National Aeronautics and Space Administration

Increased Mach Number Capability for the NASA Glenn10x10 Supersonic Wind Tunnel

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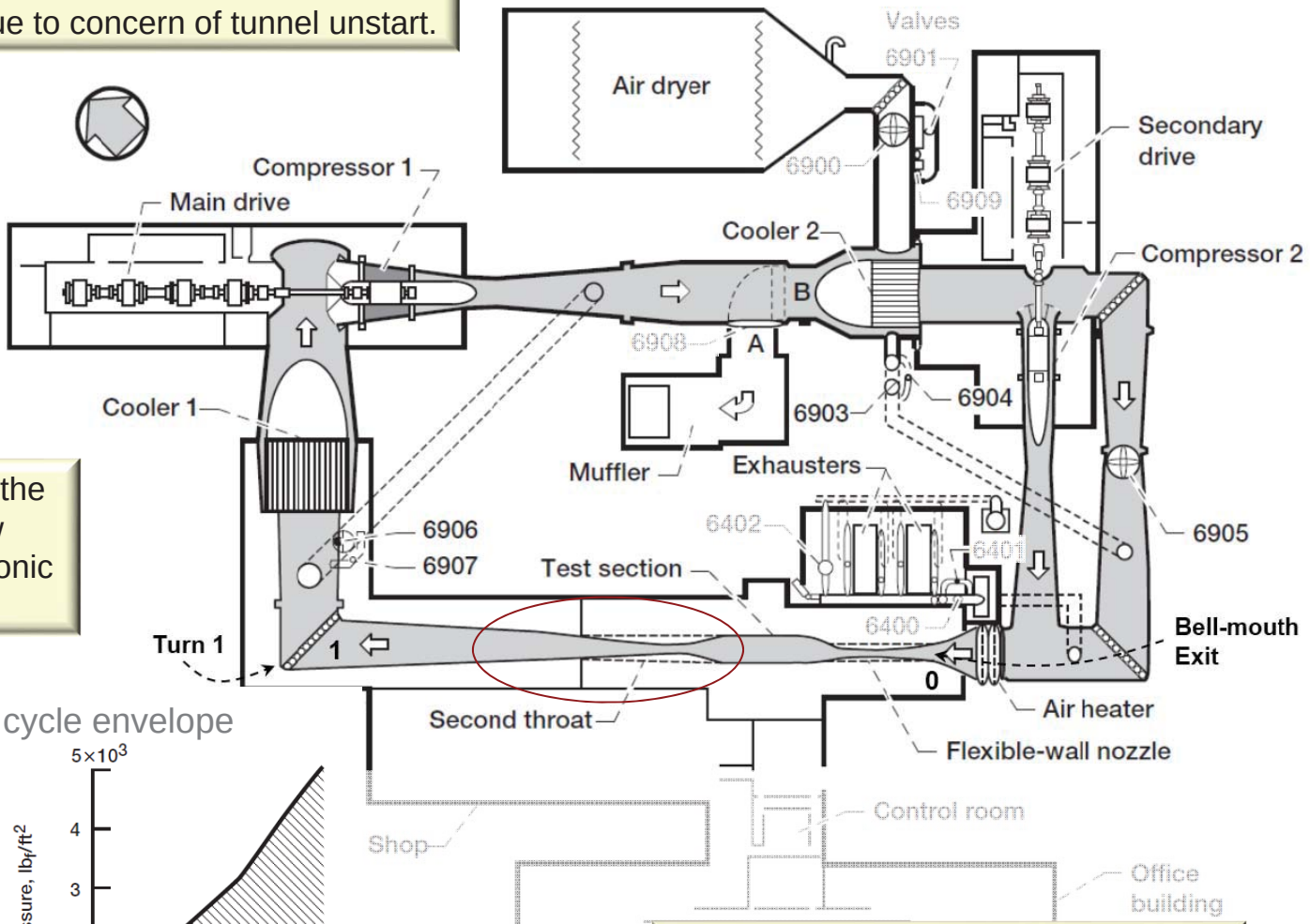
NASA Glenn 10x10 Supersonic Wind Tunnel

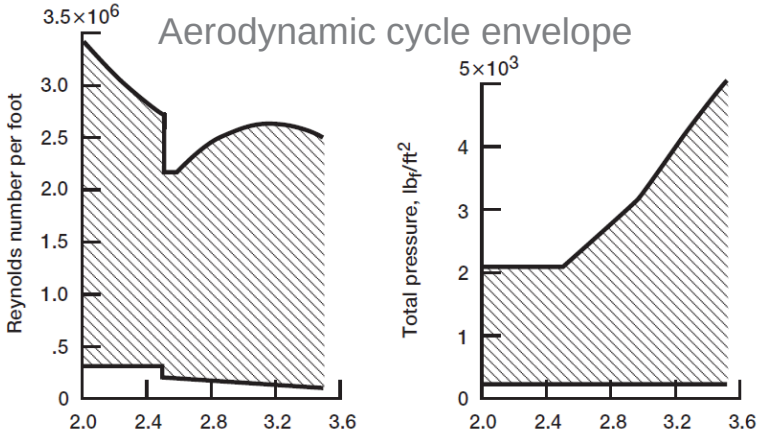
The 10x10 SWT was designed for Mach 4 test section speeds, but limited to 3.5 due to concern of tunnel unstart.

Compressors capable of a tunnel pressure ratio, TPR = p_{t0}/p_{t1} = 7.11.

Most losses occur in the second throat as flow reduces from supersonic to subsonic.

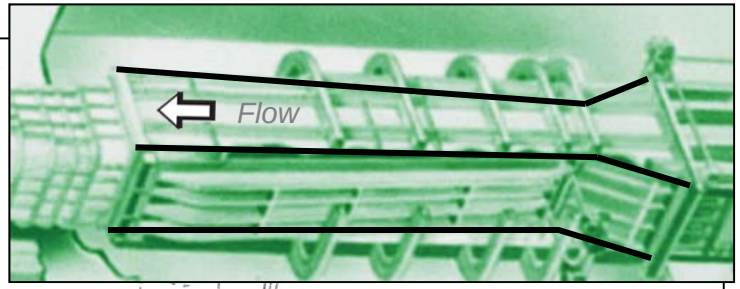


Aerodynamic cycle envelope



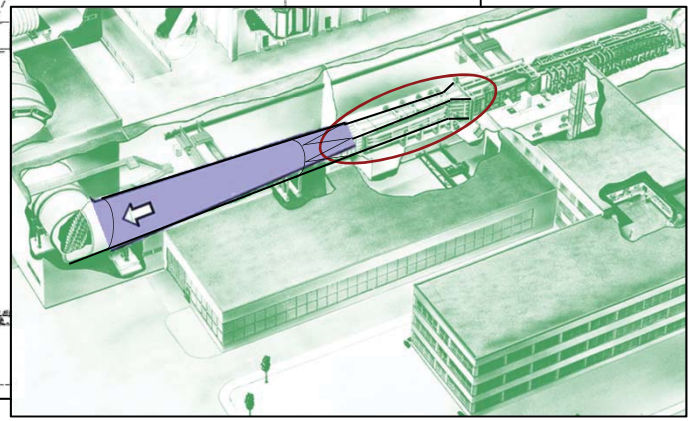
A capability of testing above Mach 3.5 would enhance the 10x10 SWT and be of interest for hypersonic testing.

NASA Glenn 10x10 Second Throat Detail



The second throat consists of movable converging and diverging ramps that create a throat downstream of the test section.

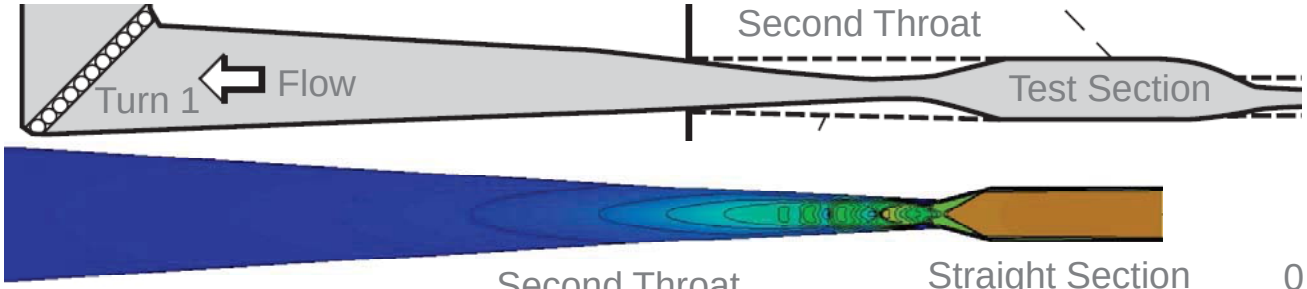
Very large hydraulic actuators are used to position the ramps.



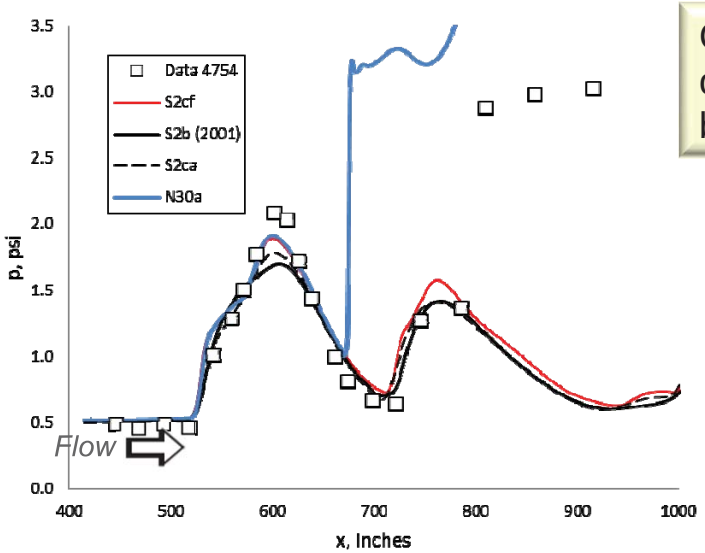
CFD Simulations

CFD simulations and wind tunnel tests were conducted to understand the flow field within the second throat and explore tunnel operation at speeds greater than Mach 3.5.

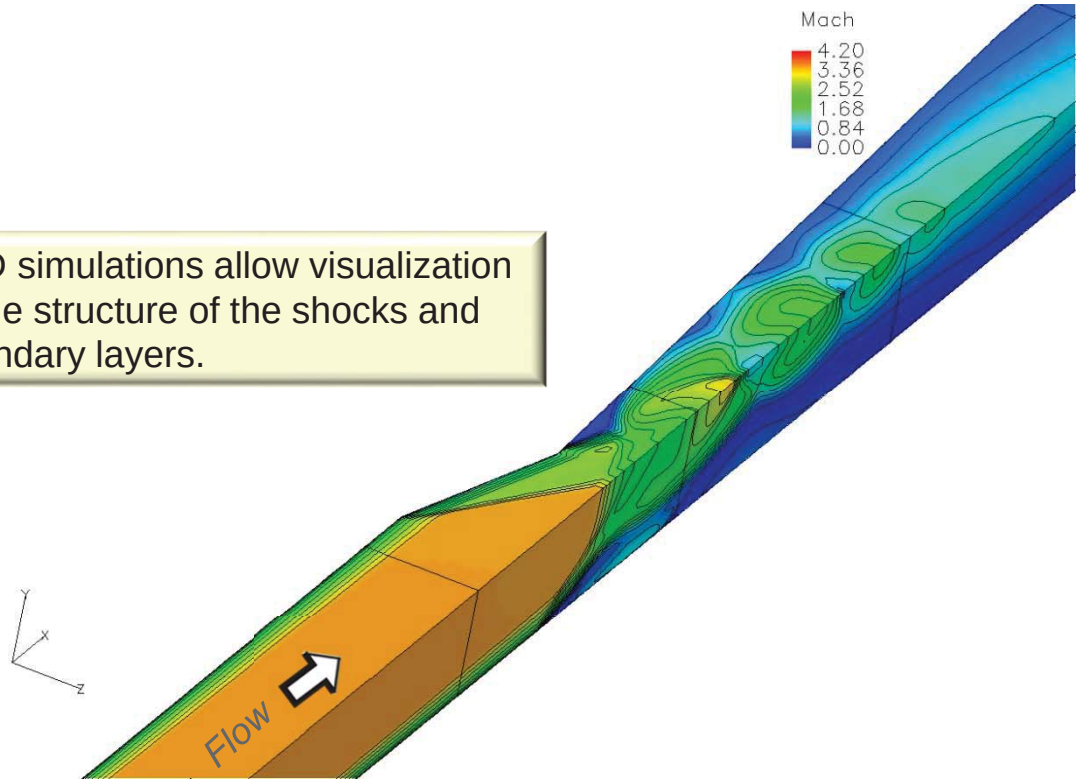
CFD domain includes test section, second throat, and tunnel to turn 1. An outflow nozzle section creates back-pressure.



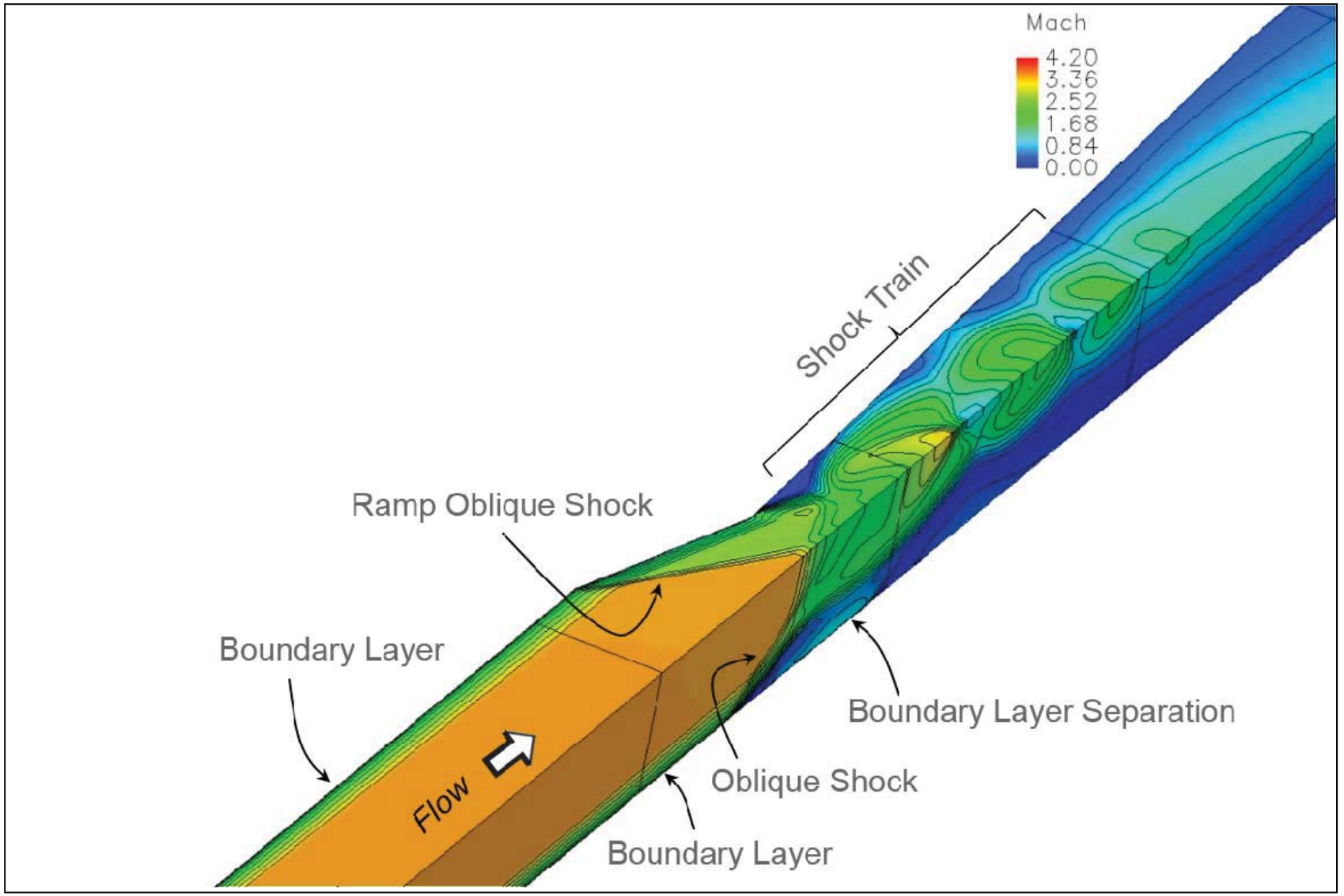
CFD simulation compares well to wall static pressures collected during a calibration.



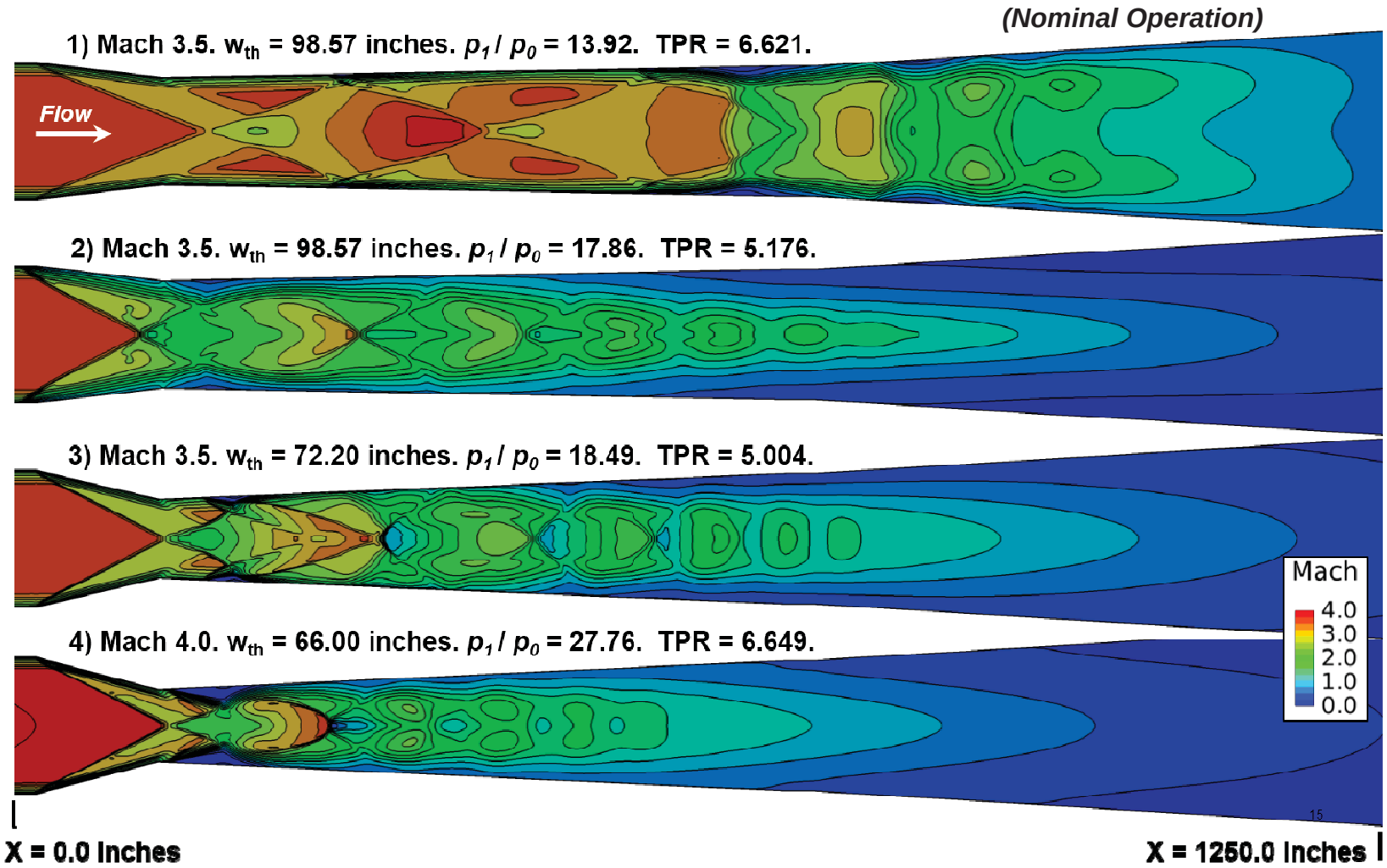
CFD simulations allow visualization of the structure of the shocks and boundary layers.



Observations from the CFD Simulations

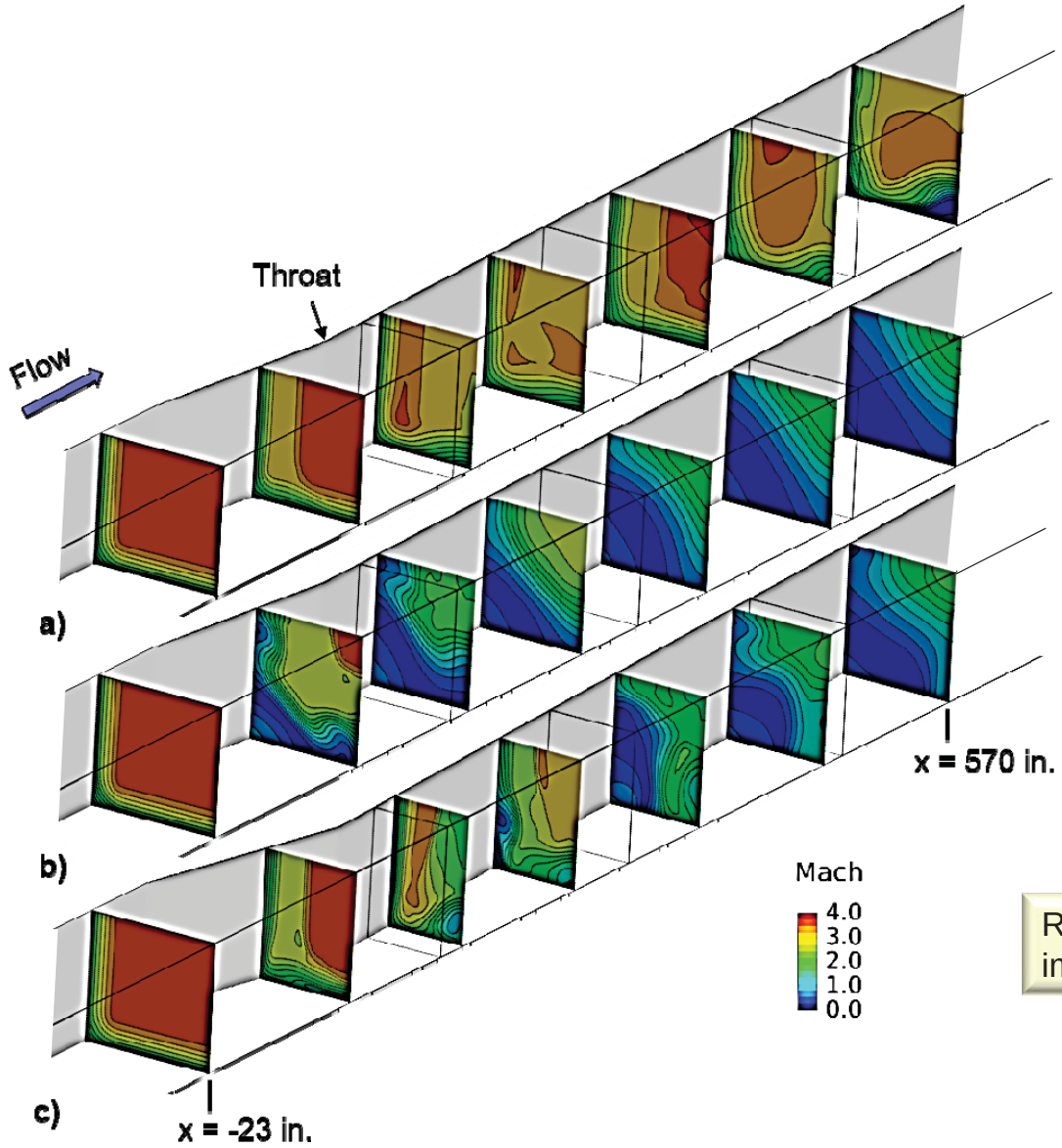


Observations from the CFD Simulations



Reducing the width of the second throat improves efficiency, which reduces tunnel pressure ratio (TPR).

Observations from the CFD Simulations



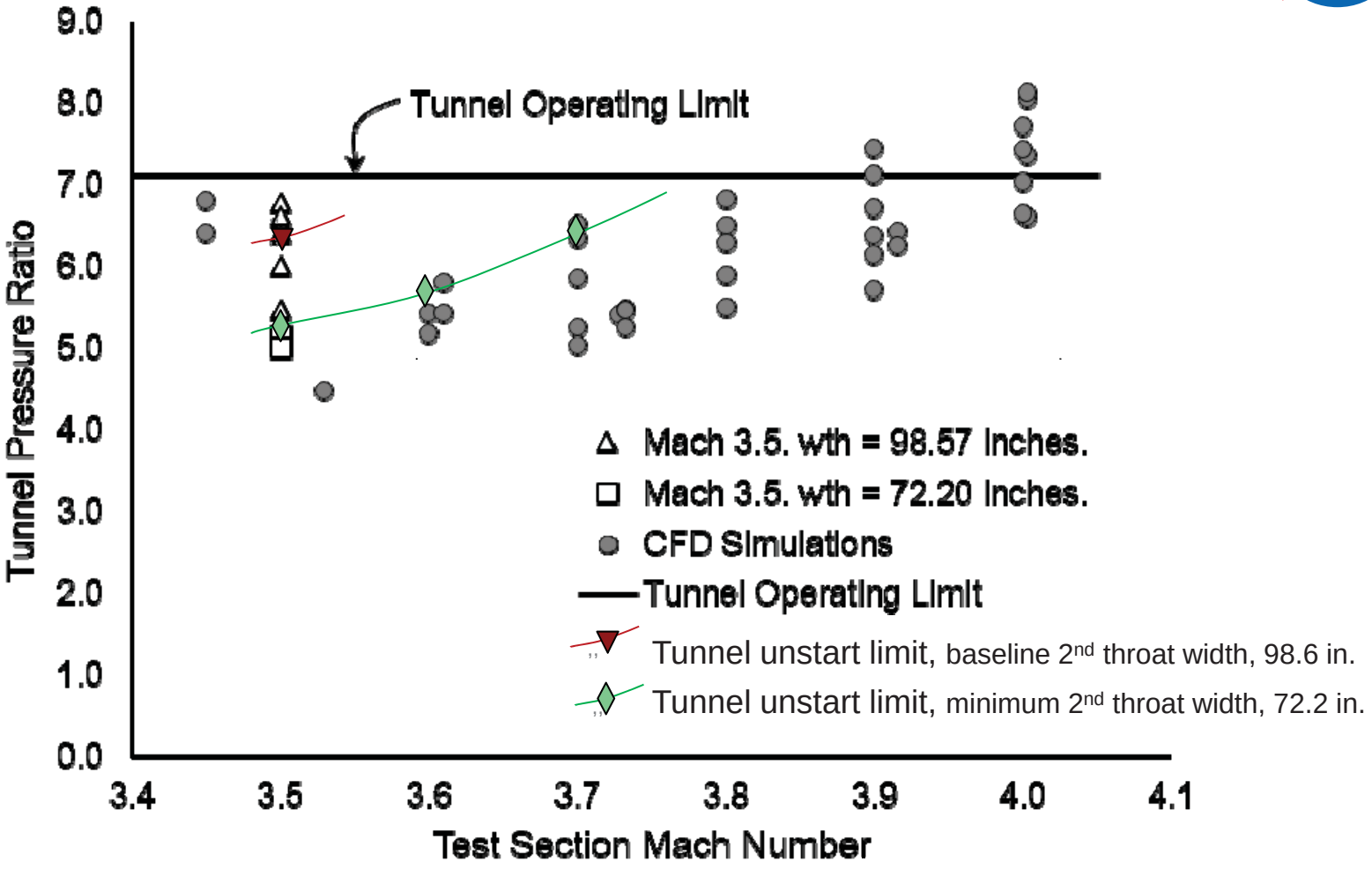
1) Mach 3.5. w_{th} = 98.57 inches.
p_1 / p_0 = 13.92. TPR = 6.621.

2) Mach 3.5. w_{th} = 98.57 inches.
p_1 / p_0 = 17.86. TPR = 5.176.

3) Mach 3.5. w_{th} = 72.20 inches.
p_1 / p_0 = 18.49. TPR = 5.004.

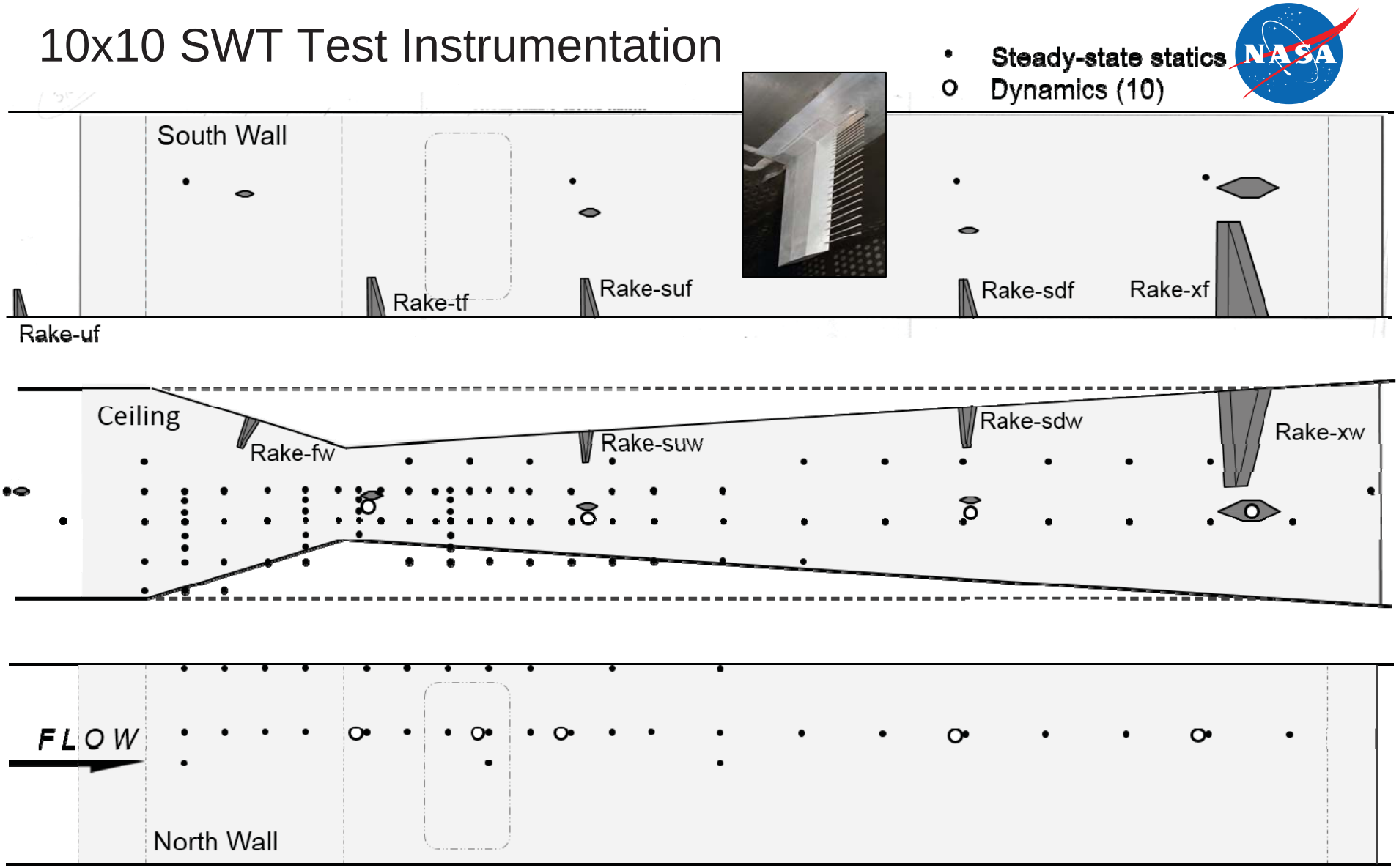
Reducing the width of the second throat improves stability of the shock system.

Comparison of Operational data to the CFD Simulations



Tunnel limits are at higher levels than CFD predictions.

10x10 SWT Test Instrumentation



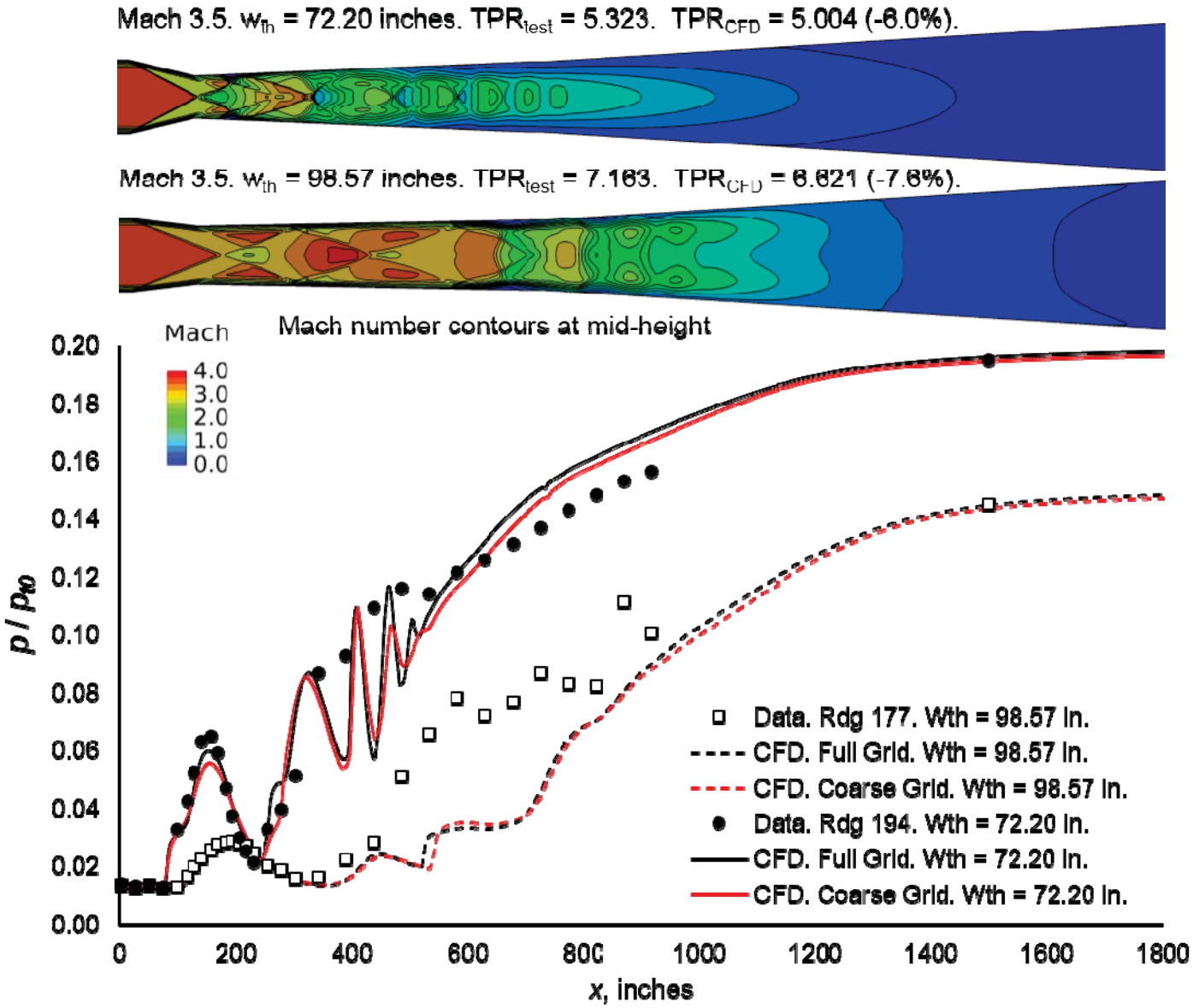
Instrumentation provided data on steady and unsteady flow (max freq 2 kHz). Allow comparison to CFD results.

The wall pressure taps will provide operators better data to determine if tunnel is operating in a stable manner.

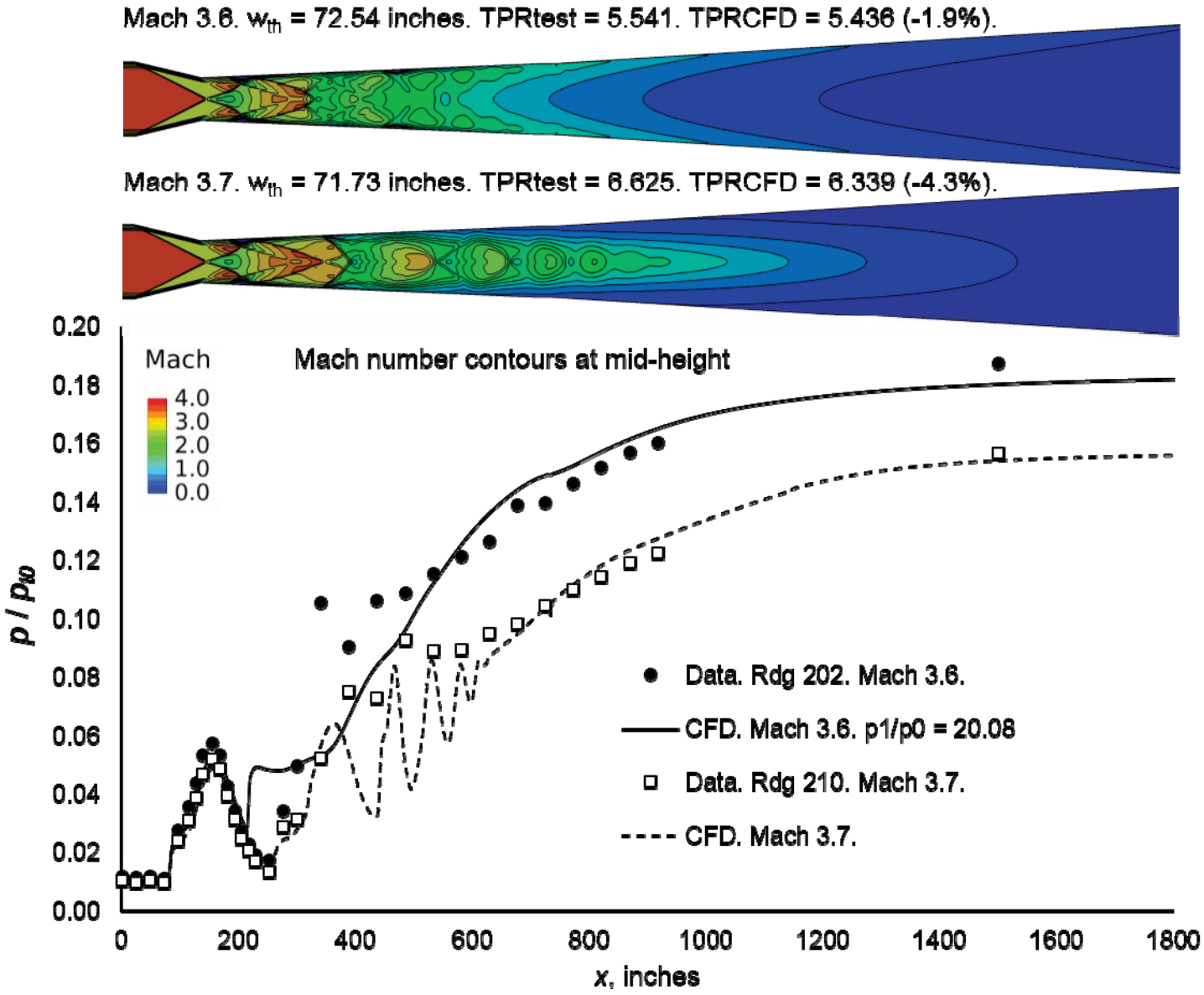
Wind Tunnel Test Procedures

- Test Conducted over 1 night of testing.
- Testing stopped due to a hydraulic leak and rake failures.
- Test Procedure:
  1. Set the test section Mach number by positioning the flex-wall. Start with Mach 3.5 and then sequence through Mach 3.6, 3.7, 3.8, 3.9, and 4.0. *Only Mach 3.6 and 3.7 were reached.*
  2. Set the second throat width. Start with the standard schedule at Mach 3.5 (w_{th} = 98 inches) and then close second throat to its minimum width (w_{th}=72 inches) for the remainder of testing.
  3. Modulate the test section pressure ratio. Nominal < 7.11 due to losses in subsonic tunnel loop. Watch and record static pressure distributions.
  4. If the tunnel unstarts, trigger the Dewetron. Initiate restart of the second-throat and continue to the next higher Mach number.
  5. Repeat items 1 through 6 for Reynolds Numbers of 2.0, 1.5, 0.5 x10^6 / ft.

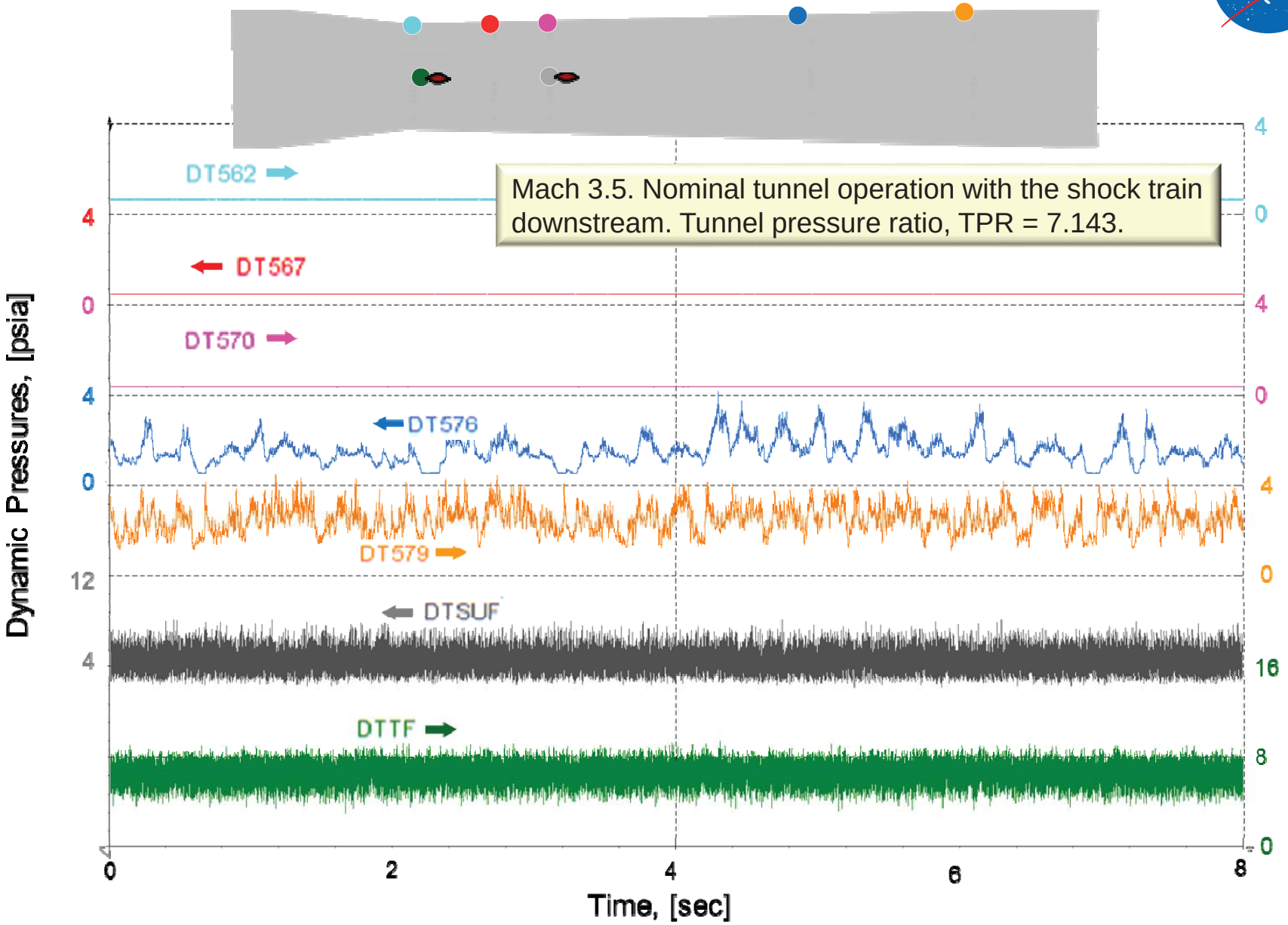
Test and CFD Results at Mach 3.5



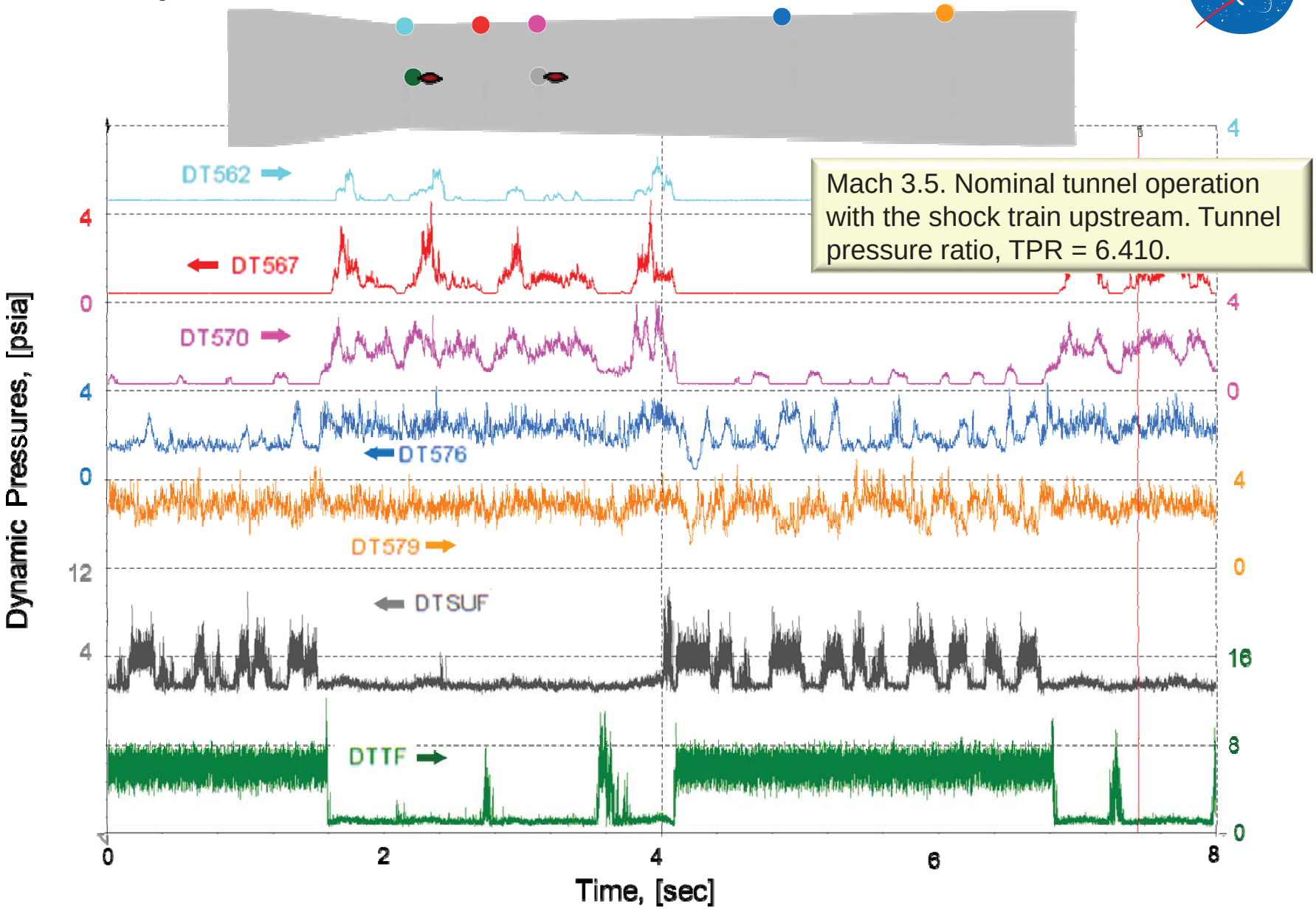
Test and CFD Results at Mach 3.6 and 3.7



Unsteady Data

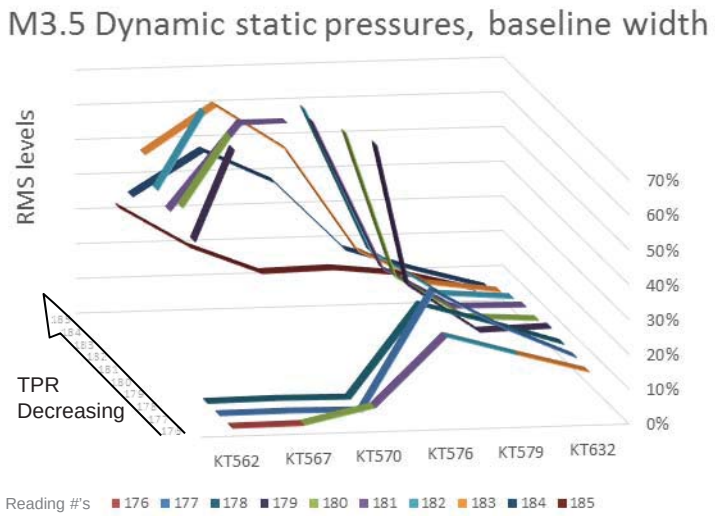


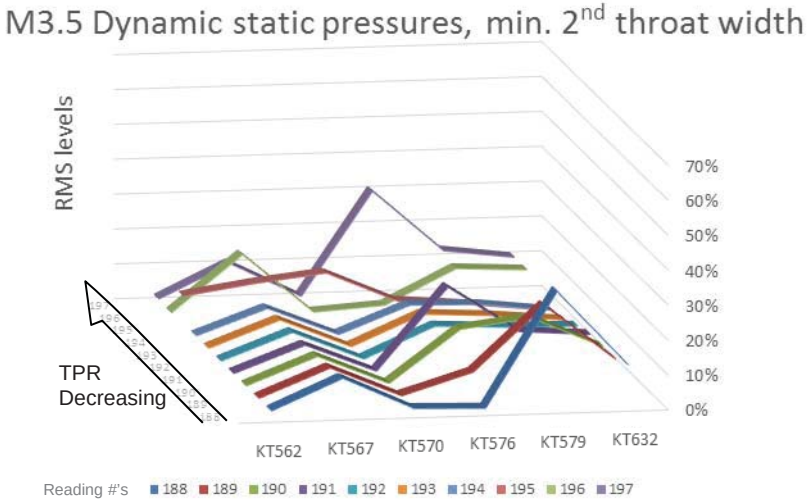
Unsteady Data

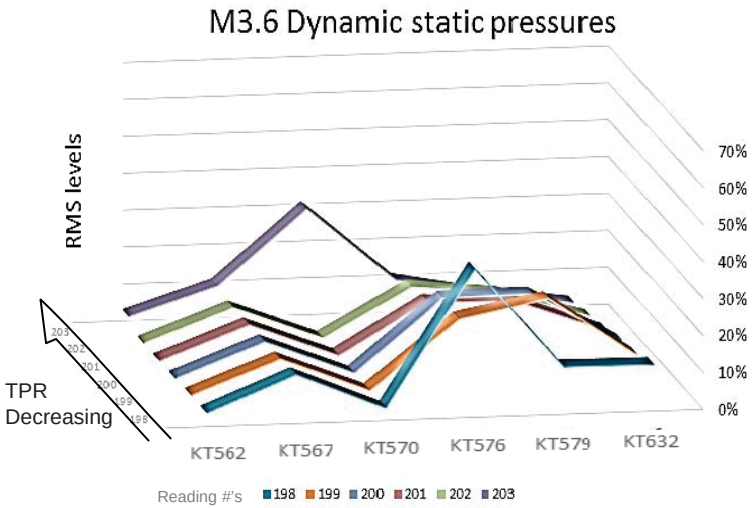


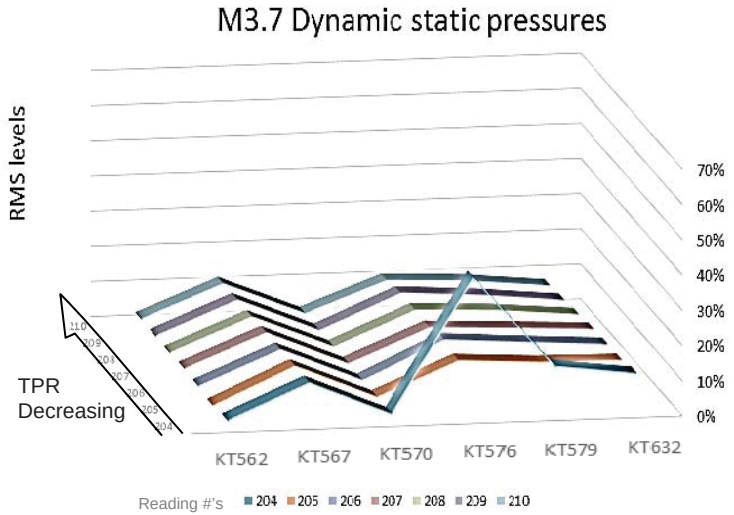
Mach 3.5. Nominal tunnel operation with the shock train upstream. Tunnel pressure ratio, TPR = 6.410.

RMS levels for started tunnel operation

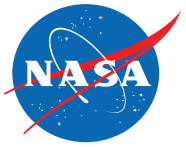








Conclusions and Future Work



- Conclusions
  - Mach 3.6 and 3.7 tunnel operation was demonstrated.
  - CFD results for pressure distributions compared reasonably with tunnel data.
  - CFD indicates tunnel operation up to Mach 4 is possible with the width of the second throat reduced to its minimum position; however, wind tunnel data suggests Mach 3.8.
  - Unsteady data shows non-linear behavior of the shock train pressure rise when the second throat width is reduced.

- Future Work:
  - Continue RANS CFD simulations at higher Mach numbers.
  - Include unsteady detached eddy simulation (DES) CFD simulation to explore unsteady aerodynamics.
  - Explore effects of tunnel blockage due to a model in the test section.
  - Couple CFD results to unsteady data to develop a control strategy for high Mach number wind tunnel operation
  - Explore a future tunnel entry to test up to Mach 4.

Questions?