Perceived Noise Analysis for Offset Jets Applied to Commercial Supersonic Aircraft

Dennis L. Huff
Brenda S. Henderson
Jeffrey J. Berton
Jonathan A. Seidel

NASA Glenn Research Center
Cleveland, Ohio 44135

AIAA Aerospace Sciences Meeting, SciTech 2016
January 7, 2016

Research Goals for Supersonic Aircraft

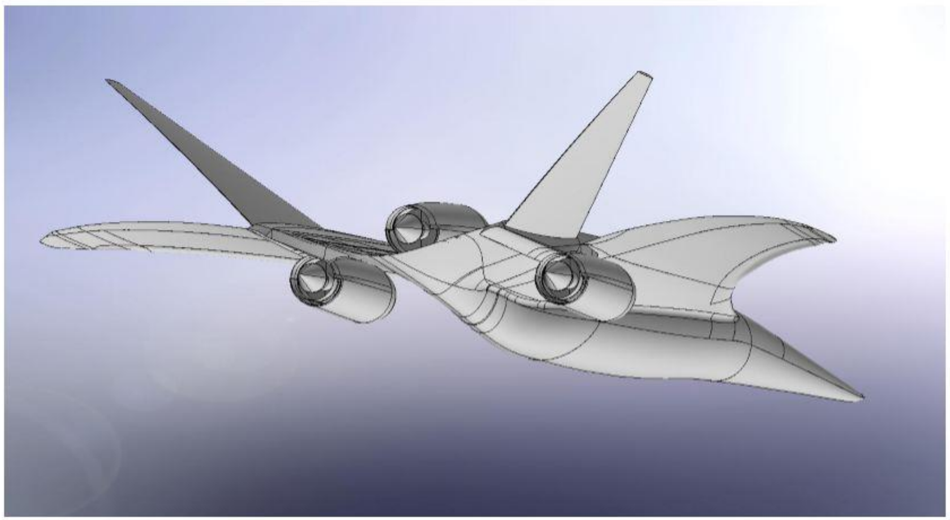
	N+1 supersonic business class aircraft (2015)	N+2 small supersonic airliner (2020)	N+3 efficient multi-Mach aircraft (beyond 2030)
Environmental goals			
Sonic boom	65 to 70 PLdB	65 to 70 PLdB	65 to 70 PLdB low-boom flight 75 to 80 PLdB overwater flight
Airport noise (cum below Chapter 4)	Meet with margin	10 EPNdB	10 to 20 EPNdB
Cruise emissions (cruise NO_x g/kg of fuel)	Equivalent to subsonic	<10	<5 and particulate and water vapor mitigation
Performance goals			
Cruise speed	Mach 1.6 to 1.8	Mach 1.6 to 1.8	Mach 1.3 to 2.0
Range (n mi)	4000	4000	4000 to 5500
Payload (passengers)	6 to 20	35 to 70	100 to 200
Fuel efficiency (pass-miles per lb of fuel)	1.0	3.0	3.5 to 4.5

Objectives

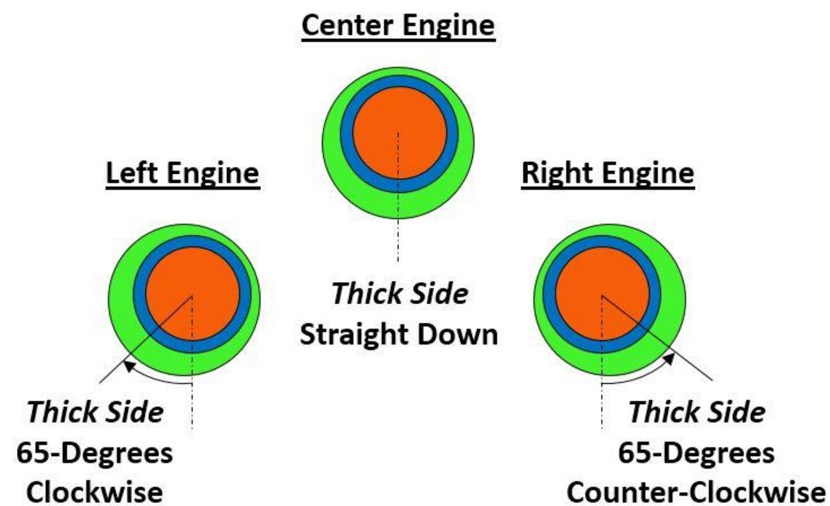
- **Investigate benefits of offset nozzles for N+2 supersonic vehicles.**
- **Conduct engine parametric study to identify design criteria for meeting performance and noise goals.**
- **Use model scale experimental data to investigate perceived noise reduction of jet noise at full scale for takeoff conditions.**
- **Determine the best azimuthal orientation of offset nozzles to minimize lateral takeoff jet noise.**
- **Investigate an alternative takeoff procedure called “programmed lapse rate” (PLR) for noise reduction.**

Aircraft Noise Assessments

Lockheed Martin "1044" Aircraft

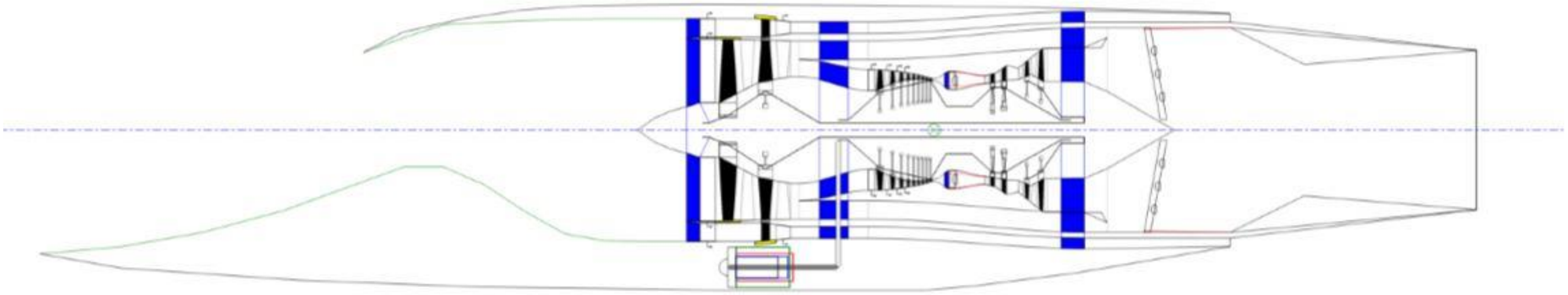


Offset Nozzle Orientations

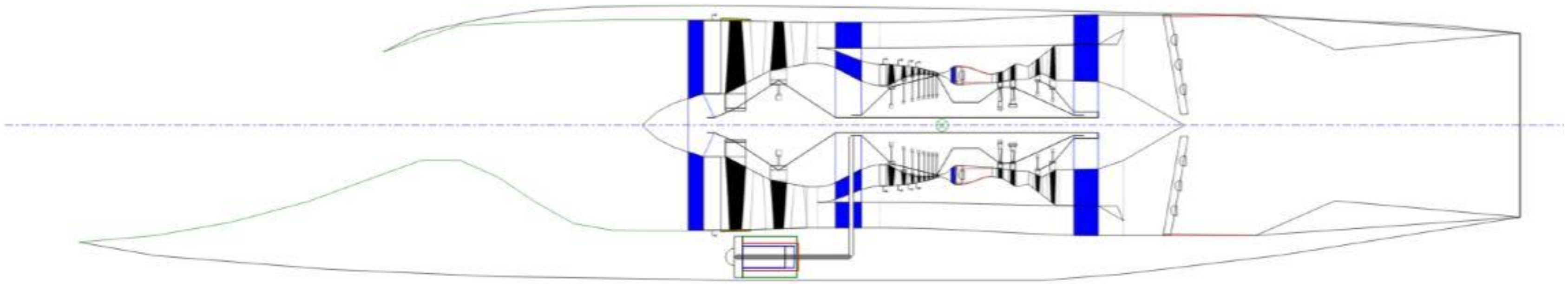


Morgenstern, J., et al., "Advanced Concept Studies for Supersonic Commercial Transports Engine Service in the 2018-2020 Period Phase 2," NASA CR-2015-218719, July 2015.

Engines for Parametric Study

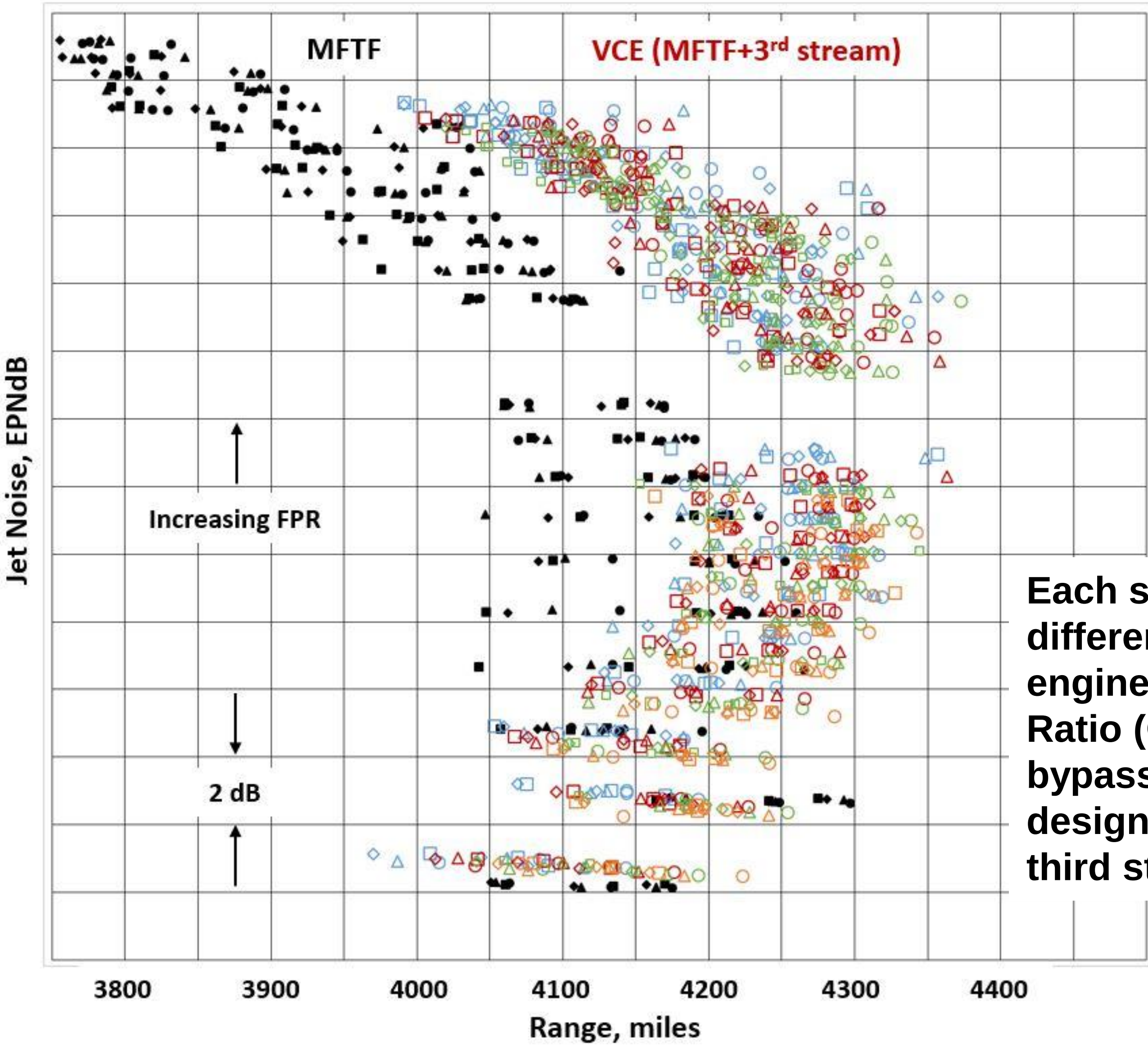


Variable Cycle Engine (VCE)



Mixed Flow Turbofan (MFTF)

Engine Parametric Study

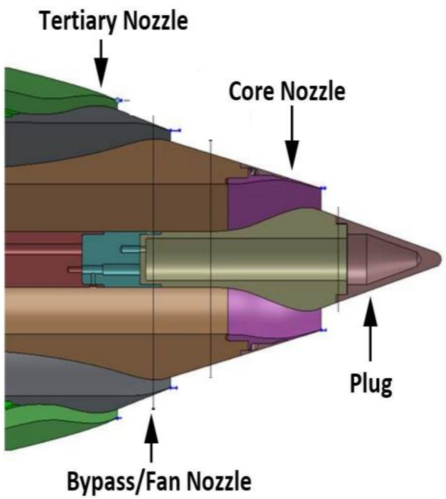


Each symbol represents a different combination of engine Overall Pressure Ratio (OPR), main engine bypass and throttle ratio, and design bypass ratio of the third stream (BPRt).

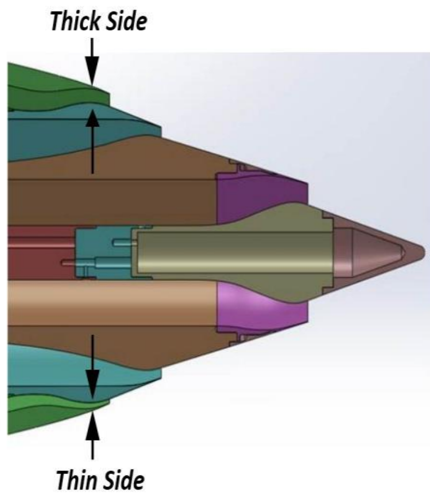
Experimental Data

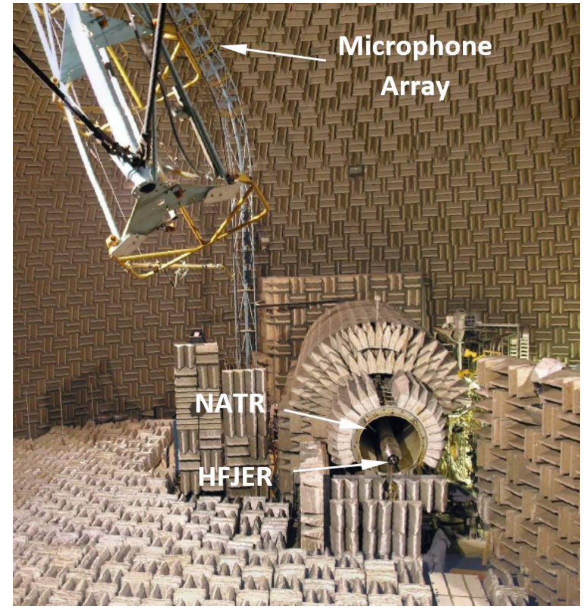
Core nozzle pressure ratio, NPRc: 1.5 to 2.3
Bypass nozzle pressure ratio, NPRb: 1.5 to 2.3
Tertiary nozzle pressure ratio, NPRt: 0, 1.0 to 2.1
Core nozzle temperature ratio, NTRc: 3.0
Free jet Mach 0.30
Bypass-to-core area ratios, Ab/Ac: 1.0, 2.5

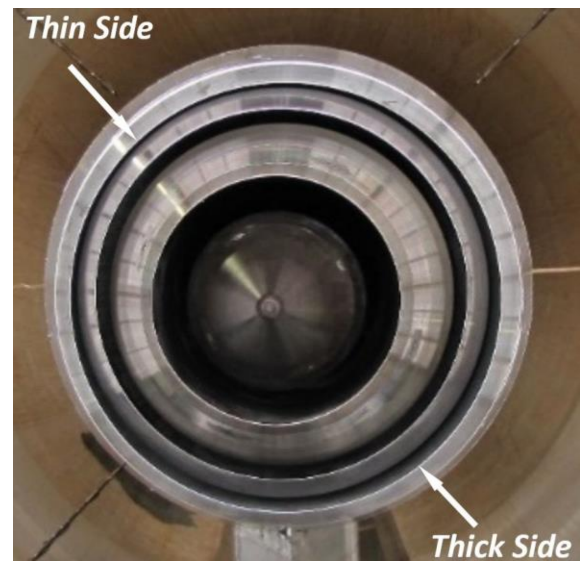
Axisymmetric



Offset







Henderson, B., Leib, S., and Wernet, M., "Measurements and Predictions of Noise from Three-Stream Jets," AIAA-2015-3120 and NASA/TM-2015-218848, 2015.

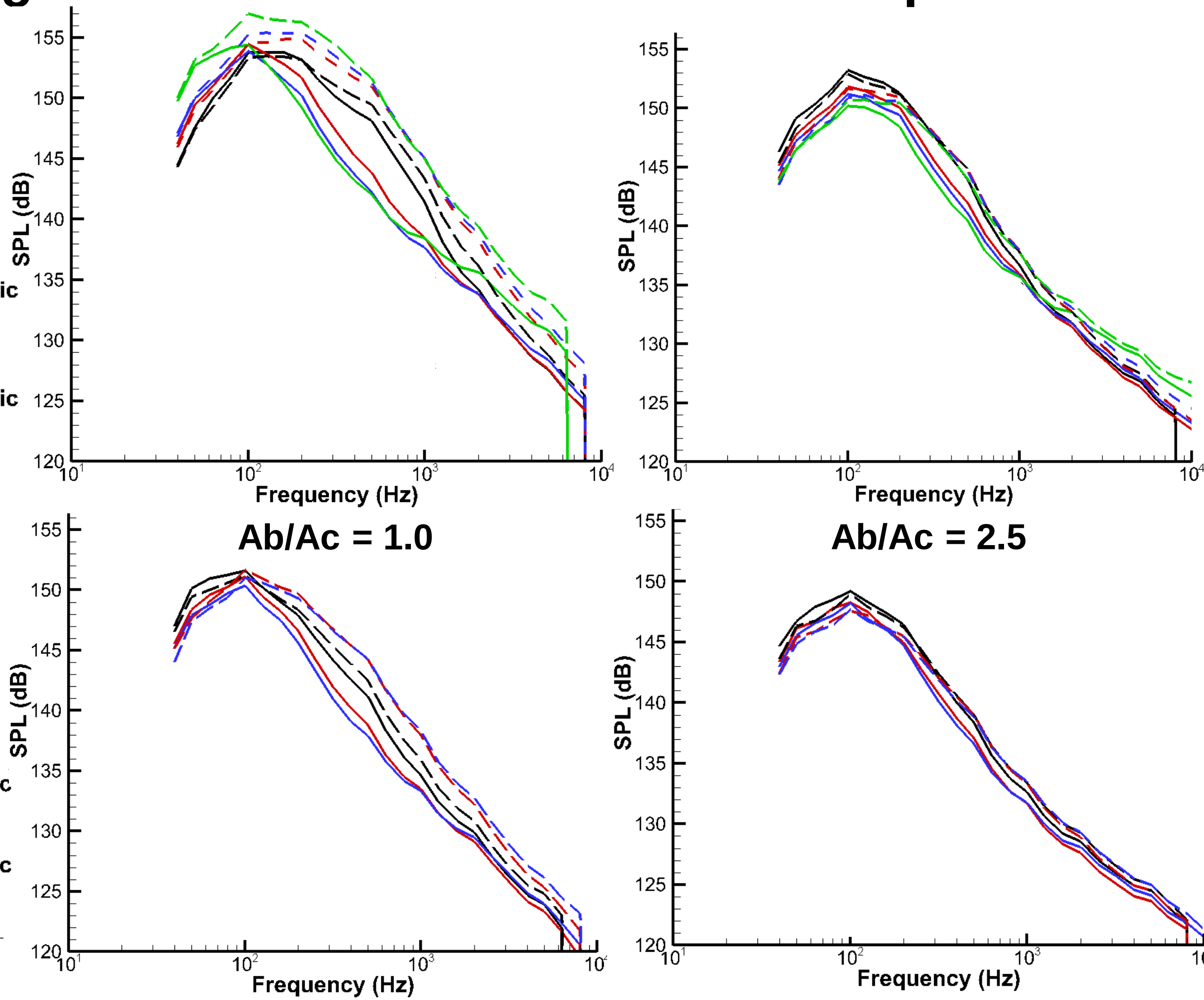
Single Engine Full-Scale One-Third Octave Spectra

Supersonic Core NPRc = 2.1

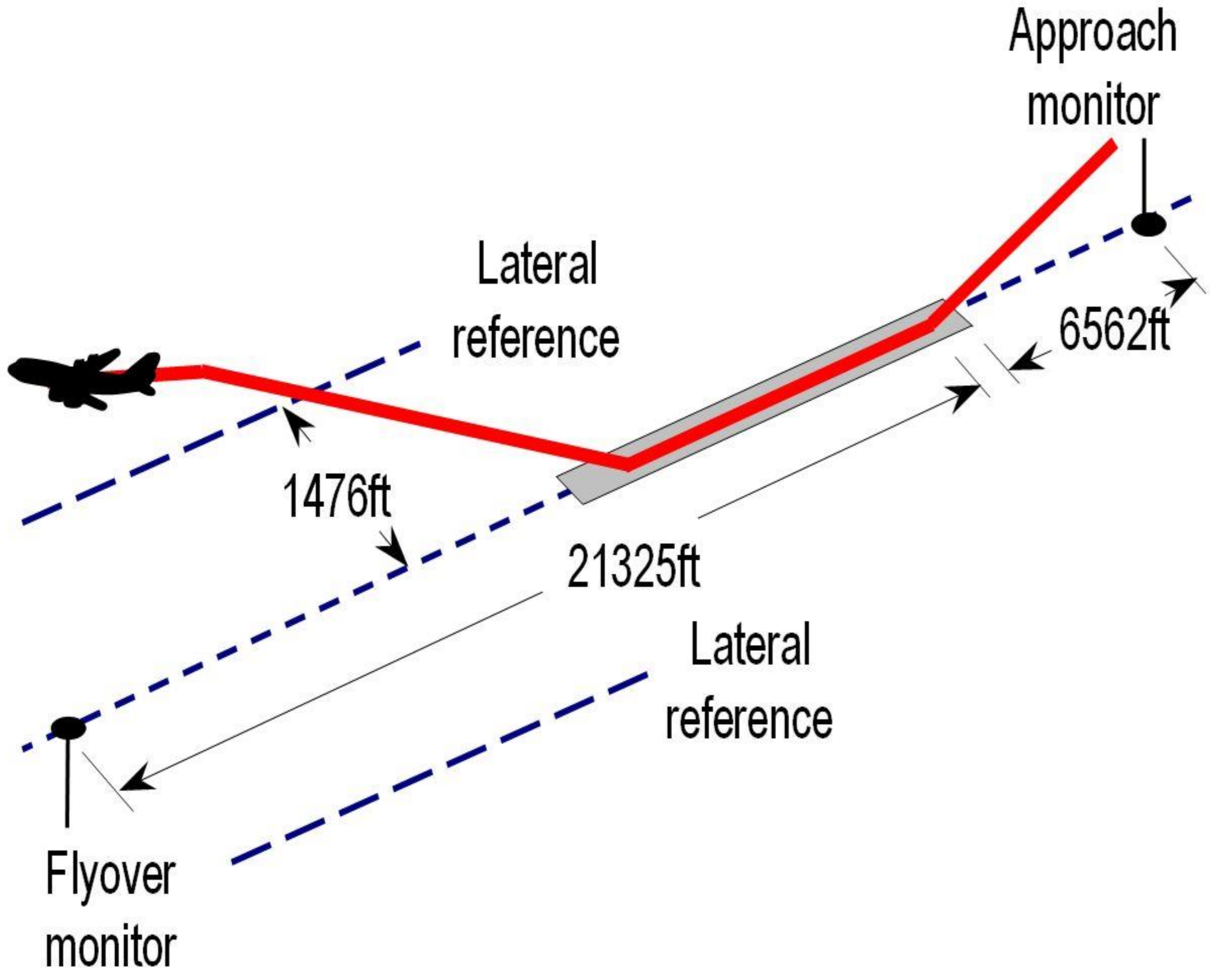
- Dual-Stream Axisymmetric (solid)
- Offset NPRt = 1.5 Thick
- Offset NPRt = 1.8 Thick
- Offset NPRt = 2.1 Thick
- Dual-Stream Axisymmetric (dashed)
- Offset NPRt = 1.5 Thin
- Offset NPRt = 1.8 Thin
- Offset NPRt = 2.1 Thin

Subsonic Core NPRc = 1.8

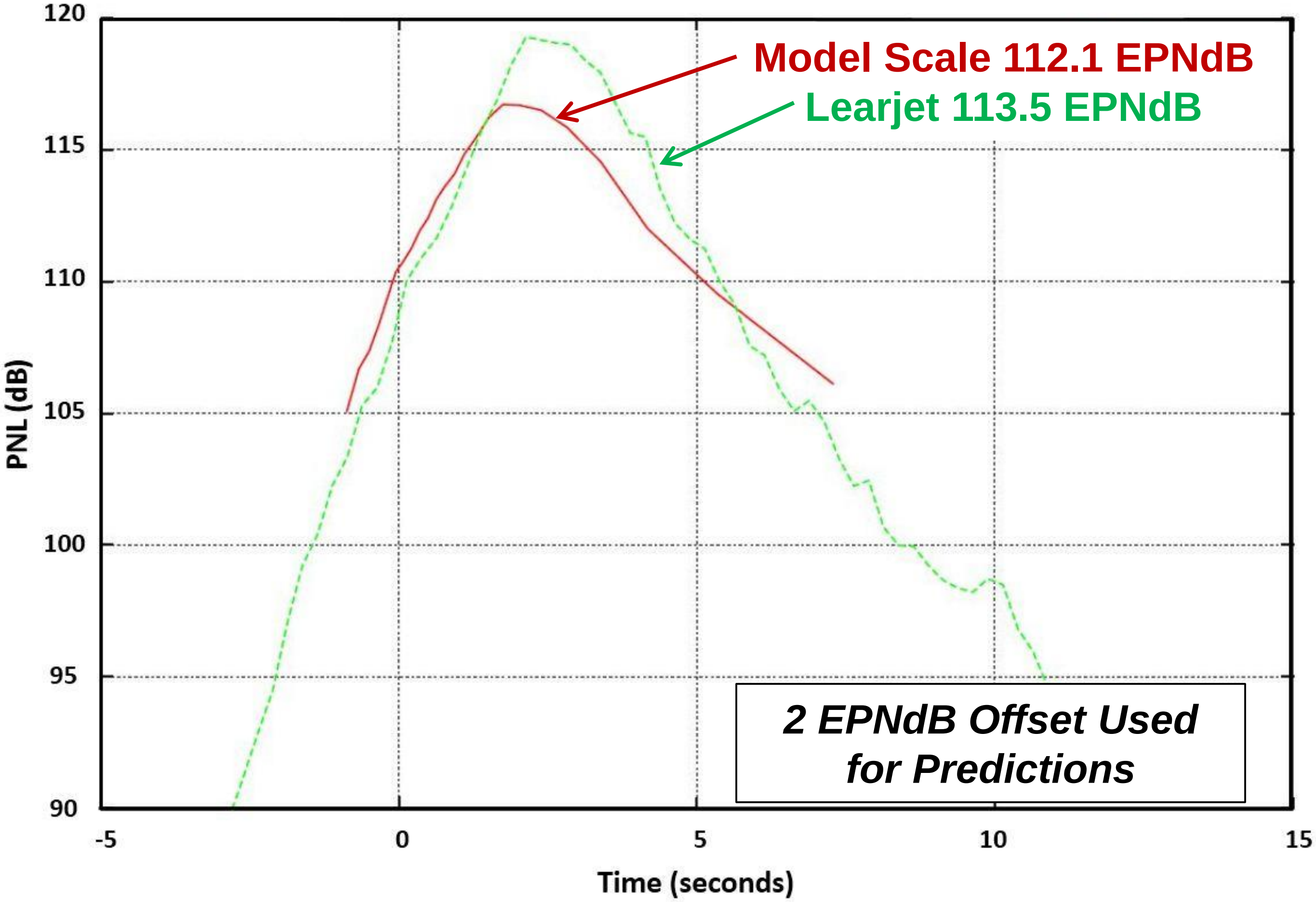
- Dual-Stream Axisymmetric (solid)
- Offset NPRt = 1.4 Thick
- Offset NPRt = 1.6 Thick
- Dual-Stream Axisymmetric (dashed)
- Offset NPRt = 1.4 Thin
- Offset NPRt = 1.6 Thin



Noise Certification

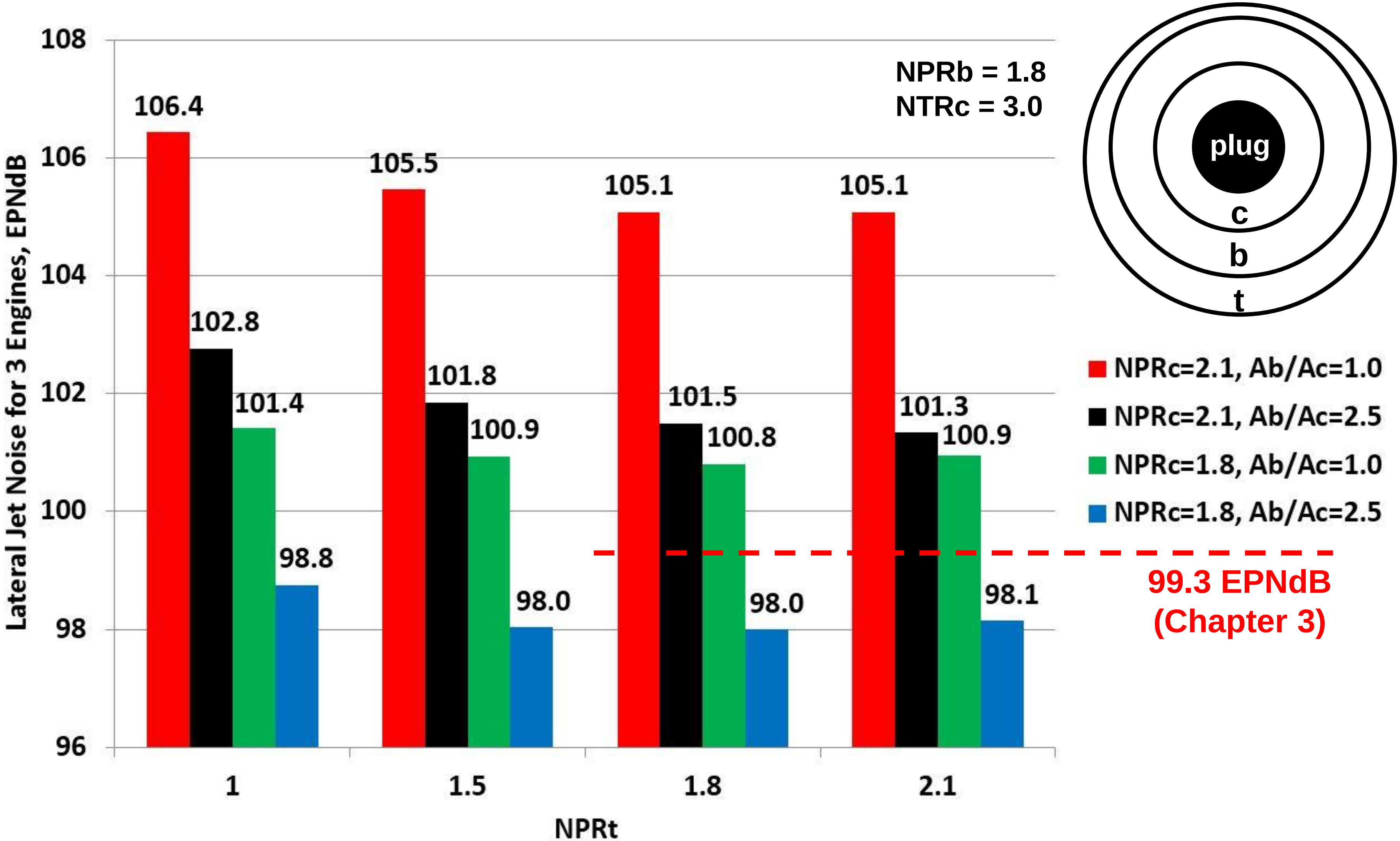


Model Data versus Flight Data

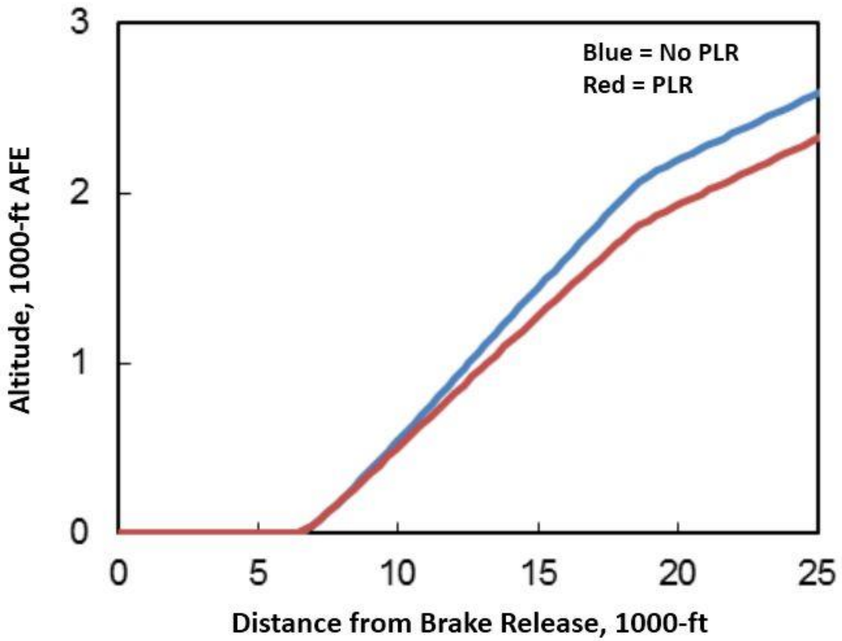


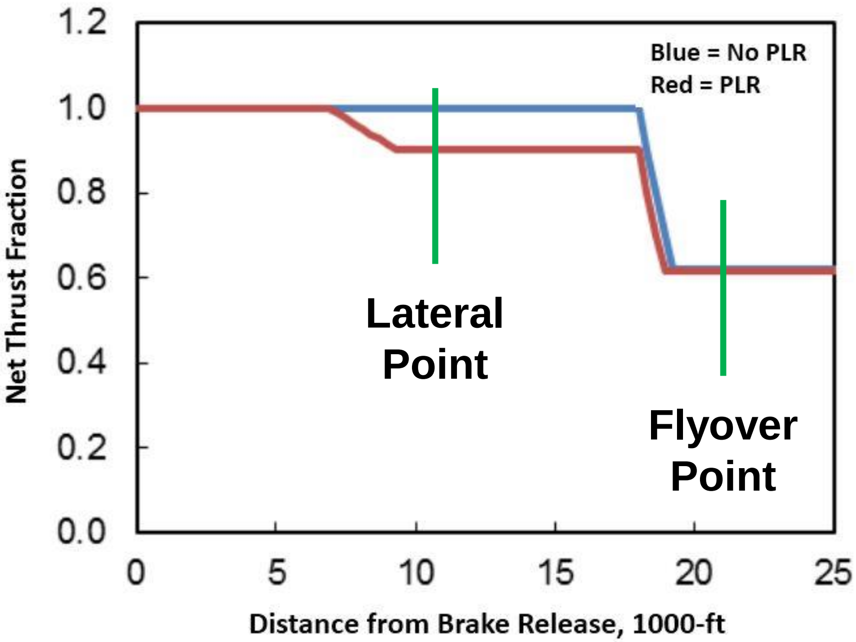
Brown, C. and Bridges, J, "An Analysis of Model Scale Data Transformation to Full Scale Flight Using Chevron Nozzles," NASA TM-2003-212732, 2003.

Perceived Noise Levels for Offset Jets



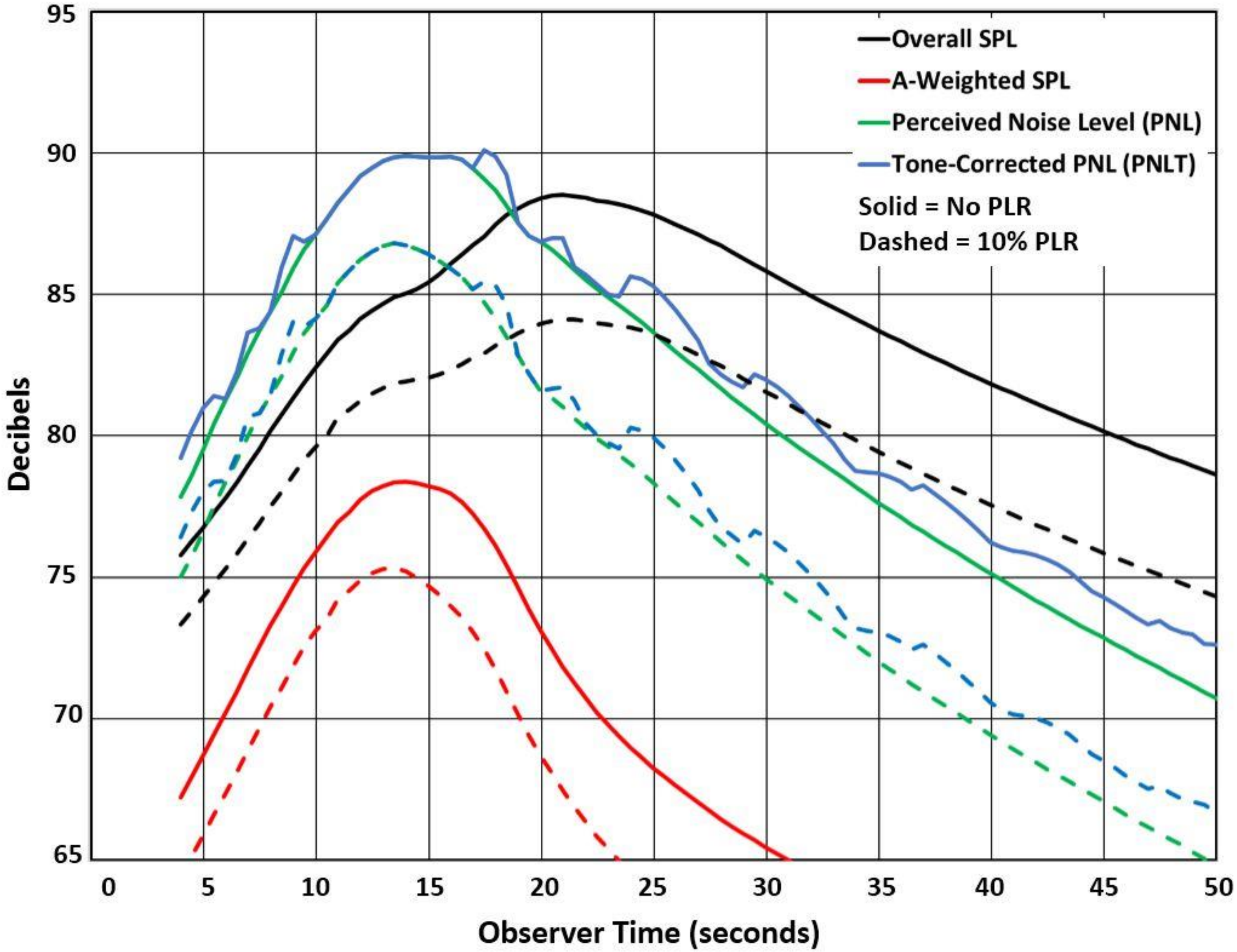
Programmed Lapse Rate (PLR)





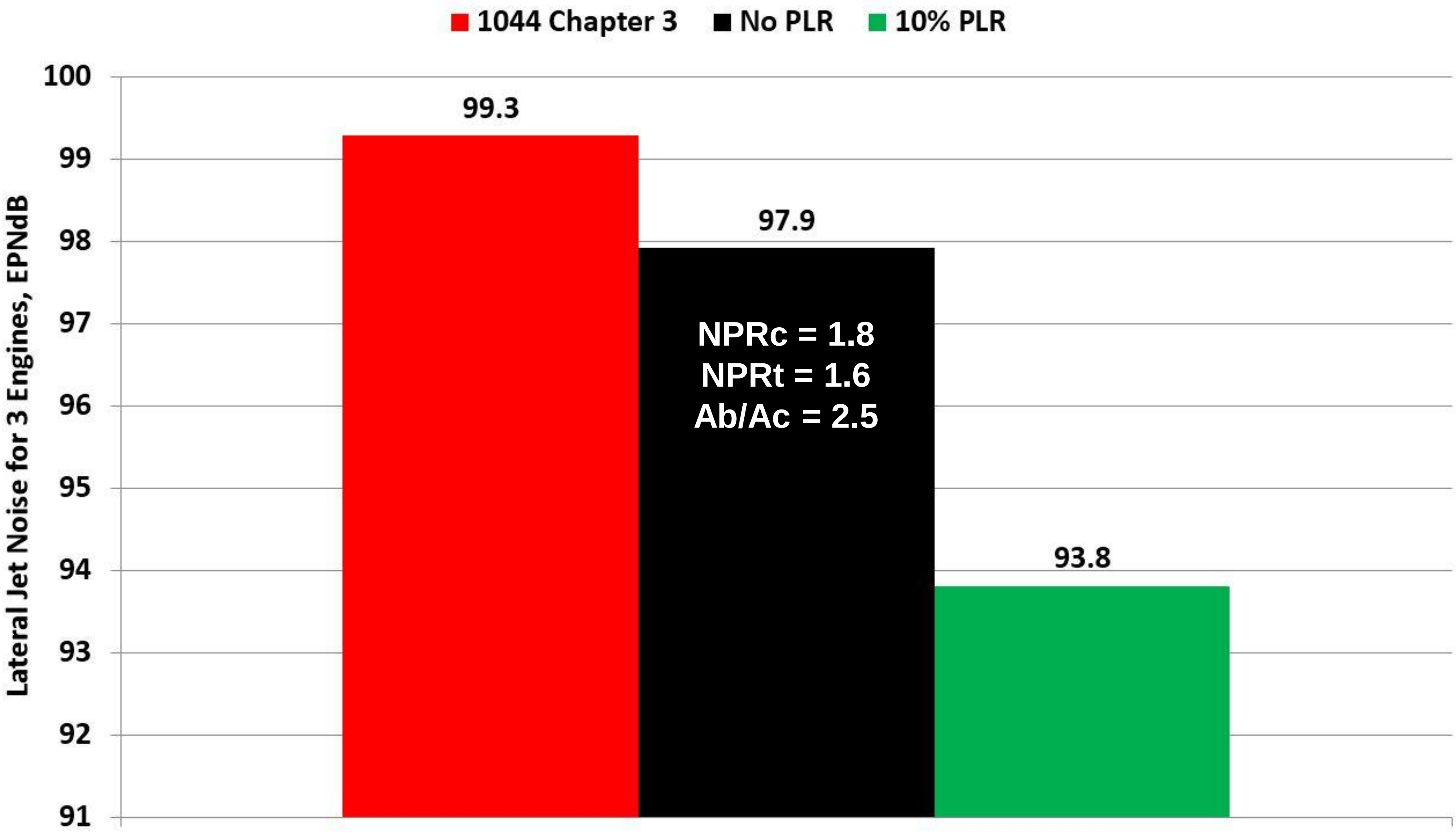
- **Thrust is reduced by 10% at lateral certification point.**
- **Small change in altitude**
- **Flyover conditions are same for both procedures.**
- **NOT APPROVED BY FAA!**

Single Engine Flyover



NPRc = 1.8
NPRt = 1.6
Ab/Ac = 2.5

Effective Perceived Noise Levels



Conclusions (1 of 2)

- **For the engines evaluated, a VCE with three-streams and maximum mission range is predicted to have jet noise levels that are 8 to 10 EPNdB higher than a lower specific thrust dual-flow MFTF.**
  - **The MFTF is predicted to have a range that is about 100 miles less than the VCE.**
  - **Larger diameter lower expansion ratio nozzles associated with the MFTF could adversely impact sonic boom signatures.**

- **Separate flow, offset nozzles reduce the noise directed toward the thicker side of the outer flow stream.**

- **The noise reduction benefits from offset nozzles due to azithmuthal directivity become less as NPRc is reduced. Results show that there is a 1.3 to 1.5 EPNdB benefit for NPRc = 2.1, and a 0.6 to 0.8 EPNdB benefit for NPRc = 1.8.**

Conclusions (2 of 2)

- **It is unlikely that offset nozzles will provide enough noise reduction for the highest range VCE considered in the engine parametric study to be quieter than a dual-stream MFTF with a lower NPRc.**

- **For a three-engine N+2 aircraft with full throttle takeoff, there is a 1.4 EPNdB margin to Chapter 3 noise regulations predicted for the lateral certification point .**
  - **Best case offset nozzle configuration with NPRc = 1.8, NPRb = 1.8, NPRt = 1.6, NTRc = 3.0 and Ab/Ac = 2.5.**

- **With a 10% PLR, the margin increases to 5.5 EPNdB and is sufficient to meet Chapter 4 regulations.**
  - **Depending on the cumulative split across certification points, can meet the new Chapter 14 noise levels**
  - **However, it is standard practice to have at least a 4 EPNdB additional cumulative margin for growth versions of the aircraft.**

Recommendations

- **Further research should focus on noise reduction technologies for low specific thrust engines applied to supersonic aircraft, including their impact on sonic boom.**

Acknowledgments

This work was supported by NASA's Commercial Supersonic Technology (CST) project in the Advanced Air Vehicles Program.