Sonic Boom Variation of a Wing-Body-Tail-Nacelle Configuration

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Background and Motivation

• At the First AIAA Sonic Boom Workshop (SBPW-1) at SciTech 2014
  – Perceived Level (PL) noise measure variation for the two simple required cases was about 1 dB
  – PL variation for the optional wing-body-tail-nacelle configuration was about 10 dB
  – Humans can discern about a 2 dB difference
• Why was the variation larger for optional case?
• How should we approach the next workshop (SBPW-2) at SciTech 2017?
SBPW-1 Models

Flat-top signature
axisymmetric SEEB-ALR

Simple Delta Wing Body

LM1021 Full Configuration

[image: Aftosmis, Nemec AIAA-2014-558]
Background and Motivation

SEEB-ALR fine-grid PL

Delta-Wing-Body fine-grid PL
Background and Motivation

**SEEB-ALR fine-grid ground**

- Flattop
- Multiple N-Waves

**Delta-Wing-Body fine-grid ground**

- Flattop
- Multiple N-Waves
LM1021 Centerline Ground Signatures from H/L=7.9

All submissions
Euler, laminar, and turbulent simulations
Workshop and participant provided grids
LM 1021 Background and Motivation

PL extracted at different H/L

PL extracted at different phi

At centerline

From \( R/(b/2) = 7.9 \)
LM 1021 Background and Motivation

PL extracted at different H/L

PL extracted at different phi

At centerline

From $R/(b/2)=7.9$
Examine Size of Variation Sources

• Far-field multipole correction
• Signature close-out reconstruction
• Contribution of each shock (i.e., nose and tail shocks)
• Extraction distance
• Off-track
Multipole Far-Field Correction

- Page and Plotkin AIAA-91-3275
- Corrects for diffraction of acoustic sources in span wise direction
  - Mitigate sampling near-field pressure too close to the configuration
  - Correction is configuration dependent and decreases to zero with distance
LM 1021 Far-Field (Multi-Pole) correction

PL extracted at different H/L  Multi-pole correction

Far-Field Correction Magnitude

At centerline  [AIAA-2014-2006]
LM 1021 Far-Field (Multi-Pole) correction

PL extracted at different phi  Multi-pole correction

From $R/(b/2)=7.9$  [AIAA-2014-2006]
Tail closure

- LM1021 wind tunnel model aft signature must be recreated to remove the mounting sting from the measurements and simulation.
• The steepness of the aft shock of this model is sensitive to the aft signature reconstruction method.
Tail closure

- Higher frequencies are impacted by tail shock steepness

Ground spectra

- 94.91 PL (dB) Step
- 91.47 PL (dB) Whitham
- 90.84 PL (dB) Ramp

Step closure 4 PL (dB) louder than ramp (ramp was used at workshop)
PL and A-Weighted Sound Exposure Level (ASEL)

- Humans perceive noises to be louder if they are 600 Hz to 10,000 Hz
- Measures have been evaluated in experiments (PL best loudness correlation)
- ASEL is a good surrogate for PL and is a continuous weighting

**A-Weighted Sound Exposure Level**

**Stevens JASA (1971) Perceived Loudness (PL)**
A-Weighted Sound Exposure Level (ASEL) and PL

Range of both axes is 11 dB
Line has unity slope with offset of 14.5 dB
Scatter of about 2 dB

All participants
On and off centerline
All extraction distances
Time Domain A-Weighted Filter

• Continuous weighting of ASEL enables time domain filtering
• Integrated to yield ASEL as a function of position
  – See the contribution of each ground signature feature to the total
LM1021 Ground Signature
LM1021 A-Filtered Pressure and Ground Signature
LM1021 ASEL and A-Filtered Pressure
LM1021 Ground and ASEL

Time (ms)

Pressure Difference (PSF)

ASEL (dB)
LM1021 Ground Signature

![Graph showing pressure difference (PSF) over time (ms) for different sensors labeled 1A, 2B, 3C, 4C, 5C, 6C, 7E, 8M, 9O, 10Q, 11Q. Arrows indicate specific time points.](image)
LM1021 Ground Signature and ASEL

Graph showing the pressure difference (PSF) over time (ms) for different ASELs and signatures.
LM1021 Ground Signature and ASEL
LM1021 Ground Signature and ASEL

The graph shows the ASEL (A-weighted sound exposure level) over time, with different colored lines representing different conditions or experiments. The x-axis represents time in milliseconds, ranging from 250 to 350 ms, and the y-axis represents the ASEL in dB, ranging from 68 to 82 dB.

- The range from 69-72 dB is marked with a downward arrow.
- The range from 70-73.5 dB is marked with another downward arrow.
- The range from 71-80 dB is marked with a third downward arrow.

Each line on the graph corresponds to a specific condition or experiment, with labels 1A, 2B, 3C, 4C, 5C, 6C, 7E, 8M, 9Q, 10Q, and 11Q.
LM1021 Ground Signature and ASEL
LM 1021 Background and Motivation

PL extracted at different H/L

Near-field extracted at diff. H/L

At centerline

At centerline
LM 1021 Background and Motivation

PL extracted at different H/L

Ground extracted at different H/L

At centerline

At centerline
LM 1021 Background and Motivation

PL extracted at different H/L

Press. extracted at different H/L

At centerline

At centerline
LM 1021 Background and Motivation

PL extracted at different H/L

At centerline

ASEL extracted at different H/L

At centerline
LM 1021 Phi = 50 Degrees

PL extracted at different phi

Ground Pressure

H/L=25, phi=50 degrees
LM 1021 Phi = 50 Degrees Ground
LM 1021 Phi = 50 Degrees

PL extracted at different phi

ASEL

H/L=25, phi=50 degrees
LM 1021 Phi = 50 Degrees ASEL

64.5-79.5 dB

69-80 dB
Conclusions

• Multiple sources of variation for LM1021 PL and ASEL
  – Centerline ground noise measures are dominated by the tail shock
  – Both bow and tail shocks contribute to the 50 degree off-track ground noise measures

• A-weighted Sound Exposure Level (ASEL) is a useful surrogate for Perceived Level (PL)

• ASEL is continuous and can be applied in both the frequency and time domains
Recommendations

• Design for reduced PL and ASEL sensitivity to small localized signature changes
• Identify the sensitive portions of the signal (and model) to target for adequate grid refinement
• Minimize the variation introduced during reconstruction of aft pressure signature for models with sting or extend aft boundary for free-flight models
• Apply far-field (multipole) correction into participant evaluations in a more consistent manner
• Use A-weighted filter and ASEL with PL for compiling statistics
Acknowledgment

• Sriram Rallabhandi, National Institute of Aerospace, and Joe Salamone, formerly Gulfstream Aerospace, provided the suggestion of A-weighted filter for time domain analysis
Participate

• Visit Sonic Boom Workshop Website
  
  http://lbpw.larc.nasa.gov
  
  – Presentations and references
  – Geometry, grids, submitted data, and derived data are available: independent analysis encouraged!
  – Sign up for the low-traffic announcement e-mail list

• See you for the next workshop
  – AIAA SciTech 2017, 7-8 January 2017, Grapevine, Texas, USA
  – Lower PL configurations from 90s to 70s
  – Expand participation to include propagation and noise metric experts
  – Include propulsion effects for optional case
  – Provide uniformly refined grids for all cases