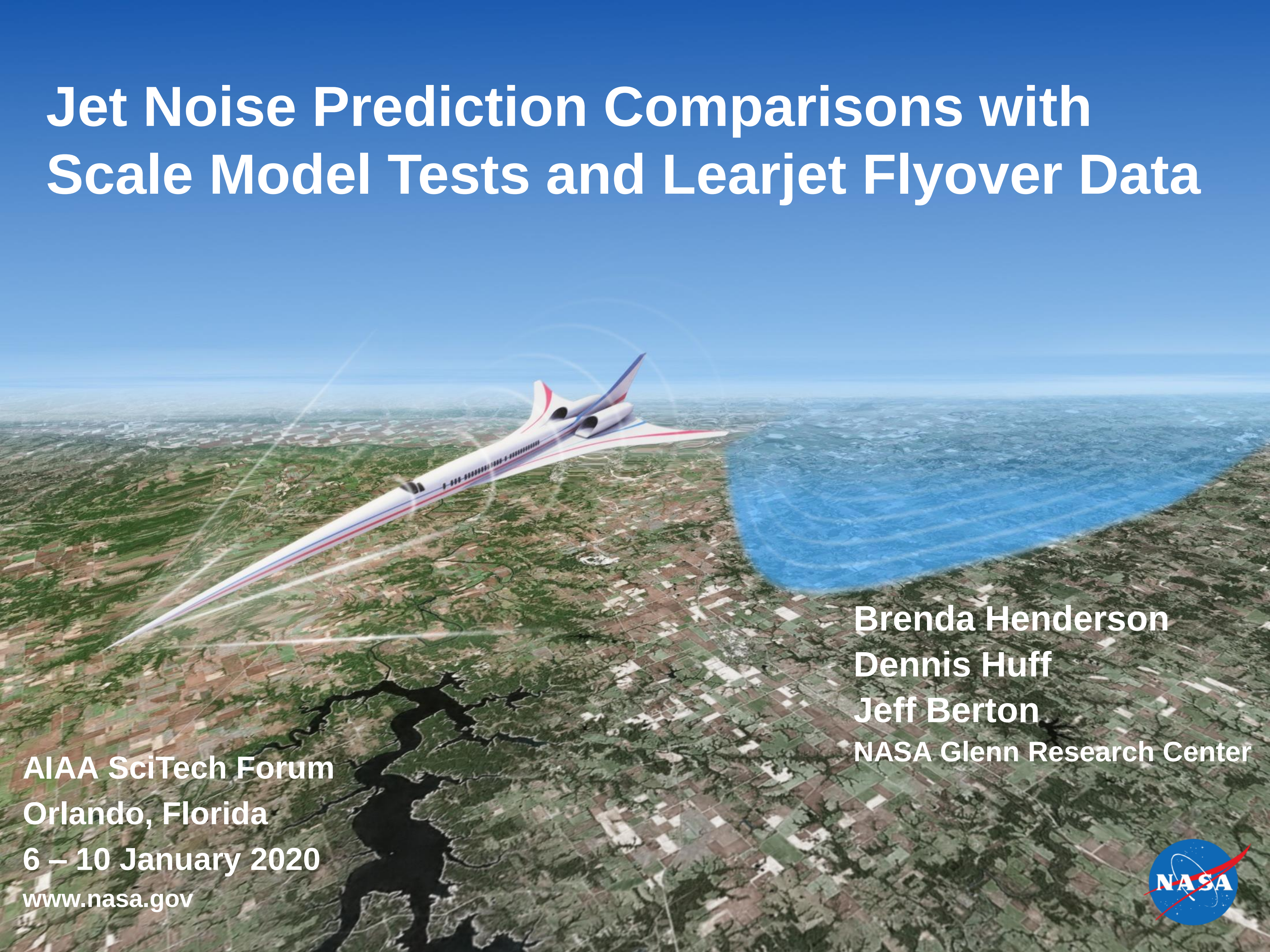
Jet Noise Prediction Comparisons with Scale Model Tests and Learjet Flyover Data



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Motivation for Study

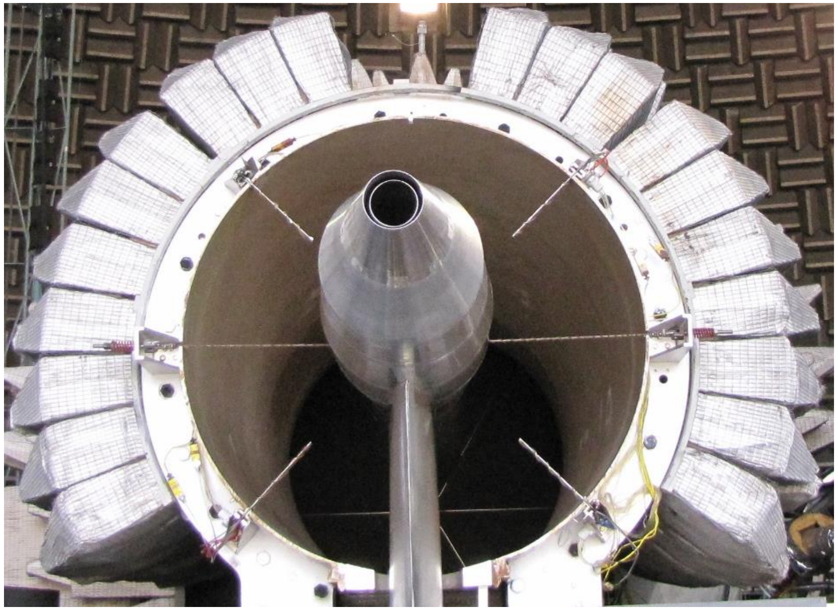
- Renewed interest in commercial supersonic flight
- Near-term entry into service aircraft
  - Business type jet
  - 2 – 3 engines
  - Fully mixed exhausts
  - Jet noise dominant at takeoff
- NASA systems studies supporting ICAO Working Group1/LTO subgroup
- Need to quantify our ability to predict absolute jet-noise levels
- Results of this study assist with error bars placed on our ICAO system results
- Comparisons are made between prediction models in ANOPP, scale-model data, and flight data

Comparisons

- Interest is in EPNL but spectra contributing to EPNL are also compared
- Three different datasets explored
  - Flight test data
    - Did not use a noise certification flight procedure
    - Intent is to determine general jet-noise prediction capability
  - Spectra obtained from jet-noise models within NASA's ANOPP
    - Stone 1 (1980)
    - Stone 2 (2009)
    - SAE 876
    - Modified SAE 876
  - Scale model data acquired in NASA Glenn's AAPL
- Angles between 70° and 150° can be used to compute EPNL that is within 0.5 EPNdB of that computed from all microphones

Flight and Scale-Model Tests

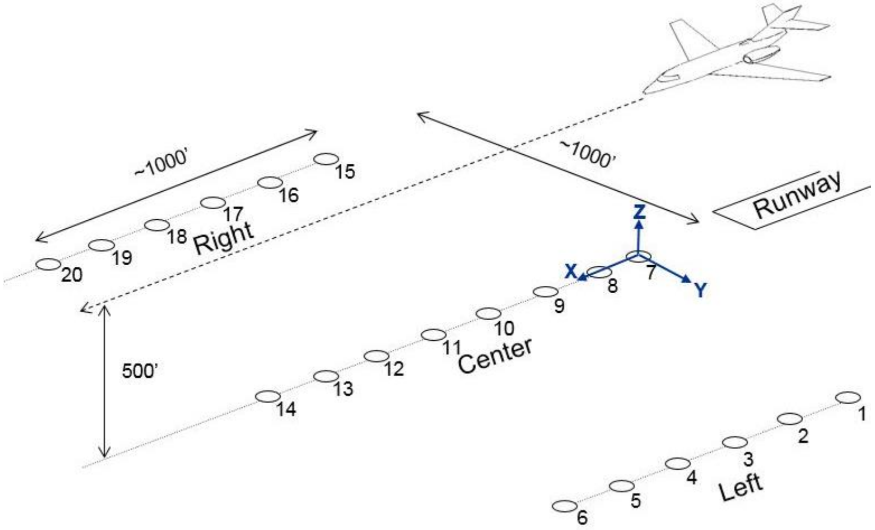
- Learjet 25 flight test conducted in 2001
  - Believed to be jet-noise dominated
  - Exhaust conditions for lower power settings of interest for supersonic business jet



- Scale model tests conducted in 2018 in NASA Glenn’s AAPL facility

Flight Tests

- Used a Learjet 25 with a CJ610 engine
  - CJ610 is a variant of the J85
  - EGT read from cockpit gauge during pretest conducted in Ohio but not during flight test
  - EPR recorded during flight test
- Performed with a constant 500 ft flyover
- Right engine at idle
- Conducted at Estrella Sailport (Phoenix)
- Measurements made with three linear arrays
  - Left - 6 microphones
  - Center (under flight path) - 8 microphones
  - Right – 6 microphones

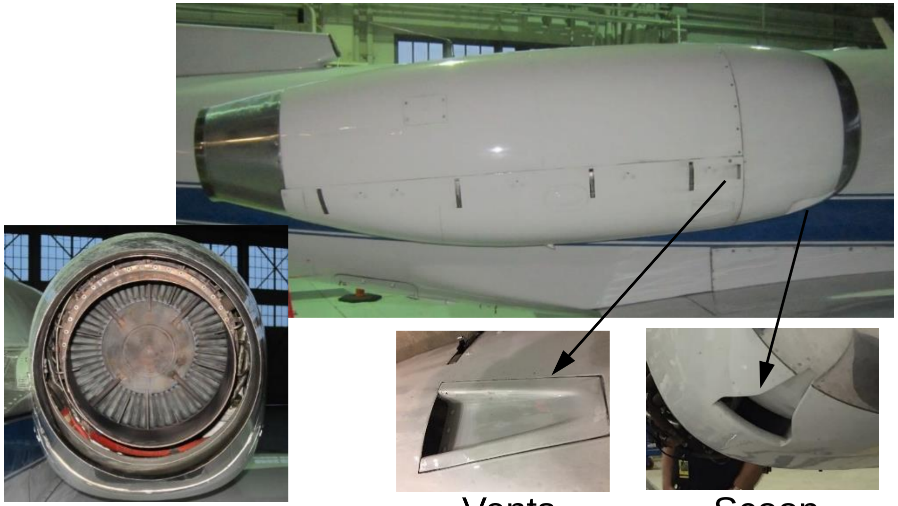


EPR	Approximate Jet Temperature °R	J85 Temperature Engine Stand °R	J85 Temperature Flight Test (M~0.38) °R	Landing Gear	Mach #
1.6	1180	1306*	1194*	Up	~0.30
1.8	1257	1402*	1288*	Down	~0.23
2.0	1374	1505*	1388*	Down	~0.26

*Brausch, J. F., "Flight Velocity Influence on Jet Noise of Conical Ejector, Annular Plug and Segmented Suppressor Nozzles," NASA CR-120961, 1972.

Scale-Model Tests

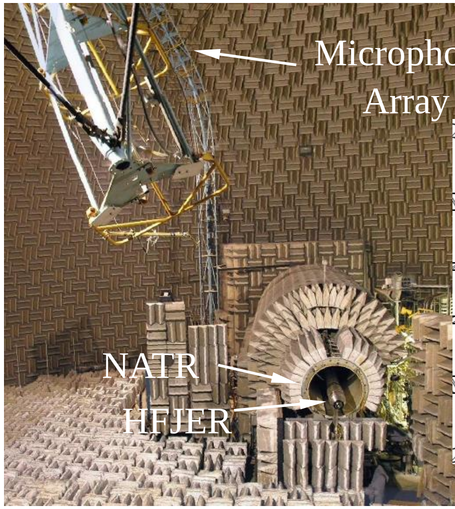
- Conducted in the Aero-Acoustic Propulsion Laboratory
- Used 0.31 scale model of Learjet nozzle system
- Secondary stream was used to mimic secondary flow through NACA scoop and vents
- Slight offset in nozzle was replicated
- Measurements made at two azimuthal angles
  - For centerline flyover array
  - For sideline flyover array
- NPR was matched to flyover EPR
- NTR was matched to temperature ratio in flyover tests
- Secondary stream NTR = 1.25
- Secondary stream set to low NPR_s



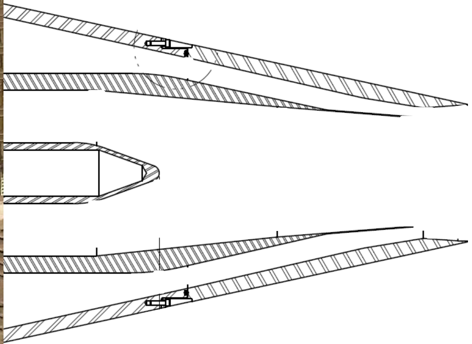
Vents

Scoop

Learjet 25 Nozzle



AAPL Facility

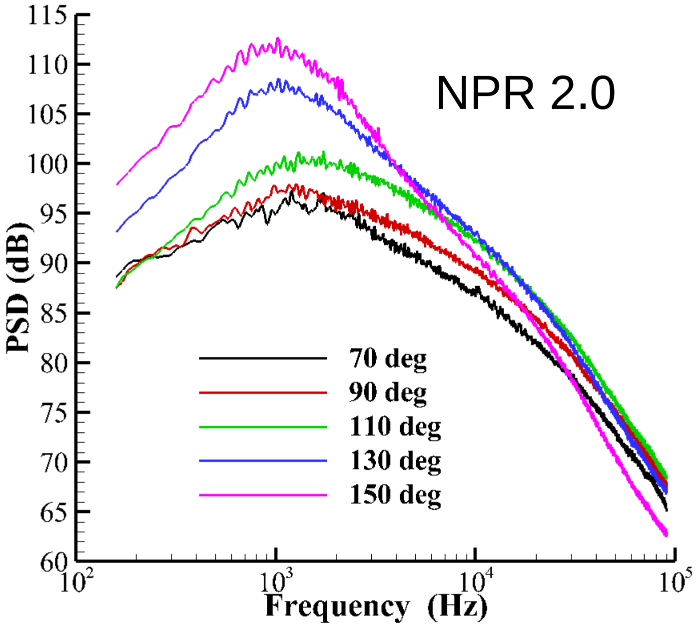


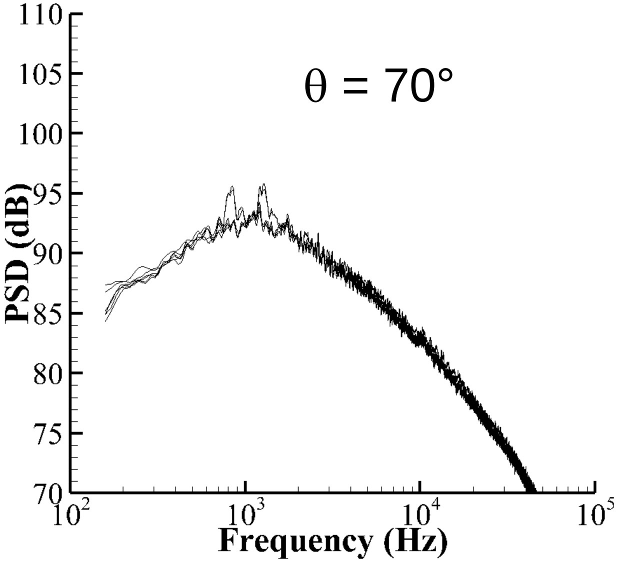
Scale-Model Nozzle System

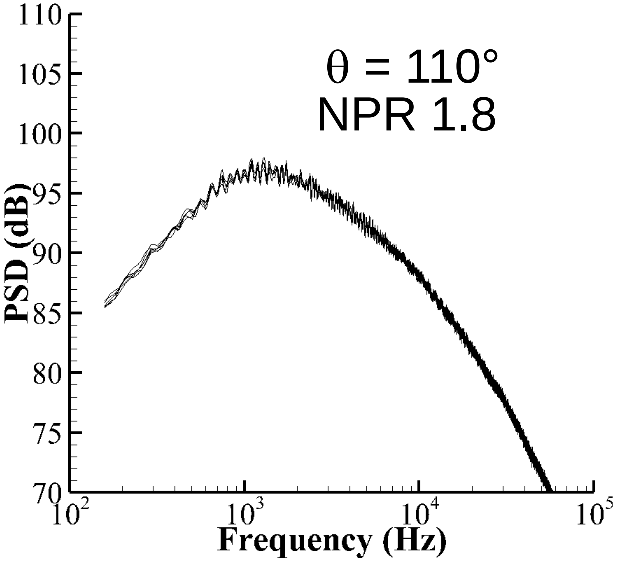
Scale-Model Data

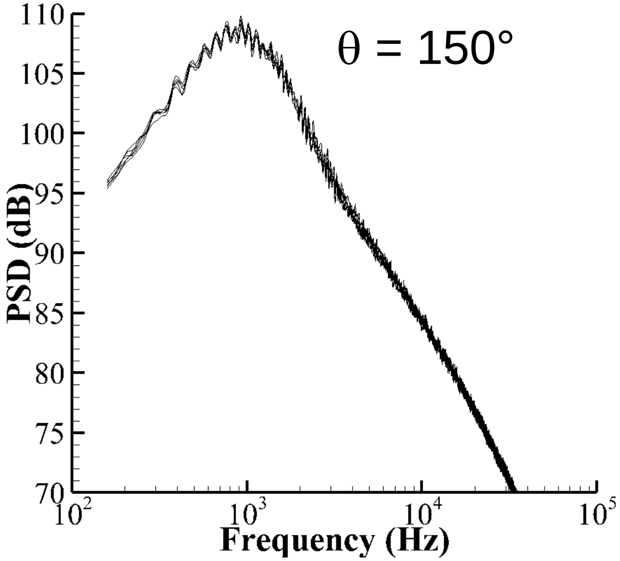
Repeatability and Mixing Noise

- No shock associated noise – study only focused on mixing noise
- Data repeatability good
- Small tones in one installation did not impact EPNLs
- No azimuthal dependency – data from multiple runs and two clocking angles averaged





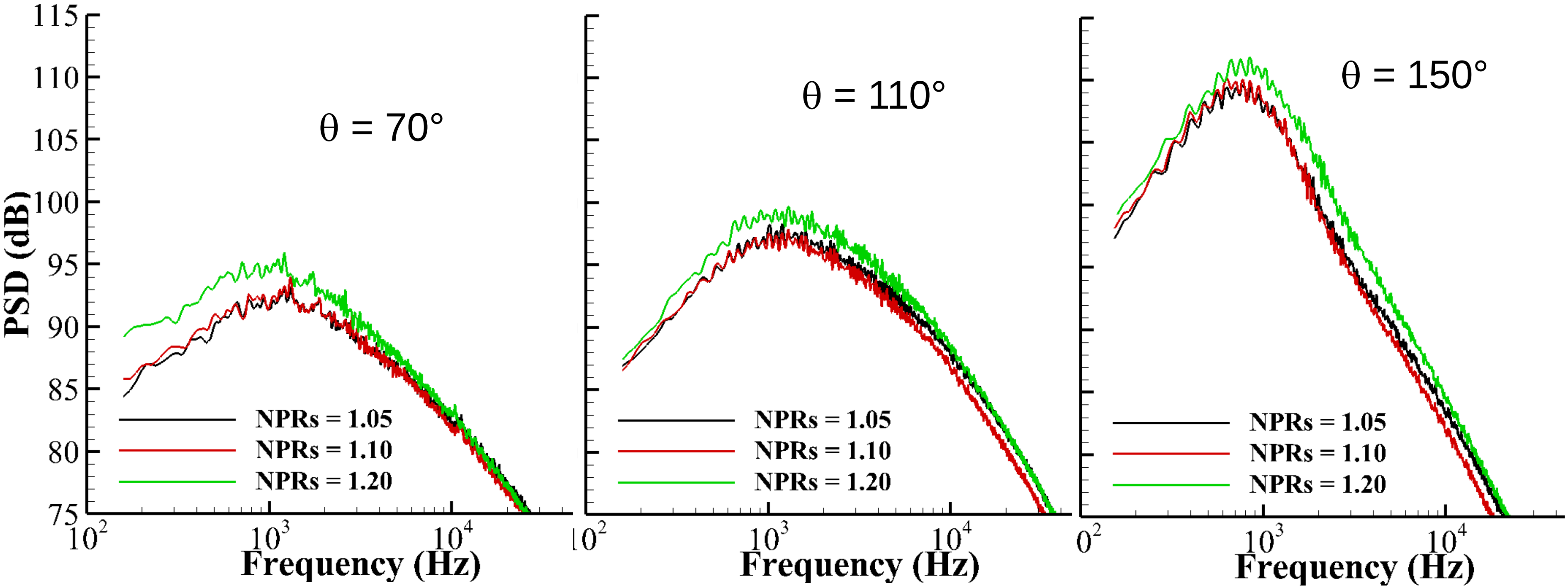




Impact of Secondary Stream

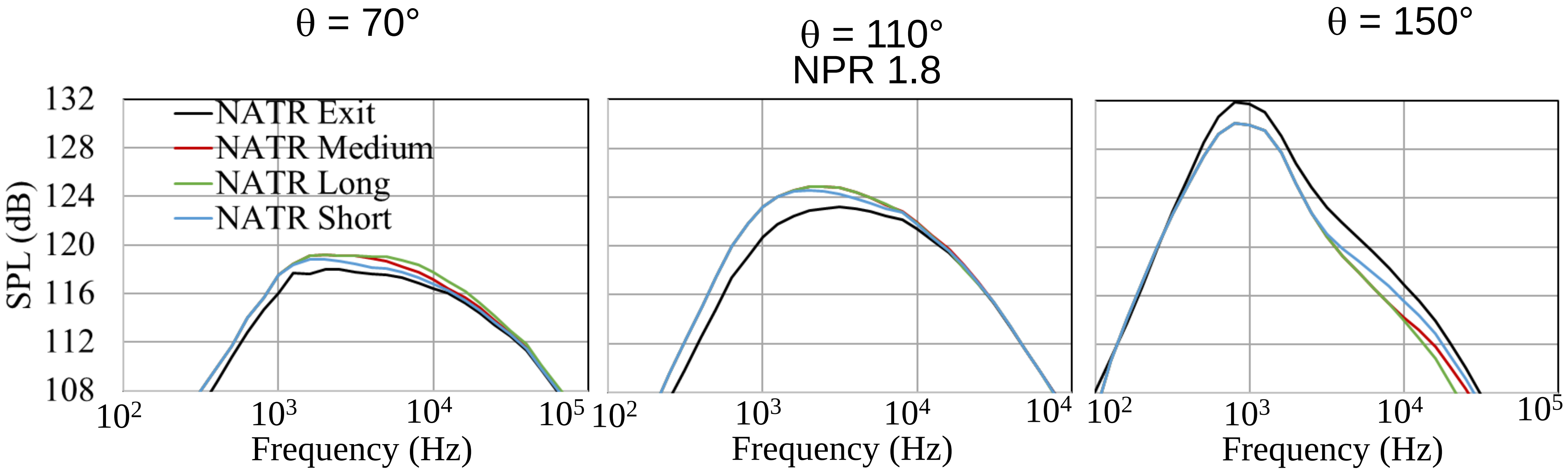
- Spectra for NPRs = 1.05 and 1.10 are similar
- Slight increased levels for NPR = 1.20

NPR 1.8

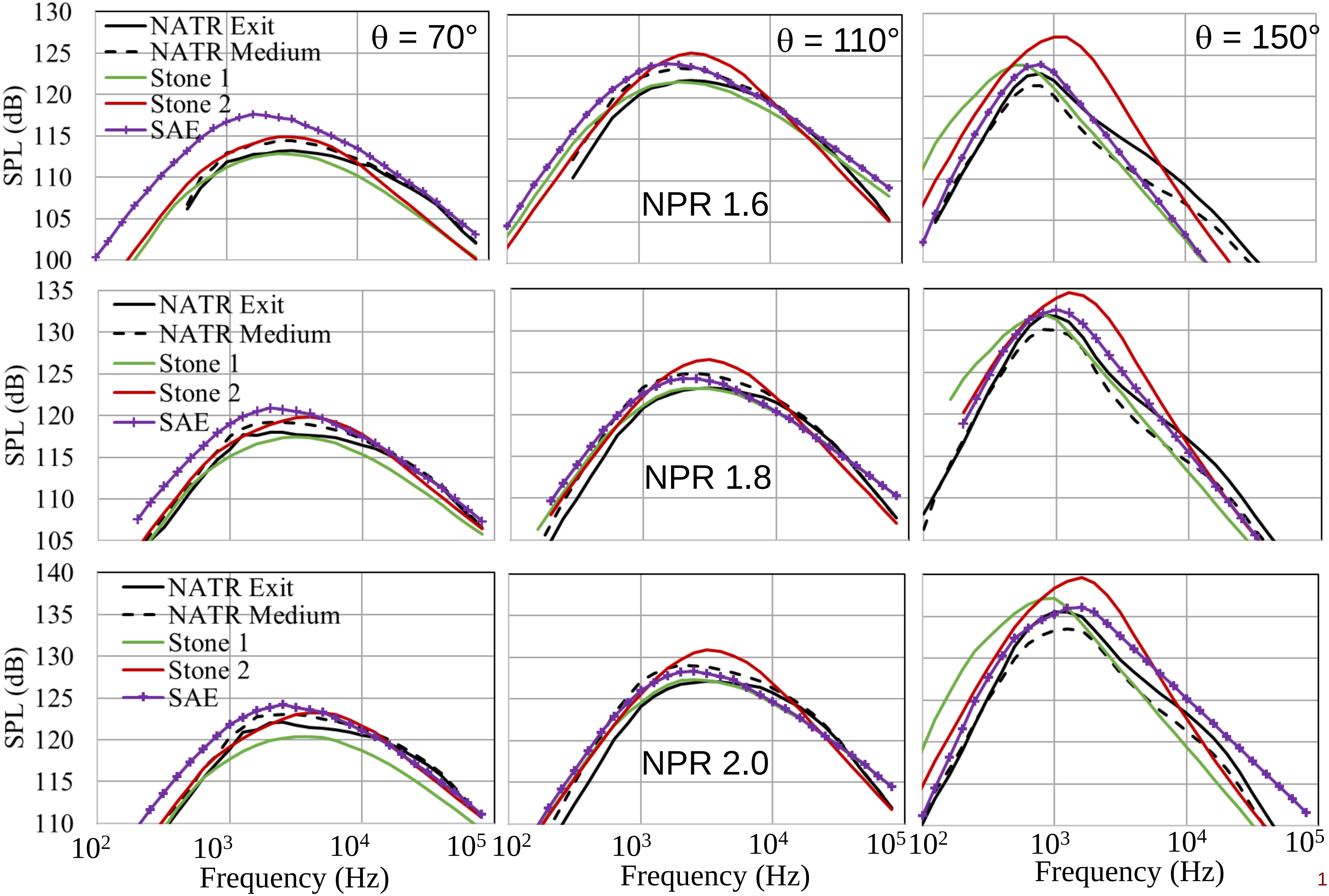


Impact of Shear Layer Correction

- Investigated impact of source distribution assumption in shear layer correction
- Source at exit peak at ~150˚
- Distributed source peaks at ~140˚
- Peak jet-noise level is roughly the same for all source distributions
- Source distribution assumption was found to have little impact on EPNL



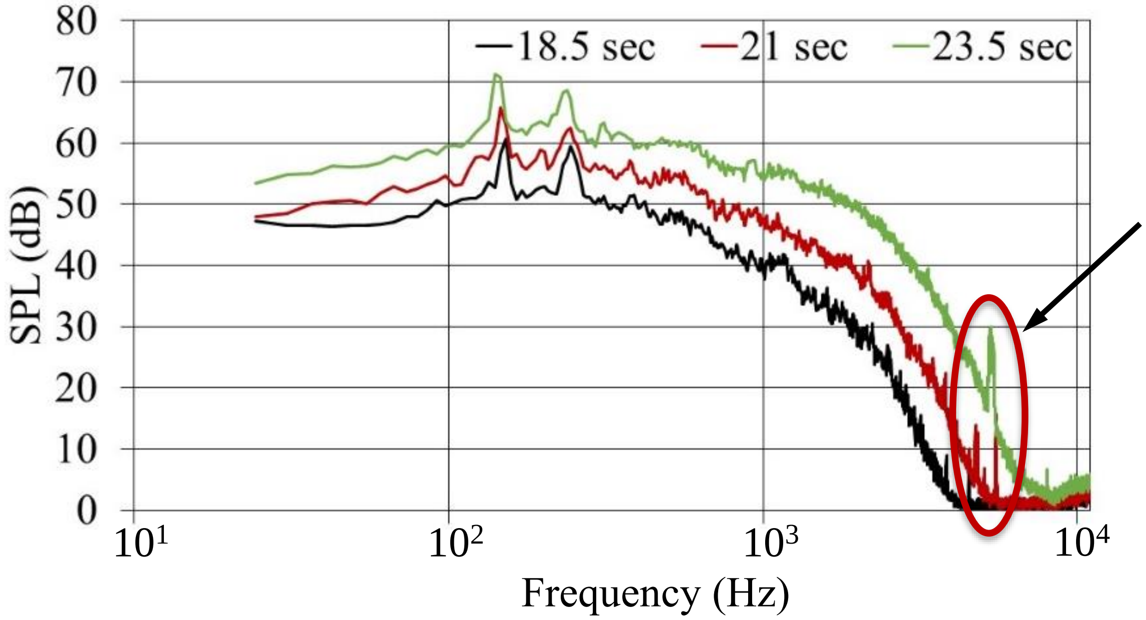
Predictions and Scale Model



Flight Data

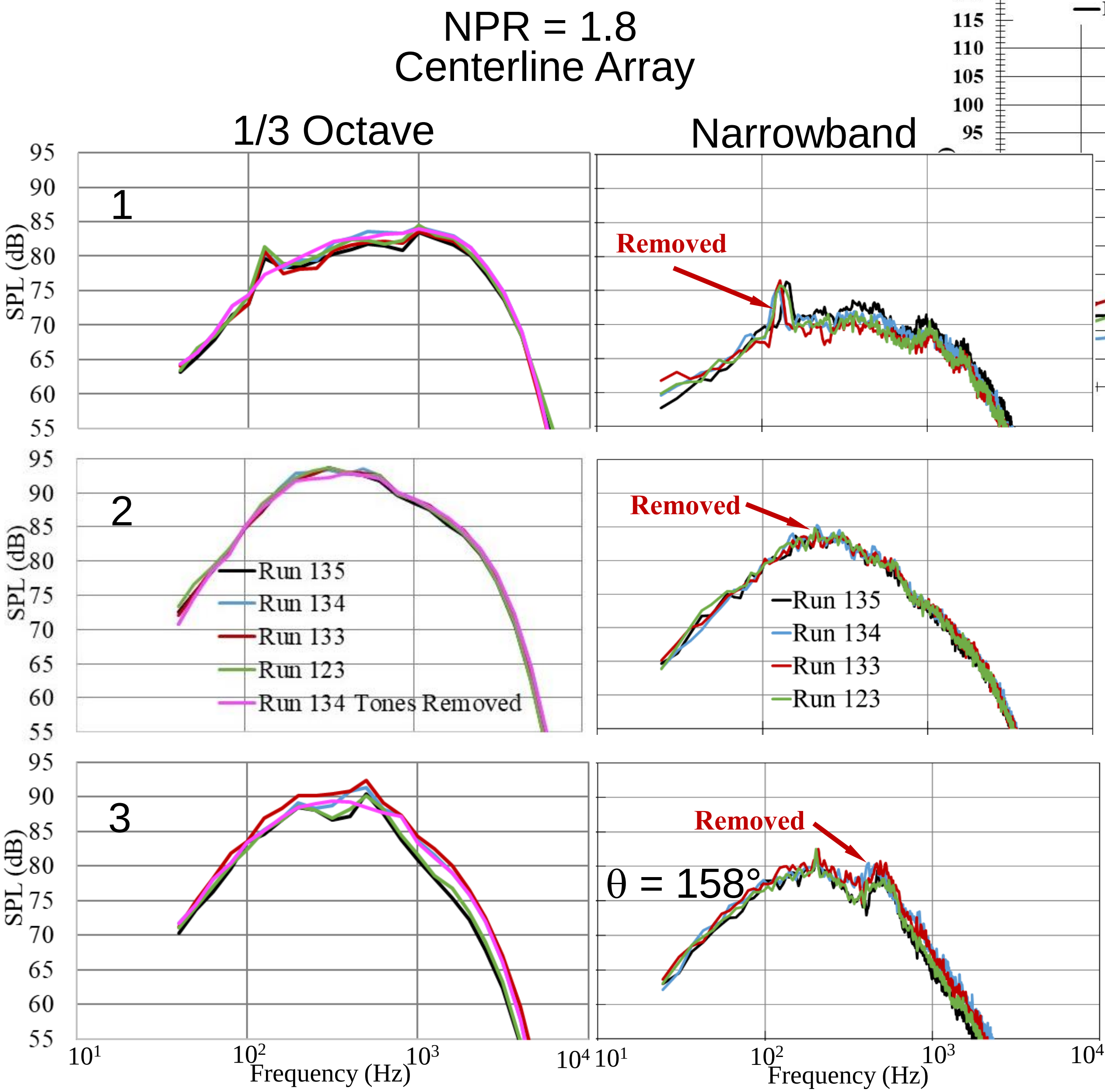
Spectral Comparisons

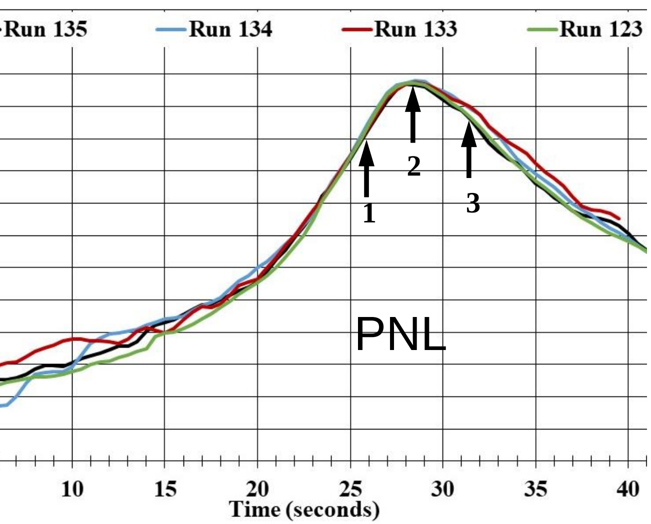
- No aircraft GPS information from flight test
- Needed aircraft position information to compare flight data to scale-model data and predictions
- Aircraft position determined from tones assuming changes in frequency only associated with Doppler shift
- Spectra obtained from data at different microphones were averaged with time shift accounting for aircraft flight



Tones used for Doppler shift calculation

Data Repeatability

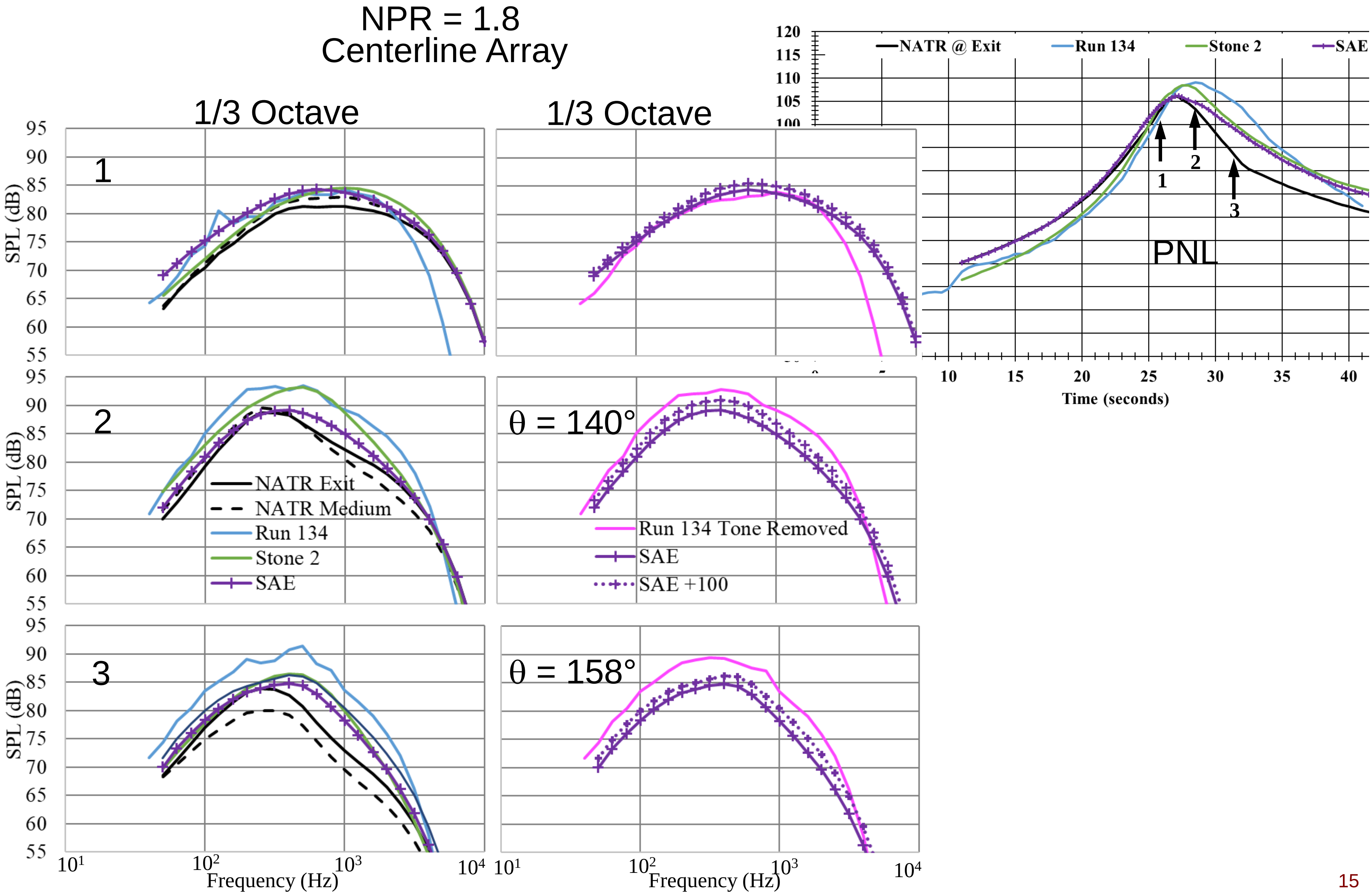




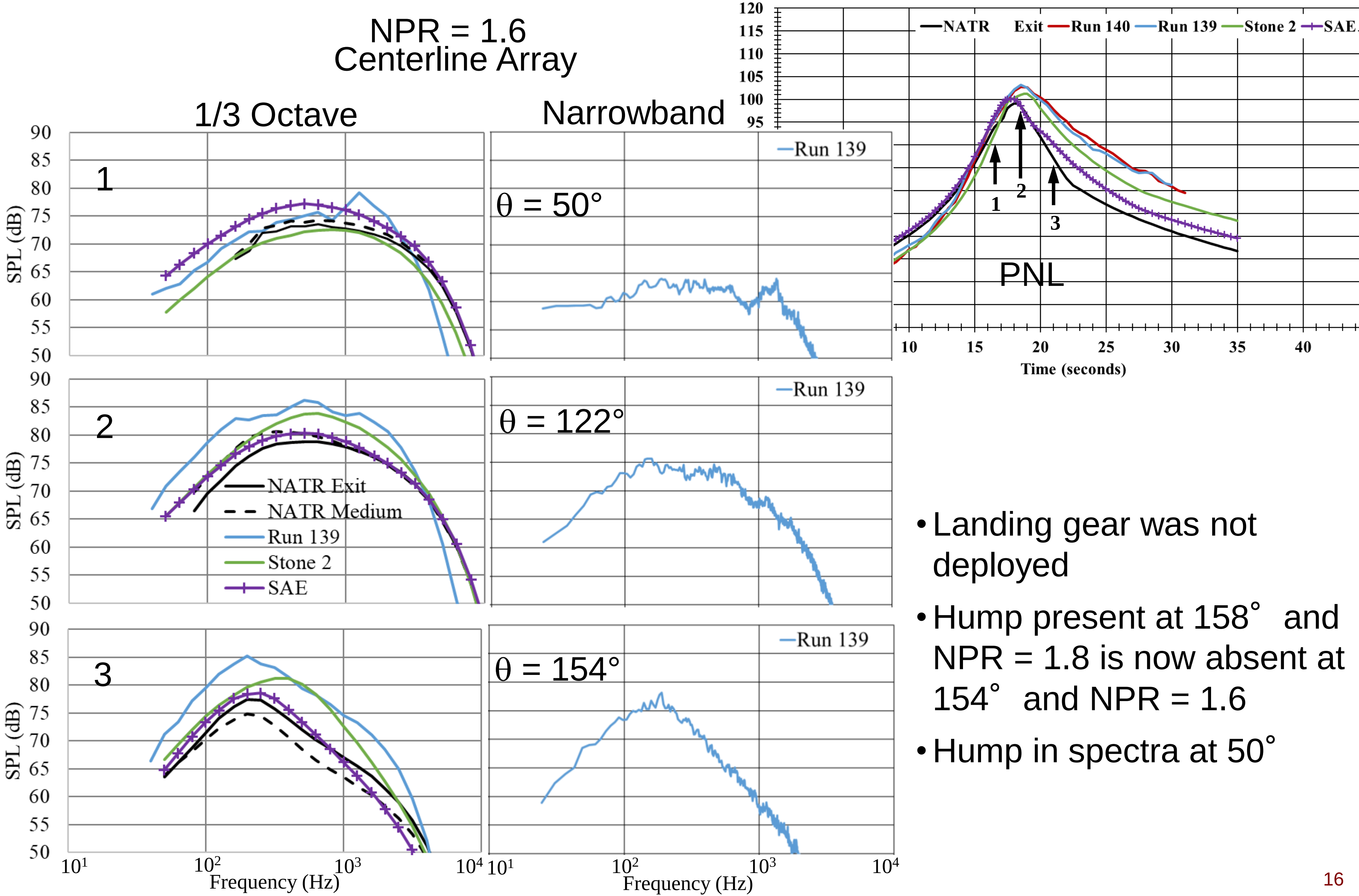
- Hump at ~500 Hz matches predicted frequency for tire noise from Fink
- Tones around 200 Hz are likely cavity tones
- Flight Mach number range 0.231 – 0.252
- Differences between runs likely associated with throttle setting
- Tone removal did not eliminate impact of tones

Predictions and Flight Data Comparisons

NPR = 1.8
Centerline Array

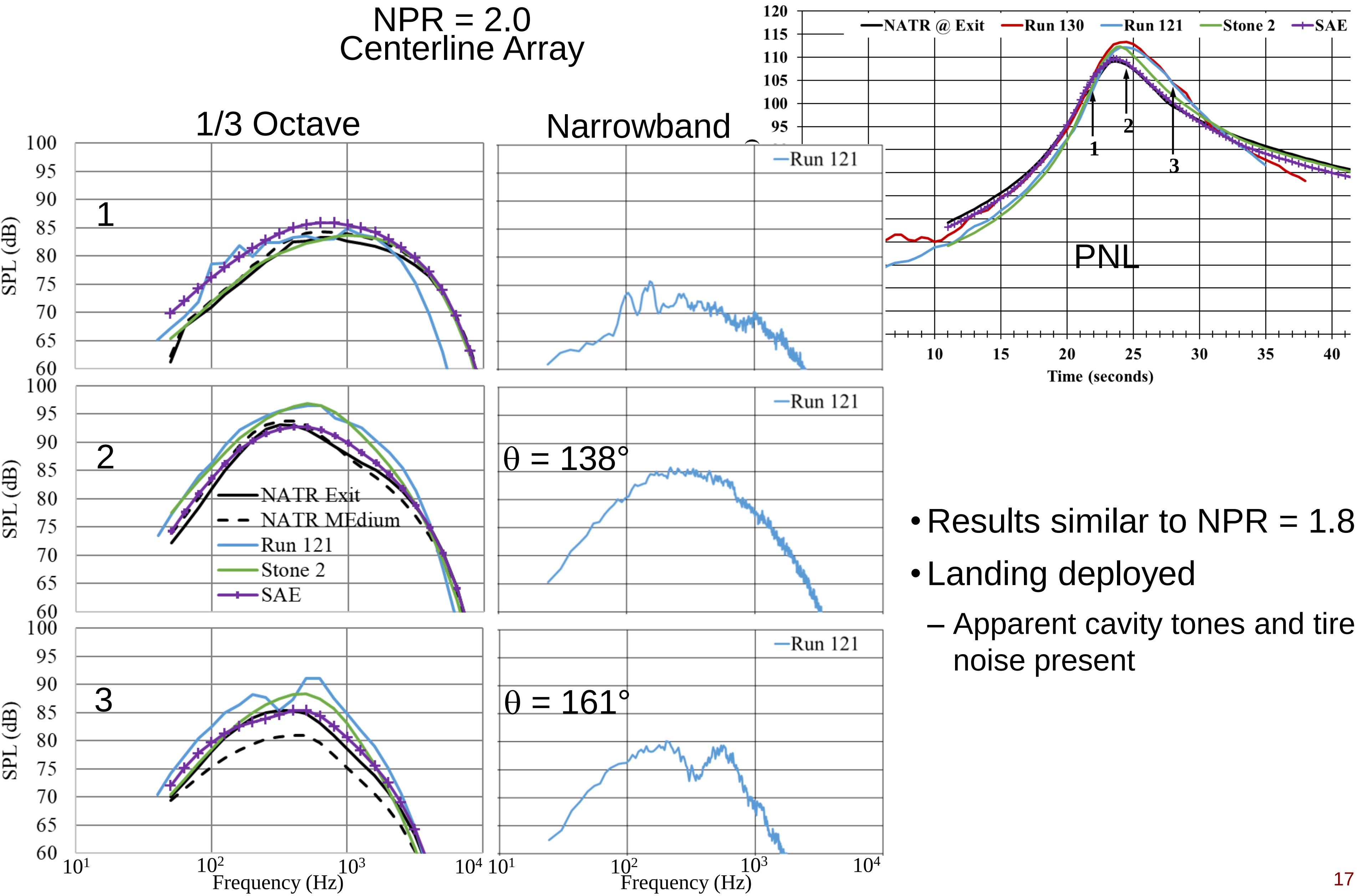


Predictions and Flight Data Comparisons



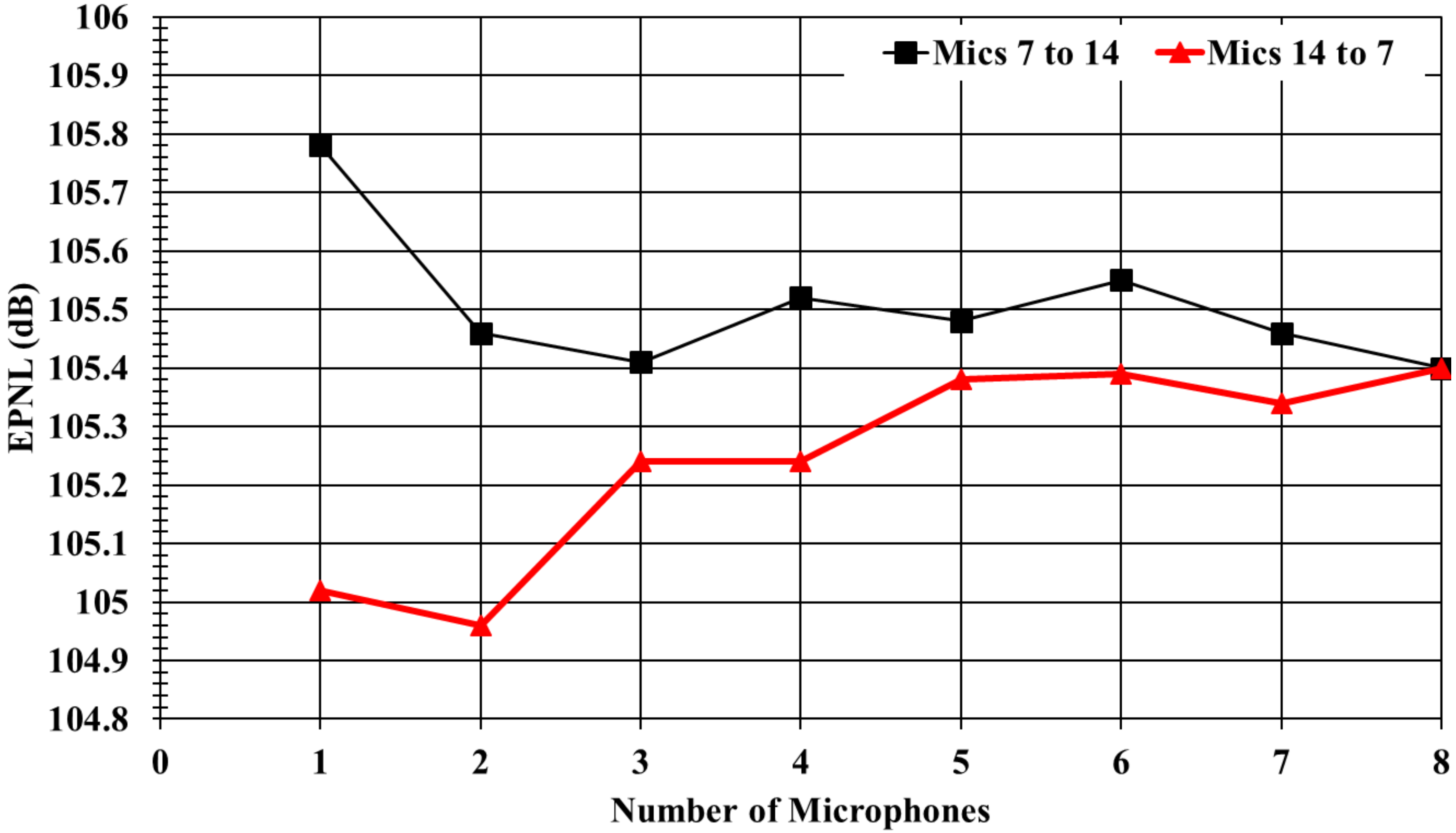
- Landing gear was not deployed
- Hump present at 158° and NPR = 1.8 is now absent at 154° and NPR = 1.6
- Hump in spectra at 50°

Predictions and Flight Data Comparisons

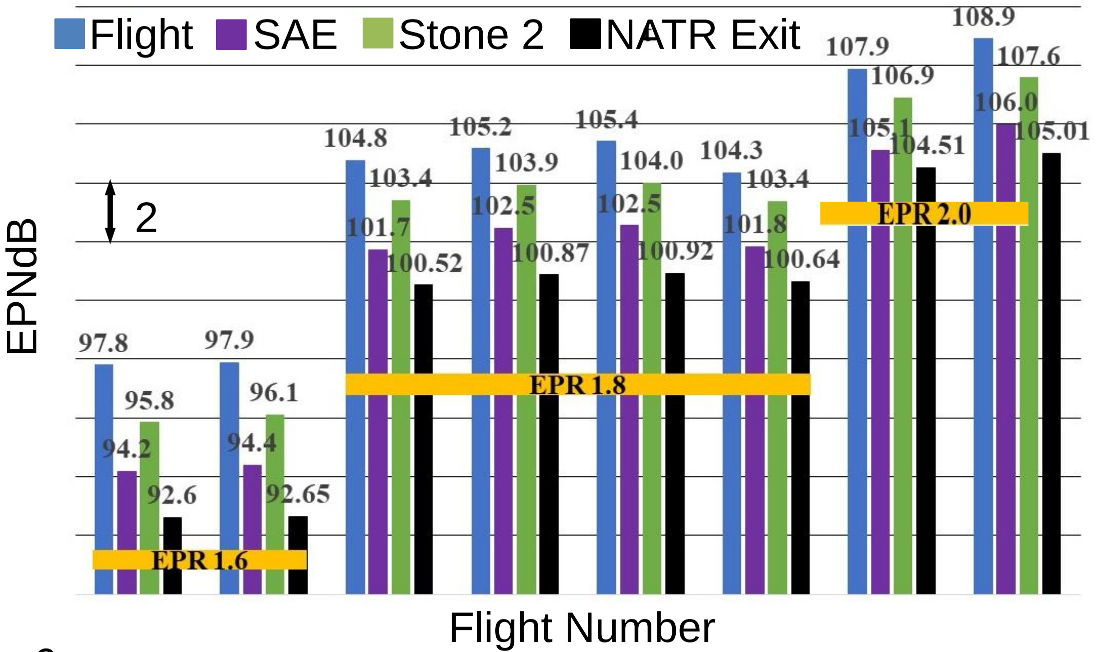


- Results similar to NPR = 1.8
- Landing deployed
  - – Apparent cavity tones and tire noise present

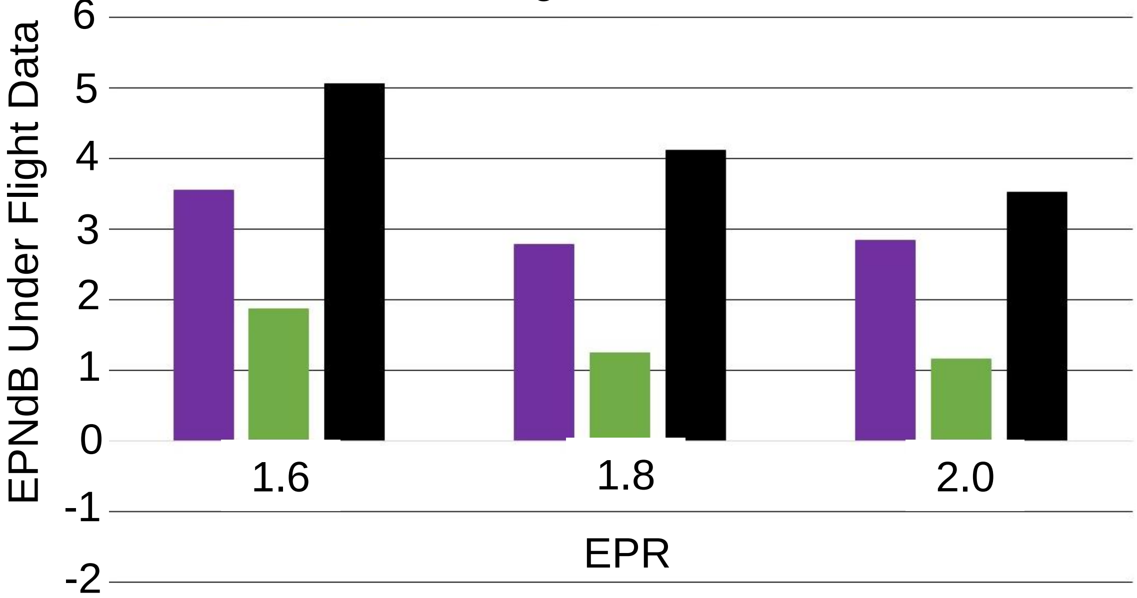
Impact of Number of Array Elements



Effective Perceived Noise Levels
Centerline Array

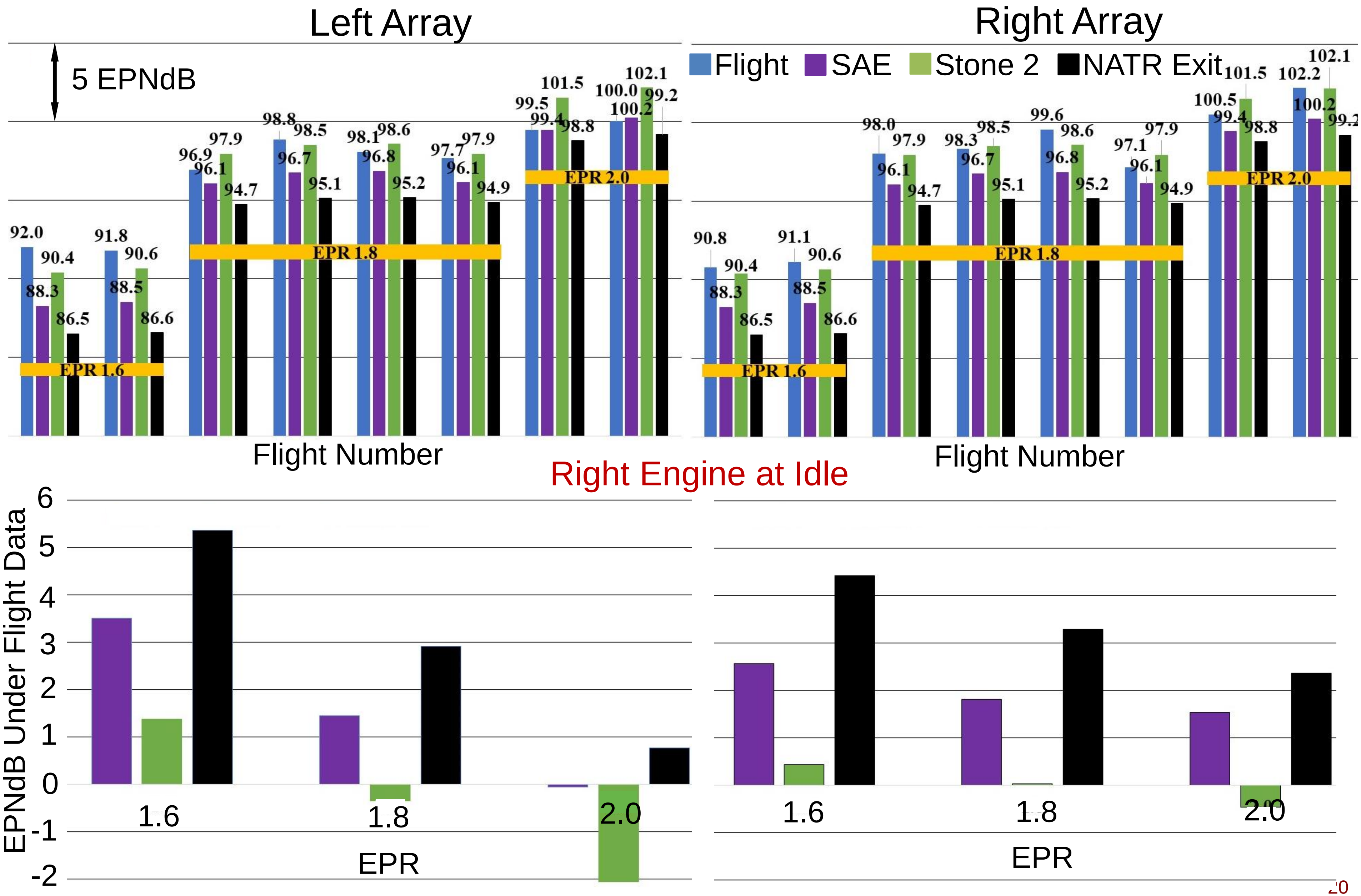


Tones not removed in flight data computation



- NATR ΔEPNdB decreases with increasing EPR
- Flight EPNdB decreases by ~0.5 EPNdB with tones removed
- Increasing temperature in SAE model increases EPNdB by 1.5 dB for each 100 °F

Effective Perceived Noise Levels



Right Engine at Idle

Conclusions

- EPNL from predictions and scale-model data were ***below*** that for the flight data for all engine EPRs
    - SAE model: 2.5 – 3.5 EPNdB
    - Stone 2 model: 1 – 2 EPNdB
    - Scale-model data: 3 – 5 EPNdB
- Differences between EPNL computed for flight and scale-model or ANOPP models are likely due to uncertainty in engine conditions
    - An increase in engine temperature of 100° F results in 1 – 2 EPNdB increase
- Source distribution assumptions in the shear layer corrections for scale-model data had slight impact on spectra but not on EPNL
- Flights tests should include multiple microphones for averaging spectra to reduce uncertainty