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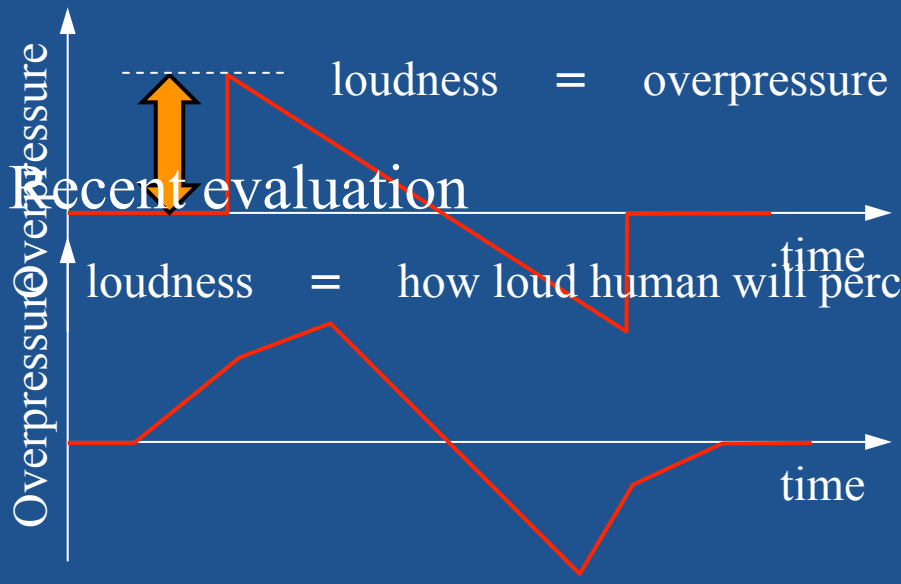
Near Field Pressure Measurement around Free Flight 69 Degree Swept Back Delta Wing Model

Atsushi Toyoda , Akihiro Sasoh , Takahiro Imaizumi , Takeshi Ooyama
Department of Engineering, Nagoya University, Aichi, 464-8603, Japan

Masashi Kanamori , Takashi Aoyama
Japan Aerospace Exploration Agency, Chofu, Tokyo, 182-8522, Japan

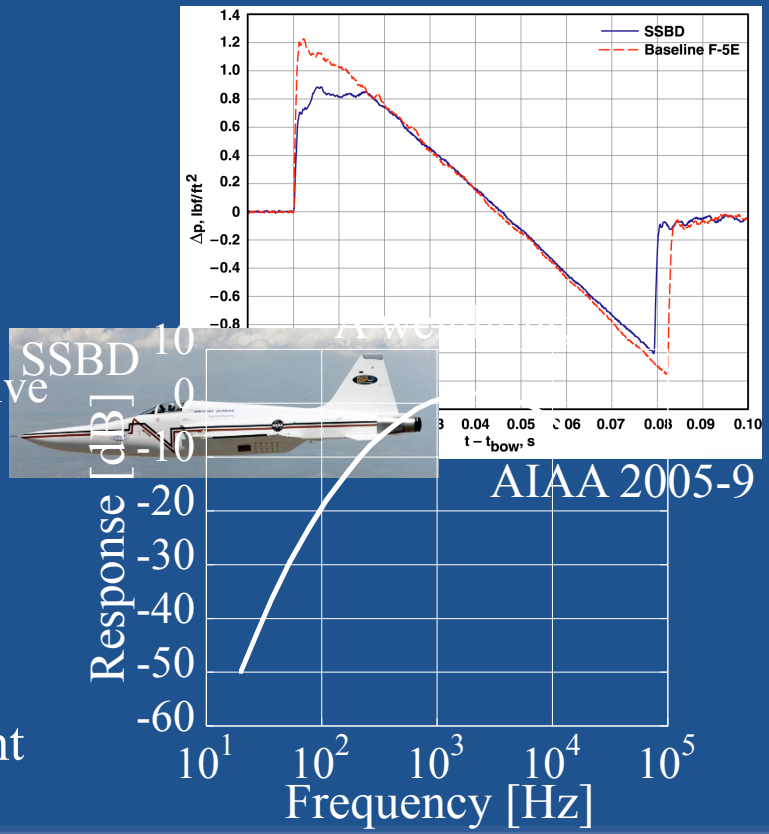
Change in sonic boom evaluation

Traditional evaluation



Recent evaluation

Whole pressure signature became important



Pressure measurement meathods

- Accurate pressure measurement is critical for the sonic boom evaluation

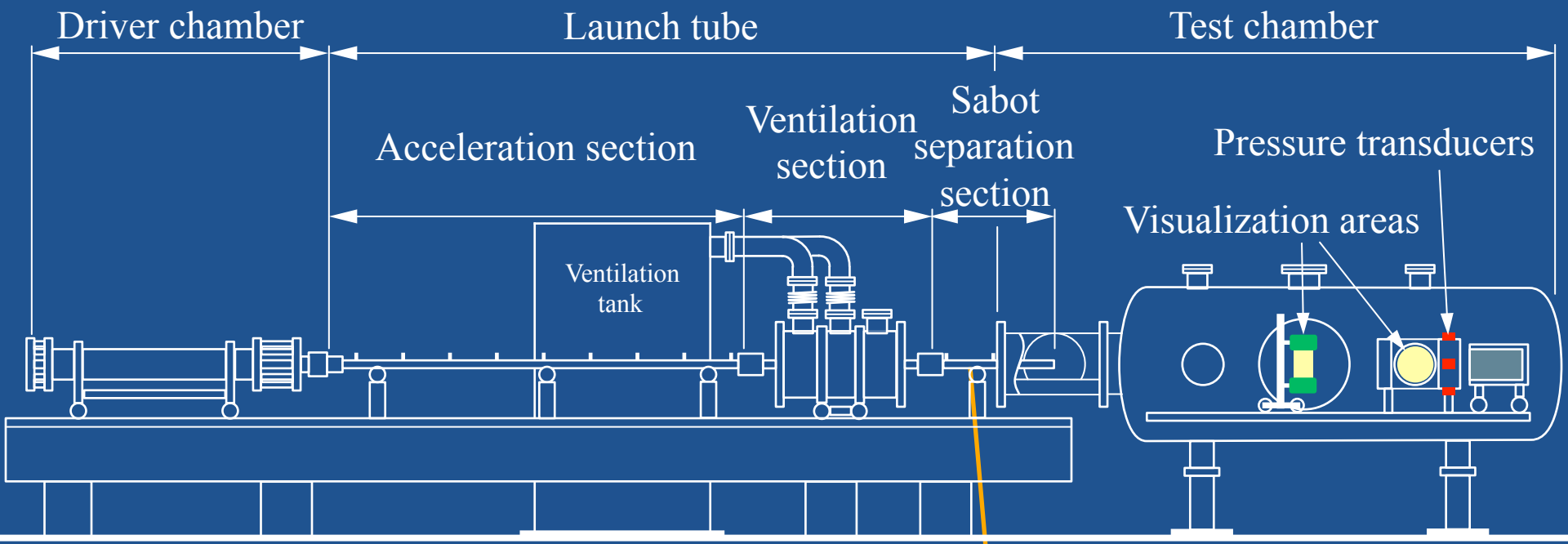
Type	Location	Pros	Cons
Flight Experiment	Far Field	• Real boom measurement • Various flight condition	• Uncontrolled environment • Extremely high cost
Wind Tunnel	Near Field	• Controlled environment • Precise attitude control	Measurements affected by • Boundary layer • Sting
CFD	Near Field	• Ideal condition	• High computational cost • Sensitive to grid quality
Aeroballistic Range	Near Field	• Quiescence ambient • No model support (can directly measure pressure recovery)	• difficult attitude control • Non-reusable model

Objective

Demonstrate the aeroballistic range's capability
of the direct pressure measurement around free flight model

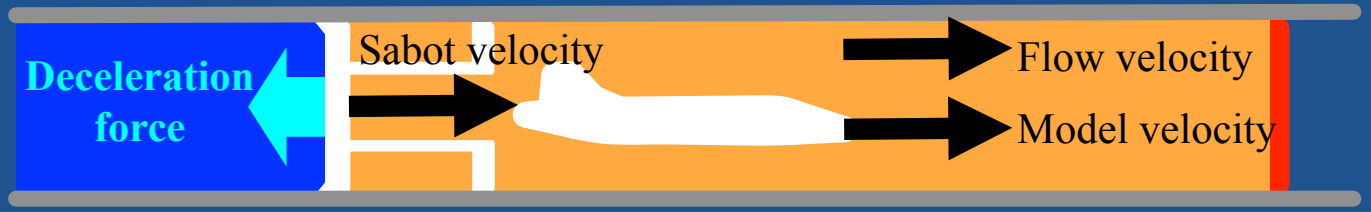
Directly measure the pressure signature propagated from
the free flight 69 degree swept back angle delta wing model

Aeroballistic range at Nagoya Univ.



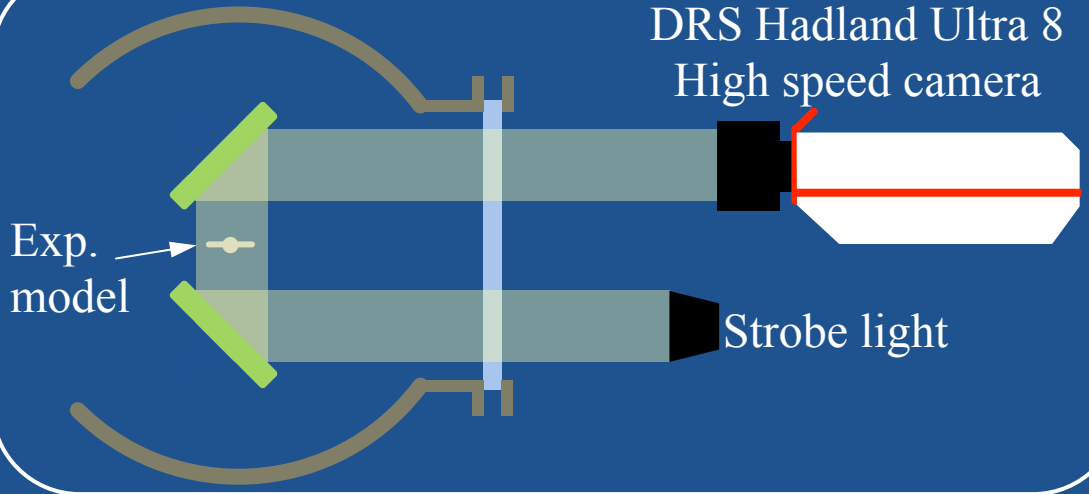
Rectangle cross section launch tube
→ Suppress roll motion

In tube aerodynamic sabot separation
→ Enable to launch a model with small A.o.A.

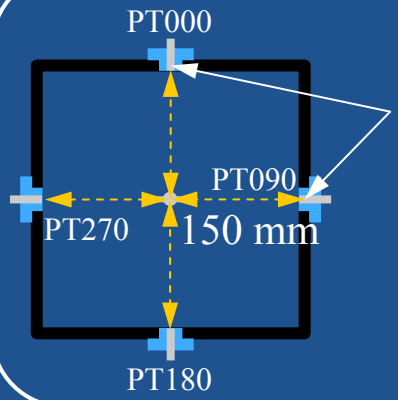


Measurements

Vertical visualization



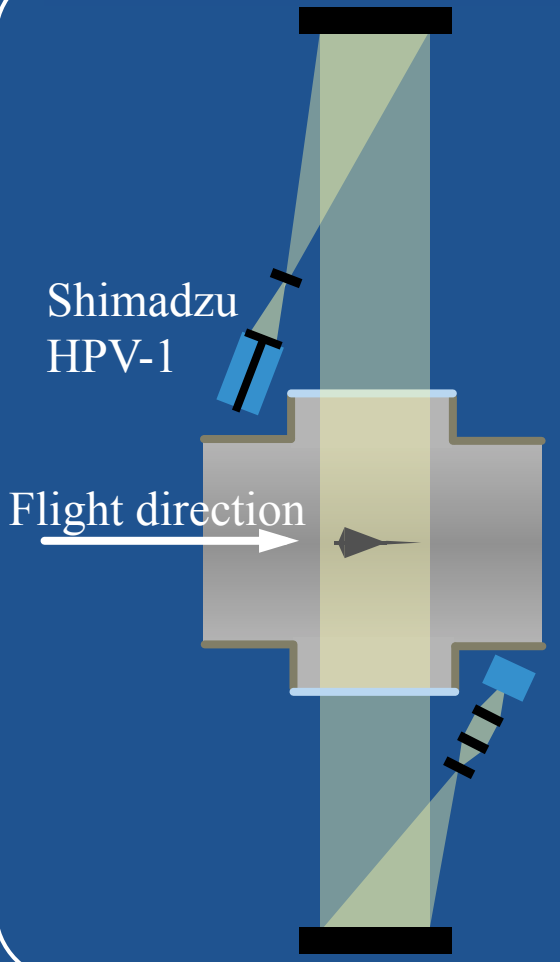
Pressure measurements



Pressure transducers
(PCB Piezotronics Inc. 113B28)

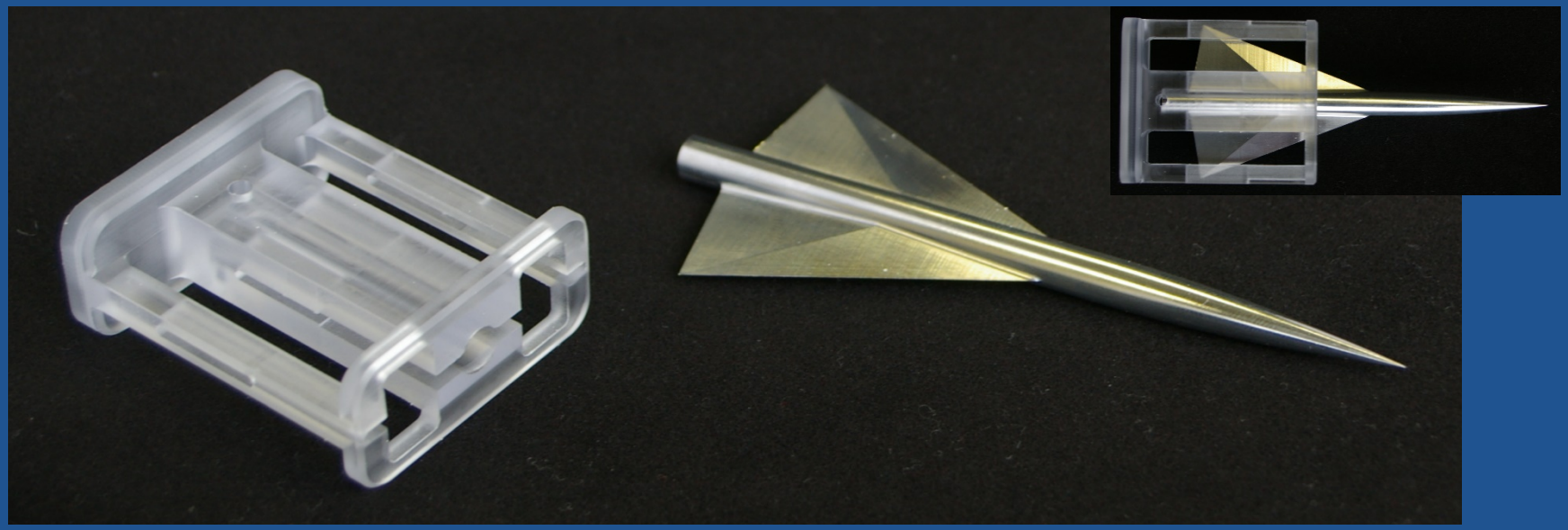
Pressure measurement (H): 150 mm
Model length (L): 105.2 mm
H/L = 1.42

Horizontal visualization



Experimental model

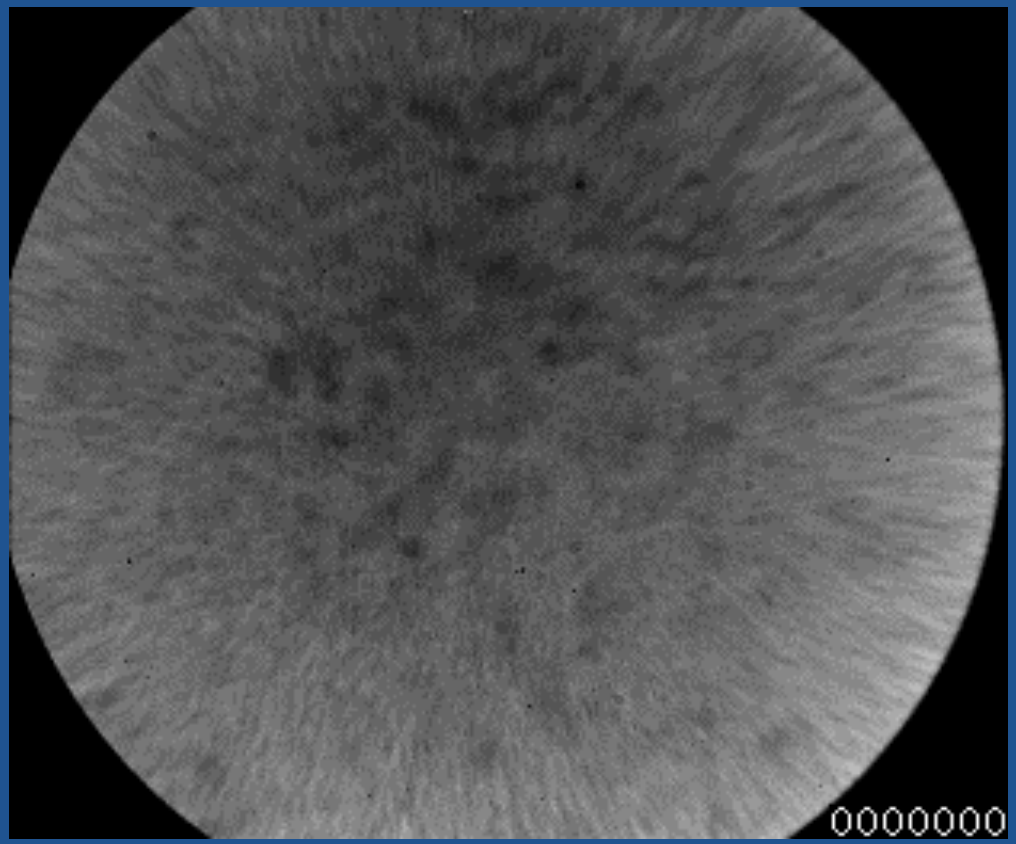
69 degree swept back angle delta wing model



Sabot
- Length: 51.5 mm
- Mass: 14.6 g
- Model length inside the sabot: 41.5 mm

Model
Length: 105.2 mm
Wing Span: 41.4 mm
Fuselage: ϕ 6.5 mm
Material: AL7075
Mass: 9.9 g

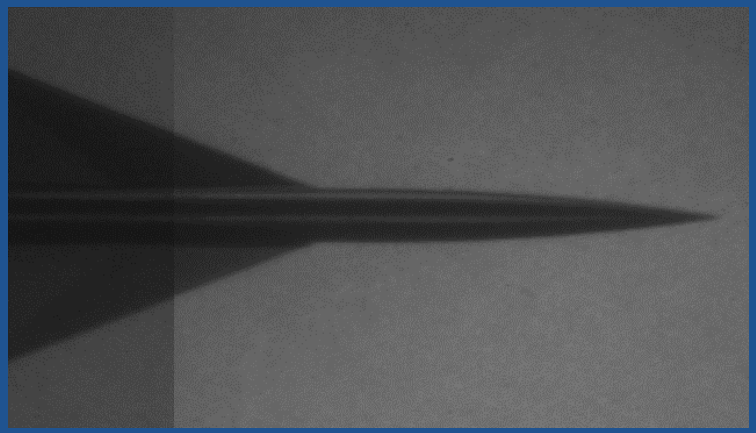
Visualizations



Shimadzu HPV-1
Frame rate: 125k frames/sec.
Exposure: 1 μs

α = -0.4 deg.

Mach 1.69

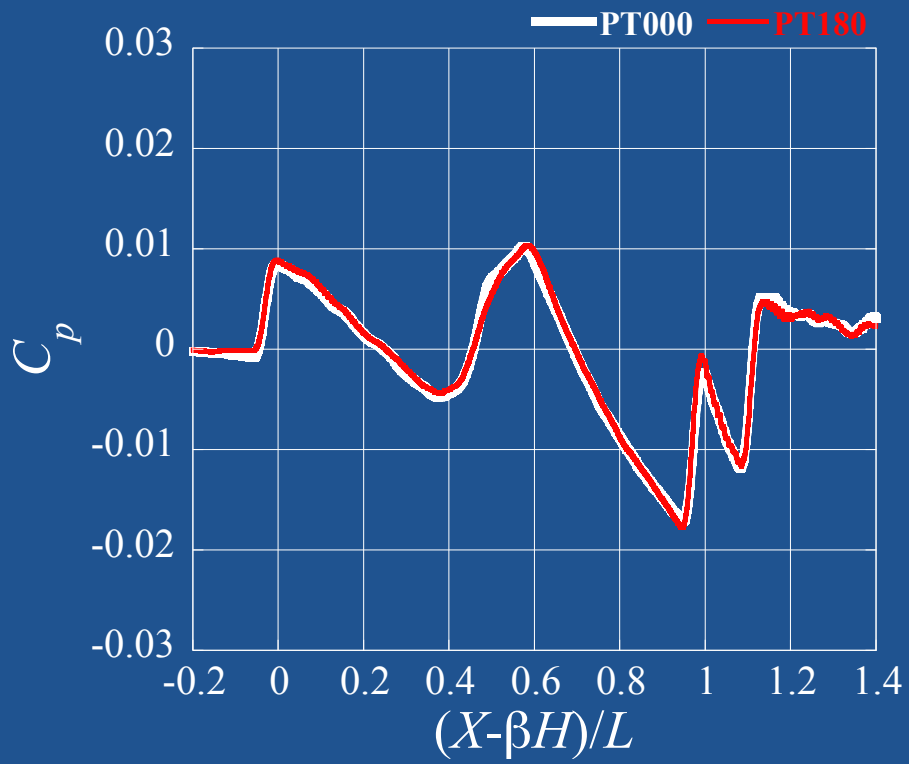


β = 0.7 deg.

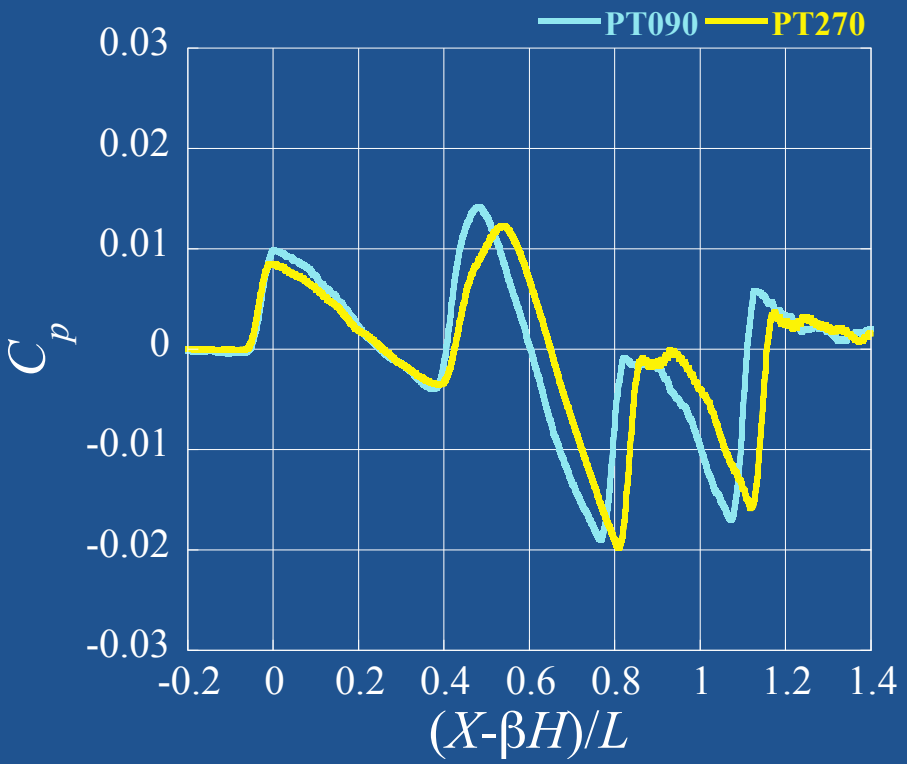
Hadland Ultra 8
Frame rage: 28.5k frames /sec
Exposure: 2 μs

Measured near field pressure signatures

Mach #: 1.69 H/L = 1.41



Above and below the model

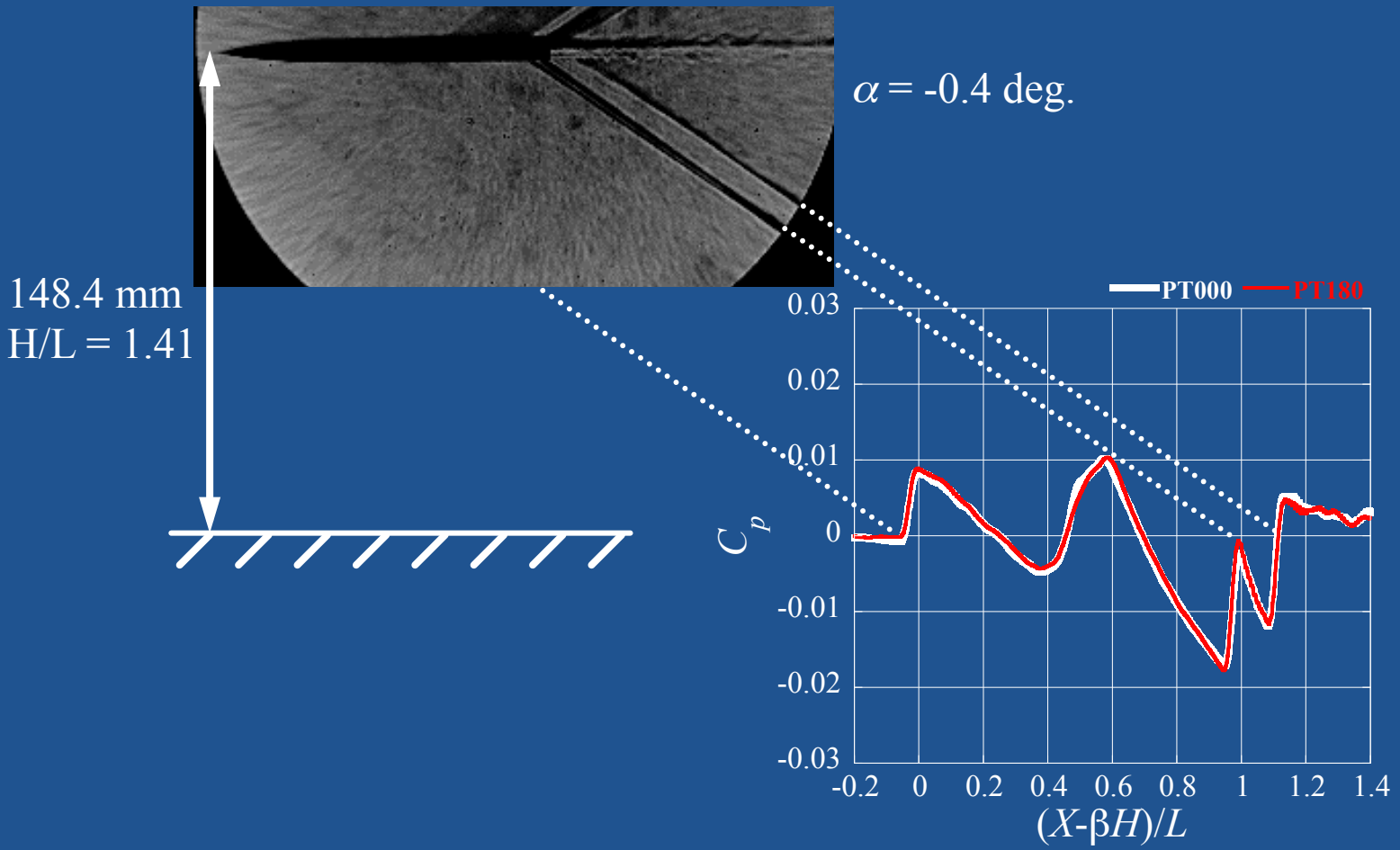


Right and left side of the model

Show great agreement

Slight disagreement due to yaw angle

Schlieren image and pressure signature



CFD Simulation condition

Simulation

HexaGrid

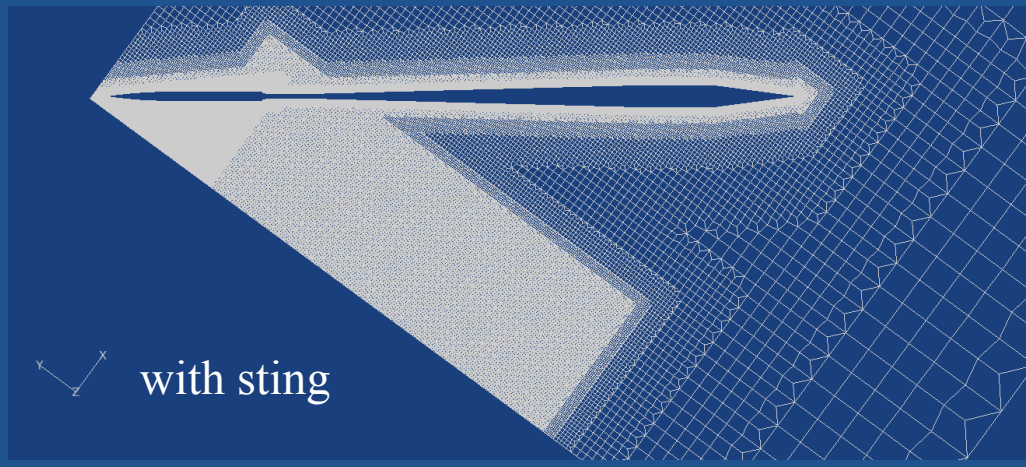
FaSTAR (developed by JAXA)

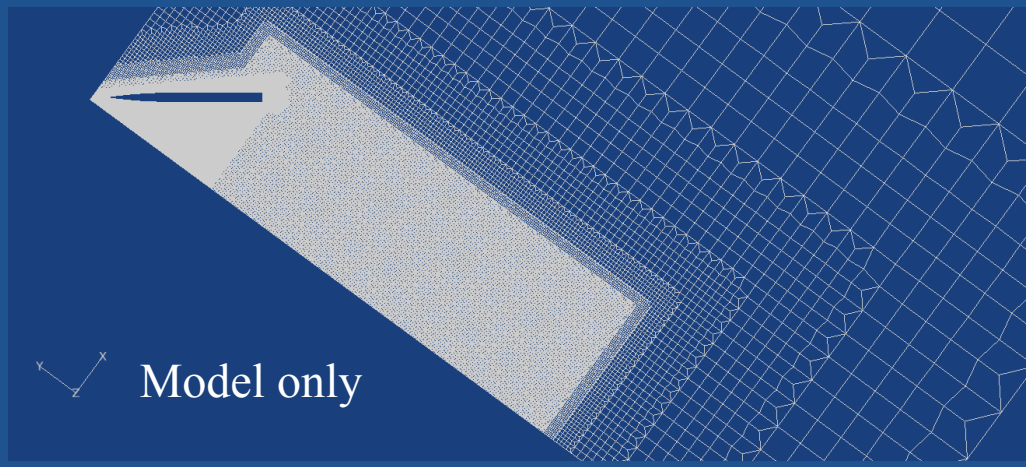
- Euler equations
- HLLEW with second order MUSCL
- LU-SGS

Simulation was conducted

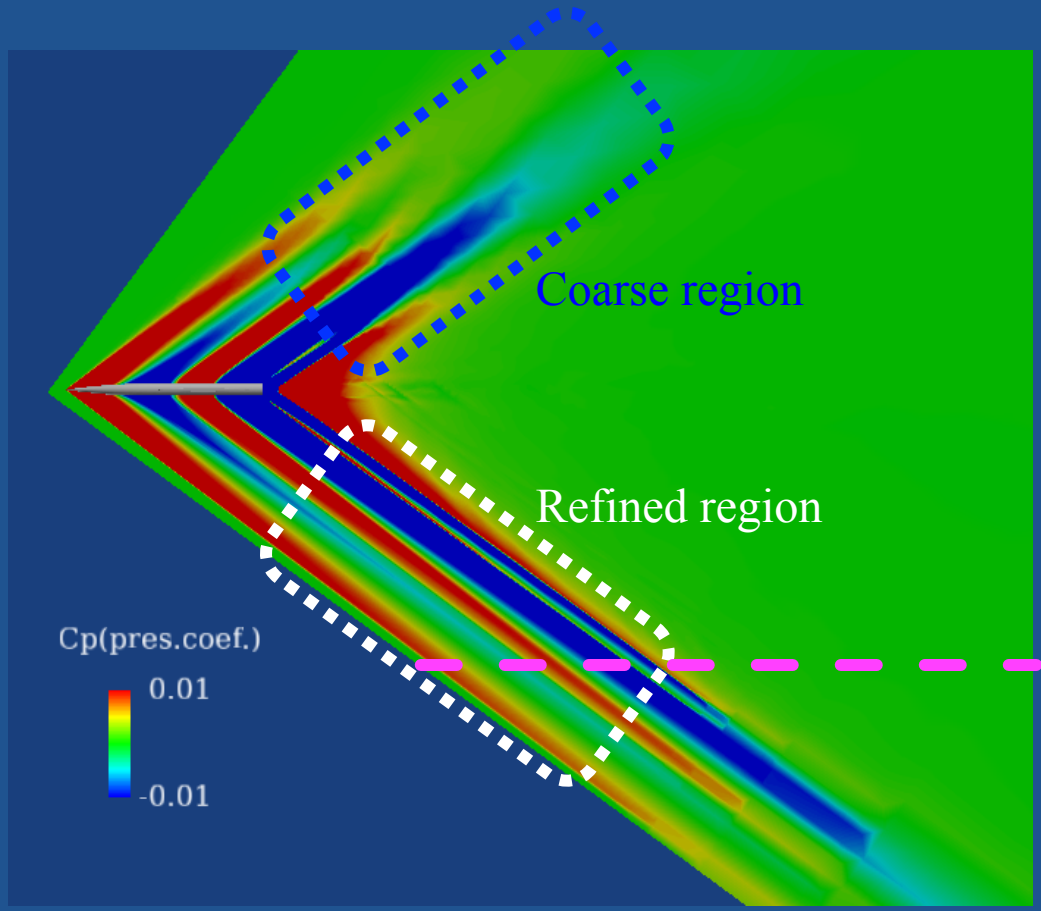
- with sting
- without sting
- at Mach 1.69

Computational grid is aligned with the propagating pressure wave





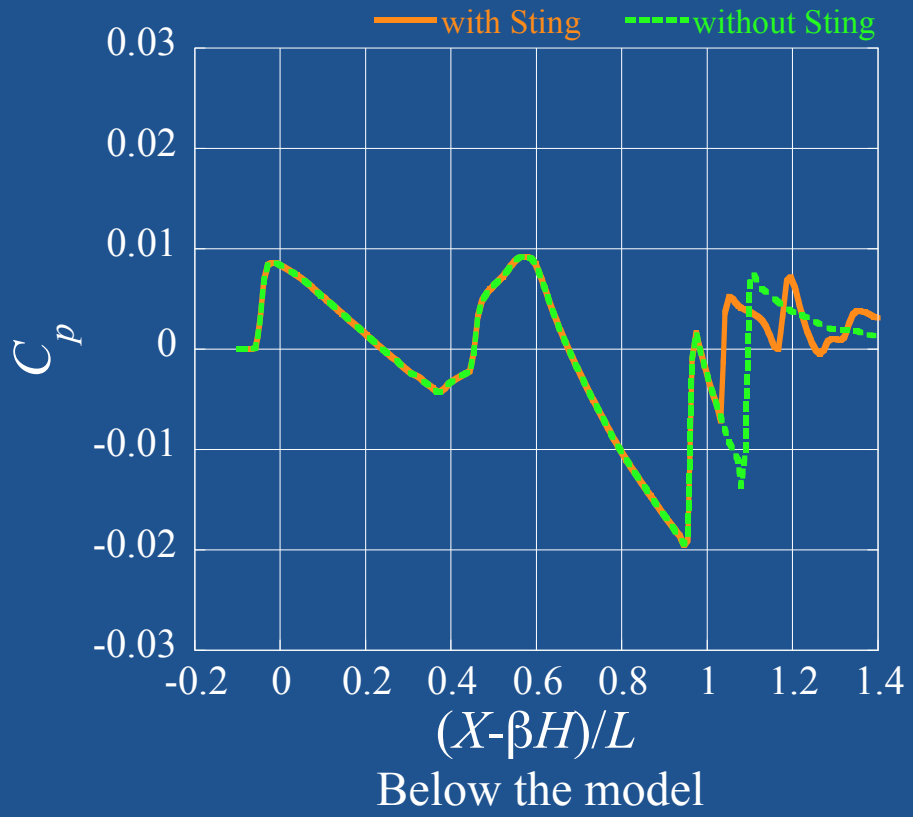
Pressure distribution



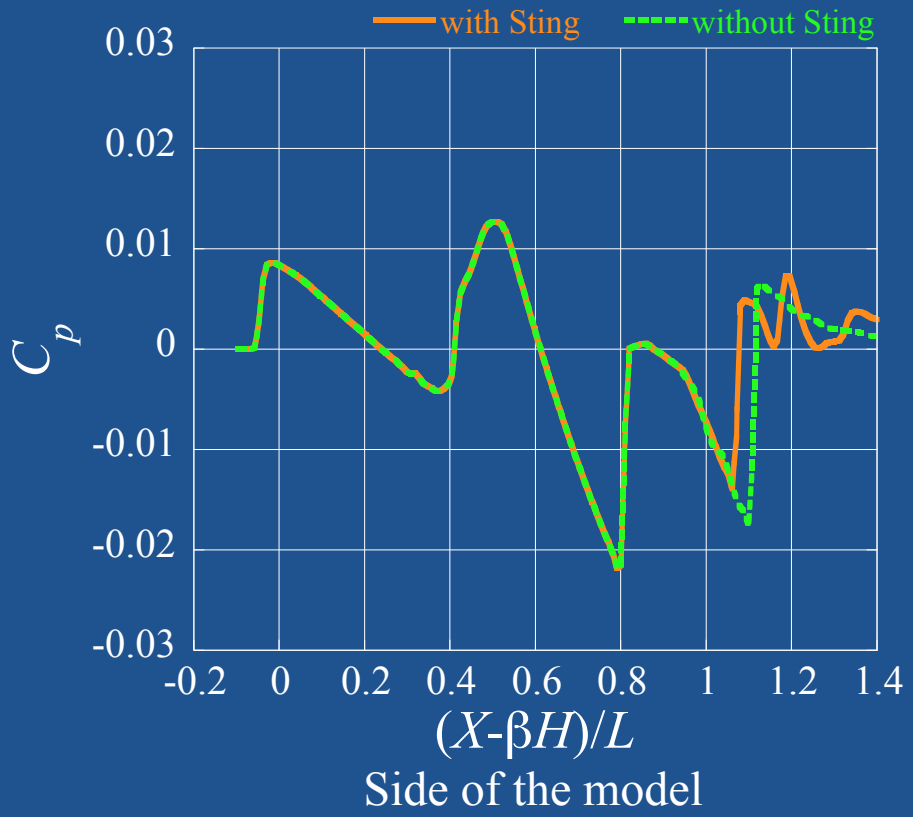
Shock wave on refined region captured pressure waves compared to the coarse region

Extracted near field pressure signatures

Mach #: 1.69 H/L = 1.41



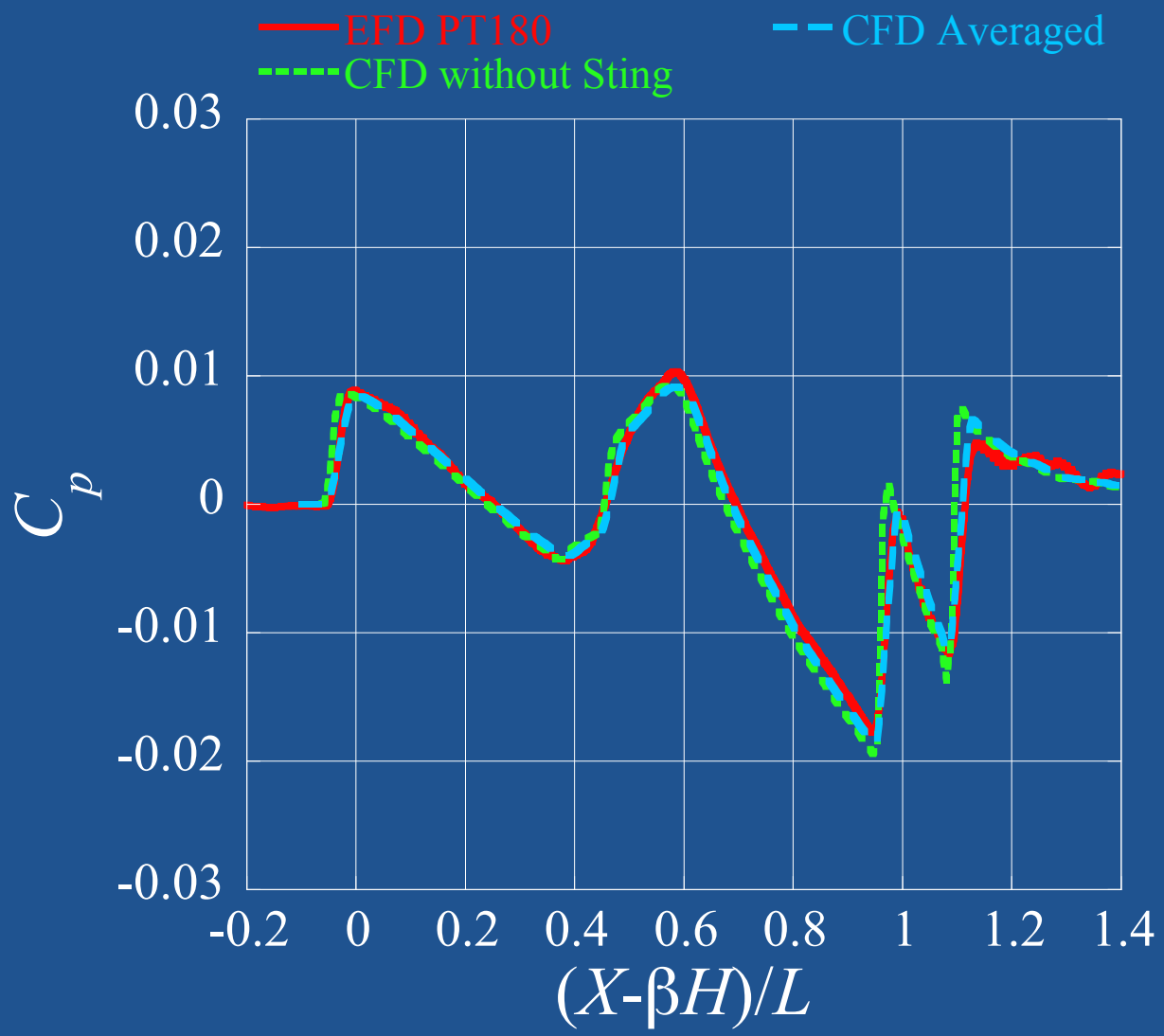
Below the model



Side of the model

The existence of sting clearly affects the aft pressure wave

Pressure signature comparison

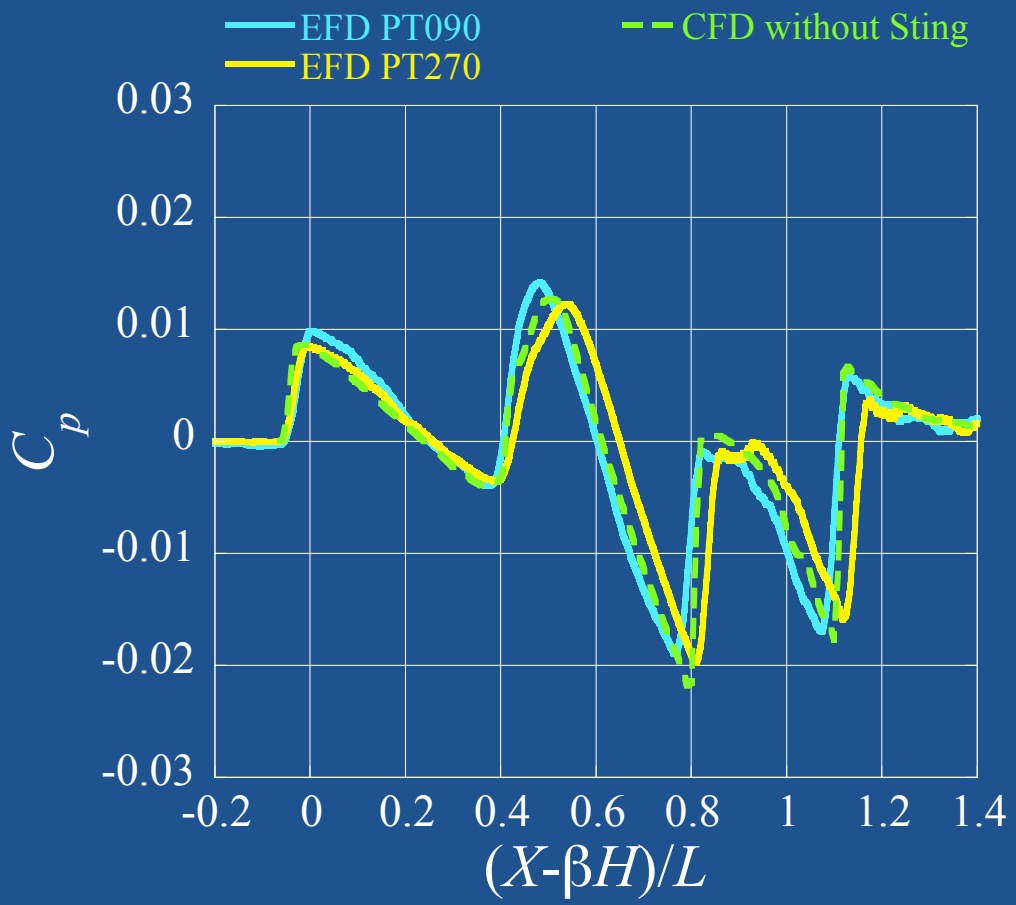


- Overall pressure signature agreed well.
- CFD and EFD showed miner disagreement at peak over pressure and the rise time.
- CFD result is averaged with 1.9% body length. Averaged result showed better agreement with EFD result.

Summary

- 69 degree swept back angle delta wing model was successfully launched using aeroballistic range
  - The near field pressure without the effect of the sting was measured without any correction
- CFD simulation indicated the sting have a strong effect on pressure signature at the aft region
- Experimentally measured pressure signature and CFD extracted pressure signature showed great agreement with each other

Thank you for listening.
Questions ?


EFD PT090
EFD PT270
CFD without Sting
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
C_p
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
$(X-\beta H)/L$

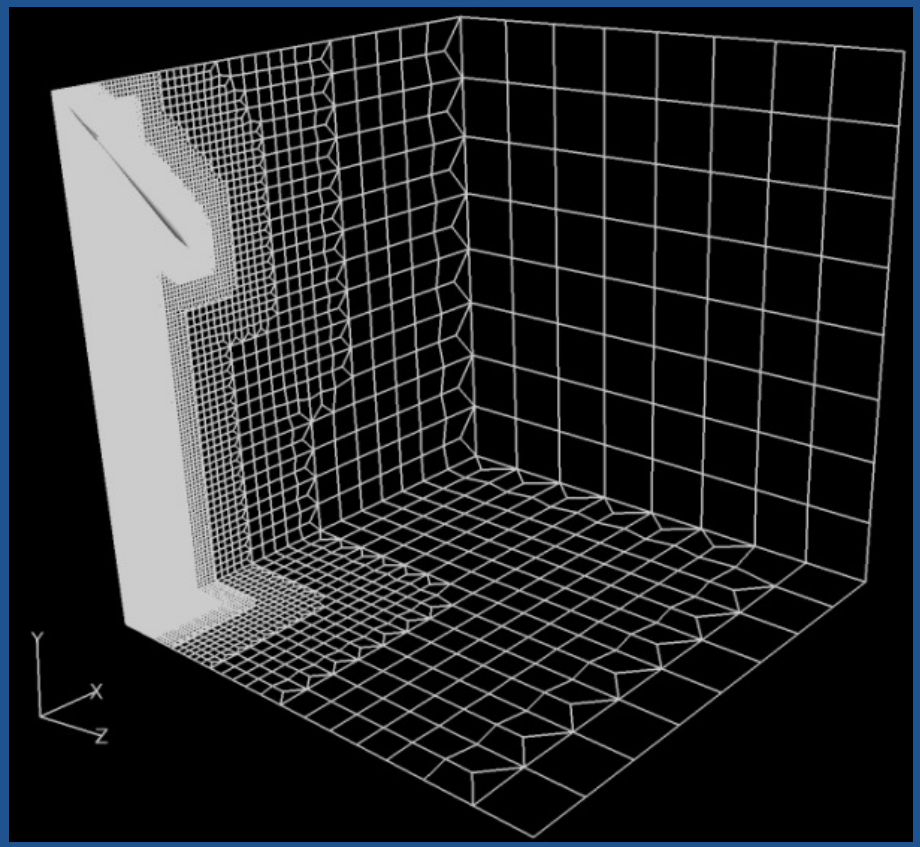
Simulation conditions

Simulation

HexaGrid

FaSTAR (developed by JAXA)

- Euler equations
- HLLEW with second order MUSCL
- LU-SGS



Simulation was conducted

- with sting
- without sting
- at Mach 1.69

Model is rotated to align the propagating pressure wave with the grid