Human Response to Sonic Booms

FAA Workshop on Civil Supersonic Aircraft

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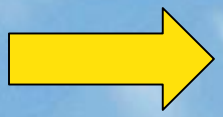
KNOWLEDGE GAINED FROM SST/CONCORDE/MILITARY

- Extensive measurements of far field booms
  - primary, secondary, focused
- Extensive measurements of building vibrations
  - including estimated probability of damage
- Subjective ratings of single events (indoors and outdoors)
- Community response to “staged” sonic boom exposures
- “Complaints” due to Concorde secondary booms (Dp< 0.5 psf)



- No overland commercial supersonic operations
- Military confined to restricted areas/corridors

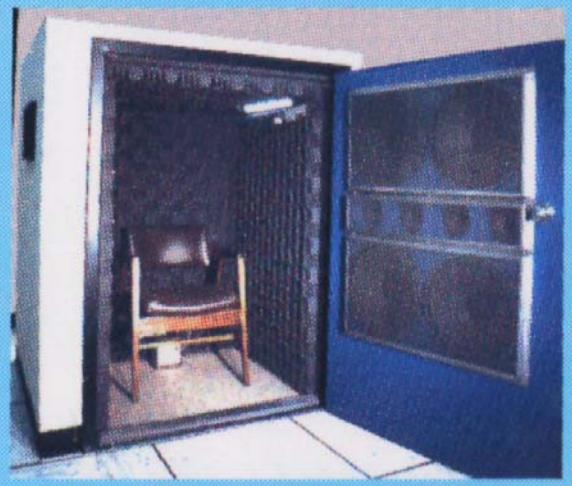
Previously Proposed Sonic Boom Loudness Criteria

Equivalent N-wave Exposure

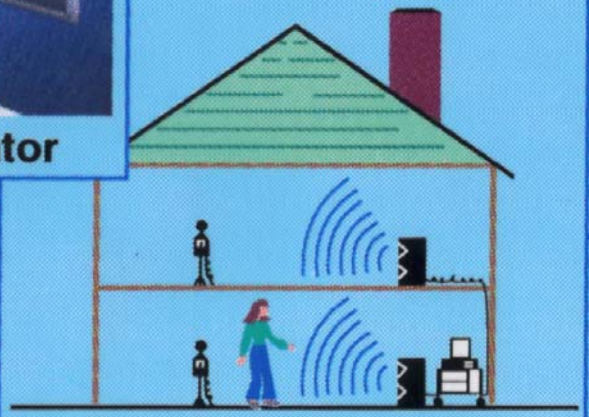
	Dp, psf	N/day	
EPA "Levels" Document	0.26	8	8%annoyed
	0.52	4	
	1.04	0.5	
ANSI S12.4 (CDNL=54dB)	0.5	4.8	5% h. annoyed
	1.0	1.2	
(CDNL=64dB)	0.5	48	20% h.annoyed
	1.0	12	
Boeing (corridors, 72dBA)	0.6	?	Acceptable
McD. Douglas (90PLdB)	0.7	?	Acceptable
Rolls Royce	0.5	?	80% acceptance

SONIC BOOM ACCEPTABILITY CRITERIA

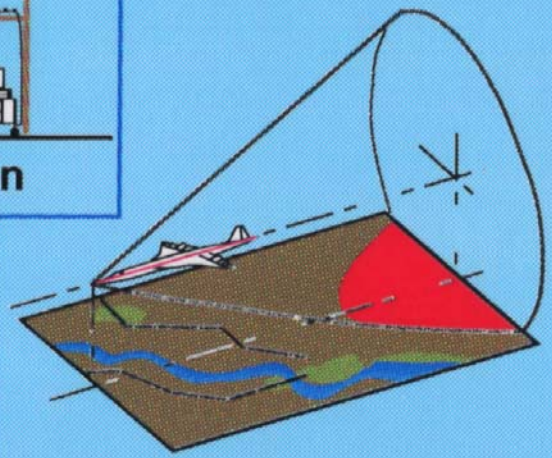
High Speed Research Program
Three Element Approach



Sonic boom simulator



In-home simulation



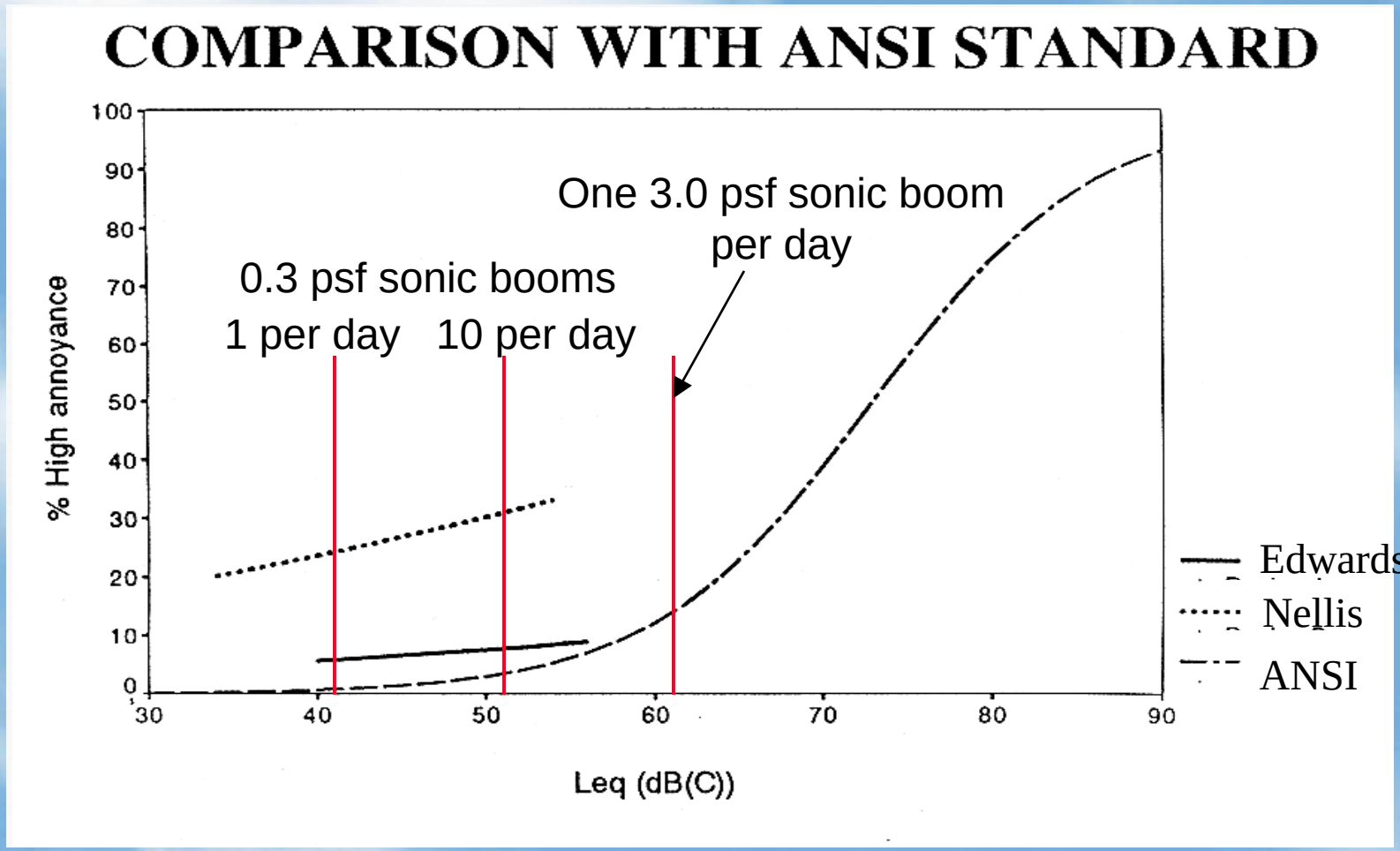
Community response

Summary of HSR Program Findings

- Validated loudness prediction method
  - provide guidance to low-boom design efforts
- Energy addition theory (Leq) valid for booms and small #'s events
- Perceptible building vibration occurs at all boom amplitudes
- Acceptable level of sonic boom exposure not determined
  - large variation between individuals & communities
  - "attitudes" are of primary importance.

HSR Community Exposure Study Findings

Agreement with Standard Depends on Public Attitude



AIRCRAFT & AIRPORT NOISE CRITERIA DEVELOPMENT
A Brief History, and a Search for a Model

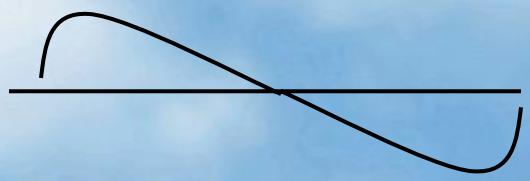
- Introduction of jet a/c led to numerous laboratory studies of aircraft noise annoyance and airport studies of noise and community impact.

- Aircraft noise certification (FAR 36) in 1969 (EPNL, dB)
  - Noise Level = *F* (Aircraft Weight, # engines)
  - Stage lll in 1975
  - Stage ll phase-out in ‘00, Stage lV in ‘06

- During 1970’s criteria developed for community noise levels due to transportation sources.
  - Dose (Leq/Ldn) - response (%highly annoyed) relationship
  - FAA select 65dB (Ldn) as boundary of significant impact
  - EPA proposed 55dB (Ldn) to protect health & welfare

Are SONIC BOOMS like AIRPORT NOISE?

- Impulsive noise
  - Energy concentrated in small DT
  - Peak energy at sub-audible frequencies
- Human response:
  - loud (high SPL)
  - startle
- Building Response
  - vibration/rattle
  - damage
- Infrequent projected exposure
- Little public experience

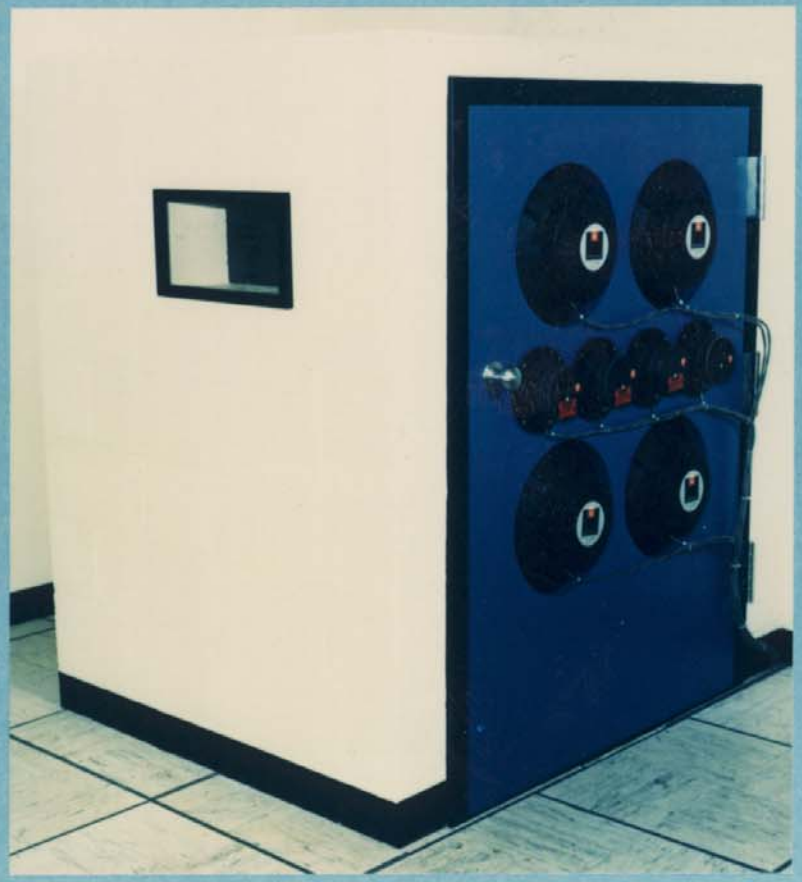


Elements of an Approach to Public Acceptance

- Determine community response to “low boom” signatures
  - relative contributions of auditory and vibratory components
- Validate sonic boom mitigation technologies in flight
- Understand political considerations
  - Public recognition of need for supersonic flight
  - Modification of Rule barring Supersonic flight overland
- Maintain awareness of other potential environmental constraints
  - -Endangered Species Act,
  - -Marine Mammal Protection Act

BACK-UP SLIDES

SONIC BOOM SIMULATOR



SONIC BOOM SIMULATOR STUDIES SUMMARY

- **Loudness model validated for:**
  - **wide range of ideal N-waves and shaped booms**
  - **“indoor” N-waves and shaped booms**
  - **ground-reflected booms**
  - **“real” booms distorted by atmosphere**

- **Major findings:**
  - **substantial benefits of boom shaping (indoors and outdoors)**
  - **reflected booms equal to or better than ground-level booms**

IN-HOME SIMULATION
System Components

IN-HOME SIMULATION EXPERIMENT

Findings:

_____- Equal-energy theory validated (i.e Leq)

- “Loudness” metrics are best annoyance predictors

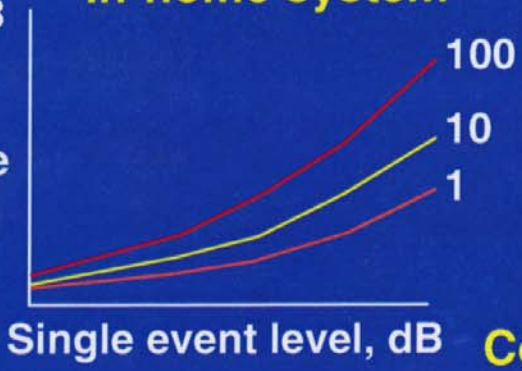
- Startle is highly correlated with high annoyance

- “In-home” annoyance less than that found in field settings at same exposure.

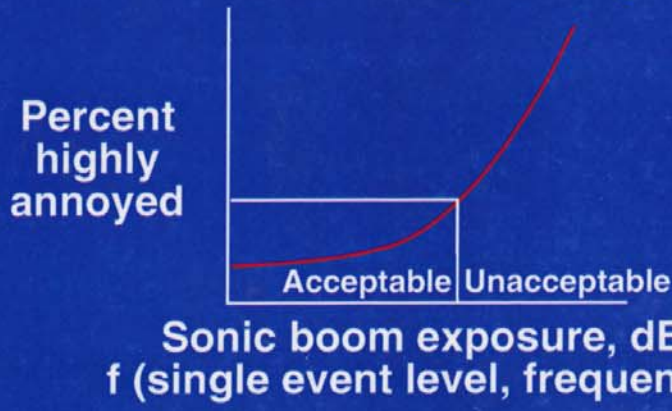
SONIC BOOM CRITERIA DEVELOPMENT

Sonic boom simulators

In-home system



Community surveys



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SONIC BOOM COMMUNITY SURVEY

Design Summary

- **Sites: Nellis (6 communities) - Phase 1 Oct '92 - May '93**
  Phase 2 May '93 - Dec '93
  Edwards (8 communities) - April '95 - Nov '95

- **Sonic Boom Exposure measured for 6 months prior to interviews.**
  Highest exposure - 2 booms/day; 1/week > 2 psf
  Lowest exposure - 1 boom/20 days; 1/100 days > 2 psf

- **Face-to-face questionnaire interviews - 1573**

NELLIS/EDWARDS COMMUNITY SURVEY

- ***Reported annoyance is <u>not</u> related to*:**

- Community characteristics (rural/ suburban, type of house construction)

- Respondent demographic characteristics (age, etc.; length of residence, commuting distance to work, employment by "noise maker")

- ***Reported annoyance is related to*:**

- Respondent attitudinal characteristics (importance of military, importance of supersonic ops. for defense, annoyance with other noises, importance of other environmental concerns, importance of developing supersonic commercial aircraft)

- Respondents' perception of other boom impact (startle, vibration, damage, fear of crashes)

SITE DIFFERENCES

- **Are <u>not</u> due to:**
  - **Noise measurement and survey administration errors**

- **Are, in part, due to:**
  - **Respondents' attitudes toward aircraft operators (pilots and officials could do more to reduce booms)**
  - **Respondents' annoyance with low-flying jet aircraft**

SUMMARY FINDINGS

"Boom Box" studies

- Loudness model validated for wide range of booms
- Substantial benefits of boom shaping

In-home studies

- Equal energy theory validated
- Loudness metrics are best annoyance predictor

Field studies

- Large variability between individuals and communities
- "Attitudes" are of primary importance

MARINE WILDLIFE AND SONIC BOOMS

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

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Objectives: **Determine behavioral effects of booms from Concorde on gray and harbor seals**

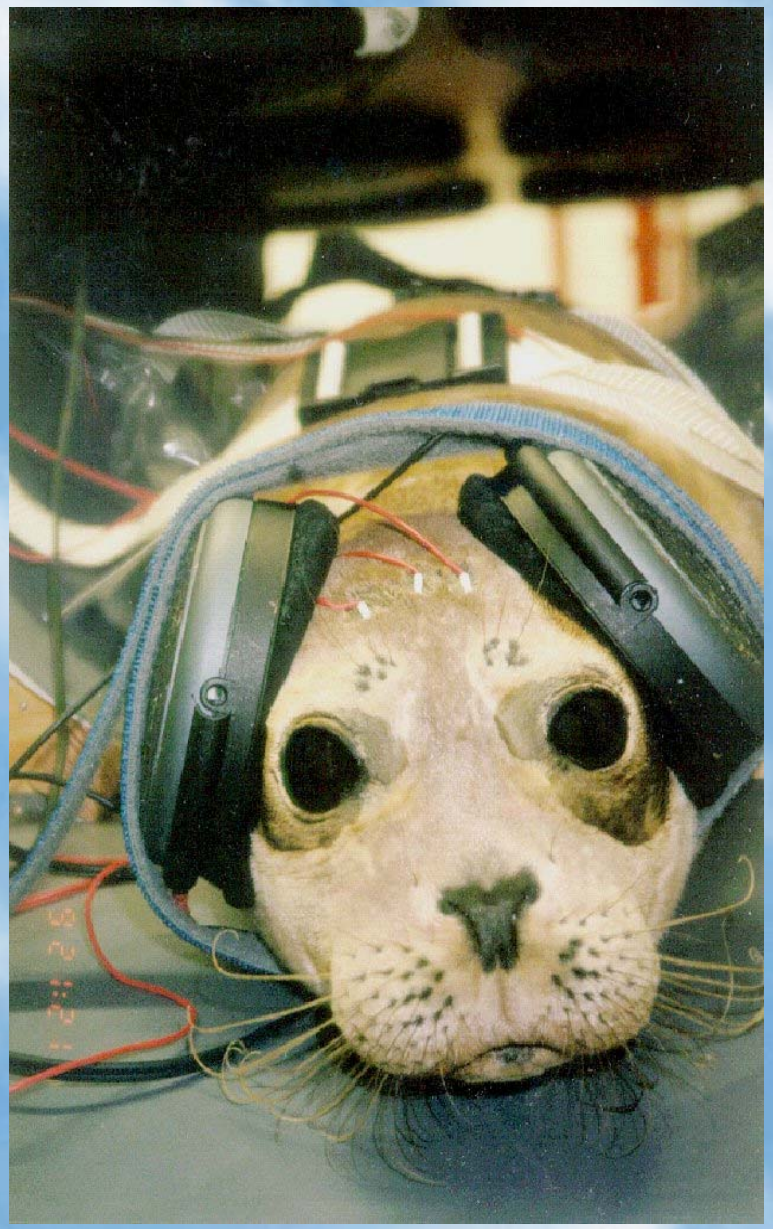
Accomplishments:

1. Behavioral data and boom data acquired from January '97 and June '98on Sable Island, Canada during gray and harbor seal breeding seasons
2. Three booms per day ranged from 0.1 to 2 p.s.f.
3. Based on extensive observational data (videotapes) and limited physiological data, sonic booms had no effect on gray seals: number of animals on beach, alertness, aggression, frequency of locomotion, nursing, and heart rate.
Minor effects for Harbor seals - increased vigilance, increased heartrate

Conclusions:

Observed effects are unlikely to affect either individuals or populations

Potential Hearing Damage from Simulated Sonic Booms



Approach:

• Develop physiological method to measure hearing threshold

• Measure threshold before and after exposure to simulated sonic booms

Results:

• Testing conducted for harbor seal, elephant Seals, and Ca sea lion

• Physiologically-determined threshold comparable with behavioral data

• No evidence of hearing loss for HSCT cruise booms