Model Experiment of Sonic Boom Signature Propagation through Turbulence in a Ballistic Range

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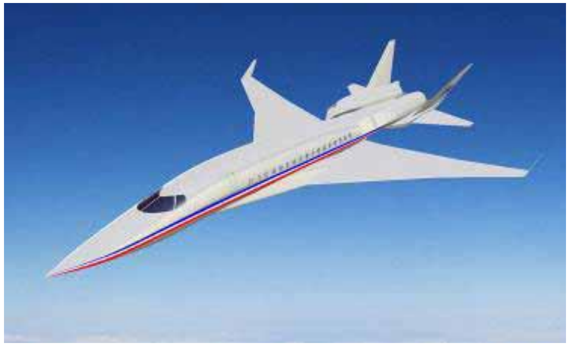
Takahiro Ukai
Institute of Fluid Science, Tohoku University, Japan

Next-generation airplane

- Super Sonic Transport (SST)



JAXA HP

Concept by Japan

European commission HP

Concept by EU

NASA HP

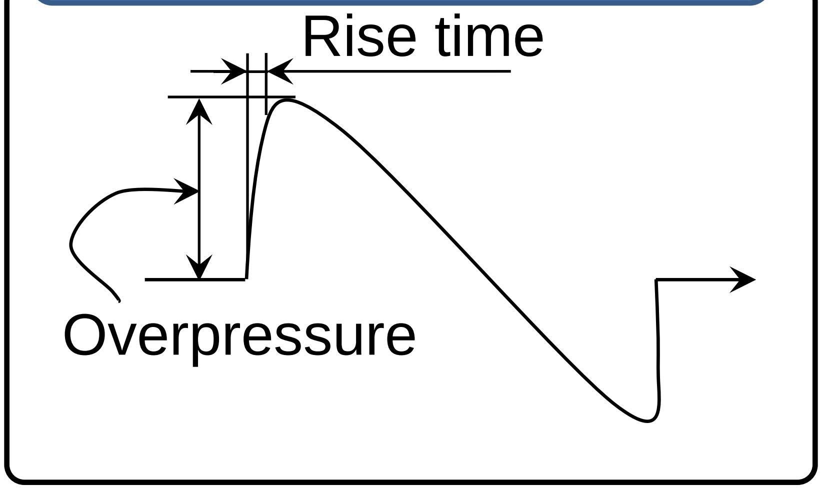
Concept by US

- Requirements for SST
  - ✓ Sonic boom redaction
  - ✓ Low-fuel consumption

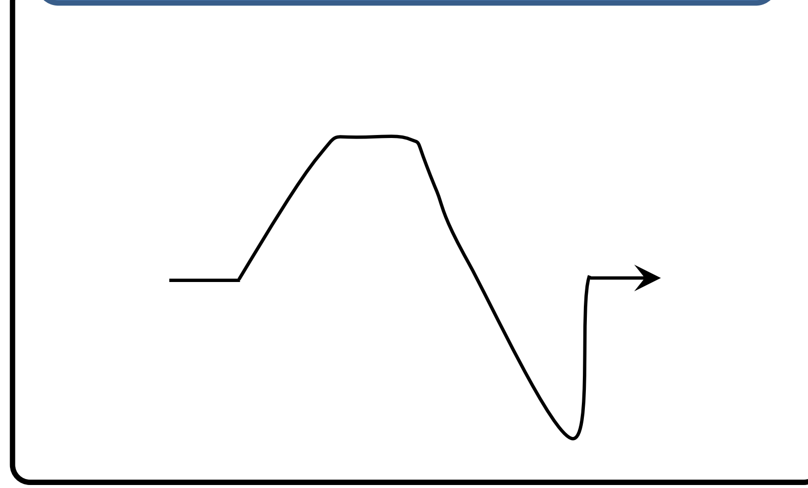
Concorde SST, http://www.concordesst.com/home.html, (cited 19 January 2010)

Sonic boom evaluation

Normal shape

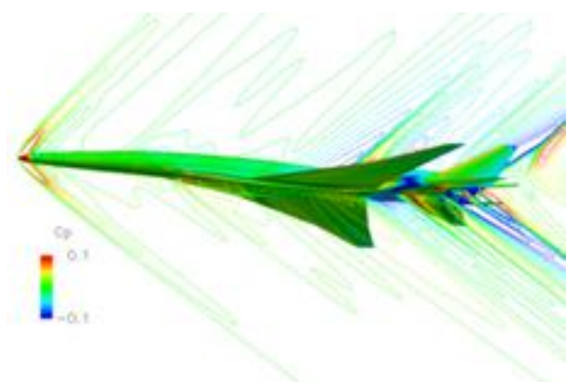


Low boom signature

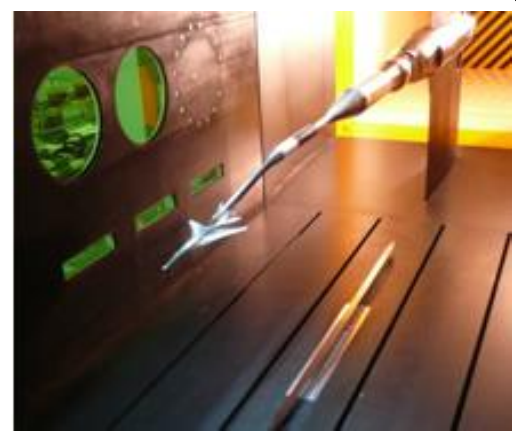


- Sonic boom estimation

Numerical simulation



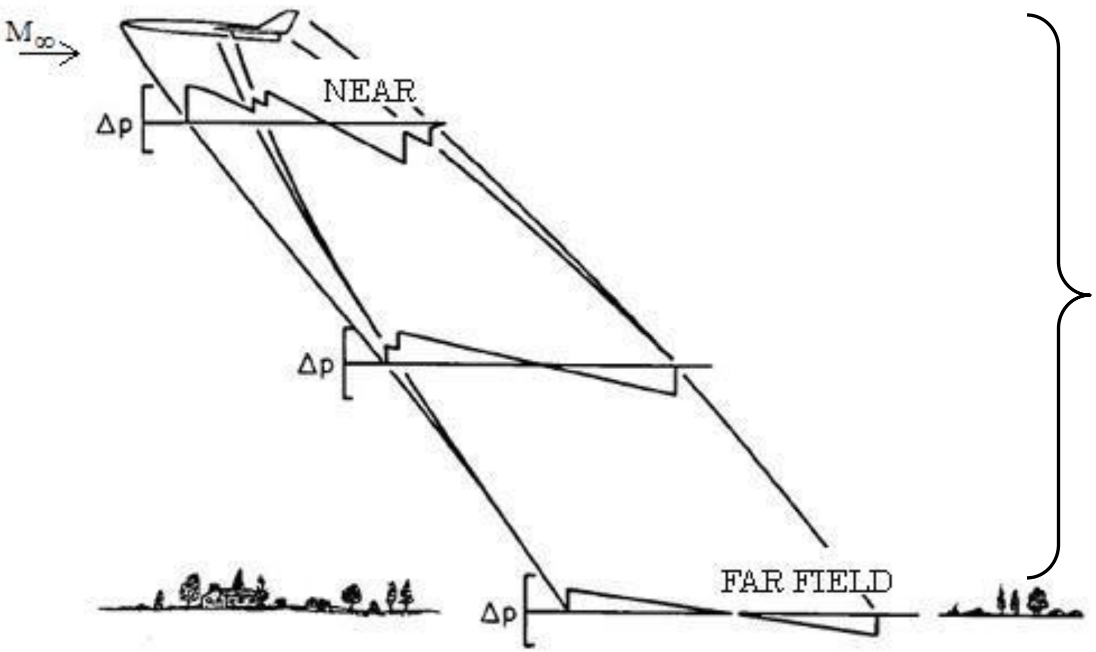
Wind tunnel testing



JAXA HP http://www.aero.jaxa.jp/research/kitaisystem/cyoonsoku/co-index.html

Effect of the real atmosphere

- Sonic boom propagating



Real atmosphere

Various conditions

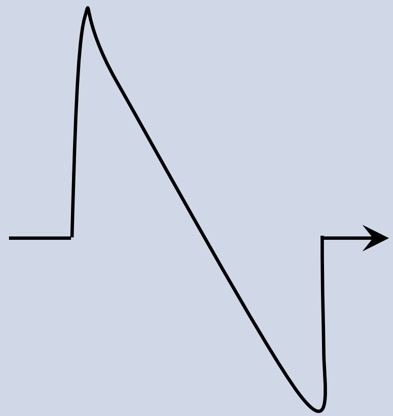
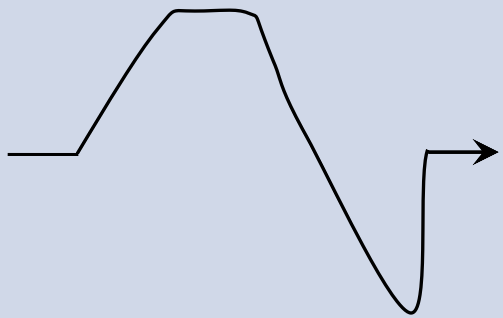
- ✓ Turbulence
- ✓ Humidity
- ✓ Temperature

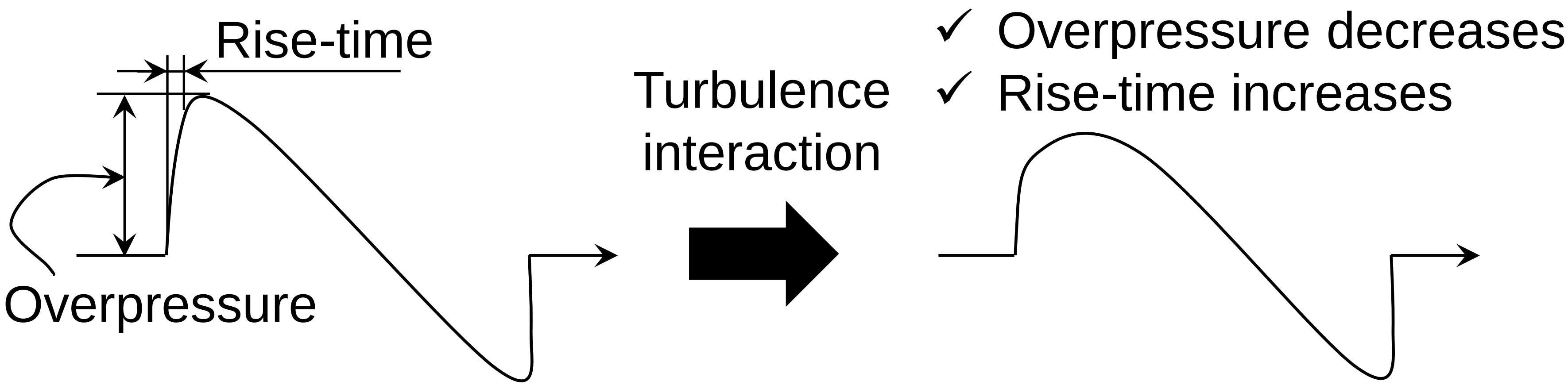
Carlson, NASA SP-147, p.10, (1967)

- The changed pressure waveforms by turbulence

Lee *et. al*, AL-TR-1991-0099, (1991)

Effect of turbulence

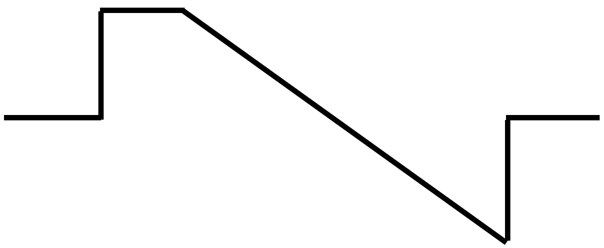
	Normal sonic boom signature	Low sonic boom signature
Typical waveform		
Turbulence effects	Known	Unknown



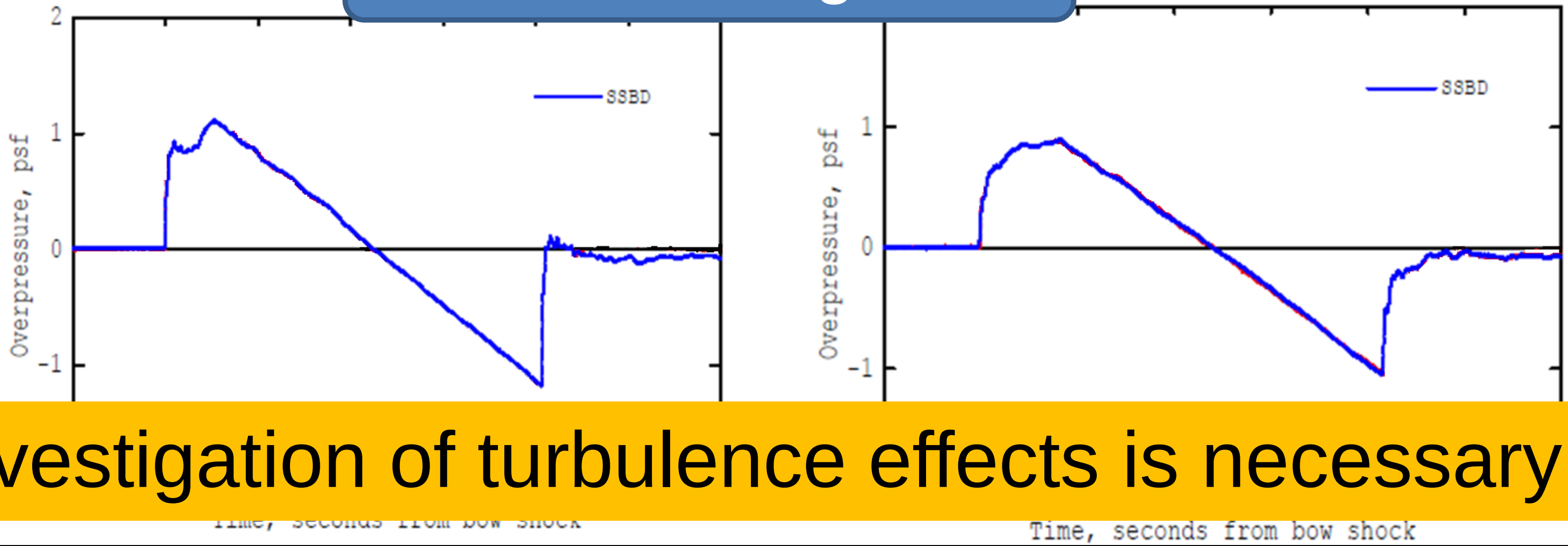
Phenomenon observed in flight test

Kenneth *et al*. AIAA paper 2004-2923 (2004)

Estimated



Measured at ground

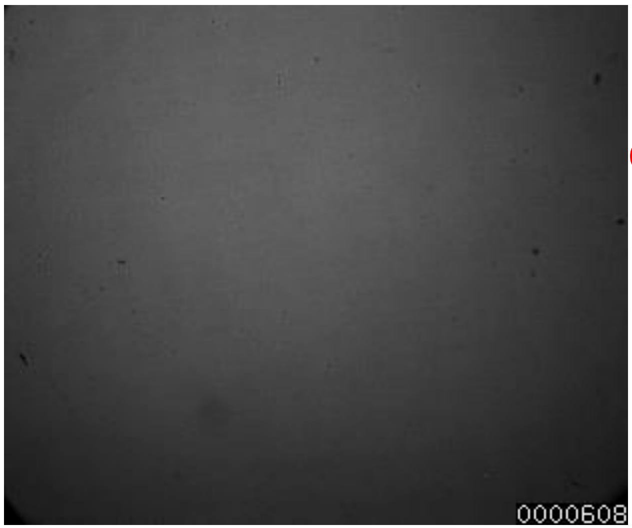


Plotkin *et al.* AIAA paper 2005-10, (2005)

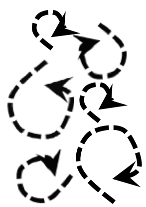
Investigation of turbulence effects is necessary

Laboratory-scale experiments

Ballistic range

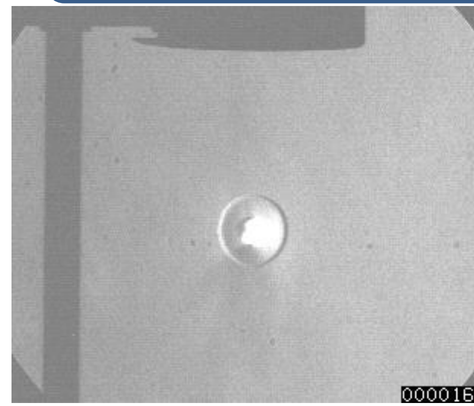


Controllable turbulence

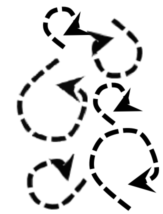


Arbitrarily shaped Waveform

Spark generator



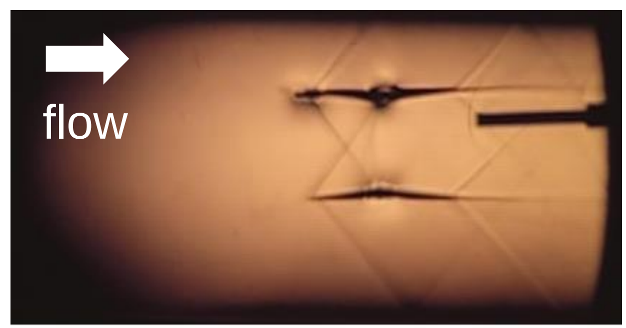
Controllable turbulence

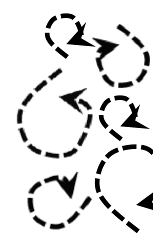


Waveform with N-shape

Wind tunnel

Uncontrollable turbulence





Ballistic ranges have ability to conduct shock-turbulence interaction

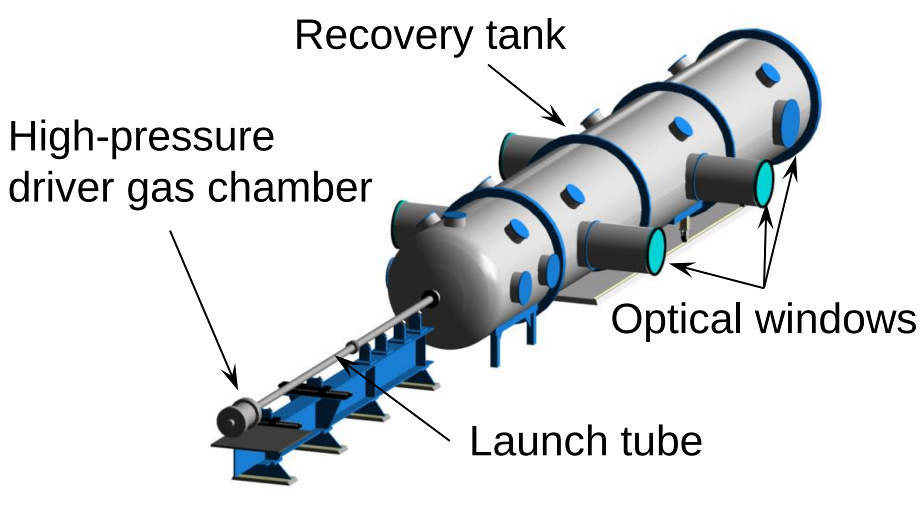
Objective

Establish an experimental technique for shock-turbulence interaction

- Evaluate a distortion of waveform with N-shape
- Evaluate a distortion of low boom pressure waveform

Experimental setup

- **Ballistic range in Institute of Fluid Science, Tohoku Univ.**
  - ✓ Flight Mach number up to 2.0
  - ✓ Projectile diameter of 51 mm
  - ✓ Test section: *L*= 12 m, *D*= 1.66 m
  - ✓ Optical windows of three pair



- **Measurement techniques**
  - ✓ Shadowgraph method: <u>Density field</u>

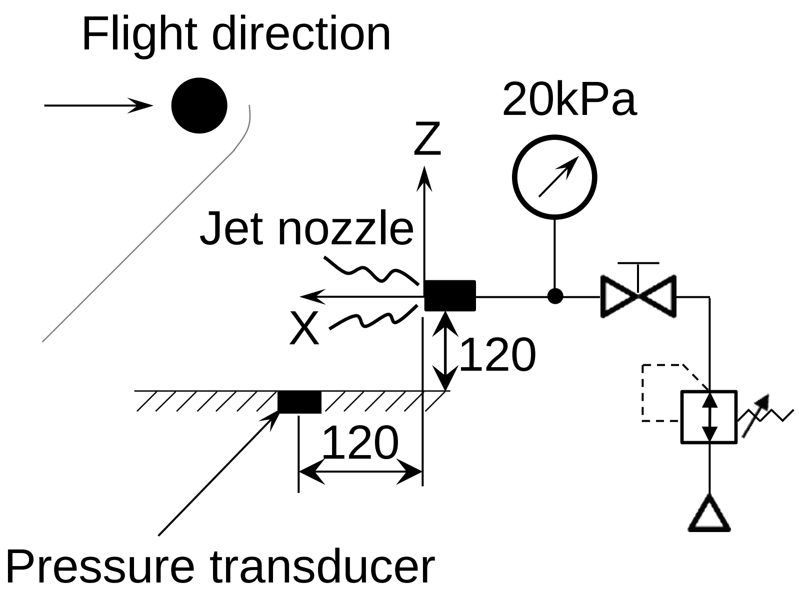
    HPV-1 Shimadzu Corp., high-speed camera

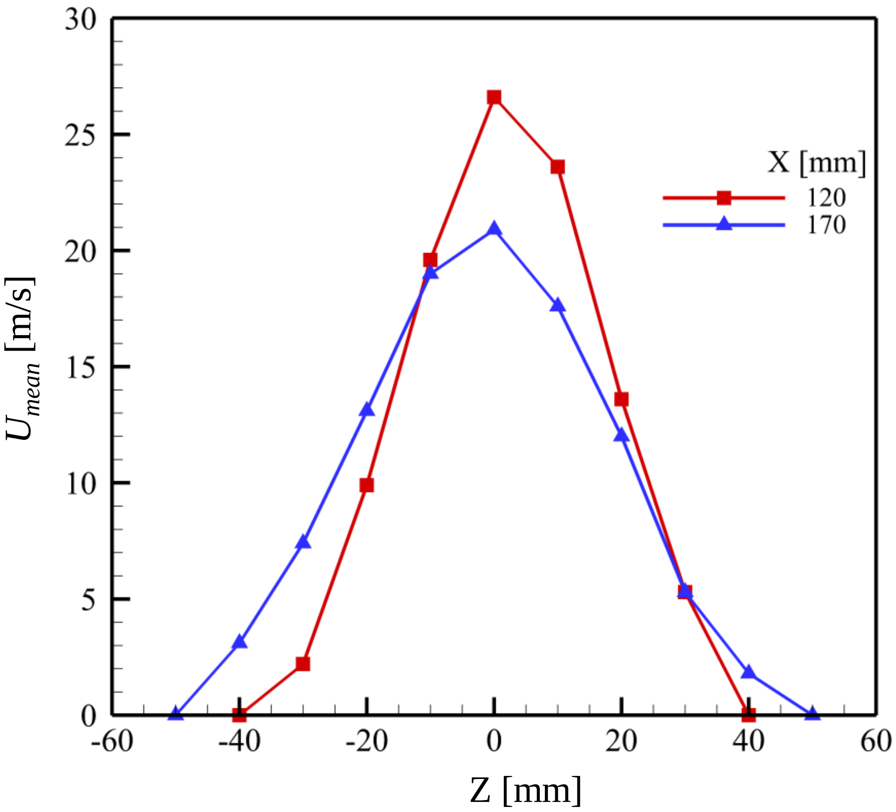
    125kfps and 1μs, exposure time
  - ✓ Pressure transducer: <u>Pressure waveform</u>

    PCB Piezotronics, INC. Model-113B28

    Rise-time of under 1μs, resolution of 7Pa

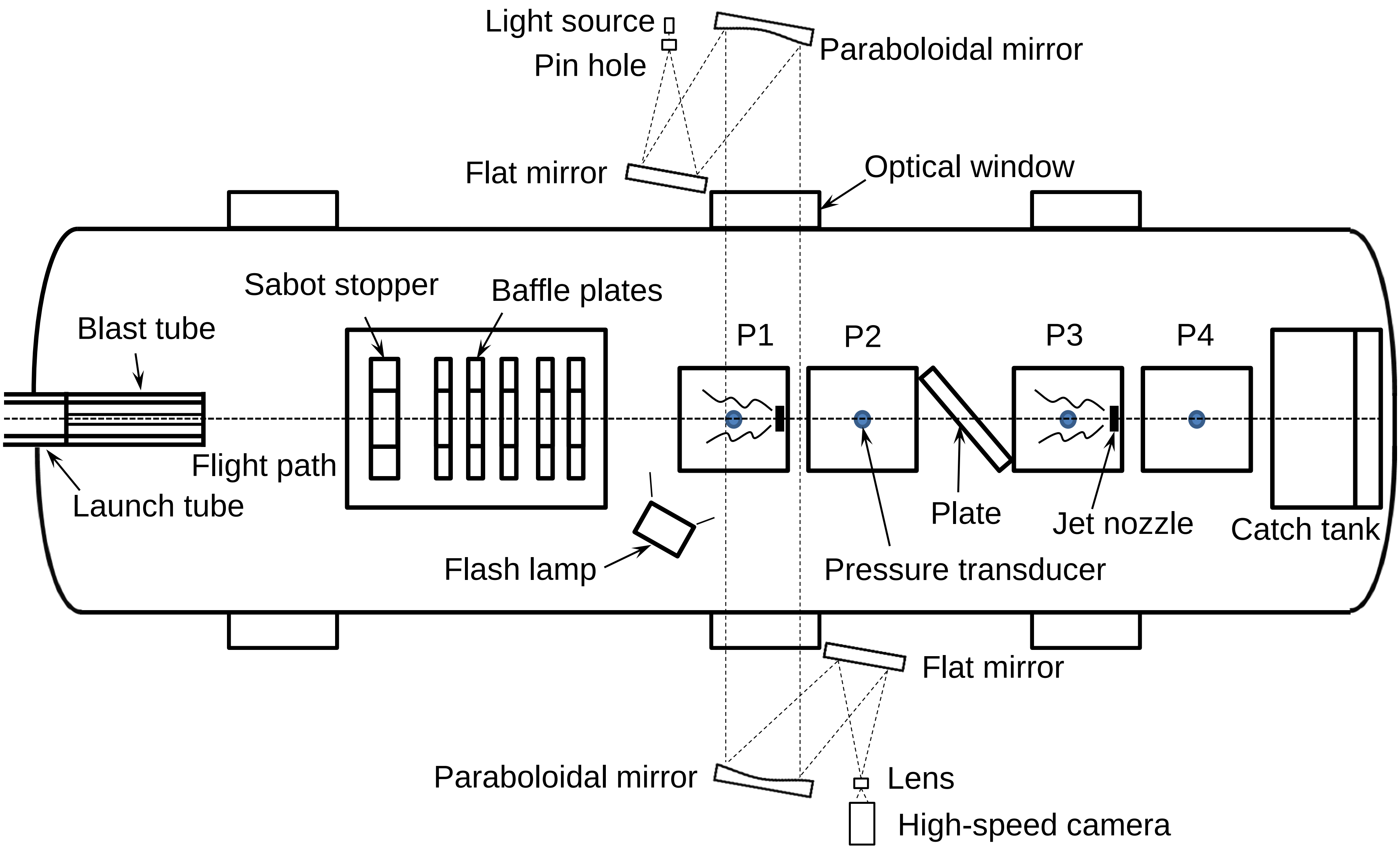
Specification of jet impingement



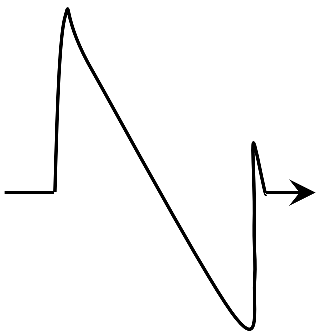


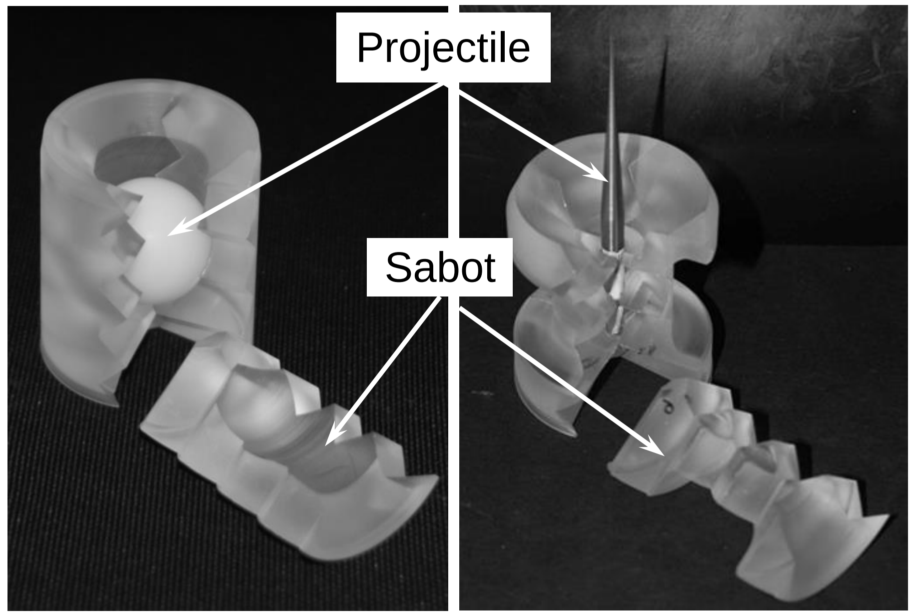
- ✓ Slit nozzle： 2mm × 10mm (height × width)
- ✓ Jet gas： Dry air

Test section

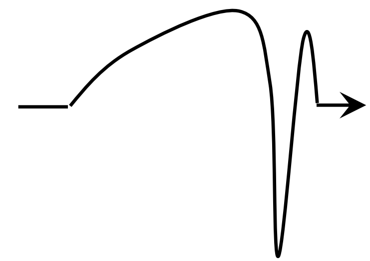


Projectiles





Spherical projectile   Axisymmetrical projectile

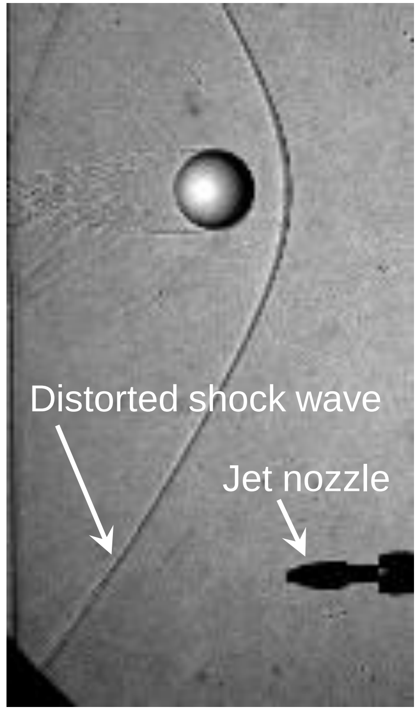


- ✓ Flight Mach number of 1.4
- ✓ Number of shots： Spherical projectile= 6 shots

  Axisymmetrical projectile= 9 shots

Results

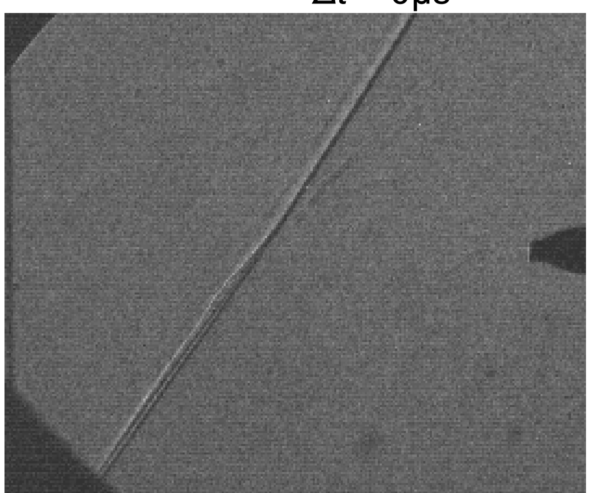
Spherical projectile



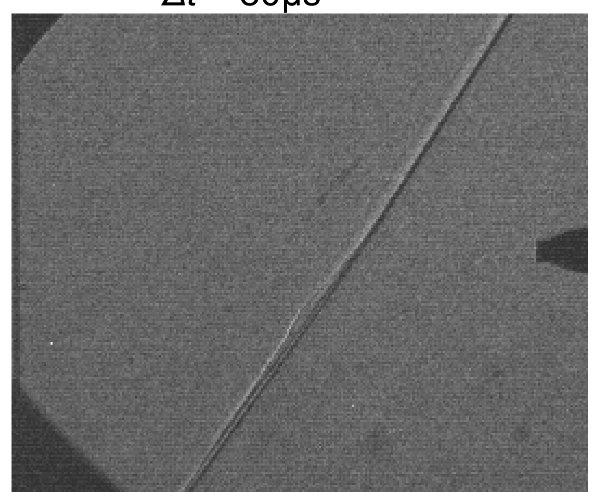
Δt = 0μs

Δt = 80μs

M = 1.32



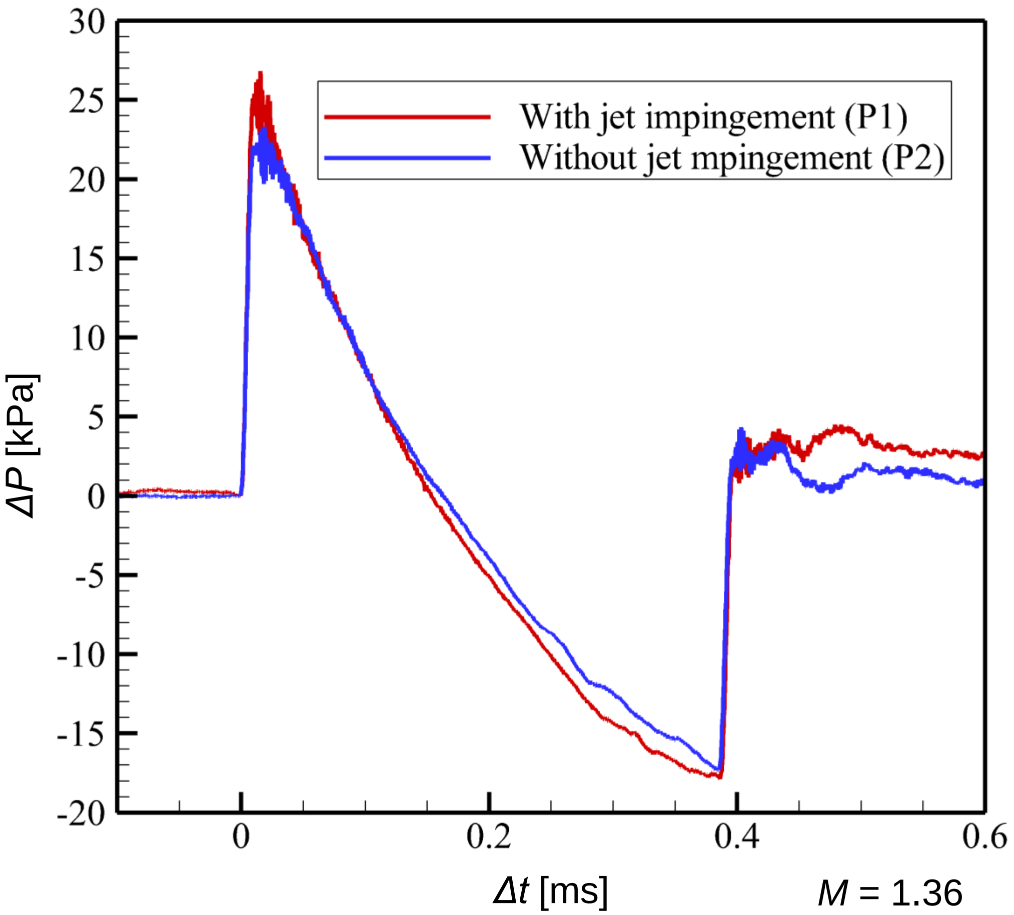
Δt = 0μs



Δt = 40μs

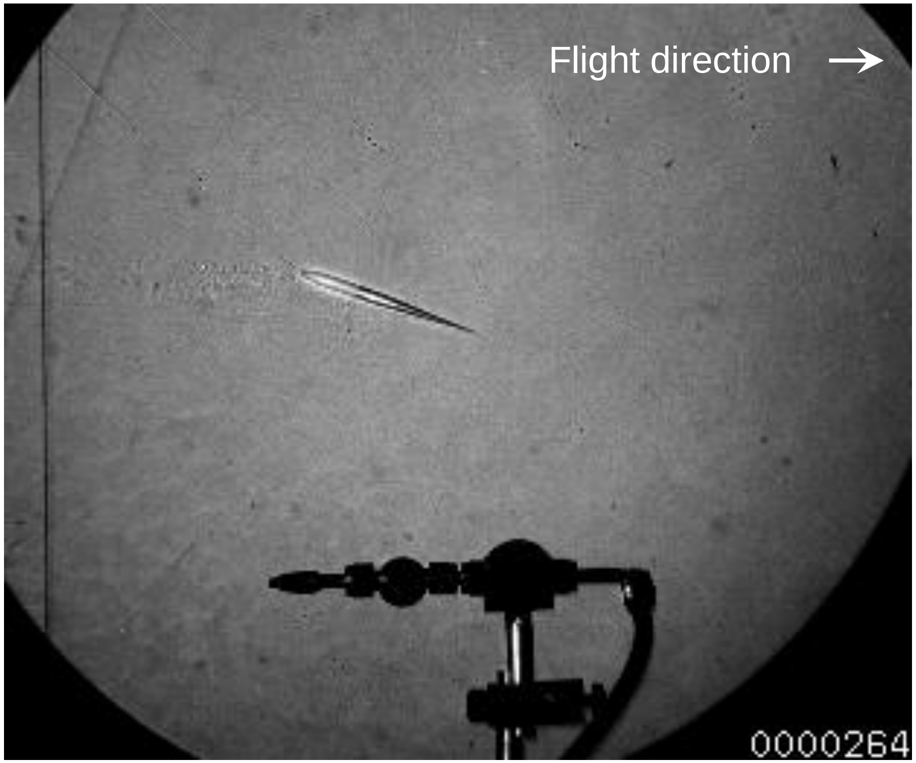
M = 1.36

Distortion of N-shaped waveform

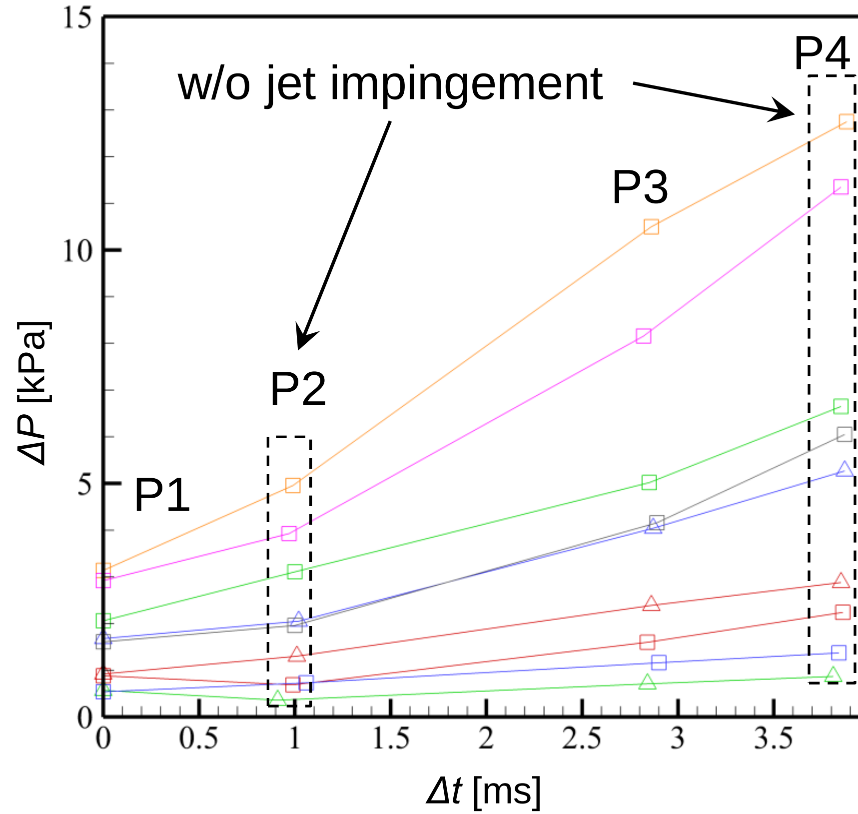


The effect of jet flow direction appeared dominantly

Axisymmetrical projectile



M = 1.46



The overpressure was increased by changing flight attitude

Summary and future plan

Evaluated a distortion of waveform with N-shape

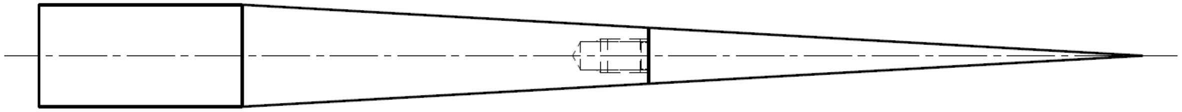
- ✓ The shock wave was distorted by the jet impingement
- ✓ The large overpressure appeared due to the jet direction

Evaluation of a distortion of low boom pressure waveform

- ✓ The effect of the flight attitude strongly appeared

Future plan

- ➢ Do not use a sabot to make the projectile fly horizontally



- ➢ Change jet flow direction and turbulence intensity