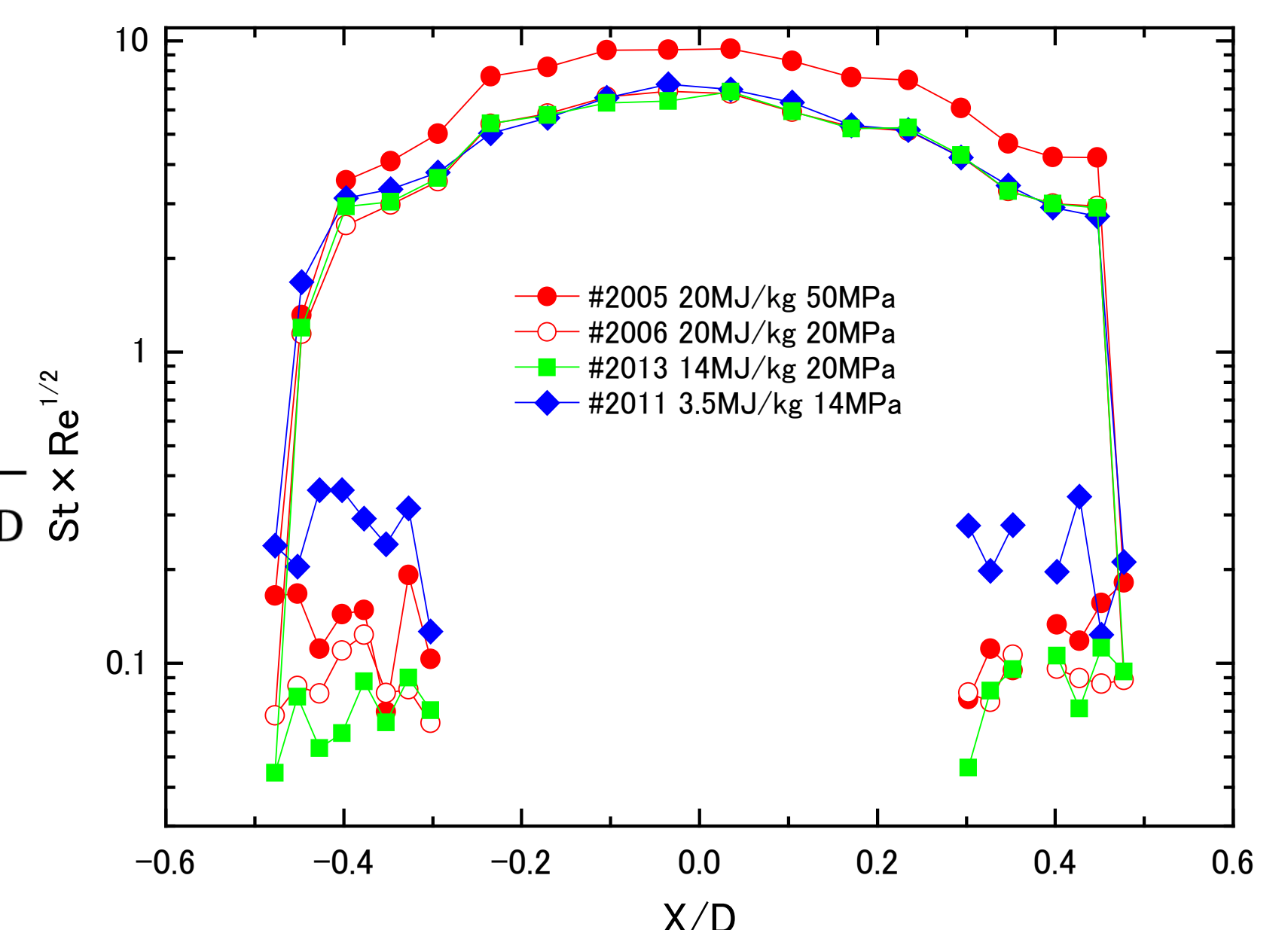
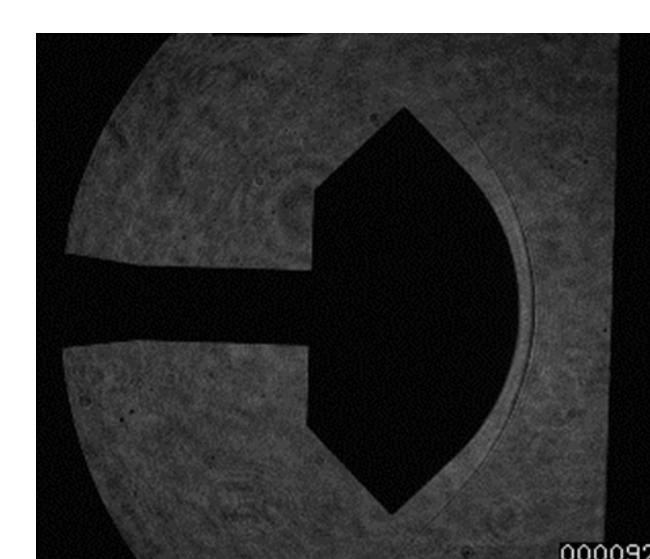
Data reduction

$$Q_n = \sqrt{\frac{\rho c k}{\pi}} \sum_{i=1}^n \frac{T_i + T_{i-1}}{\sqrt{t_n - t_i} + \sqrt{t_n - t_{i-1}}} (t_n - t_{n-1})$$

$$\dot{q}_n \approx \frac{\Delta Q_n}{\Delta t} = \frac{-2Q_{n-8} - Q_{n-4} + Q_{n+4} + 2Q_{n+8}}{40(t_n - t_{n-1})}$$

Normalization

$$St \times \sqrt{Re_{\infty, D}} \frac{\dot{q}}{\rho_{\infty} u_{\infty} (H_0 - H_{wall})} \times \sqrt{Re_{\infty, D}} \approx \frac{\dot{q}}{\rho_{\infty} u_{\infty} (H_0)} \times \sqrt{Re_{\infty, D}}$$



Measured heat flux distribution of the windward and reward of the model.

CONCLUSION & OUTLOOK

- ◆ Aeroheating test with a Hayabusa re-entry capsule 70% scaled model has conducted in JAXA-Hiest. Aeroheating characteristics were observed at model angle of attack 0 degree with fully laminar except $H_0=3\text{MJ/kg}$ condition. Measured heat flux was normalized by the products of the Stanton number and the square-root of the Reynolds number for correlation with other wind tunnel results.
- ◆ In FY2012, Free-flight technique in Hiest is planned to measure heat flux at model aft without any interference from model supports system such as sting.