ACRP 02-44 Helicopter Noise Modeling Guidance

Presentation to SAE A-21 Committee

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Delft, Netherlands

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Outline

- ACRP 02-44 Objectives
- Project Team
- Background
- Technical Approach
- Outcomes
- Discussion

ACRP 02-44 Objectives

1. Review, evaluate, and document current helicopter noise models.
2. Identify potential improvements to INM/AEDT to better capture the unique complexity of helicopter and tiltrotor* operations.
3. Develop a supplemental document providing guidance for modeling and helicopter noise.

Motivation: *"The fixed-wing aircraft noise prediction techniques employed in INM/AEDT rely on the widely accepted methodologies described in documents such as SAE International's SAE-AIR-1845 and the European Civil Aviation Conference's Document 29. However, in contrast to guidance related to fixed-wing aircraft, there is no peer-reviewed guidance document describing an integrated modeling technique for the prediction of helicopter noise."*

 * Tiltrotors are included in this study to a limited degree.

ACRP 02-44 Team

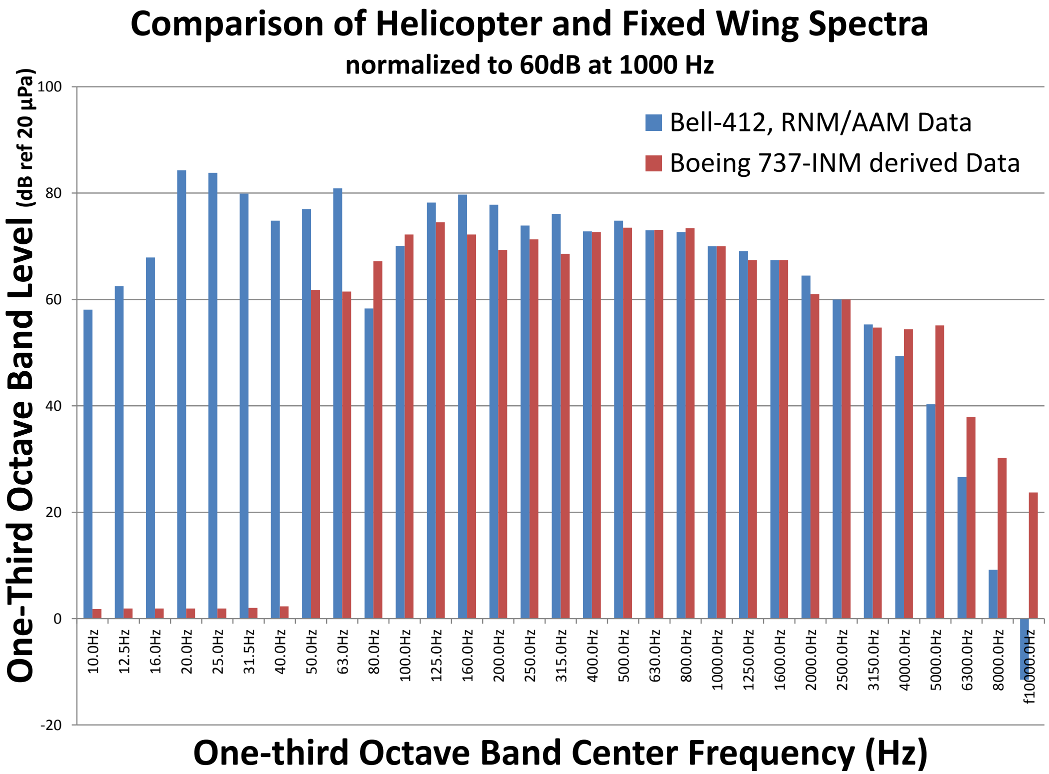
- Wyle
  - Juliet Page, Principal Investigator
  - Chris Hobbs, Benjamin May
- The Volpe Center, DOT
  - Eric Boeker, Lead
  - David Senzig
- National Aerospace Laboratory, Netherlands
  - Harry Brower, Lead
  - Marthijn Tuinstra
- K.B. Environmental
  - Clint Morrow, Lead

Background: Spectral Content

- Significant Low-freq. energy for Rotorcraft
- INM 50Hz:10kHz /AEDT 10Hz:10kHz

(AEDT Database might need expansion)

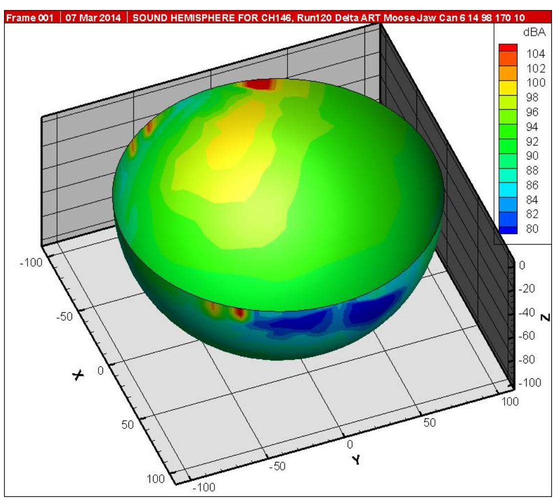
Data: AAM CH-146, 1000 Ft AGL, POI 1000Ft Laterally (Port side), 5Ft AGL, Spectra at Lmax, USSTD Atmos.



Background: Complex Noise Source

- Helo Noise Emission: function(Flight Path Angle)
  - Approach Physics: Blade-Vortex-Interaction (BVI)
- INM/AEDT: 6^{o} Approach Only (Single App. NPD)

3^{o}



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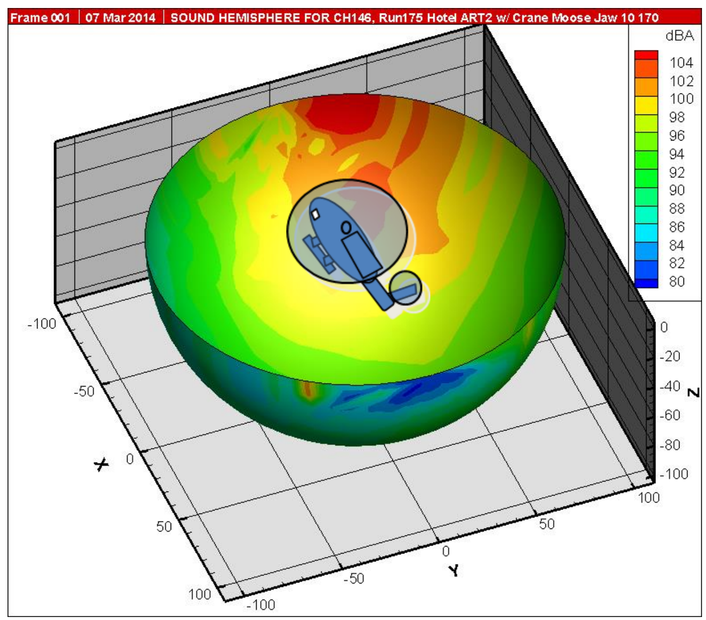

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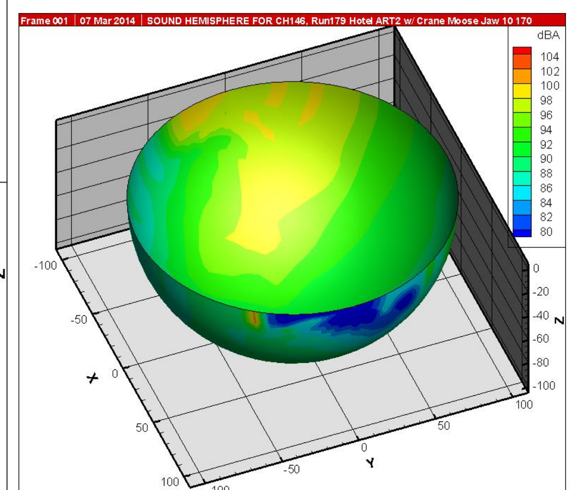
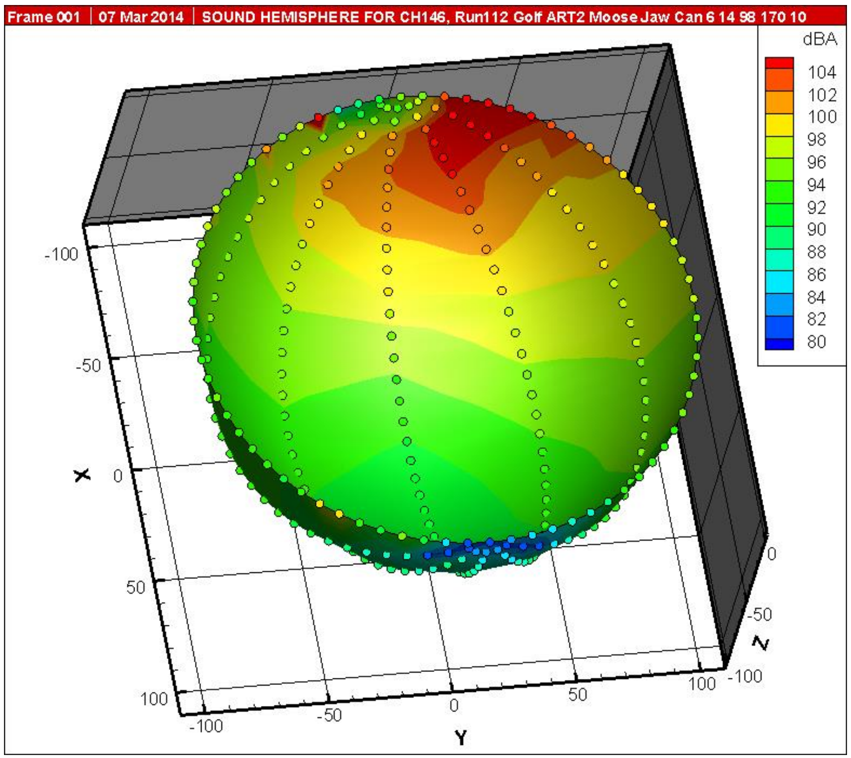
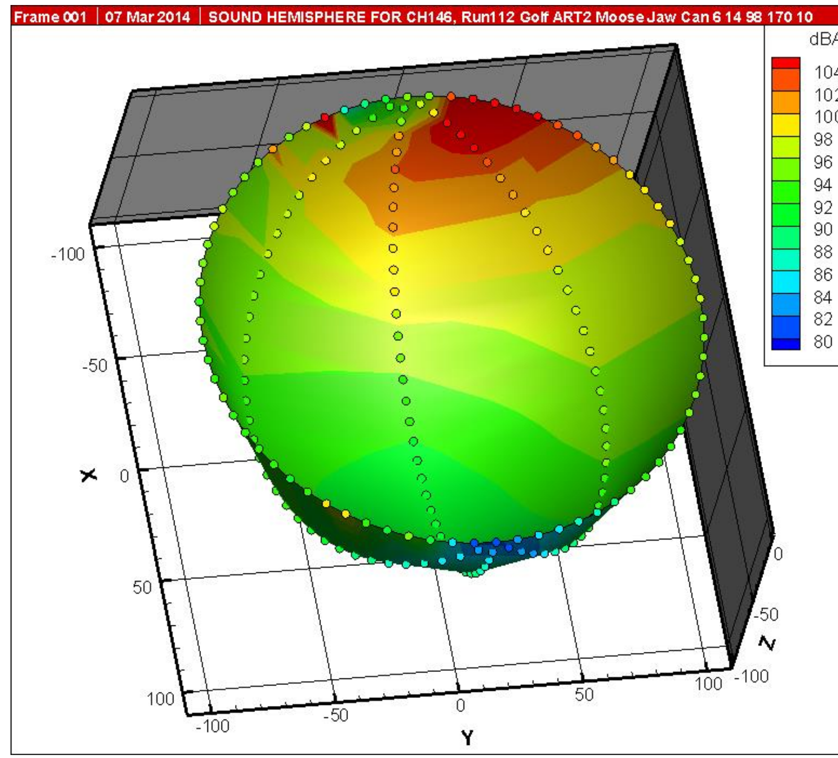


Background: Complex Directivity

- INM/AEDT: Right-Center-Left Directivity





Decimated Noise Spheres, 30° and 45° Spacing, SPL (dBA)

Vehicle Noise at top, Control Dots indicate Data Points. High Speed, 128 kts, Run 112.

Technical Approach

- Vary modeling fidelity to assess results sensitivity to various parameters including:
  - Source Noise Modeling (Spectral Content, Directivity)
  - Operational Modeling (Movements and Sources)
  - Propagation Modeling (Environment)
  - Receptor Modeling (Metrics for Helos / Tiltrotors)
- Conduct targeted “Mini Trade Studies”
  - Determine Sensitivity to Modeling Parameters
  - Develop Recommendations (Team & Panel)
- Seek Rotorcraft Community Review / Feedback

<u>Mini Trades:</u> Collection of targeted analyses which determine output sensitivity to various modeling features and leverage prior research.

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Mini-Trade Study List p.1/3

INM	AAM	HELENA	Objective	Analysis	Dataset Vehicles	Comparisons
How well do models compare? What's driving deltas? (Source, propagation, environment?)						
X	X	X	**Model Comparison**: Selected Cases	Multiple Comparisons using Common Datasets	MD902 CH146, TBD	Contours, Metrics @POIs
What is the minimum lateral granularity to capture noise sources across flight modes?						
	X	X	**Lateral Source Directivity**	Comparisons of varying lat. Fidelity w/ Meas	MD902 CH146, TBD	Lateral metrics (max, integ.) & d', Taud, dBC…
How low should the source data be defined for community noise / annoyance?						
	X		**Low-Freq.** Spectral Assessment	Source w/ varying low-f included	CH146 MD902	Compare Metrics for various scenarios
Define minimum Tiltrotor trajectory modeling Capabilities (VTOL, helo vs. airplane, etc…)						
X	X		**Tiltrotor Source & Trajectory** Modeling Reqmts.	ID 'typical' Ops & minimum movement reqmts. (DoD NEPA)	MV-22 XV-15 LCTR2	Compare Profiles & Tracks, Sources. "Trick" INM.
What atmospheric propagation modeling capabilities are needed?						
	X		**Atmos. Propagation** Effects	Terrain, Shielding, Atmospheres, Prop Methods	Various	Case-by-case Contours, Levels, Metrics # POIs

X *Preliminary* example to be shown

Mini-Trade Study List p.2/3

INM	AAM	HELENA	Objective	Analysis	Dataset Vehicles	Comparisons
What kinds of measurements are needed to obtain model source noise data?						
X	**X**	**?**	Address **source data flight test** procedure pros, cons, costs & impact.	NPDs: FAR36 vs. Mfgr INM inputs vs. AAM style flight testing vs. ???	TBD	Source charactistics. Compare w/ other trades.
How to best capture approach BVI noise or avoidance?						
	X		**Varying Approach FPAs,** incl. segmented app.	Sensitivity to approach FPA (steady flight)	MD902 CH146, TBD	Metrics@POIs, contours dBC, BVISPL, D',
What helicopter performance modeling capabilities are needed?						
X	**X**	**?**	Effects of temp/humid on lower-f Helo spectra. High alt, hot day source effects? Tip-Mach effects etc?	Simple analyses under different env. conditions	TBD	Source changes & Ground Metrics
What data is needed for vertical flight?						
X	**X**		**HIGE/HOGE,** directivity incl. **tail rotor** in-plane noise etc	ID 'typical' Ops & (Heliports) single event modeling. Case studies.	TBD Helos & Tiltrotors.	Contours and Metrics @ POIs.

X *Preliminary* example to be shown

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Mini-Trade Study List p.3/3

INM	AAM	HELENA	Objective	Analysis	Dataset Vehicles	Comparisons
How well do the models predict FAR36 / ECAC Cert levels?						
X	X	X	Sensitivity to sources (HNM, Legacy RNM, full RNM, mfgr process)	Pred. vs. Published Meas data.	TBD. Could use Mfgr input.	Levels at FAR36 / ECAC Cert locations
How to best capture maneuvering flight noise (gentle commercial, not high-G military ops)?						
	X		Determine **Source Modeling** Reqmts.	Comparison using AAM Q-SAM method (Longit Accel FPA equival.)	TBD, Possible NASA data	Metrics at POIs, Comparison w/ Meas data
How and when can you substitute one vehicle for another?						
X	X		**Substitution Guidance .** General size classes vs. individual models.	Limited sensitivity trade: Weight, # blades, class. Leverage past studies	TBD	Source Level & Spectral Class comparison

Low Frequency Content

- Tested CH146 empirical spheres against spectral data with other resolutions
  - Examine effects of including various low frequency third octave bands (beyond INM spectral class data)
  - Results depend on metric chosen:
    - SEL (dBC, unweighted) show strong differences as low-f energy is removed (as expected)
    - SEL (dBA), LmaxA, EPNL and $PNLT_{max}$ show no changes

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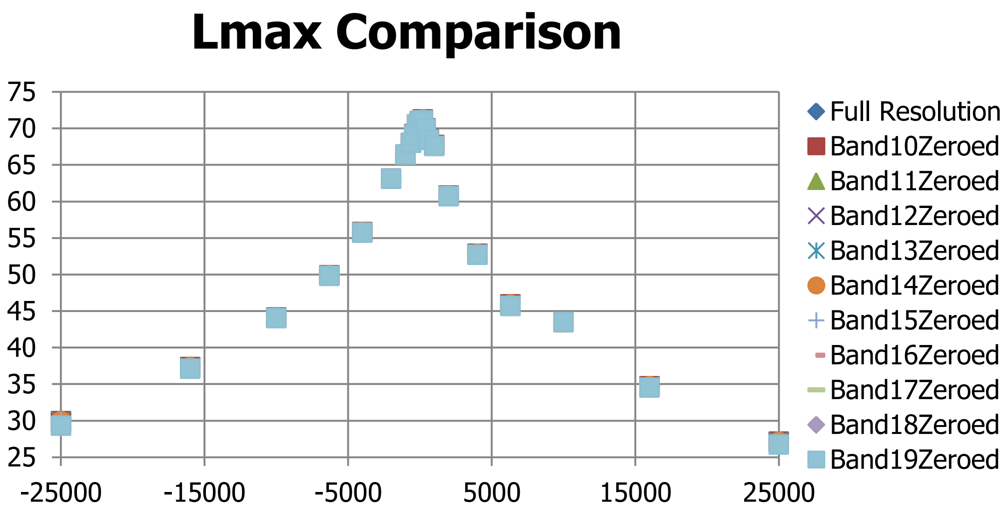
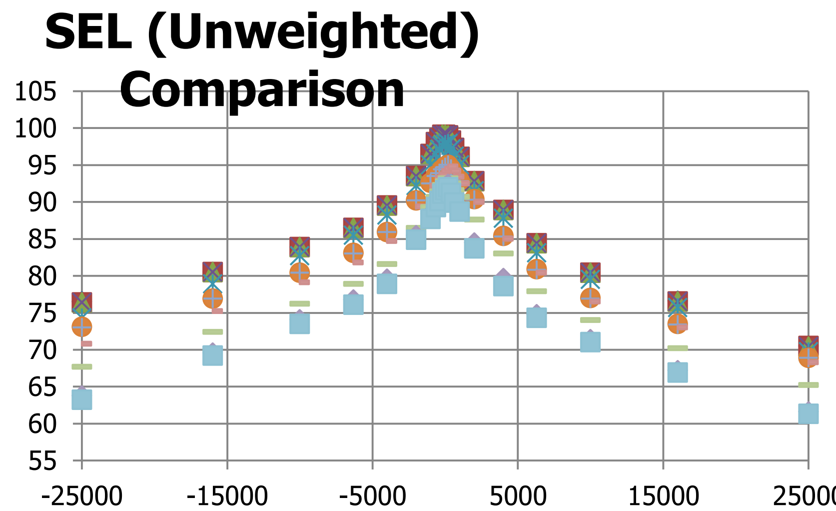
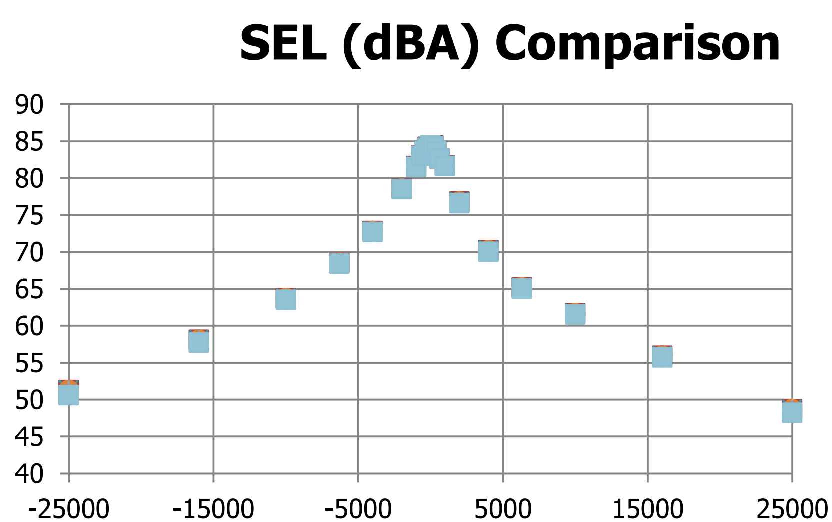
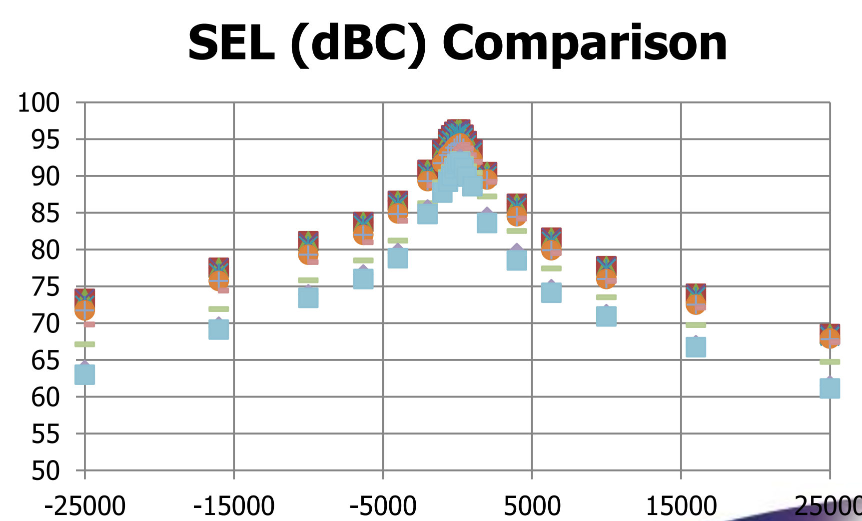
Low-f Band Decimation (Slow, 78 kts)

Low Frequency Content Mini-Trade



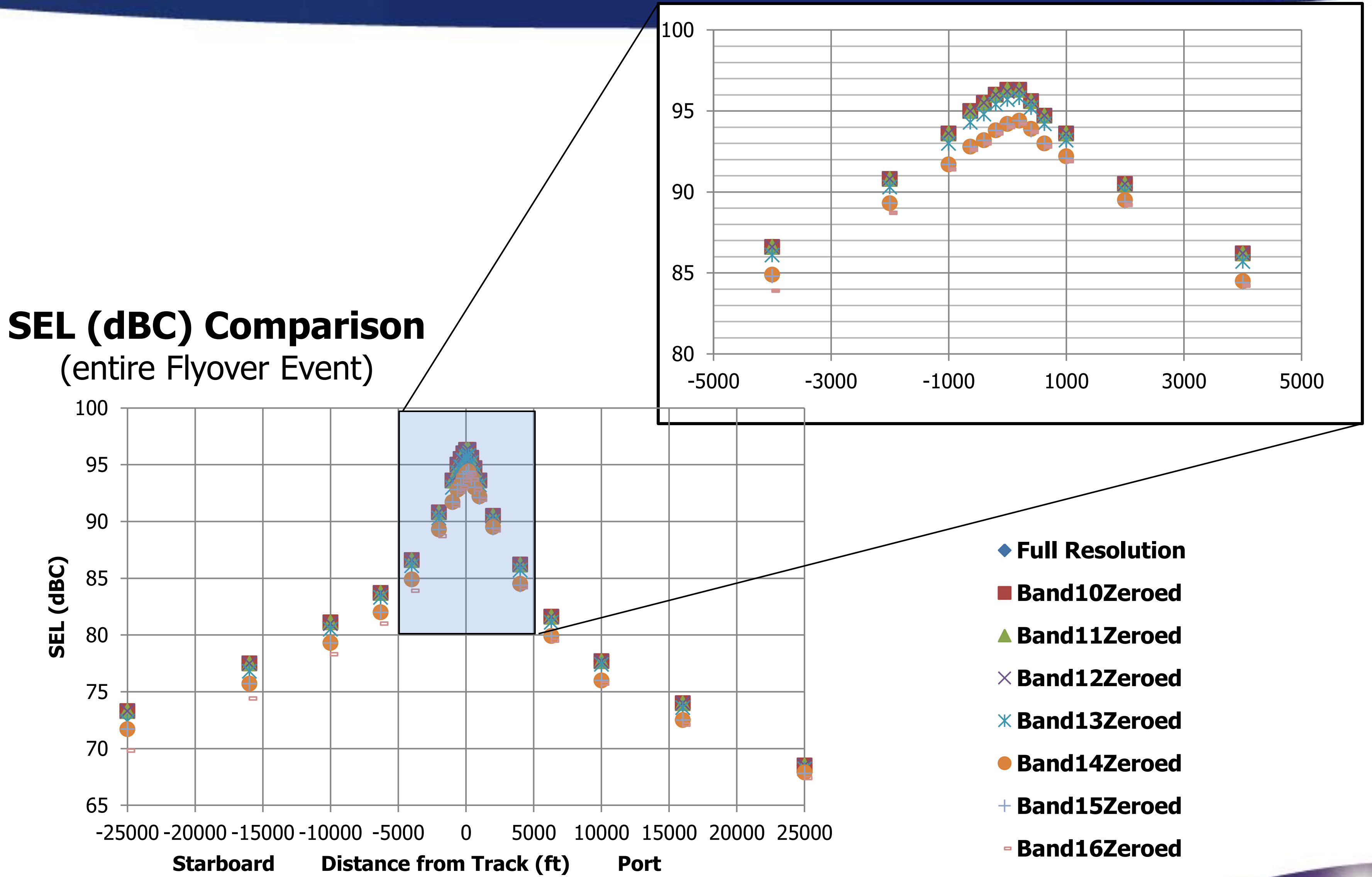






Slow, 78 kts, Sphere 120

Low Frequency Content Mini-Trade



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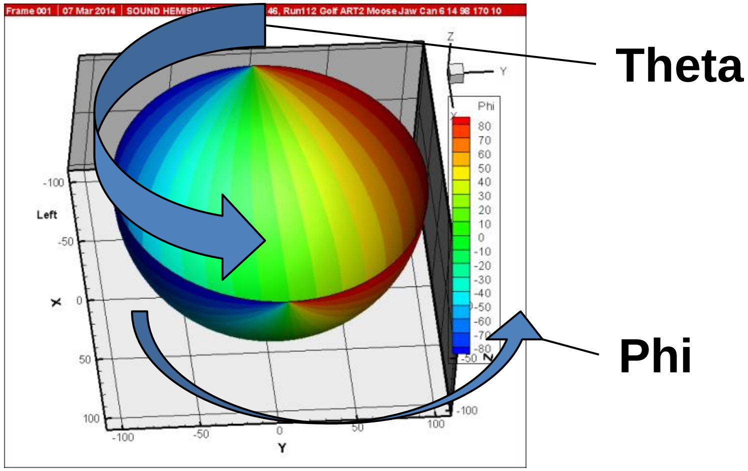
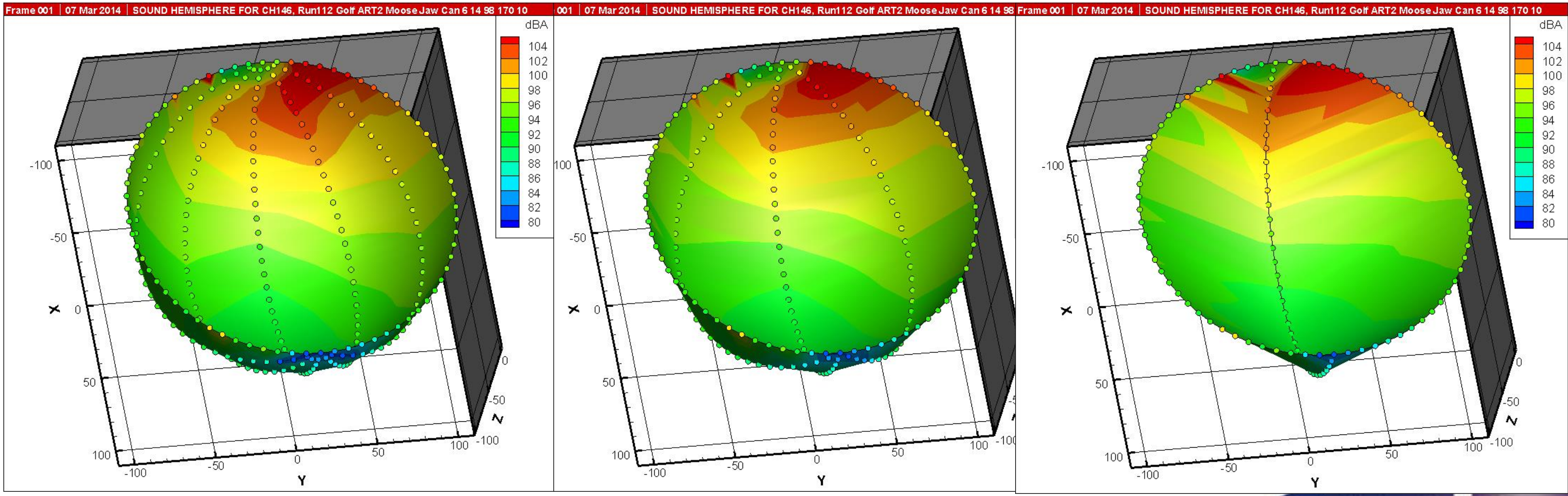
Lateral Directivity

- Create decimated CH146 spheres with reduced lateral fidelity
  - Linear interpolation between source definition in modeling software (INM & AAM)
- Measurement fidelity drives model accuracy
  - Microphone data from tests used to develop spheres
  - Spheres used to model helicopter operations
- Characterize the modeling sensitivity as a function of lateral resolution
  - metric dependent

Lateral Directivity Method

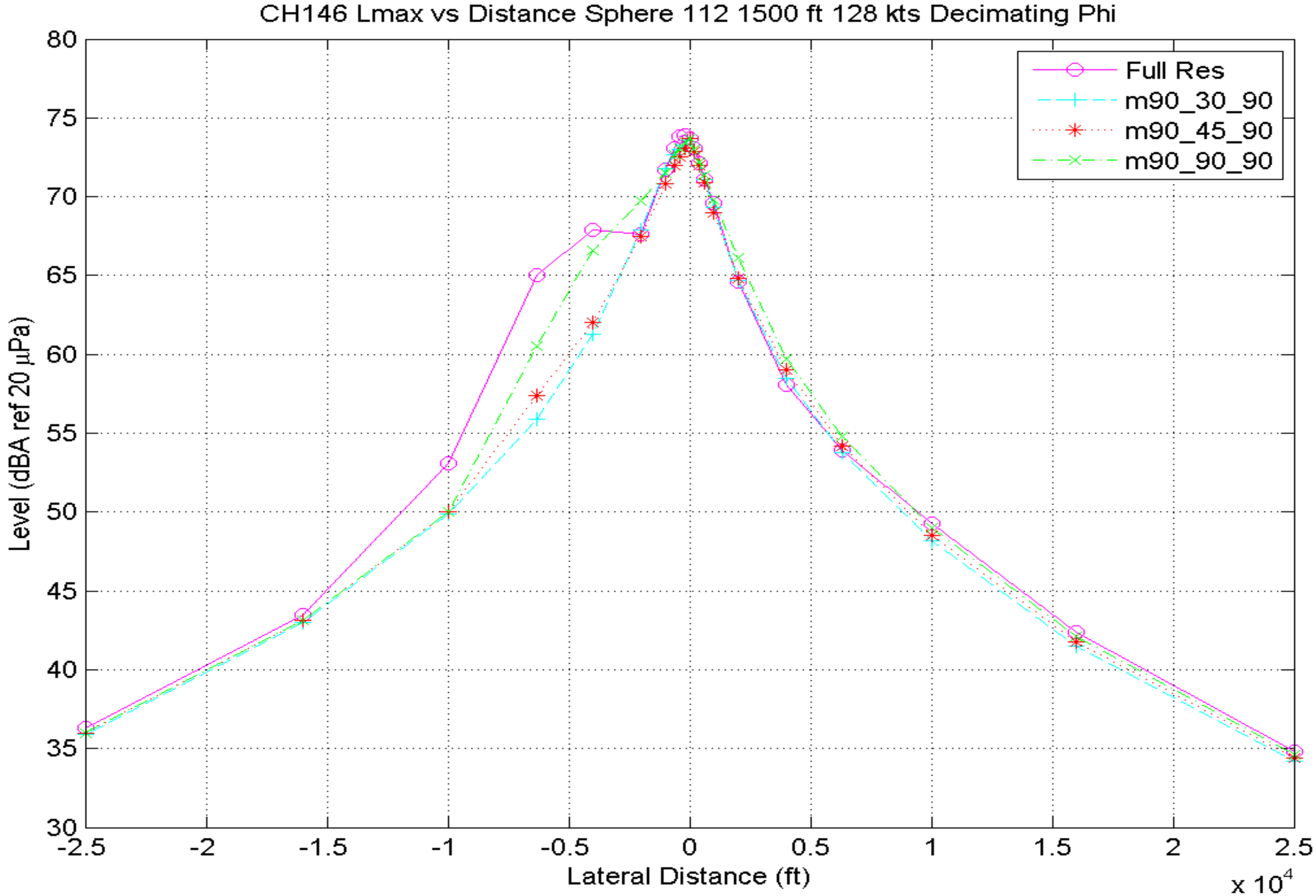
- Reduce Phi Resolution:
  - Full resolution to every 30, 45, and 90 degree resolution with linear interpolation between points





Lateral Variation in Metrics

- Phi decimated spheres, High Speed flight



Lateral Source Directivity Mini-Trade

Starboard **Port**

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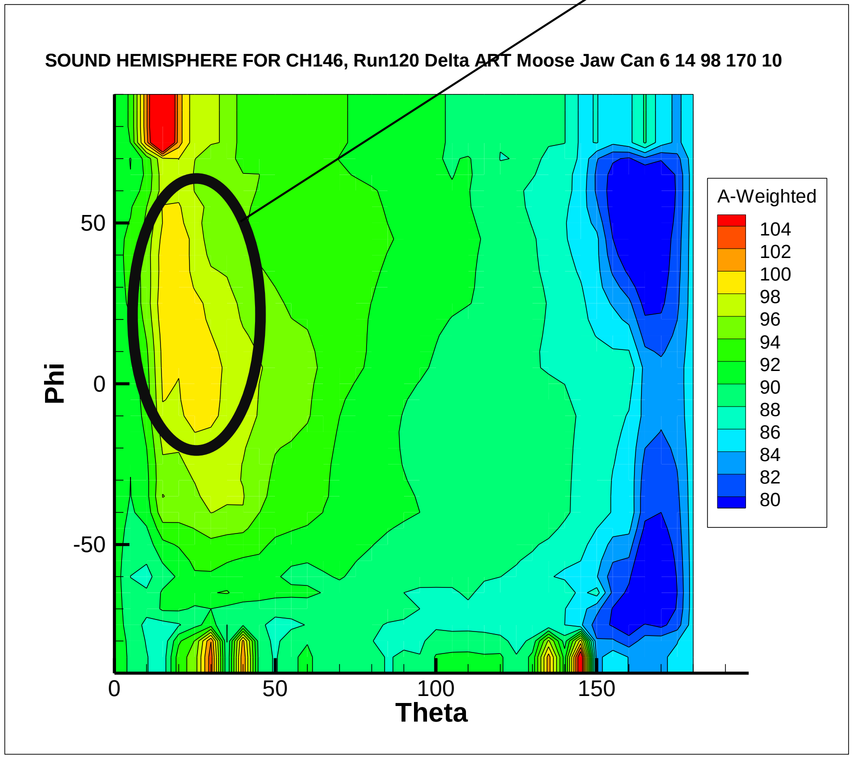
Metrics at Lateral POIs

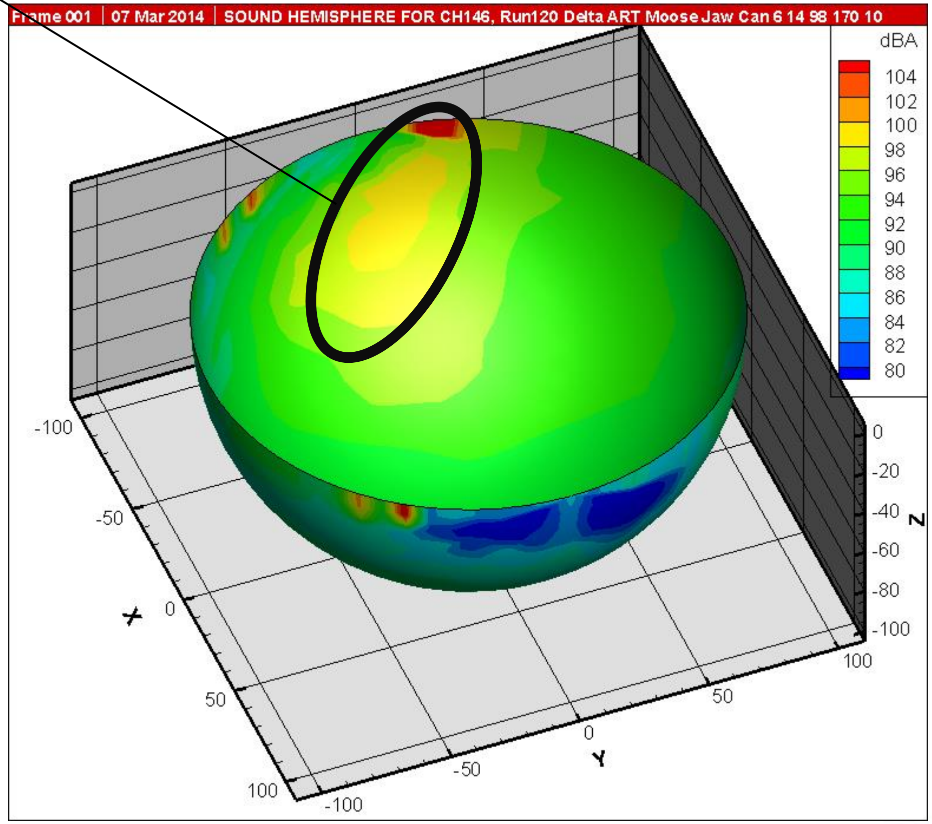
Lateral Source Directivity Mini-Trade

POINT OF INTEREST RESULTS - High Speed, 128 kts (Sphere 112)																				
	Lmax				SEL				SEL				EPNL				PNLMAX			
POI	(dBA)				(dBC)				(dBA)				(dB)				(dB)			
(feet)	All Phi	30-Deg	45-Deg	MaxDelta	All Phi	30-Deg	45-Deg	MaxDelta	All Phi	30-Deg	45-Deg	MaxDelta	All Phi	30-Deg	45-Deg	MaxDelta	All Phi	30-Deg	45-Deg	MaxDelta
-25000	33.3	32.9	33.0	0.4	75.1	75.2	75.1	0.1	53.1	52.8	52.9	0.3	54.5	53.9	54.1	0.6	46.1	45.4	45.6	0.7
-6300	64.3	54.9	56.7	**9.4**	86.4	87.0	86.8	0.6	75.3	72.4	72.8	2.9	77.4	75.7	76.1	**1.7**	75.1	67.6	69.3	**7.5**
-2000	67.8	68.0	67.7	0.2	93.5	93.1	93.3	0.4	82.0	81.9	82.3	0.3	84.3	83.9	84.8	0.5	80.5	79.9	80.7	0.6
0	74.5	74.5	74.5	0.0	95.1	95.1	95.1	0.0	84.9	84.9	84.9	0.0	87.8	87.8	87.8	0.0	89.8	89.8	89.8	0.0
2000	64.6	64.7	64.8	0.2	90.6	90.6	89.7	0.9	78.7	78.8	78.5	0.2	81.0	81.0	80.2	0.8	77.6	77.3	77.5	0.3
6300	52.2	52.2	52.5	0.3	82.7	83.1	82.9	0.4	68.7	69.1	69.1	0.4	71.3	71.8	71.9	0.6	64.8	65.2	65.1	0.4
25000	31.0	30.8	30.9	0.2	71.6	71.7	71.7	0.1	51.1	50.9	51.0	0.2	51.3	50.8	51.0	0.5	42.3	41.5	41.8	0.8

Explanation of Metric Asymmetry

Noise metrics vary due to non-symmetric radiation patterns





Lateral Source Directivity Mini-Trade

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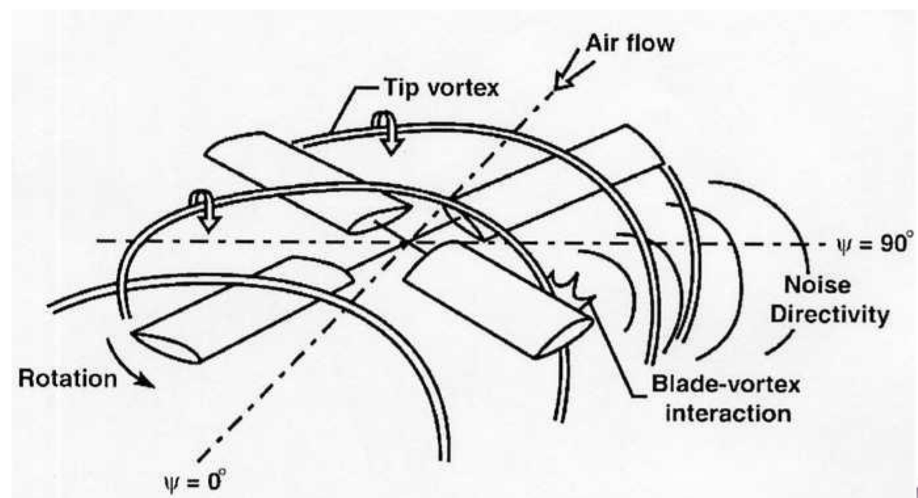
Condition Specific Spectral Requirements

- Noise generated by helicopter is specific to configuration and flight condition
  - Blade Vortex Interaction (BVI) noise spectrally different from non-BVI landing approaches
  - Directivity patterns differ between impulsive noises and standard ops noises.

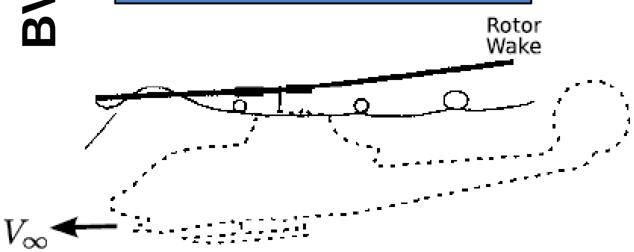


BVI: Descent Phenomena

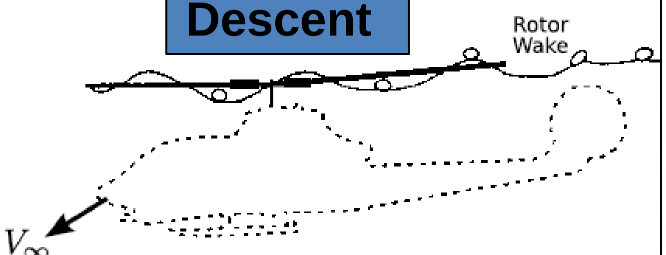
- BVI common during approach
- Loading, FPA, drag/thrust angle affect BVI
- Configuration Specific

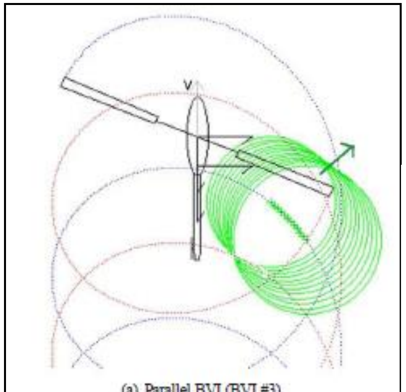
BVI Mini-Trade

Forward Flight

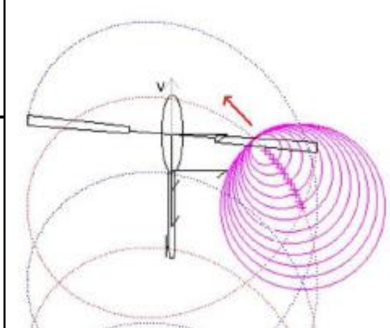


Descent



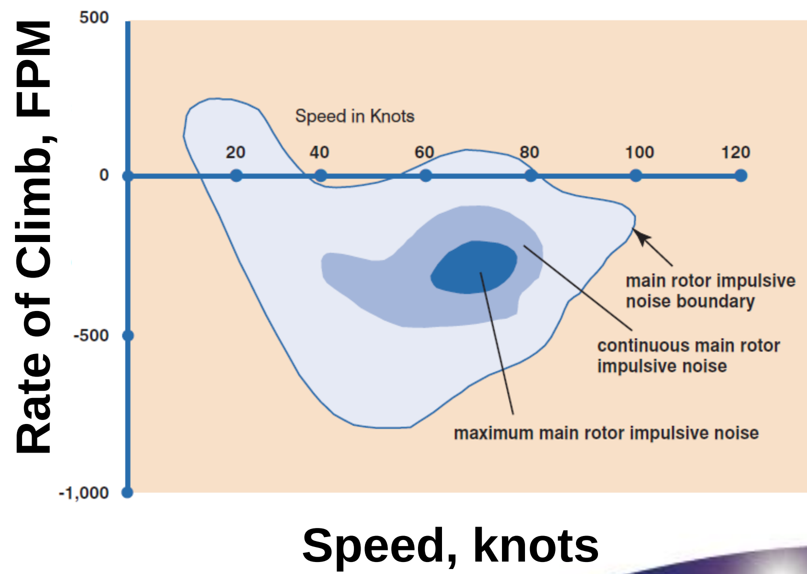


Parallel BVI



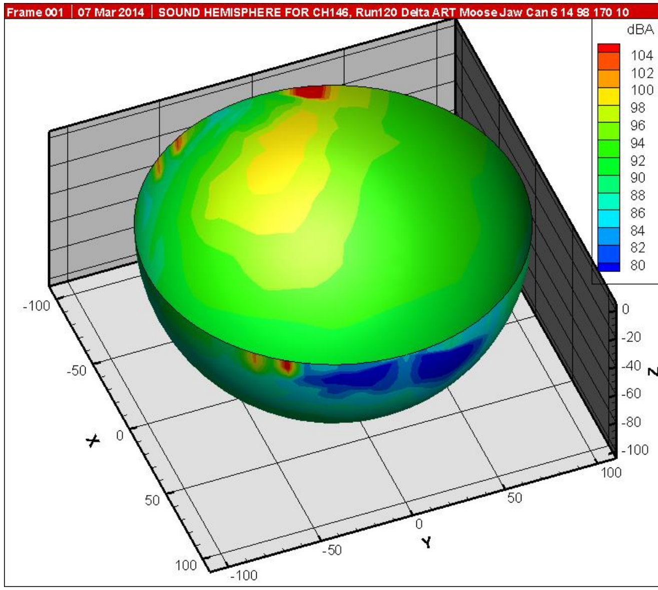
Oblique BVI

Impulsive Noise Flight Boundary



Noise Spheres: BVI Evident

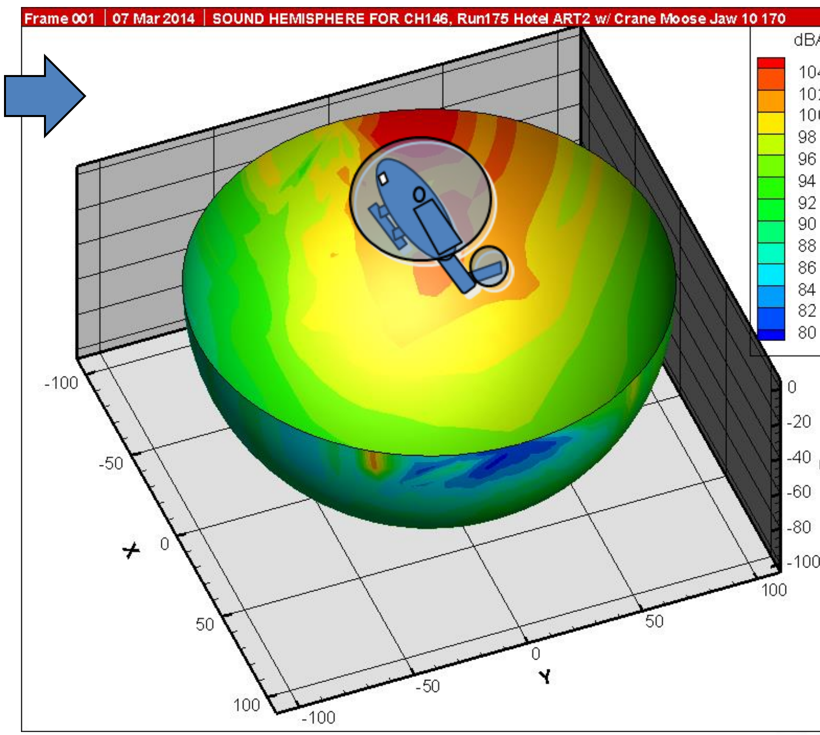
BVI Mini-Trade

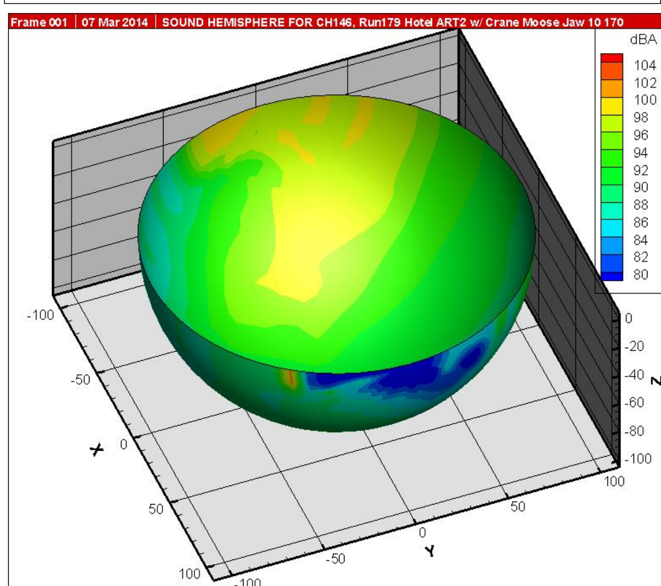


3 degree approach sphere 120

(max BVI)

6 degree approach sphere 175

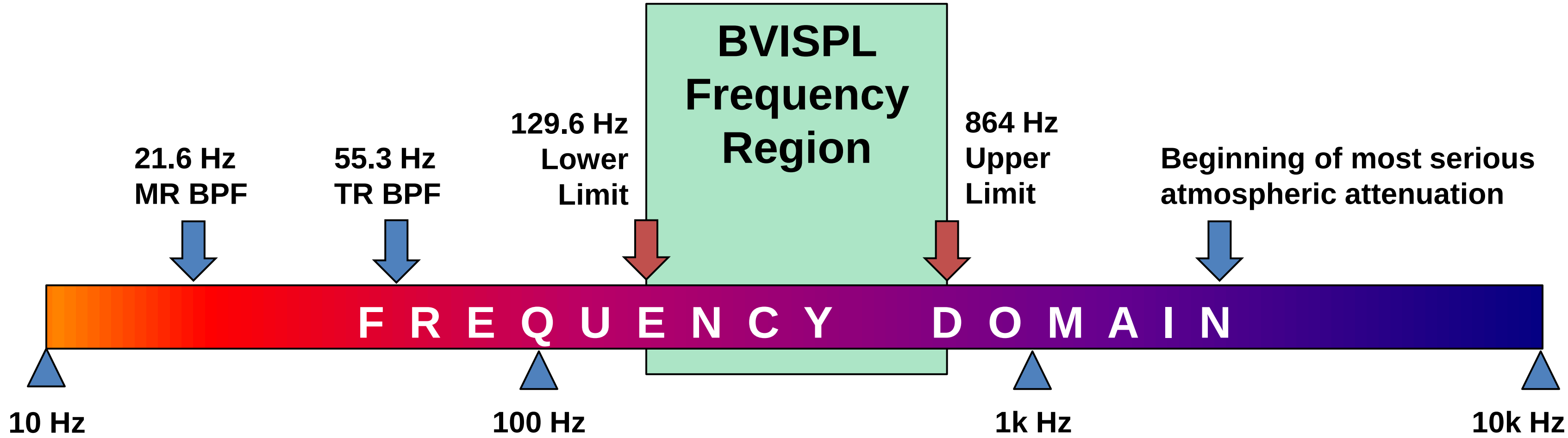




9 degree approach sphere 179

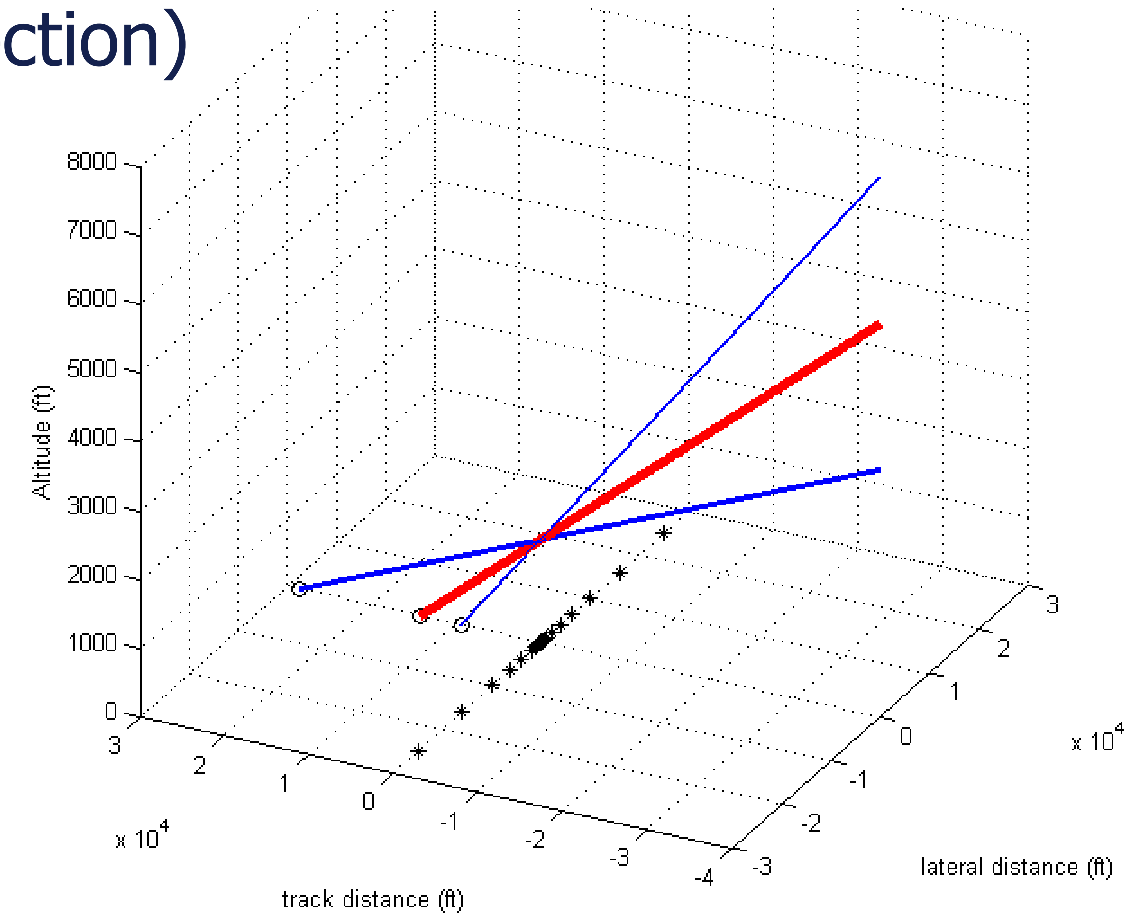
Metric: BVISPL

- SPL of spectral data for third octave bands containing frequencies from the 6th to the 40th main rotor harmonic (Ch146/Bell 412 shown)
- Isolates MR



Analysis Approach

- Three approach angles, three spheres
- Single approach angle, three spheres (forced selection)

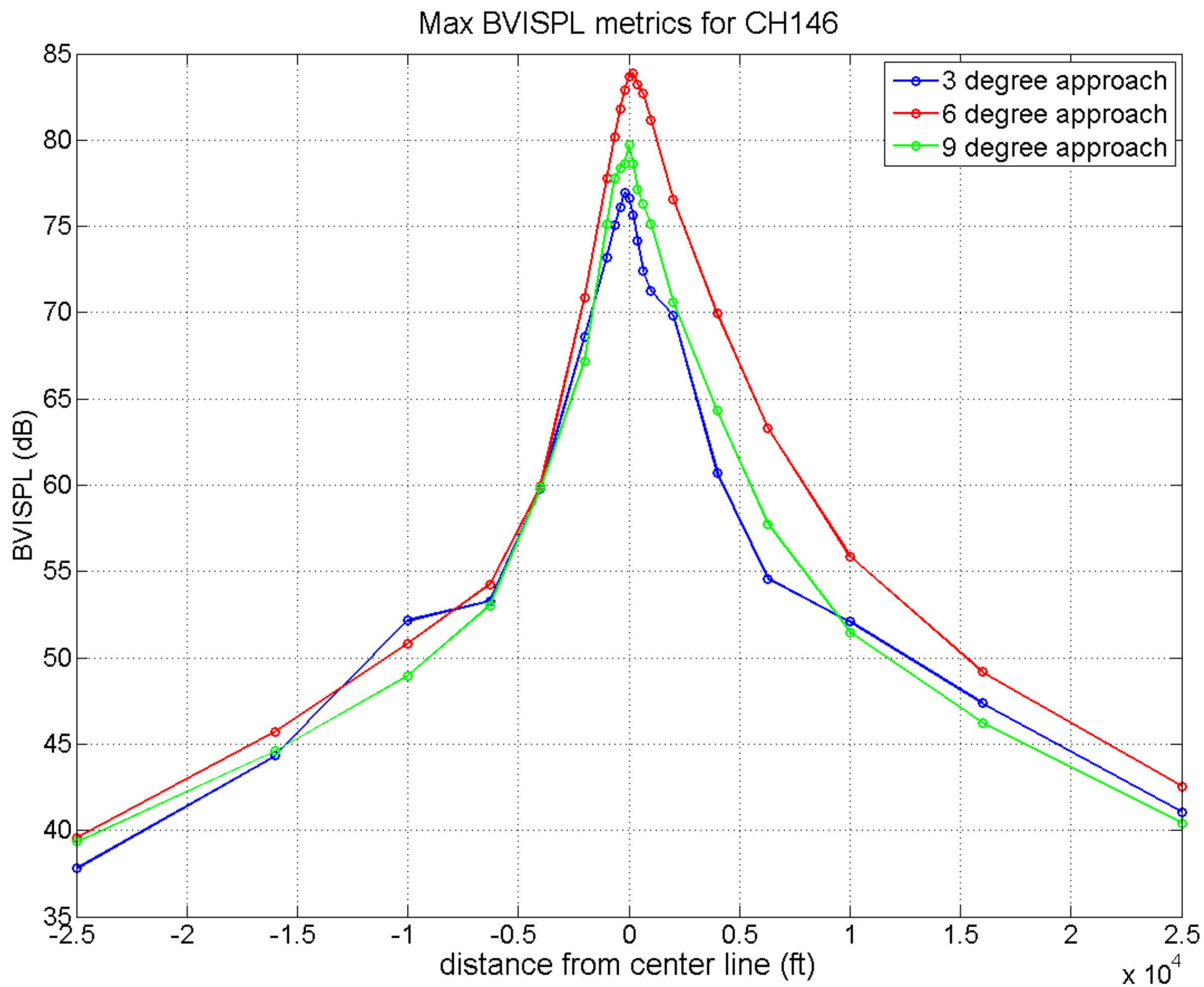


BVI Mini-Trade

3 App, 3 spheres: Max BVISPL

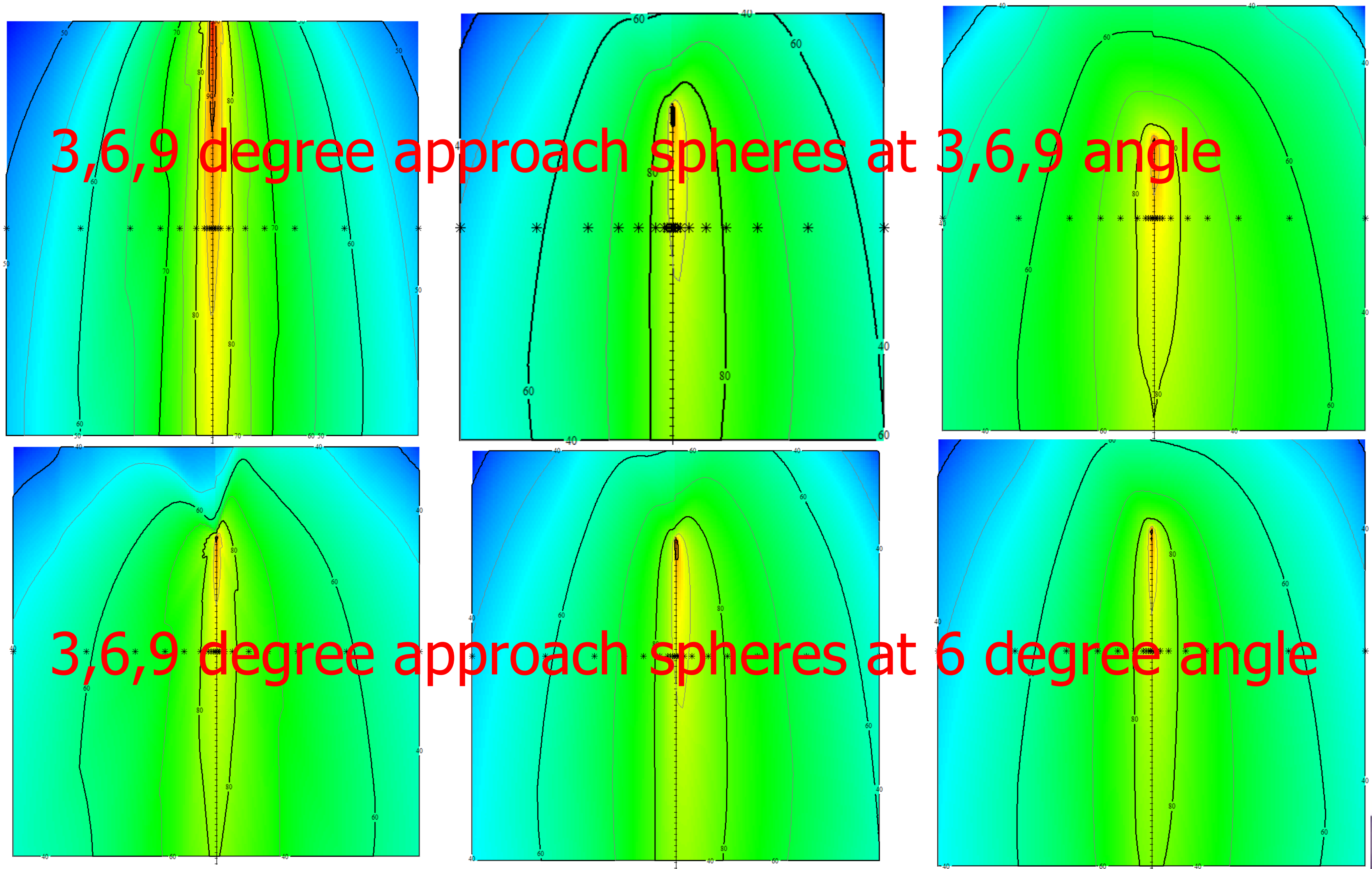
BVI Mini-Trade

- **Significant energy in BVI bands during 6 degree approach**
- **BVI mitigation strategies involve 'flying around' BVI flight profile. Needs to be captured in modeling!**
- **Need to capture directivity beyond 45º (1500ft)**



6 deg, 3 spheres: Max BVISPL

BVI Mini-Trade



Discussion

- Series of Mini-Trade Studies Underway
- Preliminary Helicopter and Tiltrotor Modeling Recommendations will be developed by the Team and reviewed by the ACRP Panel
- White Paper will be produced and provided to the International Rotorcraft Community for Feedback
- Study outcome will be a document ready for Standards Committee Review (SAE document)

Got data? ☺