

Background and Motivation

- It may be possible to fly at speeds between Mach 1 and 1.15 wherein the sonic booms do not reach the ground.
- Mach cut-off depends on atmospheric refraction to bend the sound upwards.
- This research aims to assess the possibilities for Mach cut-off flight over land.



[Diagram courtesy NASA; adapted from Maglieri et al. "Measurements of Sonic Boom Signatures From Flights at Cutoff Mach Number." NASA SP-255 (1971).]

Methodology

Sensitivity Analysis with PCBoom

- PCBoom run with a wide range of atmospheric profiles
- Effect of temperature profile on cut-off conditions analyzed
- Interactions between temperature and humidity studied

Laboratory Scale Model Design

- Laboratory-scale experiment designed for Mach cut-off
- Ultrasonic transducer identified as potential shock source
- Gel layers proposed to simulate stratified atmosphere
- Feasibility demonstrated through scaling of each component

Enhanced Ray-tracing Capabilities

- Mach cut-off operation predicted using ray tracing method
- Predictions benchmarked with existing code (PCBoom)
- Modeling includes vertical winds and horizontal variation
- Predictions run for a variety of test cases

Human Subjective Study Design

- Perceptual study divided into descriptor and annoyance tasks
- Database of recordings analyzed for inclusion as stimuli
- Facility capabilities expanded
- Descriptor task study designed

Project 42 Acoustical Model of Mach Cut-off Flight

Georgia Tech Sensitivity Analysis with PCBoom

Standard Atmospheric Profiles: GT investigated the impact of temperature profiles on cut-off conditions for vehicle flying at 45,000 ft (13.7 km) and Mach 1.1



flying at 45,000 ft (13.7 km) and Mach 1.1 to observe sensitivity of cut-off conditions to real-world atmospheric conditions, including temp. inversions







Values that should maintain similar scaling			
	Atmosphere	Water tank	Scale
Duration	0.15 s	10 ms	15000:1
Propagation dist.	17 km	1.5 m	11000:1
Shock risetime	10 ms	100 ns	10000:1
Turbulence scale	0.01-1000 m	1 mm - 100mm	10000:1
Values that should be about equal			
Waveform	$ \begin{array}{c} 1.0 \\ 0.8 \\ 0.6 \\ 0.4 \\ 0.2 \\ 0 \\ -0.2 \\ -0.4 \\ -0.6 \\ -0.8 \\ -1.0 \\ 0 \\ 0.04 \\ 0.08 \\ 0.12 \\ 0.16 \\ 0.20 \\ \hline \text{Time, s} \end{array} $	B C M O SSE C M O SSE C O O O O O O O O O O O O O	Similar
Pressure/rc	100 Pa/415=.25	1 MPa/1.5e6=.6	0.5:1
Sound speed range	295-340 m/s (10-15%)	1450-1600m/s (10%)	1:1
Attenuation	Neglected or 2nd order	Neglected or 2nd order	Similar
Dispersion	Neglected or 2nd order	Neglected or 2nd order	Similar

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EFFECT OF TEMPERATURE PROFILES ON CUT-OFF CONDITIONS



Custom Atmospheric Profiles: GT executed study for vehicle







Descriptor Task Procedure

- Subwoofers designed for existing facility
- Low-frequency capabilities improved

• Subjects will develop their own list of descriptors • Subjects then rate stimuli on their given list of descriptors • Factor analysis will be used to find commonalities across lists

Conclusions

• The cut-off Mach number is sensitive to variations in humidity, temperature, and wind speed profiles. - Wind speed may significantly affect cut-off Mach number. Laboratory scale experiments are possible. Human perception will be investigated in the coming period.