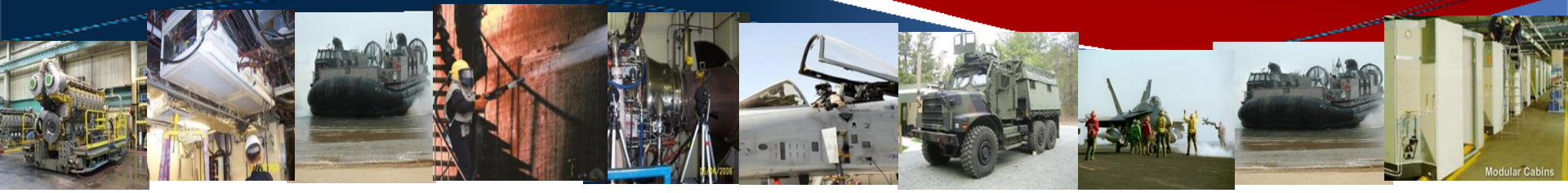

Noise Control Roadmap for Significant Noise Hazardous Operations in DoD

17th Annual Systems Engineering Conference
National Defense Industrial Association
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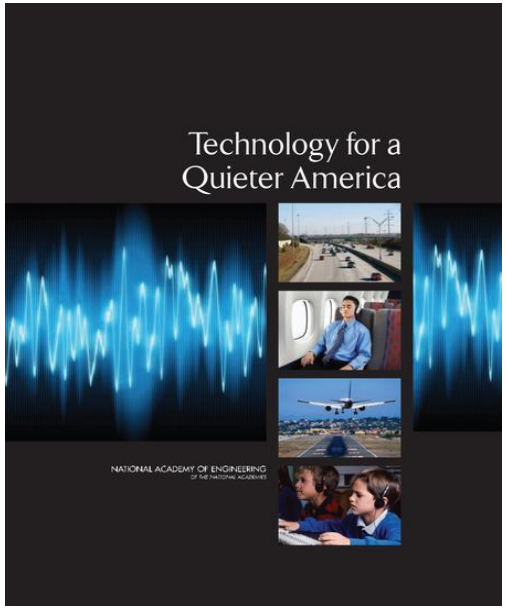
Objectives for this Session

- Describe the DoD High Noise Source Reduction Initiative, including methodology used by engineering experts and occupational safety and health professionals, and link to systems engineering.
- Discuss the noise source reduction concept design plans and how they will serve as roadmap for future noise control.
- Inspire you to help implement the roadmap.



Useful Links:

Noise Control Roadmap -DOD High Noise Source Reduction Initiative Technical Report (Noise Control Engineering, Inc.), Source Reduction Concept Design Plans, and Briefing Slides
http://www.public.navy.mil/comnavsafecen/Pages/acquisition/noise_control.aspx
Scroll down to Noise Control Technology

Noise Control Poster- "An Investigation of Potential Intervention Strategies Involving High Noise Sources within the Department of Defense (DoD)":
http://www.public.navy.mil/navsafecen/Documents/acquisition/High_Noise_Red.pdf

Background

- Hazardous Noise is a long standing concern within DoD
  - Is the only known occupational hazard within DoD with exposure levels exceeding protection capability
  - Causes significant negative impact to the quality of life of our Service men and women

- Hearing loss is the most prevalent service-connected disability
  - Over 1.2M veterans received compensation payments in fiscal year 2009
  - Costs to the tax payer is in excess of $1 Billion annually
  - Is ranked #5 for DoD civilian worker compensation payout ($32M) in Chargeback Year 2012

Defense Safety Oversight Council (DSOC) High Noise Initiative Objectives

- Identify nine significant DoD high noise (steady-state) sources and one promising technology
- Utilize noise control experts and acoustical engineers to develop noise source reduction plans and evaluate projected return on investment that will serve as a roadmap for future noise control in acquisition.
- Evaluate the modular cabin/capsule/pod as a promising noise control technology

Shipboard Diesel System

Tracked Vehicle

Shipboard Gas Turbine

Wheeled Vehicle

Ship/High Speed Craft

Shipboard Equipment

Abrasive Blasting

Aircraft Operations

Cockpit Interior

Modular Cabin/ Capsule/Pod

Nine DoD High Noise Sources and One Promising Technology

Source	Low Level dB(A)	High Level dB(A)	Allowed Worst Case Unprotected Exposure
Shipboard Diesel Driven Systems	98	120	9 seconds
Shipboard Gas Turbines	85	101	12 minutes
Ships and High Speed Craft	85	126	2 seconds
Aircraft Carrier Operations – On-deck	115	167	Less than 1 second
Aircraft Carrier Operations-Internal Compartments	85	113	45 seconds
Tracked Vehicles	90	118	14 seconds
Wheeled Vehicles	85	112	57 seconds
Cockpit Interior	85	121	7 seconds
Shipboard Equipment	84	114	36 seconds
Abrasive Blasting	85	145	Less than 1 second
Modular Cabin/Capsule/Pod	70	70	Promising Technology

Basics of Acoustics

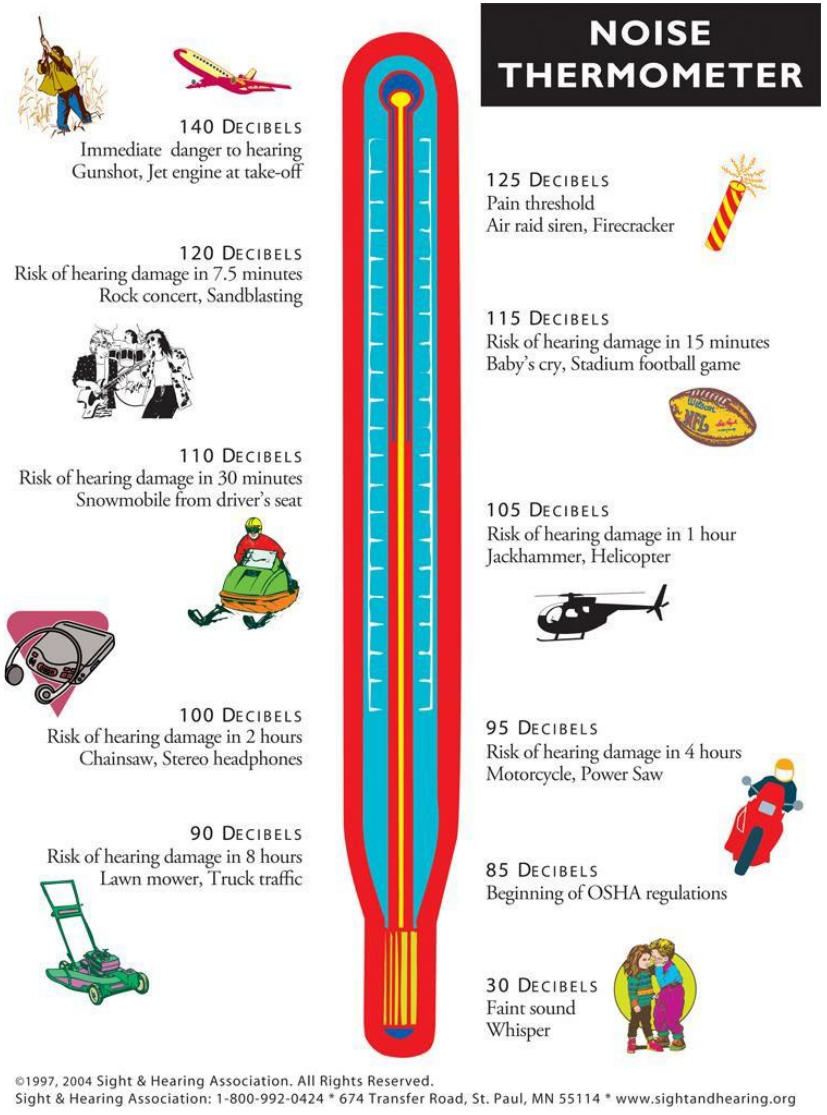
Sound is produced when a sound source sets the air nearest to it in wave motion. **Noise** is unwanted sound.

Physical Properties	Perception	Explanation
Frequency- described in Hertz (Hz)	Pitch	For hearing testing and noise control, frequencies are organized into octave bands or 1/3 octave bands and covers from 20 Hz to 20,000 Hz
Intensity level in Decibels (dB)	Loudness	(1) Usually expressed using an A-weighted scale which mimics the ear which hears less of the lower frequencies (2) The decibel was named after Alexander Graham Bell and was developed with 0 dB as the threshold of hearing, 85-90 dB as the threshold of discomfort, and 120-140 dB as the threshold of pain (3) Decibels are measured on a logarithmic scale
Duration as Time Weighted Average (TWA)	Length of time	Usually expressed as an 8 hour TWA of the exposure

Basics of Acoustics, cont.

Why these basics are important:

- Allowable noise levels are given as an 8 hour TWA
- Noise control is expressed as a reduction in dBs
- A 10 dB increase is subjective doubling of sound heard by the ear
- Two equal sources increase noise by 3 dB
- A dB increase is doubling by sound pressure squared-*and halving of the allowed exposure time (See next slide)*
- Hearing impairment compensation is determined by hearing reduction in dBs at various frequencies.



Exposure to Noise Without Hearing Protection

Noise Level Exposure Standard based on duration per day*:

Allowable Unprotected Sound Level (dBA)	Duration Per Day	Unit of Time Per Day
80	24	Hours
82	16	Hours
85	8	Hours
88	4	Hours
91	2	Hours
94	1	Hour
97	30	Minutes
100	15	Minutes
103	7.5	Minutes
106	3.75	Minutes
109	1.88	Minutes
112	0.94	Minute
115	28.12	Seconds
118	14.06	Seconds
121	7.03	Seconds
124	3.52	Seconds
127	1.76	Seconds

*This is the DoD Standard which is based on the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values for Noise

DoD Criteria for Component Hearing Conservation Programs DoDI 6055.12, December 3, 2010

Hearing Conservation Programs shall be implemented when:

- Continuous and intermittent noise levels at or above 85 dBA for an 8 hour TWA*
- Impulse noise sound pressure levels of 140 dBP (peak)
- Ultrasonic exposures (special circumstances)

Hearing Conservation Programs mandate engineering noise control as the primary method of achieving noise levels below DoD standards

*This project looked at steady state noise (continuous and intermittent), not impulse noise

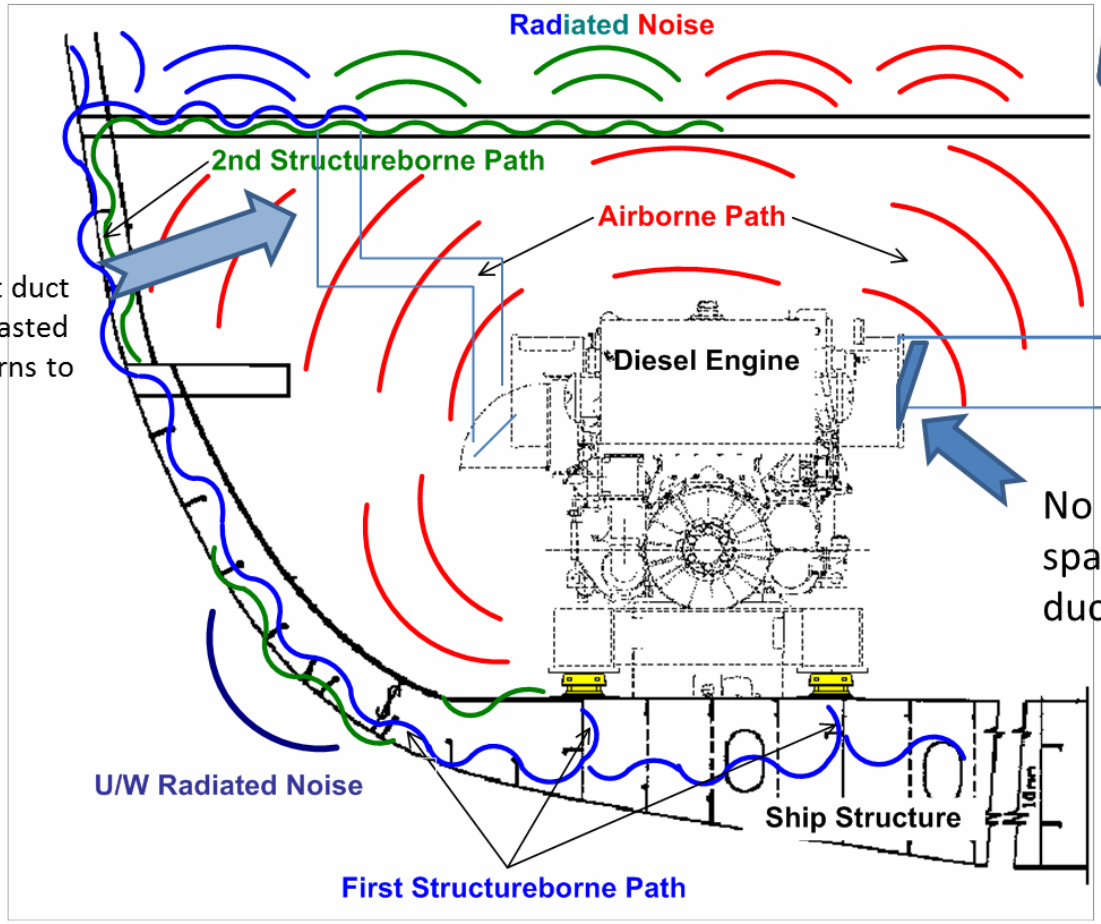
Type of Hearing Protection/Controls at Various dBA Levels

Service	Single	Double	Comments
Army	85*-103 dBA	>103-108 dBA	>108 dBA- Refer to DA PAM 40- 501
Navy	85*- < 96 dBA	≥ 96 dBA	≥ 96 dBA - Refer to BUMEDNOTE 6260 of 24 Apr 2014, that will be integrated into OPNAVINST 5100.23H and OPNAVINST 5100.19F
Marine Corps	85*- < 96 dBA	≥ 96 dBA	≥ 96 dBA - Refer to BUMEDNOTE 6260 of 24 Apr 2014
Air Force	85* dBA	Refer to AFOSHSTD48-20	Refer to AFOSHSTD48-20

*DoD Noise Standard for continuous/intermittent noise

Note: **Military Standard MIL-STD 1474D 'forbids' unprotected (i.e., without double hearing protection) exposure above 115 dBA because double hearing protection cannot provide sufficient protection to prevent permanent hearing loss.**

Noise and Energy Control are Systems Engineering Issues



Inefficient duct design :wasted energy turns to noise!

Poorly sized and installed fan

Inefficient duct design :wasted energy turns to noise!

No flexible spacer – duct rattles

DoD Criteria for Noise Control in Acquisition DoDI 6055.12, December 3, 2010

Acquisition Programs shall include implementation of noise assessment and engineering control measures through the systems engineering and system safety process as directed by DoDI 5000.02 when:

- Legacy systems have recognized exposure concerns at or above 85 dBA or 140 dB Peak
- New systems are considered likely to create noise exposures at or above 85 dBA or 140 dB Peak
- Communication is anticipated to be potentially impaired by background noise caused by new equipment

Initiative Evaluation Procedures

- Collected and established noise database for DoD sources, including
  - Physical parameters controlling noise
  - Operating conditions and utilization
- Established commercial off the shelf (COTS) and novel or advanced (non-COTS) noise control approaches
  - Possible noise reduction
  - Non-acoustic impact on space/weight/cost
- Estimated projected noise reductions with various treatments
- Recommended optimal noise reductions
- Estimated lifetime system hearing loss costs

Return on Investment (ROI)

$$ROI = \frac{(NIHL\ Cost\ Savings^* - Treatment\ Implementation\ Cost)}{Treatment\ Implementation\ Cost}$$

Noise Induced Hearing Loss (NIHL) Cost Savings* = Lifetime System Costs [audiograms, hearing aids, VA NIHL disability, VA tinnitus disability] without treatments — Lifetime System Cost with treatments.

Noise Induced Hearing Loss (NIHL) Cost Assessment Tool

Based on:

- American National Standards Institute-ANSI S3.44 & International Standards Organization-ISO 1990:1999
- The "should cost" model (Sachs 2007)* which assumes 100% compliance with the Navy Hearing Conservation Program and VA requirements (more expensive than "actual cost")

*Sachs, F.Z., Weathersby, P.K., Marshall, L., and Tufts, J., 2007, "Model for Estimating Life-Cycle Costs Associated with Noise Induced Hearing Loss," NSMRL Technical Report 1248, Naval Submarine Medical Research Laboratory, Groton, CT

http://www.dtic.mil/cgibin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA461439

NIHL Cost Assessment Tool Parameters

- Noise Level – Time-Weighted Average (TWA)
  - Representative source levels were established by averaging A-weighted sound pressure levels at various operating conditions across selected DoD platforms
  - Levels were normalized to an 8-hour work day, 5 day work week
- Number of systems
- Number of crew
- Service life of systems and crew
- Effectiveness of hearing protection
- Cost of audiograms, hearing aids & veterans' disability
- Estimated effectiveness and "cost" of treatments - materials and installation

Other Important Parameters Not Considered (Because Data Was Not Available)

- **Costs related to:**
  - Impact on crew performance and ability to perform
  - Health & social impacts
- **Benefits: Non-acoustic payback**
  - Less chance for “miscommunication" in a lower noise space.
  - Buy Quiet
    - Longer equipment life
    - Lower maintenance
  - Increased efficiency (particularly with Computational Fluid Dynamics (CFD))
  - Reduced weight/space when involved early in design

Bottom Line: Both costs and benefits are underestimated, making the ROIs an underestimation.

Nine DoD High Noise Sources and One Promising Technology

Source	Low Level dB(A)	High Level dB(A)	Allowed Worst Case Unprotected Exposure Time	Estimated Exposure Duration With Double Hearing Protection*
Shipboard Diesel Driven Systems	98	120	9 seconds	2.5 hours
Shipboard Gas Turbines	85	101	12 minutes	Unlimited
Ships and High Speed Craft	85	126	2 seconds	40 minutes
Aircraft Carrier Operations – On-deck	115	167	Less than 1 second	Less than 1 second
Aircraft Operations – Internal Compartments	85	113	45 seconds	12 hours
Tracked Vehicles	90	118	14 seconds	4 hours
Wheeled Vehicles	85	112	57 seconds	16 hours
Cockpit Interior	85	121	7 seconds	2 hours
Shipboard Equipment	84	114	36 seconds	6 hours
Abrasive Blasting	85	145	Less than 1 second	28 seconds
Modular cabin/ Capsule/Pod	70	70	Promising Technology	Promising Technology

* This is an estimate using 30 dB reduction for double hearing protection, realizing it may be a conservative best case scenario.

Typical Treatment Effectiveness

Treatment	Airborne Noise Reduction, (dB)	Structureborne Noise Reduction, (dB)
Vibration Isolation	0	10-25
Acoustic Absorption	5-7	0
High Transmission Loss	5-12	0-7
Damping	0	5-12
HVAC Treatments	5-15	0
Active Control	5-10	10-20
Pod/Module	10-20	10-15
Acoustic Design	15-25	15-25
Computational Fluid Dynamics	5-12	5

Shipboard Diesel Driven Systems
Noise Source and Controls

Noise Sources: Very high level, broadband noise and vibration sources due to combustion process and lube/cooling subsystems. Diesels tend to induce high noise at low frequencies (below 100 Hz) due to their low rotation rate and firing rate components. Noise levels can exceed the protection capability of ear muffs and ear plugs.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 98-120 dBA

Worker Exposure Time Per Day Allowed Unprotected : 9 seconds @ 120 dBA and 24 minutes @ 98 dBA

Noise Controls:

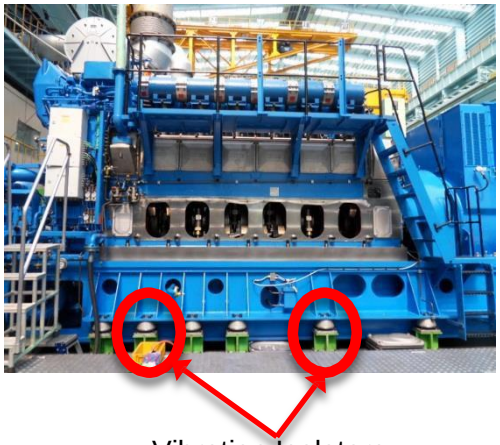
	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Walk-in enclosures (15 dB) • Cladding (2-3 dB) • Buy Quiet (3-10 dB)	• Reduce radiation from engine block (3-10 dB) • Active control of intake/exhaust (low frequency) (10-15 dB)
Structureborne Noise Control	• Vibration isolation (10-20 dB) • Hi-Impedance foundations (5-8 dB)	• Active Control – low frequency vibration (almost COTS) (15-25 dB) • Hydraulic mounts (active/passive nonlinear system) (5-10 dB) • Passive tuned 'structural' absorber (5 dB)

Shipboard Diesel Driven Systems
Pictures of Noise Controls

Noise Sources: **Diesel casing, turbocharger, intake/exhaust system, sea water cooling & lube systems.**

Noise Controls:

Enclosure

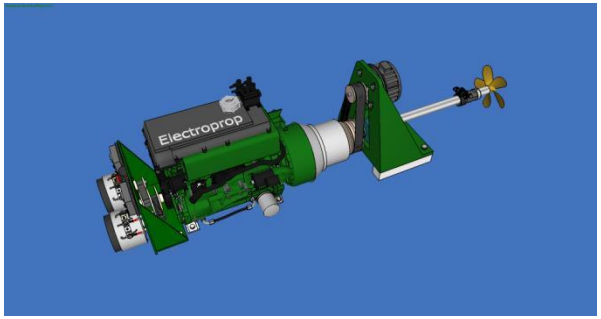


Vibration Isolators

Bulkhead/Deck Cladding

Fiberglass
Limp mass layer
Fiberglass

Hybrid Electric Drive



www.propulsionmaine.com

Shipboard Diesel Driven Systems
Summary and Justification

Feasibility : **Yes, noise control is feasible.**

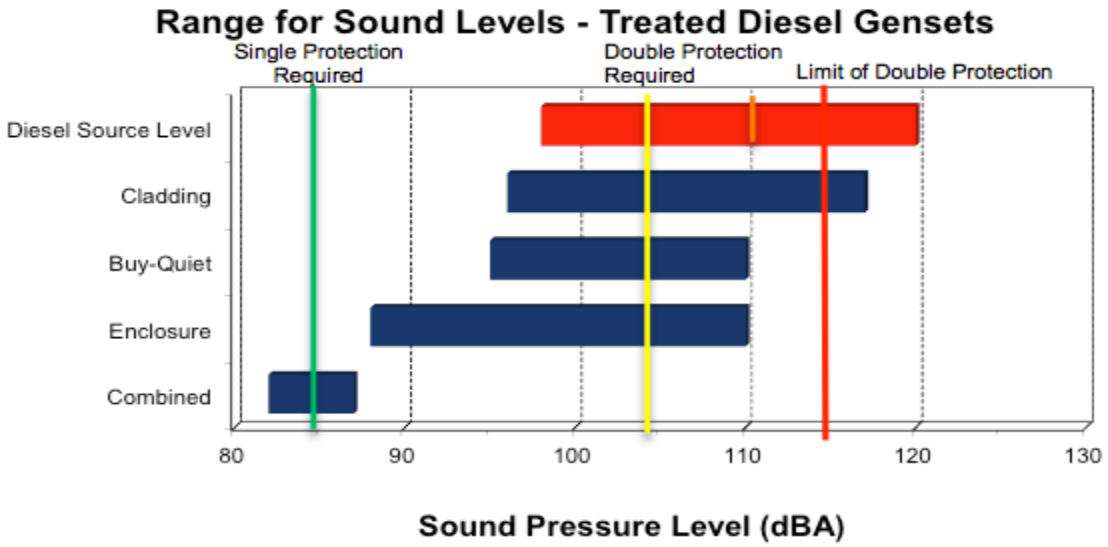
Estimated Number of DoD Acquisitions (Ships): **1095**

Estimated number of workers (Military and Civilians) Exposed: **26,280**

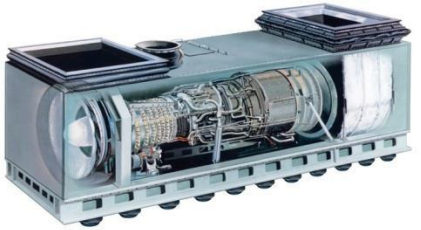
Return on Investment (ROI): **0.2:1 to 4:1; NIHL cost reduction = $775 M**

Graph showing Noise Before and After:

Source Level Used – 107 dBA
TWA Source Level Used – 110 dBA



Shipboard Gas Turbines
Noise Source and Controls



Noise Sources: High level, broadband noise and vibration sources due to combustion process. Gas turbines tend to induce high noise at mid- to high frequencies (above 500 Hz) due to high number of compressor blades operating at high rotation rates. Extensive intake/exhaust systems affect multiple spaces. Hearing loss in engine room can be prevented by protection capability of ear muffs and ear plugs; however, high noise at deck stations cannot be abated without special communications.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-101 dBA

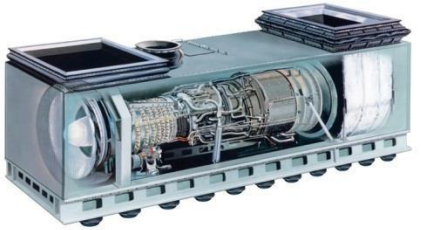
Worker Exposure Time Per Day Allowed Unprotected : 12 minutes @ 101 dBA and 8 hours @ 85 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Enclosure cladding (5-10 dB) • Intake/exhaust cladding (10-12 dB) • Cooling fan/duct cladding (10-15 dB) • Computational fluid dynamics (CFD)[1] (2-15 dB)	• Active control within enclosure (3-10 dB) • Active control of intake/exhaust (low frequency) (5-10 dB)
Structureborne Noise Control	• Vibration isolation (10-15dB) • Hi-Impedance foundations (5-8 dB)	• Active Control – low frequency vibration (almost COTS) (15-25 dB) • Hydraulic mounts (active/passive nonlinear system (5 dB) • Passive tuned ‘structural’ absorber (5 dB)

[1]Affecting on-deck stations and internal compartments

Shipboard Gas Turbines
Pictures of Noise Controls

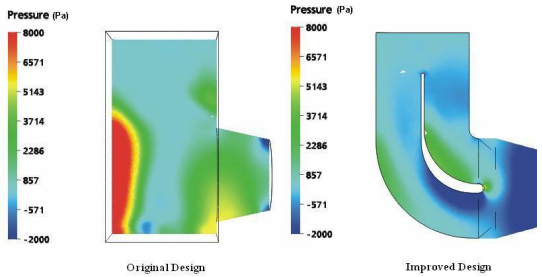


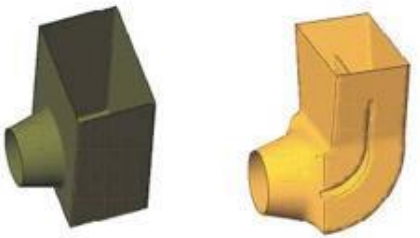
Noise Sources: **Gas turbine, cooling air supply fan and duct, intake/exhaust ducting**

Noise Controls:

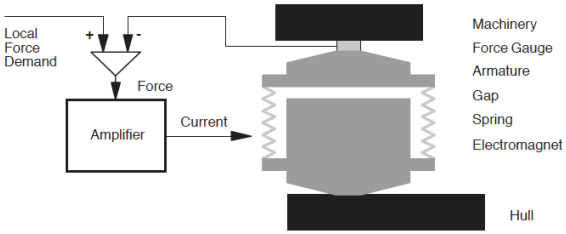
Enclosure

CFD



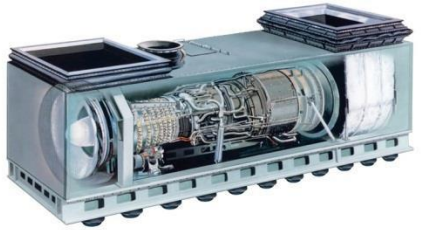


Example of Active Low Frequency Vibration Mounts



Example of machinery isolation mounts

Shipboard Gas Turbines
Summary and Justification



Feasibility : **Yes, noise control is feasible.**

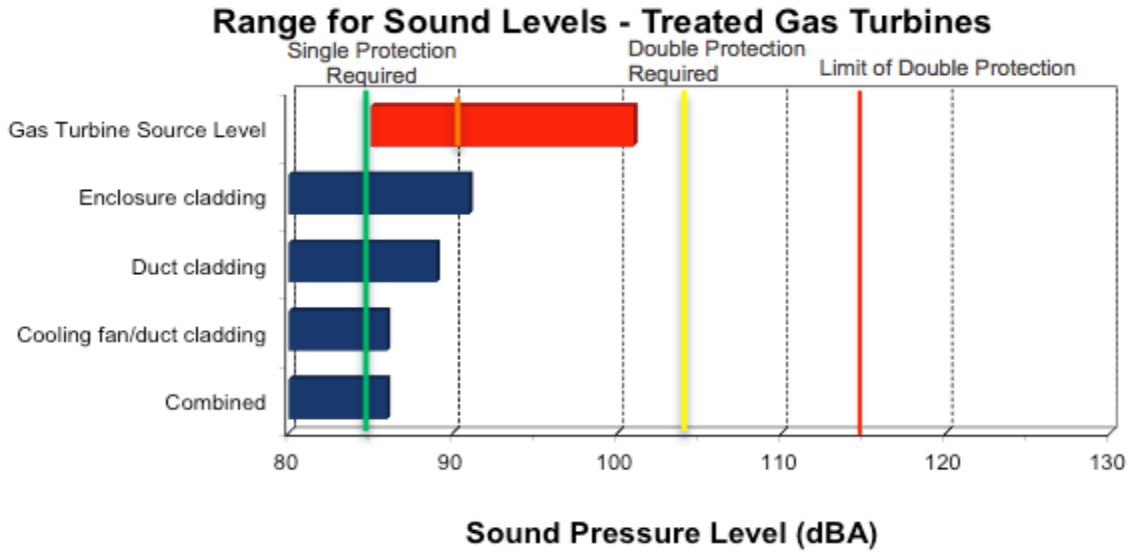
Estimated Number of DoD Acquisitions (Ships): **510**

Estimated number of workers (Military and Civilians) Exposed: **15,173**

Return on Investment (ROI): **0.2:1 to 2:1; NIHL cost reduction = $38.5 M**

Graph showing Noise Before and After:

Source level used – 87 dBA
TWA Source Level Used – 90 dBA



Ships and High Speed Craft
Noise Source and Controls

Noise Sources: Very high level, broadband noise and vibration sources on craft with high power to weight ratios. Unique propulsion systems – fans, water jets, thrusters, etc. Crew in close proximity of high noise and vibration and low transmission loss constructions. Noise levels above 126 dB exceed the protection capability of ear muffs and ear plugs.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-126 dBA

Worker Exposure Time Per Day Allowed Unprotected : 2.3 seconds @ 126 dBA and 8 hours @ 85 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• High transmission loss (TL) Constructions (15 dB) • Buy Quiet (3-7 dB) • Damping (2-10 dB) • CFD fan/thruster design (2-15 dB)	• Improved light-weight high TL materials (3-10 dB) • Combination of thermal/fire/acoustic materials (5-10 dB)
Structureborne Noise Control	• Vibration isolation (10-15dB) • Hi-Impedance foundations (5-8 dB) • Passive vibration absorbers (10-15 dB)	• Active Control – low freq. vibration (almost COTS) (15-25 dB) • Passive tuned 'structural' absorber (5 dB)

Landing Craft Air Cushion (LCAC) fan from militaryfactory.com

Ships and High Speed Craft
Pictures of Noise Controls

Noise Sources: **Diesel casing, turbocharger, intake/exhaust system, sea water cooling & lube systems.**

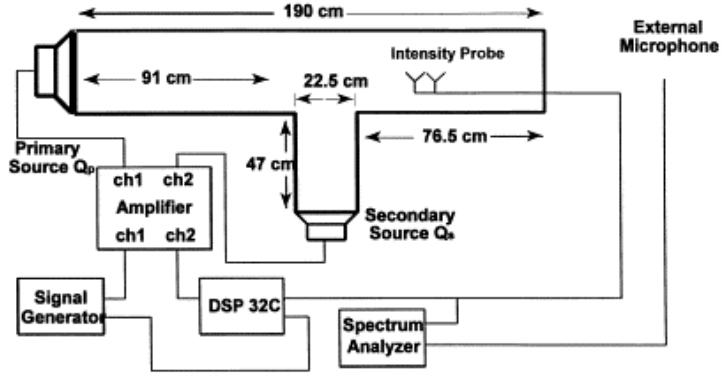
Noise Controls:

Testing Hi TL Bulkhead

Testing Spray-on Damping

Turbo Silencer (Detroit Diesel)

Example of active noise cancellation system



Example of machinery isolation mounts

Ships and High Speed Craft
Summary and Justification

Feasibility : **Yes, noise control is feasible.**

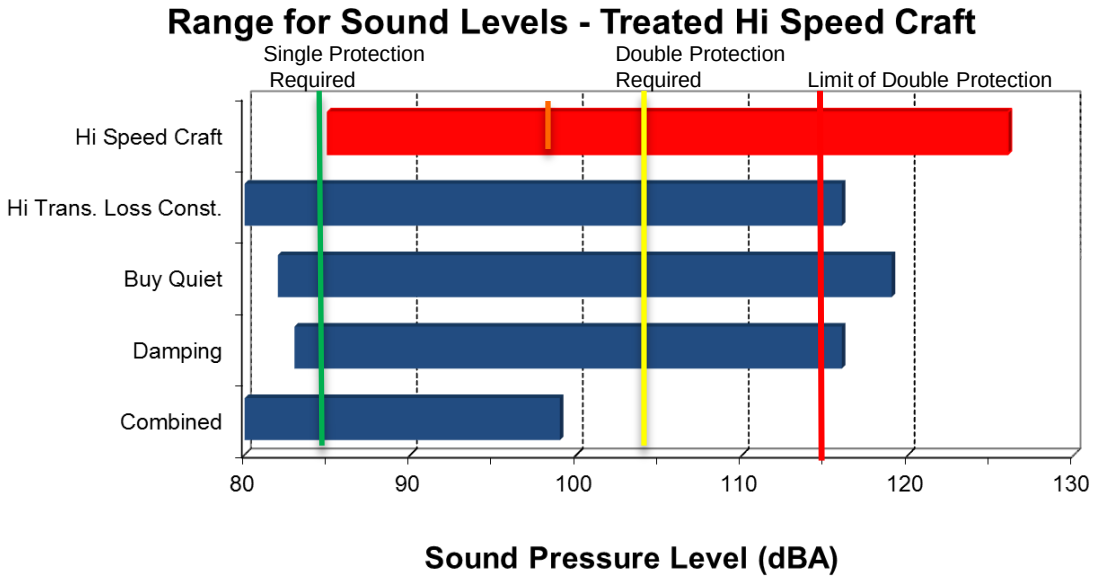
Estimated Number of DoD Acquisitions (Ships and Craft): **165**

Estimated number of workers (Military and Civilians) Exposed: **4,356**

Return on Investment (ROI): **1:1 to 3:1; NIHL cost reduction = $49.2M**

Graph showing Noise Before and After:

Source level used – 96 dBA
TWA Source Level Used – 97 dBA



Aircraft Carrier Operations--On-Deck
Noise Source and Controls

Noise Sources: Extremely high level, broadband noise from the jet engines. Deck crew in close proximity of extremely high noise and only protected by cranial helmets. Noise levels above 167 dB exceed the protection capability of cranial helmets with ear muffs and ear plugs. (Tactical jet noise being addressed separately.)

Current Noise Range Lower Estimate – Upper Estimate at ear level: 115-167 dBA

Worker Exposure Time Per Day Allowed Unprotected : Less than 1 second @ 167 dBA and 28 seconds @ 115 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Barrier on deck (5-13 dB)	• None
Structureborne Noise Control	• None	• None

Aircraft Carrier Operations--On-Deck
Pictures of Noise Controls

Noise Sources: **Jet noise**

Noise Controls:

Noise barrier similar to jet blast deflector

Aircraft Carrier Operations--On-Deck
Summary and Justification

Feasibility : Noise control treatments and their installation are difficult to achieve

Estimated Number of DoD Acquisitions (Ships): 11

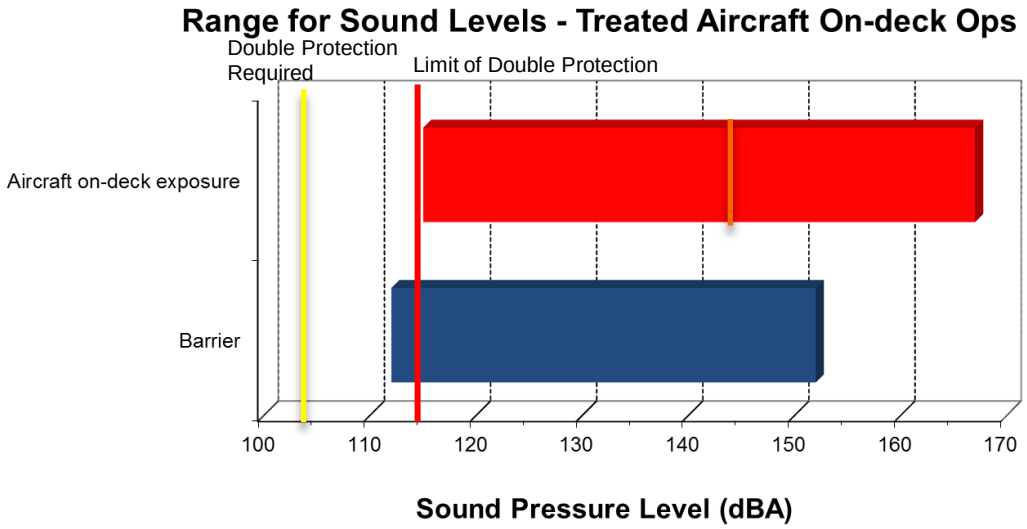
Estimated number of workers (Military and Civilians) Exposed: 11,000

Return on Investment (ROI): 203:1 to 509:1; NIHL cost reduction = $1.1B

Graph showing Noise Before and After:

Source Level Used – 140 dBA

TWA Source Level Used – 143 dBA



Aircraft Carrier Operations-Internal Compartments
Noise Source and Controls

Noise Sources: Very high level, broadband noise-from jet launches, arresting gear, and water brake-is easily transmitted to berthing and living space directly below the flight deck. Noise levels in these compartments reach hazardous levels during flight operations.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-113 dBA

Worker Exposure Time Per Day Allowed Unprotected : 45 seconds @ 113 dBA and 8 hours @ 85 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• High transmission loss (TL) Constructions (10-12 dB) • Damping (5-7 dB) • Floating Room (Capsule/Pod) (10-15 dB) • Absorptive Materials (3-5 dB)	• None
Structureborne Noise Control	• None	• None

From www.navy.mil

Aircraft Carrier Operations-Internal Compartments
Pictures of Noise Controls

Noise Sources: **Jet noise, catapult and retrieval systems and water brake**

Noise Controls:

Spray on Damping

Hi – Transmission Loss

Modular Cabin/Capsule/Pod

Aircraft Carrier Operations-Internal Compartments
Summary and Justification

Feasibility : Yes, noise control is feasible.

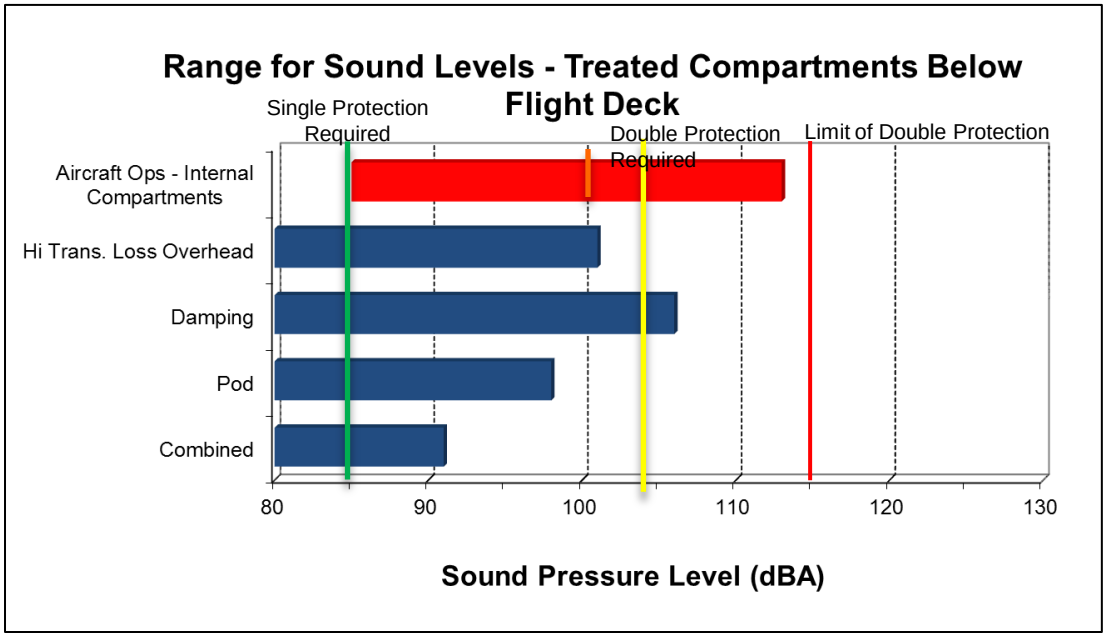
Estimated Number of DoD Acquisitions: 11

Estimated number of workers (Military and Civilians) Exposed: 38,500

Return on Investment (ROI): 37:1 to 44:1; NIHL cost reduction = $565M

Graph showing Noise Before and After:

Source Level Used – 97 dBA
TWA Source Level Used – 100 dBA



Tracked Vehicles
Noise Source and Controls

Noise Sources: Very high level, broadband noise and vibration sources on vehicle due to drive system and track. Crew in highly reverberant compartment and in close proximity to high noise and vibration sources.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 90-118 dBA

Worker Exposure Time Per Day Allowed Unprotected : 14 seconds @ 118 dBA and 4 hours @ 90 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Cladding (5-10 dB) • Buy Quiet (7-12 dB) • Fan re-design (10-15 dB)	• Internal modular compartment (capsule/pod) (5-10 dB) • Active noise cancellation (5-10 dB)
Structureborne Noise Control	• Vibration isolation (5-10 dB) • Spray on damping (2-10 dB)	• Active control-low frequency vibration (almost COTS) (15-25 dB) • Distributed vibration absorber (15-25 dB) • Sprocket re-design (10-15 dB)

Tracked Vehicles
Pictures of Noise Controls

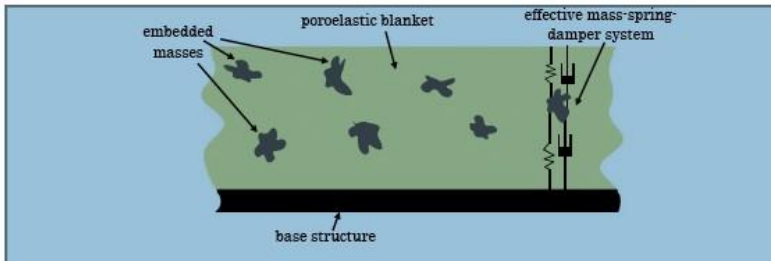
Noise Sources: **Track, sprocket, idler, wheels and cooling fans**

Noise Controls:

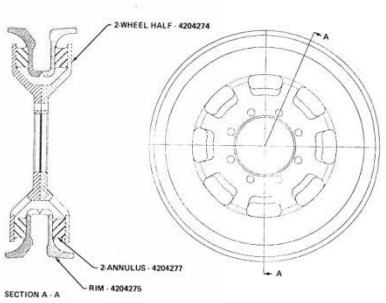
Cladding Materials

Testing Spray-on Damping

Passive Distributed Vibration Absorber



Prototype Compliant Idler Wheel



Tracked Vehicles
Summary and Justification

Feasibility : Yes, noise control is feasible.

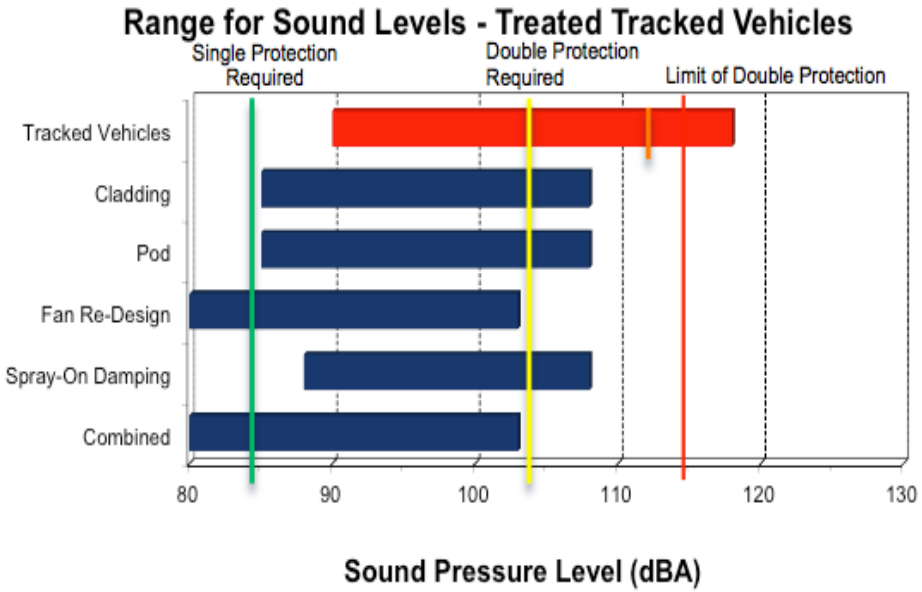
Estimated Number of DoD Acquisitions: 97,109

Estimated number of workers (Military and Civilians) Exposed: 485,545

Return on Investment (ROI): 0.1:1 to 1:1; NIHL cost reduction = $8.1B

Graph showing Noise Before and After:

Source level used – 111 dBA
TWA Source level used – 113 dBA



Wheeled Vehicles
Noise Source and Controls

Noise Sources: Very high level, broadband noise and vibration sources on vehicle due to drive system and tires. Crew in highly reverberant compartment and in close proximity to high noise and vibration sources.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-112 dBA

Worker Exposure Time Per Day Allowed Unprotected : 56 seconds @ 112 dBA and 8 hours @ 85 dBA

Noise Controls:

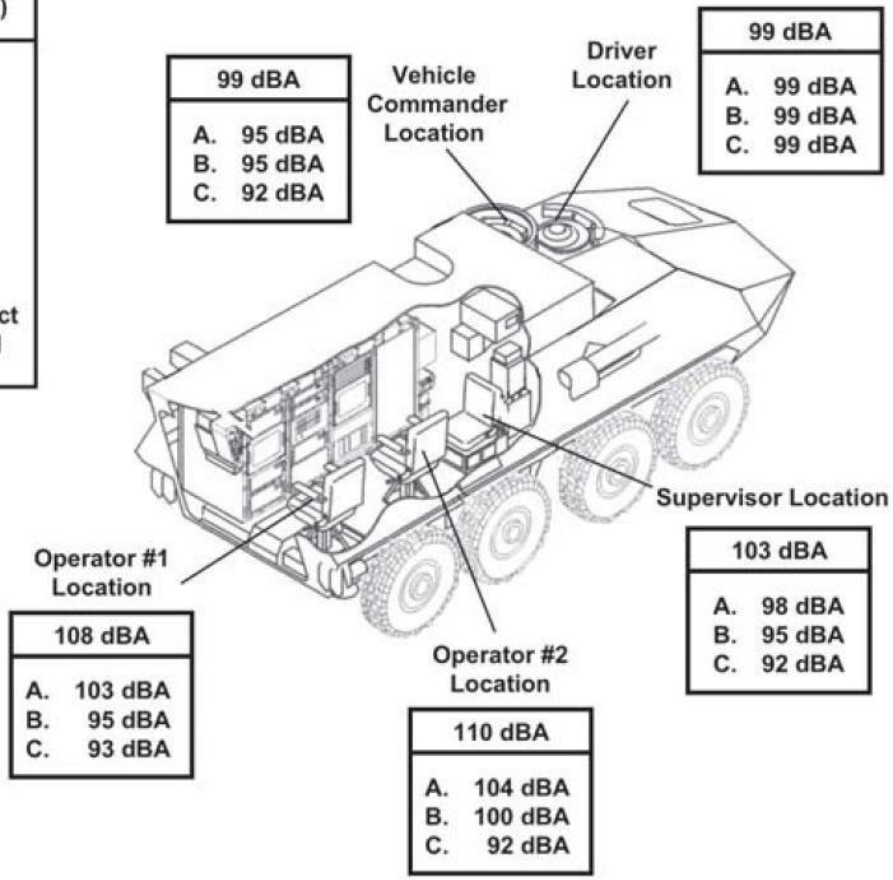
	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Cladding (5-8 dB) • Buy Quiet (7-12 dB) • Fan re-design (10-15 dB)	• Internal modular compartment (capsule/pod) (5-10 dB) • Active noise cancellation (5-10 dB) • Tire tread re-design (5-10 dB)
Structureborne Noise Control	• Vibration isolation (5-10 dB) • Spray on damping (2-10 dB)	• Active control-low frequency vibration (almost COTS) (15-25 dB) • Distributed vibration absorber (15-25 dB)

Wheeled Vehicles
Pictures of Noise Controls

Noise Sources: **Diesel/gearbox, cooling fan and tire noise**

Noise Controls:

Top - Baseline OASPL's (No Noise Control Measures Applied)	
A.	Noise Levels After ACS Evaporator Fans Replaced
B.	Noise Levels After A. + Curb-side ACS Noise Reducing Plenum Installed
C.	Noise Levels After B. + Road-side ACS Ventilation Duct Silencing Treatments Installed



Wheeled Vehicles
Summary and Justification

Feasibility : Yes, noise control is feasible.

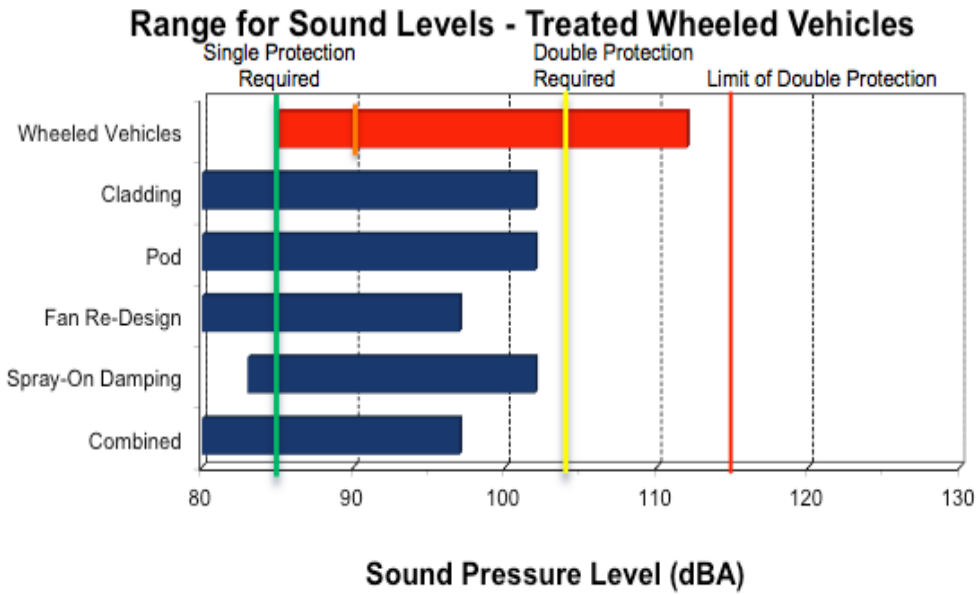
Estimated Number of DoD Acquisitions: 440,792

Estimated number of workers (Military and Civilians) Exposed: 1,322,376

Return on Investment (ROI): 2:1 to 5:1; NIHL cost reduction = $7.9B

Graph showing Noise Before and After:

Source level used – 88 dBA
TWA Source Level – 90 dBA



Modular Cabin/Capsule/Pod-Promising Technology
Noise Control – Shipboard Noise

Noise Sources: Very high level, broadband noise and vibration sources distributed throughout vessel. Noise easily transmitted to operations, topside and accommodations. Crew in highly reverberant compartment and in close proximity to high noise and vibration sources. HVAC and fluid system also contribute to high noise levels. Jet operations on CVN and amphibian ships.

Current Shipboard Noise Range Lower Estimate – Upper Estimate at ear level: 85-121 dBA

Modular Cabin/Capsule/Pod as Promising Technology: There are 2 distinct applications of this technology on ships: (1) Berthing-to make quiet areas quieter to allow ears to 'recover' and (2) Isolation booths in high noise work areas to physically separate the worker from the noise.

	Benefit of Standard Commercial Off The Shelf (COTS) Modular Cabins and Berthing Capsules/Pods
Navy	• Has high potential to control noise and vibration. This "room in a room" concept has been tested on a Navy carrier and was found to provide a 10 dB noise reduction. For shipboard machinery reduction on order of 15- 20 dB expected.
Cruise Industry	• Standard on many cruise ships to provide guests cabins with quiet spaces [Noise standard for cruise industry 49 – 55 dB(A)]

Modular Cabin/Capsule/Pod-Promising Technology

Pictures of Some Types of Modular Cabins/Capsules/Pods

Noise Sources: **Shipboard equipment and machinery for surface ship; aircraft .**

Noise Controls: Modular Cabin or 'Capsule'/'Pod'

Berthing capsule/pod

From Wikipedia

Modular cabins for work or berthing

From rm-group.com

From grainger.com

From Nauticexpo.com

Modular Cabin/Capsule/Pod-Promising Technology

Effectiveness of Modular Cabin

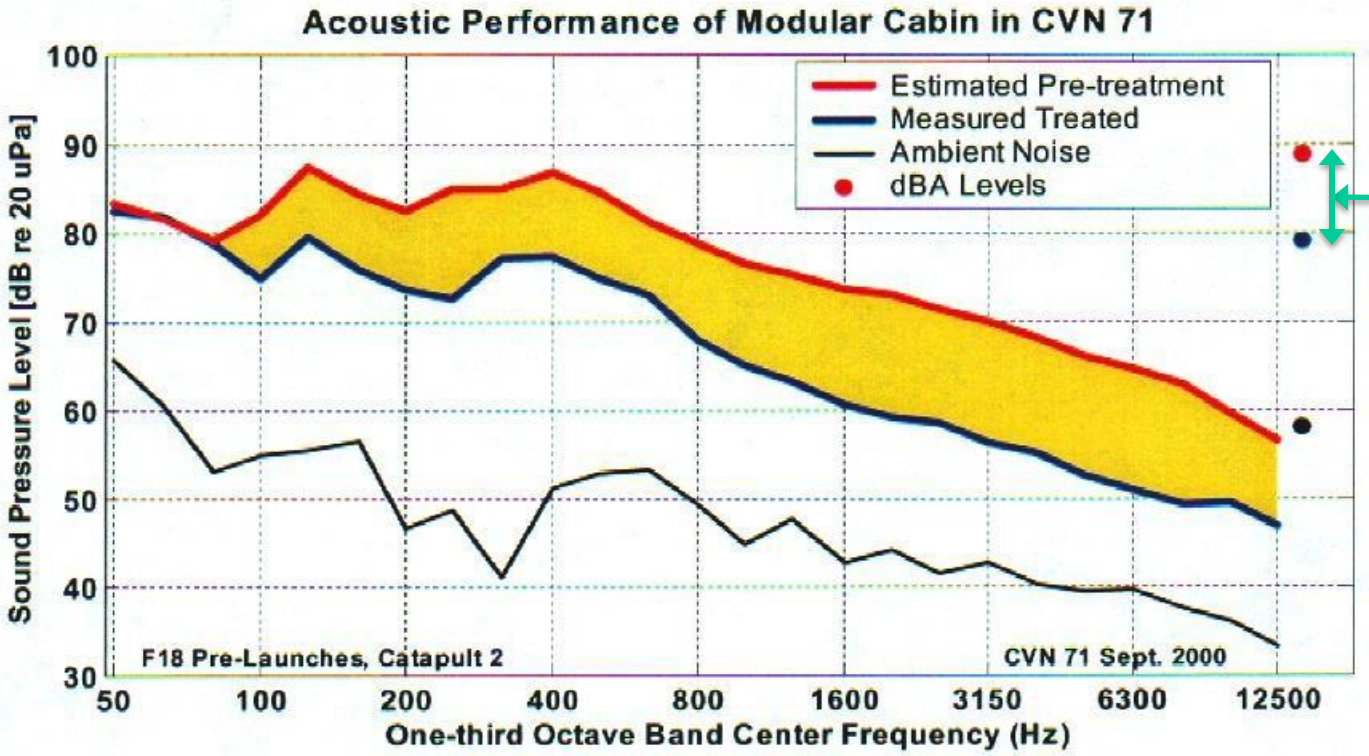


Figure 38. Performance of Modular Cabin Treatment for F-18 on Catapult 2 (10 dBA reduction)

10 dB noise reduction

Note: With modular cabin, noise level is below 85 dBA

Ref.: Kurt Yankaskas & Mike Shaw, "Landing on the Roof: CVN Noise," Naval Engineers Journal, Vol. 111, Issue 4, July 1999.

Cockpit Interior
Noise Source and Controls

Noise Sources: Very high level, broadband noise with some high frequency tonal components due to jet/turbo prop and ventilation systems. Crew in highly reverberant compartment and in close proximity to high noise and vibration sources.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-121 dBA

Worker Exposure Time Per Day Allowed Unprotected : 7.2 seconds @ 121 dBA and 8 hours @ 85 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Cladding (5-8 dB) • Buy Quiet (3-7 dB) • Ventilation Design (CFD) (5-12 dB) • Damping (2-10 dB)	• Active Noise Cancellation (5-10 dB)
Structureborne Noise Control	• Passive tuned vibration absorbers (5-10 dB)	• None

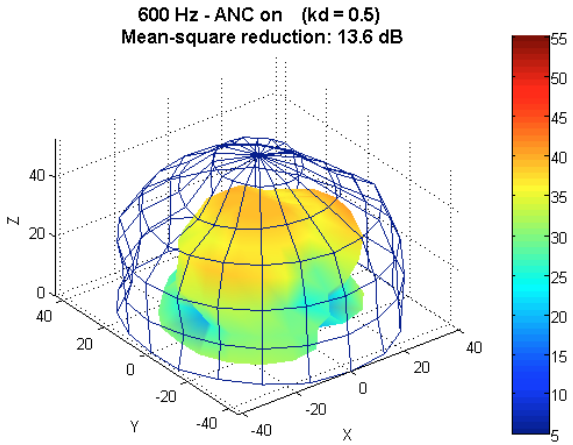
Cockpit Interior
Pictures of Noise Controls

Noise Sources: **Jet, compressor, cockpit HVAC, prop blade rate, flow noise**

Noise Controls:

Cladding materials

BYU Active Cancellation Test on Cooling Fan



Compact cooling system

A cutaway view of Hewlett-Packard's new electric-ducted server cooling fan, which was adapted from model jet airplane engines. (Image courtesy of Hewlett-Packard.)

Cockpit Interior
Summary and Justification

Feasibility : **Yes, noise control is feasible.**

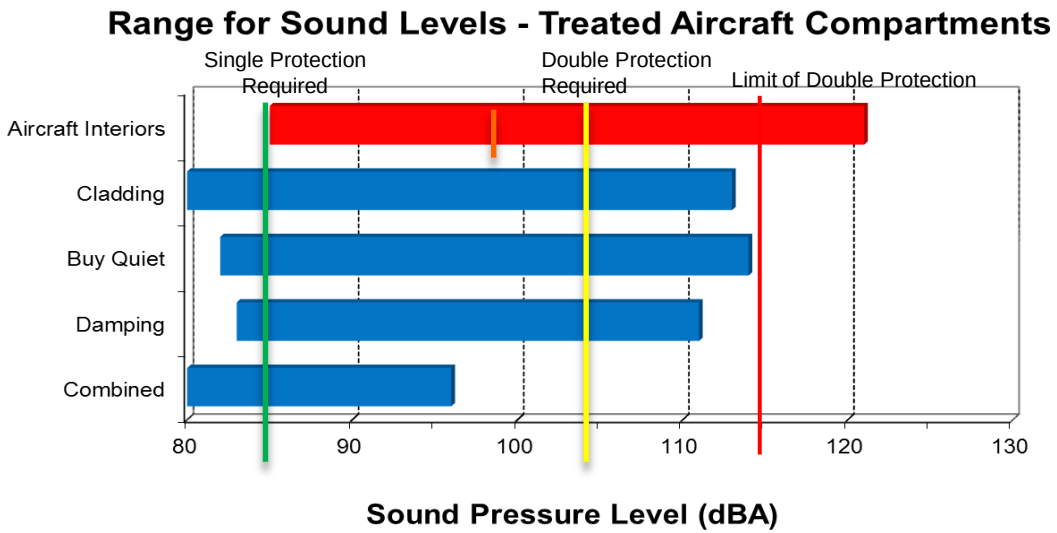
Estimated Number of DoD Acquisitions: **9,613**

Estimated number of workers (Military and Civilians) Exposed: **16,823**

Return on Investment (ROI): **0.8:1 to 4:1; NIHL cost reduction = $246 M**

Graph showing Noise Before and After:

Source Level Used – 106 dBA
TWA Source Level Used – 98 dBA



Shipboard Equipment
Noise Source and Controls

Noise Sources: Very high level, broadband noise and vibration sources distributed throughout vessel. Noise easily transmitted to operations, topside and accommodations. Crew in highly reverberant compartments and in close proximity to high noise and vibration sources. Noise sources include: pumps, hydraulic systems, HVAC* fans/air handlers/fan coil assemblies/etc., and all other (non-diesel, non-gas turbine) "auxiliary" equipment present and used in ship environments.

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-121 dBA

Worker Exposure Time Per Day Allowed Unprotected : 7 seconds @ 121 dBA and 8 hours @ 85 dBA

Noise Controls:

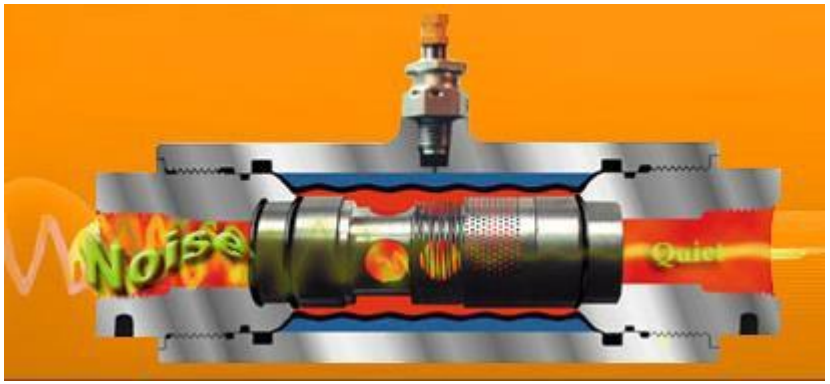
	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatments, Potential dB Reductions
Airborne Noise Control	• Buy Quiet (5-15 dB) • Computational Fluid Dynamics (CFD)propulsor design (10-20 dB) • *Heating, Ventilation and Air-Conditioning (HVAC) design (5-15 dB) • Damping (2-10 dB) • Acoustic insulation (3-5 dB) • Hydraulic silencer (5-10 dB)	• Improved light-weight high transmission loss materials (5-10 dB) • Active noise control (HVAC) (12 dB)
Structureborne Noise Control	• Vibration isolation (10-15 dB) • Hi-Impedance foundations (5-8 dB)	• Active Control – low frequency vibration (almost COTS) (15-25 dB)

Shipboard Equipment
Pictures of Noise Controls

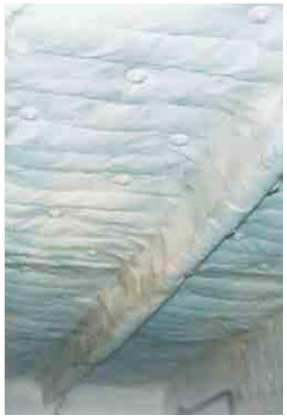
Noise Sources: **HVAC systems, propulsors, compressors and pumps**

Noise Controls:

Hydraulic Silencer



Acoustic Insulation



Quiet Propeller Design

Duct ANC

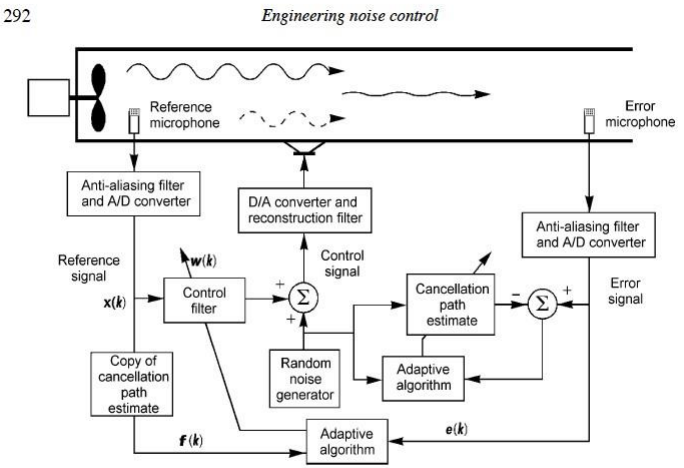


Figure 10.30(a). Configuration of a feedforward active noise control system to attenuate noise propagation along a duct (after Eriksson and Allie, 1989).

Shipboard Equipment
Summary and Justification

Feasibility : **Yes, noise control is feasible.**

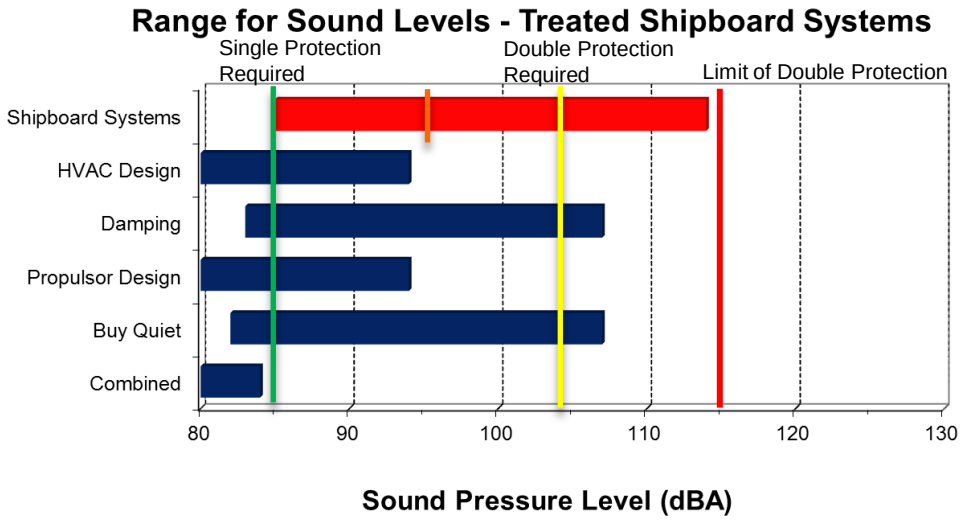
Estimated Number of DoD Acquisitions (Ships): **602**

Estimated number of workers (Military and Civilians) Exposed: **463,540**

Return on Investment (ROI): **11:1 to 40:1; NIHL cost reduction = $3.9B**

Graph showing Noise Before and After:

Source Level Used – 92 dBA TWA
Source Level Used – 95 dBA



Abrasive Blasting
Noise Source and Controls

Noise Source: High level broadband noise defined by the nozzle and delivery system, size and composition of item being blasted, blasting area and work piece angle. Critical components are air blaster nozzle, air supply to hood, air compressors, exhaust ventilation and air releases during grit pot blow-down. Dust exhaust fans and waste separation systems also create high noise

Current Noise Range Lower Estimate – Upper Estimate at ear level: 85-145 dBA

Worker Exposure Time Per Day Allowed Unprotected : < 1 second @ 145 dBA and 8 hours @ 85 dBA

Noise Controls:

	Standard Commercial Off The Shelf (COTS) Treatment, Potential dB Reductions	Advanced Treatment, Potential dB Reductions
Airborne Noise Control	• Nozzle redesign-computational fluid dynamics (CFD) (2-4 dB)	• Partial nozzle barrier (2-4 dB)
Structureborne Noise Control	• None	• None

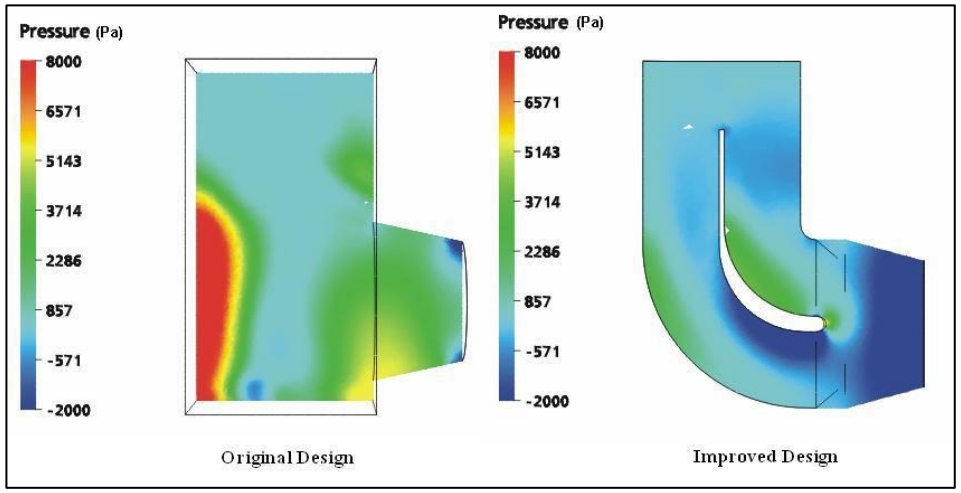
Plastic media blasting from www.army.mil

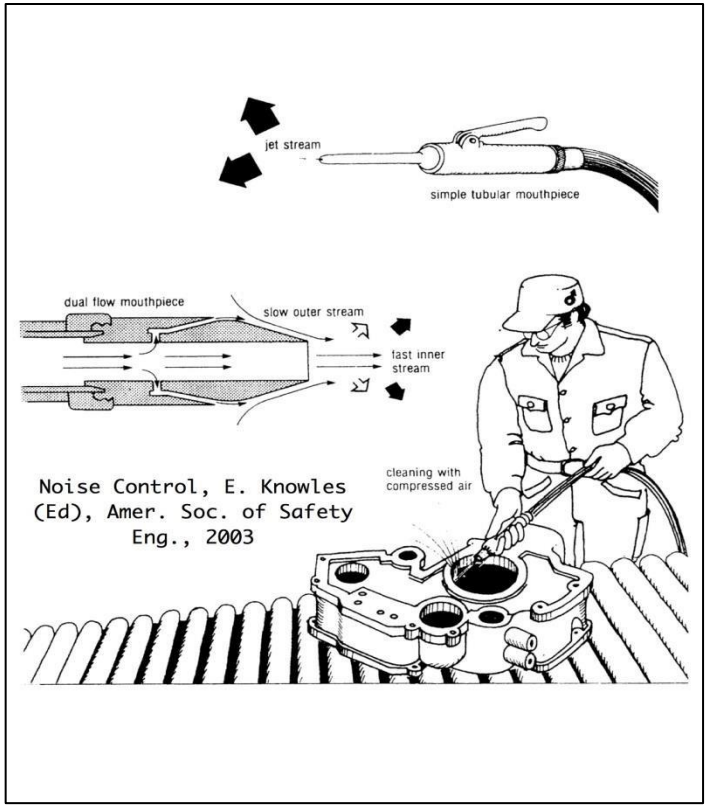
Abrasive Blasting
Pictures of Noise Controls

Noise Sources: Nozzle, air compressors and exhaust ventilation systems

Noise Controls:

Nozzle Re-Design (CFD)





Abrasive Blasting
Pictures of Noise Controls

Noise Sources: Nozzle, air compressors and exhaust ventilation systems

Iterim Noise Controls:

CAVCom

Sensear

Abrasive Blasting
Summary and Justification

Feasibility : **Noise control will require research and development.**

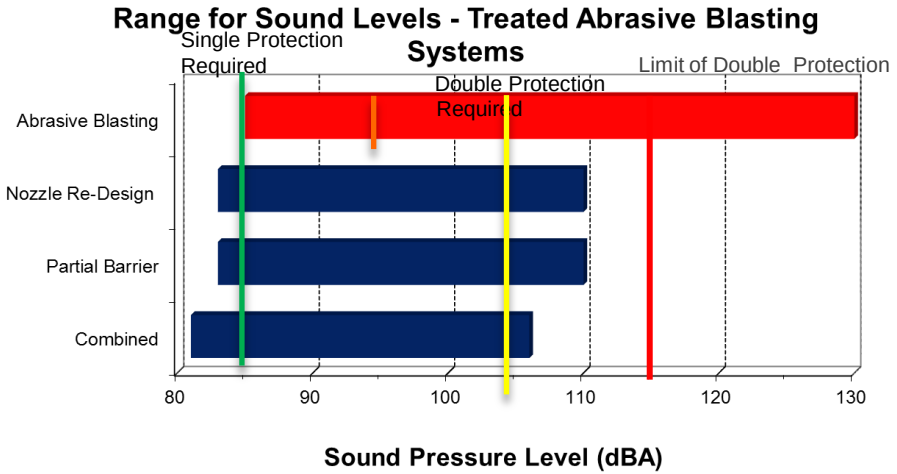
Estimated Number of DoD Acquisitions : **500**

Estimated number of workers (Military and Civilians) Exposed: **1,250**

Return on Investment (ROI): **2:1 to 5:1; NIHL cost reduction = $12M**

Graph showing Noise Before and After:

Source level used – 97 dBA TWA
Source level used – 94 dBA



Return on Investment

DoD Source	Return on Investment	Potential NIHLCost Reduction	Untreated TWA	dB(A) Reduction	Service Years
Shipboard Diesel Driven Systems	0.2:1 – 4:1	$774,708,120	110 dB(A)	33	40
Shipboard Gas Turbines	0.2:1 - 2:1	$38,509,074	90 dB(A)	8	35
Ships/High Speed Craft	1:1 – 3:1	$49,218,444	97 dB(A)	17	22
Aircraft Carrier Operations-On-Deck	203:1 – 509:1	$1,121,310,000	143 dB(A)	13	50
Aircraft Carrier Operations-Internal Compartments	37:1 – 44:1	$565,873,000	100 dB(A)	21	50
Tracked Vehicles	0.1:1 – 1:1	$8,125,110,030	113 dB(A)	16	50
Wheeled Vehicles	2:1 – 5:1	$7,958,058,768	90 dB(A)	7	30
Cockpit Noise	0.8:1 – 4:1	$246,473,773	98 dB(A)	12	35
Shipboard Equipment	11:1 – 40:1	$3,889,987,680	95 dB(A)	7	40
Abrasive Blasting	2:1 – 5:1	$12,317,500	94 dB(A)	6	50

Noise Control Successes Outside of DoD, cont.

MSHA maintains a list of "technologically and administratively achievable" and "promising" noise controls that is updated and provided to the mining industry as new controls are developed

ISSUE DATE: 06/20/2011

PROGRAM INFORMATION BULLETIN NO. P11-45

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LINDA F. ZEILER
Acting Director of Technical Support

SUBJECT: Reissue of P08-12 - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 C.F.R. Part 62)

Scope
This Program Information Bulletin (PIB) applies to all Mine Safety and Health Administration (MSHA) enforcement personnel, equipment manufacturers, coal, metal, and nonmetal mine operators, independent contractors, miners, miners' representatives, and other interested parties.

http://www.msha.gov/regs/complian/PIB/2011/pib11-45.pdf

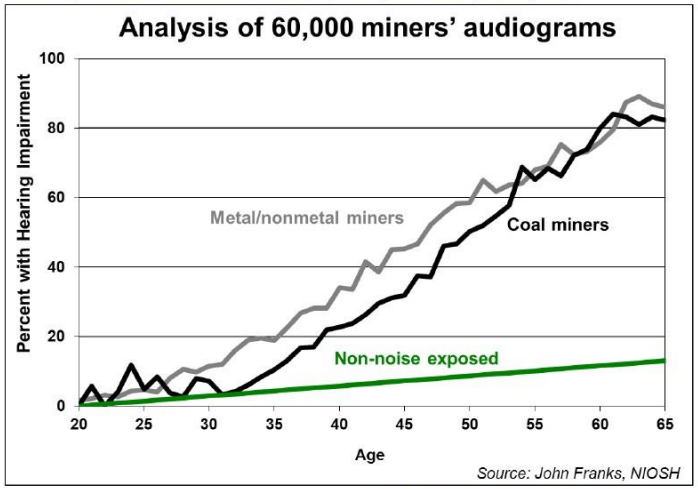
OFFICE OF MINE SAFETY AND HEALTH RESEARCH

Noise Control Successes Outside of DoD

Major strides have been made in noise control technology in the areas of:

- Mining
- Commercial aviation
- Aerospace

Miners have much greater hearing impairment compared to non-noise exposed people



Technology has improved and costs have come down

Noise Control Successes Outside of DoD, cont.

Technologically and administratively achievable noise controls

- Shown to reduce sound levels and noise exposure
- Used either singly or as part of a suite of controls
- Proven to work via widespread use or scientific study
- Reduce noise exposure (*not sound level*) by 3 dB(A)
- Have a realistic basis in present technology (can be made or bought)

OFFICE OF MINE SAFETY AND HEALTH RESEARCH

Next Steps

- Engage Service Acquisition Leads and brief initiative results
- Incorporate existing noise control requirements and detailed guidance into joint capabilities (requirements) documents
- Update MIL-STD 1474 (Design Criteria Standard-Noise Limits) to better address impulse noise, ship and aircraft noise control
- Implement noise control guidance once MIL-STD 882E is revised to provide more guidance for risk evaluations
- Partner to use the systems engineering approach to manage for efficiency in energy consumption and noise
- Design systems for sustainability
- Work to develop a DoD list of “technologically achievable” and “promising” noise controls
- Apply existing acoustic modeling methods and further develop these tools to allow for optimizing noise control approaches
- Document noise control successes in future acquisitions
- Monitor the effectiveness of noise mitigation in the system safety process and external program reviews to support risk management, accountability, and life-cycle cost mitigation

Questions?

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