Supersonics N+2 System Validation Nozzle Test: GE Inverted Velocity Profile Nozzle Concept

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Presented at Acoustics Technical Working Group

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NASA/Lockheed Martin N+2 System Study

- Aims to meet NASA N+2 Tech Challenge Goals for Supersonic Commercial Aircraft.
- Biggest challenges: Sonic Boom acceptance, Airport Noise certification, and Emissions.
- Lockheed Martin with GE and Rolls Royce Liberty Works proposed several technical solutions to meet goals.
- N+2 System Validation contract awarded to validate low boom, quiet propulsion concepts, and to further develop aircraft system.
- To create highly variable cycle engine, GE and RRLW proposed three-stream engines with different methods of achieving variable geometry nozzle.
- GE and RRLW developed nozzle models to be evaluated at NASA GRC.
- NASA modifies High Flow Jet Exit Rig for third-stream supply
- Nozzle models tested with far-field acoustics, surface pressures, phased array, particle image velocimetry.
- Tests performed April—Sept 2011

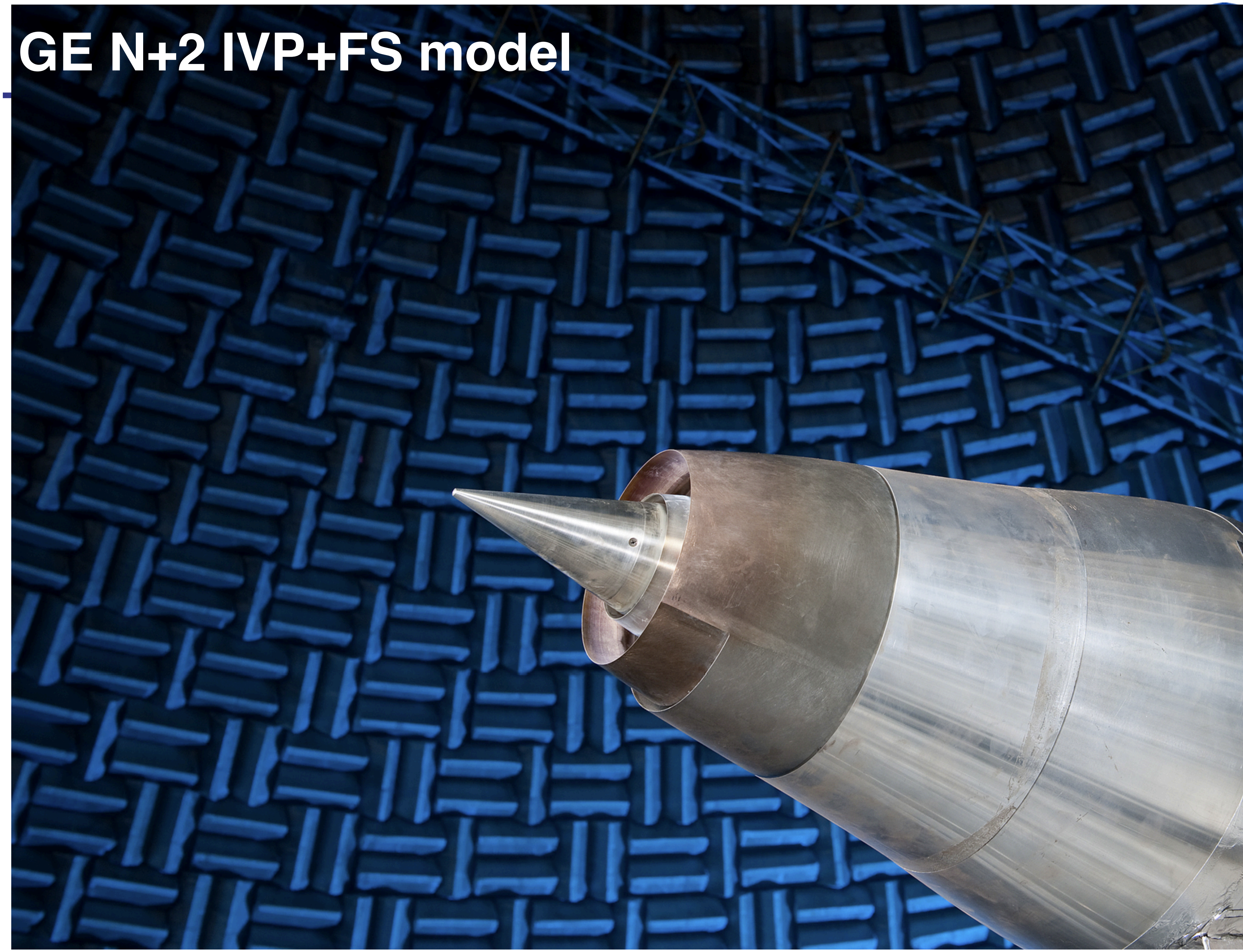
Objectives of GE N+2 Sys Val Nozzle Test

- Show benefits of IVP at low velocities
- Show benefits of Fluid Shield at low temperatures
- Reference to single-flow jet with fully mixed flow, same thrust
- Investigate causes of acoustic anomalies
- Validate noise prediction tools

Embodiment of concept in model hardware

- NASA added third stream plenum around existing dual-stream rig
  - Independent third stream pressure control
  - Third stream temperature tied to bypass
- GE/ASE designed model to invert hot core stream outside of bypass flow
- Third stream went to 180° Fluid Shield
  - Vary azimuth relative to fixed far-field microphone
- Variable hot stream A8/A9 with interchangeable throat piece.
  - 'Sideline' vs 'Cutback' configurations
  - Both inserts were strongly overexpanded at takeoff conditions.

GE N+2 IVP+FS model



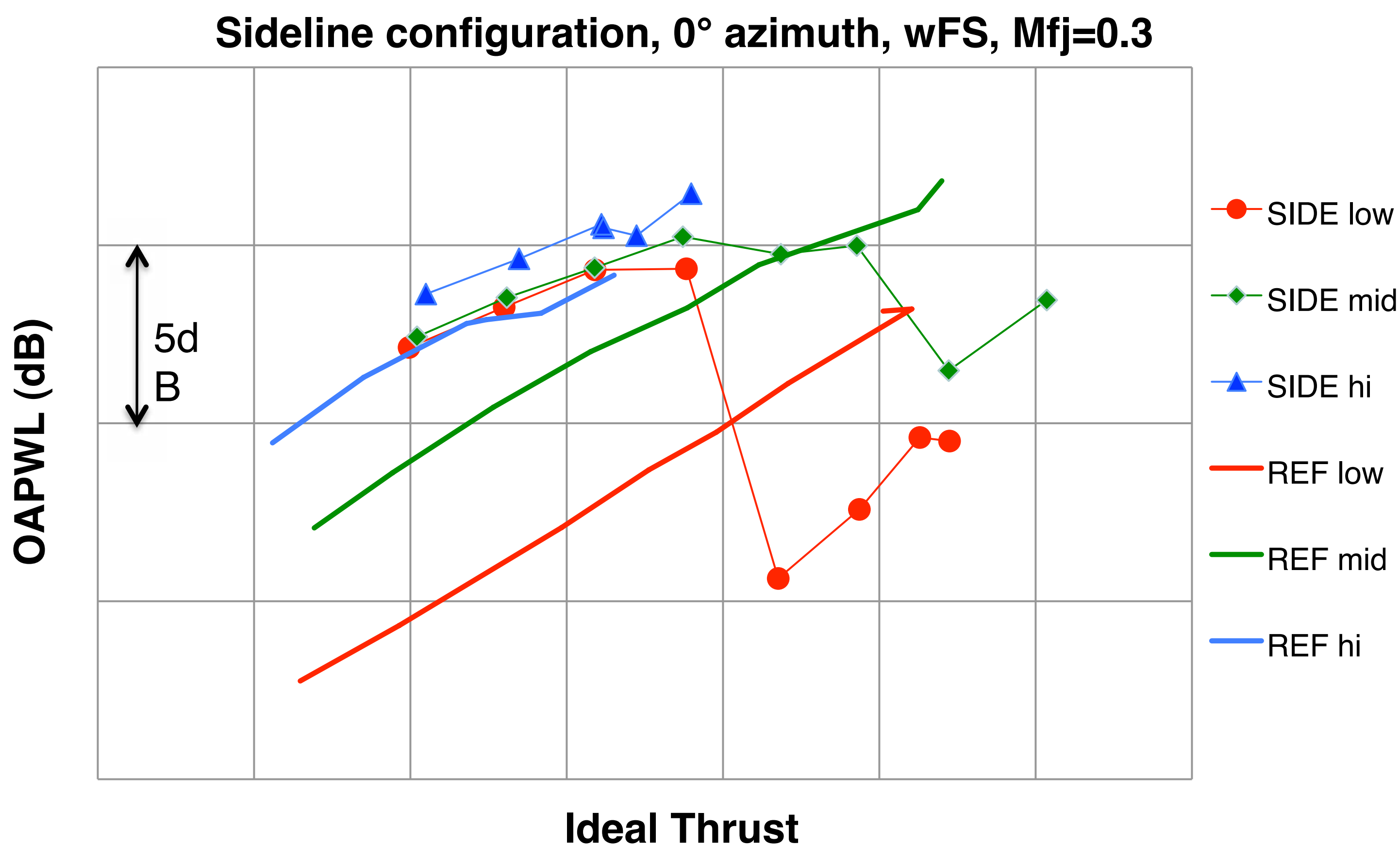
Test matrix

- Extensive set of conditions with varying pressure ratios and hot flow temperatures.
  - Ran constant NPR, Total Temperature on bypass and shield streams
  - Vary NPRp on hot primary stream with small change in temperature along cycle.
- Two C-D throats (‘Sideline’ and ‘Cutback’) on hot primary stream
- With and without fluid shield
- Static and forward flight
- Duplicate fully mixed conditions on convergent single-flow nozzle of similar size (‘Reference’).

Acoustic Highlights

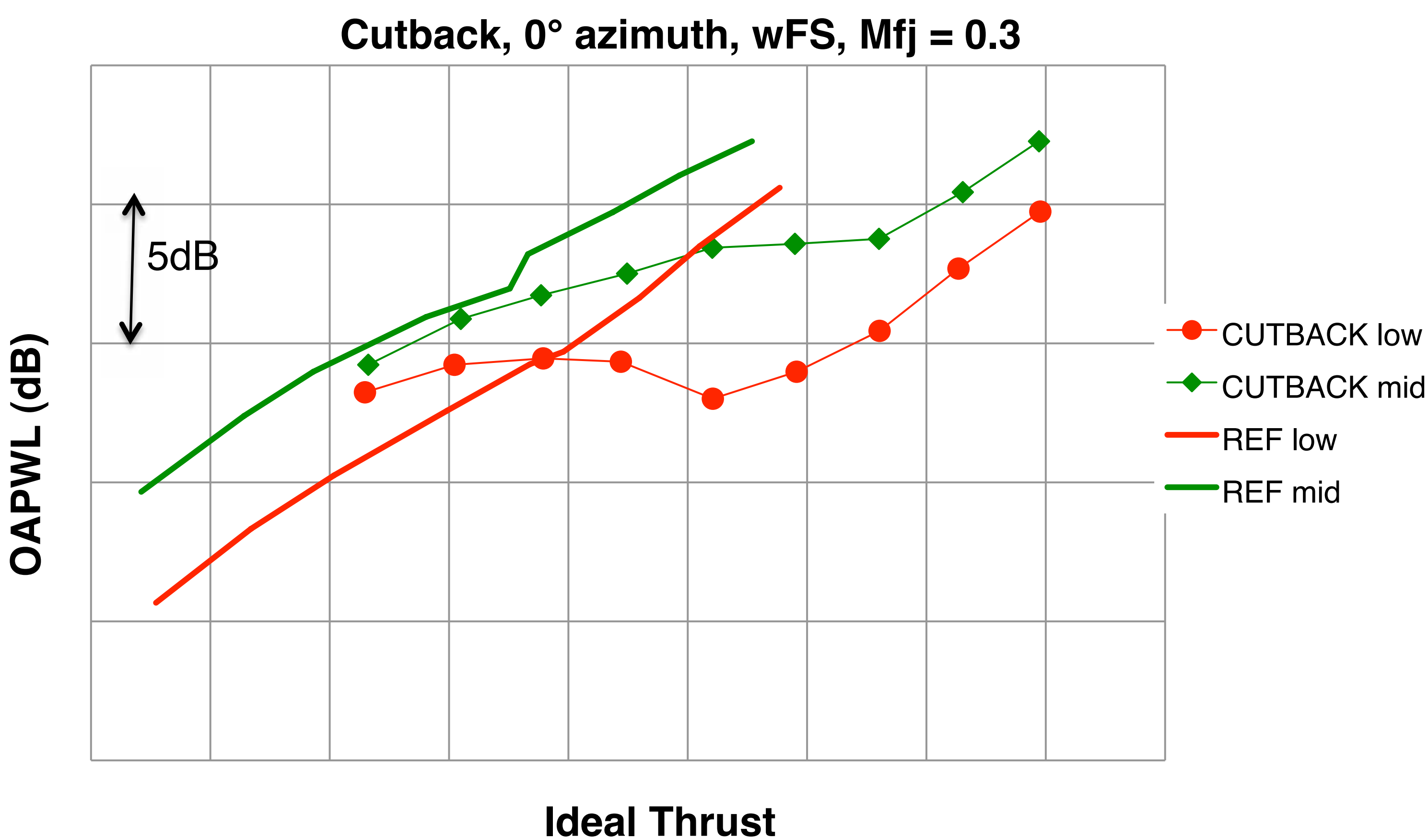
OAPWL—Sideline IVP+FS vs Reference

- Sound drops dramatically above a given cycle point (NPRp) in each temperature range



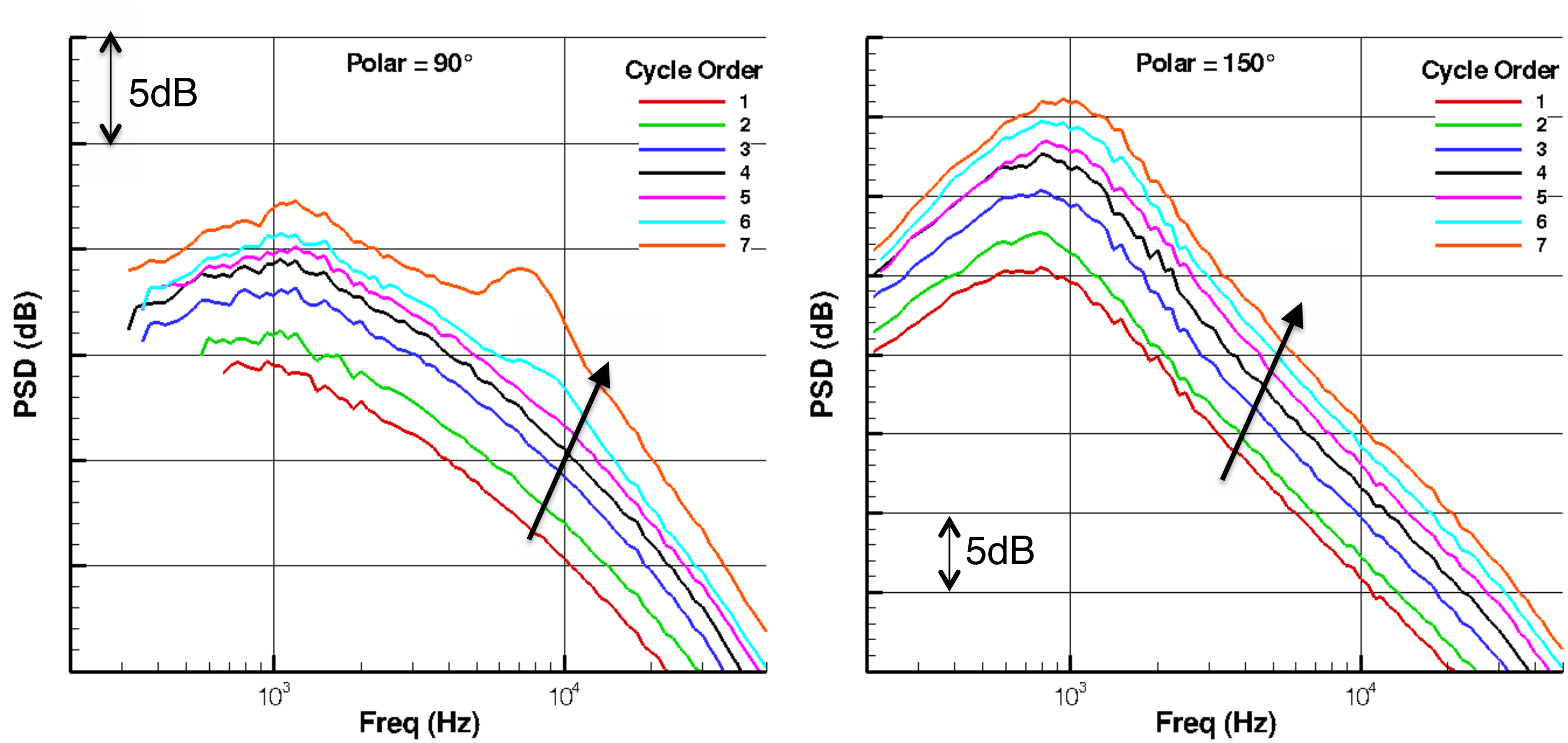
OAPWL—Cutback IVP+FS vs Reference

- Similar, but less dramatic, trend observed in Cutback config



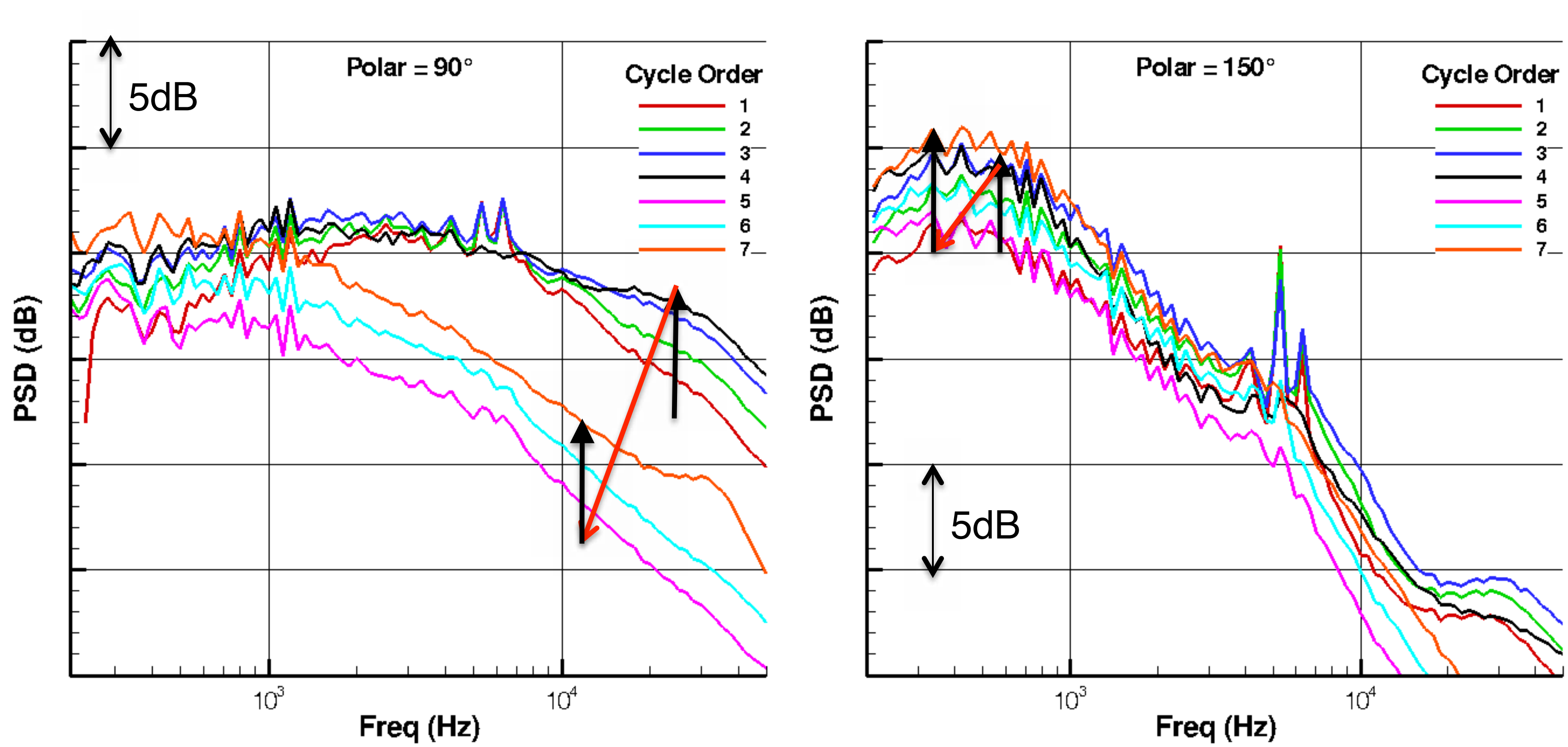
Sound Spectra for Reference config, varying cycle point

- Single-flow convergent jet at mixed flow conditions
- Monotonic increase in sound as cycle point (~NPR) increases



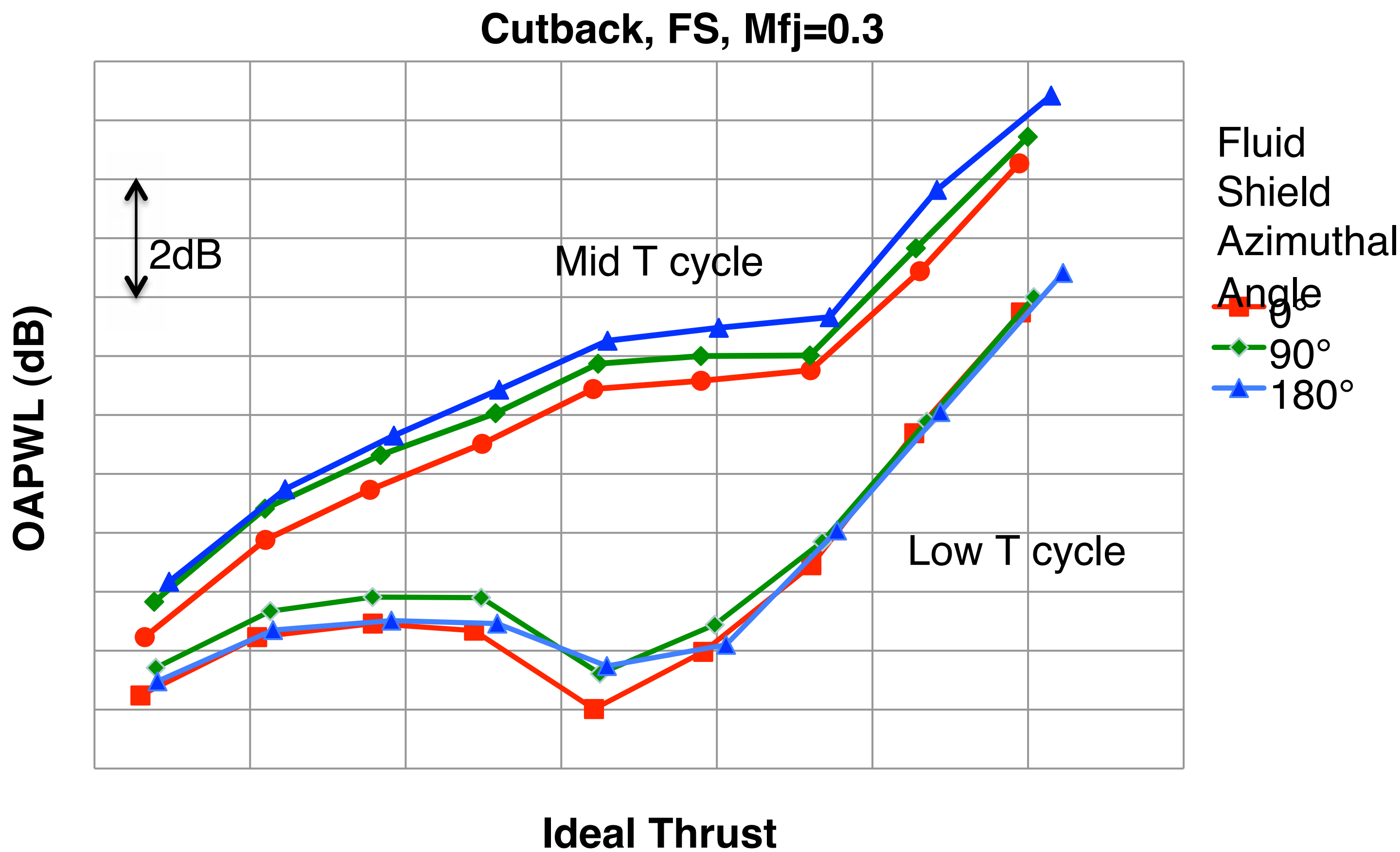
Sound Spectra for Sideline config, varying cycle point

- Sudden decrease in sound level, especially at high frequencies, as cycle point (~NPRp) increases



Effect of Fluid Shield (Vary azimuthal angle)

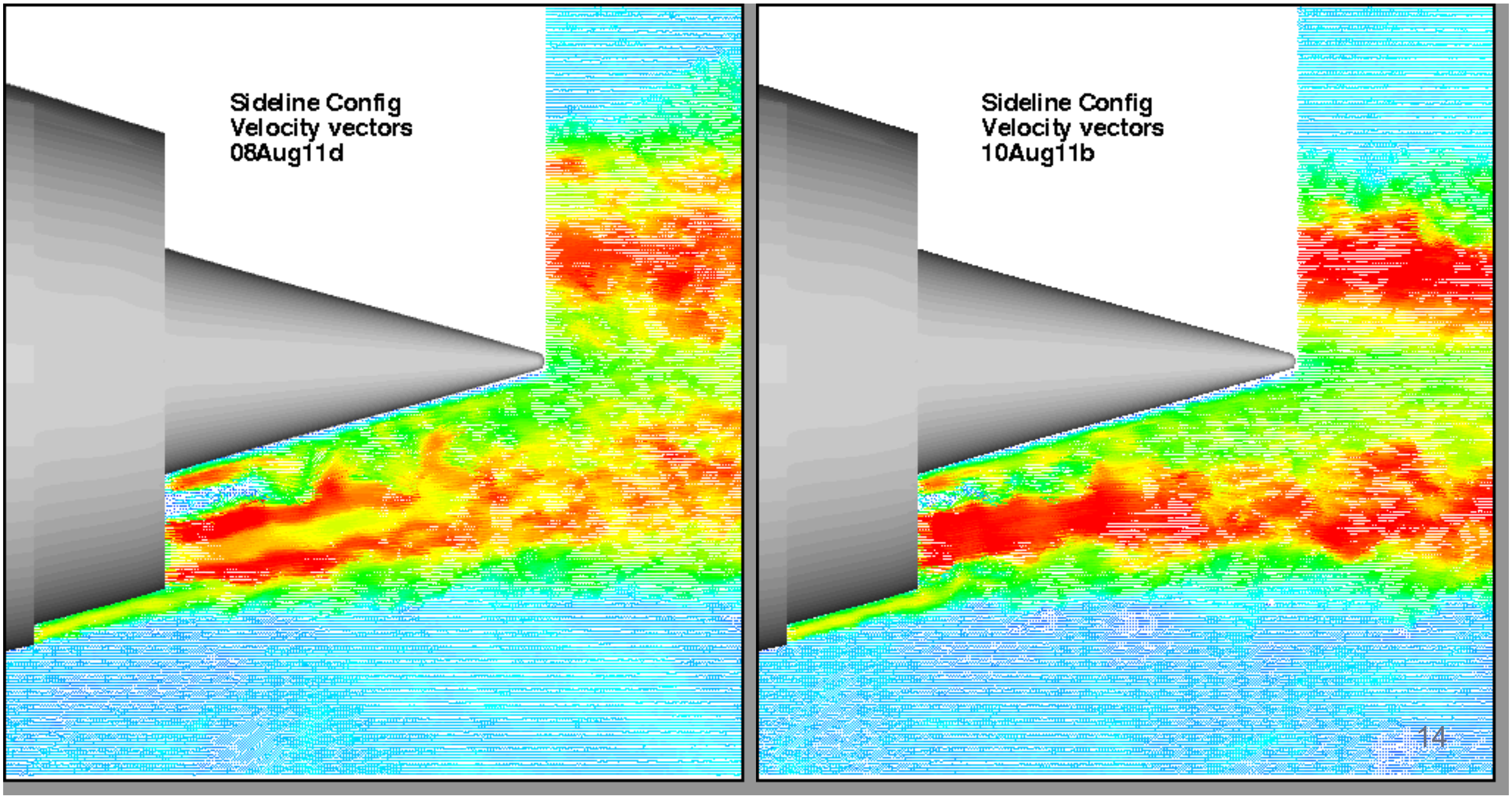
- Shield has benefit, but less than 1dB at low temperatures



PIV preview

Movie of two flows, same nozzle, same condition (different days)

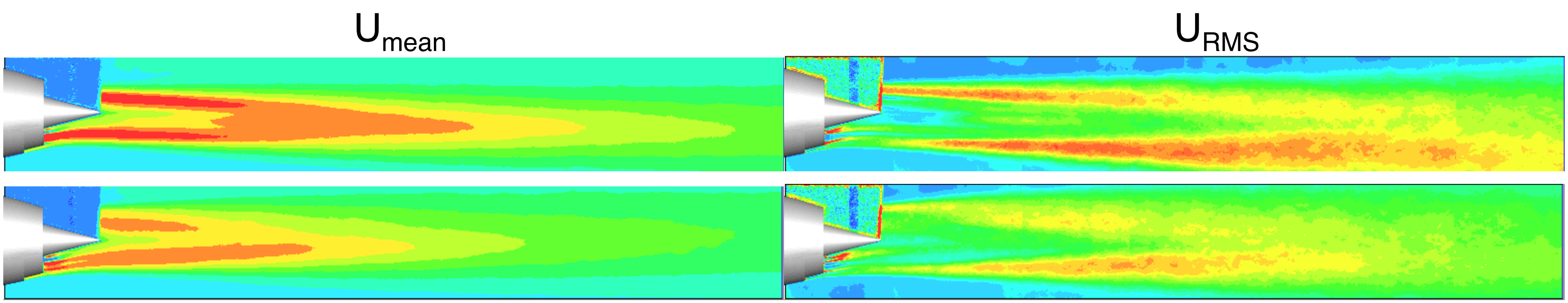
- Illustrates separation, difference in separation and trajectory
- C-D nozzle has multiple steady flows, different separations.



Mean and Turbulence Flows Measured

- Sideline nozzle with Fluid Shield, forward flight.
- Adjacent cycle points around anomaly.
- 6-8dB difference in OASPL between top and bottom flows.
- Turbulence near nozzle key to high frequencies according to phased array.

Same Config/Rig—Different Days



Conclusions

- Inverted Velocity Profile concept worked judging by reduction from reference single-jet flow *above critical NPRp*.
- Fluid Shield benefit small.
- Impact of Inverted Velocity Profile and Fluid Shield masked by flow separation issues with convergent-divergent nozzles.
- Follow-on work being negotiated with Lockheed Martin and GE Global.

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- Synopsis: The Supersonic Project commissioned two System Studies to see what technologies would be required to meet its N+2 goals for an aircraft flying in 2025. It followed with a System Validation contract to Lockheed Martin and its subcontractor General Electric Global Research to validate that some of the proposed technologies would indeed meet the goals. One such goal was acceptable airport noise and the concept proposed by GE featured inverted velocity profile. This concept was developed into a model-scale nozzle and tested at NASA's AeroAcoustic Propulsion Lab. Preliminary results of this test show that the concept does have merit, but some design decisions limited our ability to fully demonstrate that the nozzle met the noise goal. Future work to rectify these design decisions and retest the nozzle are under negotiation.