Plume and Shock Interaction Effects on Sonic Boom in the 1-foot by 1-foot Supersonic Wind Tunnel

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Outline

- Project Objectives
- Plume and Shock Interaction Experiment
- Measurement Probes
- Wedge Shock Generator Configurations
- Aft Deck Configurations
- Conclusions

Project Objectives

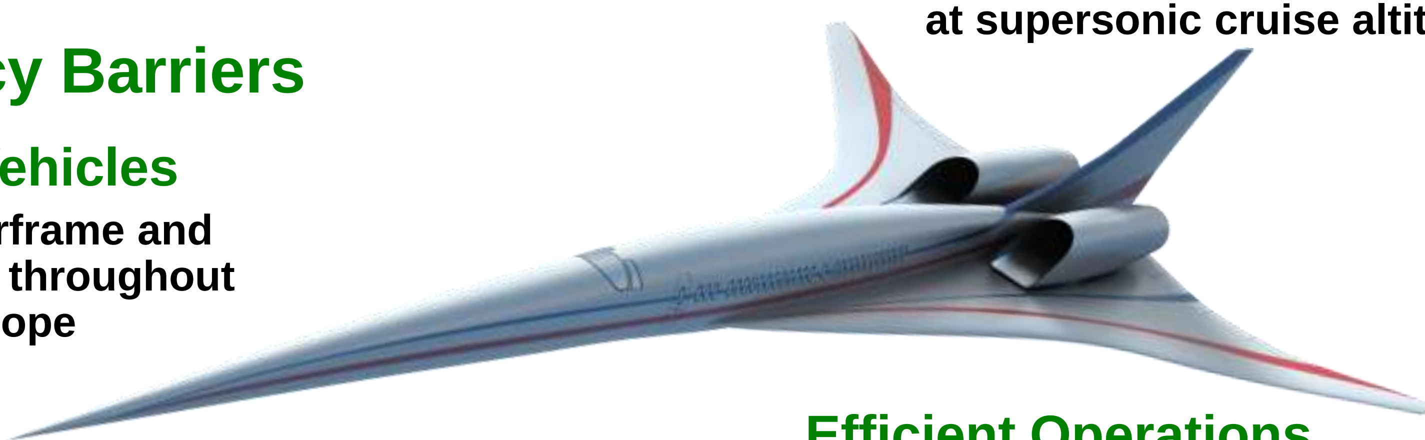
Overcoming the Barriers to Practical High Speed Vehicles

Environmental Barriers

Sonic Boom
- Design for low noise sonic boom
- Understand Community Response

Airport Noise
- Noise levels not louder than subsonic aircraft at appropriate airports

High Altitude Emissions
- No or minimal long term impact at supersonic cruise altitudes



Efficiency Barriers

Efficient Vehicles
- Efficient airframe and propulsion throughout flight envelope

Light Weight, Durable Vehicles
- Low airframe and propulsion weight in a slender flexible vehicle operating at supersonic cruise temperatures

Efficient Operations
- Airspace-Vehicle interaction for full utilization of high speed

Project Goals

Balanced Goals for Practical Civil Supersonic Aircraft (Technology Available)	N+1 Supersonic Business Class Aircraft (2020)	N+2 Small Supersonic Airliner (2025)	N+3 Efficient Multi-Mach Aircraft (Beyond 2030)
Design Goals			
Cruise Speed	Mach 1.6-1.8	Mach 1.6 -1.8	Mach 1.3 - 2.0
Range (n.mi.)	4000	4000	4000 - 5500
Payload (passengers)	6-20	35-70	100 - 200
Environmental Goals			
Sonic Boom	65-70 PLdB	85 PldB	65-70 PLdB Low Boom flight
Airport Noise (Margin to regulation)	Meet with Margin	10 EPNdB (ICAO Ch. 4)	10 EPNdB (ICAO Ch. 14)
Cruise Emissions (Cruise NOx g/kg of fuel)	Equivalent to current Subsonic	< 10	< 5 & particulate and water vapor mitigation
Efficiency Goals			
Fuel Efficiency (pass-miles per lb of fuel)	1.0	3.0	3.5 – 4.5

N+1 Business Class

N+2 Small Supersonic Airliner

N+3 Efficient, Multi Mach Aircraft

Plume and Shock Interaction Experiment

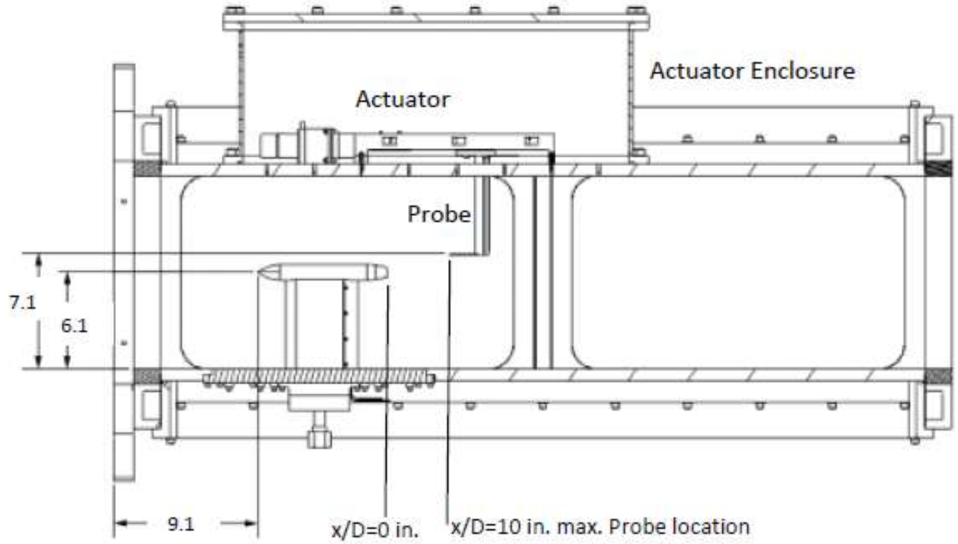
1x1 Nozzle Plume and Shock Interaction Test

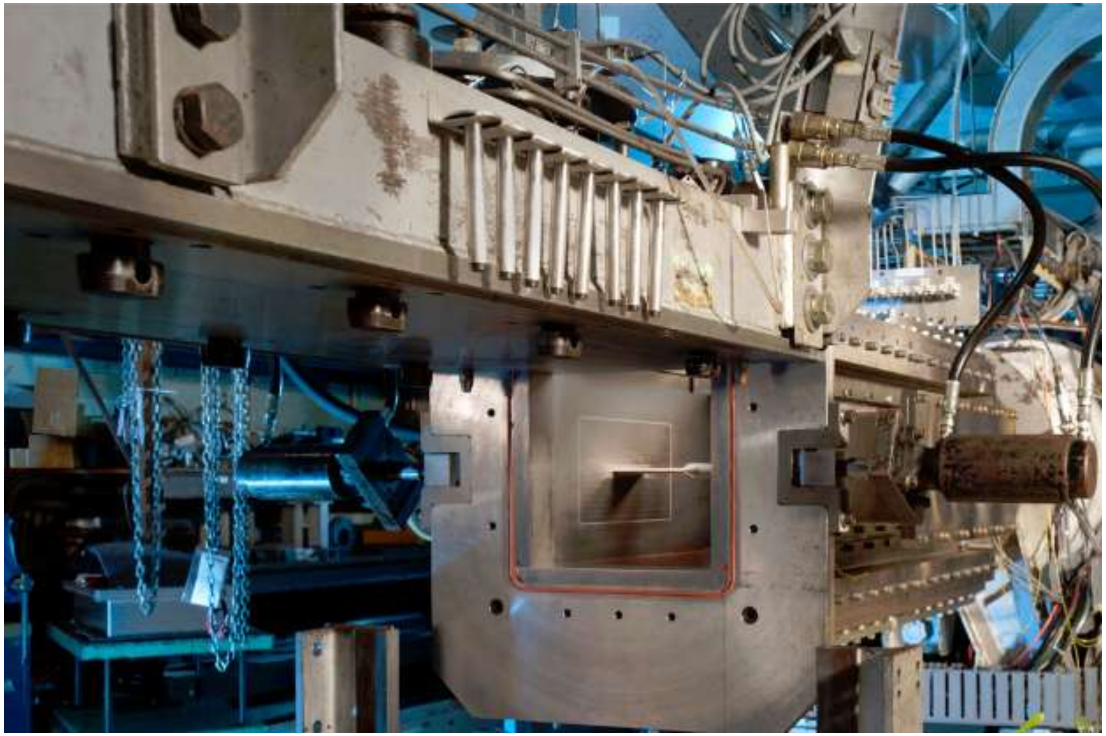
The plume and shock interaction study was developed to collect data for CFD validation where a nozzle plume is passing through the shock generated from the wing or tail of a supersonic vehicle. The wing or tail was simulated with a wing having a wedge shaped profile.

1x1 Nozzle Plume and Shock Interaction Test

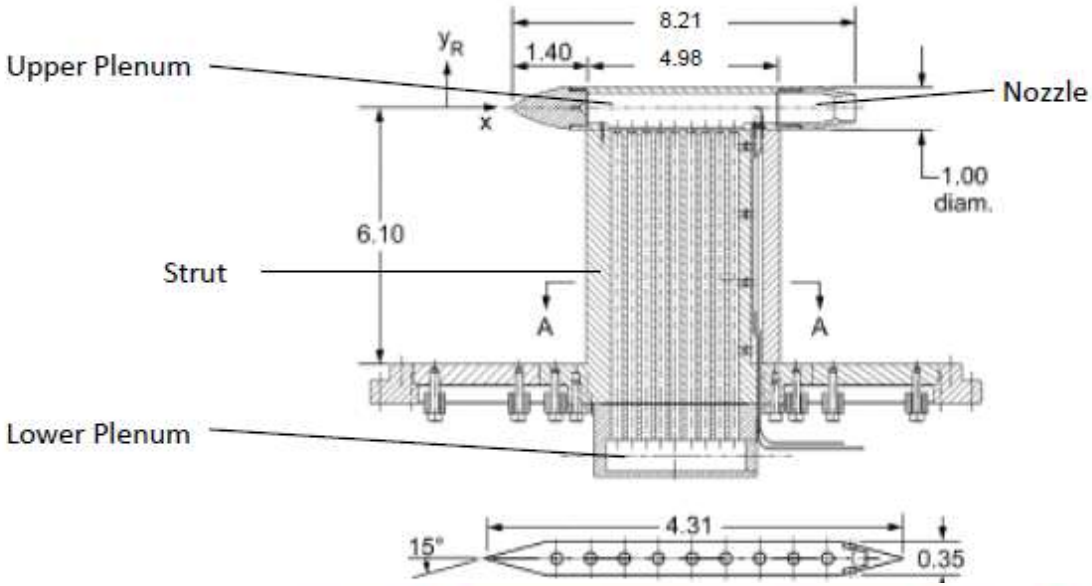
Configurations were also tested simulating the propulsion pod and aft deck from a low boom vehicle concept, which provided a trailing edge shock and plume interaction.

1x1 Supersonic Wind Tunnel





Model

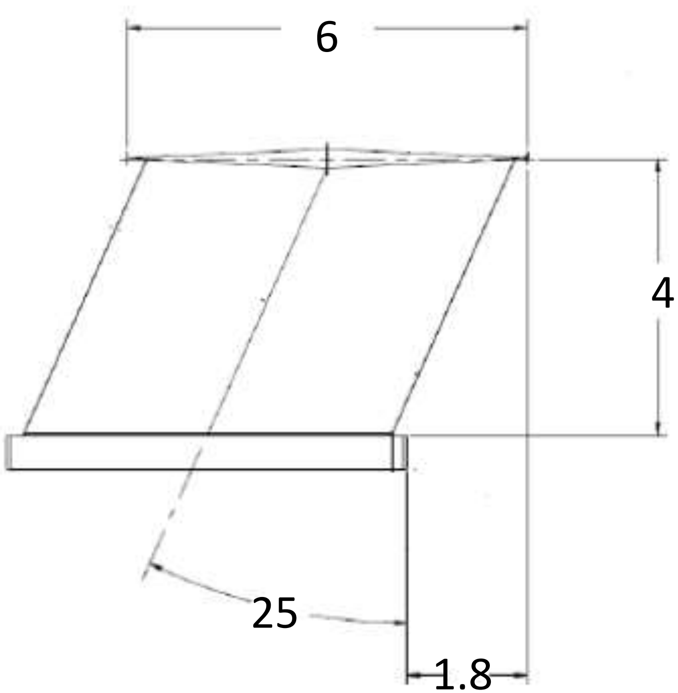


8.21
1.40
4.98
y_R
x
Upper Plenum
Nozzle
1.00
diam.
6.10
Strut
A
A
Lower Plenum
4.31
15°
0.35

Test Configurations

Three wedge configurations:

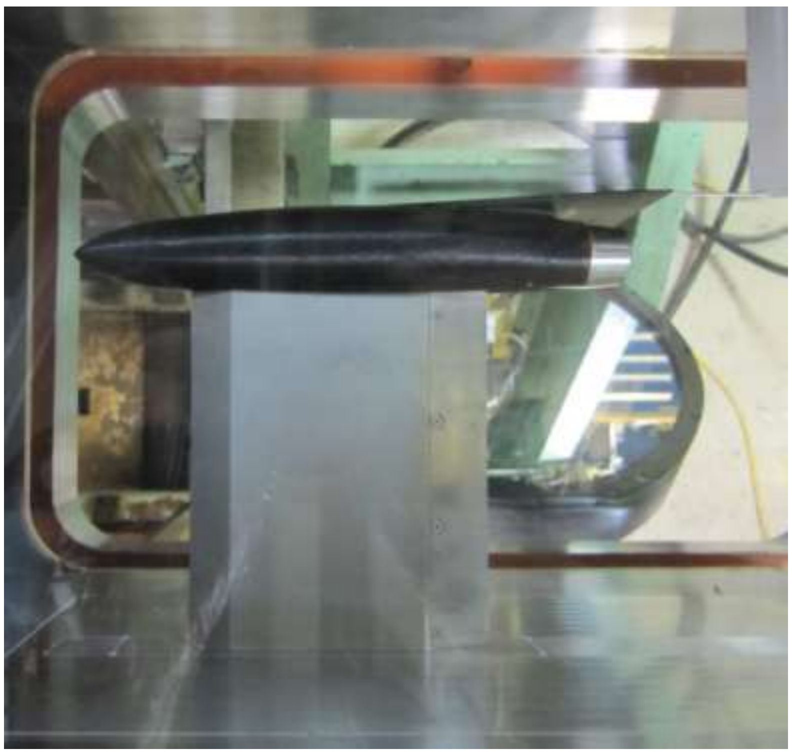
- 6 in. long, 2.5-degree wedge shock generator
- 6 in. long, 5-degree wedge shock generator
- 1.5 in. long, 5-degree wedge shock generator

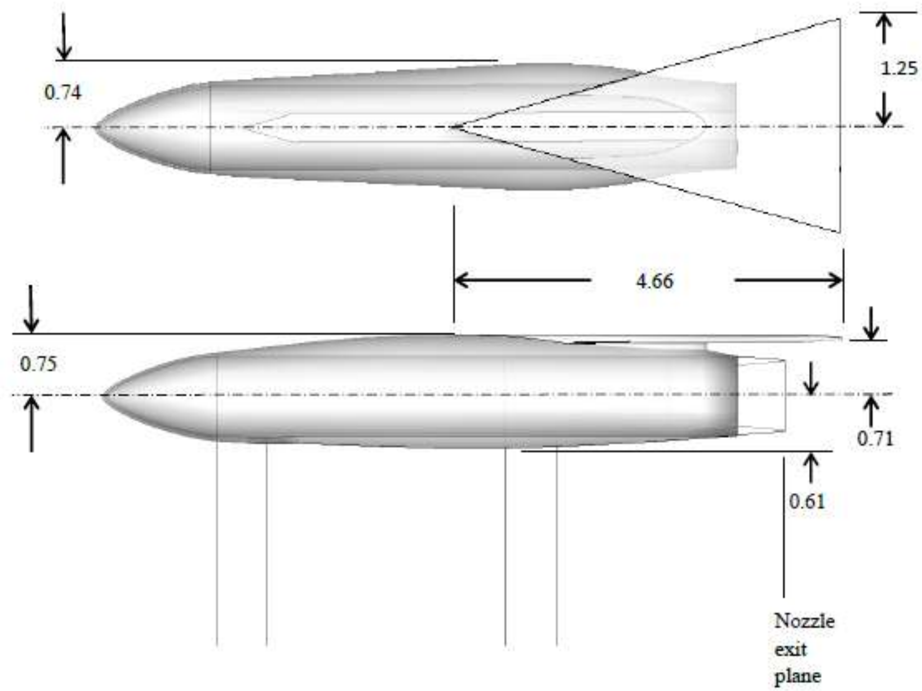


Test Configurations

Three aft deck configurations:

- Nacelle geometry with asymmetric height of 0.25 and aft deck lengths of 0, 0.5 and 1 nozzle diameter.
- Asymmetry simulates space for engine accessories.

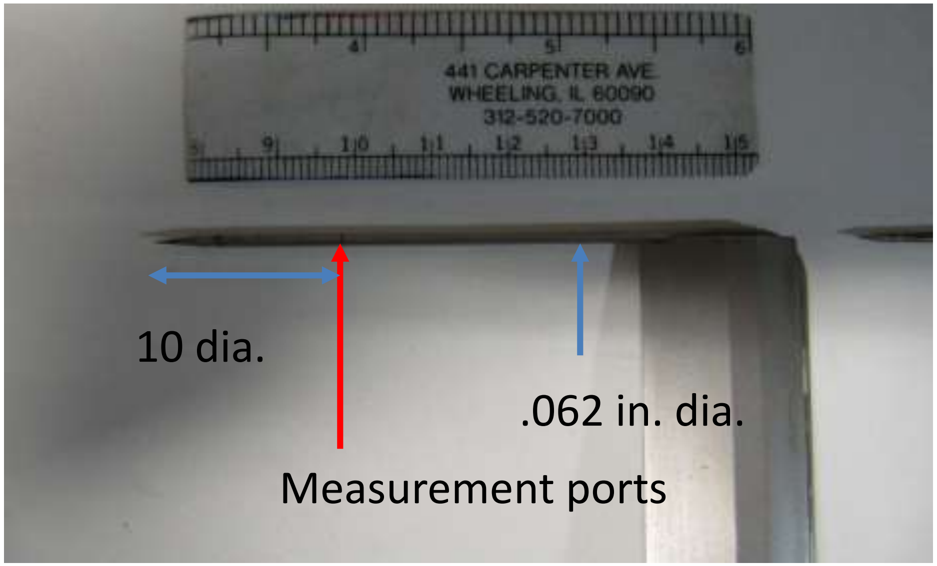


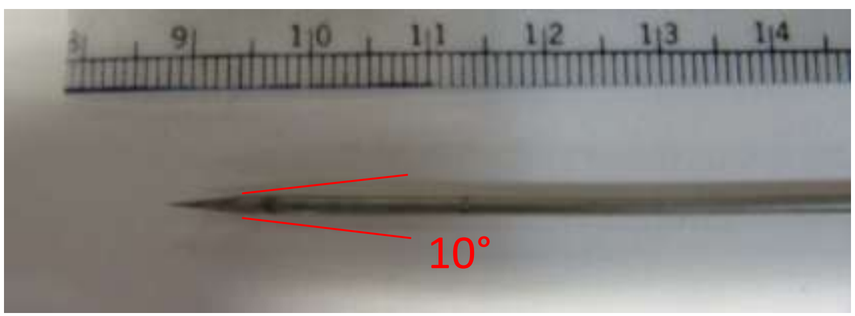


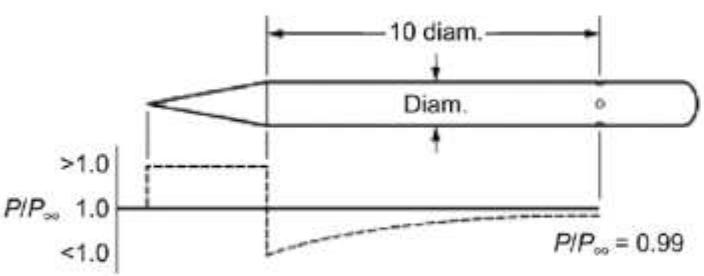
Measurement Probes

Probe Geometry

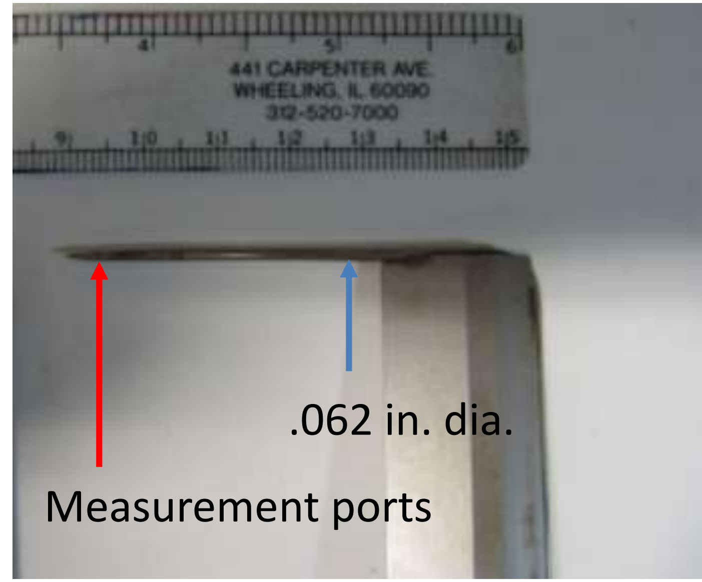
10-degree cone probe

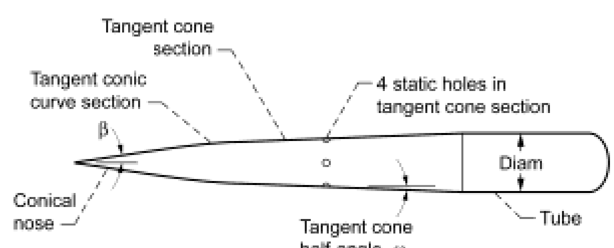




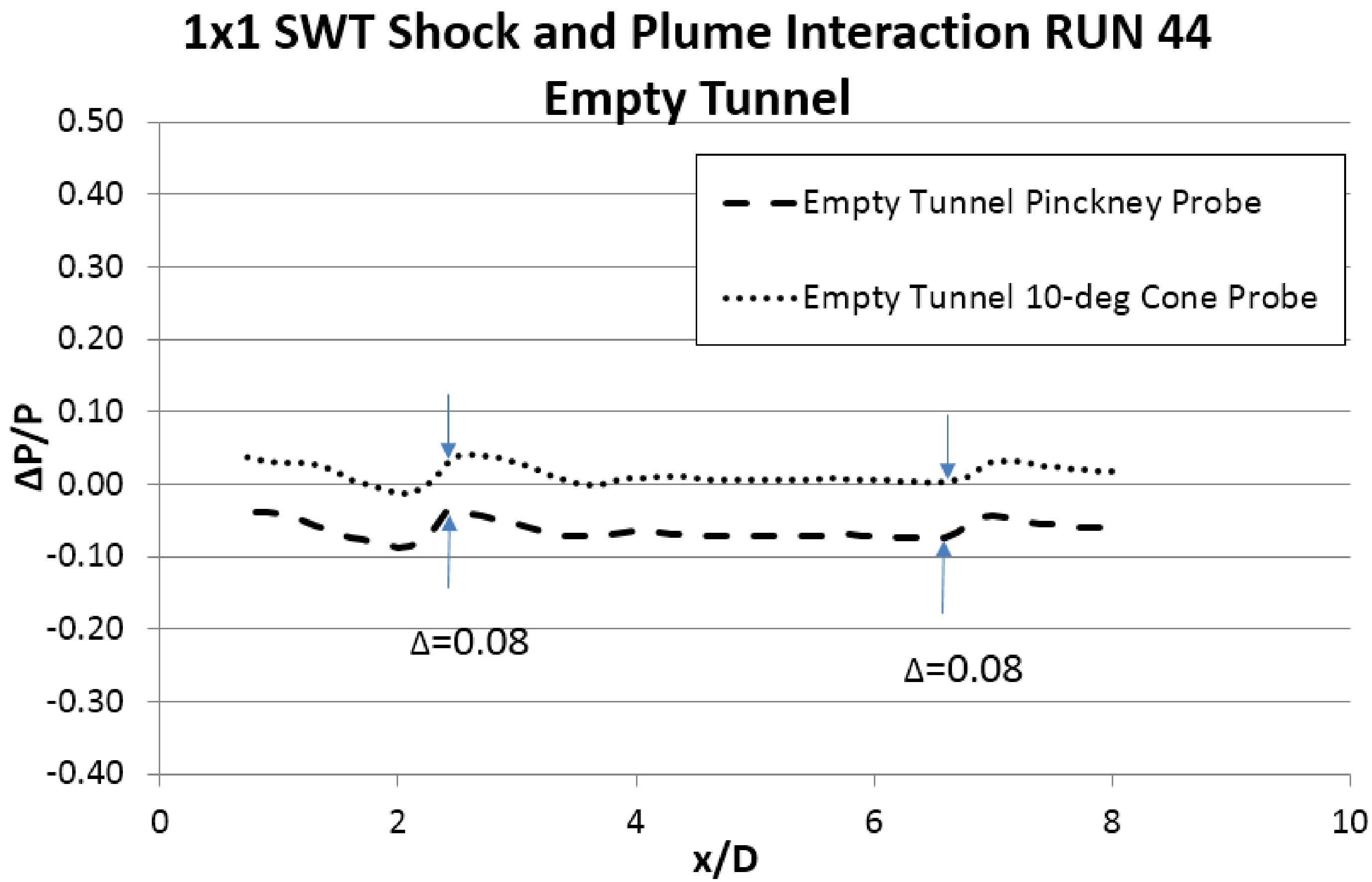


Pinckney probe

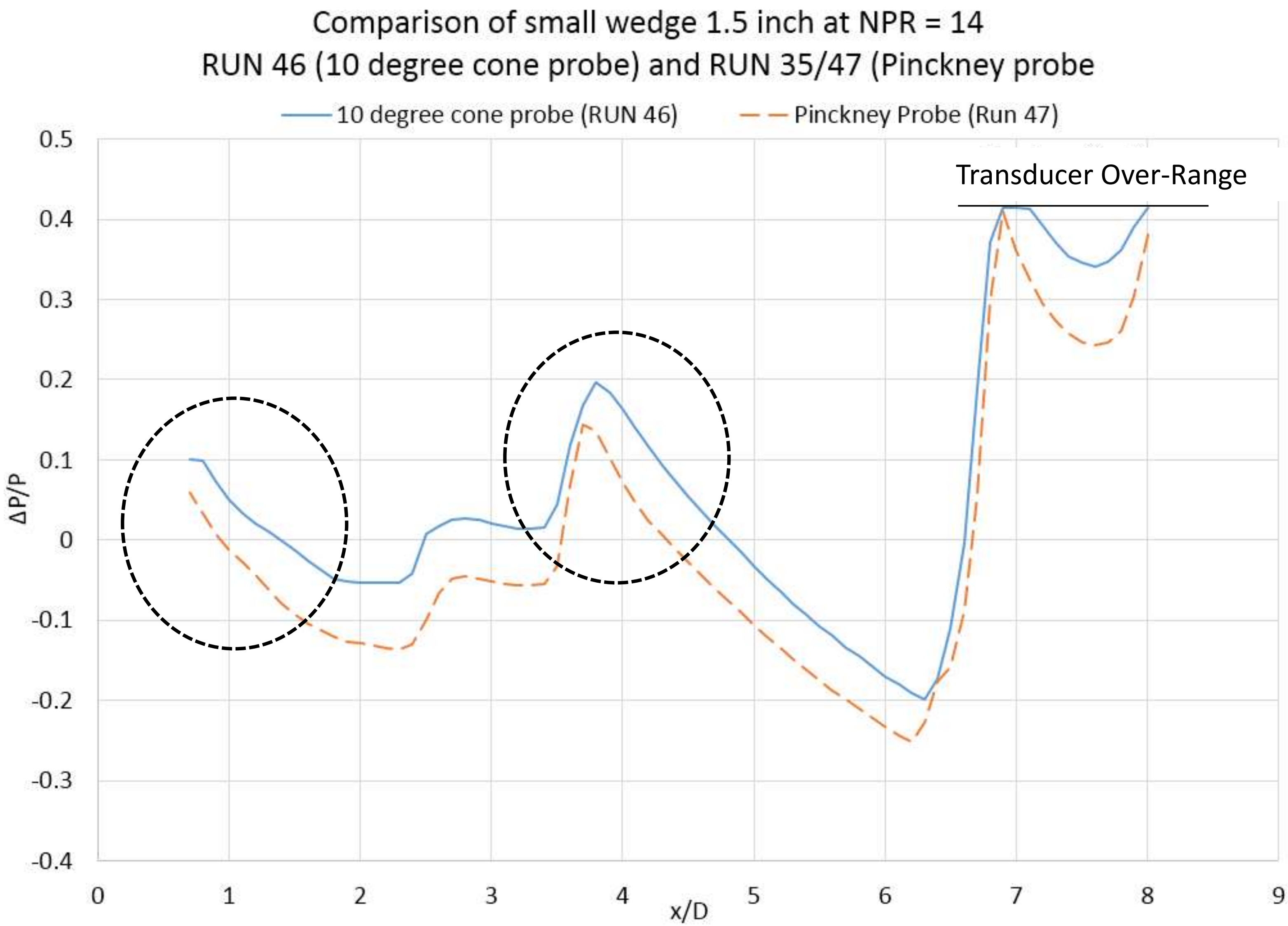




(β=10; ω=1.5)



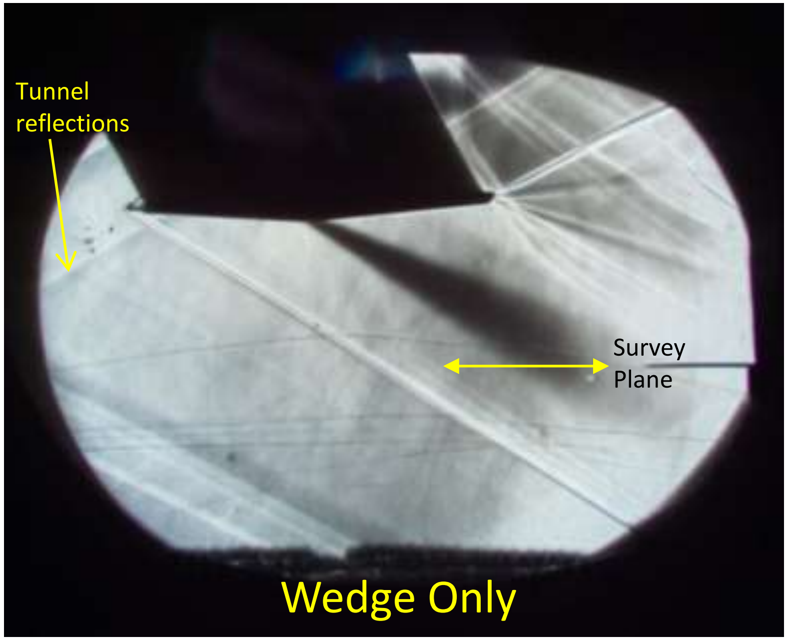
- Two static pressure probes were built, a 10-degree cone probe and a design based on Pinckney.
- Static pressure data collected with the Pinckney probe demonstrated a constant offset in $\Delta P/P$ of -0.08 when tested in an empty tunnel.



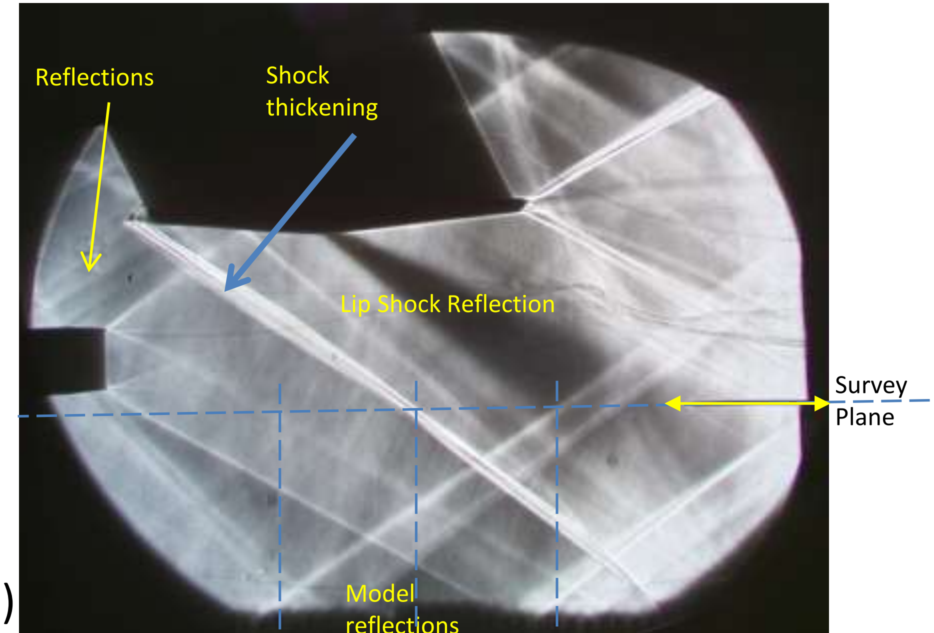
- 10-degree cone probe demonstrates a 'rounding' of the ΔP/P peaks.
- The offset between the Pinckney probe and the 10-degree cone probe was not constant.

Wedge Shock Generator Configurations

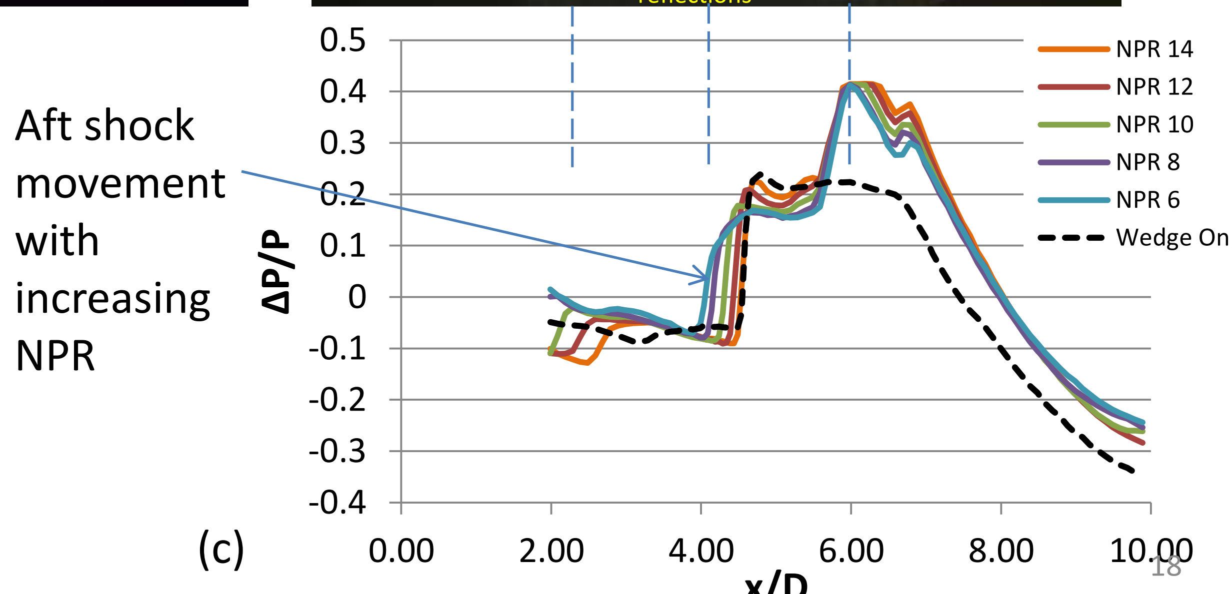
5 Degree, 6 in. Long Wedge Experiment



(a)



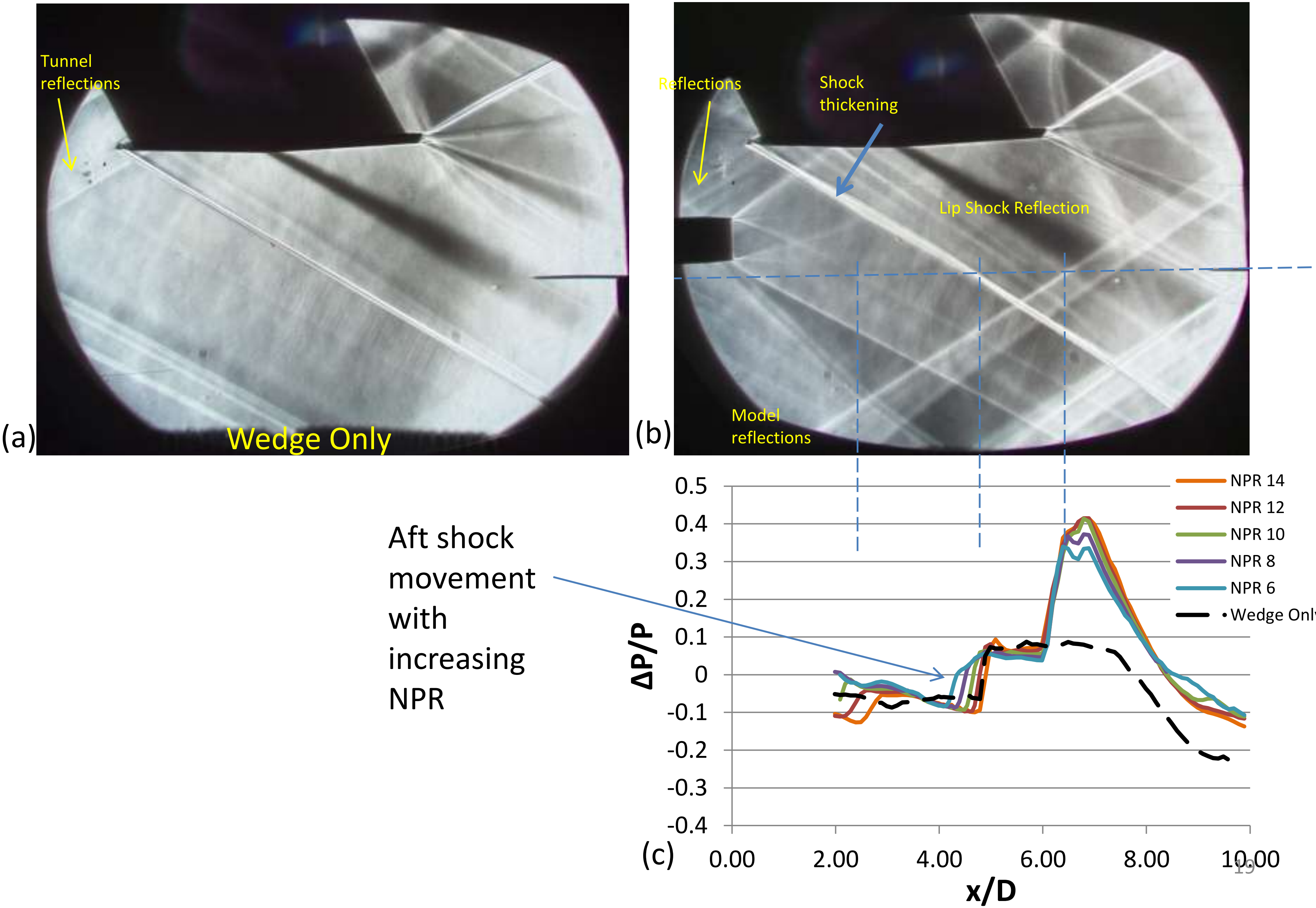
(b)



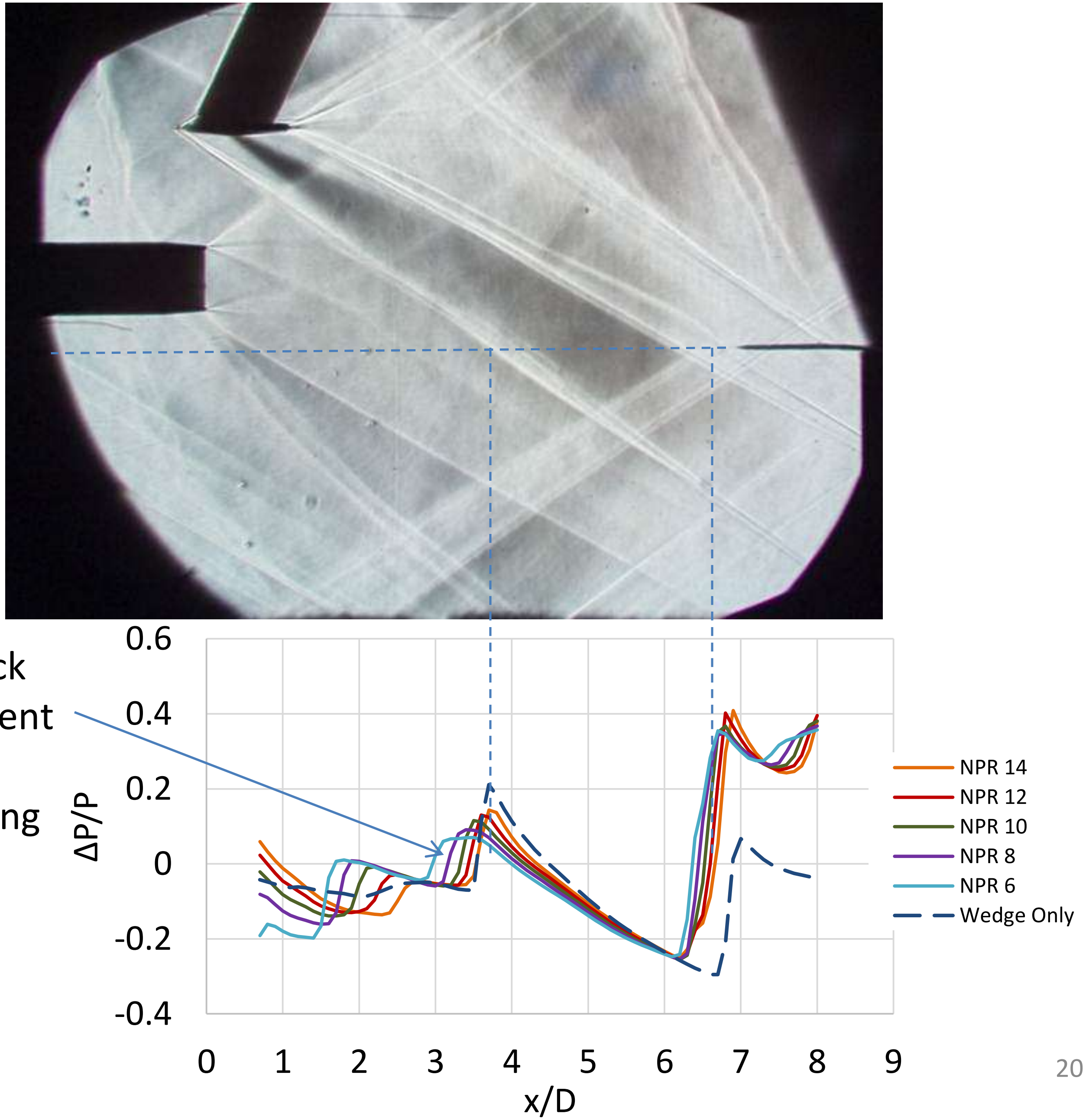
(c)

Tunnel Flow Conditions:
Mach 1.96
50,000 ft altitude
P_o=1.68 psia
P_t=12.4 psia

2.5 Degree, 6 in. long Wedge Experiment



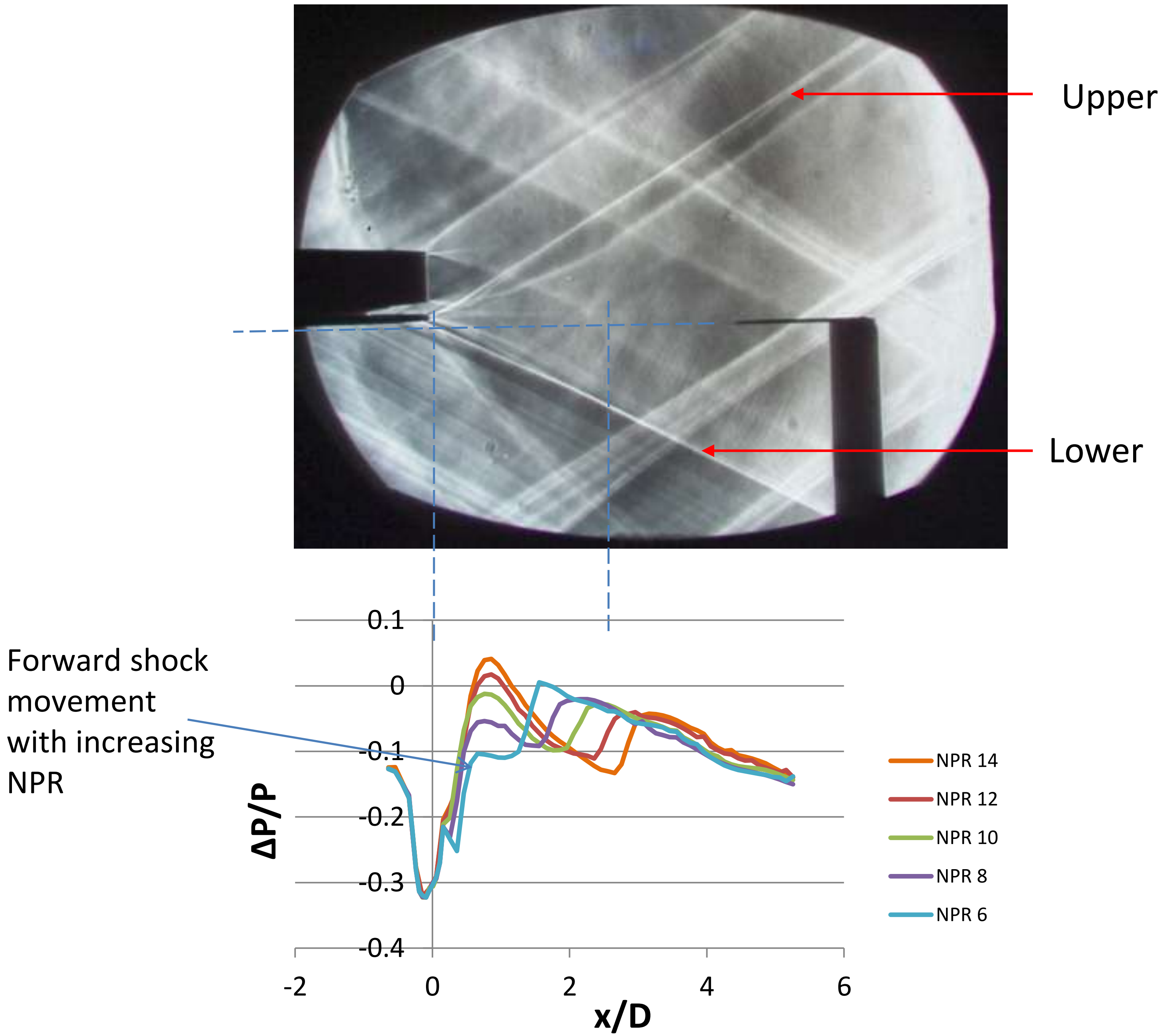
5-degree, 1.5” Wedge – Pinckney Probe (Run 46)



Aft shock movement with increasing NPR

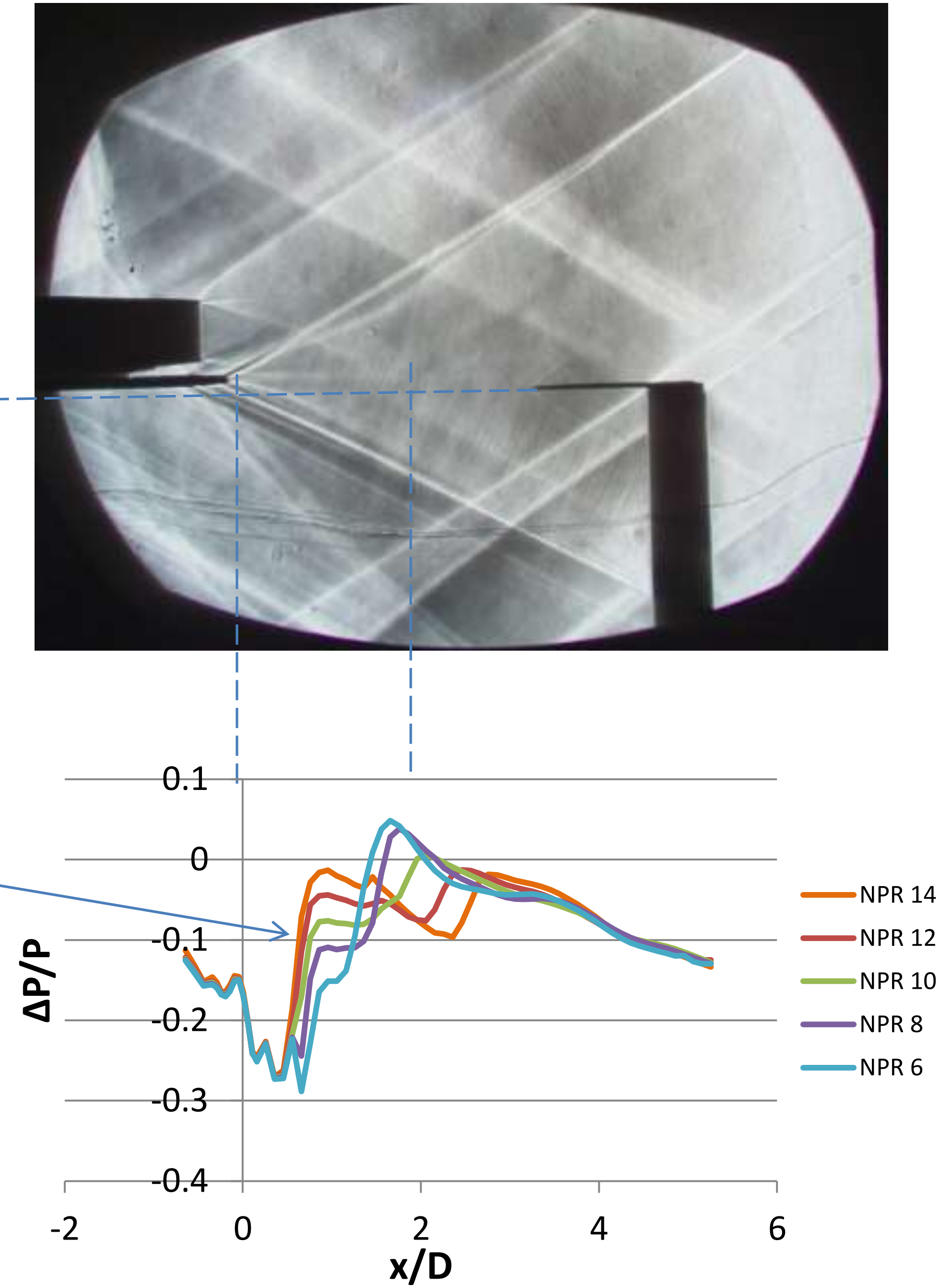
Aft Deck Configurations

Asymmetric Nacelle with 0-Dia. Aft Deck Configuration



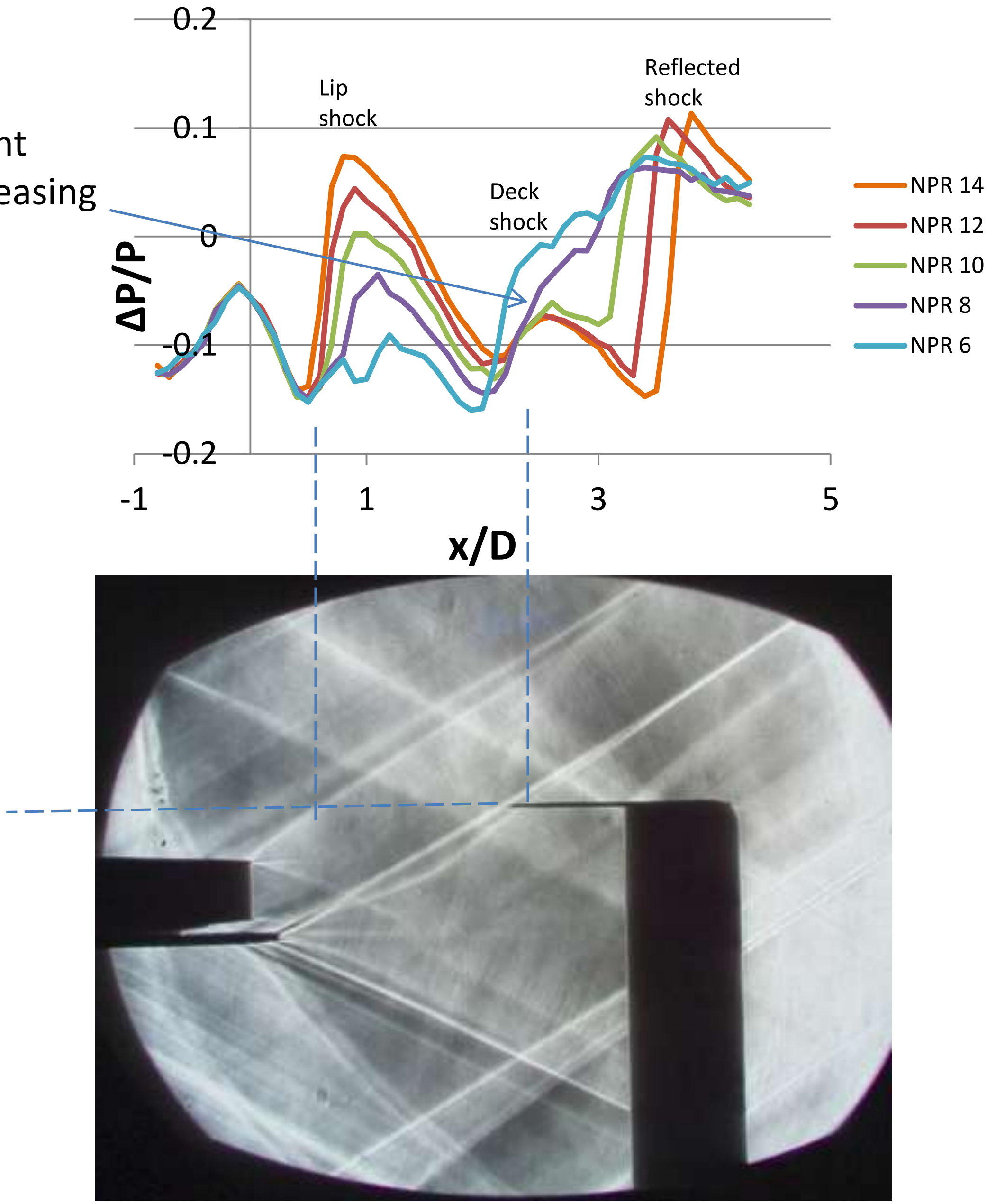
Asymmetric Nacelle with ½Dia. Aft Deck Configuration

Forward shock movement with increasing NPR

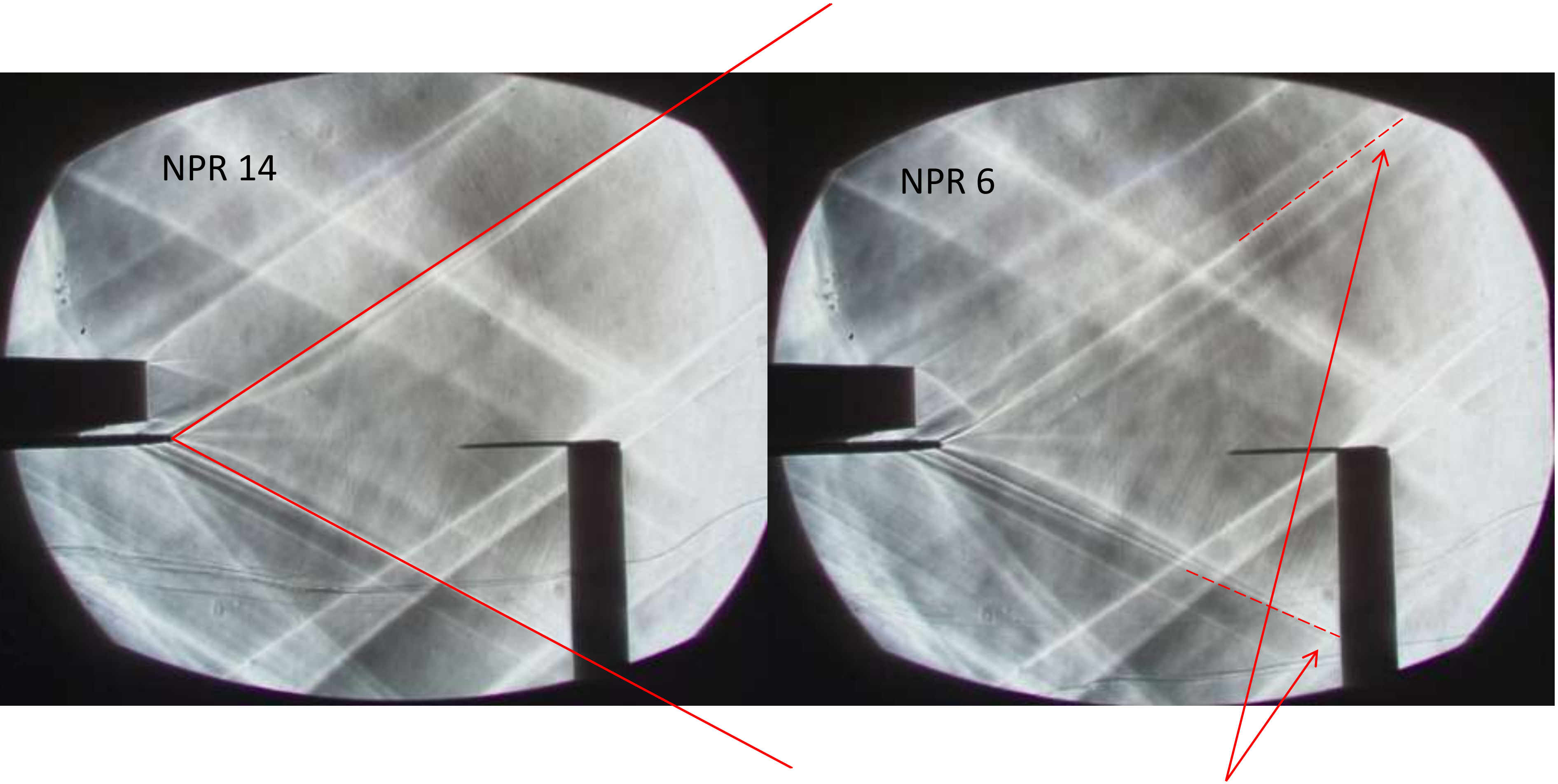


Asymmetric Nacelle with ½Dia. Aft Deck Configuration

Aft shock movement with increasing NPR

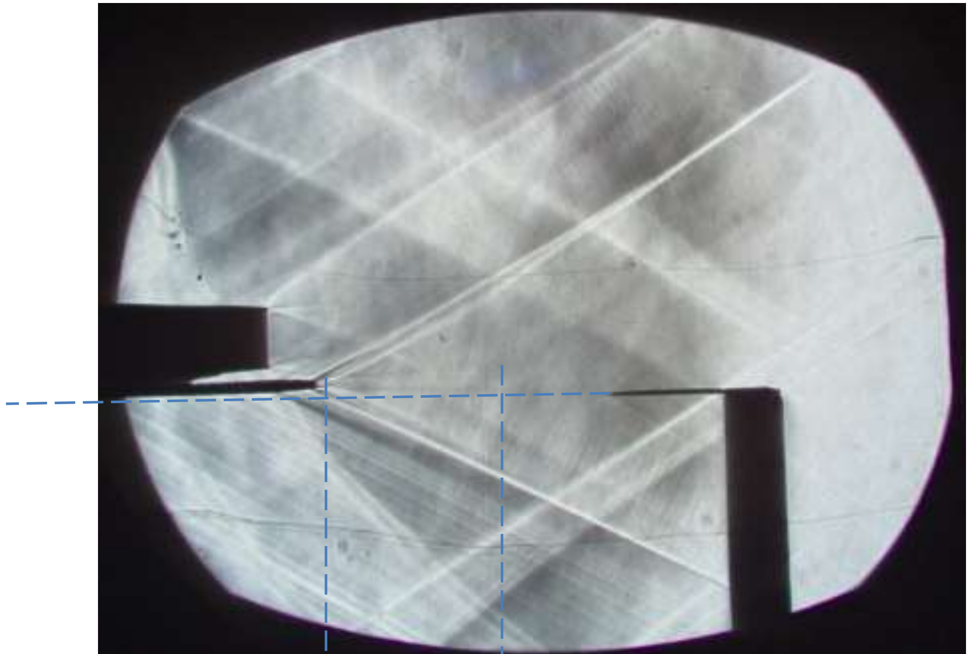


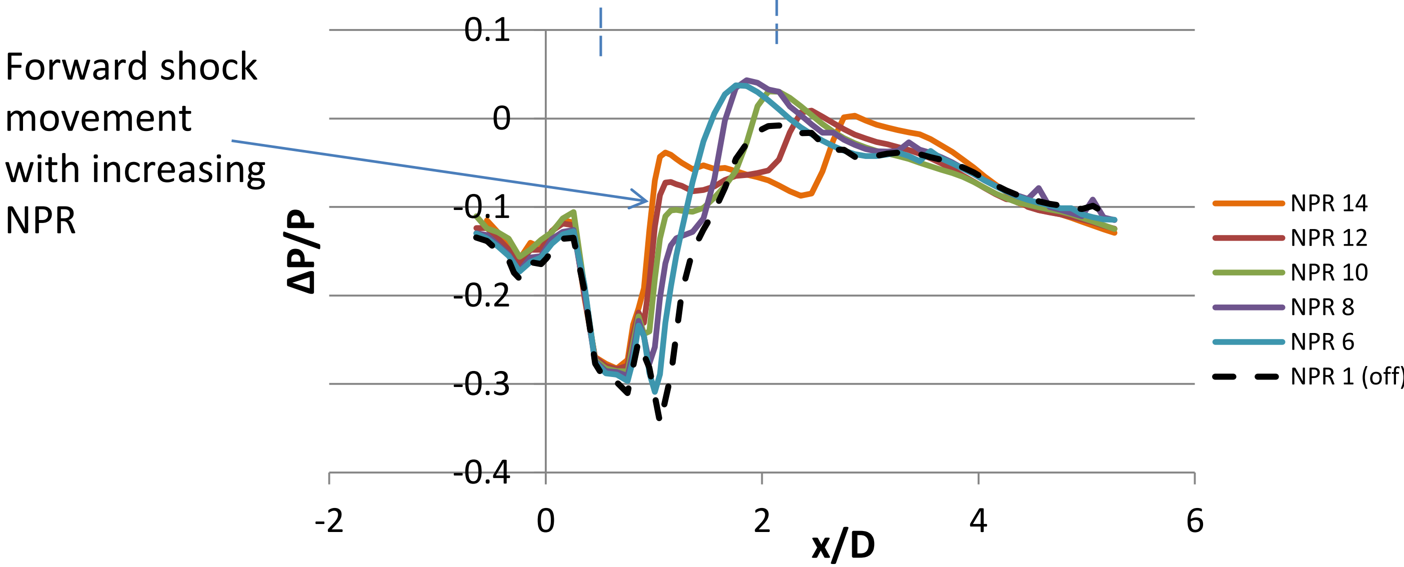
½Dia. Aft Deck Shock Movement, Run 11



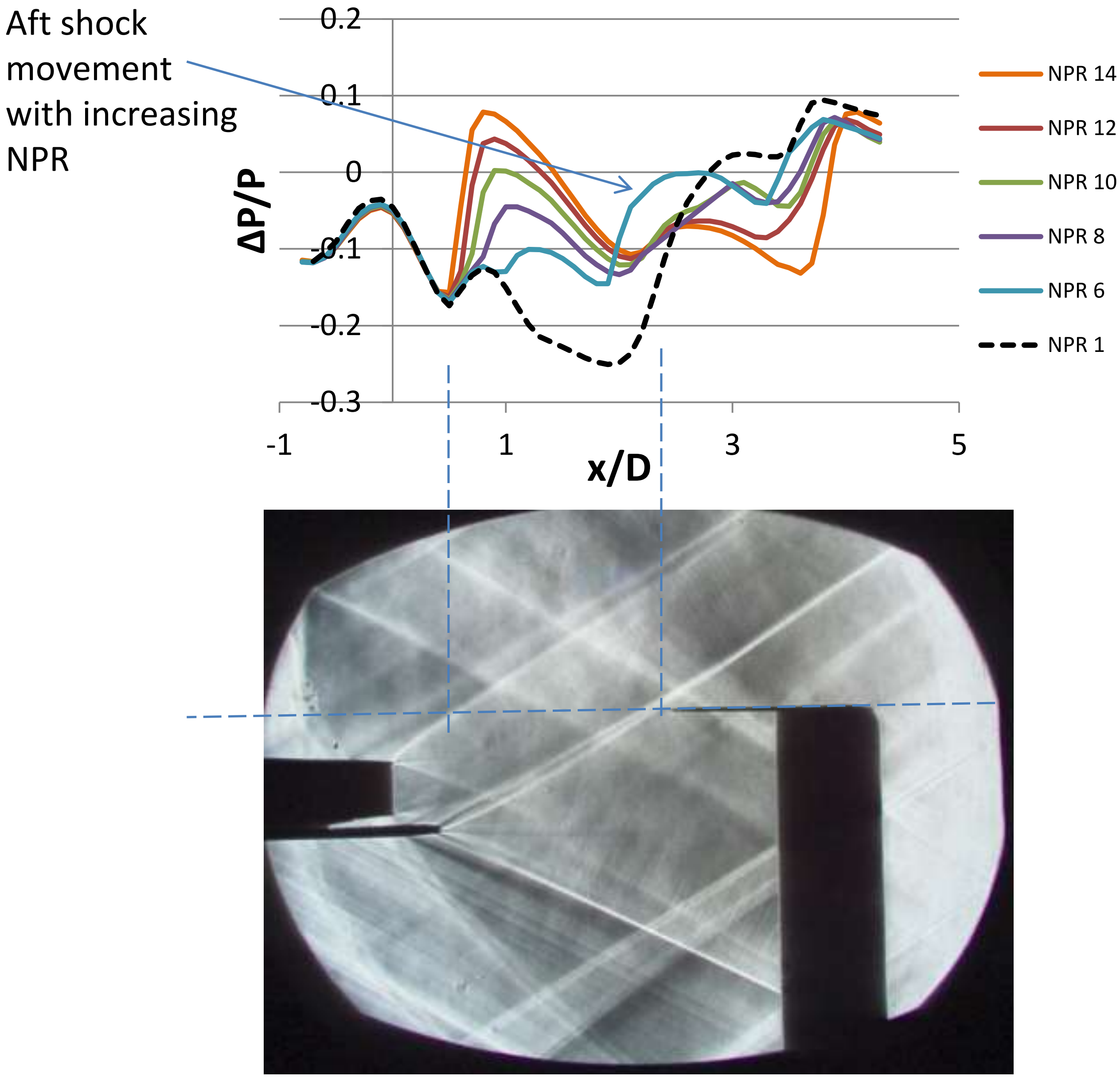
Shock movement with decreasing nozzle pressure ratio

Asymmetric Nacelle with 1Dia. Aft Deck Configuration





Asymmetric Nacelle with 1Dia. Aft Deck Configuration, upper survey



Conclusions

- **Wedge Shock Experimental Results:**
  - **Data and schlieren images demonstrated thickening of the wedge shock upon interaction with the shocks generated by the nozzle lip and the interaction with nozzle plume.**
  - **The data also demonstrated approximately 0.5 in. of shock movement between nozzle pressure ratios of 6 to 14.**
- **Aft Deck Experimental Results**
  - **The upper shock waves moved downstream with increasing NPR, and the lower shock waves moved upstream with increasing NPR.**
- **Overall Observations**
  - **These experiments do not demonstrate an optimum operating condition, however they demonstrate that shock waves from the aft deck or tail move with increasing and decreasing NPR.**
  - **For similar configurations, movement of the aircraft engine throttle setting may cause movement of aft shock waves.**
  - **To verify the impact, a sonic boom analysis may be performed at reasonable off-design throttle conditions to check if changes in NPR would result in significant shock movement and affect the sonic boom loudness.**

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