Fan Noise for a Concept Commercial Supersonic Transport

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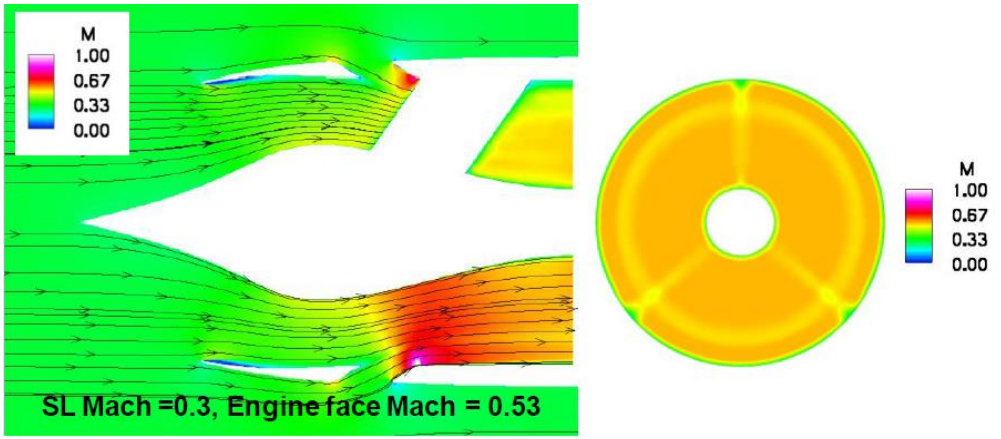
Background

- A 2015 study by Lockheed Martin, GE and Stanford described the LM 1044 vehicle
- 80 passenger, Mach 1.7 tri-jet, shaped boom
- Community noise: Jet noise and fan noise

Engine Inlet Aux Doors and Struts

- Additional inlet mass flow needed at low speeds
  - Used during all noise certification points
- Aux doors and struts introduce distortion
- Aux doors become a noise transmission path



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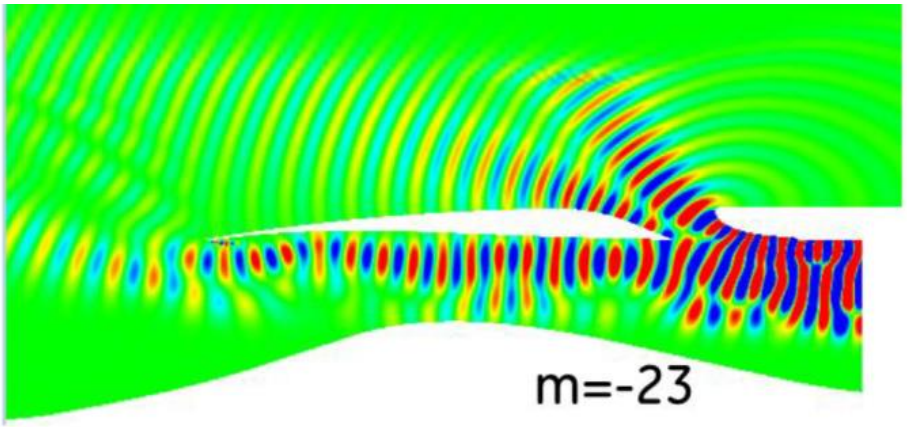
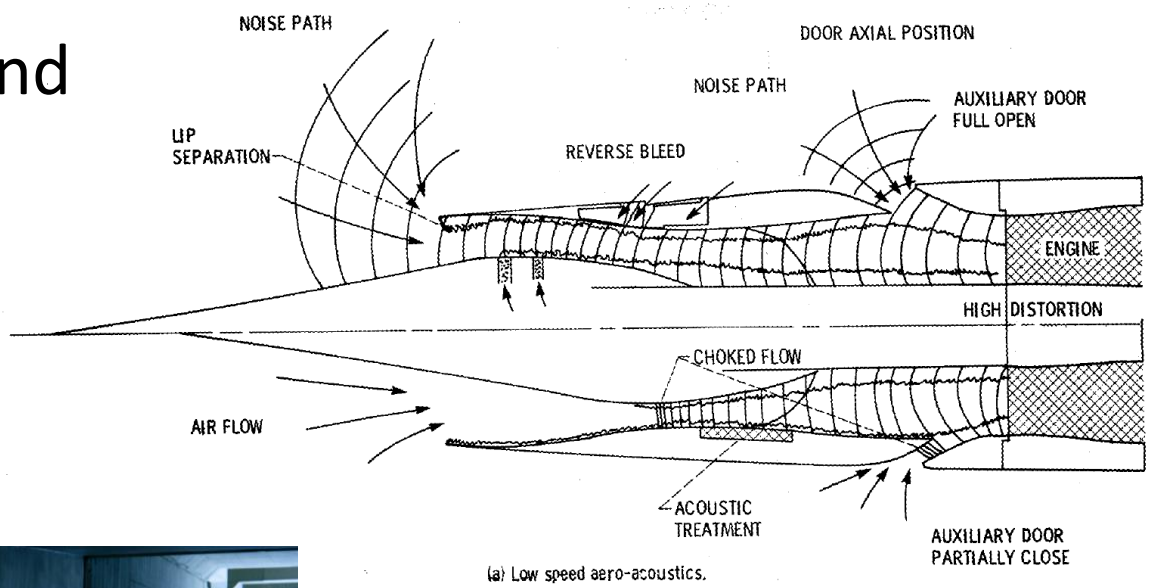


NASA P-Inlet Test (1980's)

- Inlet performance and recovery
- Fan noise and noise propagation

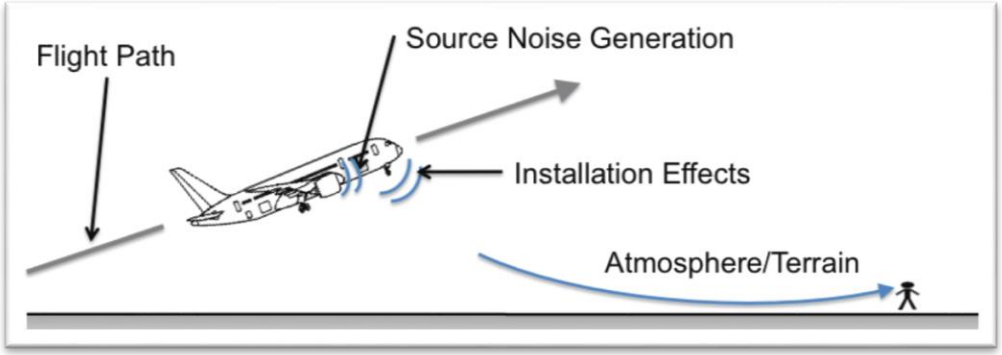


(a) Low speed aero-acoustics.

- Tested for noise in the NASA GRC 9x15
- Confirmed aux doors, bleed systems, other details can have a big effect on fan noise
- Soft choke beneficial for noise, bad for operability

Objective

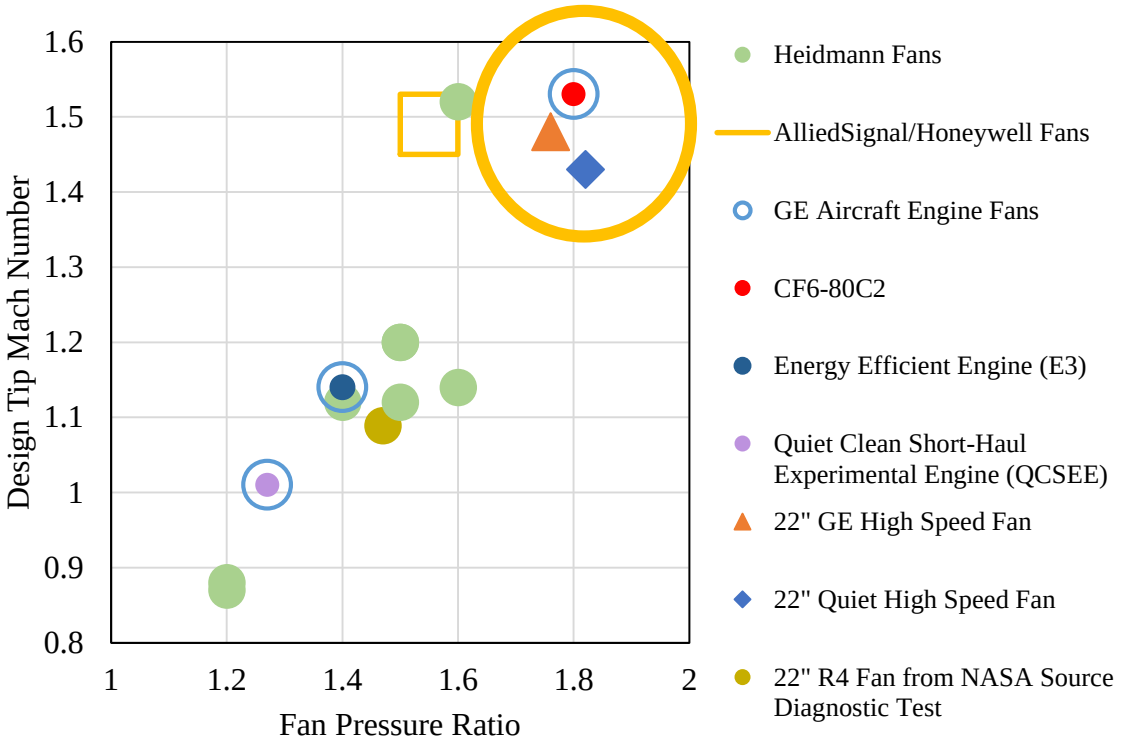
- Validate and provide guidance on use of fan noise models for CST system studies
- Investigating an optimized design for range, boom, community noise
- ANOPP2 (Aircraft Noise Prediction Program)
  - Propagation
  - Prediction
    - Airframe Noise
    - Engine Noise
      - Jet
      - Core
      - Fan
        - Heidmann
        - HSRNoise F120



Empirical Fan Noise Model #1

Heidmann

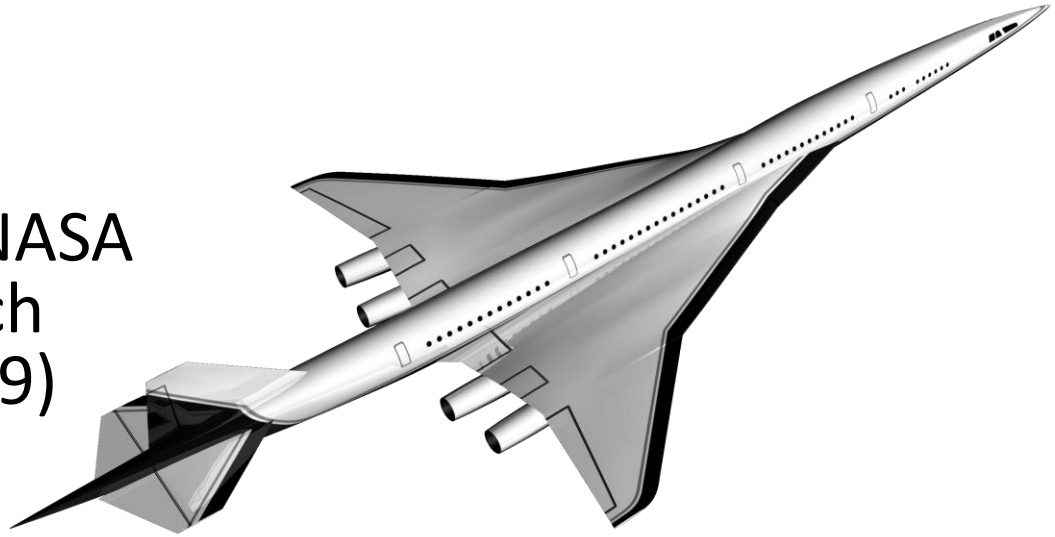
- Four versions
  - Original (1979)
  - AlliedSignal/ Honeywell (1996)
  - GE Aircraft Engines (1996)
  - Krejsa/Stone (2014)
- 5 sources
  - Inlet Broadband
  - Inlet Blade Rate Tones
  - Inlet Multiple Pure Tones
  - Aft Broadband
  - Aft Blade Rate Tones



Empirical Fan Noise Model #2

F120 Fan Model

- Developed during NASA High Speed Research program (1990-1999)
- Developed from GE Engine data
- 3-stage fan
  - Only models front fan
- 2 sources
  - Inlet Broadband
  - Inlet Blade Rate Tones



Fans to Compare vs Model

	2-Stage Fan	QHSF	GE HSF
Geometric Parameters			
Blade Count	26 and 42	22	24 or 34
Vane Count	72 and 104	52	52 or 80
Fan Inlet Annular Area, m2 (ft2)	0.162 (1.74)	0.216 (2.32)	0.222 (2.39)
Fan rotor diameter, cm (in)	48 (19)	56 (22)	56 (22)
Hub/Tip Ratio	0.34	0.35	0.31
Design Point Performance Parameters			
Design RPM	16670	15444	15105
Design Pressure Ratio	2.4	1.82	1.76
Tip Speed, m/s (ft/s)	429 (1406)	449 (1474)	442 (1450)
Axial Rotor-stator spacing (in rotor tip chords)	0.55	2.4	2.54
Corrected Fan Airflow, kg/s (lbm/s)	29.9 (66)	44.9 (98.9)	45.4 (100)
Average Bypass Fan Temperature Ratio	1.32	1.21	1.21

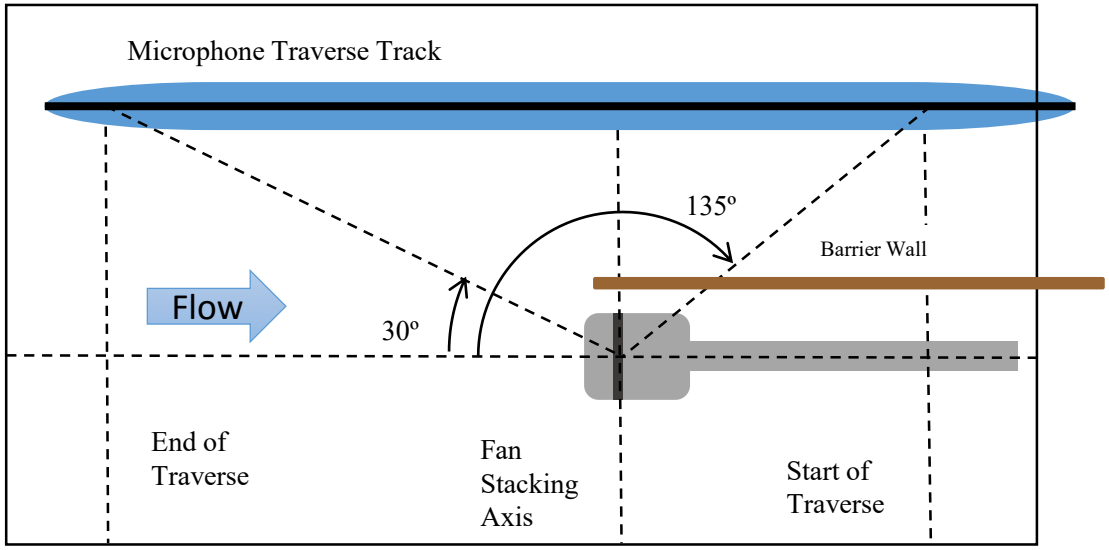

2-Stage Fan (2002)

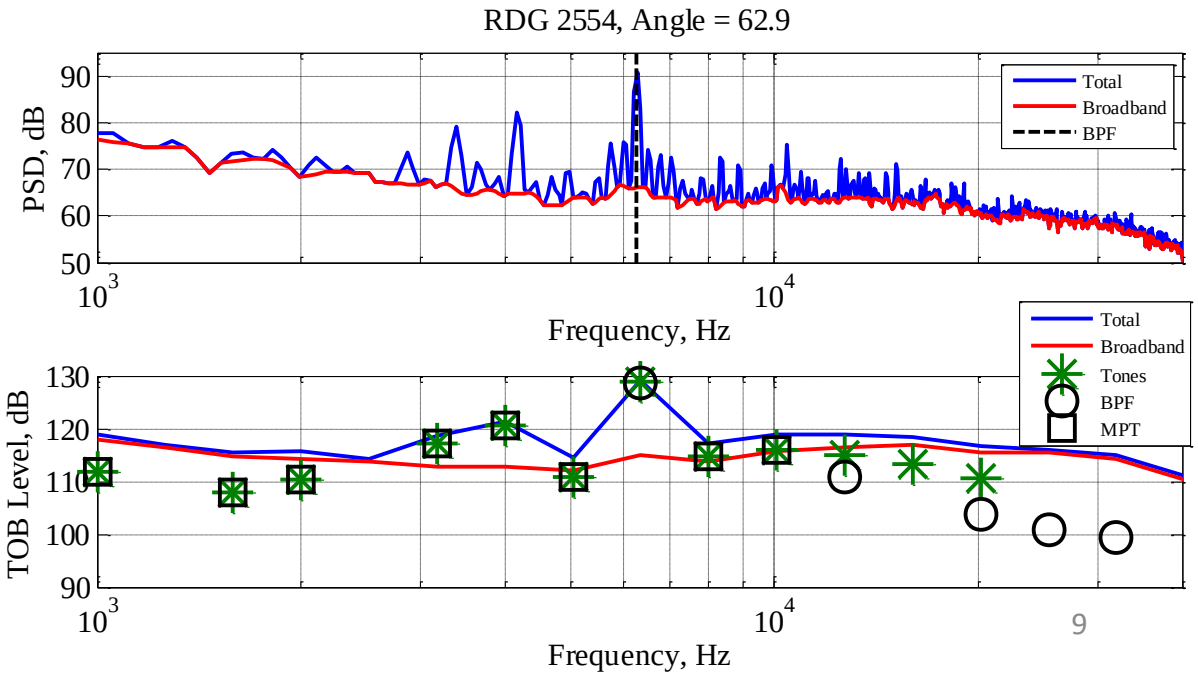

Quiet High-Speed Fan (2000)


GE High Speed Fan (1999)

Data Collection and Processing

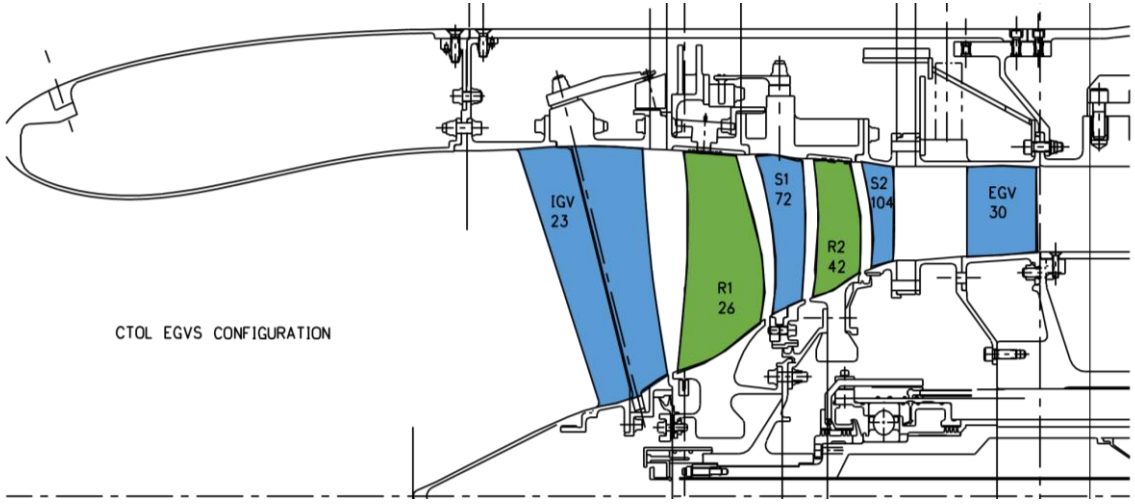
- Start with narrowband spectra, 1-ft lossless
- Separate Tones from Broadband
- Sort tones into BPF or MPT
- Convert to 1/3 Octave

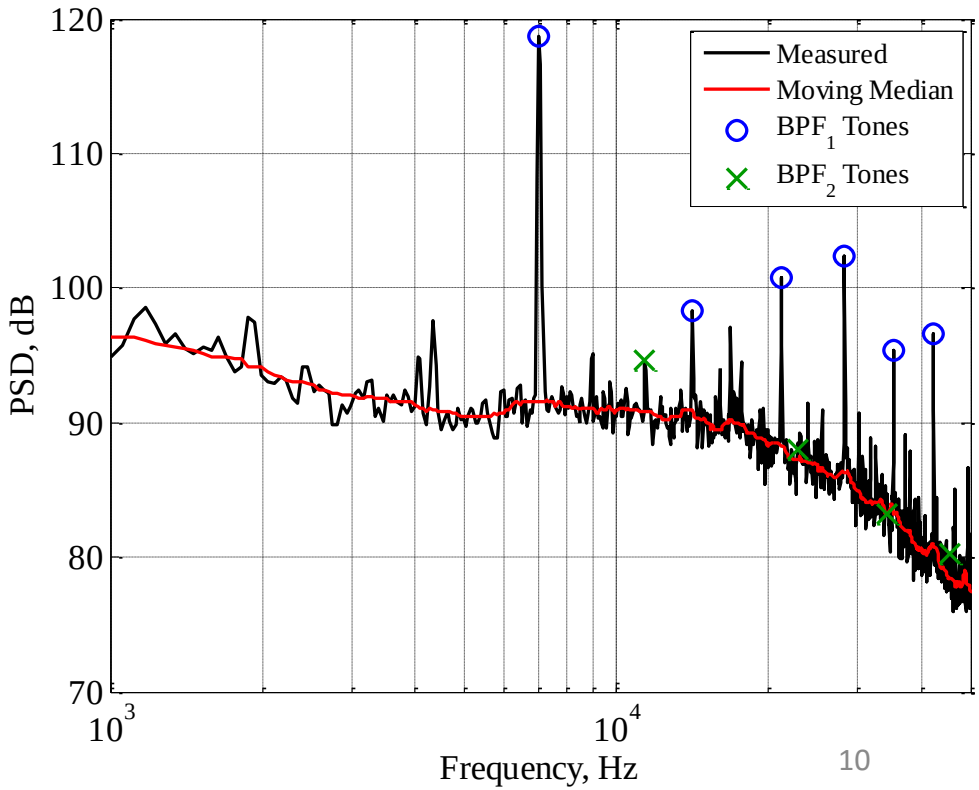




2-Stage Fan

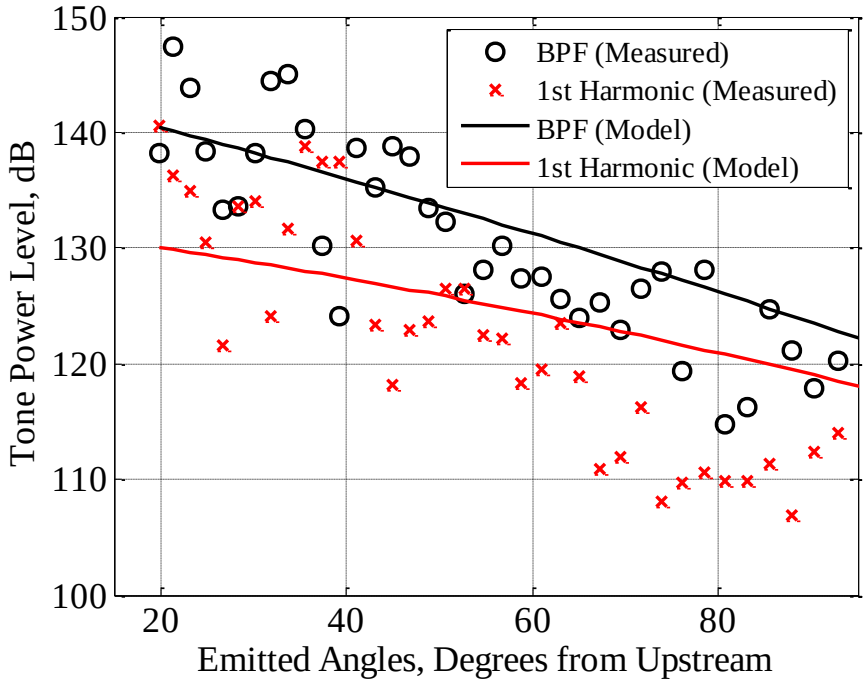
- IGVs operate on a schedule
- First fan BPF tone and harmonics dominate
  - Second fan BPF barely noticable
  - Fairly few other tones
- Broadband noise

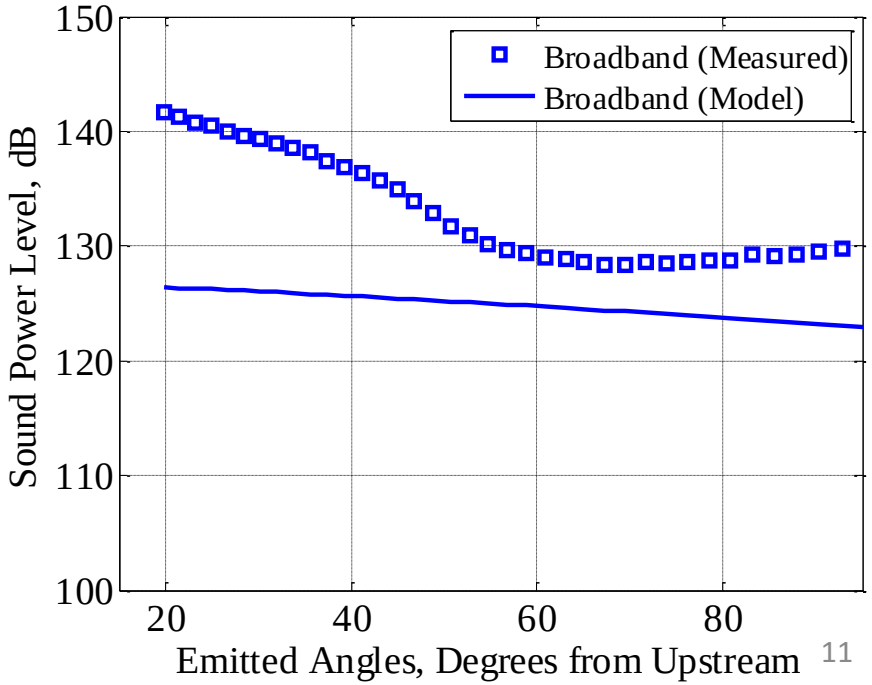




2-Stage Fan Tone Level vs F120 Fan Model

- 92.1% Speed (maximum tested)
- Model largely captures slope and level of BPF tone
  - Noise metric penalizes tones
- Broadband noise under-predicted





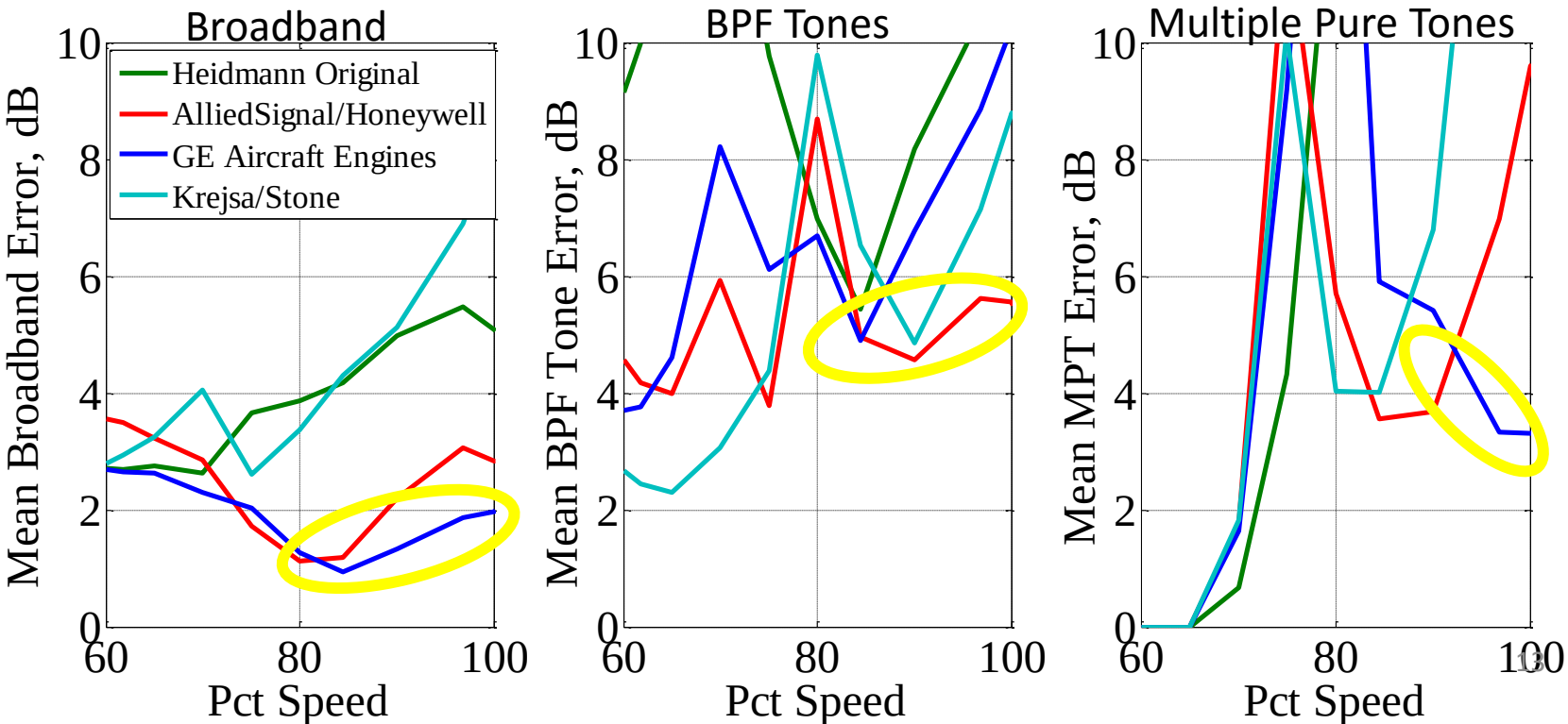
GE High Speed Fan vs Heidmann Fan Noise Model

- 3 fans
  - Wide Chord
  - Forward Swept
  - Shrouded
- 3 stators
  - Baseline Radial Sweep
  - Lean & Radial Sweep
  - Integral (not used with barrier wall)
- 12 fan speeds

Forward Swept fan with Barrier Wall in 9x15 LSWT

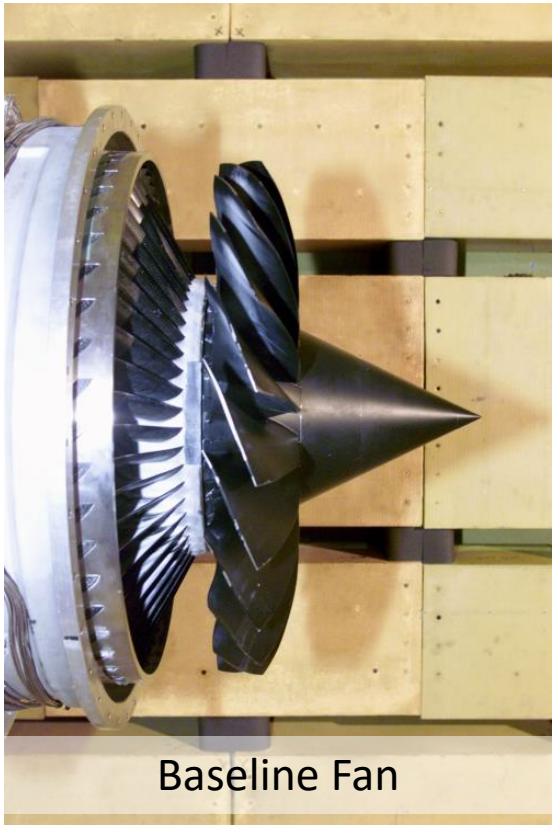
Find best fit to data

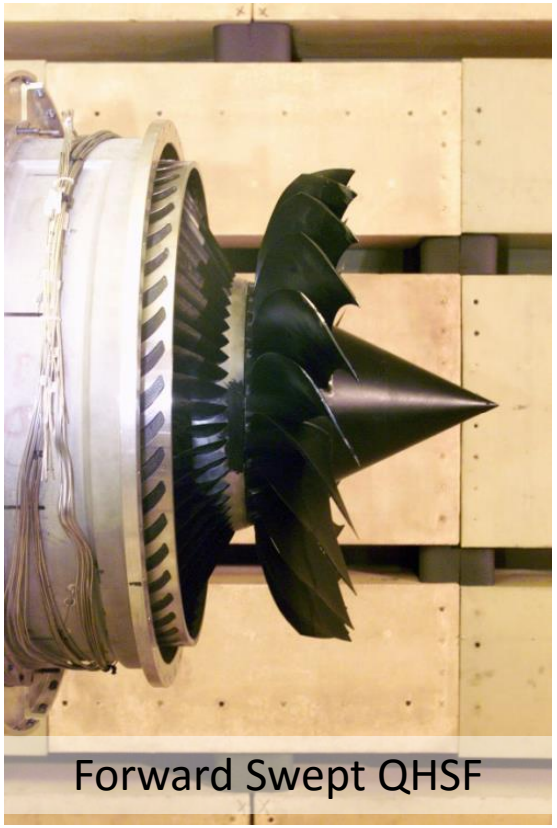
- Equal weighting for each one-third octave band & directivity
- At speeds above 85%
  - GE model works best for Broadband and MPTs
  - Honeywell model fit best for BPF tones



Honeywell Quiet High Speed Fan

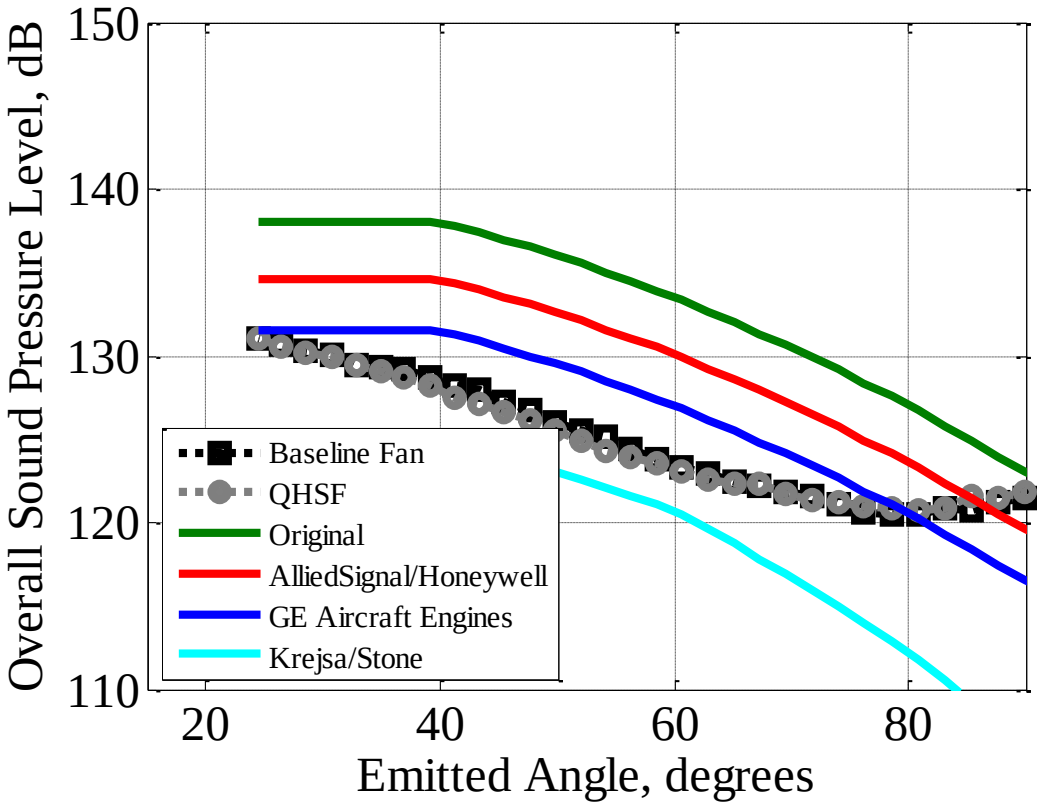
- Two fans tested
  - Baseline fan a scale model of TFE731-60
  - Forward swept fan, designed to reduce takeoff EPNL
- Stator set for each fan


Baseline Fan


Forward Swept QHSF

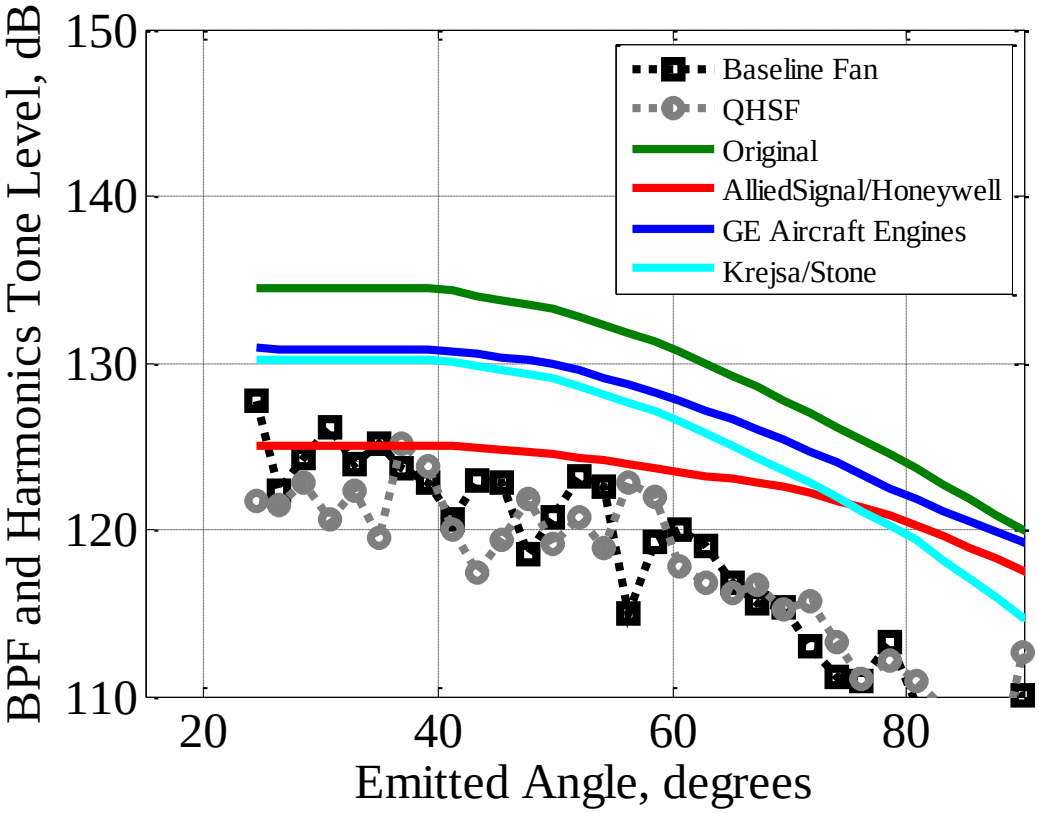
QHSF Broadband

- GE version of Heidmann fan model best fit for broadband, but over-predicts at most emission angles



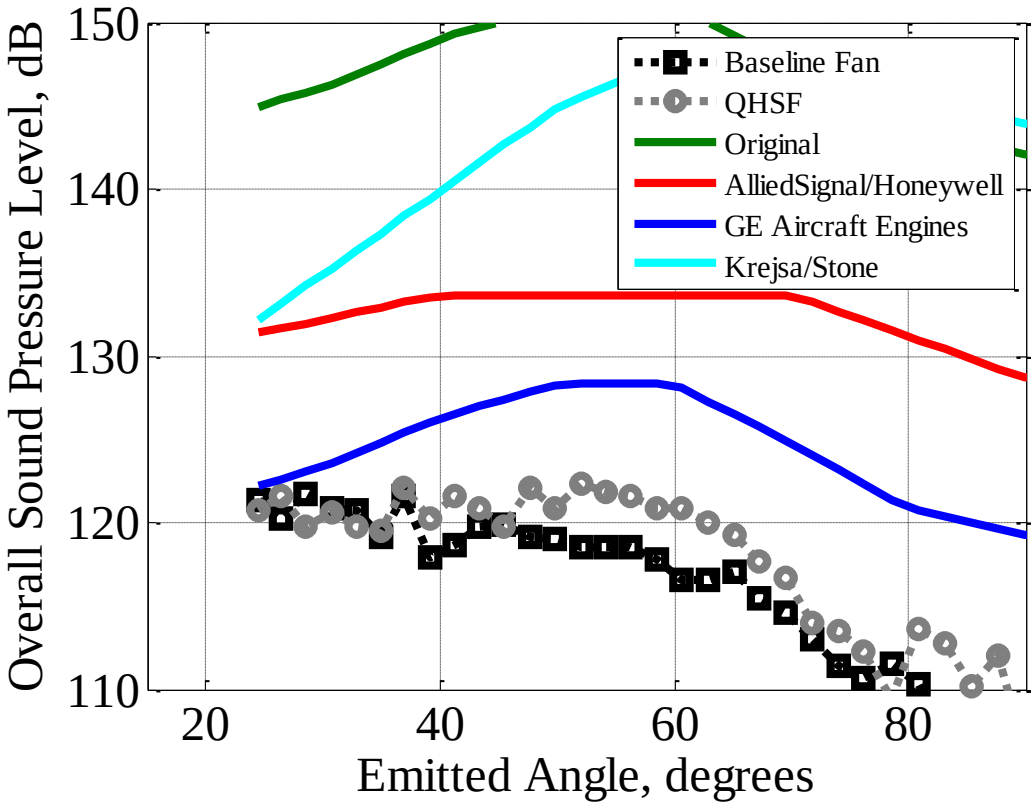
QHSF BPF Tones

- Honeywell method closest for BPF noise, but again overprediction, especially at aft angles



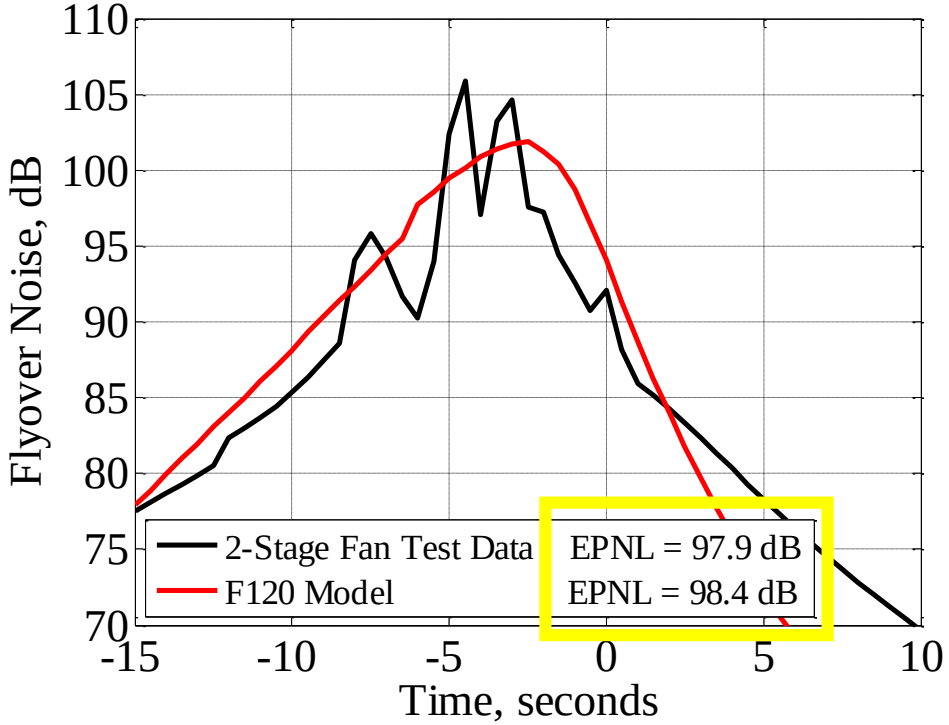
QHSF MPTs

- MPTs much lower than any models
- GE method predicts smallest MPTs



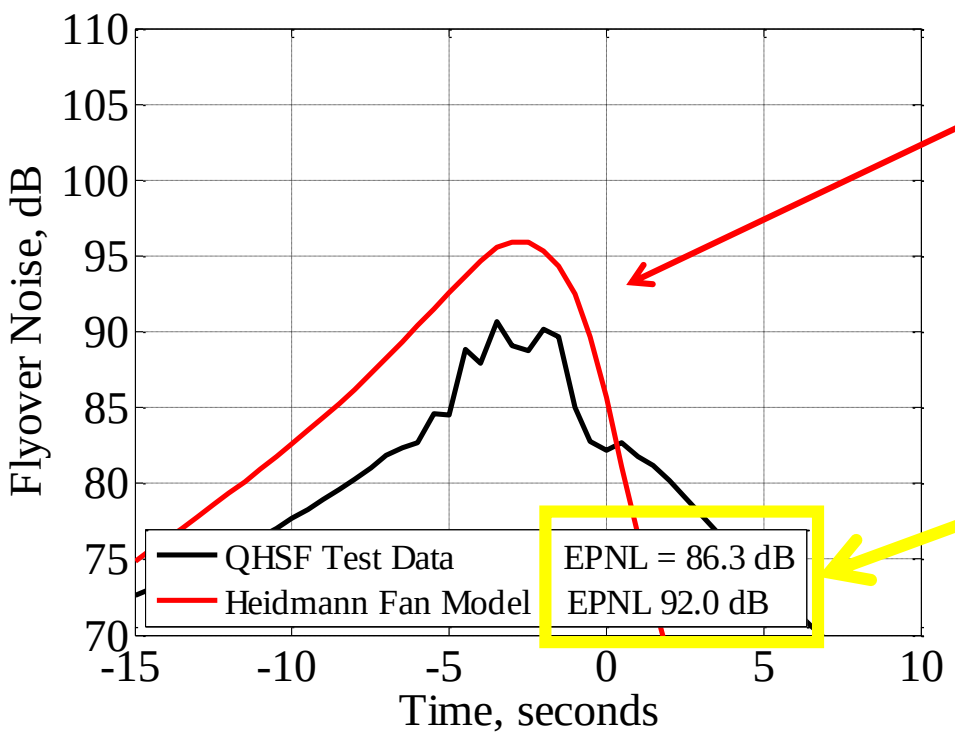
Simulated Flyover: 2 Stage fan

- Straight and level, 1000’, Mach = 0.30
- Fan inlet noise only, three engines
- 2-Stage fan sized to LM 1044 1.65 (65”) diameter
- BPF tone dominates



Simulated Flyover: Single Stage Fan

- Straight and level, 1000', Mach = 0.30
- Fan inlet noise only, three engines
- QHSF scaled to match fan thrust of 2-Stage fan
  - 2.34m (92.2") diameter



Each model component over predicted

5 to 10 dB quieter than 2-Stage Fan

Conclusions

- High speed fan data from 9x15 LSWT compared with Heidmann and F120 fan models
- 2-Stage Fan noise dominated by first rotor BPF
  - F120 model matches measurements reasonably well
- Two single stage fans evaluated
  - GE High-Speed Fan
  - Honeywell Quiet High-Speed Fan
  - Guidance for use of Heidmann fan model:
    - GEAE model for broadband
    - AlliedSignal/Honeywell model for blade rate tones
    - MPTs may be over-predicted by all models
- Single stage fan 5-10 dB quieter
- System studies should include fan noise
- Still need to consider aux doors, inlet flow distortion