Compliance with Environmental Standards for Novel SST with Consideration of Jet Noise as a Dominant Source

Victor F. Kopiev, Yu.V. Medvedev, B.S. Zamtfort, V.F. Samokhin, G.A. Faranosov

22nd Workshop of the Aeroacoustics Specialists Committee of the CEAS
Future Aircraft Design and Noise Impact

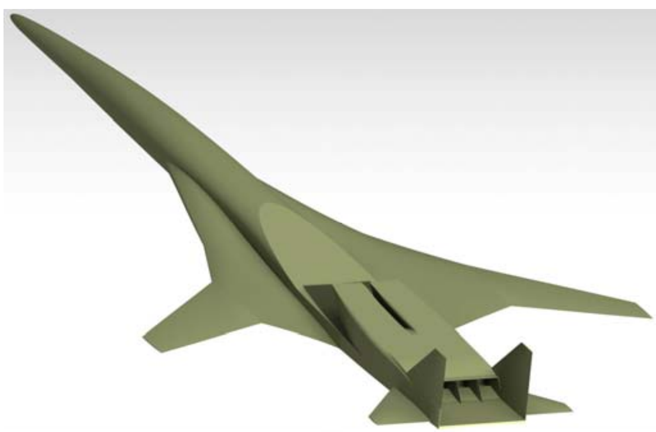
6 – 7 September 2018, Netherlands Aerospace Centre, Amsterdam

Introduction

- The purpose of the study was to investigate potential LTO noise impact mitigation for SST considering jet noise as the dominant source and assuming other sources being substantially suppressed.
- Several supersonic transport concepts with various engine numbers and MTOWs were considered as initial studies:
  - Berton, J., Jones, S., Seidel, J., & Huff, D. (2018). Noise predictions for a supersonic business jet using advanced take-off procedures. The Aeronautical Journal, 122(1250), 556-571.
  - V.F. Kopiev, V.F. Samokhin, Yu.V. Medvedev, B.S. Zamtfort «Numerical investigation of noise levels in certification points for the new generation SST», XVII Scientific and Technical Conference on Aeroacoustics, Zvenigorod, 2017.

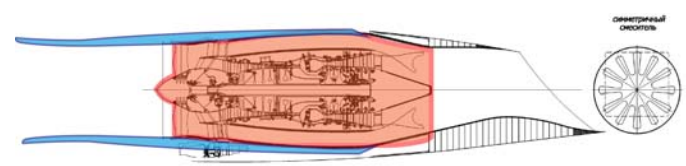
Work Rationale

- The rationale for taking into account primarily jet noise is that supersonic airplanes are likely to have **higher thrust** for a given MTOW than subsonic one due to the need for a transition through the speed of sound and flight at higher supersonic speeds (M = 1.4-1.8).
- SST engines are to have lower bypass-ratio. For **integrated SST layout**, liners with larger areas could be installed, efficiently suppressing fan noise.
- Application of the engine above the wing layout yields supplementary **fan shielding effect** but no significant suppression is granted to jet noise.



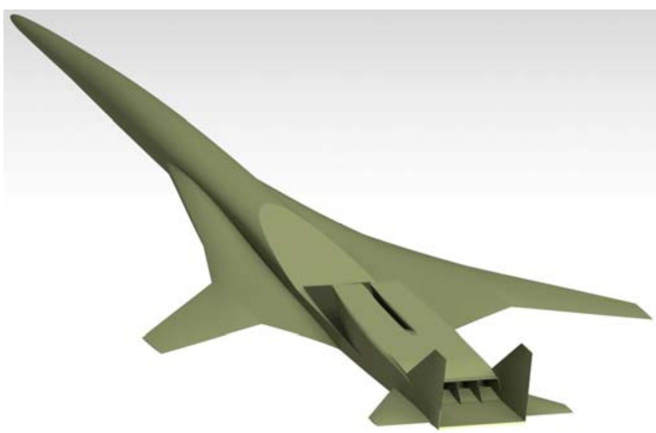
Airframe noise

Jet noise
Fan noise
Combustor noise



Work Rationale

Hence it is reasonable to assume that the noise sources associated with the fan and combustor can be suppressed by means of liners and shielding.

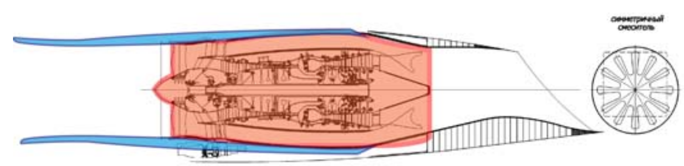


Airframe noise

Jet noise

Fan noise

Combustor noise



Previous Generation SST

- Estimations based on jet speed for previous generation SST for 2-engine aircraft with MTOW=70 tons show that high-speed jets are incompatible with the current Noise Standards.

	Jet speed, m/s	Prediction, EPNdB	Chapter 3, EPNdB	Chapter 3 Margin
Take-off	530	109.8	96.6	-13.2
Climb Out	404	96.8	91.2	-5.6
Approach	214	85.1	100.3	15.2
Total		291.7	288.1	-3.6

New Generation SST

- Various SST layouts were considered within the study:

- Engine location and different nozzle shapes were considered as potential implementation for most optimized SST concept.

Considered Problem

- The jet noise cannot be so efficiently reduced using the nozzles with specific geometry or closely located surfaces:
  - James E. Bridges, Acoustic Measurements of Rectangular Nozzles With Bevel // AIAA paper, AIAA–2012–2252.

- Hence, before considering the passive suppression options for the main noise sources, it is necessary to evaluate the maximum jet speed from the viewpoint of the total noise in certification points meeting Chapter 14, applied for subsonic aircraft.

- **For higher jet speeds there is no reason to investigate new technologies for fan noise reduction since the jet noise levels would already exceed Chapter 14 limits.**

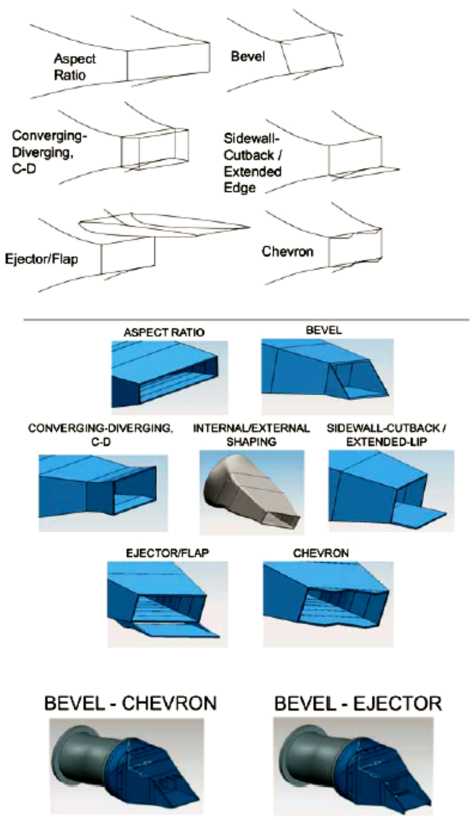
AIAA Papers

49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition
4 - 7 January 2011, Orlando, Florida

AIAA 2011-975

Extensible Rectangular Nozzle Model System

James E. Bridges[†]
NASA Glenn Research Center, Cleveland, Ohio 44135

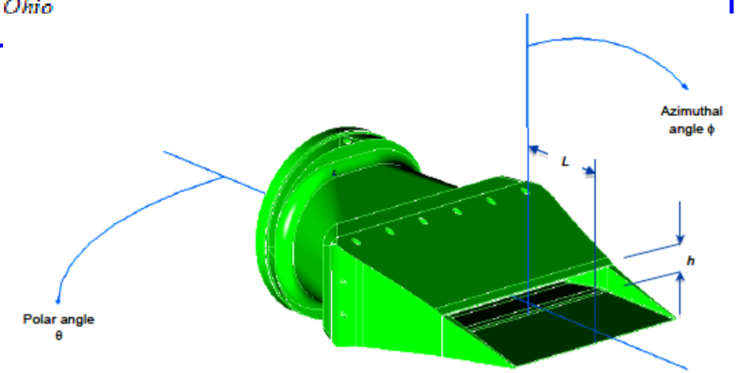


NASA/TM—2012-217674

AIAA–2012–2252

Acoustic Measurements of Rectangular Nozzles With Bevel

James E. Bridges
Glenn Research Center, Cleveland, Ohio



AIAA Papers

AIAA 2015-3119

AIAA Aviation
22-26 June 2015, Dallas, TX
21st AIAA/CEAS Aeroacoustics Conference

AIAA Aviation 2015 Conference – 22-26 June 2015

Noise Measurements Of High Aspect Ratio Distributed Exhaust Systems

James Bridges*
NASA Glenn Research Center, Cleveland, OH, 44135

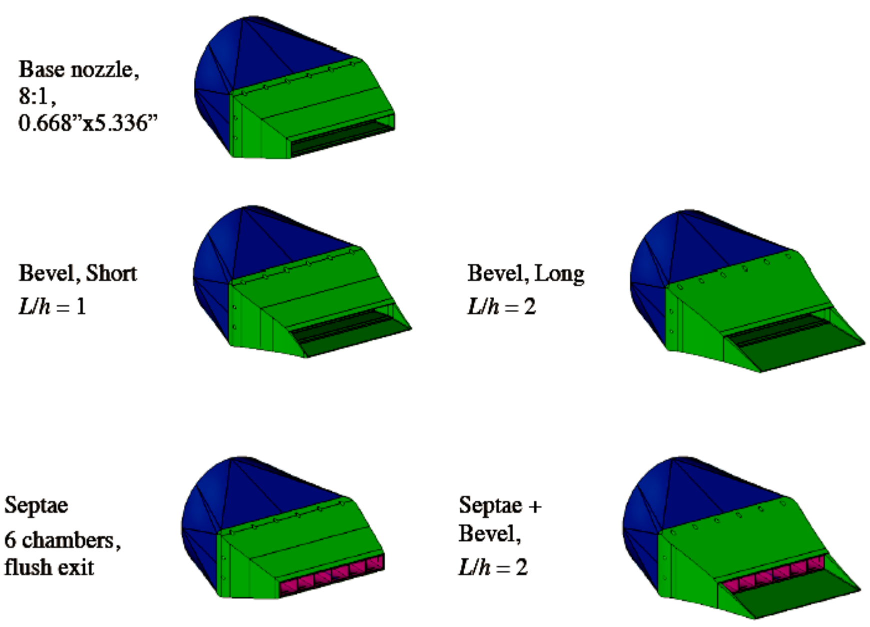
AIAA 2015-3119

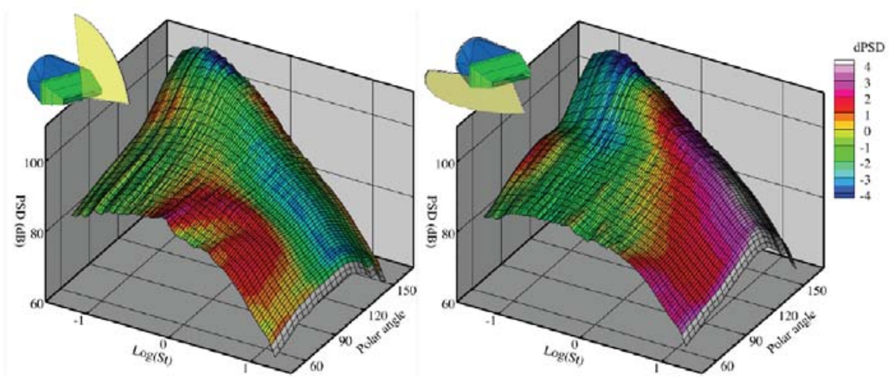
AIAA Aviation
22-26 June 2015, Dallas, TX
21st AIAA/CEAS Aeroacoustics Conference

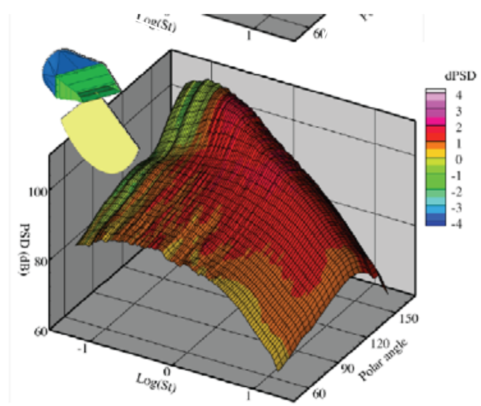
AIAA Aviation 2015 Conference – 22-26 June 2015

Noise Measurements Of High Aspect Ratio Distributed Exhaust Systems

James Bridges*
NASA Glenn Research Center, Cleveland, OH, 44135

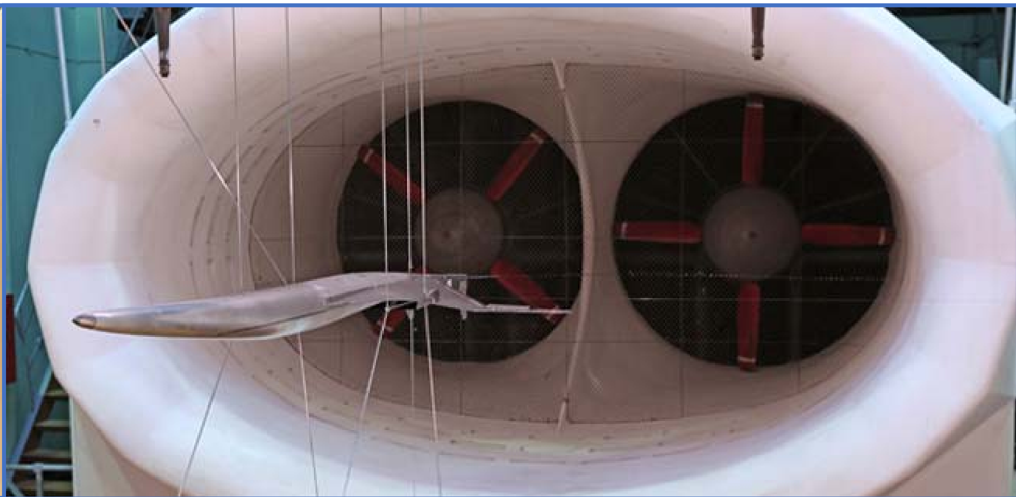






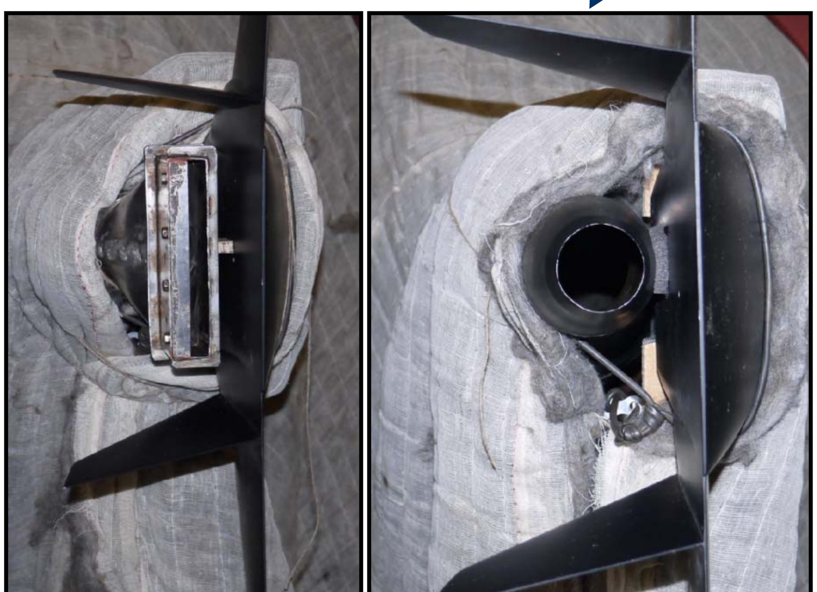
TsAGI Research

- Aerodynamic and numerical research performed in TsAGI is aimed on development of new generation SST and integrated analysis of its impact.
- The integrated analysis embraces both sonic boom and LTO noise impact, as well as potential noise suppression methods and technologies.



TsAGI Nozzle Research

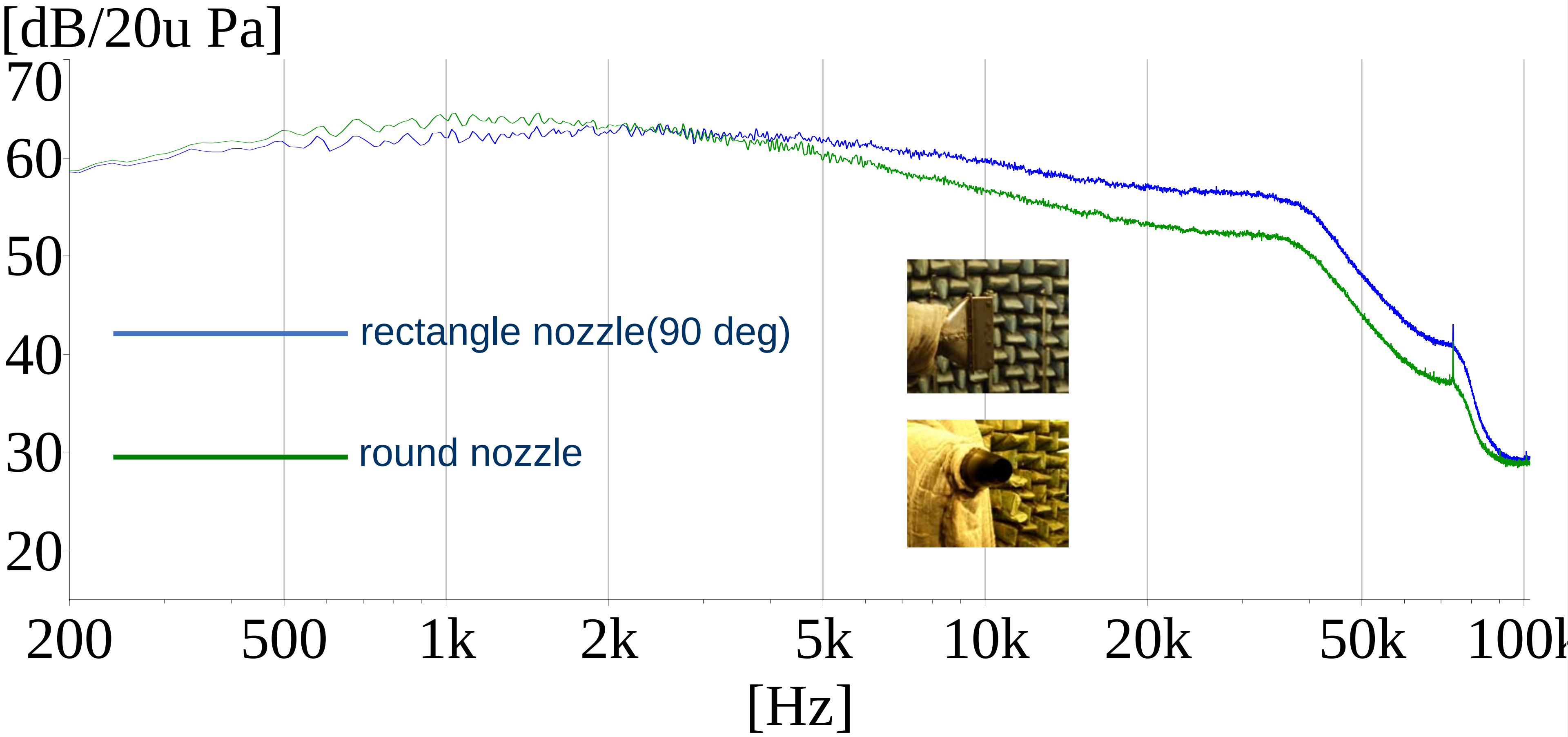
Baseline:
No-tail round nozzle



Directivity variation for analysis of both lateral and flyover/approach noise levels.

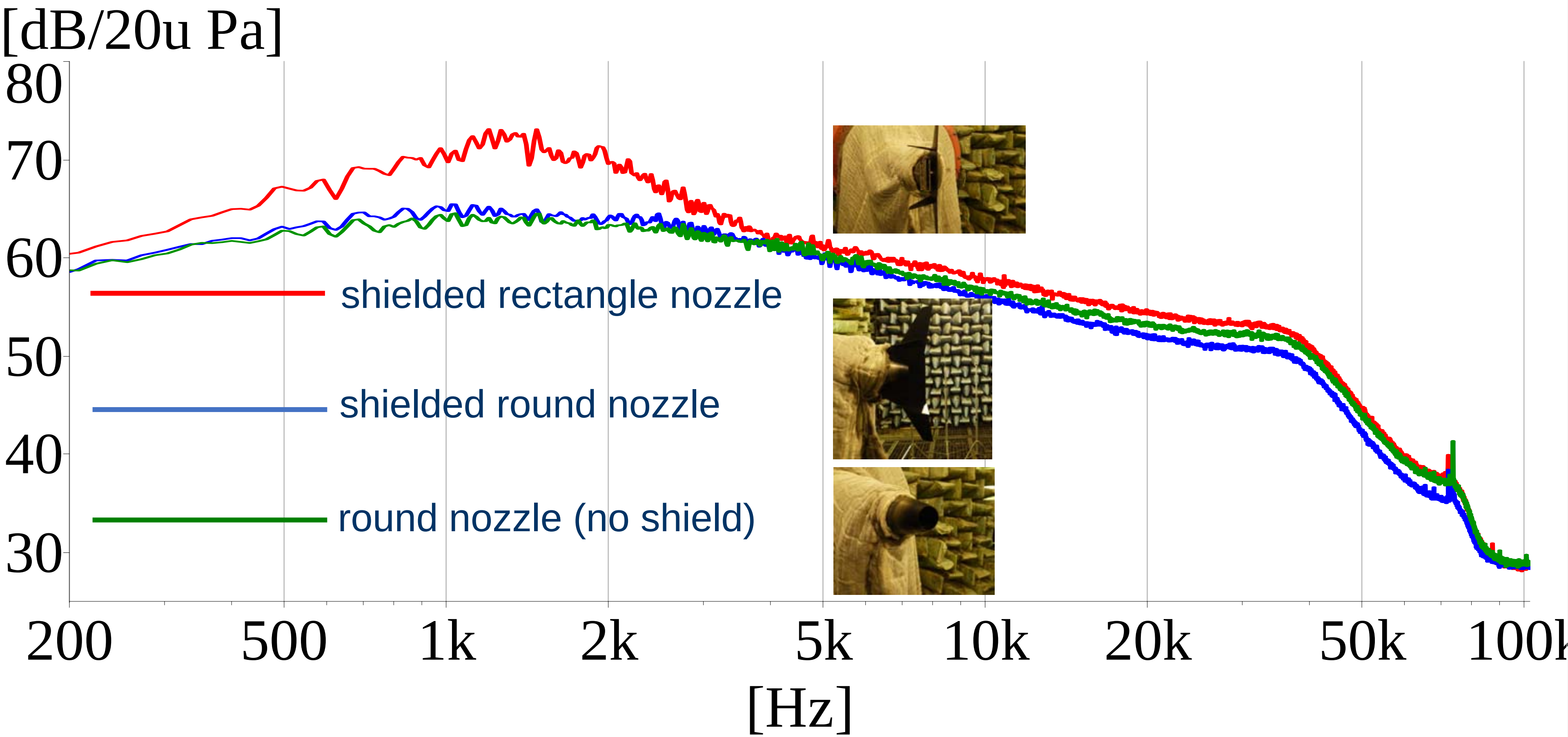
Anechoic Chamber

Experimental Results



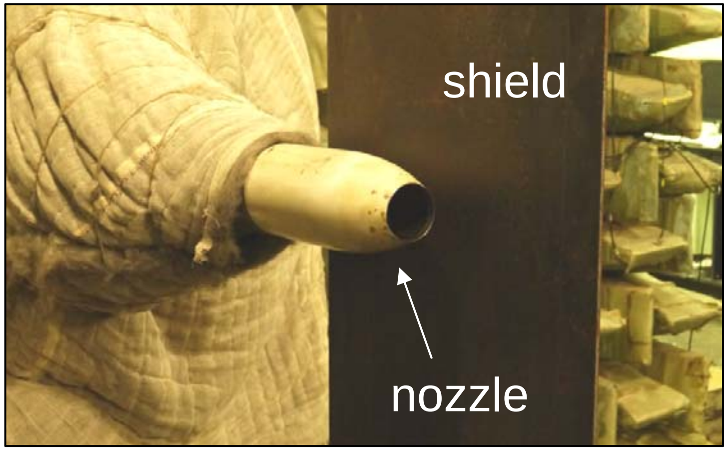
No shielding, no co-flow, **Ps = 1.25,** mic position 90 degrees to rectangle nozzle

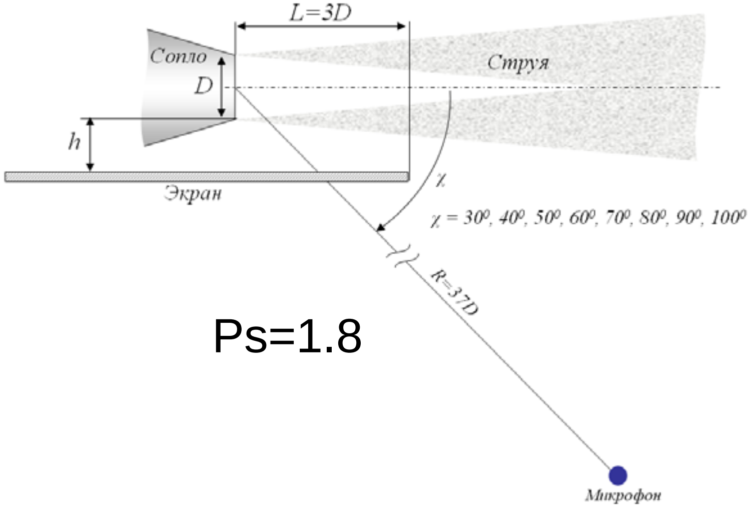
Experimental Results

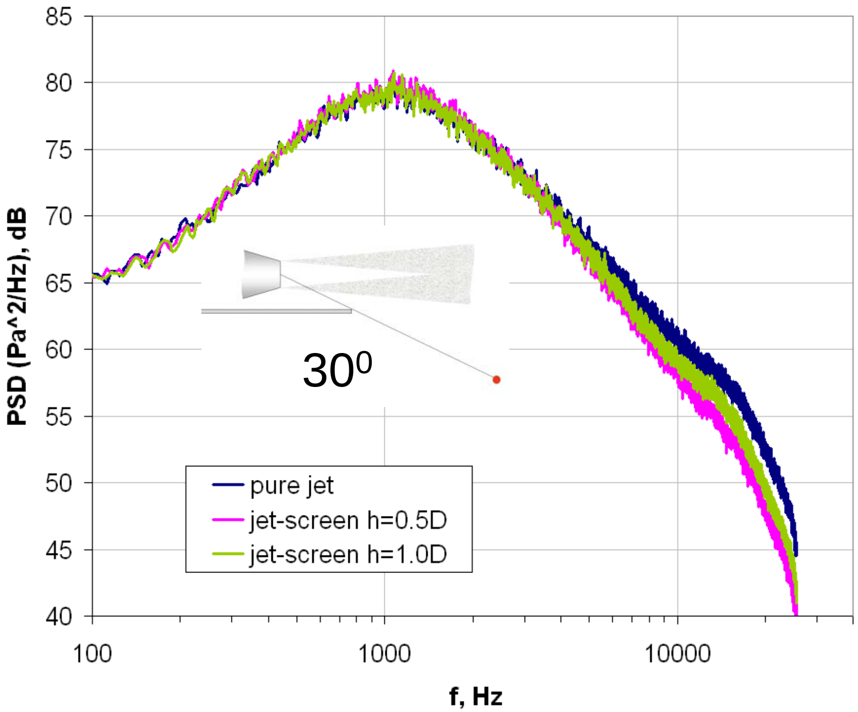


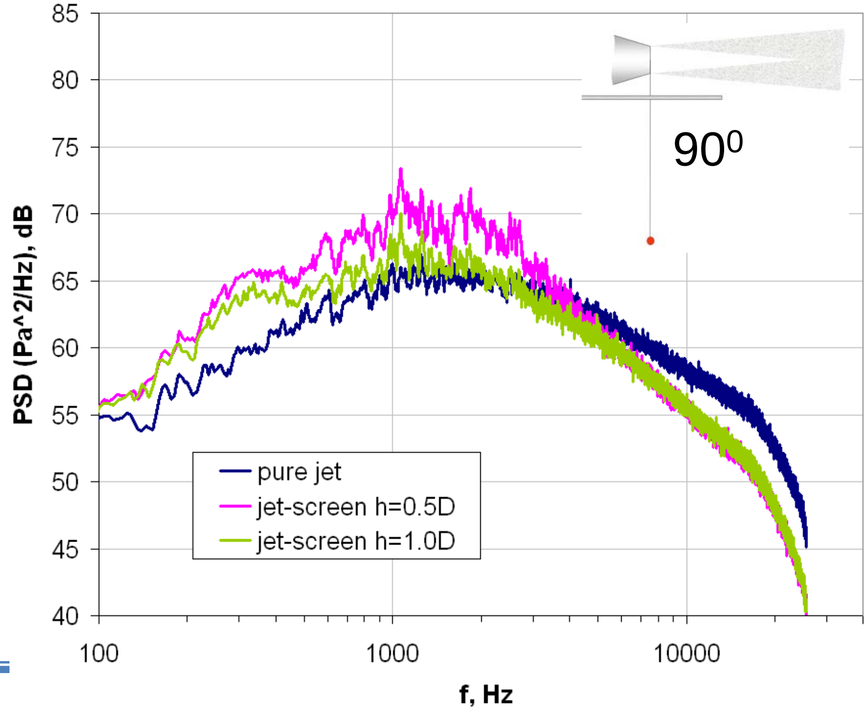
No co-flow, **Ps = 1.25,** mic position 90 degrees to rectangle nozzle

Shield Position Effect

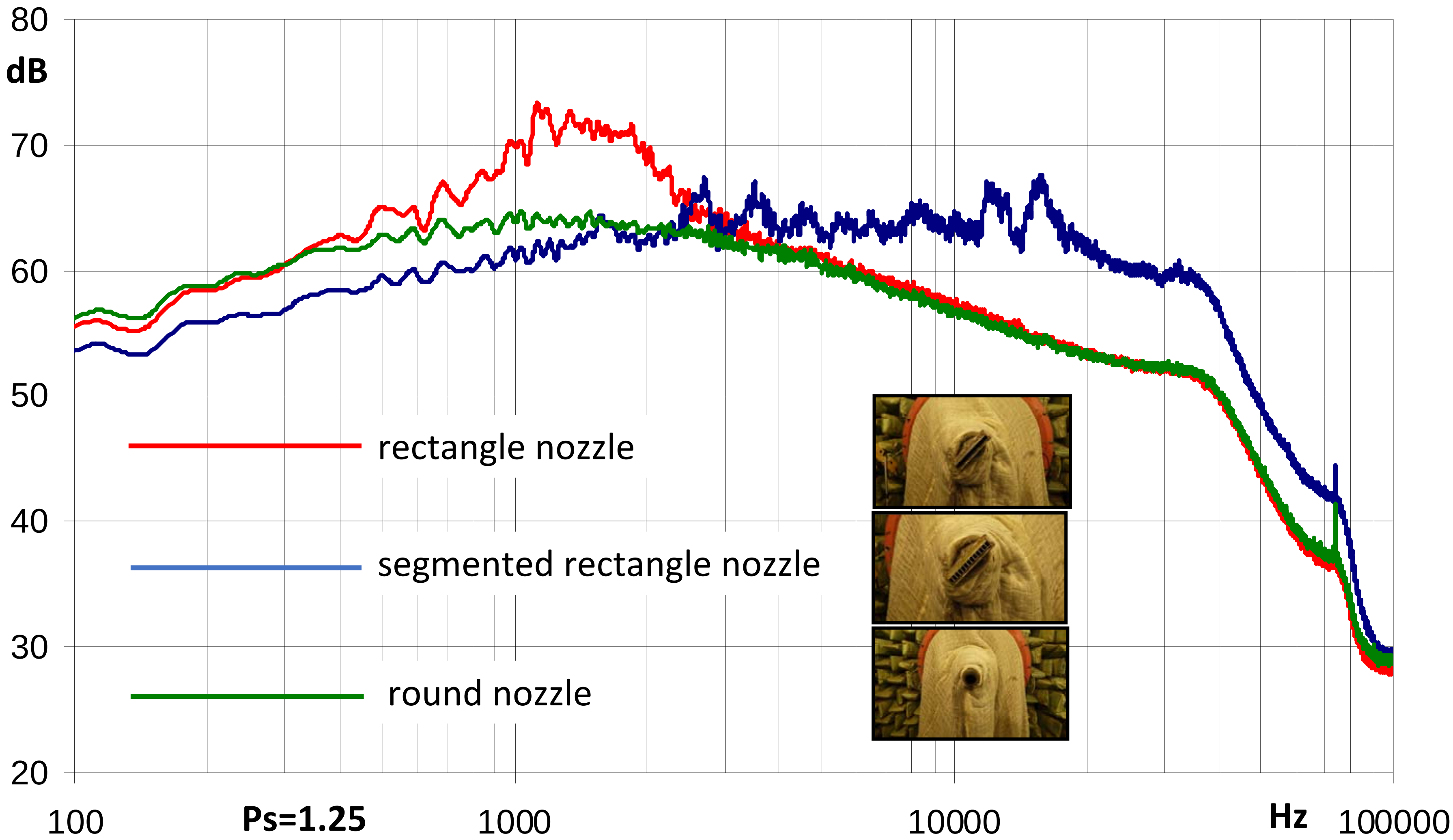




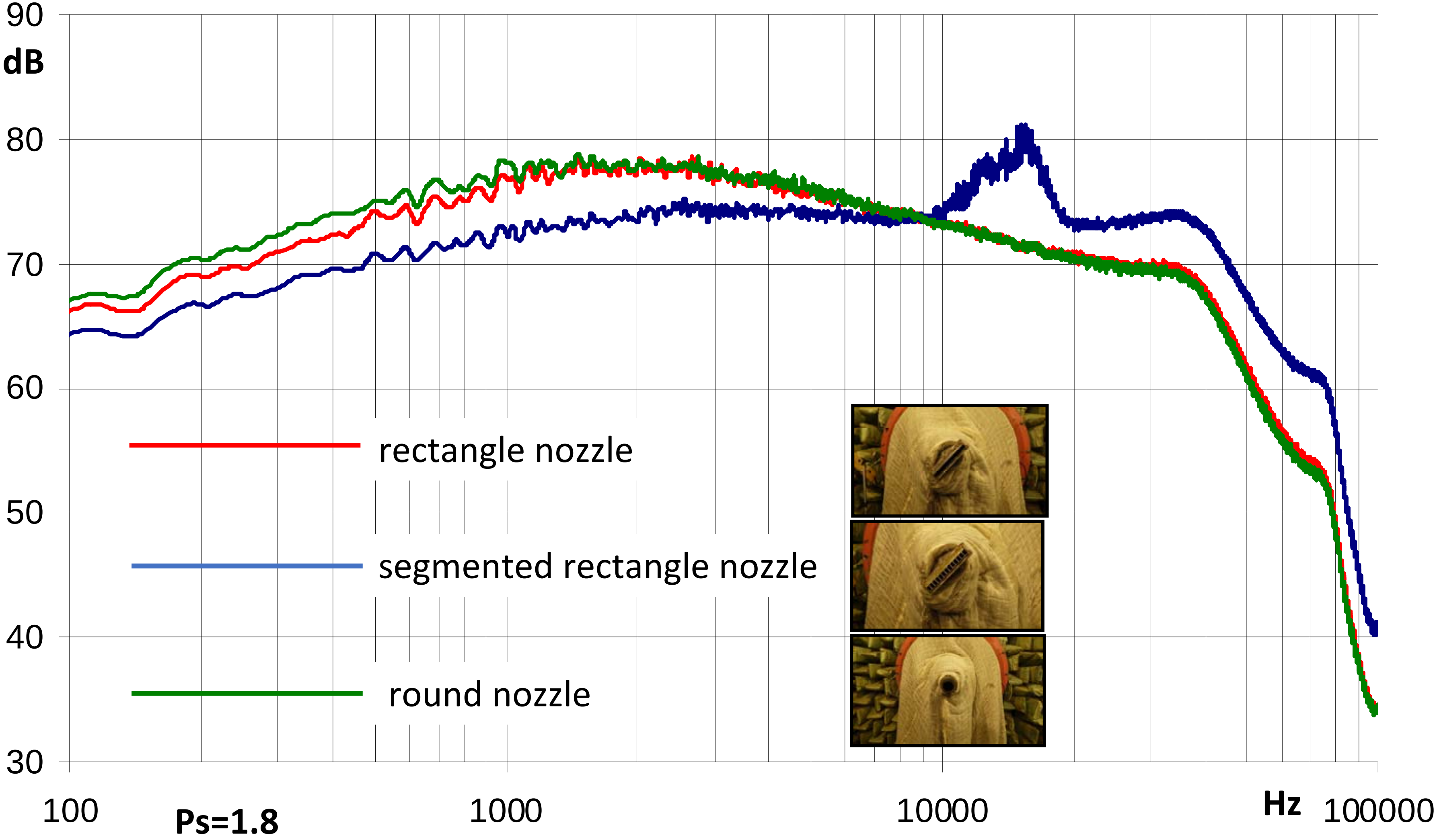




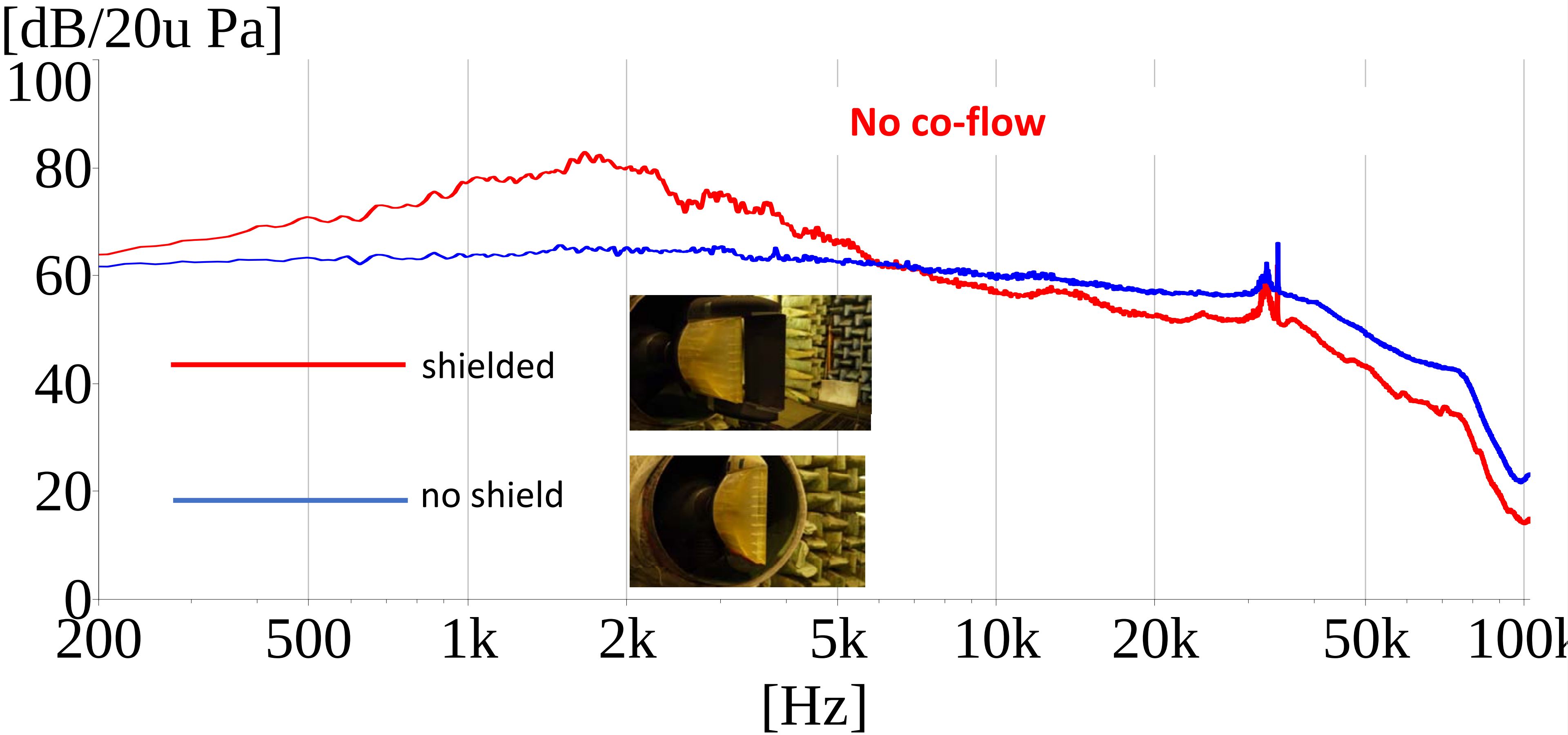
Segmented Nozzle Effect



Segmented Nozzle Effect

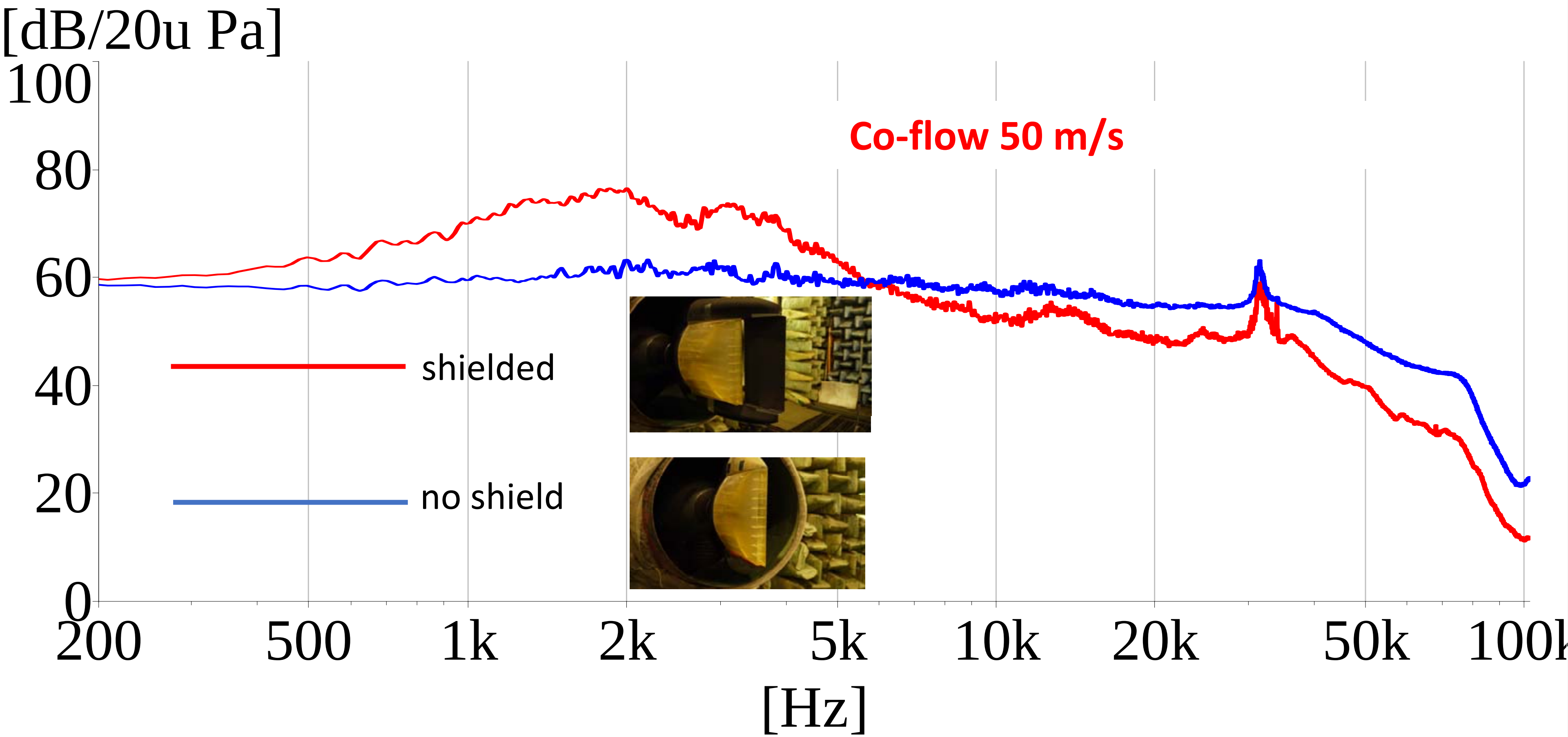


Co-flow Effect



Rectangle nozzle, Ps = 1.25, mic position 90 degrees

Co-flow Effect



Rectangle nozzle, Ps = 1.25, mic position 90 degrees

Input Parameters

- The multiparametric jet noise database was used for modeling the dominating source.
- The predictions for other components will require OEM's data input as well as corrections for subsonic aircraft adjusted standard source models, including airframe noise evaluators to account special airframe and wing geometry.
- Atmospheric absorption, ground reflection and lateral attenuation are included in modeling scheme.

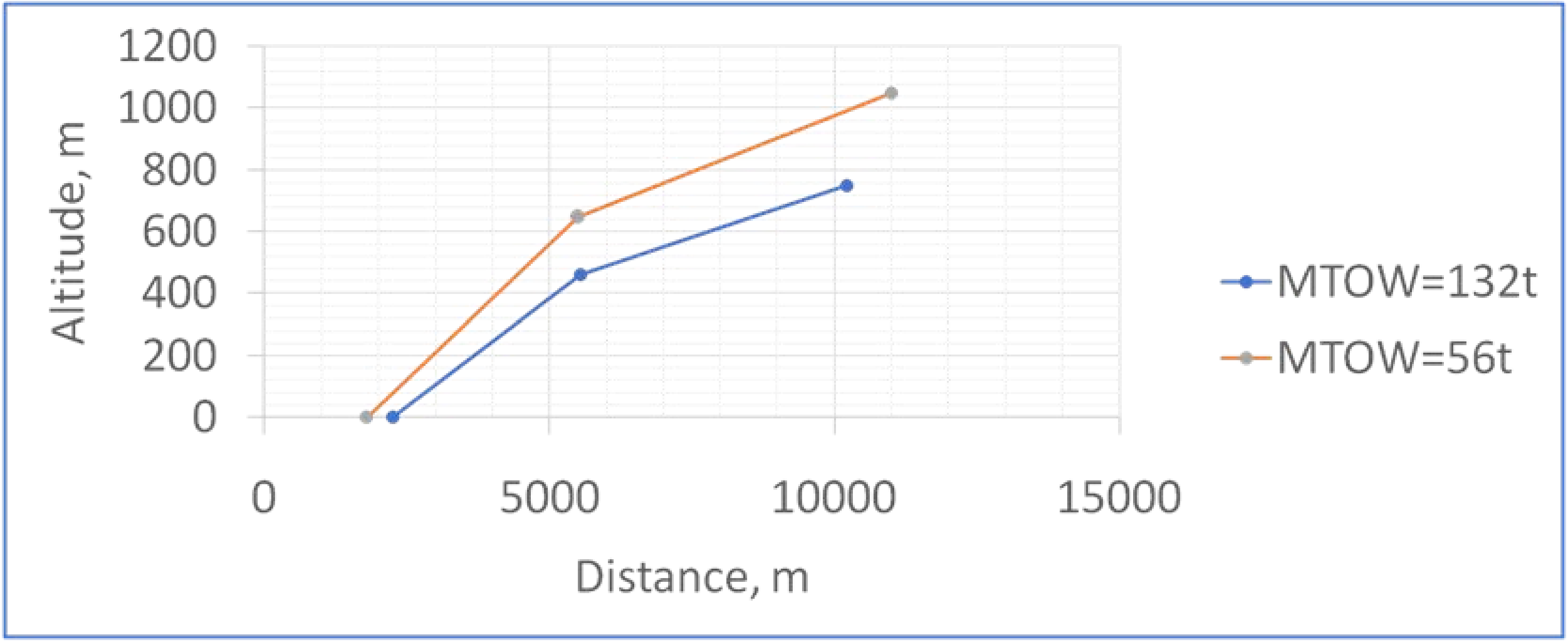
Jet Velocity Variation

- Four cases were considered (Baseline, Low-noise 1-3) with identical thrusts but different jet speeds.

Mode	Baseline	Low-noise 1	Low-noise 2	Low-noise 3
Take-off	395	395	375	360
Cutback	345	326	326	326
Approach	214	203	203	203

- It was assumed that retaining take-off thrust with decrease of jet speed has been performed by adjusting other jet parameters.

Departure Trajectory



Obtained Results

- A summary of the modeling results for the baseline and jet speed variations is shown in the Tables 1 and 2:
  - Table 1. SST#1 (MTOW=132 000 kg) results

Point	Chapter 3	Baseline	Low-noise 1	Low-noise 2	Low-noise 3
Lateral	98.9	94.0	94.0	91.8	90.6
Flyover	99.8	89.0	86.7	86.7	86.7
Approach	102.5	3 EPNLdB margin estimate based on NoiseDB data analysis			
Total Chapter 14 margin		1.7	4.1	6.2	7.4

Mode	Baseline	Low-noise 1	Low-noise 2	Low-noise 3
Take-off	395	395	375	360
Cutback	345	326	326	326
Approach	214	203	203	203

Obtained Results

- A summary of the modeling results for the baseline and jet speed variations is shown in the Tables 1 and 2:
  - Table 2. SST#2(MTOW=56 000 kg) results

Point	Chapter 3	Baseline	Low-noise 1	Low-noise 2	Low-noise 3
Lateral	95.7	90.7	90.7	88.7	87.1
Flyover	89.9	83.8	81.5	81.4	81.3
Approach	99.6	5 EPNLdB margin estimate based on NoiseDB data analysis			
Total Chapter 14 margin		-1.0	1.4	3.5	5.2

Mode	Baseline	Low-noise 1	Low-noise 2	Low-noise 3
Take-off	395	395	375	360
Cutback	345	326	326	326
Approach	214	203	203	203

Conclusion

- The standard takeoff procedure for concept SST was assessed.
- The considered jet speeds ~380m/s that correspond to contemporary considered SST engines allow meeting Chapter 14 for the most cases.
- For the engine with such parameters the investigation of noise suppression technologies for fan (forward and aft), combustor etc. are of significant importance.
- Further and more sophisticated analysis is crucial for understanding the feasibility of Chapter 14 for supersonic airplanes. Future work should embrace various SST concepts utilizing new noise reduction technologies.
- The compliance could require alternative takeoff procedures (e.g. programmed thrust lapse rate, etc.). Potentially, in order to ensure compliance with Chapter 14, the changes may also be applied to standard certification approach procedure.