Controlling Machinery Induced Underwater Noise

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NOAA Vessel Quieting Technology

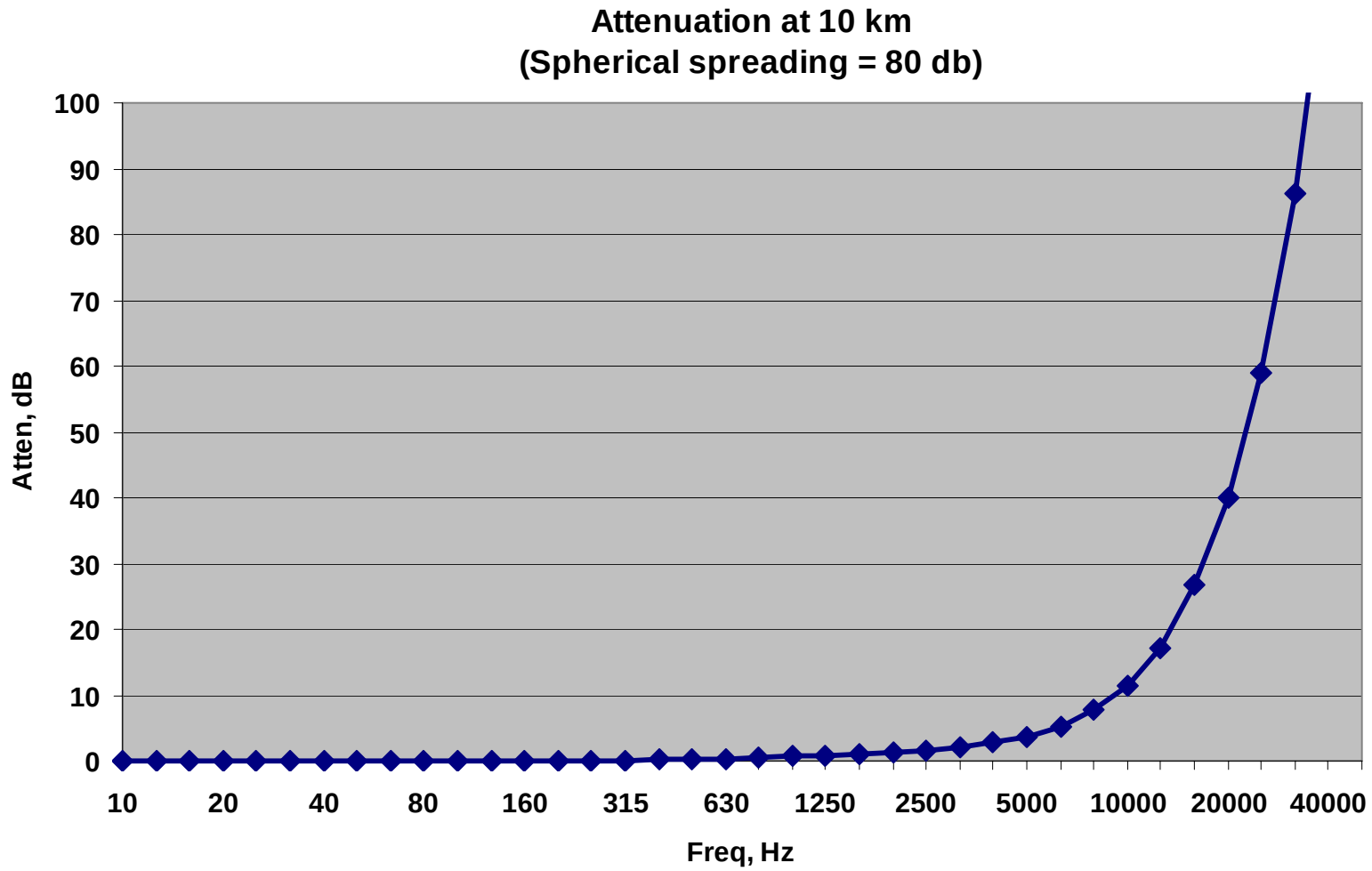
Approach

- How much U/W noise reduction is required?
- Critical sources
  - Machinery
  - Propulsor (covered by others)
- Critical paths
  - Airborne and structureborne
- Noise/Vibration control approaches
- Use NOAA Fisheries R/V as illustration

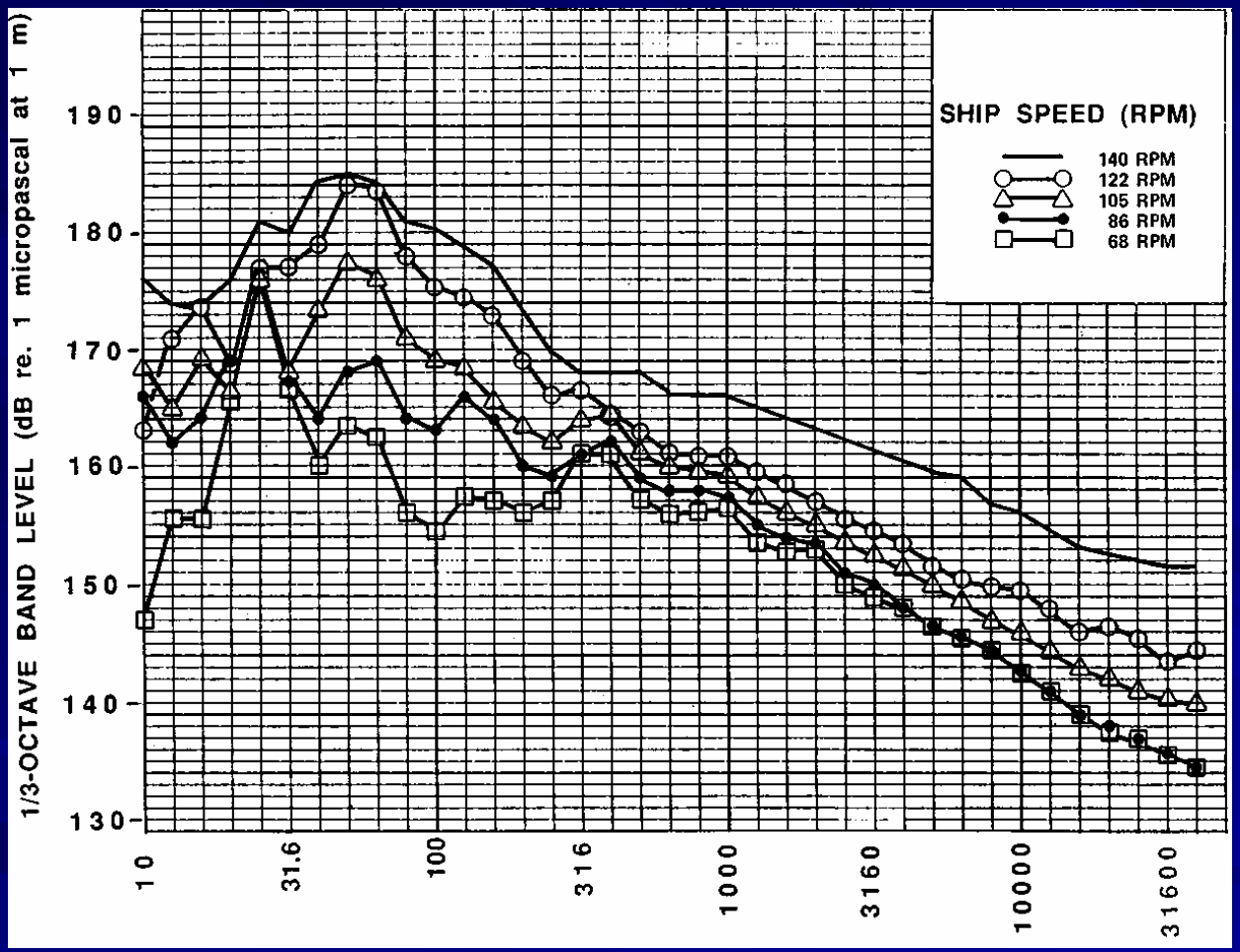
Range to achieve 120 dB Level

	Source Level, dB re 1µPa @1m	range, km Spherical spreading	range, km 1.5 power spreading	range, km Cylindrical spreading
5-m Zodiac	156	0.06	0.25	4
Tug & Barge	171	0.35	2.5	125
Supply Ship	181	1	11.7	1260
Large Tanker	190	3	46.4	10000
Drill ship, rigs, platforms				
Drill Ship	175	0.6	4.6	320
Conical Drilling Unit	185	1.8	21.5	3200
DREDGING				
Ship 1	172	0.4	2.9	160
Ship 2	185	1.8	21.5	3200

Ocean Attenuation



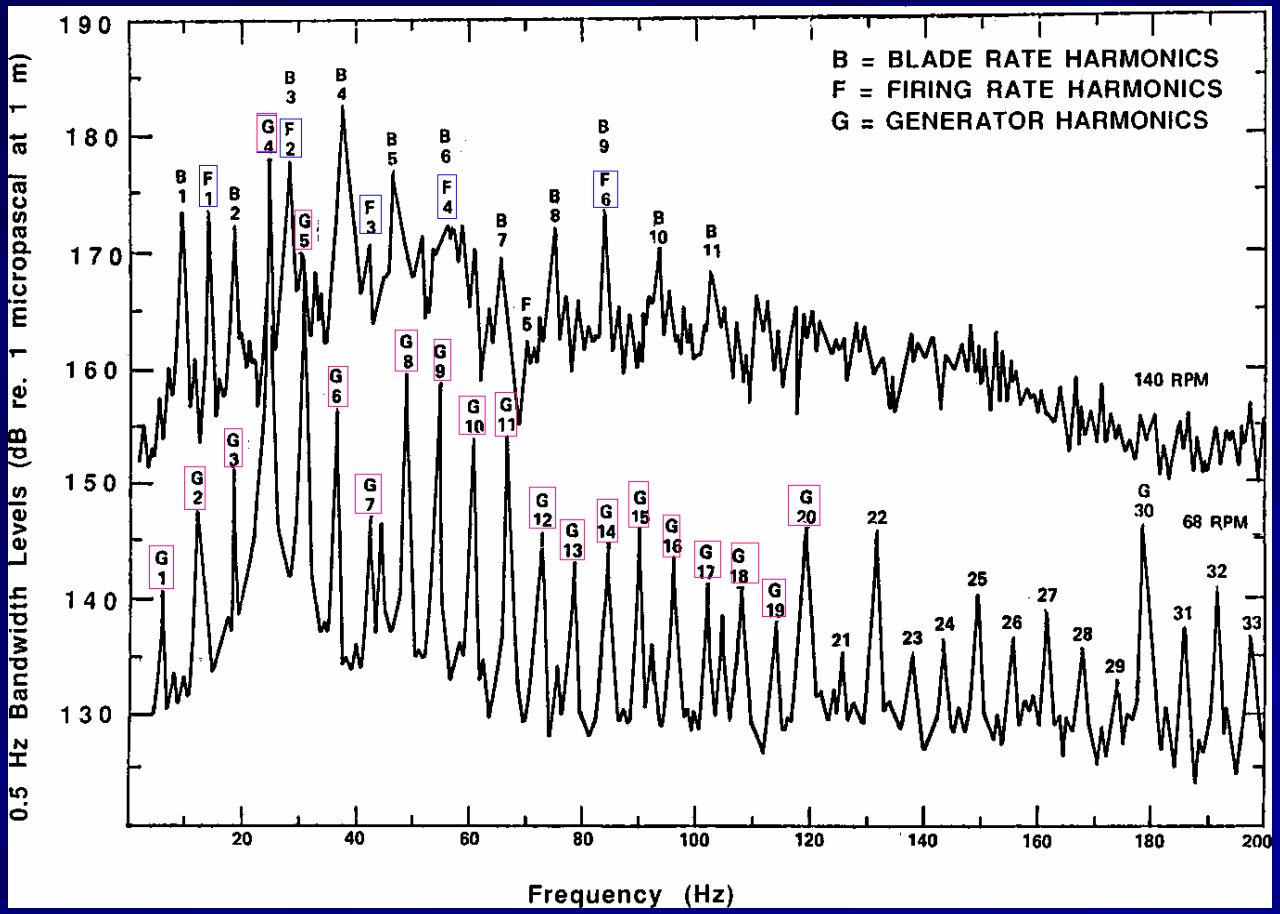
Cargo Ship Broad Band Noise



Radiated Noise Characteristics of a Modern Cargo Ship, Arverson & Vendittis, JASA 107 (1), Jan. 2000.

173 m Direct Drive

Cargo Ship Broad Band Noise



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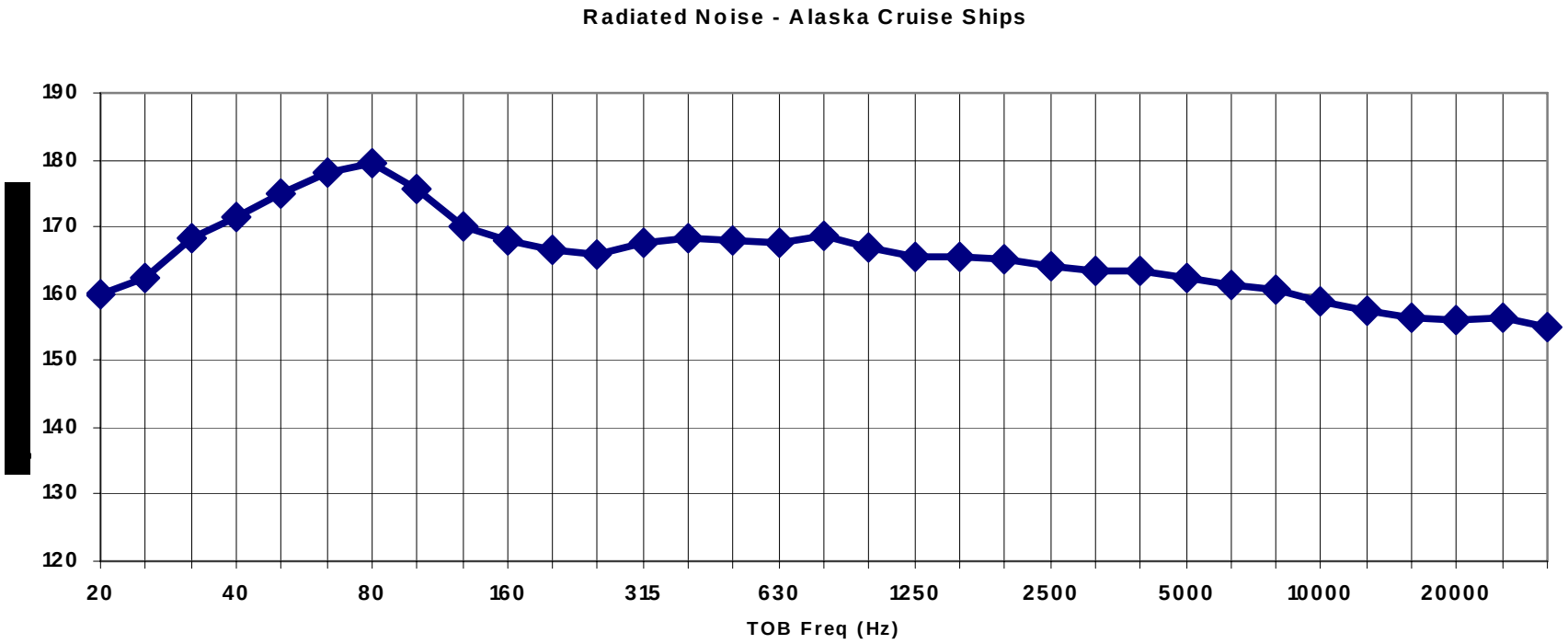
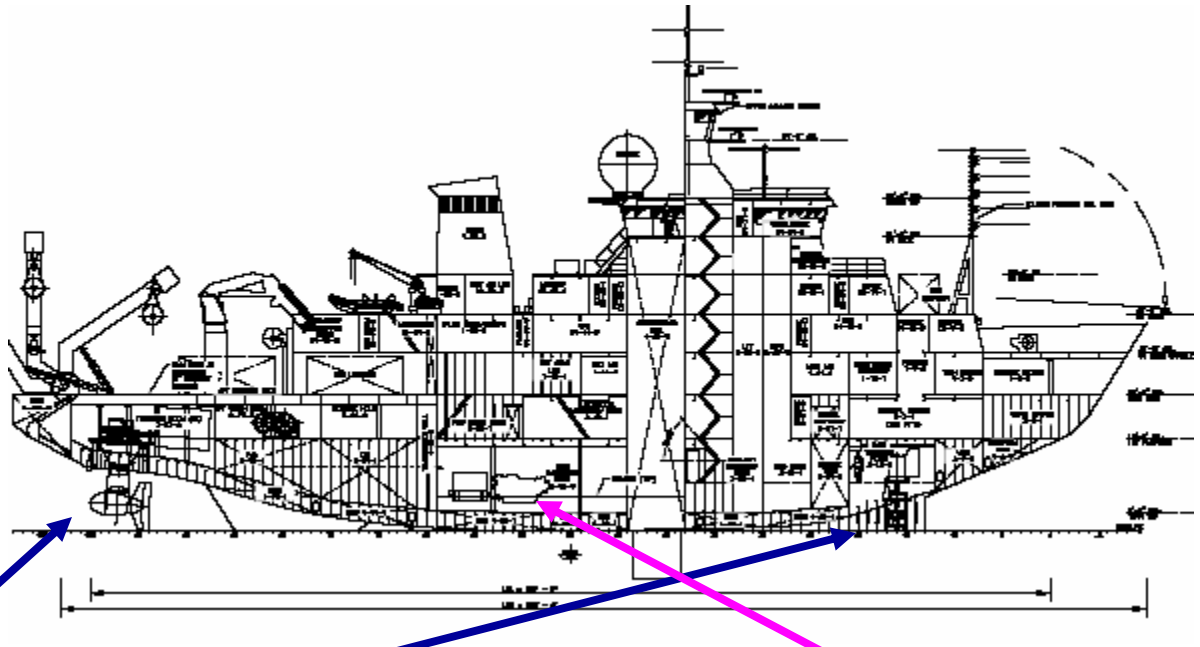
173 m Direct Drive

Radiated Noise – Cruise Ship



Ship Noise Sources



Propeller Noise Sources

Cavitation noise
& structural re-radiation

Machinery Noise Sources

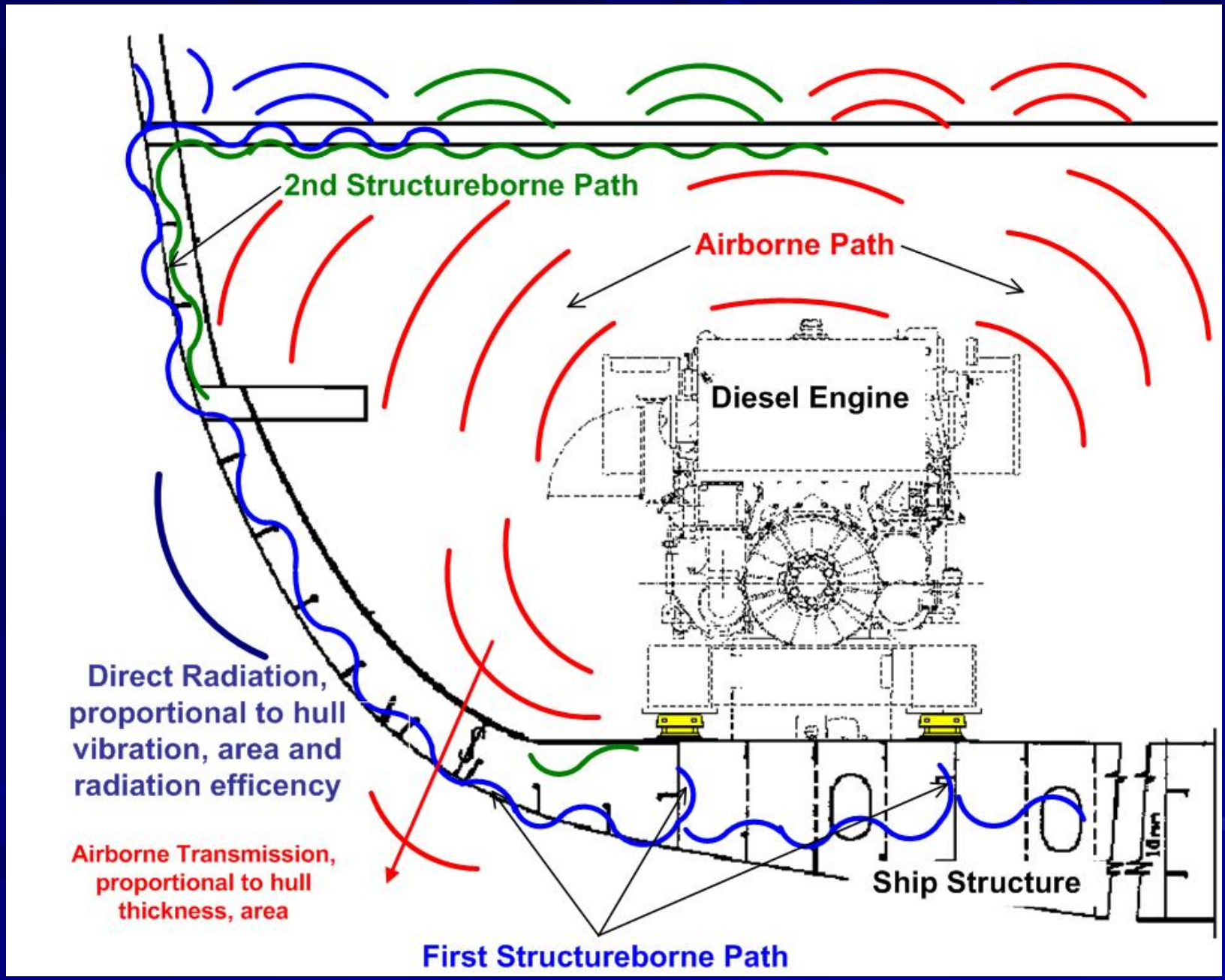
Main propulsion system

Aux. Equipment

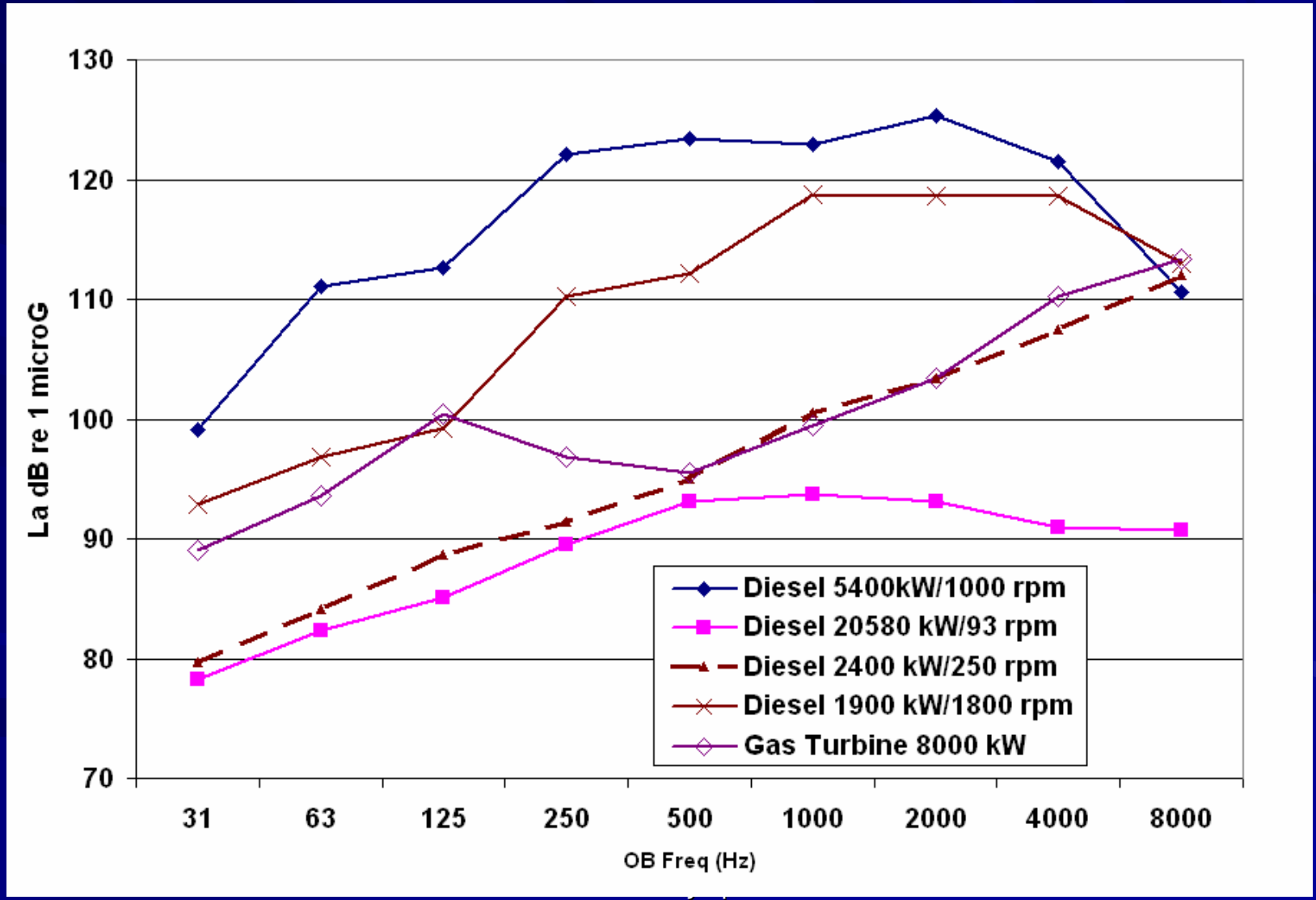
Structural-borne path

Air-borne path

Sea-connected system


2nd Structureborne Path
Airborne Path
Diesel Engine
Direct Radiation, proportional to hull vibration, area and radiation efficency
Airborne Transmission, proportional to hull thickness, area
Ship Structure
First Structureborne Path

Various Drive Vibration Levels



Best Acoustic Design

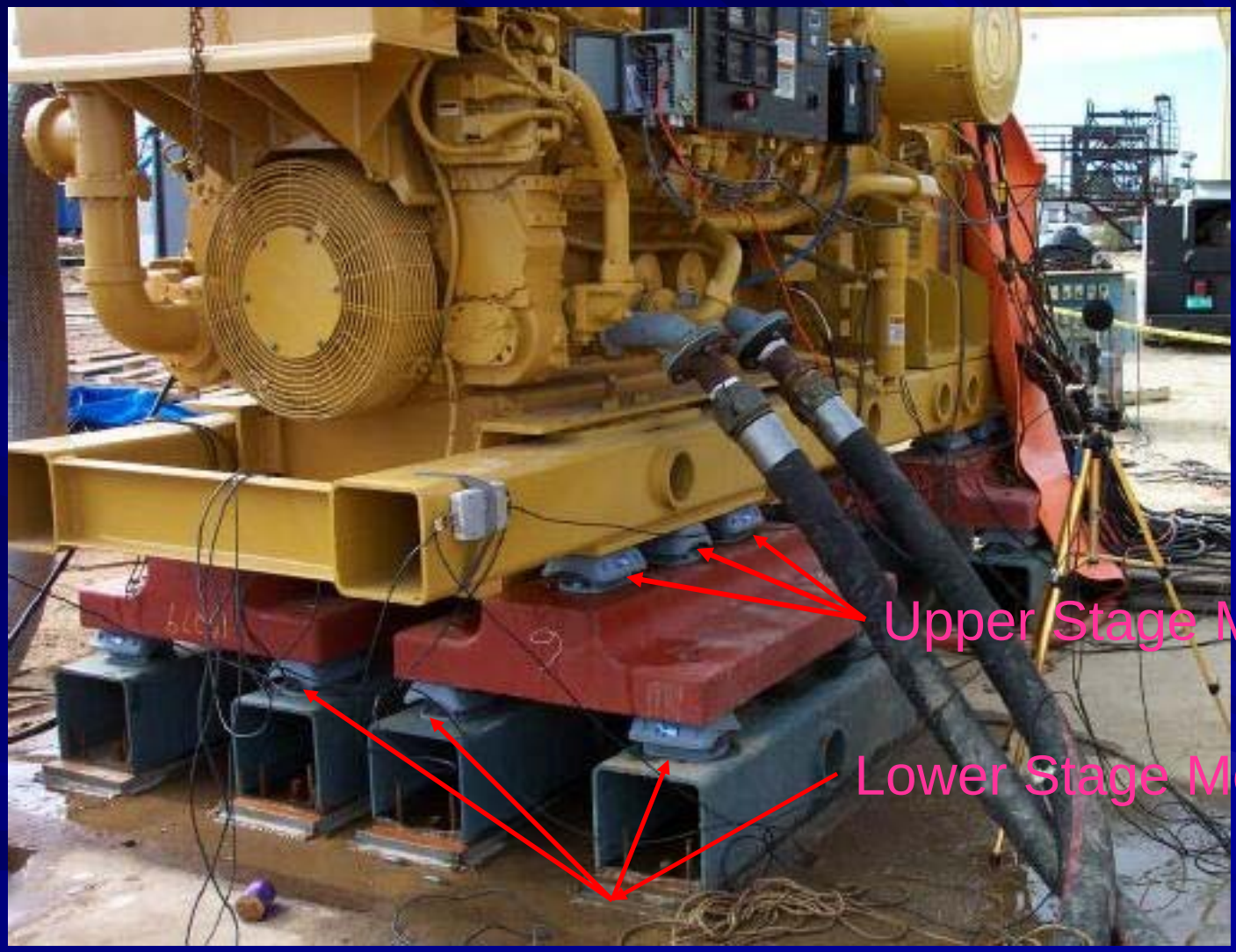
- Use inherently quiet equipment
  - Rotating rather than reciprocating
- Use (dynamically) stiff foundations
- Place noisier equipment toward centerline
- Use double hulls or tanks outboard of Engine Room
- Diesel-Electric offers greatest opportunity
  - Isolation mounts for gensets, quiet motors

Vibration Isolators

- Best shipboard noise control element.
- Reduces SB path.
- Isolation of Propulsion Engines requires flexible coupling and other components.
- Use only Elastomeric Marine-Grade Mounts.
- Requires dynamically stiff foundations.

Does not eliminate low frequency noise!

Two-stage Genset Isolation System for NOAA FRV



Acoustic Insulation

- Reduces AB & SSB Transmission.
- Typically insulation's base material is either fiberglass or mineral wool.
- High Transmission Loss (or HTL) material has middle layer of limp mass (usually leaded vinyl).
- Transmission Loss or STC (Sound Transmission Class) defines performance.

Treatment Effectiveness

Treatment	AB	FSB	SSB
Vibration Isolation – passive $20-$400/mt	0	10-20	0
Raft mount equipment Steel framing	0	5	0
Acoustic Insulation 3 to 8 pcf; $1-$4/ft^2	5-10	0	5-10
Damping; 2-3 psf; $8-$12/ft^2	0	5-10	5-10
Bow Thruster Treatments	10	10	10

"Quiet Vessel" approximately 7% to 10% total cost of vessel. Quiet R/V 15% to 20% cost of vessel.

Values are approximate dB reduction of overall sound.

Follow Through

All the treatments in the world will not overcome a poor inspection/ QA and verification program!

Advanced Treatments

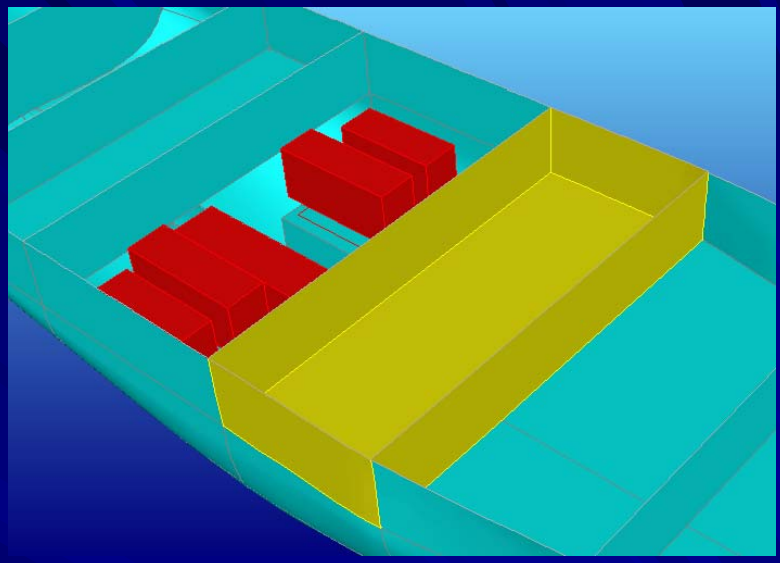
- Air layer (belt forward of engine room)
  - Effective mid- to high-frequency (10+ dB)
  - Amplifies low freq (-5 dB over 50 Hz bw)
  - Holes can clog if not maintained
- Hull coating
  - Effectiveness depends on material ‘compliance’ and thickness (>10 dB)
  - Adherence and damage issues

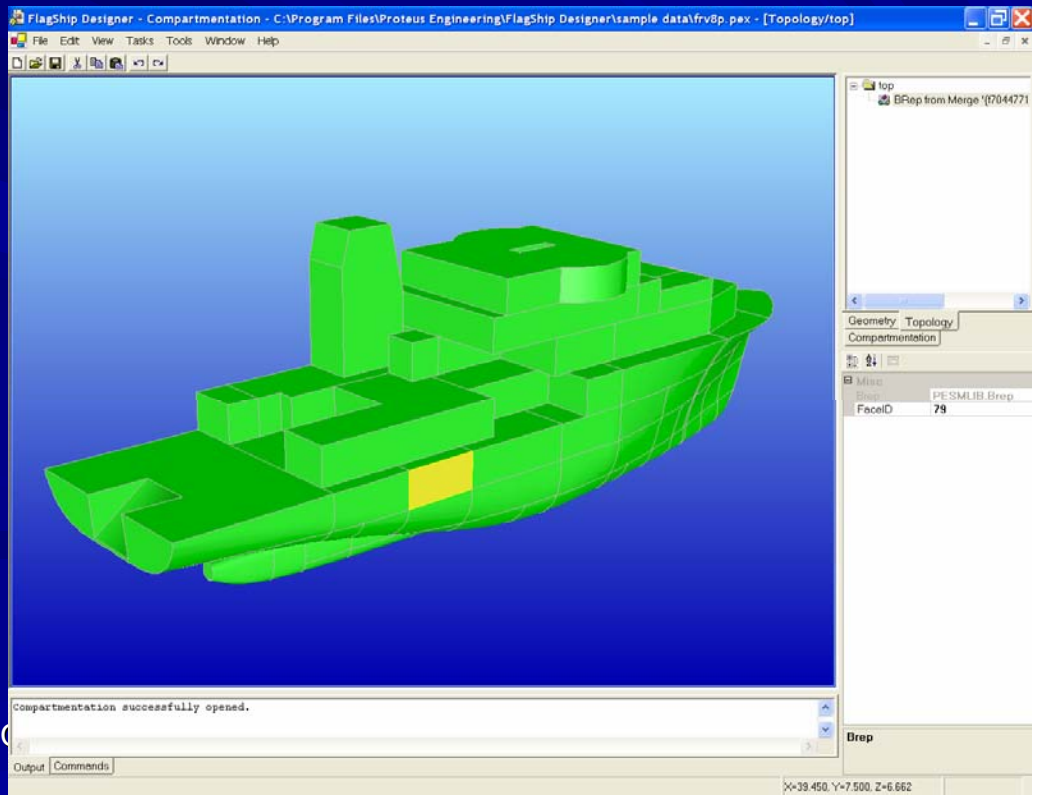
Advanced Treatments

- Active mount system
  - Improved low frequency performance
  - Cancels tones and multiples
- Keep machinery inside hull (Azipods currently radiate significant mechanical noise)

Designer NOISE

- Program for shipboard noise prediction
- Created under US NAVY SBIR Project
- Part of Flagship Designer suite from Proteus Engineering
- Ship specific
  - Modeling, constants, etc.

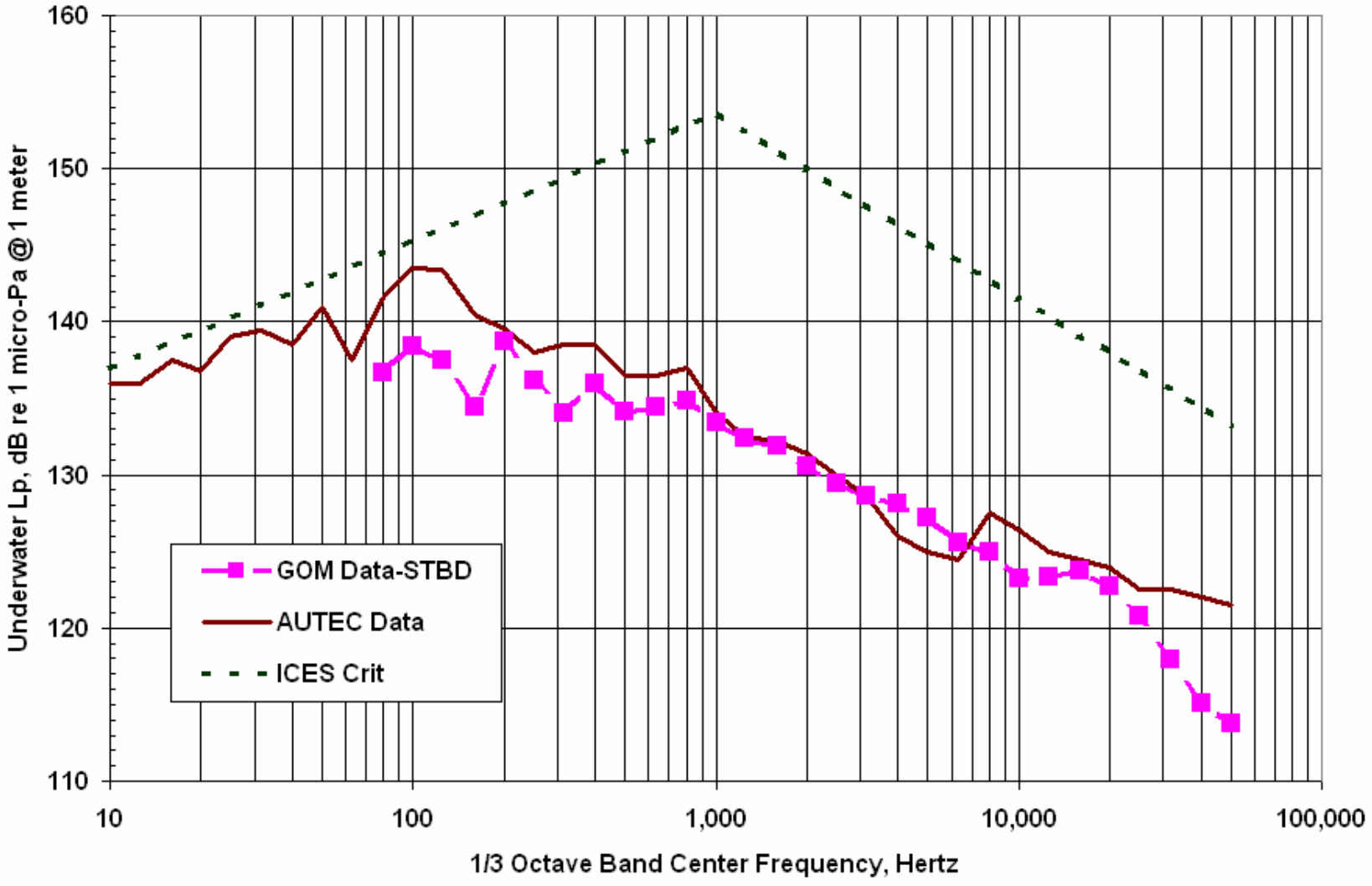




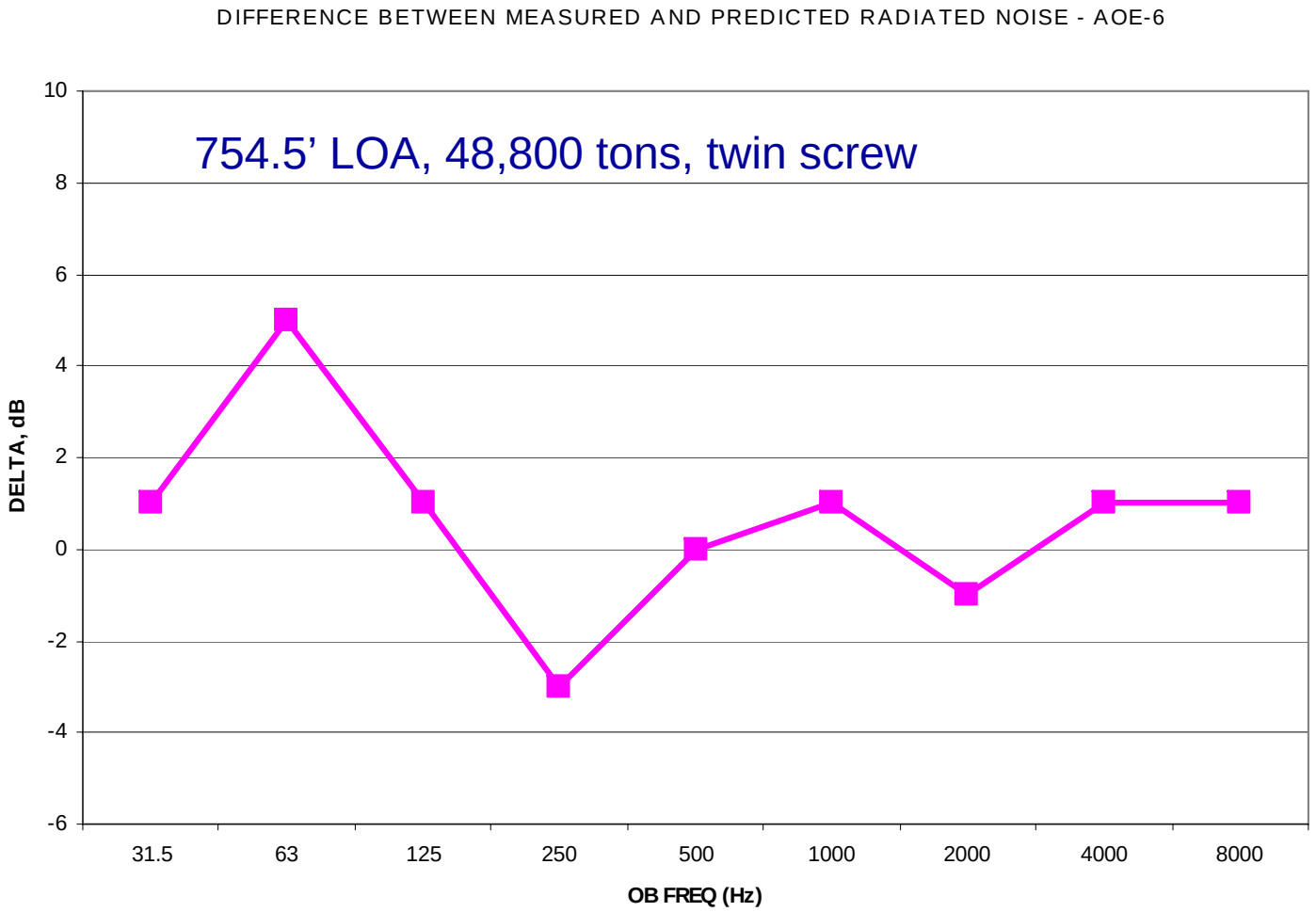
FRV-40 Noise Control Treatments

Low Noise Equipment	**Propulsion Motor Specially Designed**
Double Stage Vibration Isolation	**Diesel Gens & Reciprocating Equipment 3512 system – 18,113 kg; 3508 system – 14,770 kg**
Single Stage Isolation	**Auxiliary Equipment & HVAC**
Acoustic Insulation	**Perimeter of Engine Room and other noisy spaces**
Damping Tiles	**Applied to hull and bulkheads (16 tons)**
Hull & Propeller	**Specially designed by U.S. Navy (NSWC)**

FRV Radiated Noise – 11 kts



Prediction Tools



Range to 120 dB Level

	Source Level, dB re 1 µPa @1m	range, km Spherical spreading	range, km 1.5 power spreading	range, km Cylindrical spreading
FRV-40	150	.03	.1	1
5-m Zodiac	156	0.06	0.25	4
Tug & Barge @	171	0.4	2.5	130
Supply Ship	181-20=161	1.1->.11	12->.54	1260->12.6
Large Tanker	190-20=170	3.2->.32	46->2.1	10000->100
Drill ship, rigs, platforms				
Drill Ship	175-20=155	0.6->.06	4.6->.2	320->3.2
Conical Drilling Unit	185-20=165	1.8->.02	22->1	3200->32
DREDGING				
Ship 1	172-20=152	0.4->.04	3->.1	160->1.6
Ship 2	185-20=165	1.8->.02	22->1	3200->32

Summary

- Technology exists to evaluate and control ship noise & should be applied to vessels that operate in environmentally sensitive areas
- Primary noise sources are the propulsion drives – low frequencies and the propulsors – mid to high frequency (can trump once cavitating)
- Drives should be selected based on having low vibration source levels and/or utilizing vibration isolation mounts
- Novel treatments show potential but need development

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