Noise from Aft Deck Exhaust Nozzles—Differences in Experimental Embodiments

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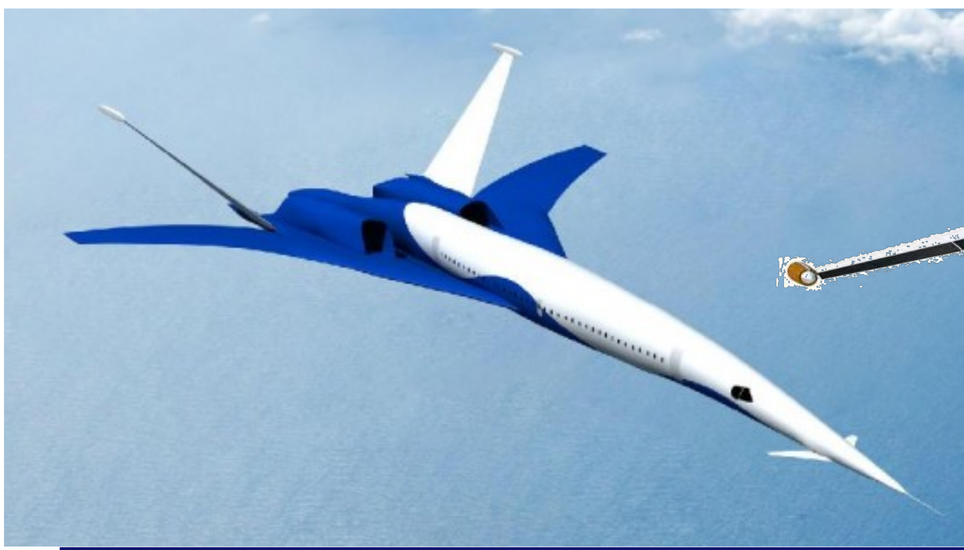
52nd AIAA Aerospace Sciences Meeting
13-17 January 2014, Nat'l Harbor, MD

Supported by NASA Fundamental Aeronautics Program/Supersonics Project

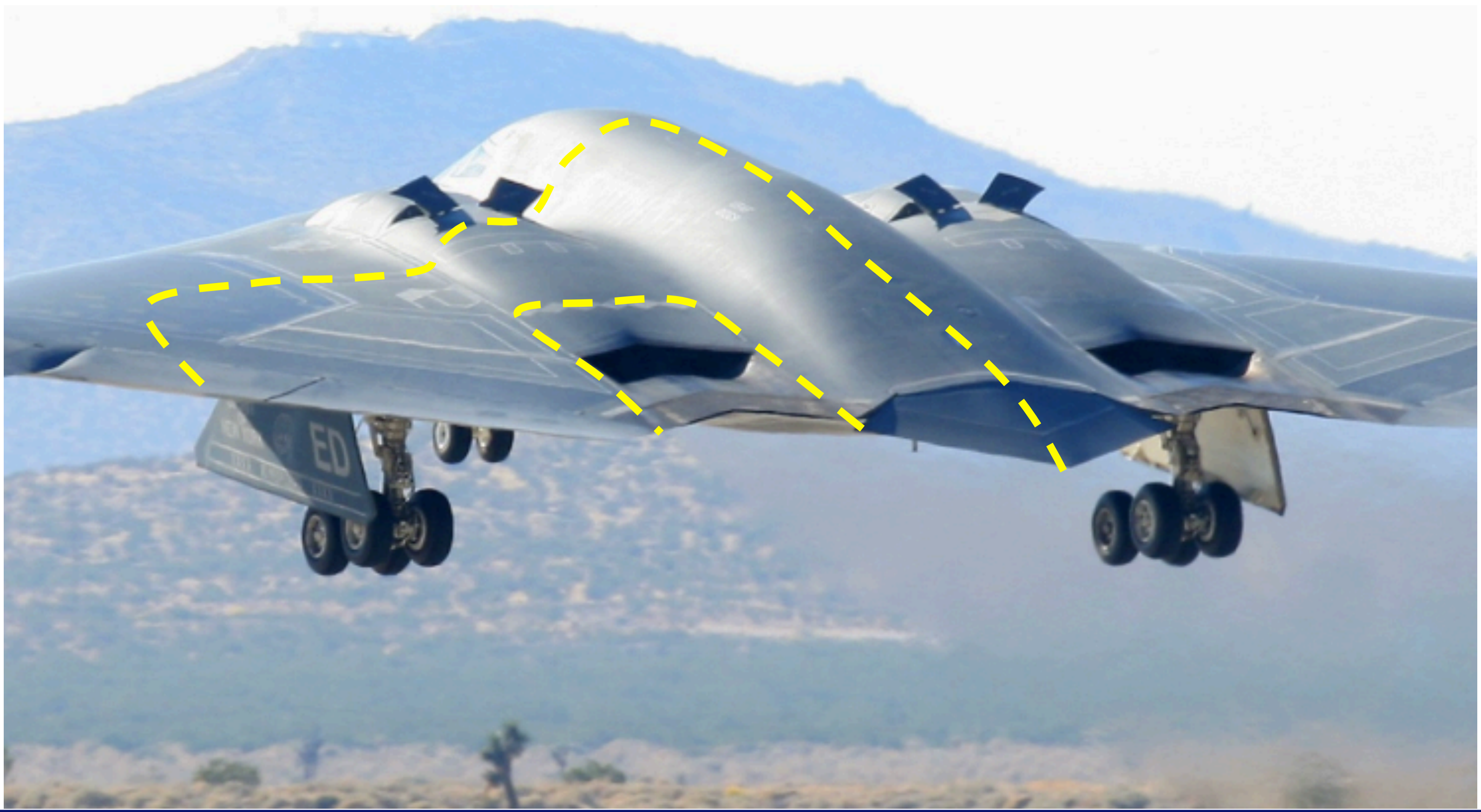
Motivation

- Highly embedded propulsion systems, such as may be required for low sonic boom, often employ high aspect ratio nozzles and aft decks.
- Existing databases and design tools for embedded exhaust systems are very weak.
- Most jet noise predictions assume axisymmetry and no surfaces.
- To evaluate futuristic aircraft concepts NASA Systems Analysis groups need predictive capability (empirical, RANS-based, LES) for jet noise in ***subsonic plume*** regime.



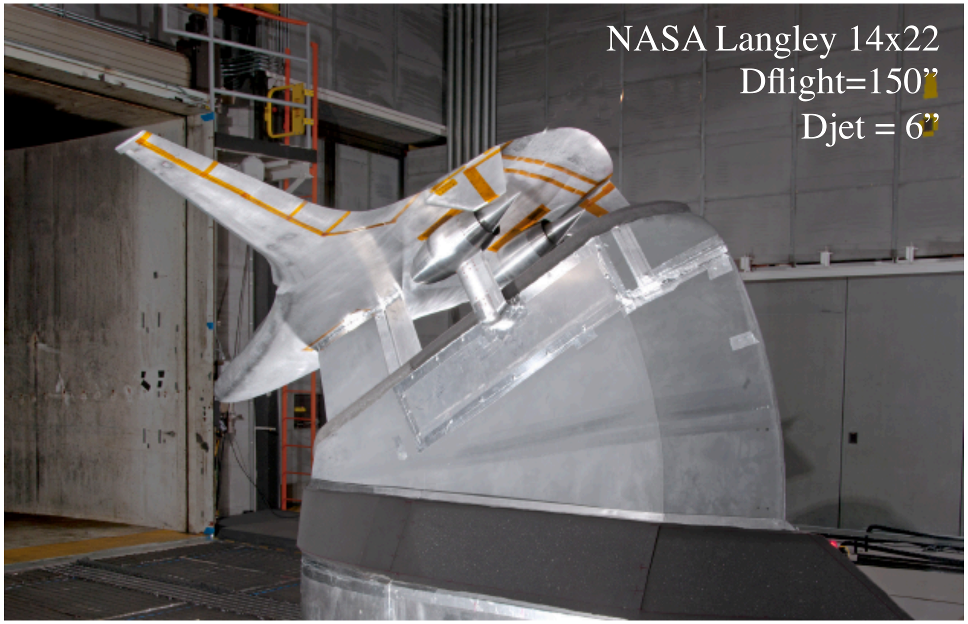
Example Problem

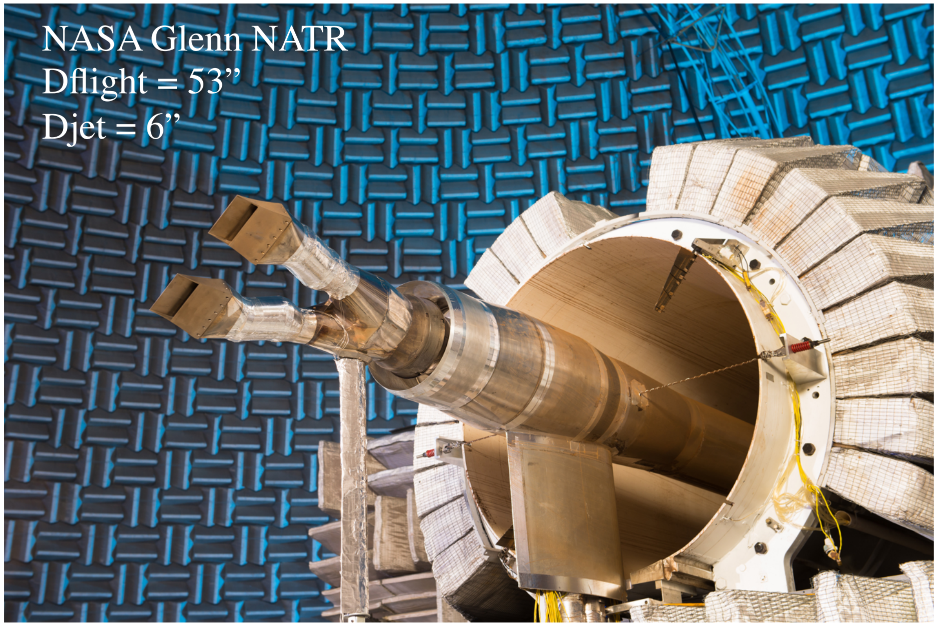
- Evaluate propulsion noise of conceptual aircraft with complicated, embedded exhaust system
- How to represent in model hardware to capture aeroacoustic effects on exhaust noise?



Scale-Model Aeroacoustic Testing of Embedded Exhaust Systems

- Propulsion-centric models for exhaust noise must draw a line on how much airframe to include.
- Model must fit in anechoic wind tunnels without compromise of installation effects or scale.
- Requires VERY large facility, or strong understanding of effects of compromise.





Brief Historical Highlights

- Many papers on noise from **rectangular jets** in past 50+ years*
  - Increase noise on wide side, decrease on narrow side
- Significant work on **slot jets** for high lift from 1970's
  - Introduction of solid surfaces in flow ***often increases noise***
- Recent interest in **shielding** propulsion noise by airframe.
- Jet-surface interaction creates **trailing edge dipole source**†
- Sensitivity to details of **external geometry** lacking
  - Hard to generalize effects

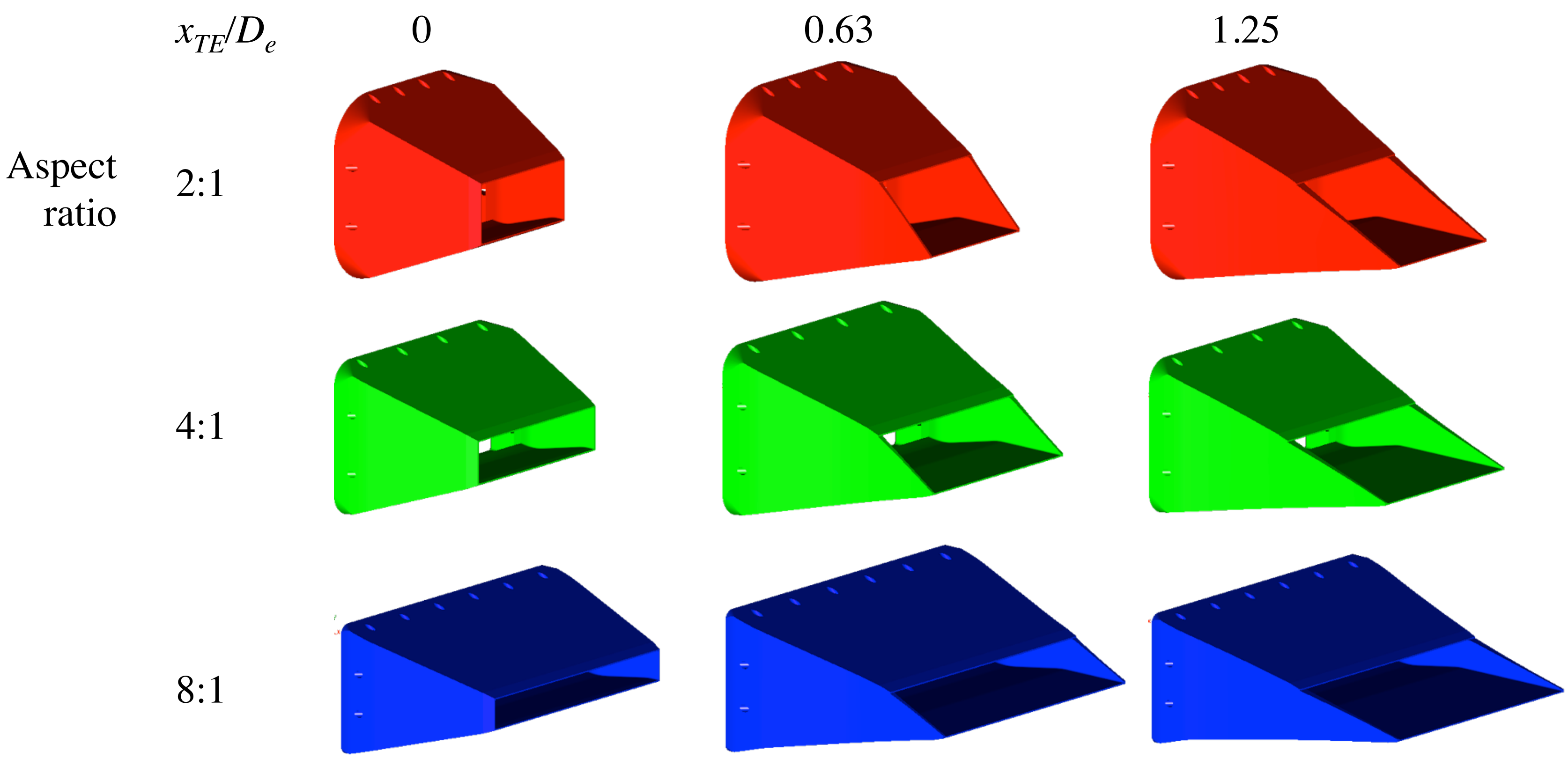
Figure 4. - 100:1 Slot nozzle with jet flap.

*Coles, W. D. "Jet-Engine Exhaust Noise from Slot Nozzles" NASA Technical Note D-60, Lewis Research Center, September 1959.

†Brown, C.A. "Developing an Empirical Model for Jet-Surface Interaction Noise" AIAA 2014-0878.

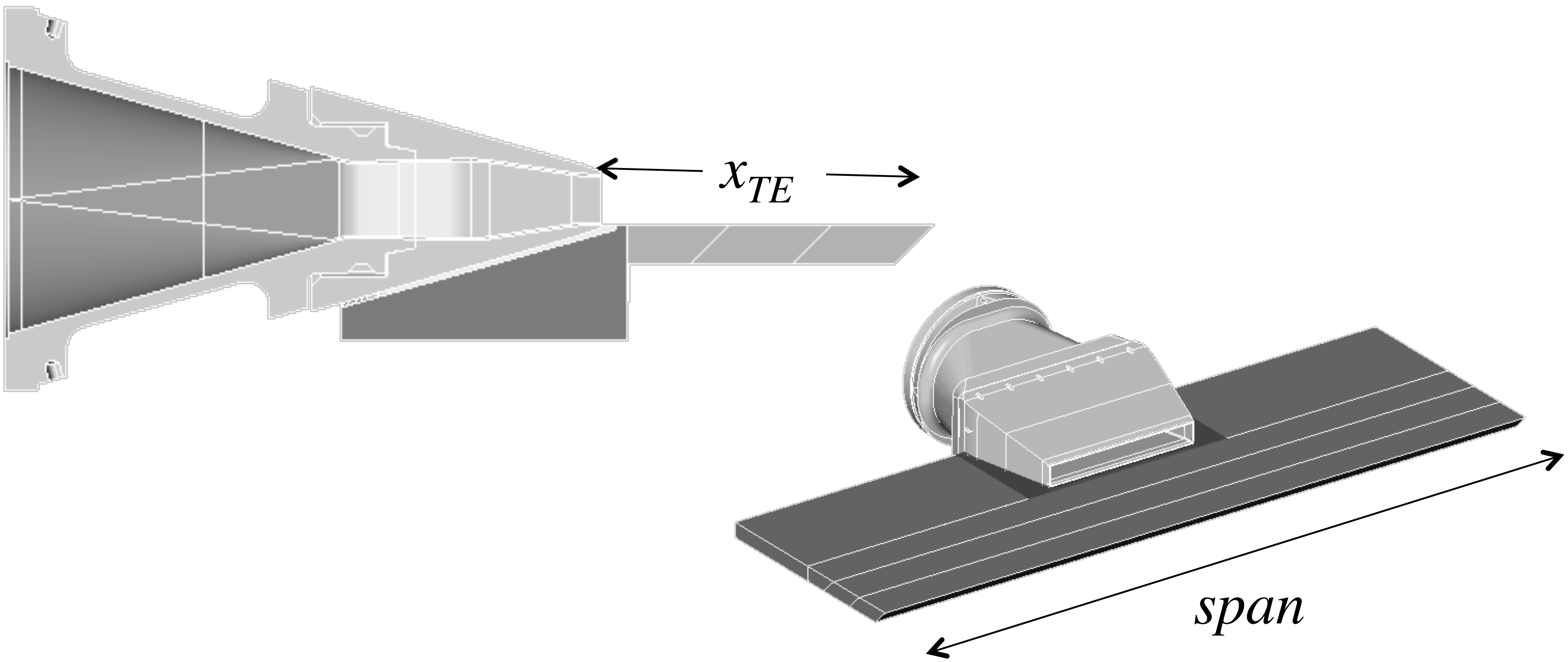
Embodiment 1: Beveled Nozzle

- Extend rectangular nozzle to capture flow-surface interaction.
- Ignore acoustic shielding, etc from embedding.
- Expensive to fabricate!

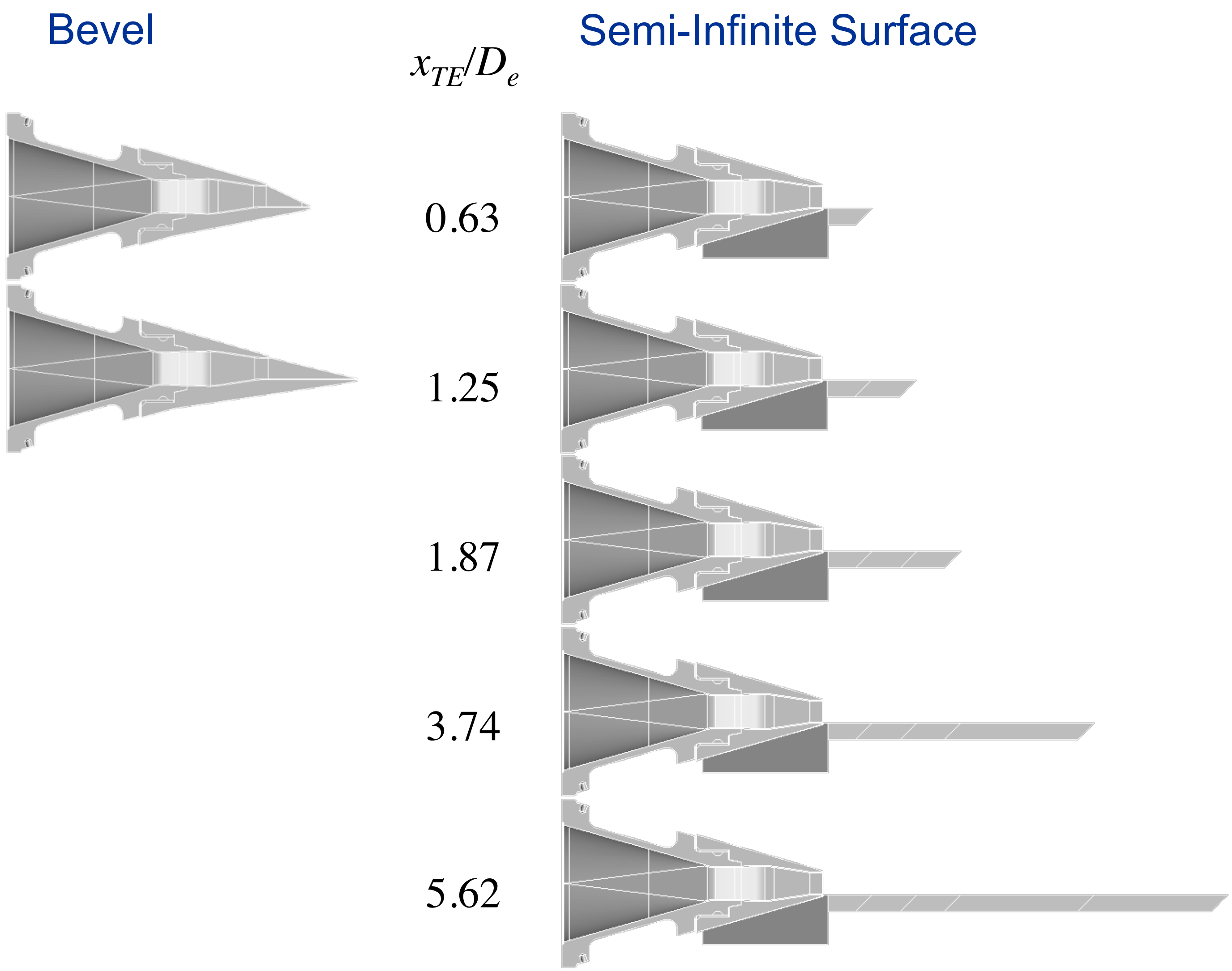


Embodiment 2: Semi-Infinite Surface

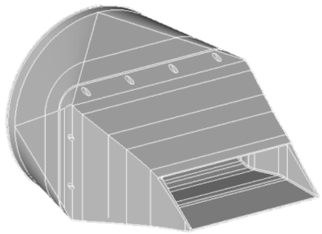
- Maximize acoustic impact of embedding.
- Large span—ignore details of spanwise edges.
- Inexpensive!



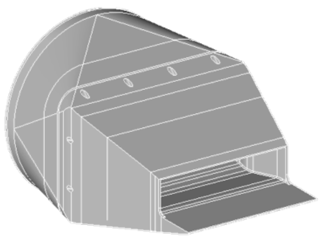
Deck Lengths Tested



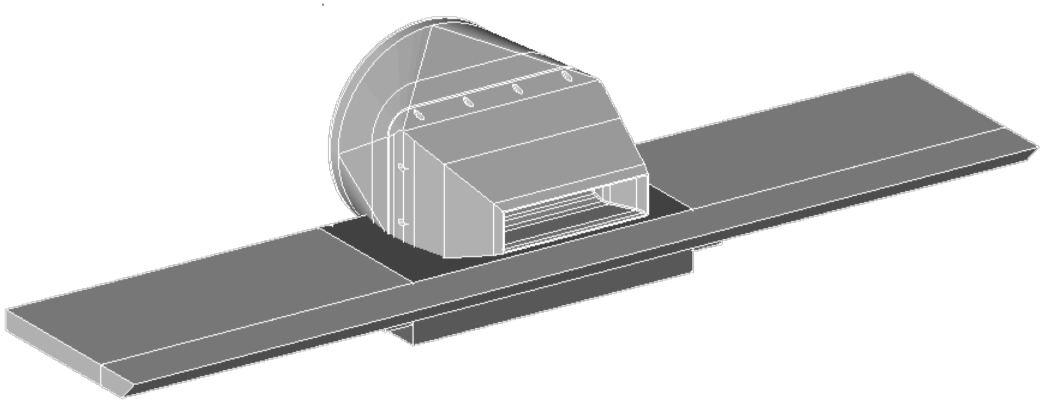
Missing Link Configuration



Beveled Nozzle



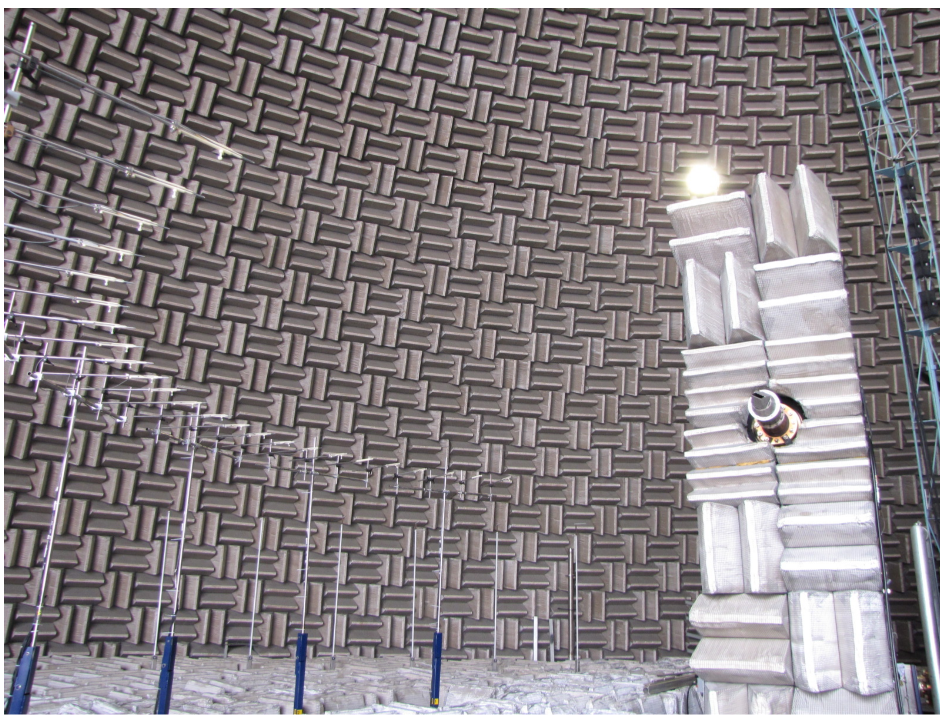
Beveled Nozzle w/o Sidewalls

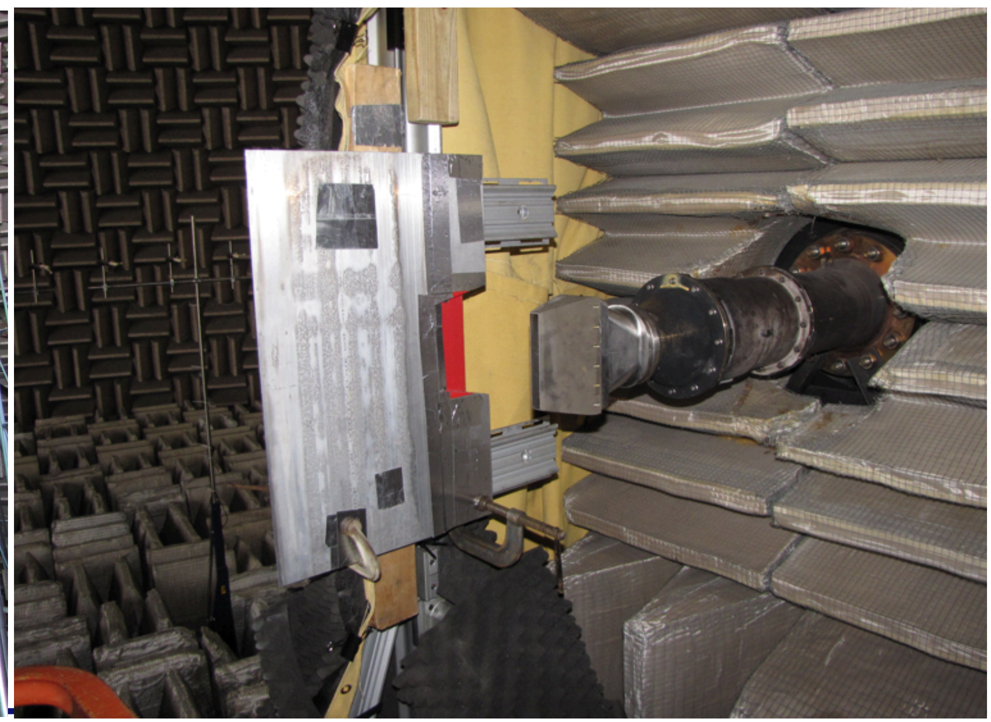


Semi-Infinite Surface

Facility and Instrumentation

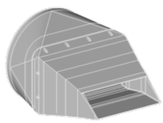
- Small Hot Jet Acoustic Rig (SHJAR) at NASA Glenn
- D_e = 2.14” (54.3mm) (based on area)
- M = 0.5, unheated flow in presentation
- $r = 75D_e$ (only polar = 90° presented)
- Azimuthal variation by nozzle rotation, wall reinstallation
- Heavy blankets extend surface to infinity upstream
- Spans up to 72” tested (24” used in presented results)



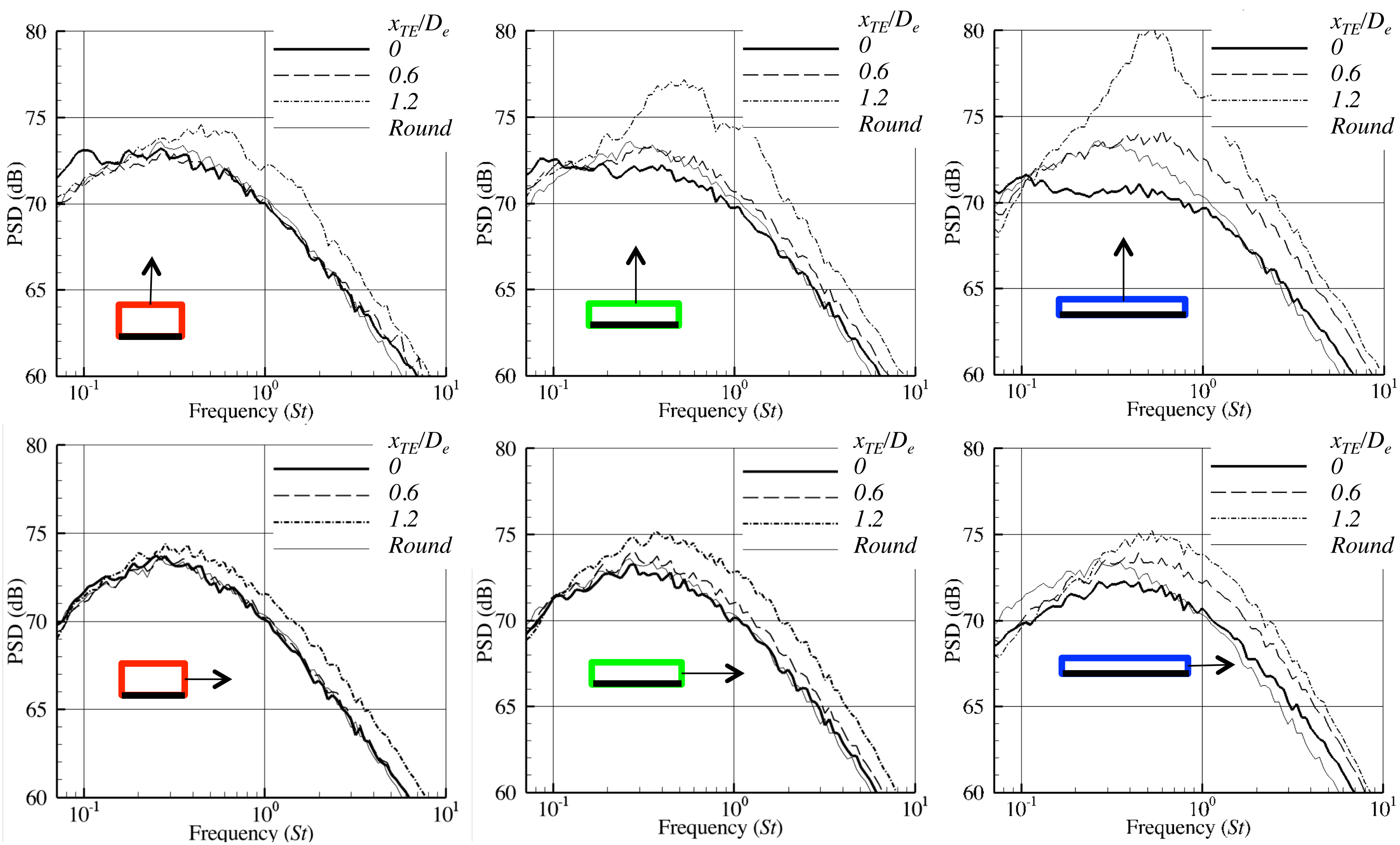


Experimental Results

Beveled Nozzle Deck Length



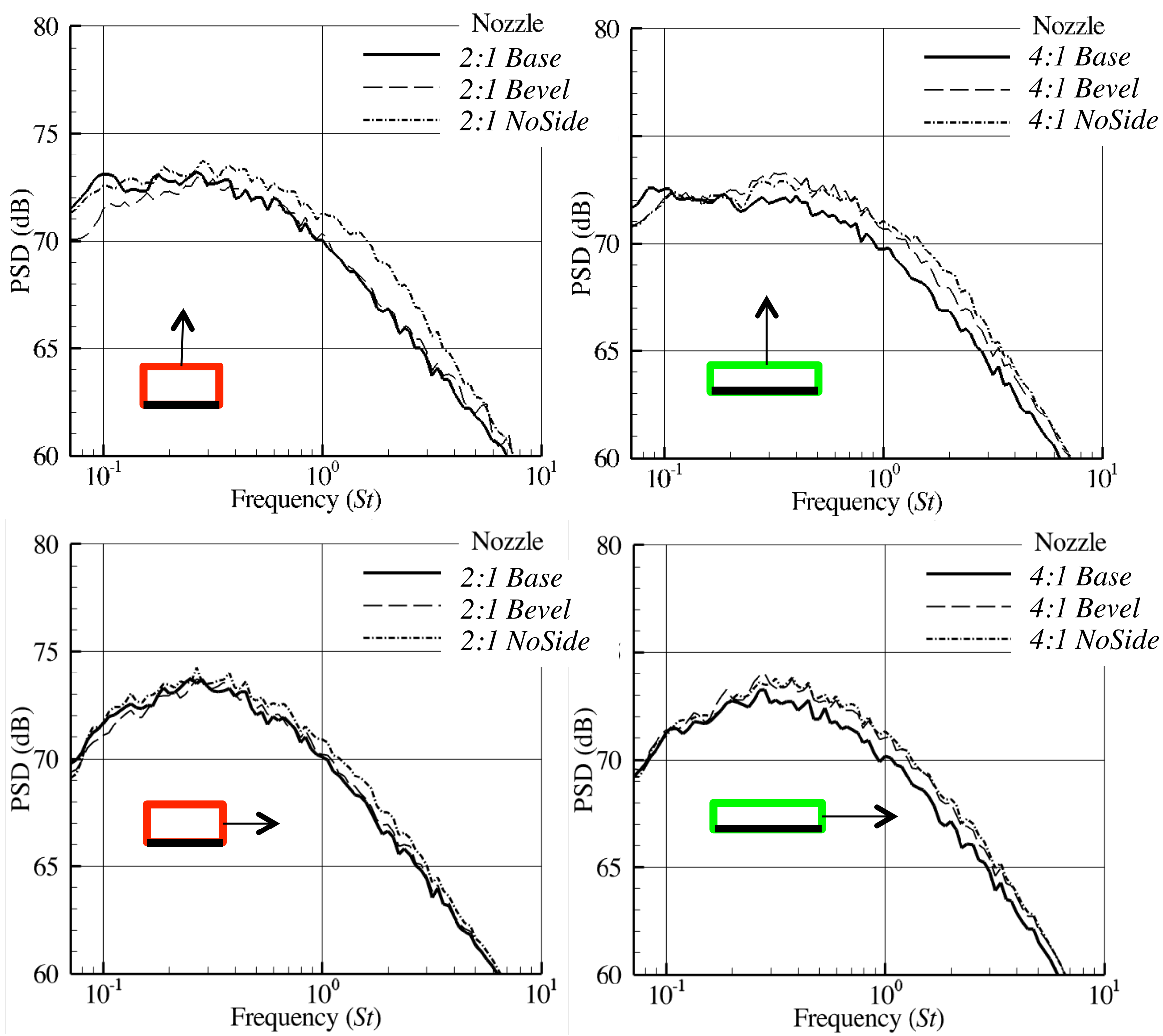
Polar angle = 90°

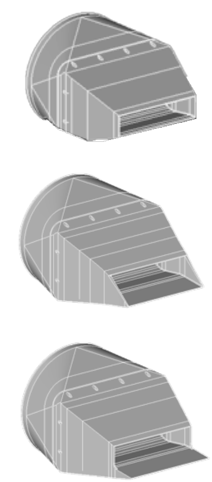


Beveled Nozzle
With and Without Sidewalls

Polar angle = 90°

$x_{TE}/D_e = 0.6$



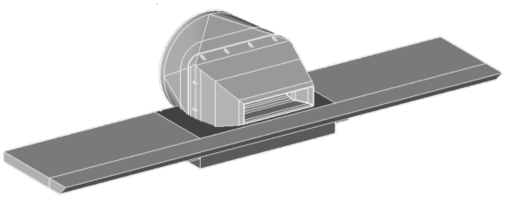


Base

Bevel

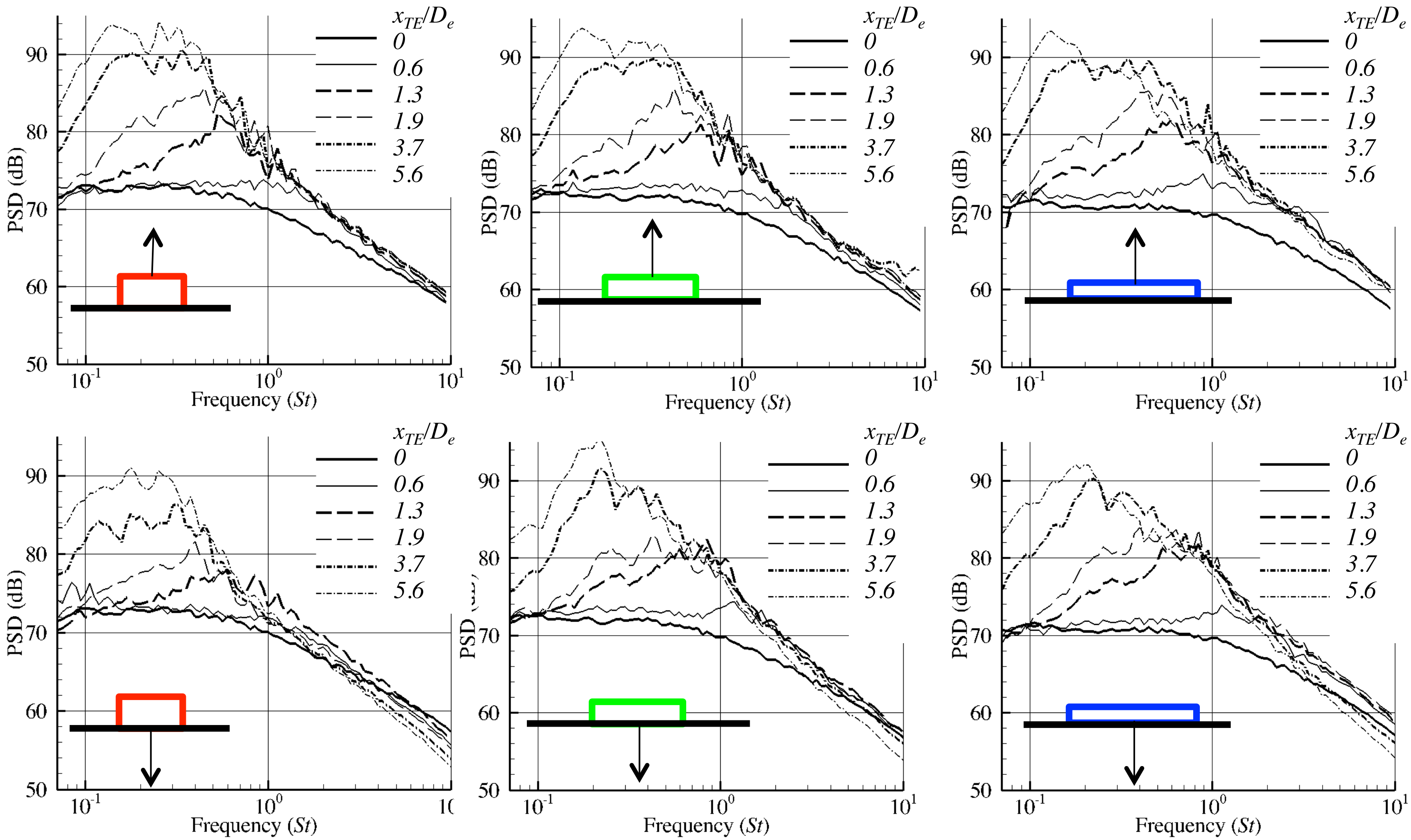
NoSide

- Sidewall not significant at this length



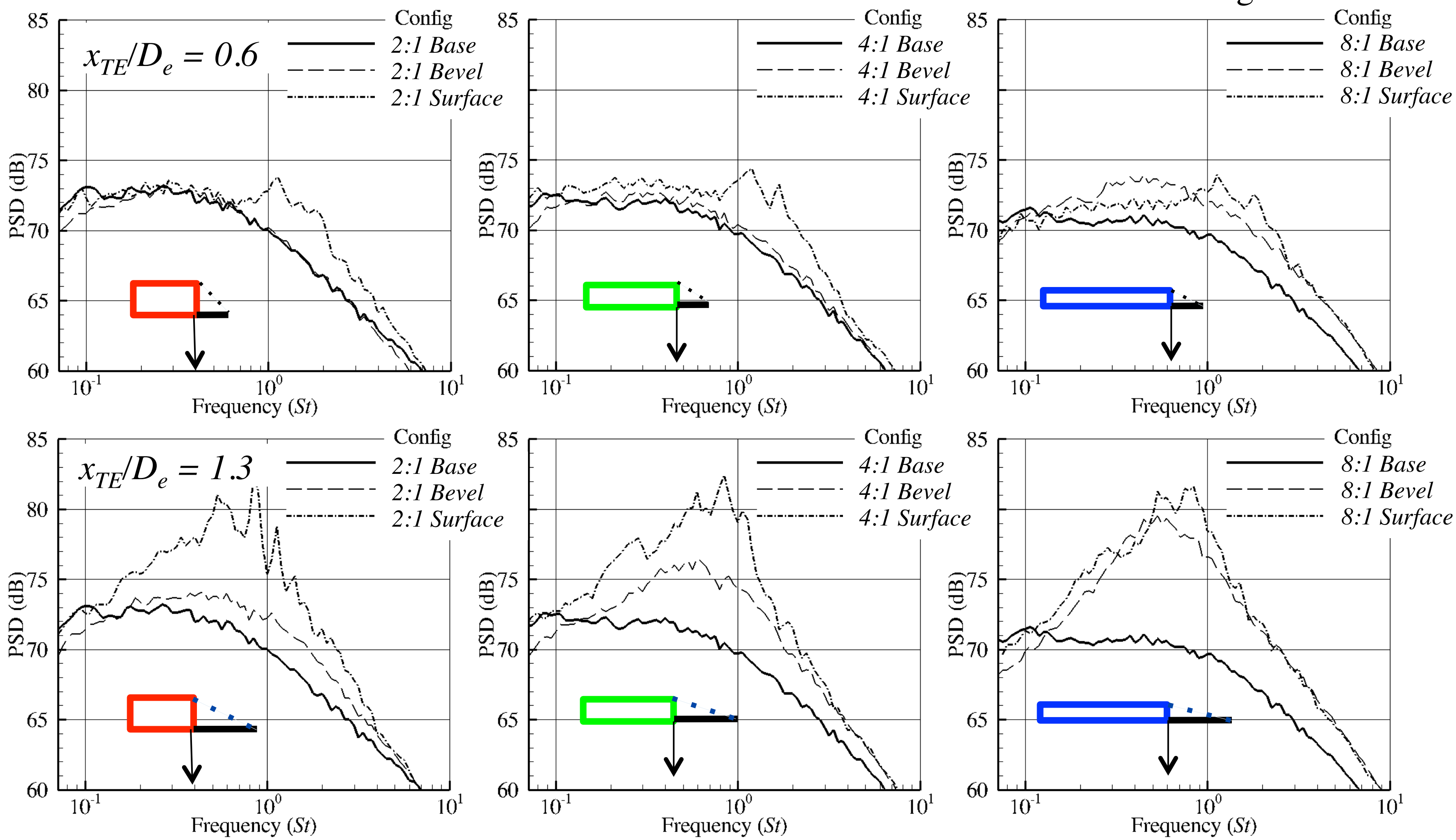
Semi-Infinite Surface Deck Length

Polar angle = 90°



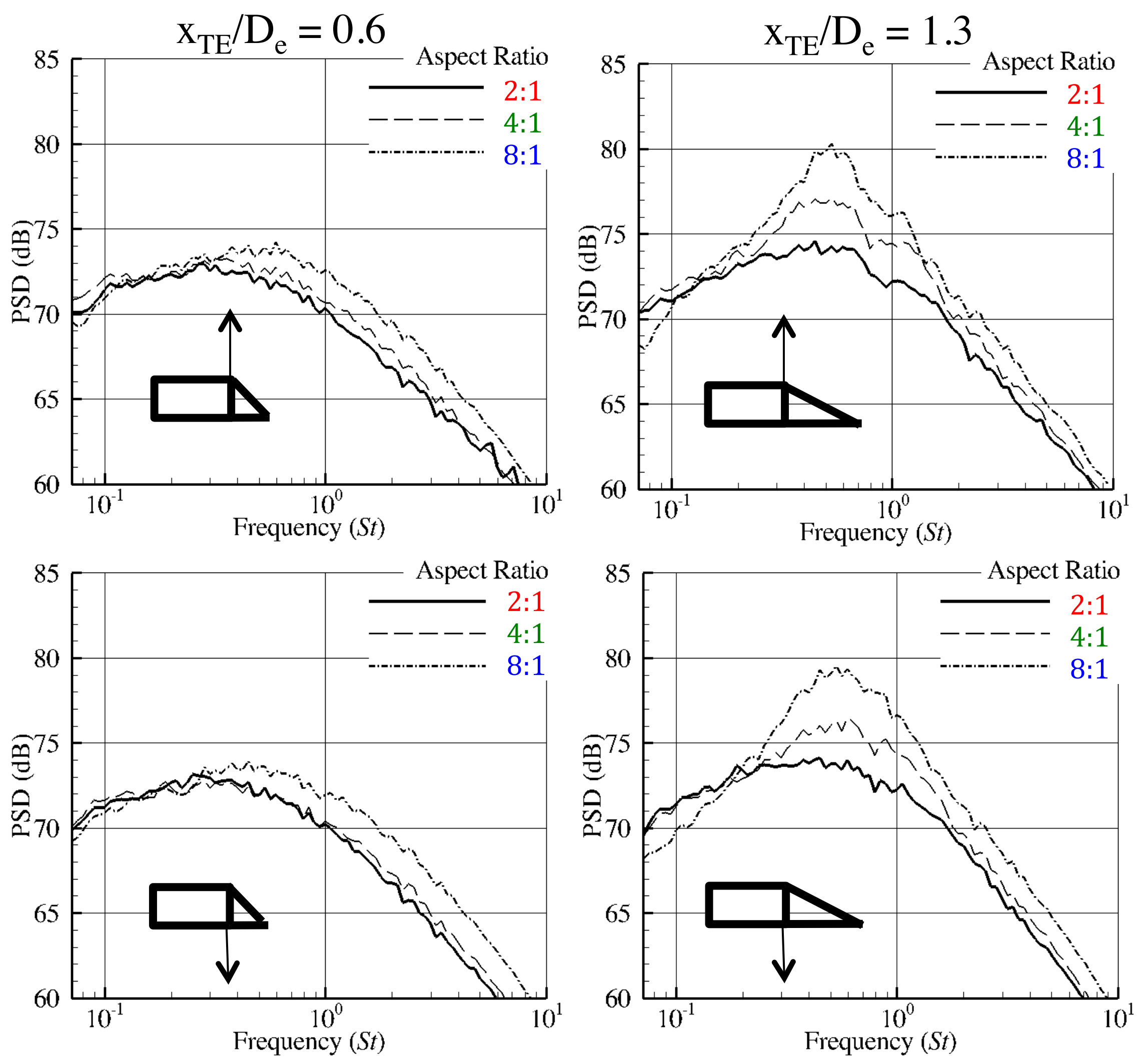
Direct Comparison of Deck Style
Bevel vs Surface

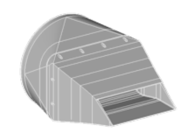
Polar angle = 90°
Azimuth angle = 180°



Beveled Nozzles
Aspect Ratio

Polar angle = 90°

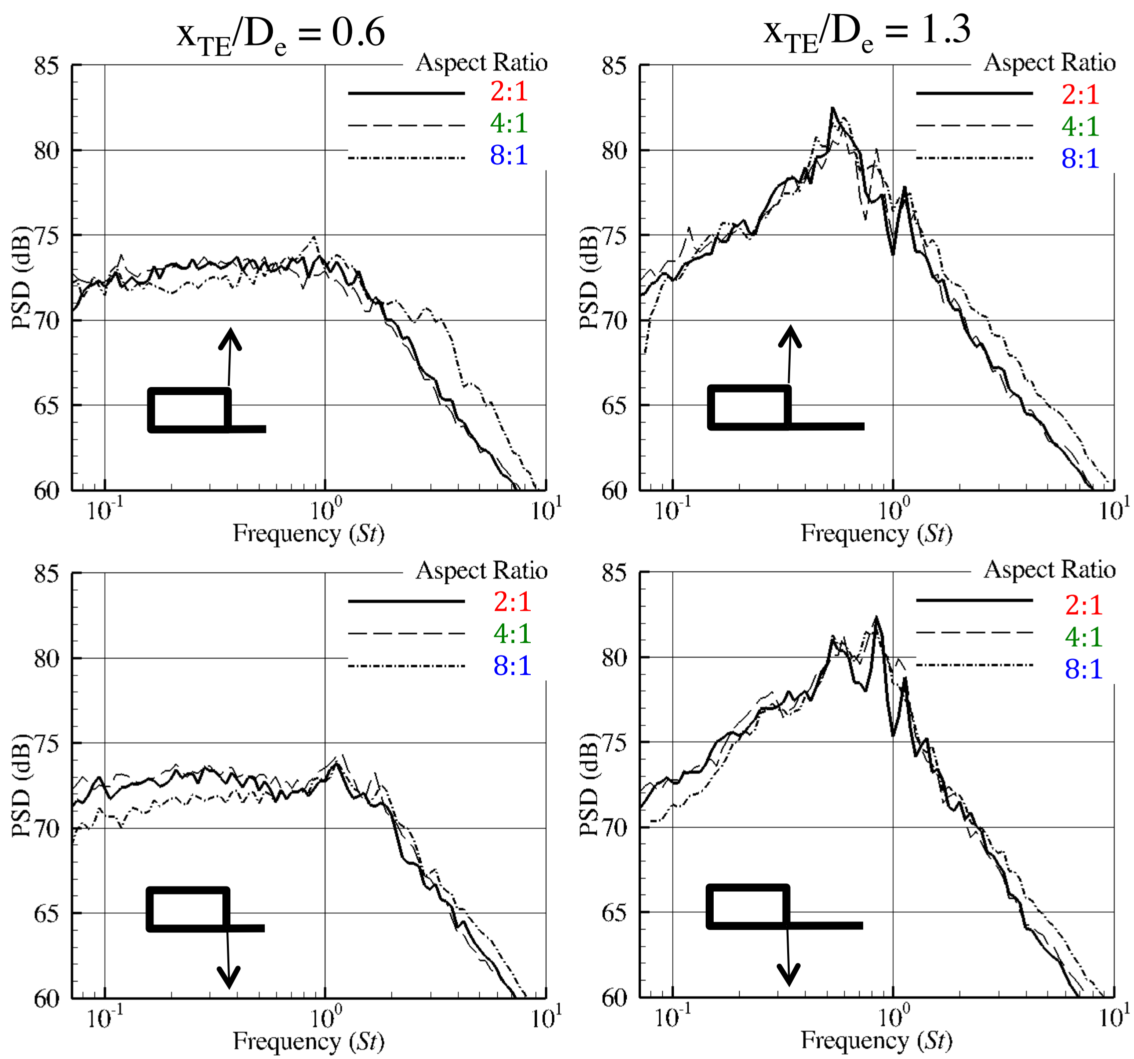


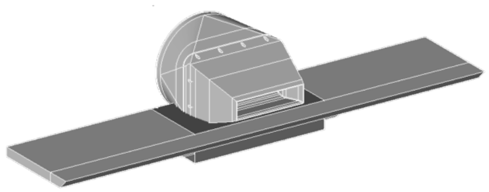


- Noise same on both sides of nozzle
- Noise increases with aspect ratio

Semi-Infinite Surface
Aspect Ratio

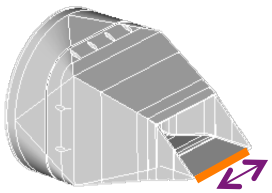
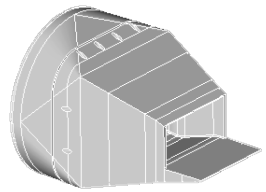
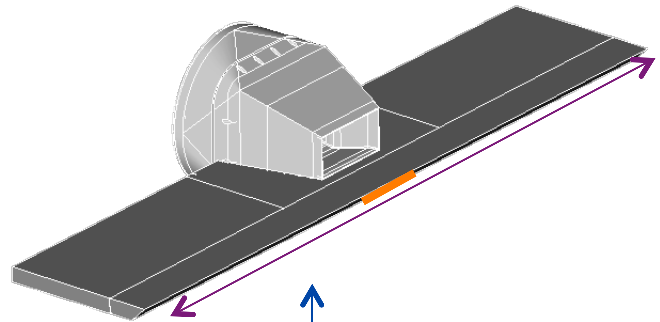
Polar angle = 90°



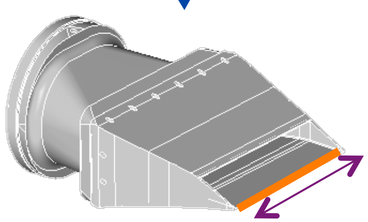


- Noise same on both sides of nozzle
- Noise ***unchanged*** with aspect ratio

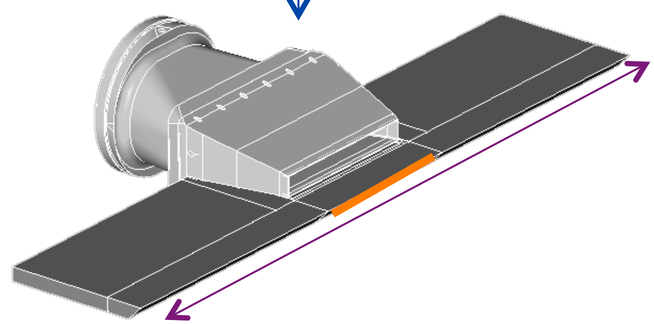
Discussion

Bevel		Bevel, No Side		Semi-Infinite Surface
	=		≠	

Change aspect ratio
Change wetted edge
Change span
Change noise



Change aspect ratio
Change wetted edge
Same span
Same noise



- Span of deck is key to trailing edge dipole

Summary

- **Embedded nozzles** important in advanced aircraft applications.
- **Extent of airframe** required for propulsion-noise models unknown.
- Two embodiments of **embedded rectangular nozzle in aft deck** explored:
  - beveled nozzle (sidewall, minimal airframe planform)
  - semi-infinite surface (no sidewall, infinite airframe planform)
- Acoustic impact of variations in aspect ratio, sidewall, aft deck length explored.
- Aft deck introduces **edge noise** both above and below deck, but not strong along deck, indicative of dipole-like trailing edge source.
- **Edge noise dominant** when aft deck more than an equivalent diameter long for $M = 0.5$ unheated jet.
- Presence of **sidewall not** a significant **factor**.
- **Span** of airframe planform is **critical parameter**.

Future Work

- Explore **intermediate spans** (1 < $span/D_e$ < 10).
  - Impact of span greater than 10D_e previously found not significant for round jet.
- Explore impact of **standoff** of surface from lipline.
- **Empirical modeling** of edge noise, impact of aspect ratio.
- Map azimuthal dependence of edge source.
- Impact of other geometric features: slanted trailing edges, chevrons, dual stream shielding.
- Include thrust impact of deck.