SUMMARY REPORT:

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
12-13 November 2008
Newport, Rhode Island

and

Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model
17-18 November 2008
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EXECUTIVE SUMMARY

The US Navy is submitting a series of Environmental Impact Statements (EIS) that provide the basis for their requests for Letters of Authorization for the incidental take of marine mammals by anthropogenic sound associated with training activities in a number of ranges from the Atlantic to the Pacific. These EIS use models to predict the number of marine mammal takes by Level A or Level B harassment expected during training operations over large ranges during the five years of the requested authorizations. A panel of four independent experts was assembled to determine if the models used to determine these takes met certain standards.

The panel spent two days (out of three allocated) at each of two programs that have developed models for predicting the number of takes of marine mammals: the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island and SAIC, a Navy contractor, in Arlington, Virginia. Each facility used the same acoustic propagation model (CASS/GRAB), but used somewhat different approaches to calculating the number of marine mammal takes associated with the sound field.

The Terms of Reference required the panel to independently determine if each model (two models at NUWC and one at SAIC) sufficiently considered all relevant biological and physical variables; accounted for the scientific uncertainty in estimating acoustic exposure conditions for animals within the models; and met EPA's Council for Regulatory Monitoring (CREM) guidelines for model development. In addition, the panel was required to assess the validity of the post-modeling correction factors used in the SAIC model.

The overall conclusion of each member of the panel is that there is nothing inherently wrong with any of the three models. The initial Navy area-density model adopts a conservative approach which overestimates the number of takes by collapsing the 3-Dimensional grid of analysis points into a 2-Dimensional grid which assigns the highest received value in the water column (z axis) to the corresponding x-y location in the 2-D grid. The new Navy NEMO (NUWC Exposure Model) model responds to criticisms that the area-density model did not consider animal behavior with the addition of animats (acoustic dosimeters programmed to behave as marine mammals) that can serve as an excellent research tool and has the potential for being a sophisticated second or third generation acoustic impact model when sufficient data are available. The SAIC model is at first encounter very simplified, but the panel felt that its average of averages approach is probably best for the current EIS process given the uncertainties inherent in marine mammal behavior, density, and distribution; variability in the environment;

unknown details of naval operations over the large training ranges; the five years of take authorization considered by the EIS, and the definitions for marine mammal takes established by National Marine Fisheries Service (NMFS).

Validation of all components of the models is lacking. The extent to which the acoustic propagation models have been validated is classified, but known validation of similar Gaussian ray bundle models suggests that received levels are likely overestimated. There has been no validation of the animal exposure criterion for Level A harassment defined as permanent auditory threshold shift. The criterion for Level B(I) harassment, defined as temporary auditory threshold shift, is based on a few species and in some cases only one representative of the species. The risk assessment models for Level B(II) harassment, defined as behavioral disturbance, are reasonable based on available data, but have not been and, in the opinion of the panel, cannot be validated with current or foreseeable technology.

The modeling expert raises legitimate concerns as to why the National Marine Fisheries Service asks for only an expected number of takes by harassment level and by species in light of all the uncertainties in the models, and he suggests that including stochasticity, sensitivity, and scenario analyses would result in a much richer information environment in which to assess adaptive mitigation strategies and more effectively implement the real intent of the Marine Mammal Protection Act and the Endangered Species Act to safeguard marine mammals.

BACKGROUND

The Navy must abide by the requirements of the Marine Mammal Protection Act (MMPA) and obtain a Letter of Authorization if its activities result in the incidental "taking," as defined in the MMPA, of marine mammals. If a given marine mammal species also is listed as endangered, then the requirements of the Endangered Species Act (ESA) also apply. Specifically, the Navy must addresses the possible effects of noise associated with various activities.

In order to issue an LOA, the National Marine Fisheries Service must determine that the take will have a negligible impact on the species or stock(s). NMFS has defined ''negligible impact'' in 50 CFR 216.103 as: ''an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.''

The National Defense Authorization Act of 2004 removed the ''small numbers'' and ''specified geographical region'' limitations and changed the definition of ''harassment'' as it applies to a ''military readiness activity'' to read as follows (Section 3(18)(B) of the

MMPA): “(i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or (ii) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B Harassment].”

NMFS has interpreted these legal requirements as Level A harassment caused by non-explosive underwater acoustic signals occurring when the received sound energy level (SEL) exceeds 215 dB re 1 µPa, at which level cetaceans are assumed to exhibit permanent threshold shift (PTS), or exceeds 203 dB re 1 µPa for pinnipeds, at which level they are assumed to exhibit PTS when exposed in water (see Southall et al. 2007 for details and references). Level B harassment is subdivided into two types: (I) where the SEL causes a temporary threshold shift (TTS) and (II) where the sound pressure level (SPL) causes an observable behavioral change. For cetaceans TTS is assumed to occur at SEL greater than 195 dB re 1 µPa and for pinnipeds in water at SEL greater than 183 dB re 1 µPa (see Southall et al. 2007 for details and references). Level B Type II harassment is based on a logistic-like risk function (Feller 1968) where the essential parameters are the basement value for a behavioral response (taken as 120 dB SPL for all marine mammals); a parameter (K) representing 50% risk (taken as 45 dB SPL for all marine mammals); and a risk transition sharpness parameter (i.e., an indication of how closely the risk function approaches a step function) that is set at 10 for odontocetes and pinnipeds and at 8 for mysticetes, which results in an increase in the proportion of the population harassed at lower SPL compared to the curve for odontocetes and pinnipeds.

The role of the CIE panel was to determine whether the Navy and SAIC models were designed and implemented to obtain the best unbiased estimates for the Level A, Level B(I), and Level B(II) takes as defined by NMFS. The models are applied to naval activities in various operational ranges for which EIS documents and LOA requests have been, or will be, filed. The panel was provided with copies of the EIS for AFAST (Atlantic Fleet Active Sonar Training), Hawaiian Range Complex (HRC), and Southern California Range Complex (SOCAL). As an example of the type of situations for which these models need to be able to provide take estimates, the review specifically considered the use of mid-frequency sonars for the SOCAL EIS. The SOCAL range covers an area of 120,000 nmi^2. The incidental take authorization would cover five years (January 2009 to January 2014). The modelers do not know with any precision when or where mid-frequency sonar activities may take place within the range during these five years. Nonetheless, they need to estimate the number of takes by harassment in each category for marine mammal species found in this area. The

SOCAL EIS noted that in 2007 post-action reports were filed for 797 hours of mid-frequency sonar activity in the SOCAL range.

The CIE panel consisted of Dr. Christine Erbe (acoustics expert), Dr. Wayne Getz (modeling expert), and Dr. Jeanette Thomas (marine mammal expert). The panel was moderated, and this summary report prepared, by Dr. Douglas Wartzok. Each of the independent experts prepared a separate report that addresses all of the points in the Terms of Reference and the CREM Guidelines with their most extensive comments reserved for those areas in which they had the most expertise. These independent reports are referenced in this summary document as Erbe (2008a,b), Getz (2008) and Thomas (2008a,b).

REVIEW PROCESS OVERVIEW

The CIE panel was provided with the following material to download from a password protected FTP site and read in preparation for the reviews.

AFAST DEIS, excerpts from Chapter 3, Marine Mammal Densities, pages 3.2 – 3.6

AFAST DEIS Chapter 4.4 Marine Mammals, pages 4.16-4.129

AFAST DEIS Appendix H – Summary of Acoustic Modeling Results, pages H.1 – H.66

Houser, D.S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. IEEE Journal of Oceanic Engineering 31(1) 76 – 81

HRC FEIS-OEIS, Appendix J, Acoustic Impact Modeling, pages J.1 – J.104

Marine Resources Assessment for the Southern California Operating Area, Final Report, September 2005, pages 1 - 574

SOCAL Range Complex EIS/OEIS, Preliminary final version 2 (September 2008), Section 3.9, pages 1 – 132

SOCAL EIS, Appendix F, Overview and Technical Approach, pages F.1 – F.392

After the 27 October 2008 conference call the following document was added to the FTP site

Southall et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals 33:411-521.

On 27 October 2008, a conference call was held with the sponsors, representatives from the NUWC and SAIC, and three of the members of the CIE panel (Dr. Erbe was unable to participate). In addition to covering the logistics of the upcoming meetings, the Terms of Reference were discussed and clarified, and there was discussion around the two trial runs NUWC and SAIC would be conducting in advance of the review. The committee requested to review the output from both models for the same two trials run using the same inputs. There was also discussion of whether there would be merit to running a third model, the Acoustic Integration Model (AIM) developed by Marine Acoustics, Inc. and the object of a prior CIE review on which Dr. Getz and Dr. Thomas participated. After discussion, the decision was made not to consider this model. Further it was decided that NUWC and SAIC would consult and come up with a common set of parameters for the trial runs.

The specifics on two different trials were sent to the panel by Peter Hulton on 5 November 2008. It was the understanding of the panel members who participated in the 27 October 2008 conference call that NUWC and SAIC would each run both of the suggested trials. This impression persisted through the 5 November email because the text stated that Peter Hulton at NUWC and Bill Renner at SAIC had developed the scenarios. It turned out that NUWC ran both scenarios, but SAIC ran only the scenario with one ship moving in a straight line for four hours. When the SAIC model was discussed in Arlington, VA later in November, it became clear that they would have had great difficulty running the second scenario with three ships moving randomly on the range at different speeds. As discussed below, the benefits and limitations of the SAIC model are its simplicity which among other constraints restricts the range of input variables.

On 1 November 2008, Dr. Erbe sent the panel, the sponsor, and Navy contacts five pages of questions that had arisen during her review of the background documentation. Some of these questions dealt with the CASS/GRAB acoustic propagation model. Dr. Erbe has extensive experience with Gaussian ray bundle models and she also was aware of the validated errors in the these models used by the Australian Navy so she raised questions regarding how errors in CASS/GRAB in different environments and under different circumstances had been accounted for in the NUWC and SAIC models. Dr. Linda Petitpas, CNO-N45, responded that CASS/GRAB performance was classified, but that the models had been extensively reviewed and vetted for operational use. She also noted that the Terms of Reference specifically exempted the review of CASS/GRAB by the CIE review panel. The problems this exclusion presented for the CIE panel to fully address the Terms of Reference were further discussed in a telephone call between the moderator and NMFS personnel, Jolie Harrison and Brandon Southall on 7 November 2008.

The meetings at NUWC in Newport, RI took place on 12 and 13 November 2008. Three days were allocated for this meeting, but the review concluded after two days. The first day began with a discussion of the difficulty the CIE review panel had with fulfilling the Terms of Reference, specifically term number 2 “Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.” in the absence of any information on the scientific uncertainty in the received levels at range and depth predicted by CASS/GRAB. The conclusion was that the panel should simply note that the uncertainty in CASS/GRAB, which could be large if it suffered from some of the issues afflicting the Gaussian ray bundle models used by the Australian Navy, would have to be added to the other uncertainties identified by the panel (see below under the summary for the Terms of Reference).

Peter Hulton provided an overview of the Area-Density Model noting that it was written in MatLab and therefore processing speed and memory limitations meant that the calculated 3-Dimensional sound propagation was collapsed into a 2-Dimensional grid with the maximum SPL over the depth recorded for the SPL at that 2-D location. After walking the panel through the steps between the acoustic propagation to the take calculations in the Area-Density Model, Peter turned to the NUWC Exposure Model (NEMO). This model in the Terms of Reference was called “the NUWC model including the incorporation of the ESME behavioral model.” Actually this was somewhat of a misnomer. NEMO is a very different model from the Area-Density Model, whether or not it includes the ESME behavioral model. This initial 3-D model was written in MatLab and suffers from some of the same processing issues as the Area-Density Model. However, the panel was informed that NEMO II was under development and should be operational by January 2010. This model is being written in Java 1.6.

Peter Hulton and Bill Sutphin discussed data validation, internal testing, and data integrity checks associated with the Area-Density Model. They noted that no formal validation of the model has been conducted, although many subcomponents have been verified. Also there is no formal documentation of the model. It is not a plug-and-play model, rather one that requires operator judgment at most steps.

Tom Featherston summarized the animal behavior components of the Area-Density Model. The marine mammal population for the Area-Density Model is usually uniformly distributed over the specified area, but can be distributed with more granularity if there is sufficient knowledge of a marine mammal species’ distribution. He also discussed the Marine Mammal Movement and Behavior (3MB) model developed by Dr. Dorian Houser as part of the Effects of Sound on the Marine Environment (ESME) tool bench. Featherston also reviewed the noise exposure criteria for Level A (PTS) and Level B(I) (TTS) harassment and the risk function associated with Level B(II) harassment. Yadira Gilchrest reviewed the inherent and underlying assumptions in the models. Without compromising any of the classified performance information on the CASS/GRAB model, she clarified its capabilities in terms of changing bottom types, changing sound velocity profiles, changing the number of radials used, and the placement of the radials. She also noted that for frequencies below 150 Hz and in shallow water CASS/GRAB is replaced with the Range Dependent Acoustic Model (RAM) propagation model.

On 13 November, Peter Hulton presented data on the model outputs for the two trial run scenarios. Below is the description of each of the scenarios.

Trial Run # 1
(Animal Density Approach)

- Range Description
  - Location: SOCAL
  - Ref. Lat: 32.0 N
  - Ref. Long: 118.0 W
- Environmental Parameters
  - Seasons: Winter & Summer
  - Bottom Type: Sand
  - Wind Speed: 15 knots & 10 knots
  - Sound speed profile: Extracted from GDEM-V 3.0
  - Bathymetry: Extracted from DBDB-V 5.2
  - Edges of Bathymetry
    - Lat: 28.9 N & 34.1 N
    - Long: 116.4 W & 120.6 W
- Scenario Parameters
  - Operation Time: 4 Hours
  - Number of active sources: 1
- Source 1
  - Operations area: 90 km E-W & 90 km N-S
  - Platform Starting Points: Middle of southern edge of operations area
  - Platform Path: North
  - Speed: 10 knots
  - Depth: 10 meters
  - Source level: 235 dB
  - Ping length: 1 second
  - Ping rep rate: 1 minute
  - Horizontal beam pattern: 240 Deg
  - Vertical beam pattern: 180 Deg
  - Frequency: 5.0 kHz
- Marine Mammal Data
  - Species: Fin whale, Blue whale, Cuvier beaked whale
  - Density: 500 per species

Trial Run # 2
(3D Mammal Movement Approach)

- Range Description
  - Location: SOCAL
  - Ref. Lat: 32.0 N

- Ref. Long — 118.0 W

- Environmental Parameters
  - Seasons — Winter & Summer
  - Bottom Type — Sand
  - Wind Speed — 15 knots & 10 knots
  - Sound speed profile — Extracted from GDEM-V 3.0
  - Bathymetry — Extracted from DBDB-V 5.2
  - Edges of Bathymetry
    - Lat — 28.9 N & 34.1 N
    - Long — 116.4 W & 120.6 W
- Scenario Parameters
  - Operation Time — 4 Hours
  - Number of active sources — 3
- Source 1
  - Operations area — 90 km E-W & 90 km N-S
  - Platform Starting Points — Random on range
  - Platform Path — Random
  - Speed — 10 knots
  - Depth — 10 meters
  - Source level — 235 dB
  - Ping length — 1 second
  - Ping rep rate — 1 minute
  - Horizontal beam pattern — 240 Deg
  - Vertical beam pattern — 180 Deg
  - Frequency — 5.0 kHz
- Source 2
  - Operations Area — 60 km E-W & 40 km N-S
  - Platform Starting Points — Random on range
  - Platform Path — Random
  - Speed — 5 knots
  - Depth — 200 meters
  - Source level — 210 dB
  - Ping length — 2 second
  - Ping rep rate — 5 minute
  - Horizontal beam pattern — 120 Deg
  - Vertical beam pattern — 60 Deg
  - Frequency — 8.0 kHz
- Source 3
  - Operations Area — 20 km E-W & 20 km N-S
  - Platform Starting Points — Random on range
  - Platform Path — Random
  - Speed — 20 knots
  - Depth — 100 meters
  - Source level — 240 db

- Ping length 0.5 seconds
- Ping rep rate 15 seconds
- Horizontal beam pattern 60 Deg
- Vertical beam pattern 45 Deg
- Frequency 15 kHz

- Marine Mammal Data
  - Species Fin whale, Blue whale, Cuvier beaked whale
  - Density 500 per species

The results of the trial runs are on the following two pages.

Density Data for <Test Name> November		Required Area for Zero Exposures with 10/3/08 Densities
Species	<Reference> 10/3/08	
Mysticetes	Animals / sq km	
Blue whale	0.002464	20.25162338
Fin whale	0.002464	20.25162338
Odontocetes		
Cuvier	0.002464	***202.51623377***

Trial Run 1 - CIE Review - Summer SEL & Behavioral Response Thresholds CASS analysis point: 32 N, 118 W					
Raw Numbers			Rounded Numbers		
Behavioral	Level B (TTS)	Level A (PTS)	Behavioral	Level B (TTS)	Level A (PTS)
120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215	120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215
3.941839	0.015854	0.000000	4	0	0
3.941839	0.015854	0.000000	4	0	0
3.488037	0.015854	0.000000	3	0	0

Key	
ESA: exposures are >=	0.05
MMPA: exposures are >=	0.5
Mysticetes (ESA)	
Mysticetes (non-ESA)	
Odontocetes (ESA)	
Harbor Porpoise	

Sound Exposure Level (SEL) Areas		
SEL Areas (sq km)	*Areas in dB Bands*	
≥ 195 dB	*195 to 215 dB*	*≥ 215 dB*
6.434375	6.434375	0.000000
≥ 215 dB		
0.000000		

Behavioral Response Areas		
Mysticetes	Ondonticetes	Harbor Porpoise
120 to TTS	*120 to TTS*	*120 to TTS*
1599.772184	1415.599240	N/A

Density Data for <Test Name>		Required Area for Zero Exposures with
Species	<Reference> 10/3/08	
Mysticetes	Animals / sq km	
Blue whale	0.002464	20.25162338
Fin whale	0.002464	20.25162338
Odontocetes		
Cuvier	0.002464	***202.51623377***

Trial Run 1 - CIE Review - Winter					
Raw Numbers			Rounded Numbers		
Behavioral	Level B (TTS)	Level A (PTS)	Behavioral	Level B (TTS)	Level A (PTS)
120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215	120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215
2.856962	0.015531	0.000000	3	0	0
2.856962	0.015531	0.000000	3	0	0
2.515207	0.015531	0.000000	3	0	0

Key	
ESA: exposures are >=	0.05
MMPA: exposures are >=	0.5
Mysticetes (ESA)	
Mysticetes (non-ESA)	
Odontocetes (ESA)	
Harbor Porpoise	

Sound Exposure Level (SEL) Areas		
SEL Areas (sq km)	*Areas in dB Bands*	
≥ 195 dB	*195 to 215 dB*	*≥ 215 dB*
6.303125	6.303125	0.000000
≥ 215 dB		
0.000000		

Behavioral Response Areas		
Mysticetes	Ondonticetes	Harbor Porpoise
120 to TTS	*120 to TTS*	*120 to TTS*
1159.481394	1020.781871	N/A

Density Data for <Test Name> November		Required Area for Zero Exposures with 10/3/08 Densities
Species	<Reference> 10/3/08	
Mysticetes	Animals / sq km	
Blue whale	0.002464	20.25162338
Fin whale	0.002464	20.25162338
Odontocetes		
Cuvier	0.002464	***202.51623377***

Trial Run 2 - CIE Review - Summer
SEL & Behavioral Response Thresholds
CASS analysis point: 32 N, 118 W

Raw Numbers			Rounded Numbers		
Behavioral	Level B (TTS)	Level A (PTS)	Behavioral	Level B (TTS)	Level A (PTS)
120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215	120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215
3.964204	0.018063	0.000000	4	0	0
3.964204	0.018063	0.000000	4	0	0
3.547482	0.018063	0.000000	4	0	0

Key	
ESA: exposures are >=	0.05
MMPA: exposures are >=	0.5
Mysticetes (ESA)	
Mysticetes (non-ESA)	
Odontocetes (ESA)	
Harbor Porpoise	

Sound Exposure Level (SEL) Areas		
SEL Areas (sq km)	*Areas in dB Bands*	
≥ 195 dB	*195 to 215 dB*	*≥ 215 dB*
7.330625	7.330625	0.000000
≥ 215 dB		
0.000000		

Behavioral Response Areas		
Mysticetes	Ondonticetes	Harbor Porpoise
120 to TTS	*120 to TTS*	*120 to TTS*
1608.848937	1439.724931	N/A

Density Data for <Test Name>		Required Area for Zero Exposures with
Species	<Reference> 10/3/08	
Mysticetes	Animals / sq km	
Blue whale	0.002464	20.25162338
Fin whale	0.002464	20.25162338
Odontocetes		
Cuvier	0.002464	***202.51623377***

Trial Run 2 - CIE Review - Winter

Raw Numbers			Rounded Numbers		
Behavioral	Level B (TTS)	Level A (PTS)	Behavioral	Level B (TTS)	Level A (PTS)
120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215	120 ≤ SPL < TTS	195 ≤ SEL < 215	SEL ≥ 215
3.506615	0.018321	0.000000	4	0	0
3.506615	0.018321	0.000000	4	0	0
3.071012	0.018321	0.000000	3	0	0

Key	
ESA: exposures are >=	0.05
MMPA: exposures are >=	0.5
Mysticetes (ESA)	
Mysticetes (non-ESA)	
Odontocetes (ESA)	
Harbor Porpoise	

Sound Exposure Level (SEL) Areas		
SEL Areas (sq km)	*Areas in dB Bands*	
≥ 195 dB	*195 to 215 dB*	*≥ 215 dB*
7.435625	7.435625	0.000000
≥ 215 dB		
0.000000		

Behavioral Response Areas		
Mysticetes	Ondonticetes	Harbor Porpoise
120 to TTS	*120 to TTS*	*120 to TTS*
1423.139219	1246.352071	N/A

The meetings at SAIC in Arlington, VA took place on 17 and 18 November 2008. Three days were allocated for this meeting, but the CIE review panel review concluded after two days. The first day began with a review of the Terms of Reference, particularly as they applied to the SAIC model. This was followed by a presentation by Ray Cavanagh covering a range of concerns that have been expressed regarding the SAIC approaches to risk assessment and calculation of takes. The presentation attempted to preempt any similar concerns arising among the CIE review panel with respect to the simplifying assumptions employed in the SAIC model. The basic message was that because of the uncertainty with respect to details of the naval operations and the locations, densities, and behaviors of the animals, the best measure for takes was the expected value of the random variable representing the number of takes.

Bill Renner presented an overview of how SAIC overlays bathymetry classes, sound velocity profile provinces and high frequency bottom-loss environmental data to determine unique intersections within the range covered by the EIS and from these intersections to establish the environmental provinces SAIC will model. He then described how transmission loss and energy accumulation are determined with range in each province.

Janet Clarke participated by conference call to describe how she acquires species-specific marine mammal densities, diving patterns, seasonal distribution, and age and sex variability. She discussed the general paucity of data and the need to glean data from peer reviewed literature, gray literature, conference presentations, etc. In the end, the data entered into the model are the best available estimates and are entered into the model as expected values without any confidence intervals.

Next Mark Lockwood presented how energy flux impact volumes were calculated for Level A and Level B(I) harassment and how the risk function was used to calculate volume histograms related to proportional risk of Level B(II) harassment. He presented a sensitivity analysis of how impact volume changed with changing assumptions on analysis grid size and dB bin width. He next discussed the post processing that SAIC conducts to account for land shadow, multiple ships zone of influence overlap, and density dilution, which recognizes that an animal can be taken only once in a 24 hour period (or shorter period if the operation lasts less than 24 hours). Finally he described how data are presented in a spreadsheet that converted to the number of marine mammal takes to per unit (e.g. hours) of operation.

On 18 November Mark Lockwood and Bill Renner lead a discussion of the results of scenario 1 of the two planned scenarios. As noted earlier, there was some confusion regarding the second scenario. SAIC thought it was only to be modeled by NEMO, but the actual run parameters had no such specifications. When asked about the possibility of running the second scenario, the CIE review panel was told that it would require at least a week of computer run time. Also, the SAIC model is not designed to handle multiple ships operating at different speeds with different source characteristics moving randomly and independently of each other in the same range at the same time.

The SAIC model output is provided on the next page and a comparison of the NUWC and SAIC models on the following page.

SAIC Summary

	CIE-SOCAL
CIE Hours of Operation (Summer)**:**	4
CIE Hours of Operation (Winter)**:**	
Number of Ships:	1

Reset Time (hours)	4
DR Harassments at 10 km	0.95
CNA multiple ship adjustment	1

Mammals \ Exposures	**Behavioral**	**TTS**	**PTS**
Blue_whale	1.38624503	0.022551	7.75E-05
Fin_whale	1.31563732	0.009653	3.16E-05
Cuviers_beaked_whale	1.15699342	0.016533	2.2E-05

Level B(II) Harassment Calculations

Source:	All	reset hours	4		Area	214440.4		Diagonal	671.4	km
Area:	Area 1							Circumferer	1866.4	km
		Resets	Remainder		Land Shadow	Multiple Ship		Area	192204	sq km
Sonar Hours of Operation (Summer):	4	1	0		1	1		Swim distar	22	km
Sonar Hours of Operation (Winter):	0	0	0							
CIE Demo Source	pings/hr	60	pings/reset	240						
Threshold	Per ping		Shadow & multiple-shi		Per reset		Density S	Density W	Pop S	Pop W
Mammals \ Exposures	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Blue_whale	0.00578318	0.010744	0.005783	0.010744	1.386245	2.572565	0.002601	0.0026014	557.8459	557.8459
Fin_whale	0.00548827	0.006767	0.005488	0.006767	1.3156373	1.621804	0.002601	0.0026014	557.8459	557.8459
Cuviers_beaked_whale	0.00482579	0.00673	0.004826	0.00673	1.1569934	1.612915	0.002601	0.0026014	557.8459	557.8459

Level A and Level B(I) Harassment Calculations

Source:	CIES					
Area:	CIE_General					
Units of Operation (Summer):	4					
Units of Operation (Winter):	0					
Threshold	195 dB			215 dB		
Mammals \ Exposures	Summer	Winter	Annual	Summer	Winter	Annual
Blue_whale	0.00563782	0.004406	0.022551	1.94E-05	1.937E-05	7.75E-05
Fin_whale	0.00241318	0.0021	0.009653	7.89E-06	7.889E-06	3.16E-05
Cuviers_beaked_whale	0.00413313	0.003124	0.016533	5.49E-06	5.491E-06	2.2E-05

Comparison of outputs from Trial 1 between NUWC and SAIC models

	Number of		**Number of**		**Number of**			
NUWC results	**Level B(II)**		**Level B(I) takes**		**Level A takes**		Density	Density
Take Exposure Levels	120 dB < TTS		195 dB	SEL	215 dB	SEL	Summer	Winter
Mammals	Summer	Winter	Summer	Winter	Summer	Winter		
Blue whale	3.941839	2.856962	0.015854	0.015531	0	0	0.002464	0.002464
Fin whale	3.941839	2.856962	0.015854	0.015531	0	0	0.002464	0.002464
Cuviers beaked whale	3.488037	2.515207	0.015854	0.015531	0	0	0.002464	0.002464
	Number of		**Number of**		**Number of**			
SAIC results	**Level B(II)**		**Level B(I) takes**		**Level A takes**			
Take Exposure Levels	> 120 dB max SPL then calculated from risk function		> 195 dB and < 215 dB SEL		>215 dB SEL		Density	Density
Mammals	summer	winter	Summer	Winter	Summer	Winter	Summer	Winter
Blue whale	1.386245029	2.5725652	0.0056378	0.0044056	1.94E-005	1.94E-005	0.0026014	0.0026014
Fin whale	1.31563732	1.6218037	0.0024132	0.0021001	7.89E-006	7.89E-006	0.0026014	0.0026014
Cuviers beaked whale	1.156993424	1.6129151	0.0041331	0.0031237	5.49E-006	5.49E-006	0.0026014	0.0026014

Although the trial parameters for both models were 500 whales of each species, the SAIC model implementation led to a total of 558 whales subject to potential taking because of the incorporation of whales at the boundary that could be directly affected and whales outside the border that could swim into the operations area.

FINDINGS

Terms of Reference 1: Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).

The overall opinion of the CIE review panel was that each model *sufficiently* considered all relevant biological and physical variables. The key idea is "sufficiently" and this must be answered within the context of what the models are being asked to determine. The models are to determine the number of takes at three different harassment levels for a variety of species of marine mammals over the extended ranges of naval operations during the five years for which LOAs are sought based on the EIS. It is clear from the CIE review panel members' reports that if the questions were more specific, the models would need to take into consideration more specific biological and physical variables. The modeler (Getz 2008) emphasized the problems inherent with trying to use the model output for management and mitigation because the models provide only the expected number of takes and provide no data on stochasticity as reflected in the variance in the number of takes, conduct no sensitivity analyses on how uncertainties in the data and processes propagate through the model, and require no scenario analyses.

Each of the models is capable of handling animal distribution at the level to which it is known. Lacking any specific knowledge of areas of operation, an average density over the range is used [Getz (2008) notes that in spite of the statements of SAIC modelers, they do not use a uniform density which would also have a variance component]. The models collapse annual variation in environmental conditions as related to acoustic propagation into two seasons and when seasonal data are available on species occurrence within the range, or at more specific locations within the range, these data are incorporated in the models. Thomas (2008a,b) notes a number of additional distribution factors that could be considered in the models, such as the haulout patterns of pinnipeds, which takes them out of the water to varying extents on a seasonal basis; the lack of modeling distribution of plankton as a factor influencing mysticete distribution; diel patterns of dive behavior that will result in changed distributions in the water column; age and sex differences in distribution; and the extent to which different species are clumped in their distributions. The SAIC modelers specifically noted that the manner in which they model operations results in the same number of takes, regardless of whether the animals are distributed individually or in aggregations. Erbe (2008b) supports the validity of this assumption.

Two of the models, NEMO and SAIC, distribute the animals in the z-axis (depth), as well as in the x-y plane. This approach was uniformly regarded by the panel as superior to the Area-Density Model approach of NUWC in which all three dimensional distributions are collapsed to the x-y plane and the maximum SPL in the water column is assigned to that x-y location. This approach overestimates the number of Level B(II) takes. The panel members felt that the animat approach in NEMO was most suited for research model development, but was not appropriate to use at this time in models estimating marine mammal takes. Although it responds to many criticisms of prior models that have not taken animal behavior into consideration, it provides a false sense of improvement by incorporating a lot of essentially unknown animal behavior. Even basic animal responses, such as whether they move away from areas of higher noise to reduce their exposure, are unknown.

> Given the lack of biological behavioral data, I don't believe that the level of sophistication provided by the NUWC+ESME methodology can currently lead to more accurate estimates of "take" rates than, say, the SAIC model discussed next. However, the NUWC+ESME approach can be used to improve our understanding of how adaptive behavior, once known, might impact the "take" rates. (Getz 2008)
>
> While I see great potential for the 3MB model as a tool in behavioral research, I don't believe it is at a stage yet where it should be included in EIA models. There are a lot of physical and biological parameters that determine an animal's behavior and response to noise. 3MB aims to model a very complex scenario, requiring quite detailed information. It is my opinion that we do not have adequate data (neither in quality nor quantity) that warrants the implementation of an individual behavior module. (Erbe 2008a)
>
> I encourage the investigators to continue development of this model, which will help identify any important behavioral indicators related to behavioral takes. However, given the small amount of data available on marine mammal dive profiles, especially in pinnipeds, the use of the NUWC, three-dimensional model, but without moving the animats is likely to be sufficient for estimating takes. (Thomas 2008a)

The panel recommended that NEMO distribute animals along the z-axis in the manner SAIC does, i.e., using all available dive profile data to determine what proportion of time a typical individual of a given species spends at various depths and distribute that species proportionately by depth for the exposure calculations.

The lack of information on the distribution of animals is a significant impediment to obtaining valid estimates of take. The panel felt that obtaining better data on distribution, particularly with respect to environmental features defining habitat, is much more important than fine tuning the movements of individual animals in response to noise.

An analysis of the consideration of physical variables fell primarily within the purview of the oceanic acoustician, Dr. Erbe, who has extensive experience in performing similar acoustic propagation modeling.

NUWC handles bathymetry via a limited number of analysis points and typically eight radials around each analysis point. In the implementation described, they used three analysis points (shallow, slope, deep) to calculate footprints that were then used throughout the region. In one of the examples shown, the difference in sound propagation between radials was 40 dB at distance from the analysis point. Both Erbe (2008a) and Getz (2008) recommend using more radials if the differences are greater than 10 to 20 dB and Getz (2008) recommends using smoothing functions so the received level for an animal does not change by orders of magnitude if its placement is shifted by a few meters.

SAIC uses bathymetry only to determine environmental provinces within the operational area.

> At first glance, this horrifies the acoustic modeler. Transmission loss is computed over ranges in excess of 150 km, assuming a flat bottom and radial symmetry. Bathymetry is completely ignored except for the water depth at the location of the ping. Clearly, on the continental slope, in between islands, near seamounts or coast lines, this is far from reality. But, considering that the modeler does not know where the ship is going and in which direction it is pinging, all that the model considers is the water depth underneath the ship at the location of the ping…. on average, over all source locations and bearings within an operational region, the assumption of locally flat bottoms is probably valid, not leading to consistent over-estimating or under-estimating of exposures. (Erbe 2008b)

Although the two models include sound velocity profiles somewhat differently, Erbe's (2008a,b) assessment is that each handles sound speed profiles correctly. Each model uses two cases, summer and winter although each defines summer and winter somewhat differently. Similarly, sea floor geology is assessed through different databases, but appears to be properly incorporated in the models (Erbe 2008a,b).

The greatest concern arises in the unknown of how well the CASS/GRAB acoustic propagation model performs. Knowing this is essential to being able to make any statements on the overall validity of the number of marine mammal takes estimated by any of the models. The panel was assured that the classified CASS/GRAB model was reliable enough to be used for national defense and that it had been reviewed by knowledgeable individuals whose names and associations were given to the panel. It is also an accredited model within the Oceanographic and Atmospheric Master Library (OAML). However, as pointed out in Erbe (2008a)

> While this argument seems convincing at first glance, one has to remember that the requirements for naval operations and environmental assessments are different, if not

opposing. I assume for naval operations, the further the sonar reaches, the better. For the purpose of modeling sound propagation over very long ranges, CASS/GRAB will have advantages over other sound propagation models, because ray models are very fast. Using CASS/GRAB to model target detection at very long ranges will be quick. An error in received level of several dB at very long ranges is likely not an issue for naval operations; as long as the bearing is properly resolved, one could always investigate in that direction more closely. For bioacoustic impact assessment, the farther the source reaches, the worse the impact. An error of several dB can significantly affect the number of 'takes' by NMFS definition. An error in SPL of 20 dB can change the output of the behavioral risk function from 10% to 90% of a population being 'taken' (10% @ 155 dB, 90% @ 175 dB).

The Australian Defense did some field verifications of three different ray models, two of them Gaussian ray bundle models (Jones *et al.* 2007). They found reasonable agreement between the models and the field data at 400 Hz. At 1 kHz, all models over-predicted the received levels by up to 10 dB for ranges greater than 4 km. At 3 kHz, the models all over-predicted the received level by up to 20 dB for ranges greater than 12 km. The environment was shallow and downward refracting.

Both NUWC and SAIC model one frequency for a particular source. This is appropriate for mid-frequency sonars, but for broadband sources the center frequency of each adjacent 1/3 octave band should be modeled (Erbe 2008a). The larger concern regarding modeling with a single frequency relates to the animal impact assessment (see below).

SAIC only models ships moving in straight lines. NUWC can model ships moving in straight lines or randomly. The second of the two trial run scenarios had ships moving randomly and the inability to handle random movement may have been one of the reasons SAIC only modeled the first trial run scenario.

Neither the NUWC nor the SAIC models considered ambient noise. Although this will not change the propagation models, it can change the animal impact assessments. The SEL for TTS will likely to be different under masked and non-masked situations and the behavioral risk curve may be displaced under conditions of high ambient noise. Ambient noise may also affect the distribution of animals within the operation area.

NUWC and SAIC both use the same criteria for determining Level A, Level B(I), and Level B(II) harassment. These criteria are based on NMFS guidelines. Neither model looks at species-specific hearing sensitivities. The only place where any difference in species hearing sensitivities enters the models is via the risk curves in which the sharpness parameter changes from 10 for cetaceans and pinnipeds to 8 for mysticetes. For the mid-frequency sonars, which were the focus of this review, ignoring the species-dependent frequency sensitivities probably does not introduce significant errors. Thomas (2008a,b) recommends NUWC and SAIC develop separate risk curves for each of the four ear types of marine mammals identifies by Southall et al. (2007): mysticete, mid-frequency odontocetes, high-frequency odontocetes, and pinnipeds. As more data become available to estimate the B, K, and A parameters of the risk curve for odontocetes and pinnipeds, these curves can be constructed. It is not clear whether this should be the responsibility of the Navy and its contractors, or whether this should be established by NMFS as they have done for other criteria for determining levels of harassment. As Getz (2008) points out: “in the case of most species, the biological basis for the use of the function appears to be convenience rather than the function being firmly rooted in data.”

Although the risk function is defined as the proportion of a population that reacts at a given received SPL, both models assume that all animals react the same and thus the probability of any one animal reacting is considered equal to the percentage of a population that reacts. This was deemed to be a reasonable assumption.

However the way the risk curve is used in both models, in line with NMFS criteria, raises concern.

> Whether this NMFS endorsed risk function makes much sense biologically, is a different question. In my opinion, it makes little sense to relate the probability of a response to the maximum level received over a 24 h period. An animal is not going to sit in the water, being pinged at, waiting for a higher SPL to come within the next 24 h. At any one time that it receives a ping, it decides whether to react or not. With the next ping, it faces the same decision. The probability of response should be a function of the actual level received at any one time. The probability of an animal reacting at least once every 24 h is then equal to the cumulative probability for all pings received. (Erbe 2008a)

Similarly the calculation of SEL for TTS and PTS assessment has implementation problems in that neither model considers any possibility of recovery between pings.

> In the computation of SEL values, it is clear to me that 24 pings in quick succession are not going to have the same affect on an animal as 24 pings each an hour apart. Is it appropriate to disregard such differences in calculating “take” rates? (Getz 2008)

It was mentioned in the presentation at NUWC that NEMO in the 2010 version will be able to record the time of arrival of the pings at each animat and when more is known about TTS recovery these data can lead to refined predictions of Level B(I) takes. Right now, both models are conservative in that they overestimate the number of Level B(I) takes because they do not consider partial, or complete, recovery of the temporary threshold shift during the 24 hour accumulation period.

Terms of Reference 2: Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.

As the panel pointed out to Dr. Linda Petitpas on the first day at NUWC, having no information on the uncertainties associated with the CASS/GRAB propagation model undermined any ability to estimate the scientific uncertainty associated with acoustic exposure estimates.

Both NUWC and SAIC models use standard databases; this is as good as one can do. The real world obviously changes on temporal scales not captured in standard databases, but there is no reason to assume that the variability would bias the take estimates toward either higher or lower values.

In the absence of any particular knowledge about future naval operations, NUWC moves the ships on random tracks. This was judged to be reasonable and to provide an unbiased estimate of takes. On the other hand, SAIC's approach that moves ships in straight lines was also judged to provide unbiased estimates when considered within the complete SAIC modeling paradigm.

> SAIC does not attempt to model a specific scenario of ship tracks and animal movement. SAIC takes a very general approach producing average harassment numbers per unit of operation. The model does not require exact knowledge of the physical and biological parameters at the time of operation. Rather, mean profiles are extracted from databases to produce expected numbers of 'take'. There is a lot of averaging happening at any stage and level in the model. Therefore, even though some parameters could be extracted with more accuracy, this is not useful for the approach taken. (Erbe 2008b)

As noted before, neither model includes ambient noise which probably results in higher estimates of takes than if it were included.

As has been noted several times previously, the NUWC Area-Density Model over estimates Level B(II) takes because it collapses the 3-D propagation data into a 2-D grid and assigns the highest SPL in the water column at that x-y location to the corresponding 2-D grid point.

Because TTS and PTS accumulate SEL without consideration for recovery over the 24-hour summation period, the takes are higher than if recovery were included.

Given the minimal knowledge available on animal responses to noise, modeling the animals as stationary and distributing them evenly throughout a habitat or province will neither under-estimate nor over-estimate takes. Obviously if we knew more about the response of animals to noise and other factors that affect their distribution, such as prey availability, the take estimates could be improved, but lacking that knowledge and instead guessing the animals' behavior, e.g., avoidance, can lead to biased estimates.

As required by NMFS, each model produces an expected number of takes with no variance. This approach, as pointed out by Getz (2008) makes it impossible to model catastrophic events. It is recognized that catastrophic events, such as the Bahamas beaked whale strandings, are major drivers in the concern about naval sonar operations and primary contributors to the legal proceedings the Navy and NMFS encounter when procuring and providing authorization for sonar training activities.

> In the context of acoustic harassment "take" rates, the average is important because it provides an estimate on the size of the phenomenon. But the variance associated with this average becomes important if one is concerned as well with risk. Purely as an illustrative example,

> suppose NMFS wanted to assess the acceptability of the following two exercises. For the first exercise a model predicts that one fatality is expected in each repetition of the exercise. In the second exercise a model predicts that 0 fatalities are expected with probability 0.9 for each repetition, but that 10 fatalities can be expected with probability 0.1 in each repetition. (This is not as far fetched as it sounds if individuals of the species were always located in pods of around size 10). Both exercises have an expected mortality rate of 1? If a permit were sought for the second exercise as a one-off case, then NMFS perhaps would approve it based on the likely outcome that no individuals would be harassed. If permits were requested for 10 repetitions of both the first and second exercises over a five year period (say one every 6 months), then perhaps NMFS would approve the first because 2 deaths a year may be an acceptable annual "take" rate, but not the second because an event of 10 deaths occurring during a single exercise may be unacceptable in some sense (e.g. because of the publicity generated by the event). If a relatively high number of deaths in one exercise were labeled a "catastrophe" by some group, then in regulating "take" rates, NMFS is expected to be risk-averse to the occurrence of "catastrophes" because of the adverse publicity attached to such events; even though such events may be no more threatening to the population in the long run than operations of the first type described above. Thus, in general, estimates of probabilities associated with potentially "catastrophic" events (however they are defined), are useful to know. (Getz 2008)

Thomas (2008a,b) agrees with the assumptions of each model, but makes the following suggestions: recovery time needs to be considered in the TTS and PTS estimates; the probability of take will depend on age and sex differences and these should be included; calculating the propagation for a given month and a given location will produce better results; the SAIC model does not address whether multiple sources operating at the same time might cancel-out some of the noise or how complex sound fields from different frequency sources might interact; the SAIC assumption that all ships move in straight lines is not valid; the SAIC model does not address the real world situation of an animal deciding to leave the operational area or change its behavior during an operation; and the SAIC model assumes pinnipeds have their heads under water 100% of the time and this is not correct. Thomas (2008a,b) also raises again the point that takes will be different if the animals are in pods compared to being placed individually, but other reviewers and the presenters noted that this is not the case in terms of expected number of takes. It is relevant when considering potentially catastrophic events as noted in the quote from Getz (2008) above.

Terms of Reference 3: Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.

SAIC uses three post-modeling correction factors: density dilution, land shadowing, and multiple ships. The panel felt the density dilution and land shadowing were valid correction factors with the density dilution calculation being termed "clever." (Erbe 2008b). The multiple ship correction factor expands on the assumption that ships move only in straight lines to suggest that multiple ships move only in parallel lines and move at a spacing of 20 km. Whereas the assumption that one ship moves in a straight line is reasonable for determination of the expected number of takes over an operational range when ship motions are unknown, the expansion of this to assume that multiple ships always operate on parallel tracks 20 km apart was not considered valid by the panel. The NUWC model, which can track multiple ships moving at varying speeds independently in defined or random patterns, is a superior approach.

Terms of Reference 4: Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

ToR 4.1: Have the principles of credible science been addressed during model development?

The panel had some disagreement on this term of reference. Erbe (2008a,b) and Thomas (2008a,b) found that, given the quality of available biological data, the principles of credible science had been addressed during the model development. Getz (2008) had substantial concerns:

> …the requirements of the EIS/OEIS framework demand a near-to-impossible task of the modeling group: build a scientific credible model for a system that is very poorly understood and for which inadequate data exist with the expectation that the model is then able to predict with some credibility the three kinds of "take" rates for the acoustic activities under consideration. The credibility of the science for the physical module is much higher than for the biological module. In addition, the credibility of the combined physically and biological modules is reduced if they are run sequentially rather than simultaneously (as in the case of the SAIC and NUWC density area approaches).

Erbe (2008a,b) and Getz (2008) both emphasized the need for the sound propagation models to be verified, but Getz noted that there is much more credible science underlying the formation of the physical models than there is biological data underlying the formation of the marine mammal exposure models.

> The marine mammal exposure modules in all three models are not scientifically credible as predictive tools. To gain credibility the predictions need to be tested against empirical data using accepted statistical procedures. This is not been done because it cannot be done at this time: empirical "take" data are not available and are unlikely to become available in the near future. Further, even if one could observe a population closely, it would be very difficult to identify "takes" because the definitions of "takes" are either conceptual (level B harassment type II) or, if operational (level A harassment and level B harassment type I), can only be assessed through unacceptable levels of interference with subjects that have been harassed…. However, the models do have value as tools that can be used to assess the potential of interventions to mitigate harassment and to compare the relative impact of different operation scenarios (i.e. as an operations' design tool). (Getz, 2008)

ToR 4.2: Is the choice of model supported given the quantity and quality of available data?

Erbe (2008a,b) felt that the sound propagation components of the model could be improved by better selection of model—CASS/GRAB, RAM, RAMS—as appropriate to the environment. More analysis points should be used, as well as more radials, in most circumstances. The 3MB model should only be used for research purposes, not for estimating takes. Because we do not have adequate biological information or prior knowledge of ship operations in the area, the SAIC model that takes a very general approach is the most appropriate for the current EIS documents.

Thomas (2008a,b) found the choice of models appropriate for the available data.

Getz (2008) found the NUWC Area-Density Model deficient because of its overestimate on the Level B(II) takes. The NEMO model is the best when sufficient data are available. This is likely to occur only when operating in a small area where the animals have been well studied. Outside of these bounds, this model is best for research and operations design. Use of the SAIC model is fine so long as only the expected number of takes is required. If the regulatory agencies ever start asking for confidence limits on the expected number of takes, the current SAIC model is inadequate and would have to be extended.

ToR 4.3: How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?

As noted in earlier sections, the panel felt they could not say how closely the models simulated the system of interest ranging from the sound field to the acoustic impact on marine mammals to effects on marine mammal populations, to the ecosystem. At each level, validation is lacking, classified, difficult to obtain, or impossible in the foreseeable future. The CASS/GRAB acoustic propagation is the subcomponent easiest to determine how closely it can simulate the actual sound field and such a determination has likely been done. The panel did not have access to these results.

As has been noted before, the NUWC model that uses the maximum SPL in the water column as the value at the equivalent x-y location is not a good model of the system.

The NEMO model has the greatest potential to model the system, but is well in advance of the available data and by seeming to take into consideration more than is really known leads to a false level of confidence about its predictions. If it assigned animats to depth levels proportionate to the amount of time tracked individuals spend at various depths, as does the SAIC model, NEMO could be the model that could best simulate the system.

The SAIC model is interesting in that on the one hand it is the farthest from simulating the system, but on the other it is the best for providing the one thing required of a model in the EIS/LOA framework—i.e., the expected number of takes by species and by harassment level over large ranges with unspecified operations and over a five year time horizon. SAIC has done some sensitivity analyses and found that over reasonable parameter ranges, the model is relatively robust (see Erbe 2008b for details).

None of these models can, nor should they purport to, model ecosystems.

ToR 4.4: How well does the model perform?

In terms of providing an output that gives an expected value for takes by harassment level, the NUWC model overestimates Level B(II) takes. All models show a greater number of takes in the summer than winter for similar operations and this difference makes biological sense. The NUWC model was used to obtain an estimate of marine mammal takes from an operation in which two sources were operating simultaneously and these results were compared to the summation of the estimates from two separate runs with each source operating in isolation. The results were comparable.

> The main uncertainties in both models stems from the lack of a priori knowledge on source location and movement and the lack of data on animal distribution. We can model the sound field reasonably well, we have some understanding of impact thresholds, but if we don't know where the ships and animals are, then any exposure model will be highly speculative. (Erbe 2008a)

Getz (2008) rates model performance as being seriously deficient because the models report only average takes with no confidence intervals. He provides several examples of how consideration of stochasticity, sensitivity, and scenario analyses would lead to a much richer framework for accomplishing the tasks on which NMFS should really be focused.

> All three models reviewed here are used in the context of the first approach to modeling listed above [to address a specific problem]. They all lack the accuracy and precision needed to be used as tools—but this is not surprising since the problem of predicting "take" rates from acoustic harassment is too complex a problem to lend itself to solution by a general modeling tool…Thus, what is needed is a much better articulation and implementation of the "*necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities.*" (Getz 2008)

ToR 4.5: Is the model capable of being updated with new data as it becomes available?

The NUWC Area-Density Model "can be used in a Monte Carlo framework to compute how inherent stochasticity in population distribution data inputs translates in to distribution of 'take' rates." (Getz 2008). Erbe (2008a) noted that the Area-Density Model is running against the limits of memory and computational power and has little capacity to be updated. If it had capacity, the first update would be to not collapse the 3-D data into a 2-D array.

The NEMO model has the greatest potential for updating as new data become available. Erbe (2008a) noted "I believe we need a better risk function, and I believe the risk function will eventually become a function of instantaneous received level rather than a function of maximum, received level over some artificial time. In NEMO, this change would be minimal." The problem with the model primarily relates to the lack of data on animal behavior. Until these data are much more completely known, this model has its greatest potential as a research tool.

The SAIC model “is the least flexible, but most efficient.” (Getz 2008). However, the modelers at SAIC impressed the panel with their ability to devise new models to answer new questions. The SAIC model was designed to calculate the number of marine mammal takes in the context of limited data on timing, ship movement, location, and animal density, distribution, and behavior. As more data become available and the questions become more sophisticated, the feeling of the panel was that these modelers would be able to devise a more sophisticated model.

CONCLUSIONS AND RECOMMENDATIONS

The panel agreed that given the questions currently asked, the SAIC model has taken a very reasonable approach and probably is as good as we can do when so many of the variables are unknown. The panel consensus is well stated by Erbe (2008b)

> Given the fact that the Navy will be unable to disclose specifications of its intended operations beyond the source type, level, frequency and beam pattern, SAIC took a very general approach. No specific ship movement is modeled. Ships move in straight lines. No detailed sound propagation is modeled. Instead, the environment is simplified into a representative set of provinces, each with a constant sound speed profile, seafloor type and seafloor depth (bathymetry is ignored other than for the depth underneath a source). Animals are distributed evenly in subregions (habitats) according to published sightings. They are distributed in depth according to published data on time spent at certain depths (from dive profiles). Animals remain stationary. Given our lack of understanding of individual animal behavior, in particular as it relates to reactions to sound, I believe this approach is reasonable.
>
> The SAIC model produces a spreadsheet tool which allows the operator to instantly assess the number of ‘takes’ as a function of hours of operation and number of ships; a tool which I can imagine is quite useful. Given this goal, I believe the SAIC model has taken the appropriate approach, and I do not see how the model could be significantly improved.

The panel was also in agreement that NEMO should be developed further. It has great flexibility, can adapt to future scenarios, more refined regulatory requirements, and can accommodate (indeed relies on by necessity) enhanced data. The panel thought that the near term development of NEMO should concentrate on placing the animats stationary in the water column at depths proportional to the known time that tagged animals of that species spend at varying depths. For example, using the dive data presented on Blainville’s beaked whales, “NEMO should place 80% of animals in the top 5 m, 15% down to 800-1000 m, and 5% evenly between 5 and 800 m depth. Animals should then remain stationary for the duration of the operation.” (Erbe 2008a). Introducing animal movement with the current uncertainties of response in the presence of noise and other environmental forces driving animal behavior could lead to severe under-estimation or over-estimation of takes and there is no way at present to determine the extent or direction of bias.

> If, on the other hand, animals remain stationary, one can use fully-accepted statistical methods to assign means and standard deviations. Using the ergodic situation above, one could say that animals were placed within the operational area according to their documented mean depth distribution. One way of computing variance would be to overpopulate an area, compute exposures at each animal and then repeatedly resample from that population. (Erbe 2008a)

Erbe (2008a) provided extensive recommendations for improved handling of bathymetry in the NEMO framework.

The panel also agreed that although the NUWC Area-Density Model led the way in attempting a scientific assessment of mid-frequency sonar on marine mammal harassment takes within an overly conservative, precautionary framework, it is now time to retire this model and use either the SAIC or NEMO models, as appropriate based on the questions being asked.

For all models the panel noted that the computational resources required to model out to 120 dB range could be much better used with a finer grain analysis at closer ranges (e.g., more provinces for SAIC model; more radials and analysis points for NUWC models). Calculated Level B(II) takes can be increased based on the area of the curve that lies below the minimum dB level modeled. For example, if the Level B(II) takes were modeled out to 157 dB, then the risk function suggests that increasing this number by 10% would yield approximately the same number of takes as a complete modeling out to the 120 dB range. The only reason for modeling out to 120 dB is because of the apparent step function response of harbor porpoises to their initial exposures to signals at this level. In areas where harbor porpoises are not present, there is no reason given the overall uncertainties in take estimates to carry the calculations out to 120 dB received levels. [But note the point made by Thomas (2008a,b) that one tagged Blainville's beaked whale responded strongly to received levels of playbacks of killer whale vocalizations at <110 dB.]

Going beyond the specific task at hand and confronting the "elephant in the room" (Getz 2008) the panel agreed with the larger perspective brought to the table and summarized by Getz (2008).

> In conclusion, I reiterate that both the NUWC and SAIC modeling teams have shown considerable diligence in trying to meet the demands of the EIS/OEIS process laid out by NMFS. However, during my participation in the review reported here, I have become convinced that the models are being inappropriately used to generate "take" rates as though these rates are both accurate and precise and have meaning in their own right. To the contrary, there is no evidence that the rates are accurate, they are likely biased, though probably on the conservative side; and they provide no insights into issues relating to the potential occurrence of catastrophic events, however we want to define a catastrophe. Further, the models have potential to be used as tools for designing less invasive exercises or operations, but they are not used in this regard. They also need to be more closely tied to the design of monitoring and reporting procedures that can lead to better estimates of model parameters in the future, but I have seen no evidence of this feedback loop between the collection of biological data and the modeling

enterprises in the EIS/OEIS documents. I think the ball is now in the NMFS court to find a more constructive and informative way for models to be used in the EIS/OEIS process.

REFERENCES

Erbe, C. 2008a. Naval Undersea Warfare Center (NUWC) Marine Mammal Acoustics Exposure Analysis Models. *Submitted to* The Center for Independent Experts, University of Miami, Miami, FL. 37 pages.

Erbe, C. 2008b. Science Applications International Corporation (SAIC) Marine Mammal Acoustics Exposure Analysis Model. *Submitted to* The Center for Independent Experts, University of Miami, Miami, FL. 31 pages.

Feller, W. 1968. Introduction to probability theory and its applicaton. Vol. 1, 3rd ed. John Wiley and Sons. New York.

Getz, W. 2008. Review of Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) Marine Mammal Acoustics Exposure Analysis Models. *Submitted to* The Center for Independent Experts, University of Miami, Miami, FL. 22 pages.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W. J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33:411-521.

Thomas, J.A. 2008a. Review of Naval Undersea Warfare Center (NUWC) Marine Mammal Acoustics Exposure Analysis Model. *Submitted to* The Center for Independent Experts, University of Miami, Miami, FL. 19 pages.

Thomas, J.A. 2008b. Science Applications International Corporation (SAIC) Marine Mammal Acoustics Exposure Analysis Model. *Submitted to* The Center for Independent Experts, University of Miami, Miami, FL. 23 pages.

External Independent Peer Review

by the Center for Independent Experts

of the

Naval Undersea Warfare Center (NUWC)

Marine Mammal Acoustics Exposure Analysis Models

Individual Review Report

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Executive Summary

Three different models have recently been used to assess the impact of naval underwater acoustic sources on marine mammals: the so-called Area Density Model and NUWC Exposure Model (NEMO), both developed by NUWC, and a model developed by SAIC. An independent scientific review of all three models was initiated to assess whether the models were correctly implemented, whether they adequately incorporated all relevant physical and biological variables, and whether they met the Environmental Protection Agency's Council for Regulatory Monitoring guidelines. This report reviews the two NUWC models.

While the implementation of the Area Density Model is very different from that of the Exposure Model, both models use a number of sub-models and databases that are the same.

To model the source(s), both models use the source characteristics provided by the Navy (frequency, source level, beam pattern, duration, duty cycle) and the operational specifications (which are often unknown prior to operations). In the absence of information on source location and movement, both models randomize these. Both models can directly account for multiple simultaneous sources (directly as opposed to indirectly in post-processing). The approach to modeling the source(s) taken in both the Area Density Model and the Exposure Model is scientifically sound in my opinion.

To model sound propagation, both models utilize a ray model, CASS/GRAB, and access standard databases for environmental parameters (bottom geology, sound speed profile, bathymetry, wind conditions). The way that bottom geology, sound speed profile and wind conditions are included, seems reasonable to me. However, bathymetry is highly simplified and only modeled at a small, limited number of analysis points, and for a small, limited number of radials. Given that NUWC takes a detailed approach to source modeling, including movement and to animal modeling in NEMO, I think the way bathymetry is accounted for can be improved, and I have included suggestions for how to do this.

The sound propagation model, CASS/GRAB, is a Navy standard, and I can imagine that it serves the Navy's operational needs more efficiently than other sound propagation models. However, the needs of environmental impact assessments differ from those of operations, and there will be environments in which a Gaussian ray bundle model is not ideal, yielding large deviations in modeled received levels. A large variety of sound propagation models are available these days and areas in which they excel or fail are generally known. I recommend that prior to impact modeling, the sound propagation model be matched to the current environment.

The Area Density Model is running into the limits of computational power and memory. The 3d footprints of the source(s) have to be collapsed into 2d footprints, by taking the maximum energy and pressure over all depths. In other words, receiving animals always sit at the worst possible depth. This approach can greatly over-estimate exposures. The NUWC Exposure Model is implemented quite differently and can handle 3d footprints.

To model bioacoustic impact, both models utilize the latest scientific data on noise effects on marine mammals. While there are still many unknowns, this is as good as it gets at this stage.

The NUWC Exposure Model includes an individual behavior module (3MB), which moves animals in three dimensions over the time of operations. In my opinion, this approach is not (yet) warranted. We have too few and too poor data on animal distribution and movement. There are many variables that determine an animal's behavior (in particular whether or not and how it reacts to sound), that are not yet included in 3MB. I find 3MB too deterministic at this stage. The main problem with that is that the output will depend on how the model is implemented (i.e. how the biological parameters get used) and how it is initialized (i.e. which options the user selects and how the user distributes the animals initially). It is my feeling that the output can be highly variable and subjective, rather than reliable, reproducible and statistically meaningful.

NUWC wants to phase out the Area Density Model and move towards the Exposure Model. I agree that the Area Density Model has reached its computational limits and can't be upgraded without a major restructure. The Exposure Model seems more flexible, more efficient, and can readily be updated as new biological information becomes available. However, I do not agree with the individual behavior module in the Exposure Model.

I recommend an intermediate model, which follows the Exposure Model framework for efficiency, which distributes animals more intelligently than the Area Density Model, and which computes statistically meaningful exposures. I have made suggestions for how this model can be implemented.

1. Introduction

1.1. Background

Since the beginning of the industrial revolution the world's oceans have become increasingly noisy. Ship traffic, hydrocarbon and mineral exploration, offshore construction, naval activities, ocean acoustic research, all contribute to the 'noise pollution' of the marine environment. The effects of underwater noise on marine mammals in particular are of increasing interest and concern to the public, research organizations and environmental management. Many countries around the world require that environmental impact assessments be done of ongoing and future marine activities. Environmental impact assessments, in particular in the case of planned activities that have not yet commenced, are largely based on models. Models for bioacoustic impact on marine mammals typically rely on a number of sub-models and databases. There are acoustic source models, which predict the noise field around marine activities. There are sound propagation models, which predict how acoustic energy propagates from the source through the marine environment. There are bioacoustic impact models, which predict the effects of received noise on marine animals.

The Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) have developed models to estimate the bioacoustic effects of naval activities on marine mammals. The Center for Independent Experts (CIE) organized a review of these models in October/November 2008. The purpose of the review was to assess whether the models were correctly implemented, whether they adequately incorporated all relevant physical and biological variables, and whether they met the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines.

The review involved reading background material, participating in a teleconference call with other CIE reviewers and NMFS scientists on October 27, 2008, and attending two, three-day panel meetings (at NUWC in Newport, Rhode Island, from November 12-14, 2008, and at SAIC in Arlington, Virginia, from November 17-19, 2008) to discuss the models, to develop test runs, and to generate an independent review report.

The current report reviews the NUWC models. The SAIC models are reviewed in a separate report.

NUWC developed the so-called Area Density Model in 1998. It has been used for the AFAST and East Coast Range Complex's EIS. Due to increasing modeling demands and limitations with this model, NUWC has begun the development of a new model, the so-called NUWC Exposure Model (NEMO).

1.1.1. NUWC's Area Density Model

The Area Density Model is used to estimate marine mammal sound exposures from naval underwater acoustic sources. This model can be broken down into the following steps.

1. Given a particular active source (e.g. a mid-frequency sonar) or any combination of simultaneously operating sources, and given the sources' operational specifications, duty cycles and acoustic characteristics (such as frequency and beam pattern), the model first computes the three dimensional (range, depth and bearing) acoustic field of the sources in the geographical region of operation and for the time of year (season) of operation. Sound propagation is modeled using the Comprehensive Acoustic Simulation System based on Gaussian Ray Bundle propagation (CASS/GRAB). For low frequencies (<150Hz) and in shallow water, the publicly available Range-dependent Acoustic Model (RAM) is used. The acoustic field is modeled to a distance where the sound pressure level (SPL) drops below 120dB.

2. To reduce computational memory, the model then reduces the 3d sound field to a 2d footprint by taking the maximum sound exposure level (SEL, an energy metric) and the maximum SPL over all depths.

3. The model then moves the sources through the operational area. The footprints are overlapped from one sound emission to the next. On a 2d receiver grid that evenly spans the operational area, SEL are summed. Current marine mammal guidelines consider both the cumulative received energy (SEL) and the maximum received SPL. NUWC's model therefore keeps track of both the cumulative SEL and the maximum SPL. For every new emission of sound, the model compares the maximum SPL received at all 2d receiver grid points to the stored maximum SPL. If the new SPL exceeds the stored SPL, then it is replaced, otherwise not.

4. In line with current scientific understanding of noise effects on marine mammals, the NUWC model compares the cumulative SEL to thresholds for permanent hearing loss (permanent threshold shift, PTS) and temporary threshold shift (TTS). The maximum SPL modeled is passed through a risk function to determine the probability of inducing a behavioral change. The behavioral risk function determines the proportion of an exposed population that is likely to respond to an exposure. The SEL thresholds and the risk function differ for different species or species groups.

5. Databases on marine mammal population density are accessed to estimate how many animals of which species are likely encountered in the geographic region at the time of operation. These animals are then evenly distributed over the 2d receiver grid. Animal densities are then multiplied by the total area receiving SEL above threshold to yield the total number of exposures producing TTS or PTS. Animal densities are also multiplied by the probability of behavioral change and then summed over the 2d grid in order to yield the total number of exposures resulting in a behavioral change.

6. Finally, numbers are rounded and the total number of exposures potentially producing a behavioral change, a TTS or a PTS are reported for each species (group). Exposures are only counted once over all three categories. The sound level required to induce PTS is greater than the level required for TTS, which in turn is generally greater than the level required for a behavioral change (keeping in mind that the criterion switches from energy for PTS and TTS to pressure for behavioral change). An exposure that produces a PTS is therefore not counted again in the TTS or behavioral change categories. Each animal is reported at its highest impact received.

1.1.2. NUWC's Exposure Model (NEMO)

The sound propagation algorithm used for the new model is the same as that used for the Area Density Model. However, in the NEMO model, SEL and SPL values are not maximized over all depths, rather a 3d footprint of the source is kept. Marine mammals are no longer uniformly distributed in space, but are instead modeled individually using Dorian Houser's Marine Mammal Movement and Behavior Simulator (3MB), which was originally developed for ONR's Effects of Sound on the Marine Environment (ESME) program.

3MB allows the user to select a region to be populated by marine mammals. The user chooses whether the animals will be inserted randomly, or randomly about selected points, individually or in pods. The user can also insert animals or animal groups by clicking on the bathymetry map of the operational region. Animals are inserted by species. 3MB has behavior profiles built-in for a number of species. Typical parameters include dive patterns, swim speed, affinity to certain environmental factors (e.g. shallow vs. deep water). 3MB lets animals move around the 3d habitat, either individually or in pods by following a focal animal. At this stage, 3MB does not include animal reactions to noise. These could be either aversion or attraction. NEMO simulates what might happen in the operational region step by step in time. The iteration progresses in the following way: For every step in time, all animals are moved to a new location according to their behavioral parameters. The sound sources are moved to their new location and fired. The location of each animal is determined relative to the 3d footprint of each source, and received SEL and SPL are looked up in the stored footprints. SEL is accumulated. The maximum received SPL is updated. The iteration then proceeds to the next step in time. NEMO keeps track of SEL and SPL for every individual animal. At the end, NEMO outputs the total number of pings and the levels received by each animal or the statistics of received levels by species. Level A and B harassment are then determined using the same thresholds as in the Area Density Model.

1.2. Terms of Reference

The following Terms of Reference (ToR) guided the review process.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model. Not applicable to the NUWC models.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

1.3. Panel Membership

The review panel consisted of four independent reviewers:

1. an underwater acoustician (Dr. Christine Erbe) with expertise and working experience with propagation loss models, in particular ray propagation and parabolic equation models,
2. a modeling expert (Dr. Wayne Getz) having expertise with individual-based exposure assessment models that integrate multiple data streams,
3. a marine mammalogist (Dr. Jeanette Thomas) having expertise with marine mammal behavior and physiology, and a
4. moderator (Dr. Douglas Wartzok) with expertise in marine mammalogy, underwater acoustics and modeling.

I took the role of the underwater acoustics reviewer. I have done research in underwater acoustics and bioacoustic impact since 1993. I regularly carry out environmental impact assessments for clients in government, academia and the marine industry. I use a variety of sound propagation models and bioacoustic impact models for my research and consulting work.

1.4. Description of Review Activities

I began the review with a search for peer-reviewed and unreviewed literature on the NUWC and SAIC models. These searches included the general internet, as well as scientific abstract and citation databases. Additional documents were provided by NUWC and SAIC for the review. I made a list of comments and questions while reviewing the documents and submitted this list prior to the meetings in order not to hold up the discussions during the meetings.

A teleconference was held on October 27, 2008, to discuss the roles and responsibilities of the participants, as well as the terms of reference. NUWC and SAIC gave an overview of their models.

Specifications for the trial runs were discussed. I was unfortunately unable to participate in this conference call.

From November 12-14, 2008, the participants met at NUWC in Newport RI. On the first day, Linda Petitpas gave an introduction to the meeting and some background information on the CASS/GRAB model “ground rules”. Peter Hulton followed with an overview of the NUWC software models. He first presented the Area Density Model, then the Exposure Model (NEMO) which includes the ESME behavioral module. Peter Hulton and Bill Sutphin showed some slides about NUWC’s testing and software validation. Tom Fetherston presented the Animal Behavior Parameters used for both the Area Density Model and the NEMO Exposure Model, and the derivation of exposure thresholds. Yadira Gilchrest reviewed the models’ underlying assumptions.

On Day 2, NUWC demonstrated two trial runs of the Area Density Model and the NEMO Exposure Model.

2. Findings

2.1. ToR1: Assess whether the NUWC Area Density Model and the NEMO Model implementation sufficiently consider all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sound propagation).

2.1.1. Physical variables

The physical variables are the same in the Area Density Model and the NEMO Exposure model.

Bathymetry

The models use the DBDB-V 5.2 (OAML) and NGDC databases for bathymetry. I have used both myself. In certain geographic regions there are other databases as well, sometimes with much finer resolution. The finest resolution is not required here, as the model averages received levels into range bins, depth bins and azimuth bins, and uses the same footprint for a large area. Fine-scaled changes in bathymetry will have a negligible effect on the modeled sound fields and impacts, in particular compared to some of the more significant uncertainties and potential errors in this model and bioacoustic impact models in general.

What can be improved with the way bathymetry is handled in both the Area Density and NEMO models though is the number of analysis points and the number of radials modeled. In the example presented in Newport, the acoustic footprint of the source was computed at three analysis points. I.e., three locations within the entire operational region were chosen for their environmental uniqueness, one in deep water, one on the sloping shelf and one in shallow water. Only three footprints were computed and applied to all sound emissions in the entire region. NUWC will have to use more analysis points in regions where the physical environment is more varied. I assume that NUWC does this already. Setting up the environment for sound propagation modeling is a tricky task that is not easily automated and that requires a lot of picking and setting by hand. An experienced acoustician should do this.

Sound propagation was modeled along eight radials at 45 degree intervals. In my opinion, this was too few for the environment presented. Sound propagation is modeled over a 100km range, sometimes out to a 300km range. At such long ranges, the distance between the endpoints of two adjacent radials would be between 80-230km. The variation of the sound field over these distances is ignored. In the presented case, the sound field jumped by over 40dB from one radial to the next. In deep water, where the bathymetry does not change much as a function of bearing, this approach is sufficient, but there will be environments where it isn't. I suggest automating this process. Shoot eight radials to start with, check the difference in received level at the endpoints of two adjacent radials. If this is in excess of 10 or 20dB, shoot twice as many radials and compute the difference in received level again to determine if even more radials need to be computed. Land needs to be accounted for here, such that levels received in the water column do not accidentally get compared to zeros (no sound) received on land if one of the radials heads for land.

Another way of avoiding a loss in horizontal resolution as range increases is to employ a tessellation approach. One would start with a small number of radials. Once the distance between the endpoints exceeds a preset limit, new radials must be fed in. These don't have to be recomputed from the source. Instead, these can be seeded with the mean level of the two bordering rays at the preceding range step. This is computationally the most efficient approach, but I don't know whether CASS/GRAB could easily be wrapped into such an approach.

Of course, it makes no sense to compute a finely resolved footprint, which then gets used for all shots in an area that can span 100km x 100km or more. A balance needs to be struck between the number of analysis points and the resolution of the footprint.

Sound speed profiles

NUWC uses the GDEM-V 3.0 database to extract sound speed profiles for the geographic region and time of year. GDEM allows you to extract mean monthly or seasonal profiles. NUWC averages monthly profiles into seasonal profiles. In my opinion, this is okay. I mostly use GDEM myself. I usually consult other databases such as the updated Levitus, too. There also is the Master Oceanographic Observational Data Set (MOODS). I routinely do a literature search for each geographic region I model, as there often are peer-reviewed articles on the physical oceanography and sometimes long-term monitoring, in particular in coastal regions. Sound speed profiles vary with time of day, day of the year, month, season, and from year to year. In some regions there are strong currents leading to sharp edges in sound speed over short distances, and these can sometimes have a multi-year cycle. As a result, the profiles found in various databases can differ substantially. If one compares mean monthly profiles from various databases at a specific location, one might find differences in sound speed of several m/s. I have even seen comparisons where one database showed a surface duct and the other didn't for the same region and the same month of year. Chu *et al.* (2002) computed changes in received level of up to 30dB over 1km range when they introduced deviations in sound speed profile of the order of 1m/s using the

CASS/GRAB model. It must be said, however, that they introduced tiny nicks in their sound speed profiles, which led to convergence and shadow zones at a certain depth. If NUWC computes mean seasonal profiles, then such nicks are unlikely to occur. Clearly, it would be impractical to model a number of sound speed profiles from various databases. NUWC's approach of using GDEM for mean seasonal profiles is reasonable, and is a common approach taken by the underwater acoustic impact modeling community.

Seafloor geology

NUWC accesses information on the seafloor properties through the Applied Physics Laboratory at the University of Washington or the Marine Geophysical Survey (MGS) Program. In addition, I would like to mention that NGDC has some information on sediment. The Integrated Ocean Drilling Program (IODP) has core samples, mostly from offshore locations, which are often very good, giving not only sediment composition but also density and velocity data. Such data are necessary if the sound propagation model can handle sound propagating through the seafloor, as can RAM. CASS/GRAB, however, does not model sound propagation through the seafloor. It simply computes the transmission loss at the water/seafloor interface. For this, it only requires information on the type of seafloor at the surface, such as "sand", "silt", "clay" etc. This is a limitation in certain environments, however, given that CASS/GRAB is the accepted Navy standard, I think that the environmental parameters (including wind speed data) are properly accessed and included.

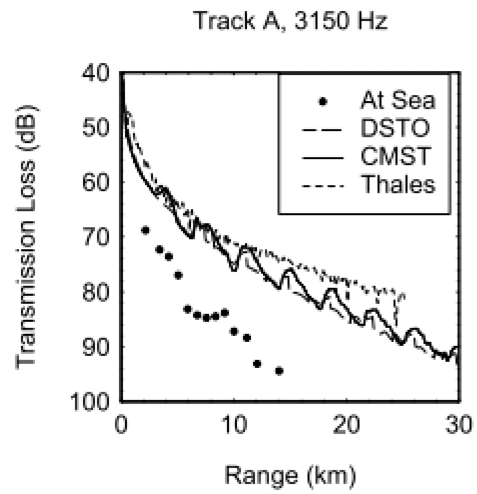
CASS/GRAB sound propagation model

As Linda Petitpas stressed in her introduction on Day 1, the propagation model itself was not to be subjected to this CIE review, but rather its implementation within the NUWC/SAIC exposure models. CASS/GRAB is an accredited model within the Oceanographic and Atmospheric Master Library (OAML). It serves to support the operational fleet with consistent and credible standardized results. While this argument seems convincing at first glance, one has to remember that the requirements for naval operations and environmental assessments are different, if not opposing. I assume for naval operations, the farther the sonar reaches, the better. For the purpose of modeling sound propagation over very long ranges, CASS/GRAB will have advantages over other sound propagation models, because ray models are very fast. Using CASS/GRAB to model target detection at very long ranges will be quick. An error in received level of several dB at very long ranges is likely not an issue for naval operations; as long as the bearing is properly resolved, one could always investigate in that direction more closely. For bioacoustic impact assessment, the farther the source reaches, the worse the impact. An error of several dB can significantly affect the number of 'takes' by NMFS definition. An error in SPL of 20dB can change the output of the behavioral risk function from 10% to 90% of a population being 'taken' (10% @ 155dB, 90% @ 175dB).

I would like to make a few comments about sound propagation modeling. I have not actually used CASS/GRAB myself, but I have worked with other ray propagation and ray bundle models and written parts of a ray model myself. Ray models are fast. They work well in water that is deeper than one wavelength, i.e. they have limitations for low frequencies or shallow water. They work well when bottom interactions are insignificant, such as when the source operates in an acoustic duct or over very deep water.

The Australian Defense did some field verifications of three different ray models, two of them Gaussian ray bundle models (Jones *et al.* 2007). They found reasonable agreement between the models and the field data at 400Hz. At 1kHz, all models over-predicted the received levels by up to 10dB for ranges greater than 4km. At 3kHz (see picture), the models all over-predicted the received level by up to 20dB for ranges greater than 12km. The environment was shallow and downward refracting.

During the presentation, it was mentioned that usage of CASS/GRAB was approved down to frequencies of 150Hz. In some additional online documentation that I consulted (Vares 2002, Chu *et al.* 2002), CASS/GRAB was said to be usable down to 600Hz. While this is no issue for mid-frequency sonar (1-10kHz), I was left wondering whether field tests had been done to determine over what frequency range this model was reliable.



Phase-incoherent *TL* versus range for Track A, 3.15 kHz

NUWC switches to RAM in shallow water and for low frequencies. RAM will only work for unconsolidated seafloors. Where the seafloor is consolidated (rock), RAMS should be used instead, as much energy will propagate through the seafloor at high speeds and low attenuations, and some of it will radiate back into the water column at some range.

I believe that the sound propagation part can be improved. I don't mean that a better resolution of the sound field is necessary. In fact, I agree with the models ignoring phase and 'averaging' received levels into depth bins, range bins, azimuth bins and dB bins. I am, however, concerned about the 'mean' predicted level at some range, as in the figure above by Jones *et al.* (2007). A multitude of sound propagation models exist, which have been tested in the field and which have been shown to excel in different environments. I think for these EIAs, NUWC could choose a model that best suits the particular ocean environment. I understand that CASS/GRAB is accredited. I also understand the need for the whole model to be as automatic as possible, reducing the need for hand-picking and reducing the need for an experienced operator who makes knowledgeable yet subjective decisions. And CASS/GRAB might well be the one model that works best on average over all environments that NUWC encounters.

The sheet of input parameters for the NUWC model showed a maximum number of surface reflections and bottom reflections set to 100. From my experience, one does not need to keep track of that many rays, with one exception: surface reflections in a surface duct. Each ray or ray bundle loses energy with each surface and bottom reflection. At any receiver, most energy will come from direct rays and refracted rays, not so much from reflected rays. In a surface duct, rays will reflect off the surface but bend before hitting the seafloor. I think rays with more than 10-20 bottom reflections can be ignored. Limiting the maximum number of reflections should speed up the sound propagation process, depending on when in the model rays departing at greater angles are discarded.

Frequency

NUWC models mostly only one frequency. For very narrowband sonars, that is fine. For broadband sources, such as ships or explosions, that is problematic. Sound propagation is frequency-dependent. Acoustic energy loss (e.g. from scattering or molecular agitation = heat loss) is frequency-dependent. Ray models are usually, in their basic form, frequency independent. Whether CASS/GRAB has been enhanced to include frequency dependent propagation and loss, I don't know. For broadband sources, high frequencies get attenuated faster than low frequencies, and this can easily be included in post processing of ray propagation. NUWC mentioned they sometimes model only the mean frequency for broadband sources. I don't think that is good enough. They sometimes model each center frequency of adjacent 1/3 octave bands; that is preferable. SEL and SPL will have to be summed over all frequencies prior to the application of impact thresholds. The current CIE review focused on very narrowband sonar sources, for which frequency is modeled properly, in my opinion.

All impact thresholds for PTS, TTS and behavior, as they are applied by NUWC, are frequency independent; all frequencies affect all species equally. The hearing sensitivity of marine mammals is a function of frequency and differs with species. In other EIAs that I have reviewed an attempt was made to relate the probability of a behavioral reaction, TTS and PTS to a species' audiogram (detection threshold as a function of frequency). This is not the approach NUWC and SAIC have taken, and is not the approach NMFS takes. Southall *et al.* (2007) reviewed the scientific literature to-date on marine mammal bioacoustic impact, and suggest M-weighting SEL. M-weighting reduces the contribution of energy at frequencies outside of the hearing bandwidth of marine mammal species groups. It does not weight SEL with regards to a species' absolute sensitivity. For the narrow-band mid-frequency sources considered under the current CIE review, M-weighting has no effect.

Maximum range

My understanding is that NUWC lets CASS/GRAB model the acoustic footprint in 3d far enough out that the SPL drops below 120dB. This is perfectly fine, because 120dB SPL is the lowest level that can cause Level B harassment. The criterion for behavioral 'take' is not cumulative. If it were, then the acoustic footprint of each source would have to be modeled over longer ranges, because sub-threshold levels would add up over multiple pings. The criterion used, however, is the maximum SPL over all received pings, and therefore not cumulative.

Beam pattern

When the acoustic footprint of the beamformed sources is computed, the sound field is truncated at the -3dB points. I would probably have truncated at the -6dB down points, allowing the SEL for receivers on the edges to add up. Two pings received on the edge increase the SEL by 3dB, four pings by 6dB. I assume the drop-off at the edges of the emitted beam is very sharp, and a cut-off at -6dB as opposed to -3dB will only make a tiny difference to impact volumes.

Source level

NUWC computes footprints by running CASS/GRAB with a nominal source level of 200dB re 1 Pa. The footprint is then adjusted to the correct source level by adding the difference in dB. This method is fine.

Source movement

Given that the movement of the sources is sometimes defined, other times not, the model can model either preset transects or random movement. From the demonstrations we've seen, the models correctly adjust the emitted beam pattern (e.g. rotation) from one emission to the next. Random movement over the operational area also seemed to be implemented correctly.

Ambient noise

Neither model includes ambient noise in its impact assessment. Ambient noise would affect the models at various stages. Animals living in areas of high ambient noise might be somewhat accustomed to noise. TTS in this case would be masked and masked TTS threshold levels could be used instead of the unmasked TTS here. Behavioral reactions might be reduced in areas of high ambient noise. Or, regions of high ambient noise might have fewer marine mammals. Ambient noise will not add to the impact of naval sources, because it is generally much lower in level, usually contained at lower frequencies and random in phase.

2.1.1. Biological variables

TTS/PTS Thresholds

In my opinion, the derivation of the SEL thresholds used for TTS and PTS are reasonable given our current scientific understanding of acoustically induced hearing loss. Southall *et al*. (2007) summarize the best available information on this topic to-date, and threshold levels were taken from this publication. Southall *et al*. (2007) use M-weighted SEL as a means of including some frequency selectivity of the species. Over the frequency range of mid-frequency sonars (1-10kHz), the weighting functions are flat (with the exception of low-frequency cetaceans for whom the M-weighting function starts to drop off at about 3kHz). SEL thresholds are thus largely unaffected by M-weighting. PTS is considered Level A harassment, TTS falls into Level B harassment, which agrees with the definitions.

Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice? Yes.

Behavioral Thresholds

NUWC uses a risk function to estimate the probability of inducing a behavioral change from exposures between 120dB SPL and 195dB SPL. One exception: In the case of harbor porpoise, a 120dB step function is used. Exposures to levels above 195 dB SEL are counted in the TTS category. Both behavioral response and TTS are considered Level B harassment, which corresponds to the MMPA definitions.

The risk function is defined as the percentage of a population that might react to a sound at a given level. In the models, however, the risk function is used for the probability of a behavioral reaction of one animal as a function of the maximum SPL received over a specified (24h) time period. For the purpose of EIAs, it is reasonable to simplify that all animals react the same, and therefore the percentage of a population that might react to a certain level can be assumed equal to the probability of any one animal reacting at that level. In my opinion, NUWC implements the risk function correctly.

Whether this NMFS endorsed risk function makes much sense biologically, is a different question. In my opinion, it makes little sense to relate the probability of a response to the maximum level received over a 24h period. An animal is not going to sit in the water, being pinged at, waiting for a higher SPL to come within the next 24h. At any one time that it receives a ping, it decides whether to react or not. With the next ping, it faces the same decision. The probability of response should be a function of the actual level received at any one time. The probability of an animal reacting at least once every 24h is then equal to the cumulative probability for all pings received. NMFS' risk function, however, is not defined like that.

Furthermore, the levels which NUWC has been asked to model, seem to me unreasonably low. If NMFS wants to consider exposures to 120dB SPL Level B harassment, or 'takes', then every ship, even small boats and jetskis, would have to apply for a permit. The computational demands for modeling sound to 120dB SPL are huge, because sound attenuates more slowly the further away from the source one gets. Most energy is lost within the first km. Modeling down to 120dB SPL requires propagation over more than 100km, depending on the environment. Substantial computation time, effort and memory could be saved, if NUWC only needed to model to higher thresholds; and the saved effort could be spent on increasing the accuracy of the model in other parts.

Recovery time

In both the Area Density Model and the NEMO Exposure Model, SEL is accumulated until all the sources are quiet for 24h. TTS is a temporary threshold shift and is fully recoverable over time. Data on recovery times in marine mammals are very scarce, but it seems that most recovery happens soon after the cessation of sound exposure. If a Navy source pinged for only a few seconds twice a day, energy would be accumulated over an entire operation which could last many weeks. This is conservative.

Exposure Metrics

Both models report the total number of exposures. In the case of TTS and PTS, energy was accumulated until the source was quiet for 24h. In the case of behavioral risk, an animal can only be taken once every 24h at its highest SPL received. This implies a 24h refresh rate for exposures. In the end, exposures for PTS, TTS and behavior can be larger than the total number of animals in the region, because animals can be taken more than once. They can be taken once a day for the behavioral criterion; they can be taken again after a 24h rest for the energy criterion. There is nothing wrong with how these metrics get computed. There are obviously other metrics that could be computed, such as harassment rates or expected number of takes. Scientifically speaking, I don't see why one should be favored over the other. The main point is that they get interpreted properly, that the regulator understands their meaning and implementation, and that they get related properly to the current regulatory requirements. NEMO keeps track of every ping an animal receives, the number of pings and the received levels. From this, various different metrics (per animal or per population) can be computed if necessary or if regulatory statements change in future.

Marine mammal density distribution

Data on marine mammal distribution in the world's oceans as a function of latitude, longitude, depth and time (time of day, month, season) is scarce. NUWC accesses databases and reports from marine mammal surveys, reflecting the currently best available information on marine mammal distribution.

<u>A. Area Density Model</u>

The Area Density Model distributes the total number of animals (for each species) expected in the geographic region at the time of operation evenly over the 2d receiver grid or subregions within this grid. In my opinion, this is the most reasonable approach, given our limited knowledge on marine mammal distribution. The model errs on the conservative side, because animals are not distributed in depth, but effectively sit at the depth of maximum SEL and SPL (as the 3d sound field was reduced to 2d footprints by maximizing received levels over all depths).

This could be improved. Data on dive profiles exist for a number of individuals of a few populations. These data indicate how much time animals spend at a certain depth. Assuming that all animals in a population have similar dive profiles, these data can then produce the percentage of animals likely encountered at each depth at any instant in time. If the model distributes animals not only in latitude and longitude (2d) but also in depth, then the acoustic footprint of the sources has to be considered in 3d. This considerably increases the demands for computational memory and processing. The way the Area Density Model is set up, and the limits imposed by it being programmed in Matlab, make a 3d approach impractical. NUWC has therefore begun a different approach with its NEMO model.

<u>B. NEMO</u>

NEMO is more flexible with regards to marine mammal distribution. The user can select regions to populate on a bathymetric map. Animals can be seeded randomly or randomly about some hand-picked points. Individuals or pods can be placed. The model does not give any guidance on how many animals should be placed where and how. The user has to consult the literature and databases to make a decision about animal placement. If animals are not seeded evenly, but randomly in subregions or individually (and subjectively) by clicking on the map, then NEMO can still produce mean exposures (expected number of exposures) by running the model more than once with different initial conditions.

The main advantage of NEMO over the Area Density Model, with regards to marine mammal distribution, is that NEMO can handle 3d footprints and can distribute animals with depth. In the Area Density Model animals effectively sat at the depth of maximum SEL and SPL. In NEMO, animals can be distributed over depth according to measured dive profiles, and this depth might be quite different from the depth of maximum received level.

Horizontal + vertical movement patterns (NEMO)

In the Area Density Model, animals are stationary. In NEMO, they move around. Their vertical movement is governed by built-in depth profiles. Their horizontal movement is random, unless affinities for certain environments (e.g. deep vs. shallow water, or cold vs. warm water) have been set. I believe our understanding of marine mammal movement is very limited and does not warrant the modeling of individual movement.

Behavior simulation (NEMO)

Only the NEMO Exposure Model attempts to model marine mammal behavior. While its behavioral module (3MB) has great potential for aiding research on marine mammal behavior and for data warehousing of behavioral parameters, I think it is too early to be incorporated into EIAs.

Once the user has placed pods and/or individuals of various species into the operational area, 3MB moves them around in 3d (latitude, longitude and depth). 3MB has built-in dive profiles for five species (blue whale, two beaked whales, harbor porpoise and fin whale). Dive profiles are under construction for three extra species (sperm whale, North Atlantic right whale, elephant seal). 3MB distinguishes between shallow and deep dives, feeding and migration dives. Dive profiles will still be reviewed and accepted by N45 and NMFS prior to use.

There is quite some uncertainty associated with dive profiles. Data exist from few individuals in few species populations. The percentage of time spent at a certain depth will obviously depend on the availability of food, which in turn depends on physical oceanographic parameters such as temperature, salinity and light. The latter will differ from day to day. On a cloudy day, food might sit higher up in the water column than on a sunny day. There must be considerable variation in dive profiles, and I don't think we have anywhere near enough data to assess this.

3MB allows the user to model pods. Animals within a pod will move according to what the focal animal in the group does. The user can tick whether he wants to include the option of pods breaking up. I believe there is not enough data to model this detail in pod cohesion and movement.

There are a lot of biological variables that determine an animal's behavior, which are not yet included in 3MB. For example, 3MB models one species at a time. But some species are actually attracted to each other, others avoid each other. 3MB moves predators and prey independently. Foraging behavior will depend on where the prey is, but the prey is not modeled. Socializing behavior will depend on what other individuals are near-by. Travelling will depend on general migration routes as well as small-scale patterns, which we barely understand for many species. All behaviors will depend on the individual, its gender, age, and what stimuli (visual, acoustic, olfactory) the animal receives at the time. Behavioral reactions to sound will also differ on an individual level, depending on the animal's gender, age, prior experience (sensitization vs. habituation). Behavioral reactions such as attraction or avoidance are not yet included in 3MB.

In general, I see a problem whenever a model is too detailed or too definitive, because the results depend on who implemented or ran the model. The results become unreliable and not reproducible. If two people were to write the behavioral module, basing it on the same data, the model implementation could easily be so different that the results were significantly different. Also, if people initialize and run the model without understanding the underlying assumptions and limitations, the results can be quite different from person to person, and results might easily be misinterpreted. A more general model is less dependent on who implemented and ran it. The results are reproducible.

2.2. ToR2: Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC models.

Both NUWC models rely on sub-models and databases. Models and databases are always a representation of the true environment under certain conditions and at some point in time. They therefore carry an inherent error or scientific uncertainty when they are used to model a specific environment. Most of these errors and their effects on the resulting acoustic exposures are difficult to assess.

2.2.1. Area Density Model

NUWC uses standard databases for sound propagation modeling, and I would say the implementation of environmental parameters is as good as it gets. Of course, the physical environment is not stationary but changes with time. It is impossible to say whether the scientific uncertainty associated with environmental parameters will lead to an under-estimation or an over-estimation of exposures. There is no reason to expect a consistent error in either direction. If one truly wanted to assess the resulting error, the Navy would have to collect some bottom samples and CTD (conductivity, temperature, depth) profiles at the time of operation, run the model with those and compare to the predicted results. One could also extract environmental profiles from different databases and run the model on all sets of data, comparing exposures. There are ways to assess the error resulting from scientific uncertainty about environmental parameters, but still, my opinion is that the current implementation is as good as it gets for any predictive model.

The effect of not modeling the true bathymetry between source and receiver will sometimes lead to over-predicting, sometimes to under-predicting. NUWC uses a limited number of analysis points and a limited number of radials. I think this can be improved, and I have made some suggestions.

The potential error introduced by exclusively using CASS/GRAB can only be assessed through acoustic field measurements around naval sources. If CASS/GRAB is out by 20dB over intermediate ranges (as were the three ray models tested in shallow water by the Australian Defense), e.g. if an SPL of 175 dB was modeled at a true SPL of 155dB, then the true probability of behavioral ‘take’ could be as much as 80% less (from 90% at 175 dB down to 10% at 155 dB, see picture below from a Navy EIS). There are other models that are known to excel in certain environments and I would recommend matching the model to the environment to reduce any potential error. Having said that, from my own experience, in most cases the acoustic propagation model over-predicts the received level at long ranges, but of course that depends on the environment and the model.

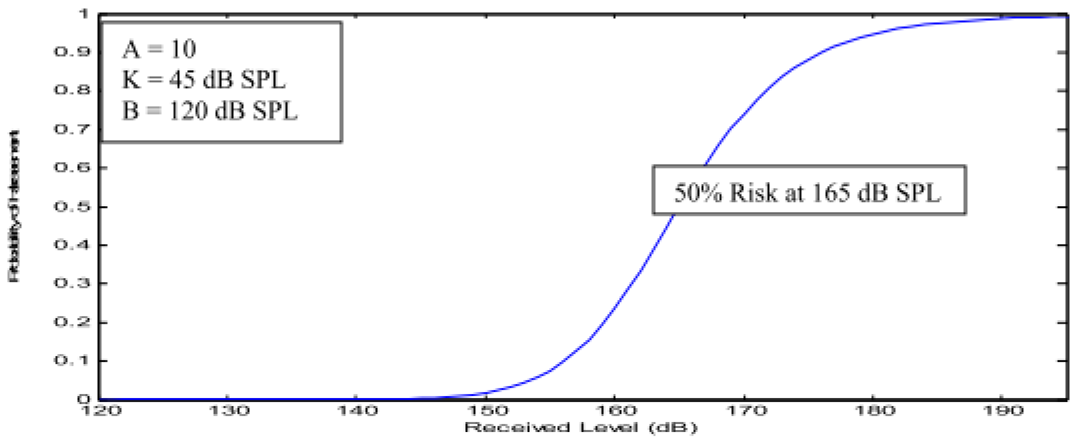


Figure 4-8. Risk Function Curve for Odontocetes (toothed whales except harbor porpoises) and Pinnipeds

My feeling is that the most serious contribution to over-predicting exposures comes from the fact that the Area Density Model collapses the 3d footprint of the source to a 2d footprint by taking the maximum SEL and SPL over all depths, and by not distributing animals with depth. In the case of an environment exhibiting a surface duct and being home to deep-diving mammals, the received levels can differ by a few tens of dB depending on whether the animal is in or below the duct.

In the absence of prior knowledge of the movement of the source, NUWC moves the sources around randomly in the area of operation. I think this is sensible. If the pinging ship were to circle (which is probably a most unlikely operation), then the cumulative SEL inside the circle could rise to levels way above those modeled randomly; a modeled TTS might actually be a PTS. The number of behavioral exposures would not rise, as the criterion is only concerned with the maximum SPL received; it's not a cumulative metric. If the ship travels in a straight line, then the true volume triggering behavioral takes will be largest, but the model assuming random motion will somewhat under-predict the number of behavioral 'takes'.

By not including ambient noise, both NUWC models can be considered conservative.

I think it is further fair to consider the prediction of TTS conservative in both NUWC models, because neither model allows for recovery during quiet times of less than 24h. The smaller the duty cycle, the more the model will over-predict TTS. If the source emits more than once a day, the model will continue integrating energy over the entire area and operation, even if some regions receive only barely audible levels while the ship is in the opposite corner of the operational area. Animals in some regions will have quiet times of 24h or more before the ship comes back, but because 'quiet time' is not defined as a period where the received level drops below a certain threshold, but rather as the time of no sound emission, the model will continue to integrate energy over multiple returns of the ship even if these are days apart.

The Area Density Model does not move animals around, but distributes them evenly and makes them stationary. This approach cannot model catastrophic events where a significant proportion of a population happens to be very close to the source or in a convergence zone, receiving high SEL. In this case the model will under-predict exposures. On the other hand, assuming that marine mammals will move away from potentially damagingly loud sources (if given the chance), the model will over-predict exposures. My feeling is that by having animals stationary and by distributing them evenly throughout a habitat (a subregion of the operational area), NUWC models a 'mean' scenario, neither consistently over-estimating nor under-estimating.

2.2.2. NEMO Exposure Model

The errors resulting from scientific uncertainty about the environmental parameters are the same as for the Area Density Model, except that NEMO does retain a 3d footprint and thus models received levels more accurately.

Exposure criteria are the same for both models. NEMO also does not allow for recovery from TTS over quiet times of less than 24h, and will continue to sum energy over multiple returns of the ship even if the levels received in the meantime were very low for extended periods. This is conservative. Given that the models use step functions for TTS and PTS, this will only over-estimate exposures if sub-threshold levels eventually add up to above-threshold levels.

I believe we don't have enough knowledge of marine mammal behavior to include the behavioral module (3MB) in models for EIAs. There is no way of telling whether the addition of 3MB leads to an over-estimation or an under-estimation of exposures. 3MB includes affinity parameters which determine animal movement in the horizontal direction. These parameters include bathymetry (some animals might like to move towards shallow water or towards slopes), or temperature and salinity (animals might prefer warm water). Clearly one can think of lots of other factors that might determine where an animal goes, none of which are included. These factors can be constant in time (such as geographic features or oceanographic features, e.g. currents) or transitory (an animal might smell something here, see something there or hear something over there). The danger is that by ignoring all of these, 3MB might make animals move into areas where they would not normally go. It would thus model not an average scenario ± standard deviation, but a completely improbable scenario. And there is no way of telling.

The dive patterns stored in 3MB, on the other hand, can be used to distribute animals more intelligently with depth. Animals should then be kept stationary at their initial depth and location. Using a 3d footprint of the source, received levels can thus be computed more accurately than with the Area Density Model.

In the case that data on animal density distribution does not exist for a particular species in a particular geographic region, my understanding is that NUWC uses data from similar environments. Again, this seems the most reasonable approach to me. The only way of assessing the resulting error would be by undertaking marine mammal surveys at the time and location of operation.

2.3. ToR4: Assess whether the Area Density Model and the NEMO Model meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

2.3.1. Have the principles of credible science been addressed during model development?

Yes. Altogether I would say that the models and their sub-models are based on our currently best available data and up-to-date scientific understanding of noise effects on marine mammals.

2.3.2. Is the choice of model supported given the quantity and quality of available data?

I think the sound propagation modeling part can be improved. Different sound propagation models are known to excel in different environments. One would ideally match the sound propagation model to the environment. I would not use CASS/GRAB in shallow water. NUWC switches to RAM in such situations. RAMS or other software capable of modeling shear waves would be better for rocky bottoms. For most environments the Navy encounters, CASS/GRAB might well be the best model (and it probably is the fastest), but I think this should at least be verified at the beginning of the EIA.

The bathymetry is being highly simplified by choosing a (small) limited number of assessment points where acoustic footprints are computed, and by using a (small) limited number of radials. Within the Area Density Model it might be difficult to improve this, as the model is already running out of memory, and the 3d footprint has to be condensed into a 2d footprint. Within the NEMO Model, I believe bathymetry can be accounted for more effectively, see my recommendations in Section 3.2.2.

While I see great potential for the 3MB model as a tool in behavioral research, I don't believe it is at a stage yet where it should be included in EIA models. There are a lot of physical and biological parameters that determine an animal's behavior and response to noise. 3MB aims to model a very complex scenario, requiring quite detailed information. It is my opinion that we do not have adequate data (neither in quality nor quantity) that warrants the implementation of an individual behavior module.

2.3.3. How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?

Neither the Area Density Model nor the NEMO Exposure Model has been verified in the field as a whole. A field validation would be largely impractical and partly impossible as it would require, amongst other difficulties, that individual animals be detected and tracked over large operational areas, and be collected for TTS and PTS assessment after the operation. The sub-models, however, can be tested separately to some degree.

According to the presenters, the CASS/GRAB model has been verified in the field; for security reasons no supporting data were shown. Given that it is a ray propagation model, there will be environments in which it does not perform well, e.g. shallow water. NUWC switches to RAM in that case, however, RAMS or other software that handles shear propagation through rocky bottoms might be better in certain environments. It shouldn't be too difficult to include a different propagation model in environments where other models are known to excel. There is no need to improve any one model. Many scientists have spent their entire careers optimizing sound propagation models. I think it's merely a matter of matching the right model to the right environment, in which case the sound propagation module will simulate the actual sound field as well as possible.

To model the source, NUWC uses the acoustic specifications of the source (frequency, source level, beam pattern). In the absence of a priori information on source movement, the source model moves the source randomly within the operational area. Again, I think this is reasonable.

To compute acoustic footprints, NUWC had to make several simplifications, such as computing the footprint at a limited number of analysis points and for a limited number of radials. I think this can be improved yielding an increase in accuracy, as I will outline in the recommendations.

To model bioacoustic impact, NUWC uses thresholds for TTS and PTS, and a risk function for behavior, all three of which are based on up-to-date scientific knowledge. The impact model is therefore as accurate as currently possible.

The main difference between the Area Density Model and the NEMO Exposure Model lies in the animal distribution and behavior module. In the Area Density Model, animals are stationary and evenly distributed in 2 dimensions (latitude + longitude), either over the entire operational area or within subregions. Animals are not distributed with depth, but instead sit at the depth of maximum SEL and SPL. The Area Density Model is overly conservative in that sense. NEMO allows one to distribute animals more intelligently, however, care has to be taken that initial distributions are sensible and that the model is run over a number of different initial distributions in order to yield statistically meaningful results. NEMO allows animals to move around over the course of the operation. I don't think there are enough scientific data to warrant an individual behavior module. I think a new approach to modeling animals is needed, as outlined in the recommendations.

How closely do the models simulate the 'ecosystem'? The ecosystem includes all physical and biological parameters and entities, and their interaction. An ecosystem model would have to include relationships such as temperature, salinity, light determining prey distribution, prey distribution relating to predator distribution, naval activities affecting the physical environment as well as prey and predator distribution indirectly and directly. If any one entity in an ecosystem changes, the model would have to compute how all other entities in the ecosystem change as a result. We are far from an ecosystem model here, but for acoustic EIAs this is not really necessary. The 3MB module in NEMO does aim for the capability of modeling marine mammal distribution as a function of selected physical parameters (affinity to certain environments, reactions to noise) and selected biological parameters (pod cohesion), but I don't think we have anywhere near enough data to support this approach yet.

2.3.4. How well does the model perform?

Certain parts of the model can easily be tested for performance. The physical oceanographic databases used for sound propagation modeling are all widely accepted within the ocean acoustics community. The sound propagation model can be tested in the field by using a controlled source and a number of receivers (hydrophones). The combination of source model and sound propagation model can be tested in the field by using a sonar as a source and measuring the 3d footprint with a number of receivers. In environments that suit CASS/GRAB, the sound propagation model and source model perform as well as possible, in my opinion. Also, the impact model is based on our current scientific understanding of noise effects on marine mammals.

Both the Area Density Model and NEMO have built-in checks for data integrity, and in my opinion these were reasonable. During the modeling process, the modeler routinely performs a number of checks and input and output data inspections. Intermediate results are plotted at various stages and log files kept.

The Area Density Model has been tested against itself by breaking down a complex scenario into its components. For example, the model was run to estimate exposures from two simultaneous sources. It was then run on each operation separately, combining SEL and SPL matrices afterwards. The results were consistent.

The main uncertainties in both models stem from the lack of a priori knowledge on source location and movement and the lack of data on animal distribution. We can model the sound field reasonably well, we have some understanding of impact thresholds, but if we don't know where the ships and animals are, then any exposure model will be highly speculative.

2.3.5. Is the model capable of being updated with new data as it becomes available?

The Area Density Model is limited in what it can do, because it is already running into memory and computational exhaustion. The NEMO model appears more efficient and can readily be updated as new data becomes available. A nice feature about the NEMO implementation is that it keeps track of all pings received by each animal. As regulations change, NEMO would easily be able to compute various metrics.

I believe we need a better risk function, and I believe the risk function will eventually become a function of instantaneous received level rather than a function of maximum received level over some artificial time. In NEMO, this change would be minimal. In the Area Density Model, this change would be a major headache, if not impossible to implement, because this model is not able to keep track of single exposures.

However, I think at this stage, NEMO requires too much input data and too detailed information on animal behavior, which makes it hard, if not impossible, to assess the output. I believe an intermediate approach would be best.

3. Conclusions and Recommendations

NUWC presented two models: the Area Density Model and the NEMO Exposure Model. While the implementations of these are quite different, the sub-models are largely identical with the exception of the animal distribution and behavior module.

3.1. Relative Error Assessment

All of the models and databases used by NUWC/SAIC carry an inherent error, because they are representations of the real environment under certain conditions at some point in time. One could assess the relative effect of these errors on the final number of Level A and B 'takes' in order to determine which of the models and databases need to be improved. The relative error can be assessed by means of sensitivity analyses.

Chu *et al*. (2002) introduced small deviations in the sound speed profile of 1m/s resulting in deviations of received level of up to 30dB over a 1km range using the CASS/GRAB model. They artificially introduced small convergence and shadow zones, and placed the receiver at the zone depth, creating a worse deviation. I think it would be more meaningful for the current case if NUWC took a sound speed profile from different databases for the same month of year, and if the profiles differ substantially, then compare the resulting footprints, and the resulting exposure numbers for a very simple operational scenario. While, no matter what the outcome, one would still continue to access these databases for future EIAs, a sensitivity analysis of sound speed profiles would allow a judgment of the error in exposures as a result of uncertainties in the sound speed profile.

I don't think a sensitivity analysis of bottom geology is necessary or useful. In deep water, the geology will hardly matter. It is most crucial in shallow water. I recently performed a field validation of sound propagation models in shallow water with rocky bottoms (no unconsolidated sediment). Modeled received levels were 20dB too high at 3km range, with the error increasing with range. This was a result of the bottom being more weathered (more porous and attenuating) than the databases had suggested. Data on bottom geology are scarce for many geographic regions. There is no way of assessing the variation in geology other than by in situ sampling. A sensitivity analysis is therefore impractical.

The error in the sound field as a function of uncertainty in bathymetry can be assessed by computing a footprint of the source with the bathymetry extracted for all 360 (if you want to run it in 1 degree steps) radials, and comparing to a footprint with the standard 8 radials. From the plot we were shown, the error can be up to 40dB at long ranges (This was the jump in SEL from one radial segment to the next.). The effect of bathymetry will be largest in regions where the bathymetry changes rapidly, i.e. on slopes. I think bathymetry can be dealt with much more efficiently, as I will outline below.

The error of the sound propagation model (CASS/GRAB) would best be tested in the field, but it will depend on the particular environment. A sensitivity analysis could be done by comparing a CASS/GRAB run to a PE run or other model for the same environment. Again, differences will depend on the physical parameters at the location. I think that as long as an experienced acoustician looks at the environment and chooses a propagation model that is known to perform well under the given conditions, then the sound propagation model will be alright.

A sensitivity analysis of the biological parameters used in NEMO/3MB can be done by varying the parameters. Peter Hulton mentioned that Dorian Houser recommended running 3MB a large number of times with different initial conditions to compute exposure statistics. This seems sensible to me.

My feeling is that exposures will be highly sensitive to animal distribution, and future research effort in this area is needed.

3.2. Model Improvement

3.2.1. Moving from the Area Density Model to NEMO?

NUWC intends to phase out the Area Density Model and to replace it with the NEMO Exposure Model. The Area Density Model is very computationally intensive, because of the way it is programmed. It tries to keep track of SEL and SPL on a receiver grid spanning the entire operational area. For large regions, this becomes impractical. The Area Density Model already does not manage to do this in 3d, and sound levels have to be maximized over all depths. I don't see how the computational task can be made more efficient with this approach. I wrote an Area Density Model myself some time ago and also ran into the limit of computational power and memory on top-end computers. An entirely different approach is needed.

The NEMO framework is different in that it does not need to keep track of SEL and SPL over the entire operational area, but only at the location of the animals. It stores 3d footprints of the sources in environmentally different regions and simply looks up the SEL and SPL for each animal at every step in time. If operational areas increase, and if the number of animals increase, NEMO will be able to handle this without running into computational limits.

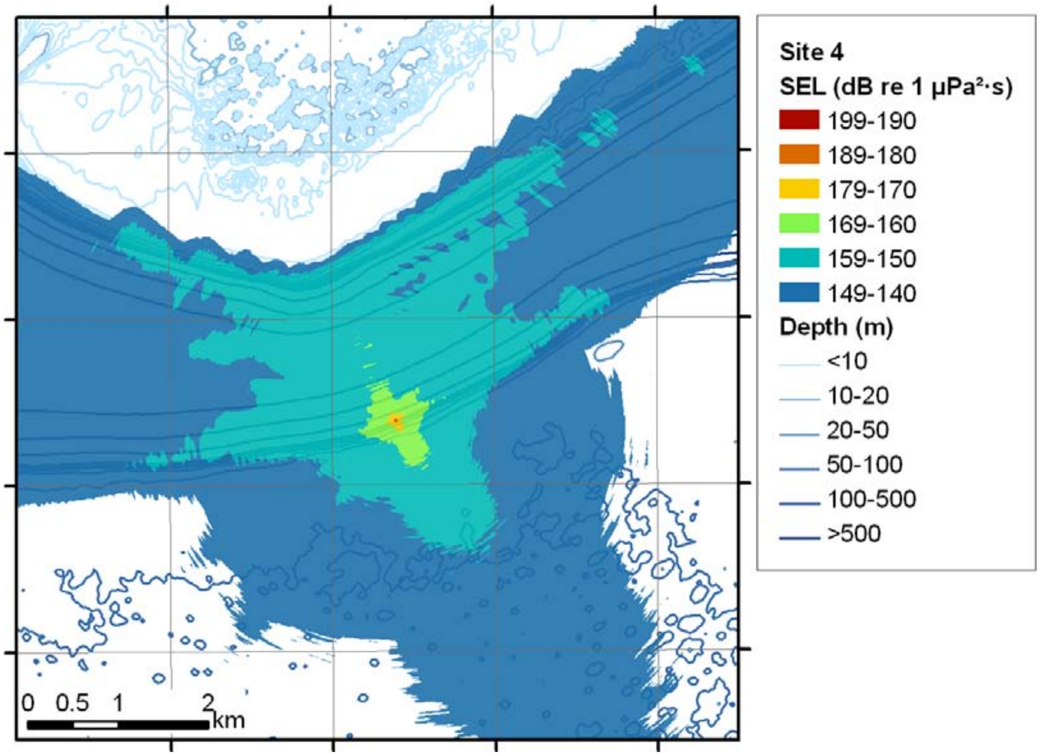
However, I do not agree with the individual behavior module in NEMO. I don't think that the next step from the Area Density Model should be an individual behavior model, but rather an improvement in marine mammal distribution and an improvement in computational efficiency. NEMO allows for the latter. To improve marine mammal distribution from a uniform density, NEMO could be run with stationary animals. Animals could be placed more intelligently than evenly. In fact, existing data on dive profiles could be used to estimate the percentage of animals found at various depths at any instant in time. For example, let's consider the dive profile for a Blainville's beaked whale, which was handed out during the meeting in Newport. This animal spent about 80% of its time in the top 5m of the water. 15% of the time was spent between 800-1000m depth. 5 % of the time the animal was transitioning from shallow to deep water and back. If this is 'normal' behavior for Blainville's beaked whales in the area of operation and during the season of operation, then one can assume the problem is ergodic: The mean depth distribution at any instant in time averaged over all animals in the population should be the same as the mean depth distribution of any one animal averaged over time. In other words, when it comes to populating the area with Blainville's beaked whales, NEMO should place 80% of animals into the top 5m, 15% down to 800-1000m and 5% evenly between 5 and 800m depth. Animals should then remain stationary for the duration of the operation.

It only makes sense to include animal movement once there are enough data on behavioral reactions to sound. Once 3MB can reliably model aversion and attraction, animals can be allowed to move. At this stage we have very little information on animal reactions to sound, how they respond and what factors make them respond or prevent a response. If NEMO includes the 3MB module, there is therefore no way of assessing the uncertainty and error, and no way of judging the results. If, on the other hand, animals remain stationary, one can use fully-accepted statistical methods to assign means and standard deviations. Using the ergodic situation above, one could say that animals were placed within the operational area according to their documented mean depth distribution. One way of computing variance would be to overpopulate an area, compute exposures at each animal and then repeatedly resample from that population.

3.2.2. Improving sound propagation

As discussed above, the environmental databases that NUWC accesses for both models are as good as they get. The sound propagation models that are currently available within the ocean acoustics community are also as good as they get at this stage. Some scientists have spent their entire careers optimizing these models, and there is no need for NUWC to improve the models. But I see potential for improvement with the way that bathymetry is accounted for. NUWC computes the 3d footprints of each source by modeling sound propagation at a limited number of analysis points and for a limited number of radials. As discussed above, at long ranges, SEL jumped by 40dB from one radial to the next. Two neighboring receivers or two animals swimming next to each other could receive an SEL differing by 40dB if the animals happen to sit in different radial segments. If the ships sweep the operational area evenly (effectively transmitting from every point in the area and into all directions), then this will hardly matter, because only the maximum SPL and the cumulative SEL determine a 'take', and a level of 40dB less received at some time during the operation won't contribute to either metric. However, if specific operations are modeled and if animals are not evenly distributed, then this can matter significantly.

To further illustrate the effect of bathymetry on received level, I am including a picture from a sound propagation model over an area that exhibited a 500m deep channel. Plotted are maximum SEL over all depths as is done in the Area Density Model. The channel ran roughly from west to north-east. Towards the north, water depth decreased fast, the bathymetry rapidly became more shallow. The source was operating at the southern edge of the channel. The source was somewhat directional with more energy being emitted towards the north and south than east and west. This can be seen from the oval shaped contours close to the source. The long axes of the yellow and the green ovals (representing an SEL of 170-179 dB and 160-169dB respectively) run from north to south, i.e. more energy is emitted in the north-south direction. The bathymetry, however, ducts sound into the channel. Even though the source emits more energy into the north-south direction, energy travels much further in the east-west direction through the channel. As the bathymetry climbs towards the north, energy is absorbed very fast. Levels dropped to less than 140dB over 2km towards the north. Towards the north-east and west, inside the channel, energy propagated to ranges in excess of 12km before dropping below 140dB. If one was to shoot only 8 radials here, one would not be able to resolve the channel and would potentially make errors of several 10s of dB at long ranges. If one was to use this same footprint for subsequent pings that occur only 1-2km further north, the map of received levels would be simply wrong. One would put high energy into regions where there should be hardly any and vice versa. But this is exactly what both the Area Density Model and the NEMO Model do; a limited number of footprints are computed at selected analysis points, and these footprints get applied to a large number of pings over large areas.



In the Area Density Model, the handling of bathymetry can only be improved by increasing the number of analysis points and the number of radials as outlined in Section 2.1.1. A much better way of accounting for bathymetry is as follows. It will only fit into the NEMO framework.

1. Put a very coarse receiver grid over the entire operational area, leave out area in which there will never be any marine mammals (e.g. land). This grid will not be used for animal locations, it will only be used for bathymetry modeling; it can thus be very coarse.
2. Put a very coarse source grid over the entire operational area, leaving out regions where the sources would never go (e.g. land).
3. Estimate the maximum range you need to model, the same way as you have done in the current models. For typical sources and minimum impact levels of 120dB, this might be of the order of 100-200km. For the following discussion, let us assume it is 150km.
4. Match every receiver grid point with every source grid point and compute the distance.
5. For all pairs that are about 20km – 150km apart, extract the bathymetry. There will be many tens of thousands of them. Pairs that are close together (perhaps < 20km, depending on the environment) will be ignored, as their bathymetry is expected to be included in the longer bathymetries.

6. Cluster these bathymetries into a manageable number of around 1000. I use a self-organizing neural net to do so. You can use supervised or unsupervised networks. There are also other clustering algorithms to choose from. I run a K-means clustering program after a self-organizing map.
7. Compute the mean of all bathymetries in each cluster to yield a limited number of cluster centroids.
8. Model sound propagation for the centroid bathymetries. This is your library of TL and replaces your 3d footprint.
9. Proceed with NEMO as normal. For every animal or every step in time, look up the current location of both animal and source. Instead of looking at the 3d footprint, you will now have to look at the bathymetry map for your operational area, extract the bathymetry from the animal to the source and pass this through the clustering algorithm, which at this stage will simply be a multiplication of a vector by a matrix. Conceptually, you will find the cluster into which the current bathymetry path falls. Take the TL you've modeled for this cluster's centroid, add the source level accounting for the beampattern.
10. Update your SEL and SPL history and proceed as usual. Done.

I have found this approach very efficient over very large areas and operations. It accounts for the particular bathymetry between each animal and each source emission. If the geology or the sound speed profiles vary significantly over the operational area, you would need to run this in provinces or for more than one analysis point as you've already done. I have performed a number of sensitivity and error analyses on this approach and found a mean error in SEL of 0 dB (You would expect the mean error to be 0; if it was anything but 0 you would have a consistent error in your clustering algorithm.) with a standard deviation of 3dB over ranges from 10m to 10s of km. This error was computed by modeling SEL with the true, extracted bathymetry versus the neural-net-clustered centroid bathymetries for a large number of sources and receivers. This error is much smaller than the 40dB jump we saw at the NUWC meeting.

Acknowledgment

It was a great pleasure to participate in this CIE review. Thanks to CIE for selecting me. Thanks to Manoj Shivlani for organizing my participation. Thank you to NMFS and NUWC who were most helpful and welcoming.

Appendix 1: Bibliography

A number of documents were provided to the review panel prior to the meetings. These included excerpts of reports, for which the proper citation including authors and title were sometimes not passed on. The following list is therefore in no proper citation format.

- SOCAL Range Complex EIS/OEIS, Preliminary final version 2 (September 2008), Section 3.9, pages 1 – 132
- SOCAL EIS, Appendix F, Overview and Technical Approach, pages F.1 – F.392
- Marine Resources Assessment for the Southern California Operating Area, Final Report, September 2005, pages 1 - 574
- AFAST DEIS, excerpts from Chapter 3, Marine Mammal Densities, pages 3.2 – 3.6
- AFAST DEIS Chapter 4.4 Marine Mammals, pages 4.16-4.129
- AFAST DEIS Appendix H – Summary of Acoustic Modeling Results, pages H.1 – H.66
- Houser, D.S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. IEEE Journal of Oceanic Engineering 31(1) 76 – 81
- HRC FEIS-OEIS, Appendix J, Acoustic Impact Modeling, pages J.1 – J.104

In addition to the above documents provided, I also reviewed the following documents:

- Weinberg, H., and R.E. Keenan. 1996. Gaussian ray bundles for modeling high-frequency propagation loss under shallow-water conditions. *Journal of the Acoustical Society of America* 100(3), 1421 – 1431.
- Keenan, R.E. 2000. An introduction to GRAB eigenrays and CASS reverberation and signal excess. Oceans 2000 MTS/IEEE Conference and Exhibition, Vol. 2, 1065 – 1070.
- Calnan, C. 2006. BASE 04 Transmission Loss Measurement and Modelling. Report by xwave for Defence R&D Canada – Atlantic.
- Chu, P.E., C.J. Cintron, S.D. Haeger, D. Schneider, R.E. Keenan and D.N. Fox. 2002. Yellow Sea Acousic Uncertainty cause by Hydrographic Data Error. Powerpoint Presentation. www.oc.nps.edu/~chu/web_paper/conference/02/av2002_chu.pdf . Full paper available from http://www.stormingmedia.us/89/8949/A894974.html .
- Vares, N.A. 2002. Environmental variability on acoustic prediction using CASS/GRAB. www.oc.nps.edu/~chu/thesis_dir/vares_presentation.ppt

This report also cites the following literature:

- Jones, A.D., J. Sendth, A.J. Duncan, P.A. Clarke, Z.Y. Zhang and A.L. Maggi. 2007. Comparison of transmission loss models at mid-frequency against shallow water data. Proceedings 14th International Congress on Sound & Vibration, Cairns, Australia, 9-12 July 2007, 8p.
- Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4), 412 - 522.

Appendix 2: Statement of Work

Below is the original statement of work, I received. The review of the modeling of explosives was later taken out of the statement of work.

Statement of Work for Dr. Christine Erbe

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
and
Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model

Background and Scope of Work

The National Marine Fisheries Service (NMFS) requires an independent peer review of the Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) marine mammal acoustics exposure effects analysis models (the processes these two groups use to perform the analyses described herein involve more than the use of single models, but will be broadly referred to as "models" for simplicity in this document) which shall assess whether they correctly implement the sub-models and data upon which it is based, whether they adequately assess all relevant physical and biological variables in assessing effects on local marine mammal populations, and whether they meet the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines for models, which primarily involve scientific credibility. The review of the NUWC model will include an assessment of the current model (used for the Atlantic Fleet Active Sonar Training (AFAST) with additional analysis of the Effects of Sound on the Marine Environment (ESME) behavioral module, which the Navy intends to incorporate into the current model moving forward.

Minimizing and mitigating the potential effect of sound upon the environment is an increasing concern for many activities. Naval operations, seismic exploration, vessel and aircraft operations, certain construction activities, and scientific investigations now need to consider the potential effects underwater acoustic sources have on marine life. Marine mammals are usually the primary concern, due to their widespread distribution and excellent hearing ability, although impacts on fish are increasingly being considered as well. Predicting the exposure of marine mammals is complicated by several factors: a general lack of data to support a comprehensive understanding of density and distribution; horizontal and vertical movement patterns; any long-range migratory behavior; and a lack of understanding of exactly how potential sound avoidance behaviors may impact the levels of sound to which marine mammals are exposed.

Acoustic propagation and received sound levels are a function of water depth, range from the source, sound source characteristics, and a number of environmental variables. These issues, combined with the variable spatiotemporal distribution and movement of different species, contribute to a very complex problem. The NUWC and SAIC models address these specific complications in similar ways. The models predict a received level at range and depth in a 3-dimensional grid (x,y,z), then overlay the marine mammal density (animals/km^2) for each species on the 2-dimensional (x,y) grid. The third dimension (z) can be applied through the use of animal distribution in depth for a percentage of time if that data are available. Biological distribution and movement can be based on regional and seasonal behavioral data for each species evaluated. Acoustic sources are programmed to move through a virtual acoustic environment based on external environmental databases and radiated sound fields created from a selected propagation model (e.g., Comprehensive Acoustic Simulation System/Gaussian RAy Bundle (CASS/GRAB), or Range-dependent Acoustic Model (RAM)) The integration components of the NUWC and SAIC models make use of the high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation in MATLAB®. The end results of modeling represent estimated accumulated exposures above a specified criteria threshold (permanent threshold shift – PTS or temporary threshold shift – TTS) of animals for each source, scenario and marine mammal combination presented in a spreadsheet. The model also predicts received sound pressure levels that are then applied to a risk function curve to predict the probability of behavioral harassment.

For the SAIC model, the Navy developed several post-modeling corrections that *can* be applied to the output of the model to make it more realistic. These post-modeling applications quantitatively address the following factors, which are not accounted for in the models described above:

- Acoustic footprints for sonar sources do not account for land masses.
- Acoustic footprints for sonar sources are calculated independently, when the degree to which the footprints from multiple ships participating in the same exercise would typically overlap may be taken into consideration.
- Acoustic modeling does not account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

For the NUWC model, the Navy has developed the Effects of Sound on the Marine Environment (ESME) behavioral module that can be incorporated into the NUWC model to more accurately represent some of the biological variables of concern, such as animal movement and behavior. Reviewers will be asked to assess the NUWC model both with and without the inclusion of this module.

NUWC and SAIC both make use of Navy standard sub-models and databases that are housed at the Oceanographic and Atmospheric Master Library (OAML). The Chief of Naval Operations (CNO) established OAML in 1984. The OAML suite consists of Navy-standard core-models, algorithms and databases that support the Department of the Navy (DoN), Department of Defense (DoD), and research and development laboratories that support DoD and DoN and Joint and NATO activities. OAML also supports Task Force Web and Navy Enterprise Portal initiatives with state-of-the-art Navy-standard products. Some OAML databases, included sound speed profiles and the unclassified bathymetry database are available to the public.

The NUWC and SAIC models are not proprietary; however, several input data sources are either classified or restricted to the above-listed agencies and organizations. Nevertheless, the continued use of the models to provide acoustic exposure and impact predictions for regulatory assessment purposes requires that the models be reviewed independently, so that NOAA and other federal agencies can comply with the Data Quality Act.

Overview of CIE Peer Review Process:

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract for obtaining external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of stock assessments and various scientific research projects. The primary objective of the CIE peer review is to provide an impartial review, evaluation, and recommendations in accordance to the Statement of Work (SoW), including the Terms of Reference (ToR) herein, to ensure the best available science is utilized for the National Marine Fisheries Service management decisions.

The NMFS Office of Science and Technology serves as the liaison with the NMFS Project Contact to establish the SoW which includes the expertise requirements, ToR, statement of tasks for the CIE reviewers, and description of deliverable milestones with dates. The CIE, comprised of a Coordination Team and Steering Committee, reviews the SoW to ensure it meets the CIE standards and selects the most qualified CIE reviewers according to the expertise requirements in the SoW. The CIE selection process also requires that CIE reviewers can conduct an impartial and unbiased peer review without the influence from government managers, the fishing industry, or any other interest group resulting in conflict of interest concerns. Each CIE reviewer is required by the CIE selection process to complete a Lack of Conflict of Interest Statement ensuring no advocacy or funding concerns exist that may adversely affect the perception of impartiality of the CIE peer review. The CIE reviewers conduct the peer review, often participating as a member in a panel review or as a desk review, in accordance with the ToR producing a CIE independent peer review report as a deliverable. At times, the ToR may require a CIE reviewer to produce a CIE summary report. The Office of Science and Technology serves as the COTR for the CIE contract with the responsibilities to review and approve the deliverables for compliance with the SoW and ToR. When the deliverables are approved by the COTR, the Office of Science and Technology has the responsibility for the distribution of the CIE reports to the Project Contact.

Reviewer Requirements

The Center for Independent Experts (CIE) shall provide three panelists and a moderator for the review of each of the two models. The same individual will function as moderator for the review of both models. Preferably, the same three individuals would function as reviewers for both models, however, this may not be possible due to the required expertise and scheduling constraints.

CIE shall provide expertise in the scientific discipline of underwater acoustics, modeling, and marine mammalogy.

The underwater acoustician reviewer(s):

- shall have expertise and working experience with propagation loss models
- will preferably have working knowledge of the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB, which is the main propagation model incorporated in both the NUWC and SAIC models) and/or similar propagation models.

The modeling reviewer(s):

- shall have expertise with individual-based exposure assessment models
- will preferably have experience with the above type models dealing with the integration of multiple data streams (*e.g*., multiple databases).
- shall be able to understand the dynamic interaction of databases.

The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

The moderator:

- shall have expertise in marine mammalogy
- shall have expertise in either underwater acoustics or modeling

The CIE review shall be conducted during two panel review meetings organized around a three-day meeting at NUWC, Newport, RI and a three-day meeting at SAIC, McLean, VA according to the schedule stated herein. For each of the two reviews, each reviewer shall be required for a maximum of 15 days for reviewing pre-review documents, conducting the peer review during the NUWC/SAIC meeting, traveling, and completing the CIE reports. The moderator will need 17 days for each review.

Statement of Tasks for CIE Reviewers

Note: There are two sets of meetings (including teleconference, three days of on-site meeting, etc.), one set for review of the NUWC model and one set for review of the SAIC model. The organization of the two sets of meetings is identical, but on different dates.

For each set of meetings, the CIE reviewers and moderator shall review the pre-meeting documents in preparation for the peer review meetings, to be provided by the Project Contact in accordance with the schedule of milestones and deliverables herein (refer to listed in Annex I for preliminary list of documents). The CIE reviewers and moderator will participate during each three-day panel review meeting at (1) NUWC, 1176 Howell Street, Bldg 1346, Rm 407U, Newport, RI 02841, and (2) SAIC, 1710 SAIC Dr, McLean, VA 22102. After each meeting, the three CIE reviewers (of each model) shall complete independent peer review reports addressing all the Terms of Reference given below. The moderator(s) shall consolidate the individual reports into a summary report for each meeting. Details on the formats of the panelists' and moderator's reports are given in Annex II and III, respectively.

<u>Teleconference Calls with CIE for NUWC and SAIC</u>: The CIE panel and NUWC/SAIC teams will discuss via conference calls the details of the upcoming panel review meetings, providing an opportunity for the CIE reviewers to raise questions concerning background documents, specifications for trial runs, and other review-related material, including logistics. In preparation for these teleconference calls, the CIE reviewers shall review pre-meeting documents provided by the Project Contact in accordance with the scheduled milestones and deliverables herein.

<u>Day 1 of panel review meetings for NUWC and SAIC Meetings</u>: CIE reviewers shall participate during the NUWC and SAIC panel review meetings during the dates specified in the schedule of milestones and deliverables herein. During the meetings, the Term of References (ToR) will be reviewed and the NUWC/SAIC model presentations will be made by scientists from NUWC/SAIC, with questions and answer sessions as needed. Presentations shall include:

1) Introduction to the current NUWC/SAIC approaches (i.e., the ones used in the AFAST and HRC EISs) and the software, including data input requirements;
2) Explain incorporation of the ESME behavioral module into the NUWC model;
3) Review of results of internal testing of the software;
4) Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
5) How these exposure estimates are interpreted relative to noise exposure thresholds and/or guidelines?

6) Review all relevant post-modeling correction factors for the SAIC model
7) Review all inherent, underlying assumptions in each model

The CIE reviewers and moderator shall meet to develop a set of test runs for during the panel review meeting. The purpose of this evaluation is to determine how the NUWC/SAIC model responds to a set of inputs designed to test the model. The CIE reviewers shall also acknowledge the differences and the roles of the external components (*e.g.*, animal input parameter values, propagation models) and the internal component of the model (e.g., ship movement) in regard to the functionality of the model The distinction is drawn here to emphasize that the values of animal placement parameters can and should change when new data are available, and that both models can utilize that new data. Navy staff will provide a comprehensive list of all of the parameters that can be input or changed by the users, versus those that are internal components. Example scenarios for devising these runs are provided in Annex IV.

Days 2-3 of the panel review meetings at NUWC and SAIC: CIE reviewers and the moderator shall work with NUWC/SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. For the NUWC model, the scenarios will be enacted both with and without the ESME behavioral module so that the reviewers can assess both. For the SAIC model – post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of NUWC/SAIC scientists as required, design simulations and request that the NUWC/SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because NUWC/SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, NUWC/SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, NUWC/SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

Terms of Reference

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors (“business rules”) for the SAIC model.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA’s Council for Regulatory Monitoring (CREM) guidelines for model development.

1. NUWC/SAIC Model Implementation

Details relevant to the topics described below are given in the documents identified in Annex 1.

- Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

    i. accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the NUWC/SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC/SAIC models*

    ii. correctly handle the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

    iii. correctly and efficiently extract data from databases? If not, identify any errors. The NUWC/SAIC models use the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.
- Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar or explosives based on current scientific knowledge, such as:
    i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference))
    ii. Marine mammal movement (horizontal and vertical)
    iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

- Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?
- Does the NUWC/SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?
- Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model would likely result in over/underestimates of take (and the degree, if possible)

2. CREM Guidelines

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points

listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

Schedule of Milestones and Deliverables:
The CIE shall complete the milestones and deliverables in accordance with the schedule of activities provided in the following table.

Activity and Responsible Party	Date
NMFS Project Contact will provide pre-meeting background documents to CIE	17 October 08
CIE reviewers and moderator(s) shall participate in a teleconference call with NMFS, NUWC and SAIC to discuss technical and logistical details of the peer review meetings (depending on availability of participants).	27 October 08 1pm 866-620-3559 Passcode 6243699#
CIE reviewers and moderator shall participate in panel review meeting at NUWC to test models Address - 1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841	**12-14 Nov 08**
CIE reviewers and moderator shall participate in panel review meeting at SAIC to test models Address - 1710 SAIC Dr, McLean, VA 22102	**17-19 Nov 08**
CIE reviewers shall submit their CIE independent peer review reports to CIE and the CIE moderator(s)	5 December 08
CIE moderator(s) shall submit their CIE summary report(s) to CIE	17 December 08
Upon CIE Steering Committee review and approval, CIE shall submit the CIE independent and summary reports to the NMFS COTR for review and approval in accordance with the ToR	24 December 08
CIE shall submit the final CIE reports in PDF format to the NMFS COTR	5 January 09
NMFS COTR will distribute the final CIE reports to the NMFS Project Contact for distribution	12 January 09

Acceptance of Deliverables:

Each CIE reviewer shall complete and submit an independent CIE peer review report in accordance with the ToR, which shall be formatted as specified in Annex 2, to Dr. David Sampson, CIE regional coordinator, at david.sampson@oregonstate.edu, and Mr. Manoj Shivlani, CIE lead coordinator, at shivlanim@bellsouth.net. Upon review and acceptance of the CIE reports by the CIE Coordination and Steering Committees, CIE shall send via e-mail the CIE reports to the COTR (William Michaels

William.Michaels@noaa.gov at the NMFS Office of Science and Technology by the date in the Schedule of Milestones and Deliverables. The COTR will review the CIE reports to ensure compliance with the SoW and ToR herein, and have the responsibility of approval and acceptance of the deliverables. Upon notification of acceptance, CIE shall send via e-mail the final CIE report in *.PDF format to the COTR. The COTR at the Office of Science and Technology have the responsibility for the distribution of the final CIE reports to the Project Contacts.

Key Personnel:

Contracting Officer's Technical Representative (COTR):

William Michaels
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Request for SoW and ToR Changes:

The Statement of Work (SoW), Terms of Reference (ToR) and list of pre-review documents herein may be updated without contract modification as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToR are not adversely impacted. Any such requests for changes to the SoW and ToR shall be submitted to the COTR (Contracting Officer's Technical Representative) for approval no less than 15 working days prior to the CIE peer review meeting.

ANNEX I: Documents to be reviewed in preparation of the NUWC/SAIC model review. This is a tentative list and will be further refined and specified prior to the review time. Documents may be provided on an ftp site because of large size.

Document Titles
1. NUWC Marine Mammal Acoustic Effects Analysis
2. Numerical Simulation of Undersea Detonation Effects on Marine Species Life
3. NUWC Environmental Modeling for Marine Mammal Acoustic Effects Analysis
4. Oceanographic and Atmospheric Library (OAML) Summary
5. Insert PowerPoint presentation on SAIC model
6. Marine Resource Assessment for SOCAL
7. Source of density for SOCAL

Document	**Document Type**	**Number of Pages**	**Degree of Difficulty**
1. NUWC Acoustic Model	PDF		
2. NUWC Explosive Model	PDF		
3.NUWC Environmental			
4. OAML description	PDF	113	Low
5. SAIC Presentation	PowerPoint		
6. MRAs	CD/Hardcopy		
7. SOCAL Density			
8. Acoustic appendices from EISs for both the SAIC and NUWC models	PDF		

ANNEX II: Format and Contents of CIE Independent Reports

1. The report should be prefaced with an Executive Summary with concise summary of goals for the peer review, findings, conclusions, and recommendations.

2. The main body of the report should consist of an Introduction with
    a. Background
    b. Terms of Reference
    c. Panel Membership
    d. Description of Review Activities

3. Summary of Findings in accordance to the Term of Reference

4. Conclusions and Recommendations in accordance to the Term of Reference

5. Appendix for the Bibliography of Materials used prior and during the peer review.

6. Appendix for the Statement of Work

7. Appendix for the final panel review meeting agenda.

8. Appendix for other pertinent information for the CIE peer review.

ANNEX III: Moderator's Summary Report Generation and Process

1. The summary report shall include an overview of the review process.

2. The summary report shall provide a synopsis of the three panelist reports.

3. Points of agreement and disagreement among the panelists shall be documented.

4. The summary report shall also include as separate appendices copies of each of the panelists' report.

ANNEX IV: Example NUWC/SAIC Scenarios: The panel shall create their own scenarios to be sure that their questions are addressed and answered. Reviewers will develop the scenarios in close coordination with the modeling team to ensure that the scenarios are feasible. The examples below illustrate the type of scenarios that the NUWC/SAIC models can address. They cover two sources of anthropogenic noise from mid-frequency active sonar and underwater explosives. Development of scenarios (including identification of the necessary input parameters) will be addressed during the conference call and the first day of the meeting.

1. A vessel quipped with a mid-frequency (1-10 kHz) active sonar source operating in the Southern California Range Complex (SOCAL) in May. The vessel will be on the range for three days conducting sonar operations during daylight hours. The active sonar signals are one second long broadcast once a minute with a source level of 235 dB re 1 µPa at 1 meter. The active sonar can be operated in two modes; namely, search and track. The ship is moving at 10 kts randomly in a 40 km square operational area. The question to be addressed is how many bottlenose dolphins are modeled to be exposed to a received level that would lead to MMPA Level A (PTS) and Level B (TTS and behavioral) harassment if the operation goes forward? Alternatively, how would the acoustic exposure be altered if the exercise were conducted in January?

2. A similar scenario as above but instead of using mid-frequency active sonar, an explosive source will be used. Input parameters include (among others) the net explosive weight, the explosive depth, the average sediment depth and the seasonal sound speed profile.

Appendix 3: Meeting Agenda

Agenda for NUWC Meeting in Rhode Island (November 12 -14)

1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841
Navy POC – Peter Hulton - 401-832-1797

Day 1
8:00 - Introductions and Logistics (bathroom, emergency exit, etc.)
8:15 - Review of ToRs (Moderator)
Presentations by NUWC Personnel
8:45 - Description of current NUWC approach (i.e., the one used in the AFAST and East Coast Range Complex's EISs) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all of the model parameters (including for ESME) that can be input or changed by the users, versus those that are internal components.
10:15 - Break
10:30 - Discussion of the ESME behavioral module and its incorporation into the NUWC model
11:30 - Review of results of internal testing of the software
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.

Day 2
8:00 – Development of Input Data for Trial Run (AFAST/ECRC EIS Method)
10:00 – Trial Run (AFAST/ECRC EIS Method)
12:00 – Lunch
13:00 – Review of Results
15:00 – Development of Input Data for Trial Run (3D Mammal Method)
16:00 – 3D Marine mammal simulations

Day 3
8:00 - Trial Run (3D Mammal Method)
10:00 – Review of Results
12:00 – Lunch
1:00 – Review of Report format, contents, and due dates (Moderator leads)
1:30 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
2:30 – Wrap-up

External Independent Peer Review

by the Center for Independent Experts

of the

Science Applications International Corporation (SAIC)

Marine Mammal Acoustics Exposure Analysis Model

Individual Review Report

prepared by

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Brisbane, 23 November 2008

Executive Summary

Three different models have recently been used to assess the impact of naval underwater acoustic sources on marine mammals: NUWC's Area Density Model, NUWC's Exposure Model, and a model developed by SAIC. An independent scientific review of all three models was initiated to assess whether the models were correctly implemented, whether they adequately incorporated all relevant physical and biological variables, and whether they met the Environmental Protection Agency's Council for Regulatory Monitoring guidelines. This report reviews the SAIC model.

The SAIC model can be broken down into a number of sub-models. To model the source(s), the software reads in the source characteristics provided by the Navy (frequency, source level, beam pattern, duration, duty cycle). The operational specifications (source location and movement) are generally not disclosed. The SAIC model makes various assumptions at various steps. For the computation of harassment rates (number of harassments per unit of operation) SAIC moves the sources in straight lines. For the computation of the expected number of 'takes', a source is assumed to emit from every point in the operational area over the duration of operation. Multiple sources are treated separately. The impact volume for behavioral 'takes' is reduced in post-processing, assuming ships move in parallel lines, accounting for the fact that an animal can only be taken once every 24h by the highest SPL received. In the absence of any specifications on source location and movement, SAIC chose to model a general scenario, for which there is no reason to believe that it will consistently under-estimate or over-estimate exposures, but instead produce 'average' harassment numbers.

To model sound propagation, SAIC uses a ray model, CASS/GRAB, and accesses standard databases for environmental parameters (bottom geology, sound speed profile, bathymetry, wind conditions). Environmental parameters are grouped into 5-20 provinces, each having a constant sound speed profile, seafloor type and water depth. Bathymetry is ignored except for the water depth at the source location. Each province has a flat bottom. The entire operational area is split into these provinces. Sound propagation and bioacoustic impact are modeled once for each province. Harassment numbers are then combined into a weighted average, weighted according to how much of the operational area is presented by each province. This is assuming that the source movement will cover the entire operational area evenly.

Clearly, for every one shot, the true sound field will mostly look very different from the one modeled, because the model assigns one of 5-20 provinces to each shot, with constant environmental parameters over more than 100km range, and with a flat seafloor over such long ranges, ignoring bathymetry. The modeled sound field is radially symmetrical, which will mostly not be the case in reality, unless one is out over the abyssal plain. While the model makes great simplifications in sound propagation modeling, there is no reason to believe that it will consistently over-estimate or under-estimate 'takes'. It will over-estimate for some locations and bearings, it will under-estimate for others.

To model the animals, SAIC accesses data on animal sightings and distributes animals evenly within the geographic region of occurrence. SAIC uses dive profiles to distribute animals with depth. Animals remain stationary relative to ships. SAIC does not model behavior. In my opinion, we don't have enough and reliable scientific data on animal behavior to warrant an individual behavior model, and I believe SAIC takes a valid approach.

To model bioacoustic impact, SAIC uses a step function (energy) for TTS and PTS, and a risk function (pressure) for behavior. These are endorsed by NMFS and were derived from our currently best available information on bioacoustic impact on marine mammals. The process implemented to accumulate energy and to maximize pressure is valid, in my opinion. SAIC produces an expected value of the number of harassments, which is also implemented correctly, given the choice of approach taken.

The SAIC model produces a spreadsheet, which allows the user to input certain operational parameters such as the hours of operation and the number of ships. The spreadsheet instantly produces the expected number of harassments. I can imagine that this is a very useful tool for the operational fleet. To reduce impact, it is probably not possible to reduce source levels, but it might be quite easy to reduce the hours of operation within a 24h period. To produce this tool, SAIC had to compute harassment rates, i.e. the number of harassments per unit of operation (per ping, per hour, or per km of track line etc.). The harassment rate has to be an average over the entire operational region. Keeping this goal in mind, I think the approaches taken (e.g. moving ships in straight lines) and the simplifications made (e.g. simulating the entire environment by a small and limited number of provinces) are justified.

Overall, SAIC takes a very general approach. A lot of the input parameters are known in more detail than the model requires. E.g. bathymetry could be extracted with much more detail, but the model only requires the depth underneath the source. Sound propagation could be modeled with much more detail, but this would make no sense for the overall approach SAIC takes. Simplifications are made at various steps in the model and averages are taken at various levels, consistently aiming to produce an expected value of the number of 'takes'. Given that the location and movement of the source(s) are unknown at the time of modeling, and given our remaining lack of data on animal distribution and movement, I believe the approach chosen by SAIC is valid.

1. Introduction

1.1. Background

Since the beginning of the industrial revolution the world's oceans have become increasingly noisy. Ship traffic, hydrocarbon and mineral exploration, offshore construction, naval activities, ocean acoustic research, all contribute to the 'noise pollution' of the marine environment. The effects of underwater noise on marine mammals in particular are of increasing interest and concern to the public, research organizations and environmental management. Many countries around the world require that environmental impact assessments be done of ongoing and future marine activities. Environmental impact assessments, in particular in the case of planned activities that have not yet commenced, are largely based on models. Models for bioacoustic impact on marine mammals typically rely on a number of sub-models and databases. There are acoustic source models, which predict the noise field around marine activities. There are sound propagation models, which predict how acoustic energy propagates from the source through the marine environment. There are bioacoustic impact models, which predict the effects of received noise on marine animals.

The Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) have developed models to estimate the bioacoustic effects of naval activities on marine mammals. The Center for Independent Experts (CIE) organized a review of these models in October/November 2008. The purpose of the review was to assess whether the models were correctly implemented, whether they adequately incorporated all relevant physical and biological variables, and whether they met the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines.

The review involved reading background material, participating in a teleconference call with other CIE reviewers and NMFS scientists on October 27, 2008, and attending two, three-day panel meetings (at NUWC in Newport, Rhode Island, from November 12-14, 2008, and at SAIC in Arlington, Virginia, from November 17-19, 2008) to discuss the models, to develop test runs, and to generate an independent review report.

The current report reviews the SAIC model. The NUWC models are reviewed in a separate report.

1.1.1. Model Description

The SAIC model can be broken down into the following steps.

1. Environmental data (bathymetry, sound speed profile, geology, wind speed) are extracted from databases for the operational region. These parameters are grouped to make up a set of environmental provinces, which span the region. Each province has a unique combination of water depth, sound speed profile and geology. Bathymetry is usually the one parameter that varies the most over the region (by 1-2 orders of magnitude). Each province will have one fixed water depth, taken from an octave-spaced subset (10, 20, 50, 100, 200, 500, 1000, 2000 and 5000m). The geographic area represented by each province will differ.

2. Sound propagation is modeled once for each province, using a Gaussian ray bundle model (CASS/GRAB). Transmission loss data are stored as parameters describing eigenrays in two dimensions: range and depth.

3. For each province, a 3d receiver grid is initiated that is wide and long enough to receive the lowest levels that can contribute to 'takes', plus a section of straight-line transect.

4. Sound exposure levels (SEL) and sound pressure levels (SPL) are computed at each receiver grid point for a single sound emission, accounting for the vertical and horizontal beam pattern of the source. The source is then moved ahead along the x-axis to the location of the next ping. SEL and SPL are computed at the receiver grid. SEL are integrated (accumulated) at each grid point; SPL are replaced if the new values exceed the old ones. After a section of transect has been modeled, the receiver grid stores the cumulative SEL and the maximum SPL.

5. Impact volumes are computed in depth bins for PTS, TTS and behavioral risk. In the case of PTS and TTS, the impact volume as a function of depth corresponds to the volume of water (in each depth bin) around a source where the sound exposure level (SEL) exceeds a certain threshold. For behavioral

risk, the maximum SPL are grouped into bins 0.5dB wide. A volume histogram is computed showing the volume around the source (in each depth bin) that falls into each SPL bin. The histogram is multiplied by a behavioral risk function that gives the percentage of animals likely to respond at the SPL in each bin. Given that animals are evenly distributed, the product can also be interpreted as the volume of animals that react at each SPL. Impact volumes for TTS and PTS are subtracted from those for behavior, in order to avoid double counting. Every animal is only reported at the highest impact received.

6. After the first few pings, the impact volume becomes a linear function of the number of pings. Each additional ping adds the same amount of volume if the source moves in a straight line. The slope is the impact volume added per ping. Given the duty cycle of the source, the hourly impact volume vector can be computed, which contains the hourly impact volumes at each depth for every province. If the sonar source moves at a constant speed, this vector also yields the impact volume per km of straight-line transect.

7. A weighted average of the impact volumes is computed over all environmental provinces, weighted according to the geographic area spanned by each province.

8. Reports on marine mammal surveys are consulted for area and depth distributions of marine mammal species likely encountered in the operational region. SAIC distributes animals evenly within their geographic region of occurrence. SAIC distributes animals with depth according to published dive profiles.

9. Animal densities are multiplied by the hourly impact volumes to give the total number of animals 'taken' per unit (hour) of operation.

10. Three post-modeling correction factors are applied to the number of behavioral 'takes', leading to a reduction in oversampling:

   a. Density dilution: The behavioral 'take' criterion implies that each animal can only be taken once every 24h. In other words, there is an underlying 24h refresh rate. This 'density dilution' is handled by repeatedly applying the per-ping harassment rate only to the remaining unharassed population. A closed-form function was derived relating the total number of harassments to the per-ping harassment rate, the local population and the duration of sonar operation.

   b. Land shadow: Given that the range over which behavioral 'takes' must be considered is very large (out to 120dB SPL corresponding to >100km range), the model also accounts for 'land shadow'. Over such long ranges, some propagation paths will be obstructed by land (islands). The model computes the range to coast for all azimuths at each grid point in the operational area. A reduction factor is applied to the number of harassments at each source location (grid point) accounting for the percentage of harassments modeled beyond coastline.

c. Multiple ships: If multiple ships operate simultaneously, only the one passing closest by the animal will yield a behavioral take, because the criterion depends on the maximum SPL received. The total number of takes is thus less than the take rate (number of takes per hour of operation) times the number of ships. Assuming a fixed number of ships moving in parallel tracks with an average distance of 20km, a reduction factor is derived that considers the percentage of harassments that were modeled to occur beyond half the inter-ship distance.

11. A spreadsheet allows the user to change the total hours of operation and the number of ships, and computes the total number of 'takes' over the duration of the operation.

1.2. Terms of Reference

The following Terms of Reference (ToR) guided the review process.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

1.3. Panel Membership

The review panel consisted of four independent reviewers:

1. an underwater acoustician (Dr. Christine Erbe) with expertise and working experience with propagation loss models,
2. a modeling expert (Dr. Wayne Getz) having expertise with individual-based exposure assessment models that integrate multiple data streams,
3. a marine mammalogist (Dr. Jeanette Thomas) having expertise with marine mammal behavior and physiology, and a
4. moderator (Dr. Douglas Wartzok) with expertise in marine mammalogy, underwater acoustics and modeling.

I took the role of the underwater acoustics reviewer. I have done research in underwater acoustics and bioacoustic impact since 1993. I regularly carry out environmental impact assessments for clients in government, academia and the marine industry. I use a variety of sound propagation models and bioacoustic impact models for my research and consulting work.

1.4. Description of Review Activities

I began the review with a search for peer-reviewed and unreviewed literature on the NUWC and SAIC models. These searches included the internet, as well as scientific abstract and citation databases. Additional documents were provided by NUWC and SAIC for the review. I made a list of comments and questions while reviewing the documents and submitted this list prior to the meetings in order not to hold up the discussions during the meetings.

A teleconference was held on October 27, 2008, to discuss the roles and responsibilities of the participants, as well as the terms of reference. NUWC and SAIC gave an overview of their models. Specifications for the trial runs were discussed. I was unfortunately unable to participate in this conference call.

On November 17 and 18, 2008, the participants met at SAIC in Arlington VA. On the first day, Ray Cavanagh discussed the general principles and underlying assumptions of the SAIC model. Bill Renner presented an overview of the model and details on environmental modeling, sound propagation modeling and the computation of energy flux densities. We then had an opportunity to discuss how SAIC resources data on animal distribution and how these data are included in the model. Mark Lockwood presented how the risk function for behavioral 'takes' is included, what correction factors are applied during post-processing, and the eventual spreadsheet analysis where the user can alter certain operational parameters (such as hours of operation and number of ships) to see how the number of 'takes' is affected.

On Day 2, SAIC walked us through one example run of their model step by step.

2. Findings

2.1. ToR1: Assess whether the SAIC Model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sound propagation).

SAIC has taken a very general approach to assessing the impact of naval acoustic sources on marine mammals. Given that the Navy does not specify in advance where the sources are being deployed, where they are moving, how often they operate etc., and given that the scientific community still has hardly any idea of where the marine mammals are, where they are going and whether or how they will react to the sound received, SAIC has chosen to model a very general scenario without attempting to include detailed specifications, which are largely unknown. In my opinion, this is a sensible approach. SAIC's model uses 'average' (mean) input data. Therefore, some of the input parameters are actually known in more detail than the model requires. It is impossible to say whether this leads to an over-estimation or under-estimation of 'takes'. On average, the SAIC model should not lead to either, because of the averaging happening at various stages in the model.

2.1.1. Physical variables

Bathymetry

SAIC uses the DBDB-V (OAML) database for bathymetry, which is one of the standard databases, and one I am very familiar with. There are other databases as well, in some geographic regions with much finer resolution. But a fine resolution is not required here at all. The SAIC model takes a very general approach to sound propagation modeling. Transmission loss is computed for a small number of 'environmental provinces', which have a flat bottom, corresponding to radially symmetrical transmission loss patterns. Bathymetry data are merely used to assemble a histogram of the total area (within the operational region) per depth bin and to split the operational region into environmental provinces.

At first glance, this horrifies the acoustic modeler. Transmission loss is computed over ranges in excess of 150km, assuming a flat bottom and radial symmetry. Bathymetry is completely ignored except for the water depth at the location of the ping. Clearly, on the continental slope, in between islands, near seamounts or coast lines, this is far from reality. But, considering that the modeler does not know where the ship is going and in which direction it is pinging, all that the model considers is the water depth underneath the ship at the location of the ping. There is much more detail on bathymetry available, but the model does not require this. All bearings within 360^{o} are equally likely. If the source is located on a slope, the chance of shooting up the slope is equal to the chance of shooting down the slope, and on average transmission loss is approximated by that over a flat bottom.

There will be environments, where this assumption does not hold, e.g. in shallow water and for low frequencies. If the source sits over a water depth that just supports the propagation of the source frequency, then there will be basically no acoustic energy travelling up the slope; but energy will happily travel along the slope and down the slope. Still, on average, over all source locations and bearings within an operational region, the assumption of locally flat bottoms is probably valid, not leading to consistent over-estimating or under-estimating of exposures.

Sound speed profiles

SAIC uses the GDEM database to extract sound speed profiles for the geographic region and time of year. Again, GDEM is a standard database. There are others, such as Levitus, the World Ocean Atlas & Database, or the Master Oceanographic Observational Data Set (MOODS). Sound speed profiles vary with time of day, day of the year, month, season, and from year to year. In some regions there are strong currents leading to sharp edges in sound speed over short distances, and these can sometimes have a multi-year cycle. As a result, the profiles found in various databases can differ. Chu *et al.* (2002) computed changes in received level of up to 30dB over 1km range when they introduced deviations in sound speed profile of the order of 1m/s using the CASS/GRAB model. It must be said, however, that they introduced tiny nicks in their sound speed profiles, which led to convergence and shadow zones at a certain depth.

SAIC extracts sound speed profiles for a number of locations within the operating area. These are then compared and grouped into provinces together with bathymetry and geology. A representative sound speed profile is assigned to each province. Given that an underwater acoustician does the comparison and grouping, any unusual sound speed profiles would be identified and could be further investigated. The process ensures that a representative ('average') profile is assigned to each province; avoiding 'accidental' ducts. In my opinion, the SAIC model treats sound speed adequately.

Seafloor geology

SAIC uses the Low-Frequency Bottom Loss (LFBL), High-Frequency Bottom Loss (HFBL) and Sediment Thickness databases, which are part of the Oceanographic and Atmospheric Master Library (OAML), and thus standard references. Again, there are others (the National Geophysical Data Center NGDC, the Integrated Ocean Drilling Program IODP), which could be used in regions not covered by LFBL/HFBL. SAIC uses CASS/GRAB for sound propagation modeling, and this model does not require geoacoustic profiles for the bottom, because it does not model sound propagation through the seafloor. It simply computes the transmission loss at the water/seafloor interface. For this, it only requires information on the type of seafloor at the surface, such as "sand", "silt", "clay" etc. In my opinion, this is a limitation in certain environments, however, given that CASS/GRAB is the accepted Navy standard, I think that the environmental parameters (including wind speed data) are properly accessed and included.

Provincing

SAIC extracts values for the environmental parameters for the geographic area of operation. Generally, these parameters will vary over the region of operation, with bathymetry varying the most (by 1-2 orders of magnitude). SAIC groups the environmental data into a set of 5-20 environmental provinces. Each province has a unique combination of water depth, sound speed profile and bottom loss. Bathymetry does not change over one province. Each province has a flat bottom with the water depth being one of the elements in the octave-spaced vector of depths (10, 20, 50, 100, 200, 500, 1000, 2000 and 5000m). PTS and TTS will happen only over very short ranges, and approximating the bathymetry by a flat bottom will be fine. However, for behavioral risk, sound levels need to be modeled to very long ranges, where changes in bathymetry can significantly alter the received levels modeled.

It is at this stage where the concern returns to the reviewing acoustician. The operating regions to be modeled can be huge, a few hundred by a few hundred km. Splitting these into less than 20 environmental provinces, in particular if the area includes islands, continental slopes and abyssal plains, seems very coarse. Given, however, that we don't know in advance where the ships will be, an average will have to be taken over the whole region, and on average the environmental modeling will probably be fine, in the sense that sub-regions that are different will hardly have any weight on the final exposure numbers.

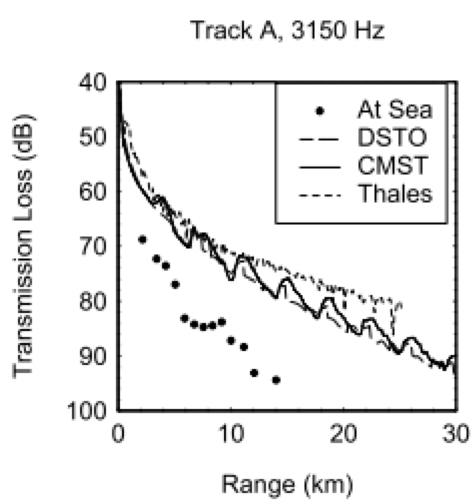
Provincing is done by hand. Given that bathymetry varies the most, at least one province is assigned to each of the octave-spaced depths. In shallow water, provinces are chosen to reflect changes in geology, because bottom interactions become more significant in shallow water than in deep water. If the sound speed profiles exhibit a surface duct, provinces are chosen to reflect the (potentially varying) depth of this duct. Provincing is subjective, but is carried out by an experienced acoustician. Provincing could be made automatic by combining all environmental data into feature vectors and by using clustering algorithms to group these, with boundary conditions or weighting factors applied to reflect the importance of shallow water geology and ducting sound speed profiles.

For year-long operations, SAIC models two cases: summer and winter. Environmental parameters are extracted for these two seasons. In terms of sound propagation, these are the 'opposing' situations yielding the lower and upper bound in harassments. For in between times or seasons, one would have to extrapolate. I think this approach is fine.

CASS/GRAB sound propagation model

As Linda Petitpas kept reminding me, the propagation model itself was not to be subjected to this CIE review, but rather its implementation within the NUWC/SAIC exposure models. CASS/GRAB is an accredited model within the Oceanographic and Atmospheric Master Library (OAML). It serves to support the operational fleet with consistent and credible standardized results. While this argument seems convincing at first glance, one has to remember that the requirements for naval operations and environmental assessments are different, if not opposing. I assume for naval operations, the further the sonar reaches, the better. For the purpose of modeling sound propagation over very long ranges, CASS/GRAB will have advantages over other sound propagation models, because ray models are very fast. Using CASS/GRAB to model target detection at very long ranges will be quick. An error in received level of several dB at very long ranges is likely not an issue for naval operations; as long as the bearing is properly resolved, one could always investigate in that direction more closely. For bioacoustic impact assessment, the farther the source reaches, the worse the impact. An error of several dB can significantly affect the number of 'takes' by NMFS definition. An error in SPL of 20dB can change the output of the behavioral risk function from 10% to 90% of a population being 'taken' (10% @ 155dB, 90% @ 175dB).

The Australian Defense did some field verifications of three different ray models, two of them Gaussian ray bundle models (Jones *et al.* 2007). They found reasonable agreement between the models and the field data at 400Hz. At 1kHz, all models over-predicted the received levels by up to 10dB for ranges greater than 4km. At 3kHz, the models all over-predicted the received level by up to 20dB for ranges greater than 12km.



Phase-incoherent *TL* versus range for Track A, 3.15 kHz

The environment was shallow and downward refracting.

Ray models are fast. They work well in water that is deeper than one wavelength, i.e. they have limitations for low frequencies or shallow water. They work well when bottom interactions are insignificant, such as when the source operates in an acoustic duct or over very deep water. It might be better to switch to a different sound propagation model in shallow provinces, certainly for low-frequency sonar; also in environments with rocky bottoms and much bottom interaction, a model that propagates sound through the seafloor might be advantageous. SAIC will have access to other models, and these should be used if the acoustic modeler identifies ray-problematic provinces.

There is no need to improve any one sound propagation model. Some scientists have spent their entire career developing these models. Also, there is no need for any fine structure in sound propagation modeling here. Received levels get averaged into range and depth bins (and dB bins for modeling behavioral impact). Fine structure in actual acoustic propagation is often temporary. Fine structure will differ with the type of model used and is generally not very convincing. Given that the SAIC model aims to simulate a very general case, there is no need for fine structure or improvement to the underlying sound propagation model here.

Frequency

For sonar sources, SAIC models only one frequency, which is perfectly fine. Given that the sound propagation model was not part of this review, we were not shown in detail how frequency is accounted for, including frequency-dependent absorption and scattering. I trust that CASS/GRAB and SAIC handle frequency correctly.

All impact thresholds for PTS, TTS and behavior, as they are applied by SAIC, are frequency independent; all frequencies affect all species equally. The hearing sensitivity of marine mammals is a function of frequency and differs with species. In other EIAs that I have reviewed an attempt was made to relate the probability of a behavioral reaction, TTS and PTS to a species' audiogram (detection threshold as a function of frequency). This is not the approach NUWC and SAIC have taken, and is not the approach NMFS takes. Southall *et al.* (2007) reviewed the scientific literature to-date on marine mammal bioacoustic impact, and suggest M-weighting SEL. M-weighting reduces the contribution of energy at frequencies outside of the hearing bandwidth of marine mammal species groups. It does not weight SEL with regards to a species' absolute sensitivity. For the narrow-band mid-frequency sources considered under the current CIE review, M-weighting has no effect.

Maximum range

My understanding is that SAIC lets CASS/GRAB model the acoustic footprint in 3d far enough that SPL drops below 120dB. This is perfectly fine, because 120dB SPL is the lowest level that can cause Level B harassment. The criterion for behavioral 'take' is not cumulative. If it were, then the acoustic footprint of each source would have to be modeled over longer ranges, because sub-threshold levels would add up over multiple pings. The criterion used, however, is the maximum SPL over all received pings, and therefore not cumulative.

Beam pattern

SAIC models cumulative energy and maximum pressure on an evenly spaced receiver grid around straight-line tracks in environmental provinces with flat bottoms. After the first few pings, the impact volumes increase linearly with each additional ping. The goal is to compute a per-ping or per-hour 'take' rate. In this computation, SAIC does account for both the vertical and the horizontal beam pattern. Transmission loss is modeled in each province in two dimensions: range and depth. Transmission loss information is saved as parameters characterizing significant eigenrays. This way the correct beam pattern can be applied at any subsequent stage in the modeling process.

Source level

I have no doubt that the source level is accounted for correctly. Mid-frequency sonars are directional sources, not omni-directional. The source level is a function of the angle of departure in the horizontal and the vertical plane. The beam pattern includes the equivalent source level in any direction.

Source movement

The future movement of the source is generally not defined at the time of impact modeling. SAIC therefore models a very general scenario in which the sources move in straight lines. Animals are stationary. Multiple sources are accounted for in post-processing, and these move in parallel lines 20km (an average ship distance) apart. In the case of a stationary source, SAIC moves the animals (the receiver grid) in a constant direction and at a constant speed equal to an average animal swim speed. We were informed that the case where the source and the receivers move at similar speeds does not normally happen in the field, as all sources that move are ships or submarines, and they move at much faster speeds than most animals.

The straight-line approach allows the computation of harassment rates (number of 'takes' per unit of operation, where the unit can be pings, hours or km of track line) and ultimately provides the operational fleet with a useful tool that allows certain operational parameters to be changed (hours of operation, number of ships) and to instantly investigate the effect on marine mammal 'takes'.

Ambient noise

Ambient noise is not accounted for in the SAIC model. Ambient noise would affect the model at various stages. Animals living in areas of high ambient noise might be somewhat accustomed to noise. TTS in this case would be masked and masked TTS threshold levels could be used instead of the unmasked TTS here. Behavioral reactions might be reduced in areas of high ambient noise. Or, regions of high ambient noise might have fewer marine mammals. Ambient noise will not add to the impact of naval sources, because it is generally much lower in level, usually contained at lower frequencies, transient, and random in phase.

2.1.1. Biological variables

TTS/PTS Thresholds

In my opinion, the derivation of the SEL thresholds used for TTS and PTS are reasonable given our current scientific understanding of acoustically induced hearing loss. Southall *et al*. (2007) summarize the best available information on this topic to-date, and threshold levels were taken from this publication. Southall *et al*. (2007) use M-weighted SEL as a means of including some frequency selectivity of the species. Over the frequency range of mid-frequency sonars (1-10kHz), the weighting functions are flat (with the exception of low-frequency cetaceans for whom the M-weighting function starts to drop off at about 3kHz). SEL thresholds are thus largely unaffected by M-weighting. PTS is considered Level A harassment, TTS falls into Level B harassment, which agrees with the definitions.

Does the SAIC model consider the appropriate acoustic exposure metrics? Yes. The model produces an average number of takes, where 'average' refers to various types of averaging that happen at various stages in the model. Mathematically speaking, the result can also be considered the 'expected' number of takes. The model does not compute a range (or standard deviation) of the number of takes, which is sensible, in my opinion. To compute a standard deviation and confidence interval, the error of each input parameter and modeling parameter would have to be assessed and propagated through the model. It is impossible to attach an error to some of the input parameters (E.g. for animal location and movement there is so little information that one is lucky to find even one data source in many cases, and it is impossible to say how representative the data are.) Great uncertainty further stems from the fact that the Navy does not disclose the source location and movement prior to operations. With no such specifications for the source, it makes little sense to compute variances and confidence intervals for the number of takes. SAIC aims to model a general case, an 'average' case leading to an 'expected' number of harassments, which is fine in my opinion.

Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice? Yes.

Behavioral Thresholds

SAIC uses a risk function to estimate the probability of inducing a behavioral change from exposures between 120dB SPL and 195dB SPL. Exposures to levels above 195 dB SEL are counted in the TTS category. Both behavioral response and TTS are considered Level B harassment, which corresponds to the MMPA definitions.

The risk function is defined as the percentage of a population that might react to a sound at a given level. In the SAIC model, the impact volume per ping is computed in a series of SPL bins. The resulting histogram is multiplied by the risk function, yielding the percentage of a population that is likely to react in this volume or at each received level. Multiplying by the animal density and summing up over all levels gives the total number of 'takes'. In my opinion, the model implements the risk function correctly.

Whether this NMFS endorsed risk function and the accompanying 24h refresh rate make much sense biologically, is a different question, which is unfortunately outside of the framework of this review.

Multiple exposures

SAIC treats multiple exposures in post-processing. The approach is clever yet mathematically straight-forward. Given that the operational fleet does not communicate where the ships are going beforehand and given that marine mammalogists have very limited understanding of where the animals are and what they are doing, SAIC accounts for multiple exposures in a very general way. An upper bound on the total number of animals that could possibly be 'taken' over any 24h period is computed by multiplying the total operational area (plus the area added by animals moving into the operational area at an average swim speed over the duration of operation within 24h, plus the expected range affected outside the area) with the animal density. Applying the per ping harassment rate only to the unharassed population from ping to ping, led to the derivation of a closed form function relating the remaining unharassed population to the per-ping harassment rate, the total number of pings and the upper bound number of animals.

Marine mammal density distribution

Data on marine mammal distribution in the world's oceans as a function of latitude, longitude, depth and time (time of day, month, season) are scarce. SAIC accesses databases and reports from marine mammal surveys, reflecting the currently best available information on marine mammal distribution.

Animals (by species) are distributed evenly over the operational area or sub-regions. If animals are known to occur only in a particular region, a province can be defined for that region. SAIC does not group animals into pods. In my opinion this is valid for two reasons: 1. Our biological understanding of animal grouping, the driving factors, and pod cohesion is very limited. 2. On average over time, it makes no difference to the number of takes whether animals move over an entire province individually or in pods. On average over time, the number of animals per unit area will be the same.

Animals are distributed with depth according to published dive profiles. In the absence of dive profiles, SAIC researches publications on stomach samples to determine what the animals feed on, which in turn points to the general depth the animal will dive to. In my opinion, animal distribution is handled as well as possible.

The SAIC model does not move animals in 3d over time and does not model animal behavior in response to sound. The model is set up to compute the average number of 'takes' per ping or unit of operation. The end user can input certain operational parameters and instantly determine the total number of 'takes'. SAIC does not attempt to model a specific operation in detail, as detailed information is mostly not known a priori.

2.2. ToR2: Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the SAIC model.

Both NUWC and SAIC models rely on sub-models and databases. Models and databases are always a representation of the true environment under certain conditions and at some point in time. They therefore carry an inherent error or scientific uncertainty when they are used to model a specific environment. Most of these errors and their effects on the resulting acoustic exposures are difficult to assess. SAIC does not attempt to model a specific scenario of ship tracks and animal movement. SAIC takes a very general approach producing average harassment numbers per unit of operation. The model does not require exact knowledge of the physical and biological parameters at the time of operation. Rather, mean profiles are extracted from databases to produce expected numbers of 'take'. There is a lot of averaging happening at any stage and level in the model. Therefore, even though some parameters could be extracted with more accuracy, this is not useful for the approach taken. There is a difference between accuracy and scientific certainty. I will discuss the underlying assumptions relating to both in this section.

SAIC uses standard databases for sound propagation modeling, and I would say the usage of environmental parameters is as good as it gets. Of course, the physical environment is not stationary but changes with time. It is impossible to say whether the scientific uncertainty associated with environmental parameters will lead to an under-estimation or an over-estimation of exposures. There is no reason to expect a consistent error in either direction. While environmental parameters (in particular bathymetry) could be extracted with much more detail and accuracy, the model does not require this. The model uses mean profiles and aims at producing average harassment rates.

The effect of not modeling the true bathymetry between source and receiver will sometimes lead to over-predicting, sometimes to under-predicting. Again, there is no reason to expect a consistent error in either direction.

The potential error introduced by exclusively using CASS/GRAB can only be assessed by comparison to other sound propagation models or to acoustic field measurements around naval sources. If CASS/GRAB is out by 20dB over intermediate ranges (as were the three ray models tested in shallow water by the Australian Defense), e.g. if an SPL of 175 dB was modeled at a true SPL of 155dB, then the true probability of behavioral 'take' could be as much as 80% less (from 90% at 175 dB down to 10% at 155 dB, see picture below from a Navy EIS). There are other models that are known to excel in certain environments and I would recommend matching the model to the environment to reduce any potential error. Having said that, my own experience with validating models in the field is that in most cases the acoustic propagation model over-predicts the received level at long ranges, but of course that depends on the environment and the model.

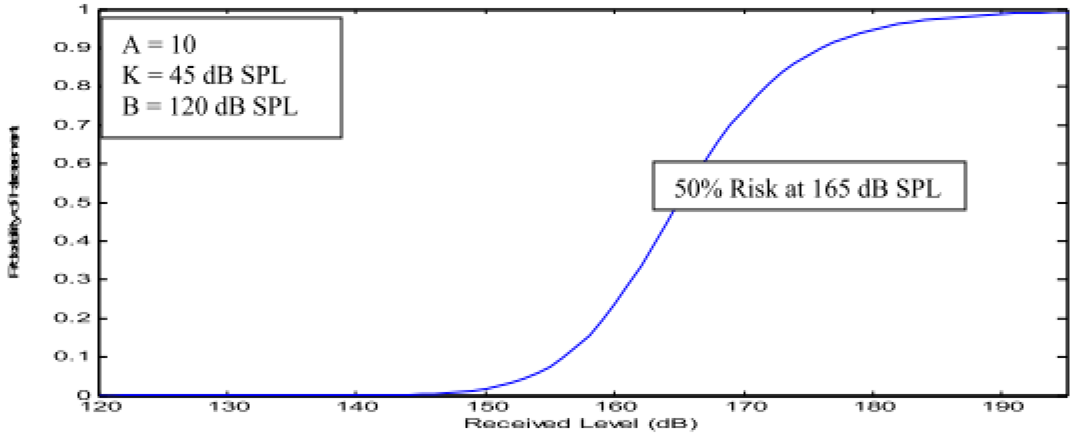


Figure 4-8. Risk Function Curve for Odontocetes (toothed whales except harbor porpoises) and Pinnipeds

By not including ambient noise, the SAIC model can be considered conservative.

The largest ‘error’ (in the sense of a deviation from the true number of ‘takes’ happening during the actual operation) stems from the uncertainty in source location and movement and the uncertainty in animal location and movement.

Given this uncertainty, SAIC models sources moving in straight lines through a grid of stationary animals. Exposure metrics such as cumulative energy and maximum pressure are computed over short straight-line tracks until the increase in impact volume becomes a linear function of the number of pings, which allows the computation of harassment rates (number of harassments per unit of operation). Multiple exposures for the behavioral ‘take’ criterion are dealt with in post-processing, accounting for the fact that each animal can only be taken once within a 24h period. The TTS and PTS criteria state that energy be accumulated over 24h. In the SAIC model, no animal will remain within the range of TTS or PTS for anywhere near 24h, because the ships move in straight lines through stationary and evenly distributed animals. SEL for TTS and PTS will only accumulate over neighboring pings. The total number of Level A harassments is given for any 24h period by multiplying the harassment rates by the total hours of operation within a 24h period.

Of course one can think of a number of scenarios, which the SAIC approach does not model, e.g. the case of a ship circling a group of animals repeatedly pinging at the same individuals, or a population following the ship. The SAIC model would under-estimate exposures in these cases. Catastrophic events are not modeled, but how likely are these? And can one model these given our lack of data on animal distribution and behavior? My opinion is that we lack in data quantity and quality and cannot predict catastrophic events with any confidence and accuracy.

The SAIC model will over-estimate exposures in cases where animals actively avoid naval sources. Again, I think we lack in data quantity and quality to accurately model this behavior. At this stage, I believe the ‘average’ approach taken by SAIC is scientifically sound.

2.3. ToR3: 3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.

The SAIC model applies three correction factors during post-processing. These factors relate to density dilution (multiple exposures), land shadow and multiple ships. All three factors reduce the number of 'takes'.

Density dilution: The model first computes the upper bound of animals that can possibly be taken by assuming a sonar operates from every point within the operating area. This area is expanded by a region from which animals can swim into the operating area during the hours of operation, and by the expected range affected outside of the operational area. The model then basically applies the harassment rate successively from ping to ping only to the remaining unharassed population. The reduction factor increases with hours of operation. In my opinion, this is a clever and sound approach to treating multiple exposures in the absence of information on where the ships are going and where the animals are going.

Land shadow: This correction factor accounts for the fact that land present within the operational region will reduce the range over which sonar can harass animals at certain points and for certain bearings. This is not 'automatically' included in the model, because SAIC does not use the true bathymetry between all source and receiver points. A harassment rate is computed within provinces with flat bottoms and no land. In post-processing land has to be accounted for. The method for land shadow is straight-forward. At each point within the operating area, the distance and angle towards coastline is computed and the number of harassments is reduced by those modeled beyond land. This approach is valid. Given that most harassments happen over the first 10km, the land shadow effect for the total operational region was very small in the HRC.

Multiple ships: Given the lack of information on where the ships go, SAIC assumes the ships move in parallel lines at an 'average' separation (20km in the HRC). The total number of harassments (which had been computed for single ships) is reduced by the harassments modeled beyond half the inter-ship distance. With most of the 'takes' happening over the first 10km, two ships 20km apart won't have much of an effect on the correction factor. Ships that are more than 20km apart can basically be considered as separate sources. Whether this approach models an 'average' scenario, whether it over- or underestimates exposures is impossible to say without more information on the particular operation. I would have expected ships to travel at greater separation, given that each sonar reaches over longer ranges than 10km. One can also quite easily imagine scenarios where the sources won't move in parallel lines, e.g. when one source is launched from another. In this case, the two sources might be so close for a very short period of time, that SEL from both add up. Given that the criteria for TTS and PTS are step functions, a slight increase in SEL won't matter as long as it stays below the TTS or PTS threshold. The summation of SEL from more than one source would only change the number of 'takes' if levels were just-below TTS or PTS separately and summed to just-above TTS or PTS levels. This would, however, only affect a very small impact volume and most likely have a negligible effect on total harassment numbers in the end. Still, without knowledge of the operational specifications, it is impossible to assess the accuracy of this approach.

2.4. ToR4: Assess whether the SAIC Model meets the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

2.4.1. Have the principles of credible science been addressed during model development?

Yes. Altogether I would say that the model and its sub-models take a scientifically sound approach given the lack of information on source location and movement and animal location and behavior. The model is based on our currently best available data and up-to-date scientific understanding of noise effects on marine mammals.

2.4.2. Is the choice of model supported given the quantity and quality of available data?

Yes. The operational fleet does not disclose any a priori information on where the sources will be located and how and where they move. Therefore, it makes no sense to model any detailed source movement. SAIC takes a very general approach, which I believe is appropriate. SAIC utilizes published sighting data (surface densities) to distribute animals over the geographic region of operation. SAIC uses depth profiles to distribute animals with depth. Again, I think this is appropriate. I don't believe we have the required quantity and quality of data to model marine mammal behavior in any detail.

2.4.3. How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?

This question would be easy to answer if one could simply verify the model in the field. A field validation would be largely impractical and partly impossible as it would require, amongst other difficulties, that individual animals be detected and tracked over large operational areas, and be collected for TTS and PTS assessment after the operation. The sub-models, however, can be assessed separately to some degree.

The source model: SAIC uses the frequency, source level, beam pattern and duty cycle information provided by the Navy. In the absence of information on source movement, the source model moves ships in straight lines and multiple ships in parallel lines. The model ultimately produces a harassment rate, i.e. the number of harassments per ping or per hour of operation or per km travelled. With this goal in mind, the source model is sensible and properly implemented in my opinion.

The sound propagation model: The only suggestion I have is that CASS/GRAB be replaced by a different model in environments where the applicability of ray models is limited and where other models are better, e.g. shallow water. For the majority of provinces, certainly in the HRC case, CASS/GRAB should be fine and model propagation as good as it gets.

At any one shot, the acoustic field around the source depends on the bathymetry in all directions, the sound speed profile (which might change after some range in some direction), the bottom geology and wind conditions. The SAIC model does not attempt to predict the environmental conditions at every shot point. Rather, it aims to model a very general case. Therefore, the environmental parameters are grouped into 5-20 provinces over the entire region of operation. Bathymetry is ignored except for the water depth underneath the source. While this is a serious simplification at any one instant in the operation, on average, over the entire operation, this approach is probably good enough. There is no reason to believe that this approach will either consistently under-estimate or overestimate exposures. The model will approximate some 'average' propagation. Again, keeping in mind, that the goal was to produce a harassment rate, from which the operator could instantly determine the total number of 'takes' by simply multiplying with the hours of operation or the number of ships (and I think this is a useful tool for the operator), there is no reason to model sound propagation as accurately as possible at any one shot. It could be done, but it is not necessary for the intended goal.

The animal distribution model: SAIC distributes animals by species evenly over the operation region or subregions based on published sightings. SAIC distributes animals with depth based on published dive profiles. For example, if a dive profile shows that an animal spends 50% of its time at a certain depth, then the SAIC model will place 50% of the animals at that depth and keep them there. In my opinion this is a valid approach and quite reasonable given the lack of quantity and quality of data on animal distribution and behavior. SAIC does not model individual behavior, but keeps animals stationary.

The bioacoustic impact model: SAIC uses thresholds for TTS and PTS, and a risk function for behavior, all three of which are based on up-to-date scientific knowledge. The impact model is therefore as accurate as currently possible.

SAIC has undertaken a number of sensitivity analyses. Given that the behavioral risk criterion requires modeling over very long ranges, SAIC has tested the sensitivity of the impact volume on some of the modeling parameters. The parameters tested were the grid size in both the x and y directions, the y-growth factor and the SPL (dB) bin size. Changing the x and y resolution by a factor 3 resulted in less than 0.1% of a change in impact volume. The same small change was found if the y-growth factor varied between 0 and 0.01 (with 0.005 used as the default in the model). The impact volume increases if SPL are grouped into wider dB bins (as one might expect). A bin width of 0.5dB is the default. A variation from 0.25 to 1 dB resulted in less than 0.1% of a change in impact volume.

How closely does the model simulate the 'ecosystem'? The ecosystem includes all physical and biological parameters and entities, and their interactions. An ecosystem model would have to include relationships such as temperature, salinity, light determining the prey distribution, prey distribution relating to the predator distribution, naval activities affecting the physical environment as well as the prey and predator distribution indirectly and directly. If any one entity in an ecosystem changes, the model would have to compute how all other entities in the ecosystem change as a result. We are far from an ecosystem model here, but for acoustic EIAs this is not really necessary. SAIC tries to model an 'average' scenario, and given the lack of data on ecosystem relationships, causes and effects, in particular as they relate to animal behavior, I believe the approach taken is currently sensible.

2.4.4. How well does the model perform?

The model reads in mean environmental data and animal distribution data. The model averages these into a small number of provinces. The model simulates a mean operational scenario (ships moving in straight lines). There is a lot of averaging happening in the model. Given that the outcome of the model is an average harassment rate, i.e. an average number of harassments per unit of operation, the approach taken and the simplifications made and the averaging performed are reasonable in my opinion. The model does not aim to simulate a very specific scenario (such as a specific source movement, or a specific case where animals are attracted to and following a source, or a catastrophic event). Instead, the model simulates a general scenario and produces a tool (spreadsheet) in which the operator can manipulate the hours of operation and the number of sources, and the spreadsheet instantly updates the expected (in the sense of mean) number of 'takes'. I assume such a tool must be very useful to the operational fleet. Given this goal, I think the model takes the appropriate steps and performs well.

2.4.5. Is the model capable of being updated with new data as it becomes available?

With regard to physical environmental parameters, SAIC accesses standard databases, which give a very reasonable characterization of the environment already. There won't be any new data coming in that would require a radical rethinking.

With regards to source parameters, the data to model source movement and operation more accurately do exist, but the Navy is unable to disclose that information. Therefore, with this lack of data remaining, the model already takes a sensible approach and won't need to be updated.

The new data that will become available will relate to animal distribution, movement and behavior. It is straight-forward to include better data on animal density distribution in this model. One could easily define an extra province if a particular habitat got identified. With regards to animal behavior, if better data on animal reactions to sound become available, then these will likely be in the form of another risk function. E.g. a function giving the percentage of animals that are likely to avoid sound at certain levels. In this case, one could multiply the TTS and PTS volumes (in SEL bins) by a risk function before adding up takes.

My feeling is that whatever data become available, we won't all of a sudden know everything about an animal that would justify the dramatic step to throw the current model overboard and to start again with an individual behavior model (in particular as the uncertainty about source movement will remain). New data will come bit by bit, and they will be synthesized into general relationships and dependencies (functions) that could be simulated by additional routines or sub-models if they can't fit into the existing routines. In my opinion it is reasonable to take the path of modeling an average scenario, aiming to predict a mean outcome, rather than to be too specific and prescriptive in the model, in which case it becomes impossible to say whether one models a mean scenario or whether one models right out at the tails of the probability distribution.

3. Conclusions and Recommendations

Given the fact that the Navy will be unable to disclose specifications of its intended operations beyond the source type, level, frequency and beam pattern, SAIC took a very general approach. No specific ship movement is modeled. Ships move in straight lines. No detailed sound propagation is modeled. Instead, the environment is simplified into a representative set of provinces, each with a constant sound speed profile, seafloor type and seafloor depth (bathymetry is ignored other than for the depth underneath a source). Animals are distributed evenly in subregions (habitats) according to published sightings. They are distributed in depth according to published data on time spent at certain depths (from dive profiles). Animals remain stationary. Given our lack of understanding of individual animal behavior, in particular as it relates to reactions to sound, I believe this approach is reasonable.

The SAIC model produces a spreadsheet tool that allows the operator to instantly assess the number of 'takes' as a function of hours of operation and number of ships; a tool which I can imagine is quite useful. Given this goal, I believe the SAIC model has taken the appropriate approach, and I do not see how the model could be significantly improved.

There are obviously a variety of approaches one could take to model bioacoustic impact. NUWC developed two very different models. During the review meetings, the panel compared NUWC's Area Density Model to the SAIC model for the case of a single sonar operating for 4h. The total number of harassments was nearly twice as large in the Area Density Model. This was expected, as the Area Density Model places animals at the depth of maximum SEL and SPL. We were unfortunately unable to compare the results of NUWC's Exposure Model (including the 3MB behavioral module) to those of the SAIC model for three simultaneous sources. However, even if both models had been run for the same case study, it would have been fairly difficult to judge which model gave the better results.

It is my opinion, that we lack in data quantity and quality of marine mammal behavior and reactions to noise to justify a detailed simulator. The unknowns about source location and movement will remain, as the Navy won't be able to disclose this information prior to operations. I think the general approach taken by SAIC is justified and produces valid expected numbers.

Acknowledgment

It was a great pleasure to participate in this CIE review. Thanks to CIE for selecting me. Thanks to Manoj Shivlani for organizing my participation. Thank you to SAIC, NMFS and NUWC, who were most helpful and welcoming.

Appendix 1: Bibliography

A number of documents were provided to the review panel prior to the meetings. These included excerpts of reports, for which the proper citation including authors and title were sometimes not passed on. The following list is therefore in no proper citation format.

- SOCAL Range Complex EIS/OEIS, Preliminary final version 2 (September 2008), Section 3.9, pages 1 – 132
- SOCAL EIS, Appendix F, Overview and Technical Approach, pages F.1 – F.392
- Marine Resources Assessment for the Southern California Operating Area, Final Report, September 2005, pages 1 - 574
- AFAST DEIS, excerpts from Chapter 3, Marine Mammal Densities, pages 3.2 – 3.6
- AFAST DEIS Chapter 4.4 Marine Mammals, pages 4.16-4.129
- AFAST DEIS Appendix H – Summary of Acoustic Modeling Results, pages H.1 – H.66
- Houser, D.S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. IEEE Journal of Oceanic Engineering 31(1) 76 – 81
- HRC FEIS-OEIS, Appendix J, Acoustic Impact Modeling, pages J.1 – J.104

In addition to the above documents provided, I also reviewed the following documents:

- Weinberg, H., and R.E. Keenan. 1996. Gaussian ray bundles for modeling high-frequency propagation loss under shallow-water conditions. *Journal of the Acoustical Society of America* 100(3), 1421 – 1431.
- Keenan, R.E. 2000. An introduction to GRAB eigenrays and CASS reverberation and signal excess. Oceans 2000 MTS/IEEE Conference and Exhibition, Vol. 2, 1065 – 1070.
- Calnan, C. 2006. BASE 04 Transmission Loss Measurement and Modelling. Report by xwave for Defence R&D Canada – Atlantic.
- Chu, P.E., C.J. Cintron, S.D. Haeger, D. Schneider, R.E. Keenan and D.N. Fox. 2002. Yellow Sea Acousic Uncertainty cause by Hydrographic Data Error. Powerpoint Presentation. www.oc.nps.edu/~chu/web_paper/conference/02/av2002_chu.pdf . Full paper available from http://www.stormingmedia.us/89/8949/A894974.html .
- Vares, N.A. 2002. Environmental variability on acoustic prediction using CASS/GRAB. www.oc.nps.edu/~chu/thesis_dir/vares_presentation.ppt
-

This report further cites the following literature:

- Jones, A.D., J. Sendth, A.J. Duncan, P.A. Clarke, Z.Y. Zhang and A.L. Maggi. 2007. Comparison of transmission loss models at mid-frequency against shallow water data. Proceedings 14th International Congress on Sound & Vibration, Cairns, Australia, 9-12 July 2007, 8p.

- Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4), 412 - 522.

Appendix 2: Statement of Work

Below is the original statement of work, I received. The review of the modeling of explosives was later taken out of the statement of work.

Statement of Work for Dr. Christine Erbe

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
and
Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model

Background and Scope of Work

The National Marine Fisheries Service (NMFS) requires an independent peer review of the Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) marine mammal acoustics exposure effects analysis models (the processes these two groups use to perform the analyses described herein involve more than the use of single models, but will be broadly referred to as "models" for simplicity in this document) which shall assess whether they correctly implement the sub-models and data upon which it is based, whether they adequately assess all relevant physical and biological variables in assessing effects on local marine mammal populations, and whether they meet the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines for models, which primarily involve scientific credibility. The review of the NUWC model will include an assessment of the current model (used for the Atlantic Fleet Active Sonar Training (AFAST) with additional analysis of the Effects of Sound on the Marine Environment (ESME) behavioral module, which the Navy intends to incorporate into the current model moving forward.

Minimizing and mitigating the potential effect of sound upon the environment is an increasing concern for many activities. Naval operations, seismic exploration, vessel and aircraft operations, certain construction activities, and scientific investigations now need to consider the potential effects underwater acoustic sources have on marine life. Marine mammals are usually the primary concern, due to their widespread distribution and excellent hearing ability, although impacts on fish are increasingly being considered as well. Predicting the exposure of marine mammals is complicated by several factors: a general lack of data to support a comprehensive understanding of density and distribution; horizontal and vertical movement patterns; any long-range migratory behavior; and a lack of understanding of exactly how potential sound avoidance behaviors may impact the levels of sound to which marine mammals are exposed.

Acoustic propagation and received sound levels are a function of water depth, range from the source, sound source characteristics, and a number of environmental variables. These issues, combined with the variable spatiotemporal distribution and movement of different species, contribute to a very complex problem. The NUWC and SAIC models address these specific complications in similar ways. The models predict a received level at range and depth in a 3-dimensional grid (x,y,z), then overlay the marine mammal density (animals/km^2) for each species on the 2-dimensional (x,y) grid. The third dimension (z) can be applied through the use of animal distribution in depth for a percentage of time if that data are available. Biological distribution and movement can be based on regional and seasonal behavioral data for each species evaluated. Acoustic sources are programmed to move through a virtual acoustic environment based on external environmental databases and radiated sound fields created from a selected propagation model (e.g., Comprehensive Acoustic Simulation System/Gaussian RAy Bundle (CASS/GRAB), or Range-dependent Acoustic Model (RAM)) The integration components of the NUWC and SAIC models make use of the high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation in MATLAB®. The end results of modeling represent estimated accumulated exposures above a specified criteria threshold (permanent threshold shift – PTS or temporary threshold shift – TTS) of animals for each source, scenario and marine mammal combination presented in a spreadsheet. The model also predicts received sound pressure levels that are then applied to a risk function curve to predict the probability of behavioral harassment.

For the SAIC model, the Navy developed several post-modeling corrections that *can* be applied to the output of the model to make it more realistic. These post-modeling applications quantitatively address the following factors, which are not accounted for in the models described above:

- Acoustic footprints for sonar sources do not account for land masses.
- Acoustic footprints for sonar sources are calculated independently, when the degree to which the footprints from multiple ships participating in the same exercise would typically overlap may be taken into consideration.
- Acoustic modeling does not account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

For the NUWC model, the Navy has developed the Effects of Sound on the Marine Environment (ESME) behavioral module that can be incorporated into the NUWC model to more accurately represent some of the biological variables of concern, such as animal movement and behavior. Reviewers will be asked to assess the NUWC model both with and without the inclusion of this module.

NUWC and SAIC both make use of Navy standard sub-models and databases that are housed at the Oceanographic and Atmospheric Master Library (OAML). The Chief of Naval Operations (CNO) established OAML in 1984. The OAML suite consists of Navy-standard core-models, algorithms and databases that support the Department of the Navy (DoN), Department of Defense (DoD), and research and development laboratories that support DoD and DoN and Joint and NATO activities. OAML also supports Task Force Web and Navy Enterprise Portal initiatives with state-of-the-art Navy-standard products. Some OAML databases, included sound speed profiles and the unclassified bathymetry database are available to the public.

The NUWC and SAIC models are not proprietary; however, several input data sources are either classified or restricted to the above-listed agencies and organizations. Nevertheless, the continued use of the models to provide acoustic exposure and impact predictions for regulatory assessment purposes requires that the models be reviewed independently, so that NOAA and other federal agencies can comply with the Data Quality Act.

Overview of CIE Peer Review Process:

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract for obtaining external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of stock assessments and various scientific research projects. The primary objective of the CIE peer review is to provide an impartial review, evaluation, and recommendations in accordance to the Statement of Work (SoW), including the Terms of Reference (ToR) herein, to ensure the best available science is utilized for the National Marine Fisheries Service management decisions.

The NMFS Office of Science and Technology serves as the liaison with the NMFS Project Contact to establish the SoW which includes the expertise requirements, ToR, statement of tasks for the CIE reviewers, and description of deliverable milestones with dates. The CIE, comprised of a Coordination Team and Steering Committee, reviews the SoW to ensure it meets the CIE standards and selects the most qualified CIE reviewers according to the expertise requirements in the SoW. The CIE selection process also requires that CIE reviewers can conduct an impartial and unbiased peer review without the influence from government managers, the fishing industry, or any other interest group resulting in conflict of interest concerns. Each CIE reviewer is required by the CIE selection process to complete a Lack of Conflict of Interest Statement ensuring no advocacy or funding concerns exist that may adversely affect the perception of impartiality of the CIE peer review. The CIE reviewers conduct the peer review, often participating as a member in a panel review or as a desk review, in accordance with the ToR producing a CIE independent peer review report as a deliverable. At times, the ToR may require a CIE reviewer to produce a CIE summary report. The Office of Science and Technology serves as the COTR for the CIE contract with the responsibilities to review and approve the deliverables for compliance with the SoW and ToR. When the deliverables are approved by the COTR, the Office of Science and Technology has the responsibility for the distribution of the CIE reports to the Project Contact.

Reviewer Requirements

The Center for Independent Experts (CIE) shall provide three panelists and a moderator for the review of each of the two models. The same individual will function as moderator for the review of both models. Preferably, the same three individuals would function as reviewers for both models, however, this may not be possible due to the required expertise and scheduling constraints.

CIE shall provide expertise in the scientific discipline of underwater acoustics, modeling, and marine mammalogy.

The underwater acoustician reviewer(s):

- shall have expertise and working experience with propagation loss models
- will preferably have working knowledge of the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB, which is the main propagation model incorporated in both the NUWC and SAIC models) and/or similar propagation models.

The modeling reviewer(s):

- shall have expertise with individual-based exposure assessment models
- will preferably have experience with the above type models dealing with the integration of multiple data streams (*e.g.*, multiple databases).
- shall be able to understand the dynamic interaction of databases.

The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

The moderator:

- shall have expertise in marine mammalogy
- shall have expertise in either underwater acoustics or modeling

The CIE review shall be conducted during two panel review meetings organized around a three-day meeting at NUWC, Newport, RI and a three-day meeting at SAIC, McLean, VA according to the schedule stated herein. For each of the two reviews, each reviewer shall be required for a maximum of 15 days for reviewing pre-review documents, conducting the peer review during the NUWC/SAIC meeting, traveling, and completing the CIE reports. The moderator will need 17 days for each review.

Statement of Tasks for CIE Reviewers

Note: There are two sets of meetings (including teleconference, three days of on-site meeting, etc.), one set for review of the NUWC model and one set for review of the SAIC model. The organization of the two sets of meetings is identical, but on different dates.

For each set of meetings, the CIE reviewers and moderator shall review the pre-meeting documents in preparation for the peer review meetings, to be provided by the Project Contact in accordance with the schedule of milestones and deliverables herein (refer to listed in Annex I for preliminary list of documents). The CIE reviewers and moderator will participate during each three-day panel review meeting at (1) NUWC, 1176 Howell Street, Bldg 1346, Rm 407U, Newport, RI 02841, and (2) SAIC, 1710 SAIC Dr, McLean, VA 22102. After each meeting, the three CIE reviewers (of each model) shall complete independent peer review reports addressing all the Terms of Reference given below. The moderator(s) shall consolidate the individual reports into a summary report for each meeting. Details on the formats of the panelists' and moderator's reports are given in Annex II and III, respectively.

<u>Teleconference Calls with CIE for NUWC and SAIC</u>: The CIE panel and NUWC/SAIC teams will discuss via conference calls the details of the upcoming panel review meetings, providing an opportunity for the CIE reviewers to raise questions concerning background documents, specifications for trial runs, and other review-related material, including logistics. In preparation for these teleconference calls, the CIE reviewers shall review pre-meeting documents provided by the Project Contact in accordance with the scheduled milestones and deliverables herein.

<u>Day 1 of panel review meetings for NUWC and SAIC Meetings</u>: CIE reviewers shall participate during the NUWC and SAIC panel review meetings during the dates specified in the schedule of milestones and deliverables herein. During the meetings, the Term of References (ToR) will be reviewed and the NUWC/SAIC model presentations will be made by scientists from NUWC/SAIC, with questions and answer sessions as needed. Presentations shall include:

8) Introduction to the current NUWC/SAIC approaches (i.e., the ones used in the AFAST and HRC EISs) and the software, including data input requirements;
9) Explain incorporation of the ESME behavioral module into the NUWC model;
10) Review of results of internal testing of the software;

11) Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
12) How these exposure estimates are interpreted relative to noise exposure thresholds and/or guidelines?
13) Review all relevant post-modeling correction factors for the SAIC model
14) Review all inherent, underlying assumptions in each model

The CIE reviewers and moderator shall meet to develop a set of test runs for during the panel review meeting. The purpose of this evaluation is to determine how the NUWC/SAIC model responds to a set of inputs designed to test the model. The CIE reviewers shall also acknowledge the differences and the roles of the external components (*e.g.*, animal input parameter values, propagation models) and the internal component of the model (e.g., ship movement) in regard to the functionality of the model The distinction is drawn here to emphasize that the values of animal placement parameters can and should change when new data are available, and that both models can utilize that new data. Navy staff will provide a comprehensive list of all of the parameters that can be input or changed by the users, versus those that are internal components. Example scenarios for devising these runs are provided in Annex IV.

Days 2-3 of the panel review meetings at NUWC and SAIC: CIE reviewers and the moderator shall work with NUWC/SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. For the NUWC model, the scenarios will be enacted both with and without the ESME behavioral module so that the reviewers can assess both. For the SAIC model – post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of NUWC/SAIC scientists as required, design simulations and request that the NUWC/SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because NUWC/SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, NUWC/SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, NUWC/SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

Terms of Reference

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

5. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
6. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
7. Assess the validity of any post-modeling correction factors (“business rules”) for the SAIC model.

8. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

3. NUWC/SAIC Model Implementation

Details relevant to the topics described below are given in the documents identified in Annex 1.

- Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

i. accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the NUWC/SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC/SAIC models*

ii. correctly handle the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

iii. correctly and efficiently extract data from databases? If not, identify any errors. The NUWC/SAIC models use the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.

- Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar or explosives based on current scientific knowledge, such as:
    i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference))
    ii. Marine mammal movement (horizontal and vertical)
    iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

- Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?
- Does the NUWC/SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?
- Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model would likely result in over/underestimates of take (and the degree, if possible)

4. CREM Guidelines

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

Schedule of Milestones and Deliverables:
The CIE shall complete the milestones and deliverables in accordance with the schedule of activities provided in the following table.

Activity and Responsible Party	Date
NMFS Project Contact will provide pre-meeting background documents to CIE	17 October 08
CIE reviewers and moderator(s) shall participate in a teleconference call with NMFS, NUWC and SAIC to discuss technical and logistical details of the peer review meetings (depending on availability of participants).	27 October 08 1pm 866-620-3559 Passcode 6243699#
CIE reviewers and moderator shall participate in panel review meeting at NUWC to test models Address - 1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841	**12-14 Nov 08**
CIE reviewers and moderator shall participate in panel review meeting at SAIC to test models Address - 1710 SAIC Dr, McLean, VA 22102	**17-19 Nov 08**
CIE reviewers shall submit their CIE independent peer review reports to CIE and the CIE moderator(s)	5 December 08
CIE moderator(s) shall submit their CIE summary report(s) to CIE	17 December 08
Upon CIE Steering Committee review and approval, CIE shall submit the CIE independent and summary reports to the NMFS COTR for review and approval in accordance with the ToR	24 December 08
CIE shall submit the final CIE reports in PDF format to the NMFS COTR	5 January 09
NMFS COTR will distribute the final CIE reports to the NMFS Project Contact for distribution	12 January 09

Acceptance of Deliverables:

Each CIE reviewer shall complete and submit an independent CIE peer review report in accordance with the ToR, which shall be formatted as specified in Annex 2, to Dr. David Sampson, CIE regional coordinator, at david.sampson@oregonstate.edu, and Mr. Manoj Shivlani, CIE lead coordinator, at shivlanim@bellsouth.net. Upon review and acceptance of the CIE reports by the CIE Coordination and Steering Committees, CIE shall send via e-mail the CIE reports to the COTR (William Michaels William.Michaels@noaa.gov at the NMFS Office of Science and Technology by the date in the Schedule of Milestones and Deliverables. The COTR will review the CIE reports to ensure compliance with the SoW and ToR herein, and have the responsibility of approval and acceptance of the deliverables. Upon notification of acceptance, CIE shall send via e-mail the final CIE report in *.PDF format to the COTR. The COTR at the Office of Science and Technology have the responsibility for the distribution of the final CIE reports to the Project Contacts.

Key Personnel:

Contracting Officer's Technical Representative (COTR):

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Request for SoW and ToR Changes:

The Statement of Work (SoW), Terms of Reference (ToR) and list of pre-review documents herein may be updated without contract modification as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToR are not adversely impacted. Any such requests for changes to the SoW and ToR shall be submitted to the COTR (Contracting Officer's Technical Representative) for approval no less than 15 working days prior to the CIE peer review meeting.

ANNEX I: Documents to be reviewed in preparation of the NUWC/SAIC model review. This is a tentative list and will be further refined and specified prior to the review time. Documents may be provided on an ftp site because of large size.

Document Titles
1. NUWC Marine Mammal Acoustic Effects Analysis
2. Numerical Simulation of Undersea Detonation Effects on Marine Species Life
3. NUWC Environmental Modeling for Marine Mammal Acoustic Effects Analysis
4. Oceanographic and Atmospheric Library (OAML) Summary
5. Insert PowerPoint presentation on SAIC model
6. Marine Resource Assessment for SOCAL
7. Source of density for SOCAL

Document	**Document Type**	**Number of Pages**	**Degree of Difficulty**
1. NUWC Acoustic Model	PDF		
2. NUWC Explosive Model	PDF		
3.NUWC Environmental			
4. OAML description	PDF	113	Low
5. SAIC Presentation	PowerPoint		
6. MRAs	CD/Hardcopy		
7. SOCAL Density			
8. Acoustic appendices from EISs for both the SAIC and NUWC models	PDF		

ANNEX II: Format and Contents of CIE Independent Reports

1. The report should be prefaced with an Executive Summary with concise summary of goals for the peer review, findings, conclusions, and recommendations.

2. The main body of the report should consist of an Introduction with
    a. Background
    b. Terms of Reference
    c. Panel Membership
    d. Description of Review Activities

3. Summary of Findings in accordance to the Term of Reference

4. Conclusions and Recommendations in accordance to the Term of Reference

5. Appendix for the Bibliography of Materials used prior and during the peer review.

7. Appendix for the Statement of Work

7. Appendix for the final panel review meeting agenda.

8. Appendix for other pertinent information for the CIE peer review.

ANNEX III: Moderator's Summary Report Generation and Process

1. The summary report shall include an overview of the review process.

2. The summary report shall provide a synopsis of the three panelist reports.

3. Points of agreement and disagreement among the panelists shall be documented.

4. The summary report shall also include as separate appendices copies of each of the panelists' report.

ANNEX IV: Example NUWC/SAIC Scenarios: The panel shall create their own scenarios to be sure that their questions are addressed and answered. Reviewers will develop the scenarios in close coordination with the modeling team to ensure that the scenarios are feasible. The examples below illustrate the type of scenarios that the NUWC/SAIC models can address. They cover two sources of anthropogenic noise from mid-frequency active sonar and underwater explosives. Development of scenarios (including identification of the necessary input parameters) will be addressed during the conference call and the first day of the meeting.

1. A vessel quipped with a mid-frequency (1-10 kHz) active sonar source operating in the Southern California Range Complex (SOCAL) in May. The vessel will be on the range for three days conducting sonar operations during daylight hours. The active sonar signals are one second long broadcast once a minute with a source level of 235 dB re 1 µPa at 1 meter. The active sonar can be operated in two modes; namely, search and track. The ship is moving at 10 kts randomly in a 40 km square operational area. The question to be addressed is how many bottlenose dolphins are modeled to be exposed to a received level that would lead to MMPA Level A (PTS) and Level B (TTS and behavioral) harassment if the operation goes forward? Alternatively, how would the acoustic exposure be altered if the exercise were conducted in January?

2. A similar scenario as above but instead of using mid-frequency active sonar, an explosive source will be used. Input parameters include (among others) the net explosive weight, the explosive depth, the average sediment depth and the seasonal sound speed profile.

Appendix 3: Meeting Agenda

Agenda for SAIC Meeting in Arlington (November 17-19)
4001 Fairfax Dr, Suite 175, Arlington, VA 22203, Navy POC – Hyrum Laney 703-907-2552

Day 1

9:00 – Introductions, Logistics, Security
9:15 - Review of ToRs (Moderator)
9:30 – Welcome aboard from SAIC Acoustic and Marine Systems Operation Manager
Presentations by SAIC Personnel
9:45 - Description of current SAIC approach (i.e., the one used in the SOCAL and HRC EIS) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all the model parameters that can be input or changed by the users, versus those that are internal components.
10:45 - Break
11:00 - Review of post-modeling correction factors for the SAIC model.
11:45 - Review of results of internal testing of the software.
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution, behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model.
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.
5:00 – Conclude Meeting

Days 2 and 3 (Navy Contacts will break this general description down into smaller pieces in advance of the meeting)

CIE reviewers and the moderator shall work with SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. Post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of SAIC scientists as required, design simulations and request that the SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

9:00 – Development of Input Data for Trial Run (HRC/SOCAL EIS Method)
11:00 – Trial Run (HRC/SOCAL EIS Method)
12:30 – Lunch
13:30 – Review of Results, or continue review of results to Day 3.
Day 3 continued
9:00 – Review of Report format, contents, and due dates (Moderator leads)

10:00 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
11:30 – Wrap-up

Review of *Naval Undersea Warfare Center* (NUWC) and *Science Applications International Corporation* (SAIC) Marine Mammal Acoustics Exposure Analysis Models

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Executive Summary

1. Due Diligence. The comprehensiveness and thoroughness of the documentation provided to us for our review of the NUWC and SAIC models used to analyze the effects of acoustic exposure on marine mammals during naval training exercises in the AFAST, SOCAL, and HRC operations areas is both impressive and indicative of the seriousness with which the US Navy has approached the task of generating the congressionally mandated EIS/OEIS statements.
2. Sound Propagation Models. The question whether or not NUWC and SAIC "accurately and efficiently implement" the CASS/GRAB acoustic propagation model is dealt with in the report of the review panel's acoustic modeling expert, Dr. Christina Erbe. As an aside: even though *"The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC models,"* empirical evaluation of the propagation model predictions is, in my opinion, an essential but missing component of a credible evaluation of the Navy EIS/OEIS marine mammal harassment analyses.
3. Marine Mammal Exposure Models. Assuming the acoustic propagation model generates accurate spatio-temporal representations of the acoustic energy fields (both point-wise energy fluxes and accumulated energy levels over 24 hour periods) generated for a particular naval exercise, then the three methods for calculating "takes" (permanent and temporary thresholds shifts—i.e. PTSs and TTSs in hearing abilities—and behavioral harassment without TSs, as defined in the Marine Mammal Protection Act and its Amendments) have the following strengths and weaknesses:
    a. NUWC density area method. This is a relatively crude method that collapses three dimensions into two by using the maximum exposure value along the depth dimension and makes several other less drastic assumptions that all lead to overestimating "take" rates.
    b. NUWC with ESME behavioral module. This method has the potential to provide the best assessment of all three methods in complex situations, particularly if the behavior of individual mammals is adaptive (i.e. is either attracted to or repelled by noise). Computations, however, are very time consuming and given the current level of biological knowledge on distributions and behavior of various relevant marine mammal species, as well as generically, rather than specifically, articulated sound generation activities of the Navy (i.e. general operating conditions with no information on actual paths taken), this method has little relevance to the current EIS/OEIS framework.
    c. SAIC method. The assumptions and approach embodied in this method are well matched to the current state of biological knowledge and information required by NMFS of the current EIS/OEIS assessment framework. The post modeling corrections component of this method is valid in terms of obtaining a better assessment of actual "takes": it moves the analysis beyond the generic to account for such phenomena as acoustic shading of islands, truncation of areas by shorelines, and scaling up from one to several independent acoustic sources.
4. CREM Guidelines. These are dealt with as they relate to the following criteria.
    a. Credible science
        i. Assessment of the sound propagation model is dealt with in Dr. Christine Erbe's review.
        ii. The marine mammal exposure models rely on two kinds of information: 1. spatio-temporal distributions of various marine mammal populations, 2. local movement behavior during feeding and other activities of individuals of different species. These data have been obtained through exhaustive searches

of the literature (a more detailed discussion of this will come from the Panel's marine mammal expert, Dr. Jeanette Thomas), for each mammalian species known to occur in the OPAREAs under consideration. Stratifications of data by province type (all models) and depth (ESME and SAIC model), where known, are important and are used in all models.

b. Choice of model
    i. NUWC density area method. 2-D spatial and seasonal distributions can be implemented, but information on distributions in the vertical third dimensions (i.e. information that can be generated when diving depths, frequency of diving, and lengths of dives are known) is not used. In my opinion, this collapse of the third dimension takes an unnecessarily conservative approach to modeling "takes."
    ii. NUWC with ESME behavioral module. The movement paths generated by the ESME model are based on correlated random walk models with diving rules that produce the desired depth distribution profiles. Adaptive response, such as aversion to a sound source, can be included; but little information is available to make this module anything more than a research or scenario analysis tool (the latter potentially of considerable value to the EIS/OEIS process).
    iii. SAIC method. 3-D spatiotemporal distribution data are included, where available. This approach as it stands, cannot include adaptive responses when known; but, in general, so little is known regarding adaptive behavior that this level of detail is unwarranted at this time in EIS/OEISs.

c. Accuracy of predictions (My comments are confined to the marine mammal exposure model. See Dr. Erbe's report for comments on the sound propagation component). The accuracy is unknown and currently unknowable given that field assessments are virtually impossible with existing monitoring technologies. Specific comments beyond this are:
    i. NUWC density area method. The approach appears to be unnecessarily conservative in estimating "take" rates.
    ii. NUWC with ESME behavioral module. Incorporation of an individual based animat approach to estimating "take" rates currently only has validity as a research or a scenario assessment tool geared towards comparative analyses such as "the number of A level takes in Scenario 1 is *x* times greater than in Scenario 2" and so on.
    iii. SAIC method. This approach computes only the average "take" rates that are expected under generic conditions, which is entirely appropriate for the level of analysis required by NMFS and imposed by the lack of specific details regarding Navy operations.

d. Model performance. The output from all three models is unnecessarily rudimentary in only reporting average "take" rates for each kind of exercise in each of the provinces, as identified in the three OPAREAs of concern. The problem here is not the models *per se*, but the analytical paradigm set up by NMFS in response to EPA requirements and MMPA language. In particular, the following are largely ignored.
    i. Stochasticity. Uncertainty of all types (in data, in model predictions, in animal responses, in environmental variability) is either treated cursorily (i.e. monthly averages for seasonally varying ocean conditions) or not at all (single numbers are reported with no assessment of confidence on these numbers). This lacuna probably has little impact on the computation of expected "take" rates, but

certainly influences how we think about the harassment problem. In particular, the concept of catastrophic events, which would need to be defined by NMFS, does not enter into the assessment process, even though the occurrence of such events is, in part, responsible for driving the EIS/OEIS process.

ii. Sensitivity. Reporting in all three modeling cases ignores the issue of sensitivity of estimates to uncertainties in the data, thereby seriously diminishing insights that can be obtained regarding the reliability of the results.

iii. Scenario analyses. None of the reports include, and the EIS/OEIS process itself does not require, scenario analyses that can be used both to better evaluate the impact of measures undertaken to mitigate harassments or to design operations that minimize, within the context of appropriate constraint sets, the impacts of naval training activities on "take" rates.

e. Model upgradability:

i. NUWC density area method. As it becomes available, this method is able to include more detailed two-dimensional distributional data; but ignores all details relating to the vertical dimension.

ii. NUWC with ESME behavioral module: This method is the only one of the three that can include adaptive behavioral data as they become available. Such information is hard to get, but would be critical to improving predictions of "take" rates for species where adaptive responses of individuals to sound are known to occur.

iii. SAIC method: this approach is designed to be efficient in the context of current EIS/OEIS requirements, and would need to be greatly modified if it were to include detailed information on the distribution of individuals, particularly as it relates to social behavior or adaptive responses of individuals to sound. In short, the design of this model is determined by the requirements of current EIS/OEIS requirements. No doubt, SAIC modelers can easily construct a more elaborate model should other kinds of analyses be required.

5. Observations and Conclusions. The SAIC model is designed to meet current requirements for EIS/OEISs in an efficient manner due to its crude, but entirely appropriate, level of resolution for the exposure analyses both required by NMFS and, in most cases, appropriate given the paucity of the behavioral and distributional data at hand. The NUWC model with the ESME behavioral component will provide a tool suitable for carrying out analyses that go well beyond the current EIS/OEIS specifications, but will also require data that, for most species, are unlikely to be available for years, probably decades, to come. The NUWC+ESME module analyses, however, will still be deficient if undertaken within a framework of analysis that I think ignores uncertainty, stochasticity, or data and model structure sensitivity issues. Finally, there was an elephant in the room during our deliberations that was only fleetingly acknowledged. I think it important to acknowledge it because, after going through the review process, I am convinced that there is a much more effective way to approach the EIS/OEIS process. I think all parties (stakeholders) will benefit and, most importantly, the intent of the Environmental Protection and Marine Mammal Protection Acts will be met if the EIS/OEISs focused on articulating how effective marine mammal monitoring programs can be put in place and adaptive mitigation plans can be executed to reduce harassment levels once marine mammals are detected in the area of operation. Further, the documents should indicate how the design of these programs could meet accepted scientific guidelines that should be drawn up by NMFS. Finally, efforts to collect such data by all applicants to NMFS for operating permits must be coordinated and standardized by NMFS to maximize their utility in adding to

our knowledge of marine mammal distributional and behavioral data.

1. INTRODUCTION

The requirements of the Marine Mammal Protection Act (MMPA) and its amendments that entities, such as the Navy, must fulfill in their application for an incidental harassment authorization (IHA) permit are an important component of the US Government's stewardship of the environment. Within the framework of the application process, the applicant must provide information mandated in Section 7 of the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA) to the authority in charge, in this case NOAA NMFS. Included in this information are:[1]

1. A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals;

3. The species and numbers of marine mammals likely to be found within the activity area;

4. A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities;

6. By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in paragraph 101(a)(5), and the number of times such takings by each type of taking are likely to occur;

7. The anticipated impact of the activity upon the species or stock;

11. The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance;

13. The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding. Guidelines for developing a site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources;

14. Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

I was particularly impressed with the due diligence the Navy in meeting requirements 3 and 4 of the

[1] For complete details and specific number of requirements see http://www.nmfs.noaa.gov/pr/permits/incidental.htm, version December, 2, 2008.

above list in their EIS/OEIS

The problem arises for any IHA applicant on how best to meet requirement 6, particularly the requirement elaborated in paragraph 101(a)(5)(D)(I) that: "harassment during each period concerned will have negligible impact on such species or stocks." Part of the difficulty is that no guidance is provided in the MMPA on how to interpret the word "negligible." Very specific guidance is provided on what is meant by the term "harassment," even though its biological basis is questionable and its operational definition raises serious scientific issues. In particular, the validity of procedures used to calculate the cumulative effects of sound on individuals periodically exposed to acoustic events, such as continual pings generated during naval activities, are questionable (as will emerge in this review). Further, as will also emerge in this review, requirement 7 is extraordinarily hard to fulfill. There is no good way to meet requirements 6 and 7 without the aid of a quantitative model that has sufficient biological realism (both process and data-wise) to accurately predict "take" rates and their impact on populations, yet we can have little confidence in the predictions of the models under review in the absence of validation of the performance of these models. No such validation was produced during the review process.

In the absence of a suitable quantitative model, which is unlikely to be developed in the next half decade, there is no scientifically acceptable way to meet requirements 6 and 7. Thus, at this time, the EIS/OEIS process may be better served by having applicants focus on requirements 11, 13 and 14 until such time that sufficient biological information is available to satisfactorily implement requirements 6 and 7. This would still require settling the question of what is meant by "negligible impact on such species or stocks.".

In my opinion, the state of biological knowledge of the species involved is such that requirements 6 and 7 cannot be met in a scientifically credible manner, as mandated by the Council on Regulatory Environmental Modeling (CREM). Further, as I will elaborate in the appropriate sections regarding other CREM standards, none of the models can be validated against empirical data because currently no suitable data exists to carry out a credible validation procedure.

In deference to the task that I agreed to undertake under the Terms of Reference for this review, and my commitment to answer the specific questions that I am being asked to address, I will go ahead and provide the answers as best I can. However, the panel was not provided during the review process with any empirical data or information pertaining to the statistics of model parameter estimation. Thus I have no basis for formulating any kind of confidence in the predications the models make, not to mention that I have no idea how to interpret the numbers generated with regard to "harassment level B takes without TS" (i.e. behavioral harassments using the risk function). The bottom line is that I think the way the EIS/OEIS framework, as currently implemented through the use of quantitative modeling, is seriously flawed and needs to be rethought by NMFS.

2. SOUND PROPAGATION MODELS

The question whether or not NUWC and SAIC "accurately and efficiently implement" the CASS/GRAB acoustic propagation model is dealt with in detail by the review panel's acoustic modeling expert, Dr. Christina Erbe. Since many assumptions are made in the way the model is implemented to generate the required sound fields, it is really important that the performance of the acoustic transmission loss models be validated in the field by checking predictions against empirically measured data under a variety of conditions. Of particular note for me was the fact that sound fields were not smoothly interpolated between model-generated eigen-rays, but only the most crude “constant sector” interpolation approach was used. If the rays are similar this is acceptable, but if adjoining rays are say 30° apart and rather different, then a smooth interpolation is likely to be much better; but without empirical evaluation it is hard to know how much better.

3. MARINE MAMMAL EXPOSURE MODELS

The marine mammal exposure models all depend on making some assumptions about how individuals belonging to various populations of interest are distributed in space and time, and on the procedures they employ for calculating sound harassment “takes”.

Certainly the distribution of some marine mammal species is much better known than others since some species have been more intensely studied than others. Also, individuals of some species are more easily observed than those of other species. The three exposure models discussed in this section handle such distributions in different ways, so I will comment on under separate subheadings below.

In terms of “takes”, all three approaches follow NMFS guidelines and so I will elaborate on these first. Three types of “takes” are recognized: “Level A harassment” (permanent injury), “Level B harassment type[2] I” (behavioral disturbance with temporary threshold shift) and “level B harassment type II” (behavioral disturbance without temporary threshold shift).

The number of “level A harassment” and “level B harassment type I” events depend on whether or not the “total sound exposure level” (SEL) impinging on an individual has been exceeded over a specified period of time[3]. Over any given period of time *T* (in seconds), the formula for SEL is[4]:

$$\mathrm{SEL} = 10\log_{10}\left(\frac{1}{T}\int_0^T p(t)^2\,dt\right) + 10\log_{10}T \qquad (1)$$

where *p*(*t*) is the instantaneous pressure[5] (micro-Pascals) of the impinging acoustic wave. The first term in equation (1) is referred to as the SPL (sound pressure level referenced to $1\mu\mathrm{Pa}^2$) so that the formula can be written more succinctly as

$$\mathrm{SEL} = \mathrm{SPL} + 10\log_{10}(\mathrm{duration}). \quad (2)$$

This presentation of the formula emphasizes the dependence of the SEL on two parameters: SPL and “duration” (measured in seconds). Equation (2) is the form that appears in the documentation supplied by NUWC and SAIC, but we need to note that equation (2) only applies for accumulating the total sound exposure energy flux if the SPL has the same value whenever the sound “duration” variable is “on.”

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[2] The type I and type II harassments associated with level B are my own designation since no succinct designation is attached other than type I being “with temporary threshold shift” and type II being “without a threshold shift.”

[3] See Table 3-1 in Appendix F of the SOCAL Range Complex EIS/OEIS Preliminary Final Version 2 (September 2008).

[4] P. T. Madsen, 2005. Marine mammals and noise: Problems with root mean square sound pressure levels for transients, J. Acoustic Society of America, 117(6):3952-3957.

[5] R. J. Urick, 1983. Principles of Underwater Sound, Peninsula, Los Altos, California.

This is only true at points from a noise source when the noise is always the same and conditions affecting the transmission loss calculation (e.g. wind and temperature) are the same.

During our review it emerged that the agreed upon standard for the period over which the SEL should be accumulated in order to calculate a "take" is a full 24 hour diurnal cycle. This implies that an animal exposed to 24 one-second pings every 5 seconds would be subject to the same SEL as one exposed to 24 such pings on a hourly basis within one diurnal cycles. While it is true from the standpoint of physics that individuals have been exposed to the same SEL levels in both acoustic exposure operations, the impact of the two kinds of operations on the behavior of the animal are bound to be different. Also, if the end of one diurnal cycle and the start of the next occurred in the middle of a 24-ping sequence, each an hour apart, then the individual in question would be subject to two exposure events, each of which involves an accumulation of 12 pings in each diurnal cycle. Everyone is aware of such anomalies: the common belief, which I think reasonable, is that these anomalies are likely to have little effect on the results, particularly as all three methods to varying degrees (as elaborated below) compute rather crude average "take" rates over time and space. Also, other assumptions, perhaps having greater affect on results, bear on the accuracy of the computations. Arguably the most problematic of these assumptions is the way individuals are assumed to be distributed over the marine environment, particularly the way in which aggregations of individuals are treated in terms of preferred habitats (crudely divided in the models into provinces—e.g. 13 in the SOCAL Range[6]) and social behavior (e.g. existence of family pods, mother-calf pairs, hunting groups).

Returning to the "takes" that depend on SPL rather then SEL—that is number of "level B harassment type II" events, it follows that from equations (1) and (2) above that the following relationship is implied:

$$\mathrm{SPL}_{\mathrm{rms}} = 10\log_{10}\left(\frac{1}{T}\int_0^T p(t)^2 dt\right), \qquad (3)$$

where the "rms" subscript is used to indicate that this is "root-mean-square" definition of SPL. Another definition for SPL based on "peak" rather than "root-mean-square" characteristics of the impinging acoustic pressure wave is

$$\mathrm{SPL}_{\mathrm{peak}} = 20\log_{10}\left(\max_{t\in[0,T]} p(t)\right). \qquad (4)$$

For purposes of computing harassment the $\mathrm{SPL}_{\mathrm{peak}}$ computation is preferred over the $\mathrm{SPL}_{\mathrm{rms}}$[7], with the result that when used, SEL calculations - if done properly - are no longer linked to $\mathrm{SPL}_{\mathrm{peak}}$ calculations through equation (2). Beyond this is the question of what definition of SPL should be used for calculating level B harassment type II "takes." The current paradigm, promoted by NMFS is to use a

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[6] See Table 4-8 in Appendix F of the SOCAL Range Complex EIS/OEIS Preliminary Final Version 2 (September 2008).

[7] *Id*. Endnote 4. Also see Southall, Brandon L. (Brandon.Southall@noaa.gov); Bowles, Ann E.; Ellison, William T.; Finneran, James J.; Gentry, Roger L.; Greene, Charles R., Jr.; Kastak, David; Ketten, Darlene R.; Miller, James H.; Nachtigall, Paul E.; Richardson, W. John; Thomas, Jeanette A.; Tyack, Peter L. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33(4):1-521.

logistic-like risk function, adapted from Feller[8], that has the SPL level as the independent variable, and the probability that a particular SPL level will result in a "level B harassment type II" event as the dependent variable. In the case of most species of concern, the biological basis for the use of this function appears to be convenience rather than the function being firmly rooted in data.

For purposes of clarity, before proceeding further, it is worth emphasizing the fundamental differences between computing the number of "level A harassment and level B harassment type I takes" versus computing the number of "level B harassment type II takes". First, recall that the former type of harassment is based on the accumulated energy sound fluxes SEL over a 24 -hour period while the latter type is based on short duration SPL events. Second, note that when SEL values exceed specified thresholds[9] then an event of the former type of harassment occurs with a weighting proportional to the average density of the species in the area/volume concerned[10], while an event of the latter type of harassment occurs with a weighting proportional to the average density of the species in the area/volume concerned multiplied by the probability determined from the risk function for the SPL level concerned.

The implementation of a computationally detailed model that includes an acoustic component based on highly credible physics provides the illusion of "credible science" (as mention in the CREM guidelines) in coming up with a prediction of "take" rates. Even though the effect of considerable averaging in the acoustic transmission loss calculations are unknown in terms of how accurately the sound fields are generated (i.e. no comparison to empirical data has been provided), the lack of biological detail imply that there is no scientific basis for giving credence to predicted "take" rates, not to mention the fact that the impact of these "take" rates on the health and long term viability of the populations themselves is completely unknown. In making these comments, I don't mean to diminish the enormous difficulties in estimating the real impact of sound harassment on marine mammal populations (cf. requirements 7 and 11 listed in Section 1 above), let alone the difficulties in estimating of the impact of particular "take" rates on the populations themselves. What I would like to convey is that the MMPA is not well served through the current EIS/OEIS paradigm, and could be better served by asking for different kinds of information that better address requirements 13 and 14 of Section 7 of the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA) (as listed above). Some of the more obvious issues I have with the current "take" computation paradigm are:

1. In the computation of SEL values, it is clear to me that 24 pings in quick succession are not going to have the same affect on an animal as 24 pings each an hour apart. Is it appropriate to disregard such differences in calculating "take" rates?
2. If an individual is subject to multiple pings from a given source, then each ping is not of the same SPL intensity because either the individual would have moved or the source would have moved or both. So accumulating SEL values by computational-cell area or volume[11] is problematic if different individuals are moving at different relative velocities with regard to the sound source. In practice this is bound to be the case, though a reasonable response to this criticism is that

[8] Feller, W. 1968. Introduction to Probability Theory and its Application. Vol. 1. 3rd ed. John Wiley & Sons. NY, NY.
[9] *Id*. endnote 3.
[10] A cell in the computed area (model in Section 3a) or volume (models in Sections 3b and 3c) that has been discretized by province and then into a finer mesh conforming to the acoustic propagation model computational procedure.
[11]The cell sizes depend on the computational procedures as outlined in the various documents. See *Ibid*.

effects are washed out in taking averages over 24-hour periods.

3. Threshold levels and risk functions for computation of harassment events have been estimated for some species, but then are applied without any further verification to other species, based solely on being members of the same phylogenetic group (e.g. cetacean family or suborder). This may be justified in some cases, but such assumptions remain untested in most cases.
4. Far more important than any of the above points is the fact that animals behave and respond to sound in ways that are generally unknown, and some of these behaviors (such as avoidance) will dramatically affect real "take" rates. Thus the assumption of random movements in the absence of a knowledge of adaptive responses to sound is not really a "best first order approximation" but likely a highly biased one.
5. Within a wide range of frequencies "take" rates are computed as being frequency independent. The consequences of this assumption remain largely unknown, particularly as different species have very different auditory characteristics.

If the exposure-modeling components of the computational processes are deeply flawed, should the computations be carried out at all? I think the computations have some value, but only in the context of comparative scenario analyses, as described in Section 4d(iii) below. The question of what I see as a more fruitful focus for the modeling effort in fulfillment of EIS/OEIS requirements is discussed in my concluding Section 5.

The Terms of Reference for this report require the panel's assessment of whether or not 1. the NUWC area density model, 2. the NUWC model including the incorporation of the ESME behavioral module, and 3. the SAIC model met the CREM guidelines in the way these models incorporate all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation). In the remainder of this section, I will continue with my assessment under the assumption that the acoustic propagation models used in the analyses generate spatio-temporal representations of the acoustic energy fields at an acceptable level of accuracy and that the methods for calculating the three kinds of "takes" mentioned above are also appropriate.

3a. NUWC Density Area Method

This approach employs a CASS/GRAB transmission loss model to construct the 3-D sound field associated with an acoustic event, but then projects the 3-D sound field onto a 2-D surface by taking the maximum SPL value along the vertical (depth) *z*-axis for each *x-y* in the horizontal plan. This I believe is done each second for both a stationary sound source or as the sound source moves through the OPAREA of interest. Further, I am not sure of the precise way the SEL is then accumulated over any 24-hour diurnal cycle. The 3 to 2-D projection is made to vastly reduce the memory requirements for the computation that would otherwise be very unwieldy. Also the SPL and SEL fields are first calculated over a 24 hour period, and then are convolved with the population distribution data to obtain the number of "takes" for the diurnal cycle in question. Other approximations made in calculating "take" rates include:

i. filling out sectors between computed CASS/GRAB eigen-ray solutions so that all rays within a filled out sector are identical rather than interpolated in a smooth way between neighboring sector rays;
ii. generating solutions in each province as though the province itself were a homogenous flat bottomed box;
iii. if a sonar source crosses a boundary from one province to the next the computation switches directly to the sound propagation characteristics of the province it is currently in;
iv. each province is given a specified density of individuals obtained, I believe, under the assumption that it reflects that average density for the OPAREA as a whole, with possible modification if it is known that the individuals of the species being considered have a greater preference for one or

more of the provinces making up the OPAREA of concern (i.e. to the extent habitat preference is known to be associated with a province type, it can be included).

At the level of generating the acoustic SPL and SEL values to be used in calculating “take” rates, this approach is relatively crude because of the projection from 3 to 2 dimensions and the averaging implicit in calculating the SPL and SEL fields first over the total diurnal cycle. Also the approach is rather conservative because the 3 to 2 D projection takes the maximum SPL value along the *z*-axis. Further, it appears that this model does not distinguish between those individuals that have been affected by the SEL sound field (level A harassment and level B harassment type I) and the SPL sound field (level B harassment type II). This double counting, though, is of very minor consequence. This approach may also lead to multiple counting of “level B harassment type I takes” which in some cases may produce more of this kind of “takes” in one 24-hour cycle than the total number of animals in the exercise area itself. This error also biases the “take” rate on the high side.

3b. NUWC with ESME Behavioral Module

The most accurate way to assess the effects of sound on individuals is to take a dosimeter approach and compute the impact of the sound fields on individuals, treated as dosimeters in a time varying sound field. This approach, however, presents the computational challenge of running the sound propagation and mammal exposure models in parallel, rather than running the sound propagation first, obtaining SPL and SEL values at grid points for the diurnal cycle under consideration, and only then convolving the sound field with the population density distribution. The ESME behavioral model that is being developed is such a dosimeter approach, which has the advantage of being able to include the adaptive behavior of individuals. At this time, however, little biological data exists on how individuals respond to various types of acoustic harassment.

The full ESME approach is to treat individuals as animat dosimeters that swim around in the sound field according to specified rules. This additional animat-movement layer is computationally burdensome if it and the sound propagation modules are run in parallel, as is needed to compute SEL exposures directly. This level of computational effort, however, is not to be justified if many other approximations are being made, including the animats moving around largely at random, but in a way that mimics known diving patterns for the species. The much simpler approach is to treat individuals as stationary animats distributed across space and depth to reflect what is know about the actual 3D distribution of the individuals for the species concerned, with possible modifications being made over the simulation to account for diurnal changes in diving behavior.

Given the lack of biological behavioral data, I don’t believe that the level of sophistication provided by the NUWC+ESME methodology can currently lead to more accurate estimates of “take” rates than, say, the SAIC model discussed next. However, the NUWC+ESME approach can be used to improve our understanding of how adaptive behavior, once known, might impact the “take” rates. It can then be used to evaluate how the impact of mitigation measures on the behavior of individuals may reduce “take” rates during an operation. In short, NUWC+ESME has value both as a research tool and as an acoustic exercise design tool.

3c. SAIC Method

In my opinion, the SAIC method has been built to carry out the analysis required by the EIS/OEIS framework in an efficient manner and at a level of resolution that matches well with the current reporting requirements and the current state (or lack thereof, to be more accurate) of biological knowledge. (The adage that one cannot make a silk purse out of a sow’s ear applies perfectly here). As with the NUWC methods, it first calculates the SPL and SEL sound fields for each 24-hour cycle.

However, it subtracts out a factor to avoid double counting of SPL "take" rates that are counted under the SEL "take" rates. It also has post-processing features that correct for situations where islands may be acoustically shading individuals from harassment or to easily scale up calculations from one to multiple sources using assumptions that have little effect on the results at the level of accuracy of the overall computation. This post processing also employs a "density dilution" procedure that ensures no individual can be counted more than once as a behavioral "take" in any 24-hour diurnal cycle.

This method employs the following assumptions to greatly reduce the computational burden:

i. The acoustic source and impacted individuals move relative to one another at a constant rate throughout the simulation period (i.e. diurnal cycles for situations lasting longer than 24 hours or the period of time specified by the operation for exercises lasting less than 24 hours).
ii. As with other the models, average monthly data are used for wind and temperature conditions.
iii. Each province that is identified in the OPAREA is treated as a box-like volume.
iv. Individuals are distributed across the provinces at densities that reflect averages for the OPAREA, with modifications to take care of known habitat preference and vertical distributions that reflect known diving behavior. (Although this approach was presented as equivalent to assuming a uniform distribution of individuals within provinces, this statement is misleading because the approach is purely deterministic and hence considers only average densities rather than uniform density distributions which have both an average density and variance component.)

4. CREM GUIDELINES

4a. Credible Science

The first question that we are asked in the context of the CREM guidelines is whether or not the principles of credible science have been addressed during model development? This is a difficult question to answer because, in my opinion, the requirements of the EIS/OEIS framework demand a near-to-impossible task of the modeling group: build a scientific credible model for a system that is very poorly understood and for which inadequate data exist with the expectation that the model is then able to predict with some credibility the three kinds of "take" rates for the acoustic activities under consideration. The credibility of the science for the physical module is much higher than for the biological module. In addition, the credibility of the combined physically and biological modules is reduced if they are run sequentially rather than simultaneously (as in the case of the SAIC and NUWC density area approaches).

4a(i). <u>Sound propagation modules</u>

The scientific credibility of the sound propagation models of all three approaches is dealt with in Dr. Christine Erbe's report. As I have already mentioned the performance of this component in the NUWC and SAIC analyses should, at some point, be tested against empirical data under a variety of conditions. This being said, whatever the accuracies of this performance, the huge disparity between this module and the exposure module brings into question the value of the whole modeling exercise in the context of prediction (though, I stress again, not necessarily as a research or design tool).

4a(ii). <u>Marine mammal exposure modules</u>

The marine mammal exposure modules in all three models are not scientifically credible as predictive tools. To gain credibility the predictions need to be tested against empirical data using accepted statistical procedures. This is not been done because it cannot be done at this time: empirical "take" data are not available and are unlikely to become available in the near future. Further, even if one could observe a population closely, it would be very difficult to identify "takes" because the definitions of "takes" are either conceptual (level B harassment type II) or, if operational (level A harassment and level B harassment type I), can only be assessed through unacceptable levels of interference with subjects that have been harassed (only in extreme cases when harassment has resulted in the death of the subject, can proper scientific assessments be undertaken during post mortem examinations).

In addition, the marine mammal exposure models rely on two kinds of information to come up with reasonable predictions of "take" rates for each mammalian species known to occur in the OPAREAs under consideration. Despite the fact that exhaustive searches of the literature have produced considerable data, they are much too incomplete to be used as predictive tools, except perhaps in very localized regions where marine mammals live in close proximity to humans. The first type of information needed in these models is the spatial distributions of individuals in the different species in the OPAREA with respect to both changes on a diurnal cycle and changes on an annual seasonal cycle. Further, ecological and social factors are going to cause distributions to be aggregated in some places and, perhaps even spread out in other places. The second type of information is behavioral: individuals are sure to respond to harassment in a way that will greatly affect "take" rates. In most cases, one might expect that animals will themselves mitigate harassment through avoidance behavior; but it is possible in areas with unusually bathymetry that animals may become trapped, panic, and become victims of what some might call "catastrophic" events (such as mass beaked-whale strandings' that have been reported on several occasions[12]). Stratifications of data by province type (all models) and depth (ESME and SAIC model), where known, are important and are used in all models.

For the above reasons, I believe that the mere reporting of "takes" does not appropriately address the requirements laid out in Section 7 of the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA). However, the models do have value as tools that can be used to assess the potential of interventions to mitigate harassment and to compare the relative impact of different operation scenarios (i.e. as an operations' design tool). One set of comparative analyses is reported in the SOCAL EIS/OEIS (cf. Appendix F for the reporting of "No Action Alternative" (Tables 4-13 to 4-19), "Alternative 1" (Tables 4-21 to 4-27), and "Alternative 2" (Table 4-28 to 4-33) results)[13].

4b. Choice of Model

The next question posed by the CREM guidelines is whether or not the choice of model is supported by the quantity and quality of available data. I will address this question separately for each of the three methods under consideration.

4b(i). NUWC density area method

Because this method collapses the 3D SPL and SEL calculations into a 2-D framework, all information relating to the vertical distribution of individuals induced by their diving behavior is not taken into account. The net effect of ignoring these data and taking the maximum value of the SPL in the vertical direction as representing the SPL that would be experienced at all depths has the effect, as already been mentioned, of overestimating "take" rates. This approach, however, can account for spatial variation in two dimensions, including how the densities of individuals may vary over the 24-hour diurnal cycle or across seasons. In my opinion, the collapse of the third dimension makes this approach unnecessarily

[12] D. P. Nowacek, L. H. Thorne, D. W. Johnston and P. L. Tyack, 2007. Responses of cetaceans to anthropogenic noise. Mammal Rev. 2007(2):81-115.

[13] I searched through the SOCAL documentation but could not find a clear description of the differences between these three alternatives.

conservative in modeling “takes.”

4b(ii). NUWC with ESME behavioral module
The NUWC+ESME approach is by far the most flexible, but highly limited at this time given the paucity of biological data and the generic way in which naval operations are specified. In very specific situations where the movement of acoustic sound sources are completely specified, and the distribution of individuals is in a physically contained region, such as a bay or inlet, then this approach can yield acceptable predictions on “take” rates, where other methods would fail. Further, this is the only method that can include the adaptive responses of individuals to sound (e.g. aversion or aggregating behavior), but given the current paucity of data and the heavy computing demands made by this approach, it is likely to only serve primarily as a research or operations design tool for some time to come.

4b(iii). SAIC method
Unlike the NUWC density area method the SAIC method takes the third dimension into account. The trade-off, however, is the assumption made that the density of individuals is a constant in each province. This implies that the model cannot deal with any information relating to aggregation behavior (e.g. pod structure), which would represent a problem if information other than just average “take” rates where required, (e.g. information such as confidence limits associated with estimates of average “take” rates). Of course, SAIC can easily extend this model to undertake such calculations, should this kind of information be required in future EIS/OEISs.

4c. **Accuracy of Predictions**
I cannot comment on the accuracy other than to make very general statements regarding the lack of accuracy for want of good data or the existence of bias. I will confine my comments to the exposure module under the assumption that at specific points in space, the sound propagation modules when run independently of the exposure modules over the duration of the operation or diurnal cycle overestimate the SPL (and hence also the SEL) in the case of the NUWC density area method, but provide acceptable estimates in the other two cases (see Dr. Erbe’s report for more detailed comments on the acoustic computations).

4c(i). NUWC density area method
The approach appears to be unnecessarily conservative in estimating “takes,” with the inaccuracies generated by collapsing three dimensions into two using the maximum SPL values in the vertical direction swamping most of the other inaccuracies that enter (but apart from the issue of inaccuracies in the data themselves which is not a modeling issue per se).

4c(ii). NUWC with ESME behavioral module
The power of this approach is most limited by a lack of biological data pertaining to the behavior of individuals. Thus it is best used as a research or design tool that evaluates the consequences on “take” rates of individuals either responding in a particular way to harassment or being made to respond in a particular way meant to mitigate the effects of impending harassment.

4c(iii). SAIC method
This approach is designed to provide as good an estimate on average “take” rates as it can within the framework of trading off efficiency against spurious precision. However, this method has little value as a tool beyond generating average daily “take” rates, and would require modifications to introduce some elements of stochasticity into the computations. Such computations, as I argue below, could provide useful information.

4d. Model Performance

The output from all three models is rudimentary in only reporting average “take” rates per operation, or over averages over diurnal cycles for operations longer than a day, for each type of exercise in each of the provinces identified in the three OPAREAs of concern. To varying degrees, the models can go beyond this; for example, analyses can be extended to report on confidence intervals associated with the prediction of “take” rates, although computation times would increase by two orders of magnitude to do a reasonable job. At this time the SAIC is the least flexible for including stochasticity because, unlike the NUWC area density model for example, it is not currently designed to consider the distribution of individuals as anything but constant over the different provinces making up the OPAREA of interest. However, I would rather see the SAIC approach extended to carry out confidence interval calculations than using the current NUWC density area approach to do this, because of the strong bias that the NUWC area density model has in overestimating “take” rates. Ultimately, though, the problem is not with the models, since they can always be modified, but with the analytical paradigm set up by NMFS in response to EPA requirements and MMPA language. I will return to this in the final section.

What are some questions worth asking that relate, not only to average “take” rates, but also to the tails of the distribution of “take” rates? I provide a limited answer to this question in the subsections that follow.

4d(i). Stochasticity

The study of any ecological or environmental system is beset by several different kinds of uncertainty. First, the data themselves are often rather crude and inadequate for addressing the problems at hand. This is true of population densities (absolute numbers once sizes of operation areas are known) data and the distributions (relative numbers) of individuals across space and time for almost all the species under consideration. Second all the key processes may not be known, so that the models themselves are inadequate. In the context of marine mammal EIS/OEISs, perhaps the most crucial missing process is how individuals behaviorally respond to acoustic harassment. The third kind of stochasticity is inherent variability in the systems themselves. In the systems under consideration this variability arises both from external environmental drivers (wind conditions, temperature fluctuations, and so on) and from inherent tendencies to cycle. Oscillations in a system may arise, even when external drivers are constant or deterministically characterizable, due to time delay mechanisms such as in the case of consumer-resource cycles with multi-year or multi-decadal delays (e.g. in whales overexploiting krill thereby resulting in reduced whale reproduction because of starvation, thereby allowing krill to recover and rise to high levels that promote whale growth, thereby leading to overexploitation of the krill and a repeat of the cycle). These cycles are hard to follow or predict in the absence of long-term data trends and long-term environmental stability (i.e. global warming will influence these cycle making them more difficult to predict).

In theory, if a particular process could be replayed (such as how many marine mammals will be harassed in a given exercise repeated in the same place several times, with time in between operations sufficient for the area to return to its normal state), we would expect the results to be different each time. In this case, predictions cannot be exact but rather can only provide an estimate of the expected number of “takes” over many repetitions of the same exercise. The answer to the question of whether or not just the average “take” rate is sufficient information to calculate depends on one’s perspective. In the context of acoustic harassment “take” rates, the average is important because it provides an estimate on the size of the phenomenon. But the variance associated with this average becomes important if one is concerned as well with risk. Purely as an illustrative example, suppose NMFS wanted to assess the acceptability of the following two exercises. For the first exercise a model predicts that one fatality is expected in each repetition of the exercise. In the second exercise a model predicts that 0 fatalities are expected with probability 0.9 for each repetition, but that 10 fatalities can be expected with probability 0.1 in each repetition. (This is not as far fetched as it sounds if individuals of the species were always located in pods of around size 10). Both exercises have an expected mortality rate of 1. If a permit were sought for the second exercise as a one-off case, then NMFS perhaps would approve it based on the likely outcome that no individuals would be harassed. If permits were requested for 10 repetitions of both the first and second exercises over a five year period (say one every 6 months), then perhaps NMFS would approve the first because 2 deaths a year may be an acceptable annual "take" rate, but not the second because an event of 10 deaths occurring during a single exercise may be unacceptable in some sense (e.g. because of the publicity generated by the event). If a relatively high number of deaths in one exercise were labeled a "catastrophe" by some group, then in regulating "take" rates, NMFS is expected to be risk-averse to the occurrence of "catastrophes" because of the adverse publicity attached to such events; even though such events may be no more threatening to the population in the long run than operations of the first type described above. Thus, in general, estimates of probabilities associated with potentially "catastrophic" events (however they are defined), are useful to know.

4d(ii). Sensitivity

At a more prosaic level than estimating the occurrence of a catastrophic event is the problem of providing an estimate of how well a particular statistic is known, whether it be an estimate of the average "take" rate, or an "estimate of the probability of the occurrence of a "catastrophic" event. Again, purely for purposes of illustration, if a model predicts that for a particular species the average "take" rate for a series of exercises is in the first case15 ± 2 (with 95% confidence) or is in the second case 15 ± 15 (with 95% confidence) this may make no difference to awarding a permit, unless NMFS has a threshold value of at most 25 "takes" for the species in question. The model predicts that in the first case, the 25 "take" threshold is much less likely to occur than in the second case. Unlike the situation described in the previous section, this is not a problem of having an inherently long-tailed distribution brought about by the fact that individuals are highly aggregated (e.g. go around in pods of around size 10), but that uncertainty exists in the model predictions because the data are not accurately known, or some of the parameters in the model are uncertain because the precise nature of the relationships between processes and the variables upon which they depend are not known. The way to deal with this type of uncertainty is to look at the levels of uncertainty in the data and process functional forms, and assess how this uncertainty propagates in the model to affect the predictions. This type of analysis comes under the rubric of sensitivity analysis, a topic on which numerous books have been written[14].

4d(iii). Scenario analyses

Even if one does not have a model that can accurately predict outcomes because the model is not sophisticated enough to include all critical biological processes, or data are inadequate to get good parameter estimates, or the system is intrinsically highly variable, one may be able to gain some confidence in the predictions of the model in a relative comparative sense. More specifically, if one has an acoustic harassment model that predicts "take" rates for which it is hard to ascribe real meaning to the actual number produced by the model, one "may be able to assign some confidence to the

[14] For example see A. Saltelli, S. Tarantola, F. Campolongo, and M. Ratto 2004. Sensitivity analysis in practice: A guide to assessing scientific models. Halsted Press, New York, NY, USA.

statement" that an exercise that has a "take" rate of N individuals is twice as damaging to the population as one that has a "take" rate of N/2 individuals. I have put the phrase "may be able to assign some confidence to the statement" in quotes because in realty it may be extremely difficult to do this. With experience a user will gain confidence in the relative value of predictions much sooner than confidence in the actual predictions themselves (accurate absolute predictions certainly imply valid relative predictions, but not vice versa).

Thus a model that lacks true accuracy can still provide some sense of how much more damaging one exercise might be compared with another. The use of the models in this context plays virtually no role in the production of the EIS/OEISs we reviewed and, I raise the question of why this is so, since this may be the only scientifically valid way to use the models at this time. In particular, the models could be used to explore possible impacts of mitigation measures ultimately leading to statements of the type "mitigation measure *M* can be expected to reduce the number of "takes" of a particular type by $P \pm p$%."

4e. Model Upgradability

4e(i). NUWC density area method

This method can be used in a Monte Carlo framework to compute how inherent stochasticity in population distribution data inputs translates into distribution of "take" rates. This approach is flexible enough to include aggregation of individuals into pods and hence to compute the probability of potentially high "take" rates that occur in the tails of the "take" distributions. The difficulty of the overestimation bias due to the way the sound field is collapsed from three into two dimensions, though, remains.

4d(ii). NUWC with ESME behavioral module

This method is the most flexible of all, but this comes at the considerable expense of computation time. It can also be used in a Monte Carlo framework to include stochasticity in the distribution of individuals in space and time, and also stochasticity in the behavioral response of individuals to acoustic harassment. As mentioned throughout, the primary value of this model is more as a research and design tool than for purposes of predicting "take" rates in the many different areas that constitute a large oceanic region—the computational demands and lack of biological data are currently just too great.

4d(iii). SAIC method

This method is the least flexible, but most efficient and does not bias "take" rates in any obvious way other than omitting potential aversion responses. It requires some modification to be used in a Monte Carlo framework to explore the affects of aggregated population distributions on "take" rates, particularly if "catastrophic" events (as may be defined in the future) in the tails of the "take" rate distribution are to be computed.

5. OBSERVATIONS AND CONCLUSIONS

In making final observations and coming to conclusions, I return to the requirements mandated by Section 7 of the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA)[15]. I would first like to comment one by one on the points I presented in the introduction.

1. A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals;

Evaluation of this requirement is beyond the scope of this evaluation, with current Navy specifications of activities only provided in a generic way.

3. The species and numbers of marine mammals likely to be found within the activity area;

Considerable work is on going to obtain the data needed to fulfill this requirement, but, as I argue below, much more can be done during operations to try and improve our knowledge of the number and species of marine mammals being impacted during operations and exercises.

4. A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities;

The same answer applies as in 3. above.

6. By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in paragraph 101(a)(5), and the number of times such takings by each type of taking are likely to occur;

The models currently do not address issues relating to age, sex, and reproductive status and are not capable of reliably predicting now or in the near future (e.g. next half decade) rates for each type of "take."

7. The anticipated impact of the activity upon the species or stock;

The models currently do not address issues relating to the impact of acoustic activities on populations (stocks, species). To predict such affects requires that many ecological factors be taken into account, the effects of most of which are not known and will not be known in the next decade.

11. The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance;

Most of the issues raised by this requirement can be addressed without the aid of models and, perhaps, some of the effort devoted to modeling should go into developing a more comprehensive response to this requirement.

[15] *Id*. Endnote 1.

13. The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding. Guidelines for developing a site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources.

One can build a model:

1. to address a specific problem
2. to be used as a tool
3. as part of on ongoing enterprise in which the model develops organically and becomes increasingly capable of addressing a particular complex problem.

In my own work, an example of the first is a model my group built in response to finding ways to manage the SARS epidemic that emerged in 2003[16]. Examples of the second are computational methods that can be used on many different data sets, such as the methods my group has developed for calculating individual or populations landscape utilization distributions[17]. I have not personally been involved in the third type of modeling endeavor, since it represents a long term, well funded, commitment taken on by substantial groups or institutions set up to address particular problems, such as the US GLOBEC program[18] that has been set up to investigate how physical processes affect the structure and dynamics of marine ecosystems and to predict the effects of climate change and variability on these systems. All three models reviewed here are used in the context of the first approach to modeling listed above. They all lack the accuracy and precision needed to be used as tools—but this is not surprising since the problem of predicting "take" rates from acoustic harassment is too complex a problem to lend itself to solution by a general modeling tool. Only the NUWC+ESME module has elements of modeling approach 3., but in terms of scientific credibility the physical module of the enterprise is too far ahead of the biological module for the whole enterprise to be credible. Thus, what is needed is a much better articulation and implementation of the "*necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities.*"

14. Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

Following on from my response to requirement 13., the application of the models to exploring and comparing different scenarios, particularly in the context of comparatively evaluating different

[16] Lloyd-Smith, J., A., Galvani, W. M. Getz, 2003. Curtailing SARS transmission within a community and its hospital. Proc. Royal Soc. B. (Lond). 270:1979-1989.

[17] Getz, W.M, S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, C.C. Wilmers, 2007. LoCoH: nonparametric kernel methods for constructing home ranges and utilization distributions. PLoS ONE 2(2): e207. doi:10.1371/journal.pone.0000207.

[18] For example see http://www.usglobec.org/features/synthesis.php

measures that may be undertaken to mitigate the effects of acoustic harassment on "take" rates, can be of considerable value in designing operations with significantly reduced harassment levels compared with current operations. This is an activity for which all three models could be used but has been largely been ignored in the current EIS/OEIS process.

In conclusion, I reiterate that both the NUWC and SAIC modeling teams have shown considerable diligence in trying to meet the demands of the EIS/OEIS process laid out by NFMS. However, during my participation in the review reported here, I have become convinced that the models are being inappropriately used to generate "take" rates as though these rates are both accurate and precise and have meaning in their own right. To the contrary, there is no evidence that the rates are accurate, they are likely biased, though probably on the conservative side; and they provide no insights into issues relating to the potential occurrence of catastrophic events, however we want to define a catastrophe. Further, the models have potential to be used as tools for designing less invasive exercises or operations, but they or not used in this regard. They also need to be more closely tied to the design of monitoring and reporting procedures that can lead to better estimates of model parameters in the future, but I have seen no evidence of this feedback loop between the collection of biological data and the modeling enterprises in the EIS/OEIS documents. I think the ball is now in the NMFS court to find a more constructive and informative way for models to be used in the EIS/OEIS process.

Appendix 1: Statement of Work

Statement of Work for Dr. Wayne Getz

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
and
Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model

Background and Scope of Work

The National Marine Fisheries Service (NMFS) requires an independent peer review of the Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) marine mammal acoustics exposure effects analysis models (the processes these two groups use to perform the analyses described herein involve more than the use of single models, but will be broadly referred to as "models" for simplicity in this document) which shall assess whether they correctly implement the sub-models and data upon which it is based, whether they adequately assess all relevant physical and biological variables in assessing effects on local marine mammal populations, and whether they meet the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines for models, which primarily involve scientific credibility. The review of the NUWC model will include an assessment of the current model (used for the Atlantic Fleet Active Sonar Training (AFAST) with additional analysis of the Effects of Sound on the Marine Environment (ESME) behavioral module, which the Navy intends to incorporate into the current model moving forward.

Minimizing and mitigating the potential effect of sound upon the environment is an increasing concern for many activities. Naval operations, seismic exploration, vessel and aircraft operations, certain construction activities, and scientific investigations now need to consider the potential effects underwater acoustic sources have on marine life. Marine mammals are usually the primary concern, due to their widespread distribution and excellent hearing ability, although impacts on fish are increasingly being considered as well. Predicting the exposure of marine mammals is complicated by several factors: a general lack of data to support a comprehensive understanding of density and distribution; horizontal and vertical movement patterns; any long-range migratory behavior; and a lack of understanding of exactly how potential sound avoidance behaviors may impact the levels of sound to which marine mammals are exposed.

Acoustic propagation and received sound levels are a function of water depth, range from the source, sound source characteristics, and a number of environmental variables. These issues, combined with the variable spatiotemporal distribution and movement of different species, contribute to a very complex problem. The NUWC and SAIC models address these specific complications in similar ways. The models predict a received level at range and depth in a 3-dimensional grid (x,y,z), then overlay the marine mammal density (animals/km^2) for each species on the 2-dimensional (x,y) grid. The third dimension (z) can be applied through the use of animal distribution in depth for a percentage of time if that data are available. Biological distribution and movement can be based on regional and seasonal behavioral data for each species evaluated. Acoustic sources are programmed to move through a virtual acoustic environment based on external environmental databases and radiated sound fields created from a selected propagation model (e.g., Comprehensive Acoustic Simulation System/Gaussian RAy Bundle (CASS/GRAB), or Range-dependent Acoustic Model (RAM)) The integration components of the NUWC and SAIC models make use of the high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation in MATLAB®. The end results of modeling represent estimated accumulated exposures above a specified criteria threshold (permanent threshold shift – PTS or temporary threshold shift – TTS) of animals for each source, scenario and marine mammal combination presented in a spreadsheet. The model also predicts received sound pressure levels that are then applied to a risk function curve to predict the probability of behavioral harassment.

For the SAIC model, the Navy developed several post-modeling corrections that *can* be applied to the output of the model to make it more realistic. These post-modeling applications quantitatively address the following factors, which are not accounted for in the models described above:

- Acoustic footprints for sonar sources do not account for land masses.
- Acoustic footprints for sonar sources are calculated independently, when the degree to which the footprints from multiple ships participating in the same exercise would typically overlap may be taken into consideration.
- Acoustic modeling does not account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

For the NUWC model, the Navy has developed the Effects of Sound on the Marine Environment (ESME) behavioral module that can be incorporated into the NUWC model to more accurately represent some of the biological variables of concern, such as animal movement and behavior. Reviewers will be asked to assess the NUWC model both with and without the inclusion of this module.

NUWC and SAIC both make use of Navy standard sub-models and databases that are housed at the Oceanographic and Atmospheric Master Library (OAML). The Chief of Naval Operations (CNO) established OAML in 1984. The OAML suite consists of Navy-standard core-models, algorithms and databases that support the Department of the Navy (DoN), Department of Defense (DoD), and research and development laboratories that support DoD and DoN and Joint and NATO activities. OAML also supports Task Force Web and Navy Enterprise Portal initiatives with state-of-the-art Navy-standard products. Some OAML databases, included sound speed profiles and the unclassified bathymetry database are available to the public.

The NUWC and SAIC models are not proprietary; however, several input data sources are either classified or restricted to the above-listed agencies and organizations. Nevertheless, the continued use of the models to provide acoustic exposure and impact predictions for regulatory assessment purposes requires that the models be reviewed independently, so that NOAA and other federal agencies can comply with the Data Quality Act.

Overview of CIE Peer Review Process:

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract for obtaining external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of stock assessments and various scientific research projects. The primary objective of the CIE peer review is to provide an impartial review, evaluation, and recommendations in accordance to the Statement of Work (SoW), including the Terms of Reference (ToR) herein, to ensure the best available science is utilized for the National Marine Fisheries Service management decisions.

The NMFS Office of Science and Technology serves as the liaison with the NMFS Project Contact to establish the SoW which includes the expertise requirements, ToR, statement of tasks for the CIE reviewers, and description of deliverable milestones with dates. The CIE, comprised of a Coordination Team and Steering Committee, reviews the SoW to ensure it meets the CIE standards and selects the most qualified CIE reviewers according to the expertise requirements in the SoW. The CIE selection process also requires that CIE reviewers can conduct an impartial and unbiased peer review without the influence from government managers, the fishing industry, or any other interest group resulting in conflict of interest concerns. Each CIE reviewer is required by the CIE selection process to complete a Lack of Conflict of Interest Statement ensuring no advocacy or funding concerns exist that may adversely affect the perception of impartiality of the CIE peer review. The CIE reviewers conduct the peer review, often participating as a member in a panel review or as a desk review, in accordance with the ToR producing a CIE independent peer review report as a deliverable. At times, the ToR may require a CIE reviewer to produce a CIE summary report. The Office of Science and Technology serves as the COTR for the CIE contract with the responsibilities to review and approve the deliverables for compliance with the SoW and ToR. When the deliverables are approved by the COTR, the Office of Science and Technology has the responsibility for the distribution of the CIE reports to the Project Contact.

Reviewer Requirements

The Center for Independent Experts (CIE) shall provide three panelists and a moderator for the review of each of the two models. The same individual will function as moderator for the review of both models. Preferably, the same three individuals would function as reviewers for both models, however, this may not be possible due to the required expertise and scheduling constraints.

CIE shall provide expertise in the scientific discipline of underwater acoustics, modeling, and marine mammalogy.

The underwater acoustician reviewer(s):

- shall have expertise and working experience with propagation loss models
- will preferably have working knowledge of the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB, which is the main propagation model incorporated in both the NUWC and SAIC models) and/or similar propagation models.

The modeling reviewer(s):

- shall have expertise with individual-based exposure assessment models
- will preferably have experience with the above type models dealing with the integration of multiple data streams (*e.g.*, multiple databases).
- shall be able to understand the dynamic interaction of databases.

The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

The moderator:

- shall have expertise in marine mammalogy
- shall have expertise in either underwater acoustics or modeling

The CIE review shall be conducted during two panel review meetings organized around a three-day meeting at NUWC, Newport, RI and a three-day meeting at SAIC, McLean, VA according to the schedule stated herein. For each of the two reviews, each reviewer shall be required for a maximum of 15 days for reviewing pre-review documents, conducting the peer review during the NUWC/SAIC meeting, traveling, and completing the CIE reports. The moderator will need 17 days for each review.

Statement of Tasks for CIE Reviewers

Note: There are two sets of meetings (including teleconference, three days of on-site meeting, etc.), one set for review of the NUWC model and one set for review of the SAIC model. The organization of the two sets of meetings is identical, but on different dates.

For each set of meetings, the CIE reviewers and moderator shall review the pre-meeting documents in preparation for the peer review meetings, to be provided by the Project Contact in accordance with the schedule of milestones and deliverables herein (refer to listed in Annex I for preliminary list of documents). The CIE reviewers and moderator will participate during each three-day panel review meeting at (1) NUWC, 1176 Howell Street, Bldg 1346, Rm 407U, Newport, RI 02841, and (2) SAIC, 1710 SAIC Dr, McLean, VA 22102. After each meeting, the three CIE reviewers (of each model) shall complete independent peer review reports addressing all the Terms of Reference given below. The moderator(s) shall consolidate the individual reports into a summary report for each meeting. Details on the formats of the panelists' and moderator's reports are given in Annex II and III, respectively.

Teleconference Calls with CIE for NUWC and SAIC: The CIE panel and NUWC/SAIC teams will discuss via conference calls the details of the upcoming panel review meetings, providing an opportunity for the CIE reviewers to raise questions concerning background documents, specifications for trial runs, and other review-related material, including logistics. In preparation for these teleconference calls, the CIE reviewers shall review pre-meeting documents provided by the Project Contact in accordance with the scheduled milestones and deliverables herein.

Day 1 of panel review meetings for NUWC and SAIC Meetings: CIE reviewers shall participate during the NUWC and SAIC panel review meetings during the dates specified in the schedule of milestones and deliverables herein. During the meetings, the Term of References (ToR) will be reviewed and the NUWC/SAIC model presentations will be made by scientists from NUWC/SAIC, with questions and answer sessions as needed. Presentations shall include:

1) Introduction to the current NUWC/SAIC approaches (i.e., the ones used in the AFAST and HRC EISs) and the software, including data input requirements;
2) Explain incorporation of the ESME behavioral module into the NUWC model;
3) Review of results of internal testing of the software;
4) Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
5) How these exposure estimates are interpreted relative to noise exposure thresholds and/or guidelines?

6) Review all relevant post-modeling correction factors for the SAIC model
7) Review all inherent, underlying assumptions in each model

The CIE reviewers and moderator shall meet to develop a set of test runs for during the panel review meeting. The purpose of this evaluation is to determine how the NUWC/SAIC model responds to a set of inputs designed to test the model. The CIE reviewers shall also acknowledge the differences and the roles of the external components (*e.g.*, animal input parameter values, propagation models) and the internal component of the model (e.g., ship movement) in regard to the functionality of the model The distinction is drawn here to emphasize that the values of animal placement parameters can and should change when new data are available, and that both models can utilize that new data. Navy staff will provide a comprehensive list of all of the parameters that can be input or changed by the users, versus those that are internal components. Example scenarios for devising these runs are provided in Annex IV.

Days 2-3 of the panel review meetings at NUWC and SAIC: CIE reviewers and the moderator shall work with NUWC/SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. For the NUWC model, the scenarios will be enacted both with and without the ESME behavioral module so that the reviewers can assess both. For the SAIC model – post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of NUWC/SAIC scientists as required, design simulations and request that the NUWC/SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because NUWC/SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, NUWC/SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, NUWC/SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

Terms of Reference

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

1. <u>NUWC/SAIC Model Implementation</u>

Details relevant to the topics described below are given in the documents identified in Annex 1.

- Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

  i. accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the NUWC/SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC/SAIC models*

  ii. correctly handle the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

  iii. correctly and efficiently extract data from databases? If not, identify any errors. The NUWC/SAIC models use the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.
- Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar or explosives based on current scientific knowledge, such as:
  i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference))
  ii. Marine mammal movement (horizontal and vertical)
  iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

- Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?
- Does the NUWC/SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?
- Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model would likely result in over/underestimates of take (and the degree, if possible)

2. <u>CREM Guidelines</u>

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points

listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

Schedule of Milestones and Deliverables:
The CIE shall complete the milestones and deliverables in accordance with the schedule of activities provided in the following table.

Activity and Responsible Party	Date
NMFS Project Contact will provide pre-meeting background documents to CIE	17 October 08
CIE reviewers and moderator(s) shall participate in a teleconference call with NMFS, NUWC and SAIC to discuss technical and logistical details of the peer review meetings (depending on availability of participants).	27 October 08 1pm 866-620-3559 Passcode 6243699#
CIE reviewers and moderator shall participate in panel review meeting at NUWC to test models Address - 1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841	**12-14 Nov 08**
CIE reviewers and moderator shall participate in panel review meeting at SAIC to test models Address - 1710 SAIC Dr, McLean, VA 22102	**17-19 Nov 08**
CIE reviewers shall submit their CIE independent peer review reports to CIE and the CIE moderator(s)	5 December 08
CIE moderator(s) shall submit their CIE summary report(s) to CIE	17 December 08
Upon CIE Steering Committee review and approval, CIE shall submit the CIE independent and summary reports to the NMFS COTR for review and approval in accordance with the ToR	24 December 08
CIE shall submit the final CIE reports in PDF format to the NMFS COTR	5 January 09
NMFS COTR will distribute the final CIE reports to the NMFS Project Contact for distribution	12 January 09

Acceptance of Deliverables:

Each CIE reviewer shall complete and submit an independent CIE peer review report in accordance with the ToR, which shall be formatted as specified in Annex 2, to Dr. David Sampson, CIE regional coordinator, at david.sampson@oregonstate.edu, and Mr. Manoj Shivlani, CIE lead coordinator, at shivlanim@bellsouth.net. Upon review and acceptance of the CIE reports by the CIE Coordination and Steering Committees, CIE shall send via e-mail the CIE reports to the COTR (William Michaels

William.Michaels@noaa.gov at the NMFS Office of Science and Technology by the date in the Schedule of Milestones and Deliverables. The COTR will review the CIE reports to ensure compliance with the SoW and ToR herein, and have the responsibility of approval and acceptance of the deliverables. Upon notification of acceptance, CIE shall send via e-mail the final CIE report in *.PDF format to the COTR. The COTR at the Office of Science and Technology have the responsibility for the distribution of the final CIE reports to the Project Contacts.

Key Personnel:

Contracting Officer's Technical Representative (COTR):

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Request for SoW and ToR Changes:

The Statement of Work (SoW), Terms of Reference (ToR) and list of pre-review documents herein may be updated without contract modification as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToR are not adversely impacted. Any such requests for changes to the SoW and ToR shall be submitted to the COTR (Contracting Officer's Technical Representative) for approval no less than 15 working days prior to the CIE peer review meeting.

ANNEX I: Documents to be reviewed in preparation of the NUWC/SAIC model review. This is a tentative list and will be further refined and specified prior to the review time. Documents may be provided on an ftp site because of large size.

Document Titles
1. NUWC Marine Mammal Acoustic Effects Analysis
2. Numerical Simulation of Undersea Detonation Effects on Marine Species Life
3. NUWC Environmental Modeling for Marine Mammal Acoustic Effects Analysis
4. Oceanographic and Atmospheric Library (OAML) Summary
5. Insert PowerPoint presentation on SAIC model
6. Marine Resource Assessment for SOCAL
7. Source of density for SOCAL

Document	Document Type	Number of Pages	Degree of Difficulty
1. NUWC Acoustic Model	PDF		
2. NUWC Explosive Model	PDF		
3.NUWC Environmental			
4. OAML description	PDF	113	Low
5. SAIC Presentation	PowerPoint		
6. MRAs	CD/Hardcopy		
7. SOCAL Density			
8. Acoustic appendices from EISs for both the SAIC and NUWC models	PDF		

ANNEX II: Format and Contents of CIE Independent Reports

1. The report should be prefaced with an Executive Summary with concise summary of goals for the peer review, findings, conclusions, and recommendations.

2. The main body of the report should consist of an Introduction with
    a. Background
    b. Terms of Reference
    c. Panel Membership
    d. Description of Review Activities

3. Summary of Findings in accordance to the Term of Reference

4. Conclusions and Recommendations in accordance to the Term of Reference

5. Appendix for the Bibliography of Materials used prior and during the peer review.

6. Appendix for the Statement of Work

7. Appendix for the final panel review meeting agenda.

8. Appendix for other pertinent information for the CIE peer review.

ANNEX III: Moderator's Summary Report Generation and Process

1. The summary report shall include an overview of the review process.

2. The summary report shall provide a synopsis of the three panelist reports.

3. Points of agreement and disagreement among the panelists shall be documented.

4. The summary report shall also include as separate appendices copies of each of the panelists' report.

ANNEX IV: Example NUWC/SAIC Scenarios: The panel shall create their own scenarios to be sure that their questions are addressed and answered. Reviewers will develop the scenarios in close coordination with the modeling team to ensure that the scenarios are feasible. The examples below illustrate the type of scenarios that the NUWC/SAIC models can address. They cover two sources of anthropogenic noise from mid-frequency active sonar and underwater explosives. Development of scenarios (including identification of the necessary input parameters) will be addressed during the conference call and the first day of the meeting.

1. A vessel quipped with a mid-frequency (1-10 kHz) active sonar source operating in the Southern California Range Complex (SOCAL) in May. The vessel will be on the range for three days conducting sonar operations during daylight hours. The active sonar signals are one second long broadcast once a minute with a source level of 235 dB re 1 µPa at 1 meter. The active sonar can be operated in two modes; namely, search and track. The ship is moving at 10 kts randomly in a 40 km square operational area. The question to be addressed is how many bottlenose dolphins are modeled to be exposed to a received level that would lead to MMPA Level A (PTS) and Level B (TTS and behavioral) harassment if the operation goes forward? Alternatively, how would the acoustic exposure be altered if the exercise were conducted in January?

2. A similar scenario as above but instead of using mid-frequency active sonar, an explosive source will be used. Input parameters include (among others) the net explosive weight, the explosive depth, the average sediment depth and the seasonal sound speed profile.

Appendix 2: Meeting Agenda

Agenda for NUWC Meeting in Rhode Island (November 12 -14)

1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841
Navy POC – Peter Hulton - 401-832-1797

Day 1
8:00 - Introductions and Logistics (bathroom, emergency exit, etc.)
8:15 - Review of ToRs (Moderator)
Presentations by NUWC Personnel
8:45 - Description of current NUWC approach (i.e., the one used in the AFAST and East Coast Range Complex's EISs) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all of the model parameters (including for ESME) that can be input or changed by the users, versus those that are internal components.
10:15 - Break
10:30 - Discussion of the ESME behavioral module and its incorporation into the NUWC model
11:30 - Review of results of internal testing of the software
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.

Day 2
8:00 – Development of Input Data for Trial Run (AFAST/ECRC EIS Method)
10:00 – Trial Run (AFAST/ECRC EIS Method)
12:00 – Lunch
13:00 – Review of Results
15:00 – Development of Input Data for Trial Run (3D Mammal Method)
16:00 – 3D Marine mammal simulations

Day 3
8:00 - Trial Run (3D Mammal Method)
10:00 – Review of Results
12:00 – Lunch
1:00 – Review of Report format, contents, and due dates (Moderator leads)
1:30 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
2:30 – Wrap-up

Agenda for SAIC Meeting in Arlington (November 17-19)
4001 Fairfax Dr, Suite 175, Arlington, VA 22203, Navy POC – Hyrum Laney 703-907-2552

Day 1

9:00 – Introductions, Logistics, Security
9:15 - Review of ToRs (Moderator)
9:30 – Welcome aboard from SAIC Acoustic and Marine Systems Operation Manager
Presentations by SAIC Personnel
9:45 - Description of current SAIC approach (i.e., the one used in the SOCAL and HRC EIS) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all the model parameters that can be input or changed by the users, versus those that are internal components.
10:45 - Break
11:00 - Review of post-modeling correction factors for the SAIC model.
11:45 - Review of results of internal testing of the software.
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution, behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model.
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.
5:00 – Conclude Meeting

Days 2 and 3 (Navy Contacts will break this general description down into smaller pieces in advance of the meeting)

CIE reviewers and the moderator shall work with SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. Post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of SAIC scientists as required, design simulations and request that the SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

9:00 – Development of Input Data for Trial Run (HRC/SOCAL EIS Method)
11:00 – Trial Run (HRC/SOCAL EIS Method)
12:30 – Lunch
13:30 – Review of Results, or continue review of results to Day 3.
Day 3 continued
9:00 – Review of Report format, contents, and due dates (Moderator leads)
10:00 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
11:30 – Wrap-up

Revised Final Report by

Jeanette A. Thomas

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)

Marine Mammal Acoustics Exposure Analysis Model

10 December 2008

Role on External Peer Review Panel: The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

Note that recommendations are highlighted in red.

I. Terms of Reference for evaluating the NUWC MODEL

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

General Comments on the NUWC model:

Under the Marine Mammal Protection Act, US Navy operations must apply for a permit from National Marine Fisheries Service to take marine mammals, at Level A and Level B harassment. These data are also needed by the US Navy for Environmental Assessment documents. The NUWC model is a method of predicting the number of takes of marine mammals at three levels: behavioral (received SPL level between 120 dB re 1 µPa and TTS level), Level B, TTS level (received SEL level 195 $\leq$ 215 dB), and Level A, PTS level (received level SEL $\geq$ 215 dB). The advantage of such a model is to simulate Navy operations of different types, at different locations, with different number of sound sources, and during different seasons. Using the estimated number of takes from the NUWC model output, operations potentially can be adjusted to reduce the number of marine mammal takes. Because of the difficulties of accurately observing marine mammal behavior at sea, the Navy cannot count the actual number of takes; rather they input into the NUWC model the number of hours of operation and how much sound was put into the water during the exercise in a specific area. Based on the available data on animal densities and distribution in the operation area, the NUWC model estimates the number of takes on a given species. Data typically used by the Navy on bathymetry, sound velocity profiles, wind speed in the operation area are input to the NUWC model and standard Navy acoustic propagation models are employed to predict the noise field around a sound source. Because of evidence that at least one species, the harbor porpoise, showed a behavioral response to sounds at a 120-dB received level; the NUWC model examines sound fields out to a level of 120 dB from the source. The NUWC model has the advantage of being able to estimate the number of marine mammal takes when there are multiple sounds sources operating at different times (this is a likely "real world" situation for most Navy operations).

During the review meeting, it was useful to conduct two Trial Runs of the NUWC model; Trial 1 was a single sound source and Trial 2 had three sounds sources that operated at different times during the operational window. The reviewers expected to see the results from the same two Trial Runs at the SAIC meeting, but SAIC only provided the output from their model for Trial Run 1.

The output spreadsheets of the NUWC model for Trial Runs 1 and 2 were easy to read and interpret, it was useful to see the raw number of estimated takes for the behavioral, Level B (TTS) and Level A (PTS) and the rounded number of takes in these categories. The rounding off takes up if the raw data are greater than or equal to X.5 and rounding down if less than X.5, which seems like a good practice.

Because of recent concerns about beaked whale strandings and military sonar operations, it was important to use a beaked whale as a species in Trial Runs 1 and 2; however, the spreadsheet reports output from the Cuvier's beaked whale, whereas the dive profile given in the presentation was from the Blainville's beaked whale. The presenters also used two mysticete whales, fin and blue whales, as other species for Trial Runs 1 and 2. It would have been useful to see the results from an odontocetes and pinnipeds, as well. Because the pinnipeds studied so far have a more sensitive hearing ability, they may be "taken" more often than cetaceans.

Comparing the output from Trial Runs 1 and 2, they both verified that takes would be slightly greater during the summer than during the winter. The addition of multiple sounds sources in Trial Run 2 did slightly increase the number of behavioral takes during the summer. The output from Trial Runs 1 and 2 did not indicate a Level B (TTS) or Level A (PTS) take during either season.

5. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).

<u>Comments relative to including ESME in the NUWC model:</u>

Effects of Sound on Marine Mammals (ESME), marine mammal behavioral component of the NUWC model, was developed by ONR not just for EIS estimates of takes, but also as a monitoring & mitigation tool and as a research tool. The goal of the model is to add real 3-dimensional data on wild marine mammal dive profiles (time spent at surface and various depths), which are different among species. This model can be updated as new data become available. For example, recent data by Robin Baird shows significant differences in odontocete behavior during the day and night, which could be an important factor in establishing animal densities during operational hours.

One benefit of the ESME model is the moving animats, which make it easier for the public and non-researchers to visualize marine mammals moving throughout a possible zone of influence around a sound source and through various depths. The ESME model ensures that the best available data on marine mammal movement is incorporated. To date, dive profile data are for cetaceans have been incorporated, with a plan to add information on pinnipeds.

The literature on the behavior of marine mammals shows significant variation among species, by time of day, by season, by sex, by age, and by individuals, so the task of incorporating this variation into a model is complicated (Southall et al., 2007). Documenting such variability is an important research need and new data will serve to refine the ESME model.

If a Navy operation is long, i.e., more than 24 hours, animals may typically converge in certain bathymetric areas to feed. The ESME model may be especially important, to address a change in behavior in the animals over a day that changes their distribution to be clumped in particular grids of the operation area, which would change their probability of exposure to noise.

The most important feature of the ESME program would be the inclusion of variables that affect animal densities for a given species. The output of NUWC is highly dependent on accurate inputs of animal density. Those variables that could adjust animal densities to be more specific to a particular operation include: 1) time of day (especially important in species that feed during the night and rest during the day and for pinnipeds that often have a diel haulout pattern), 2) age (especially important for species in which young animals remain in separate groups from adults and important for groups that might have calves), 3) sex (especially important for species in which males and female live and feed in different areas outside their breeding season), and 4) the particular species of marine mammals that reside in the operational area. Some species naturally exist in mixed-species herd for cooperative feeding, whereas, if predator and prey species are in the area of an operation their response to the noise may be different than if they were not in a potential hunting situation.

I encourage the investigators to continue development of this model, which will help identify any important behavioral indicators related to behavioral takes. However, given the small amount of data available on marine mammal dive profiles, especially in pinnipeds, the use of the NUWC, three-dimensional model, but without moving the animats is likely to be sufficient for estimating takes. By adding animats randomly in the operation area box at a species' preferred depth, and leaving them stationary, they serve as dosimeters for that specific point in the operation area. It is probably more important to know the location of the source by distance to the animat and the received level at that stationary animat based on propagation conditions. Computation time can be reduced by having the animats stationary.

A. Animal distributions and densities

The biggest problem with all models of this type is their dependence on available density and distribution in space and time information for a given species. There are some data for odontocetes and a few mysticetes, but little data are available for pinnipeds at sea. Pinnipeds typically congregate at haulout areas, when seen at sea are difficult to identify to species, and may "boat-follow" to feed on discarded material from the boat, so accurate estimates of pinniped densities may be unreliable. Even though pinnipeds have more sensitive hearing, so might likely be more impacted by noise, they have the ability to haulout and at certain times of the year remain hauled out for long periods. The NUWC model should be adapted to include the typical amount of time spent in the water, in a given area, and during a given season. This likely would serve to reduce the number of takes of pinnipeds.

One way to examine the distribution and density of marine mammals in an area in which the Navy plans to operate is to conduct a survey of the animals 1 week before the operation and 1 week after the operation. Such a pre- and post-operation study would provide another way of monitoring the possible effects of their operations on marine mammals.

The NUWC model examined effects at the individual animal level, but many of the review panel stated it might be better to examine density effects on groups of marine mammals in a given species within the operation area. In other words, do all marine mammals nearby a source shift their distribution or change their density during Navy operations?

The NUWC model distributed animals in a uniform manner throughout the operational area. This is one way to examine effects, but if a species is known to have a clumped distribution in an operational area, simulations could be run with that distribution instead.

B. <u>Animal Movements and Behavior</u>

The available literature on the behavior of marine mammals shows significant variation among species, by time of day, by season, and by individuals, so the task of incorporating this variation into a model is complicated. Marine mammal responses to noise can lead to varied responses i.e., ignore the sound and continue typical behavior, temporary startle response but remain in the same area, significant startle response leading to the abandonment of behavior and leaving the area, acclimation to the sound over time, and even attraction to the sound's source. Data presented by Southall et al. (2007) summarized all these various responses and even provided examples of the same species reacting differently based on their previous experience with noise. Furthermore, an animal's willingness to tolerate noise may be largely based on whether it is engaged in biologically important behaviors, such as feeding or breeding.

A significant problem is that animals could change their behavior after their first exposure to noise and those changes could range from avoidance to acclimation. The ESME component of the NUWC model does not incorporate changes in behavioral response after the first exposure to the sound. This would be difficult to incorporate into the model since responses are varied, but the modelers should consider this fact. This changed behavior could affect the number of estimated takes.

Currently, the zone of influence used in the NUWC model extends out to the 120 dB received level; however, recent data indicate that a beaked whale reacted to playbacks of sounds from killer whales at a received level of 110 dB. Should the zone of influence be extended out to the 110 dB level? This would be a vast area, but how would the NUWC/ESME model be able to detect such a level. Perhaps the sound of the predatory killer whale was more influential than the decibel level of exposure.

C. Seasonal and temporal differences in distributions and densities of marine mammals

The NUWC model does not incorporate the presence of plankton in the water column, which can vary seasonally in a local area. For mysticetes, knowing the distribution of plankton in the area at a time of operation could greatly affect the animal's movement, distribution, density and behavior.

The NUWC model output provides data for the summer and winter estimated takes, which is useful, and based on these Trial Runs 1 and 2, it seems that summer takes are typically higher than winter takes, which is biologically sensible. Thus, the NUWC model has the ability to modify the number of hours of operation in summer and in winter to reduce take.

The ESME component of the NUWC model could incorporate known diel behavioral patterns in marine mammals. Several species of dolphins are known to feed at night and rest during the day, thus the hours of operation could affect the animal's behavior differently. The model could be adapted to incorporate different animal densities based on whether the operation is conducted during the day or night, when data are available for a particular species. Currently data are not available to predict whether noise would have a more significant effect if disturbing resting or if disturbing feeding.

Many pinnipeds species haul out at predictable times of day. If a given pinniped species typically is not in the water during the hours of operation that should reduce the take estimate. Again, adding a day/night option to the model might better reflect the needed number of takes for pinnipeds.

D. Age and sex differences in marine mammals

For some species of marine mammals there are enough data about behavioural differences by age and sex of individuals to incorporate into the original animal densities to the NUWC model. Where available, the ESME component of the NUWC model could incorporate these differences. This may be especially important for species in which males and females are only together for a short breeding period then feed and live in different areas outside the mating time, i.e., elephant seals, humpback whales, gray whales. If operations in are the breeding area of a species that are together for only a short time, the potential for noise impacts should be higher. If operations are in an areas comprised of a particular sex, there might be a disproportion effect on the males or females.

In some marine mammals, different age classes exhibit different distributions, densities, and behaviours. It is unknown whether young individuals in a species would be more susceptible to noise impacts than more experienced adults.

Adding information on the behaviours of different age and sex classes to the ESME model might produce very different number of takes in some species.

E. Factors affecting sound propagation

As stated in the Terms of Reference, the review panel was not required nor given access to the particulars of the oceanographic data and sound propagation models used as inputs to the NUWC. I can only assume that because these data are of great importance to Navy operations that they are the best available. However, in discussions at the review there seemed to be situations where bottom features, i.e. rocky versus sandy bottom even assuming a flat bottom, the received level could vary by as much as 20 dB. I defer to Dr. Erbe, the propagation specialist on the review panel, on this point.

The original model provided to the Navy by SAIC designated 36 provinces (based on bathymetry, bottom types etc.) in warm and in cold season, in the Gulf of Mexico and along the Atlantic Coast, all had a flat bottom, but were limited to 100 km. Because of NMFS extending the zone of influence out to the 120-dB received level, NUWC modified the model to run out to 150 km. The model further partitioned the percent of each province that was near shore, at the continental shelf break, and deep water. The use of provinces and partitioning into three zones is a good method to identify differences in sound fields in different physical oceanographic conditions. However, these provinces may or may not appropriately reflect ecological/habitat differences, which are most important to the abundance, density, and distribution of animals over the operation area.

The presenter noted that the CASS model will only accept one sound velocity profile at a time, resulting in the need to rerun the NUWC model at different distances from the source.

Each province had a single sound velocity profile, single bottom type, and single frequency from the sound source for the winter and for the summer. Is this sufficient to represent the typical variation in sound propagation in an area as large as a province, especially considering that a province could be composed of near shore, at the continental shelf break, and deep water zones?

6. **Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC models**.

The NUWC model had these assumptions:

A. The Navy models and data bases used to create the sound fields around a source are adequate. I can only assume that because these data are of great importance to Navy operations that they are the best available.

B. Animats are fixed (in the 2-dimensional animal density model) and moving in the 3-dimensional model. The review panel agreed that it was not necessary to move the animats, but rather place them uniformly in the operational area and let them accumulate noise in that location, as if they were a noise dosimeter.

C. If signal is less than 150 Hz and in shallow water the NUWC model used a different propagation model, RAM, to calculate propagation. To be able to examine the special conditions of a low frequency sound in shallow water is an important feature of the NUWC model.

D. NUWC based on a 40 km square area provinces. Whether this is an adequate area to describe variation in the operational area depends on the local bottom topography, and bathymetry; however, the NUWC model also examines province zones of the near shore, at the continental shelf break, and deep water to examine sound fields in more detail.

E. NMFS specified the need for the Navy to model out to 120-dB received level for continuous, non-pulse sources and out to 160 dB for pulsed sources.
These are criteria based on recent available data on responses of marine mammals to noise.
The NUWC model is adaptable to either criterion.

F. The NUWC model assumes an animal can only be taken once in a 24-hour day (or length of the exercise, whichever is shorter); it could be taken twice on two consecutive days. Biologically this is a reasonable assumption because the behavior of many animals reflects a diel change in feeding. However, this procedure does not allow for recovery time between exposures. In the "real world" of exposures there may or may not be a recovery time if operations last more than 24 hours.

G. The NUWC model assumes that every animal has the same probability of a take if the original distribution is uniform in the operational area. This is an assumption that simplifies calculations. The NUWC model does incorporate the probability of take being different among species. Incorporating age and sex differences into probability calculations of the

ESME model might help refine the fact that there may not be an equal probability of take in all animals.

H. The NUWC model assumes that each new day the same animal could be taken. This is a reasonable assumption.

I. The NUWC model assumes a uniform distribution of marine mammals in the operation area. This assumption simplifies the calculation, but for some species in some provinces and some times of year their distribution may be clumped.

J. The NUWC model assumes the hearing of marine mammals is omnidirectional. This is a reasonable assumption.

K. The NUWC model assumes that energy accumulates over a 24-hour period
This assumption is valid. The 24-hour period is used as a time-frame to estimate human hearing damage.

7. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.

I discuss the post-modeling correction factors in the SAIC report. I am not sure if the current versions of the SAIC and NUWC models use significantly different post-modeling correction factors.

8. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) model meets the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

See comments below.

3. NUWC Model Implementation

Details relevant to the topics described below are given in the documents identified in Annex 1.

Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

i. accurately and efficiently implements the propagation model? identify any errors in the implementation. The propagation model implemented in the NUWC model is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC model.*

The NUWC model accurately implemented the propagation models. However, the time required to make a run is significant.

The CASS/GRAB model will only select a single frequency, so it assumes all species will hear that frequency and then sorts things out in post-processing. Why not calculate if a species could hear the signal initially from a lookup table, this would save a lot of processing time?

The data bases DBDBV, GDEM, HFBL, US Navy Marine Climatic Atlas of the World, and OMAL have been used by the Navy for years to generate sound propagation models. The presenter noted that the Office of Naval Research has studied the uncertainties of the CASS/GRAB model using these data bases and a report exists, but is not available to the Review panel. The areas of Navy operations are tested and extremely well known by the Navy. Expertise by propagation modelers is very important in selecting the appropriate model and inputs to those models based on the area.

Each application of NUWC is looked at individually to make sure the appropriate propagation model and input data are used.

The NUWC model uses a standard Navy training program, PC-IMAT, to take a quick look at the scenario to know how far away from the sound source the model should be run to extend out to the 120-dB level, and then propagation is measured in 25 m increments from the source. This is a much larger increment than the 5 m approach used by the SAIC model, but I believe 25 m should provide sufficient details of the sound field.

I question whether using a single bottom type, single frequency source, one of two seasons, and a single sound velocity profile per province appropriately accounted for natural variability in sound fields that might occur during an operation; however, to make more detailed measurements of the sound field would be a huge computation, so likely is not practicable.

The animal area density model eliminates land masses from the sound field to create a sound source footprint in the operation area. This is an important feature of the NUWC model, which likely reduces the number of animals that could be exposed in an operational area.

A set of model should be run to detect any peculiar results around nearby islands, above sea mounts, or near shore.

NUWC's model averages 3 month of oceanographic data to come-up with the typical summer and winter propagation. This is a long time window during which many features of the water column could change that are of biological importance to marine mammals; perhaps NUWC should start modeling a typical month's propagation.

ii. correctly handles the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

NUWC does analysis on a classified computer and then generates handouts of the analyzed data.

I question whether using a single frequency in the model adequately represents the animal's ability to hear the sound. How is this frequency selected? If the sound is sonar, selecting a single frequency would be reasonable, but if the sound is a torpedo, helicopter, or ship noises it is composed of a complex broadband signal. Is the frequency modeled at the most sensitive hearing in a given species or the frequency of the sound source with the highest amplitude? Is a different frequency used for the mysticetes, odontocetes, and pinnipeds or is the same frequency used for all runs, then interpreted after the fact based on the species hearing range?

iii. correctly and efficiently extracts data from databases? If not, identify any errors. The NUWC model uses the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.

The attached Table 1 compares the NUWC and SAIC outputs for Test Run 1 during summer and winter for blue whales, fin whales, and Cuvier's beaked whales. Note the two models used different animal densities and different areas of operations, which might account for some of the differences in the number of takes. The NUWC model also used a much greater operation area for the beaked whale compared to the blue and fin whale.

A standard deviation around the number of takes cannot be calculated from a single run. NUWC should consider providing the number of takes with ± SD by gathering data from multiple runs.

Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonars based on current scientific knowledge, such as:

i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference).

Use of the uniform distribution of animals in the operational area might under estimate takes in some provinces and over estimate takes in other provinces. Could the NUWC model stratify certain provinces as having a non-random distribution? However, such detailed data may not be available for some species in some operational areas.

ii. Marine mammal movement (horizontal and vertical)

In the animal density model, animats are stationary and in the ESME model animals move randomly outwards from their original placement site. Some species may have preferred habitats in the three zones (inshore, continental shelf, and deep water), so animats for particular species could be placed in their preferred zone initially, rather than randomly assigned over the entire operation area.

iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

The NUWC model assumes that all marine mammals hear the frequency used in the model. In fact, there is significant variation among hearing in mysticetes, odontocetes, and pinnipeds; both in frequency range and hearing sensitivity. For mysticete whales, the only available data are from anatomical, histological, and CT scans of the minke whale, a relatively small baleen whale (Ketten and Mountain, 2008; Mountain, 2008). Yet, the NUWC Trial Runs 1 and 2 concentrated on fin and blue whales, for which very little is known about their hearing. In the future, the NUWC model should concentrate on minke whales, as a representative mysticete species.

The hearing of several odontocetes has been anatomically, behaviorally, and physiologically measured. Southall et al. (2007) divided hearing in odontocetes into high-frequency and mid-frequency groups. The underwater hearing of the California sea lion, harbor seal, and elephant seal has been examined behaviorally and physiologically. The underwater hearing of the ringed seal has only been measured behaviorally. Pinnipeds tested so far have a greater sensitivity in the best part of their hearing range than odontocetes, so should be of more concern relative to the impacts of noise. The NUWC modeling efforts should concentrate on pinnipeds, which are more likely to be impacted by noise than either odontocetes or mysticetes.

It is possible that with broadband sound sources, like a torpedo, ship noise, or helicopter noise, certain species would hear only part of the frequency range of the sound or that if the model frequency is not selected properly it would be examining a frequency either outside or at a reduced hearing sensitivity.

The NUWC model only addresses the topic of harassment relative to noise exposure, it does not account for the visual presence of a tall ship, moving torpedo, or helicopter flying over head. Visual and moving objects may affect whether the noise from a source causes a reaction. They may even be more important in eliciting a response than the noise itself.

Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?

The NUWC used the highest animal density available, which would lead to a more conservative take.

Does the NUWC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?

The NUWC model appropriately uses SPL levels to calculate behavioral takes and SEL to calculate TTS and PTS takes. SPL is a sound pressure measurement with no time dimensions. SEL is an energy measurement taken over a standard time, so it is comparable among studies and among model runs. SEL measurements also allow the accumulation of noise over time of the operation and accumulation of noise with multiple sound sources.

Recent data by Finneran showed TTS in a bottlenose dolphin after only 15 sonar pings with an SEL of 214 dB. Should the NUWC revise the Level B (TTS) criteria to be less than 214 dB? This may be a NMFS decision, rather than a decision by NUWC.

Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)

A. Strengths of the NUWC model:

One advantage of NUWC model is that it can calculate the marine mammal take when multiple sound sources are operating at the same time.

If the ESME behavioral component is used the model also allows for animal movement for a particular species.

The model does not assume a 20 km distance between sound sources, as the SAIC model. The NUWC model does not make such a restriction.

In deep water, the NUWC model uses 8 radials; however, if operations are near land more radials can be added to assess finer details of the sound field.

If an animat has not accumulated enough energy over an operation to trigger a Level B (TTS) take, then the accumulated acoustic energy falls back into the behavioral category to examine a possible behavioral harassment take.

The NUWC model can overlay the acoustic footprint over the bathymetry to examine why sound propagation might be better or worse in certain radials.

The NEMO, 3-d version of the NUWC model, allows the animats to be seeded in preferred habitats and in a typical distribution. The user can pick seeding options like individual, pod or pod of a certain size, location of lead animal in pod, spacing between the pods, and specify if animals are attracted to the center animal. Any of these variables that affect animal densities will affect the number of takes. The SAIC model does not incorporate these variables.

If an animat leaves the operational box another animal randomly comes back into the box in to maintain a constant animal density.

The NUWC model can accommodate more than one species in an operational area at a time.

Using the NEMO mode, the user can specify time into the operation when another sound source starts or ends.

Using the NEMO model allows measuring the exposure of a particular individual animat, exposed multiple times. Simulations of this could help determine if there should be some maximum number of times an animal should be exposed per day. NUWC modelers could produce a histogram of how many animals were pinged how many times per day. This might be used to develop a per-day limit for the number of exposures.

B. Weaknesses of the NUWC model:

Because of the Navy's need to keep operational information restricted before an operation, the modelers using the NUWC model do not always know where and when the source(s) begin in the operational area and so cannot model that into the 24-hour window needed to calculate a take.

CASS was compiled a long time ago and can only handle 16 bits, so the programming area of the model is limited to less than 32000 lines. Presenters at NUWC review reported that a new version of CASS is being developed.

Presenters noted that data on bottom type are difficult to find, however bottom type is not as important a factor as water depth in calculating propagation.

Currently, running the NUWC model takes about 1 week to process an operational area. Some reviewers suggested running more than 8 radials for finer detail of the sound field, but if an increased number of radials were run the processing time would increase. The presenters reported they are developing a new model to replace the MATLAB program which converts CASS output into the number of radials and takes. This new program should be faster and more flexible.

Perhaps interactions between species should be programmed into the NUWC model. There might be a greater effect at the interspecies level than at the individual level. Many dolphin species are known to congregate in mixed herds in the wild and some species are known to have predator/prey relationships.

The NUWC model cannot predict a catastrophic event with a large cluster of animals, such as the beaked whale strandings in the Bahamas. The model could be improved to incorporate the probability of a catastrophic event. Catastrophic events are estimated by the tails of the distribution, not the mean. The review panel suggested that bathymetry may be the best indicator of the likelihood of a catastrophic event, like beaked whales being confined to a local canyon area with no escape route in the Bahamas.

C. Possible improvements to the NUWC model:

The NUWC model should be adapted to include the typical amount of time spent in the water, in a given area, and during a given season for pinnipeds.

If a species is known to have a clumped distribution in an operational area, simulations could be run with that distribution instead of only a uniform distribution.

The NUWC model does not incorporate changes in behavioral response after the first exposure to noise.

The risk function should be applied to preferred depths of a given species at specific times of day and in specific seasons that a species typically occurs, rather than the whole zone of influence.

The NUWC model should consider incorporating plankton locations in the output of their model.

The NUWC model should incorporate known diel behavioral patterns in marine mammals, which would affect animal densities at the time of an operation.

The NUWC model should incorporate interactions between species which would affect animal densities.

Adding a day/night option to the NUWC/ESME model might better reflect the animal density and needed number of takes for pinnipeds.

Where available, the NUWC model could incorporate age and sex differences in animal densities.

NUWC/ESME should adapt their model to identify habitat types or ecological zones important to marine mammals.

The NUWC model should calculate the sound field for a particular month in a particular location, which would better reflect the animal's environment, especially during critical breeding and feeding times of the year.

NUWC might consider providing the number of takes with ± SD by gathering data from multiple runs.

NUWC could stratify certain provinces as having a non-random distribution to better reflect the clumped distribution of some marine mammals.

NUWC/ESME should develop four dose response curves based on the four ear types of marine mammals identified by Southall et al. (2007): mysticete, mid-frequency odontocetes, high-frequency odontocetes, and pinnipeds.

Because the pinnipeds have more sensitive hearing, NUWC should start modeling the effects on pinnipeds.

In the future, the NUWC model should concentrate on minke whales as a representative mysticete because it has the best available hearing data.

NUWC should model the sound field for several frequencies within the frequency range of various military operations and within the hearing range of marine mammals.

Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model) model would likely result in over/underestimates of take (and the degree, if possible)

The panel agreed to recommend making animats stationary, randomly drop them into grids in the operation box and then look at the probability of exposure to each animat, rather than having them move. However, Navy N45 required animats to move and NMFS also wanted movement in the model.

The NUWC model did not incorporate a recovery time between sound exposures. Such a recovery time would likely lead to a reduction in the number of takes.

The NUWC presenter noted that in some cases the NUWC model calculated more exposures than there are animals (i.e., right whales).

The number of takes on Trial Run 1 using the NUWC was higher slightly than the number of takes estimated using the SAIC model (See Table 1). However, animal densities and operational areas were different between the two models, so it is difficult to know how this affected the output.

The 120-dB range was requested by NMFS, but I question if 90% to 95% of the takes occur at closes ranges to the sound source (0 to 10 km), would running the model at only this close range be sufficient? It certainly would reduce calculation time. Given the limited quantity and quality of animal density and distribution data on a few species, is it necessary to examine the zone of influence out to the 120 dB range to estimate a possible 10% of additional take?

The NUWC model should provide a variance around the number of takes. However, this would likely result in needing to use the higher value of the standard deviation around the mean as the take quota.

CREM Guidelines and the NUWC model

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/ model meets the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

Have the principles of credible science been addressed during model development?

The NUWC model has been evolving and adapting since 1998. The initial area density model has no formal documentation, except for procedures and take numbers reported in different EIS reports.

The NUWC model developers maintained a series of checks and balances during the model development. Twelve modelers working at six work stations in the same laboratory constantly view and comment on model output. The modelers work as a team and hold weekly meetings. When given a scenario to model, the managers meet with the Navy operations staff to insure that the model meets the needs of the Navy's operations. They review every step of the exercise, test planning, and environmental conditions. The modelers use debugging programs to detect any coding errors.

Any EIS is public information. Technical Reports on propagation results, appendices of the EIS, and the letter of authorization by NMFS are all on websites, which include information about models for each area. The patent application for the area density model was reviewed by marine mammal scientists.

The presenters stated they are preparing a formal handbook for the use of the NEMO, 3-dimensional version, of the NUWC model.

The presenters reported that several validation procedures have been conducted along the way:

a) Model outputs from some simple cases, such as two additive sources have been verified against manual calculations.
b) Vehicle dynamics such as course, speed, and run duration have been verified against test case geometries.

c) Sonar ping patterns and ping times have been verified against test cases.

The NUWC modelers performed tests during the extraction of the model to verify data integrity, such as the location of acoustic footprints, examination of propagation output that seemed anomalous, and review of output by multiple members of their team.

Specifically, the NUWC modelers verified their input and output data by:

a) Double-checking that input parameters from CASS were correct
b) Examining whether the propagation output looked logical
c) Verifying the maximum received level (typically the center of the footprint) with the computed CASS transmission loss.
d) Verifying inputs and computed parameters for both the footprint and the energy maps.
e) Incorporating diagnostic messages in the model to verify that calculations along the way were correct.
f) Verifying plots of energy maps by checking: number of acoustic sources, range size, operational area, ping repetition range, vehicle movement, beam pattern of acoustic source, and lastly that the SEL was subtracted correctly from the dose response curve to calculate the number of takes.

Is the choice of model supported given the quantity and quality of available data?

Given the ready access to databases and propagation models, the NUWC model does a good job of using available data to estimate the propagation pattern of different sound sources. The estimates of take for different species are only as good as the available data on animal densities and distributions, which in some cases is poor, but this is not a fault of the model.

How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?

The use of provinces partitioned into 3 zones (near shore, continental slope, and deep water) is a good start towards emulating natural ecosystems. Adding higher densities of species known to congregate around certain partitions in a province, rather than a uniform distribution through the provinces, would better simulate the animal's real world environment.

How well does the model perform?

Based on the outputs from Trial Runs 1 and 2, the NUWC model seems to run in a consistent manner to show seasonal differences in take and a greater take when multiple sources are used.

Is the model capable of being updated with new data as it becomes available?

The input models related to determining the sound field and zone of influence are standards used by the Navy. These models have a few selectable features to adapt to a particular environment. The major part of the NUWC model that can be adapted as new data become available is the ESME behavioral component. See comments above about the particular needs for better knowledge of mysticete hearing, incorporation of age and sex-specific behavior in a species, incorporation of diel changes in animal behavior, and better field estimates of pinnipeds distributions and densities.

Literature Cited

Darlene Ketten and David Mountain—Minke whale hearing: micro to macro analyses: Part 1 cytoarchitecture and head anatomy. Abstract of presentation to Joint Industry Program, 28-29 October 2008.

David Mountain—Modeling mysticete hearing. Abstract of presentation to Joint Industry Program, 28-29 October 2008.

Brandon L. Southall, Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr., David Kastak, Darlene R. Ketten, James H. Miller, Paul E. Nachtigall, W. John Richardson, Jeanette A. Thomas, & Peter L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals*, Volume 33, Number 4.

Appendix 1: Statement of Work

Statement of Work for Dr. Wayne Getz

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
and
Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model

Background and Scope of Work

The National Marine Fisheries Service (NMFS) requires an independent peer review of the Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) marine mammal acoustics exposure effects analysis models (the processes these two groups use to perform the analyses described herein involve more than the use of single models, but will be broadly referred to as "models" for simplicity in this document) which shall assess whether they correctly implement the sub-models and data upon which it is based, whether they adequately assess all relevant physical and biological variables in assessing effects on local marine mammal populations, and whether they meet the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines for models, which primarily involve scientific credibility. The review of the NUWC model will include an assessment of the current model (used for the Atlantic Fleet Active Sonar Training (AFAST) with additional analysis of the Effects of Sound on the Marine Environment (ESME) behavioral module, which the Navy intends to incorporate into the current model moving forward.

Minimizing and mitigating the potential effect of sound upon the environment is an increasing concern for many activities. Naval operations, seismic exploration, vessel and aircraft operations, certain construction activities, and scientific investigations now need to consider the potential effects underwater acoustic sources have on marine life. Marine mammals are usually the primary concern, due to their widespread distribution and excellent hearing ability, although impacts on fish are increasingly being considered as well. Predicting the exposure of marine mammals is complicated by several factors: a general lack of data to support a comprehensive understanding of density and distribution; horizontal and vertical movement patterns; any long-range migratory behavior; and a lack of understanding of exactly how potential sound avoidance behaviors may impact the levels of sound to which marine mammals are exposed.

Acoustic propagation and received sound levels are a function of water depth, range from the source, sound source characteristics, and a number of environmental variables. These issues, combined with the variable spatiotemporal distribution and movement of different species, contribute to a very complex problem. The NUWC and SAIC models address these specific complications in similar ways. The models predict a received level at range and depth in a 3-dimensional grid (x,y,z), then overlay the marine mammal density (animals/km^2) for each species on the 2-dimensional (x,y) grid. The third dimension (z) can be applied through the use of animal distribution in depth for a percentage of time if that data are available. Biological distribution and movement can be based on regional and seasonal behavioral data for each species evaluated. Acoustic sources are programmed to move through a virtual acoustic environment based on external environmental databases and radiated sound fields created from a selected propagation model (e.g., Comprehensive Acoustic Simulation System/Gaussian RAy Bundle (CASS/GRAB), or Range-dependent Acoustic Model (RAM)) The integration components of the NUWC and SAIC models make use of the high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation in MATLAB®. The end results of modeling represent estimated accumulated exposures above a specified criteria threshold (permanent threshold shift – PTS or temporary threshold shift – TTS) of animals for each source, scenario and marine mammal combination presented in a spreadsheet. The model also predicts received sound pressure levels that are then applied to a risk function curve to predict the probability of behavioral harassment.

For the SAIC model, the Navy developed several post-modeling corrections that *can* be applied to the output of the model to make it more realistic. These post-modeling applications quantitatively address the following factors, which are not accounted for in the models described above:

- Acoustic footprints for sonar sources do not account for land masses.
- Acoustic footprints for sonar sources are calculated independently, when the degree to which the footprints from multiple ships participating in the same exercise would typically overlap may be taken into consideration.
- Acoustic modeling does not account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

For the NUWC model, the Navy has developed the Effects of Sound on the Marine Environment (ESME) behavioral module that can be incorporated into the NUWC model to more accurately represent some of the biological variables of concern, such as animal movement and behavior. Reviewers will be asked to assess the NUWC model both with and without the inclusion of this module.

NUWC and SAIC both make use of Navy standard sub-models and databases that are housed at the Oceanographic and Atmospheric Master Library (OAML). The Chief of Naval Operations (CNO) established OAML in 1984. The OAML suite consists of Navy-standard core-models, algorithms and databases that support the Department of the Navy (DoN), Department of Defense (DoD), and research and development laboratories that support DoD and DoN and Joint and NATO activities. OAML also supports Task Force Web and Navy Enterprise Portal initiatives with state-of-the-art Navy-standard products. Some OAML databases, included sound speed profiles and the unclassified bathymetry database are available to the public.

The NUWC and SAIC models are not proprietary; however, several input data sources are either classified or restricted to the above-listed agencies and organizations. Nevertheless, the continued use of the models to provide acoustic exposure and impact predictions for regulatory assessment purposes requires that the models be reviewed independently, so that NOAA and other federal agencies can comply with the Data Quality Act.

Overview of CIE Peer Review Process:

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract for obtaining external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of stock assessments and various scientific research projects. The primary objective of the CIE peer review is to provide an impartial review, evaluation, and recommendations in accordance to the Statement of Work (SoW), including the Terms of Reference (ToR) herein, to ensure the best available science is utilized for the National Marine Fisheries Service management decisions.

The NMFS Office of Science and Technology serves as the liaison with the NMFS Project Contact to establish the SoW which includes the expertise requirements, ToR, statement of tasks for the CIE reviewers, and description of deliverable milestones with dates. The CIE, comprised of a Coordination Team and Steering Committee, reviews the SoW to ensure it meets the CIE standards and selects the most qualified CIE reviewers according to the expertise requirements in the SoW. The CIE selection process also requires that CIE reviewers can conduct an impartial and unbiased peer review without the influence from government managers, the fishing industry, or any other interest group resulting in conflict of interest concerns. Each CIE reviewer is required by the CIE selection process to complete a Lack of Conflict of Interest Statement ensuring no advocacy or funding concerns exist that may adversely affect the perception of impartiality of the CIE peer review. The CIE reviewers conduct the peer review, often participating as a member in a panel review or as a desk review, in accordance with the ToR producing a CIE independent peer review report as a deliverable. At times, the ToR may require a CIE reviewer to produce a CIE summary report. The Office of Science and Technology serves as the COTR for the CIE contract with the responsibilities to review and approve the deliverables for compliance with the SoW and ToR. When the deliverables are approved by the COTR, the Office of Science and Technology has the responsibility for the distribution of the CIE reports to the Project Contact.

Reviewer Requirements

The Center for Independent Experts (CIE) shall provide three panelists and a moderator for the review of each of the two models. The same individual will function as moderator for the review of both models. Preferably, the same three individuals would function as reviewers for both models, however, this may not be possible due to the required expertise and scheduling constraints.

CIE shall provide expertise in the scientific discipline of underwater acoustics, modeling, and marine mammalogy.

The underwater acoustician reviewer(s):

- shall have expertise and working experience with propagation loss models
- will preferably have working knowledge of the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB, which is the main propagation model incorporated in both the NUWC and SAIC models) and/or similar propagation models.

The modeling reviewer(s):

- shall have expertise with individual-based exposure assessment models
- will preferably have experience with the above type models dealing with the integration of multiple data streams (*e.g.*, multiple databases).
- shall be able to understand the dynamic interaction of databases.

The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

The moderator:

- shall have expertise in marine mammalogy
- shall have expertise in either underwater acoustics or modeling

The CIE review shall be conducted during two panel review meetings organized around a three-day meeting at NUWC, Newport, RI and a three-day meeting at SAIC, McLean, VA according to the schedule stated herein. For each of the two reviews, each reviewer shall be required for a maximum of 15 days for reviewing pre-review documents, conducting the peer review during the NUWC/SAIC meeting, traveling, and completing the CIE reports. The moderator will need 17 days for each review.

Statement of Tasks for CIE Reviewers

Note: There are two sets of meetings (including teleconference, three days of on-site meeting, etc.), one set for review of the NUWC model and one set for review of the SAIC model. The organization of the two sets of meetings is identical, but on different dates.

For each set of meetings, the CIE reviewers and moderator shall review the pre-meeting documents in preparation for the peer review meetings, to be provided by the Project Contact in accordance with the schedule of milestones and deliverables herein (refer to listed in Annex I for preliminary list of documents). The CIE reviewers and moderator will participate during each three-day panel review meeting at (1) NUWC, 1176 Howell Street, Bldg 1346, Rm 407U, Newport, RI 02841, and (2) SAIC, 1710 SAIC Dr, McLean, VA 22102. After each meeting, the three CIE reviewers (of each model) shall complete independent peer review reports addressing all the Terms of Reference given below. The moderator(s) shall consolidate the individual reports into a summary report for each meeting. Details on the formats of the panelists' and moderator's reports are given in Annex II and III, respectively.

Teleconference Calls with CIE for NUWC and SAIC: The CIE panel and NUWC/SAIC teams will discuss via conference calls the details of the upcoming panel review meetings, providing an opportunity for the CIE reviewers to raise questions concerning background documents, specifications for trial runs, and other review-related material, including logistics. In preparation for these teleconference calls, the CIE reviewers shall review pre-meeting documents provided by the Project Contact in accordance with the scheduled milestones and deliverables herein.

Day 1 of panel review meetings for NUWC and SAIC Meetings: CIE reviewers shall participate during the NUWC and SAIC panel review meetings during the dates specified in the schedule of milestones and deliverables herein. During the meetings, the Term of References (ToR) will be reviewed and the NUWC/SAIC model presentations will be made by scientists from NUWC/SAIC, with questions and answer sessions as needed. Presentations shall include:

1) Introduction to the current NUWC/SAIC approaches (i.e., the ones used in the AFAST and HRC EISs) and the software, including data input requirements;
2) Explain incorporation of the ESME behavioral module into the NUWC model;
3) Review of results of internal testing of the software;
4) Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
5) How these exposure estimates are interpreted relative to noise exposure thresholds and/or guidelines?
6) Review all relevant post-modeling correction factors for the SAIC model

7) Review all inherent, underlying assumptions in each model

The CIE reviewers and moderator shall meet to develop a set of test runs for during the panel review meeting. The purpose of this evaluation is to determine how the NUWC/SAIC model responds to a set of inputs designed to test the model. The CIE reviewers shall also acknowledge the differences and the roles of the external components (*e.g.*, animal input parameter values, propagation models) and the internal component of the model (e.g., ship movement) in regard to the functionality of the model The distinction is drawn here to emphasize that the values of animal placement parameters can and should change when new data are available, and that both models can utilize that new data. Navy staff will provide a comprehensive list of all of the parameters that can be input or changed by the users, versus those that are internal components. Example scenarios for devising these runs are provided in Annex IV.

Days 2-3 of the panel review meetings at NUWC and SAIC: CIE reviewers and the moderator shall work with NUWC/SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. For the NUWC model, the scenarios will be enacted both with and without the ESME behavioral module so that the reviewers can assess both. For the SAIC model – post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of NUWC/SAIC scientists as required, design simulations and request that the NUWC/SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because NUWC/SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, NUWC/SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, NUWC/SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

Terms of Reference

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors (“business rules”) for the SAIC model.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA’s Council for Regulatory Monitoring (CREM) guidelines for model development.

1. <u>NUWC/SAIC Model Implementation</u>

Details relevant to the topics described below are given in the documents identified in Annex 1.

- Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

  i. accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the NUWC/SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC/SAIC models*

  ii. correctly handle the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

  iii. correctly and efficiently extract data from databases? If not, identify any errors. The NUWC/SAIC models use the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.
- Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar or explosives based on current scientific knowledge, such as:
  i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference))
  ii. Marine mammal movement (horizontal and vertical)
  iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

- Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?
- Does the NUWC/SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?
- Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model would likely result in over/underestimates of take (and the degree, if possible)

2. <u>CREM Guidelines</u>

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points

listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

Schedule of Milestones and Deliverables:
The CIE shall complete the milestones and deliverables in accordance with the schedule of activities provided in the following table.

Activity and Responsible Party	Date
NMFS Project Contact will provide pre-meeting background documents to CIE	17 October 08
CIE reviewers and moderator(s) shall participate in a teleconference call with NMFS, NUWC and SAIC to discuss technical and logistical details of the peer review meetings (depending on availability of participants).	27 October 08 1pm 866-620-3559 Passcode 6243699#
CIE reviewers and moderator shall participate in panel review meeting at NUWC to test models Address - 1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841	**12-14 Nov 08**
CIE reviewers and moderator shall participate in panel review meeting at SAIC to test models Address - 1710 SAIC Dr, McLean, VA 22102	**17-19 Nov 08**
CIE reviewers shall submit their CIE independent peer review reports to CIE and the CIE moderator(s)	5 December 08
CIE moderator(s) shall submit their CIE summary report(s) to CIE	17 December 08
Upon CIE Steering Committee review and approval, CIE shall submit the CIE independent and summary reports to the NMFS COTR for review and approval in accordance with the ToR	24 December 08
CIE shall submit the final CIE reports in PDF format to the NMFS COTR	5 January 09
NMFS COTR will distribute the final CIE reports to the NMFS Project Contact for distribution	12 January 09

Acceptance of Deliverables:

Each CIE reviewer shall complete and submit an independent CIE peer review report in accordance with the ToR, which shall be formatted as specified in Annex 2, to Dr. David Sampson, CIE regional coordinator, at david.sampson@oregonstate.edu, and Mr. Manoj Shivlani, CIE lead coordinator, at shivlanim@bellsouth.net. Upon review and acceptance of the CIE reports by the CIE Coordination and Steering Committees, CIE shall send via e-mail the CIE reports to the COTR (William Michaels

William.Michaels@noaa.gov at the NMFS Office of Science and Technology by the date in the Schedule of Milestones and Deliverables. The COTR will review the CIE reports to ensure compliance with the SoW and ToR herein, and have the responsibility of approval and acceptance of the deliverables. Upon notification of acceptance, CIE shall send via e-mail the final CIE report in *.PDF format to the COTR. The COTR at the Office of Science and Technology have the responsibility for the distribution of the final CIE reports to the Project Contacts.

Key Personnel:

Contracting Officer's Technical Representative (COTR):

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Request for SoW and ToR Changes:

The Statement of Work (SoW), Terms of Reference (ToR) and list of pre-review documents herein may be updated without contract modification as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToR are not adversely impacted. Any such requests for changes to the SoW and ToR shall be submitted to the COTR (Contracting Officer's Technical Representative) for approval no less than 15 working days prior to the CIE peer review meeting.

ANNEX I: Documents to be reviewed in preparation of the NUWC/SAIC model review. This is a tentative list and will be further refined and specified prior to the review time. Documents may be provided on an ftp site because of large size.

Document Titles
1. NUWC Marine Mammal Acoustic Effects Analysis
2. Numerical Simulation of Undersea Detonation Effects on Marine Species Life
3. NUWC Environmental Modeling for Marine Mammal Acoustic Effects Analysis
4. Oceanographic and Atmospheric Library (OAML) Summary
5. Insert PowerPoint presentation on SAIC model
6. Marine Resource Assessment for SOCAL
7. Source of density for SOCAL

Document	**Document Type**	**Number of Pages**	**Degree of Difficulty**
1. NUWC Acoustic Model	PDF		
2. NUWC Explosive Model	PDF		
3.NUWC Environmental			
4. OAML description	PDF	113	Low
5. SAIC Presentation	PowerPoint		
6. MRAs	CD/Hardcopy		
7. SOCAL Density			
8. Acoustic appendices from EISs for both the SAIC and NUWC models	PDF		

ANNEX II: Format and Contents of CIE Independent Reports

1. The report should be prefaced with an Executive Summary with concise summary of goals for the peer review, findings, conclusions, and recommendations.

2. The main body of the report should consist of an Introduction with
    a. Background
    b. Terms of Reference
    c. Panel Membership
    d. Description of Review Activities

3. Summary of Findings in accordance to the Term of Reference

4. Conclusions and Recommendations in accordance to the Term of Reference

5. Appendix for the Bibliography of Materials used prior and during the peer review.

6. Appendix for the Statement of Work

7. Appendix for the final panel review meeting agenda.

8. Appendix for other pertinent information for the CIE peer review.

ANNEX III: Moderator's Summary Report Generation and Process

1. The summary report shall include an overview of the review process.

2. The summary report shall provide a synopsis of the three panelist reports.

3. Points of agreement and disagreement among the panelists shall be documented.

4. The summary report shall also include as separate appendices copies of each of the panelists' report.

ANNEX IV: Example NUWC/SAIC Scenarios: The panel shall create their own scenarios to be sure that their questions are addressed and answered. Reviewers will develop the scenarios in close coordination with the modeling team to ensure that the scenarios are feasible. The examples below illustrate the type of scenarios that the NUWC/SAIC models can address. They cover two sources of anthropogenic noise from mid-frequency active sonar and underwater explosives. Development of scenarios (including identification of the necessary input parameters) will be addressed during the conference call and the first day of the meeting.

1. A vessel quipped with a mid-frequency (1-10 kHz) active sonar source operating in the Southern California Range Complex (SOCAL) in May. The vessel will be on the range for three days conducting sonar operations during daylight hours. The active sonar signals are one second long broadcast once a minute with a source level of 235 dB re 1 µPa at 1 meter. The active sonar can be operated in two modes; namely, search and track. The ship is moving at 10 kts randomly in a 40 km square operational area. The question to be addressed is how many bottlenose dolphins are modeled to be exposed to a received level that would lead to MMPA Level A (PTS) and Level B (TTS and behavioral) harassment if the operation goes forward? Alternatively, how would the acoustic exposure be altered if the exercise were conducted in January?

2. A similar scenario as above but instead of using mid-frequency active sonar, an explosive source will be used. Input parameters include (among others) the net explosive weight, the explosive depth, the average sediment depth and the seasonal sound speed profile.

Appendix 2: Meeting Agenda

Agenda for NUWC Meeting in Rhode Island (November 12 -14)

1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841
Navy POC – Peter Hulton - 401-832-1797

Day 1
8:00 - Introductions and Logistics (bathroom, emergency exit, etc.)
8:15 - Review of ToRs (Moderator)
Presentations by NUWC Personnel
8:45 - Description of current NUWC approach (i.e., the one used in the AFAST and East Coast Range Complex's EISs) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all of the model parameters (including for ESME) that can be input or changed by the users, versus those that are internal components.
10:15 - Break
10:30 - Discussion of the ESME behavioral module and its incorporation into the NUWC model
11:30 - Review of results of internal testing of the software
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.

Day 2
8:00 – Development of Input Data for Trial Run (AFAST/ECRC EIS Method)
10:00 – Trial Run (AFAST/ECRC EIS Method)
12:00 – Lunch
13:00 – Review of Results
15:00 – Development of Input Data for Trial Run (3D Mammal Method)
16:00 – 3D Marine mammal simulations

Day 3
8:00 - Trial Run (3D Mammal Method)
10:00 – Review of Results
12:00 – Lunch
1:00 – Review of Report format, contents, and due dates (Moderator leads)
1:30 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
2:30 – Wrap-up

Revised Final Report by

Jeanette A. Thomas

External Independent Peer Review by the Center for Independent Experts

Science Applications International Corporation (SAIC)

Marine Mammal Acoustics Exposure Analysis Model

10 December 2008

Role on External Peer Review Panel: The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology
-

Note: recommendations are highlighted in red\

II. **Terms of Reference for evaluating the SAIC model**

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

1. Assess whether the SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).

General Comments on the SAIC model:

Under the Marine Mammal Protection Act, US Navy operations must apply for a permit from National Marine Fisheries Service to take marine mammals, at Level A and Level B harassment. These data are also needed by the US Navy for Environmental Assessment documents. The SAIC model is a method of predicting the number of takes of marine mammals at three levels: behavioral (received SPL level between 120 dB re 1 µPa and TTS level), Level B, TTS level (received SEL level 195 $\leq$ 215 dB), and Level A, PTS level (received level SEL $\geq$ 215 dB). The advantage of such a model is to simulate Navy operations of different types, at different locations, with different number of sound sources, and during different seasons. Using the estimated number of takes from the SAIC model output, operations potentially can be adjusted to reduce the number of marine mammal takes. Because of the difficulties of accurately observing marine mammal behavior at sea, the Navy cannot count the actual number of takes; rather they input the number of hours of operation and how much sound was put into the water during the exercise in a specific area into the SAIC model.

Based on available data on animal densities and distributions in the operation area, the SAIC model estimates the volume of water potentially impacted by sounds and then calculates the rate of increase in the impacted volume per ping. This is multiplied by the animal density, and thus results in a harassment rate per ping. This rate is then multiplied by the total number of pings or hours of operation to yield the total number of takes for a given species.

Data typically used by the Navy on bathymetry, sound velocity profiles, and wind speed in the operation area are input to the SAIC model and standard Navy acoustic propagation models are employed to predict the noise field around a sound source.   Because of evidence that at least one species, the harbor porpoise, shows a behavioral response to sounds at 120 dB, the SAIC model examines sound fields out to a level of 120 dB from the source or up to 150 km from the source.

The SAIC model incorporates movement of the sound source(s), not the animals. It assumes all sound sources are 20 km apart. The operational area is designated into provinces based on oceanographic/ environmental conditions and a winnowing process that can join similar provinces or eliminate some provinces in the operation area. The SAIC applies post-modeling correction analyses for multiple sound sources and density dilution. For those animals determined to be at a take level, the SAIC model applied the dose response for mysticetes or for odontocetes/pinnipeds, examines takes in 4-hours intervals, for winter or summer, separates into species, converts to an hourly scale, divides by 240 pings to get an impact per ping per season per species, and then categorizes the number of takes for behavior, Level B (TTS) and Level A (PTS) harassment categories.

During the NUWC review meeting, it was useful to conduct two Trial Runs of the model; Trial 1 with a single sound source and Trial 2 with three sound sources that began at different times during the operational window. Runs were conducted using blue whales, fin whales, and Cuvier's beaked whales. The reviewers expected to see the results from the same two Trial Runs at the SAIC meeting, but SAIC said they were not given sufficient time to make the necessary runs for Trial 2.

The output spreadsheet of the SAIC model for Trial Run 1 was easy to read and interpret; it is useful to see the raw number of estimated takes for the behavioral, Level B (TTS) and Level A (PTS) and the rounded number of takes in these categories. The rounding of takes is up if the raw data is greater than or equal to X.5 and down if less than X.5, which seems like a good practice.

Because of recent concerns about beaked whale strandings and military sonar operations, it was important to use a beaked whale as a species in Trial Runs 1 and 2.   The presenters used two mysticete whales, fin and blue whales, as other species for Trial Runs 1 and 2. It would have been useful to see the results from an odontocete and a pinniped, as well. Most available hearing data are on odontocetes and pinnipeds. Because the pinnipeds studied so far have a more sensitive hearing ability, the runs should have indicated more takes for a pinniped than for cetaceans.

Comparing the output from Trial Runs 1 verified that takes would be slightly greater during the summer than during the winter, regardless of species.

A. Animal distributions and densities:

The biggest problem with all models of this type is their dependence on available data on the density and distribution in space and time for a given species. There are some data for odontocetes and a few mysticetes, but little data are available for pinnipeds. Pinnipeds typically congregate at haulout areas, when seen at sea are difficult to identify to species, and may "boat-follow" to feed on discarded material from the boat, so accurate estimates of pinniped densities may be unreliable. Even though pinnipeds have more sensitive hearing, so might likely be more impacted by noise, they have the ability to haulout and at certain times of the year remain hauled out for long periods. The SAIC model should be adapted to include the typical amount of time spent in the water, in a given area, and during a given season for pinnipeds. This likely would serve to reduce the number of takes of pinnipeds. There should be a separate dose response curve for pinnipeds, not a combined dose curve for odontocetes and pinnipeds.

One way to examine the distribution and density of marine mammals in an area in which the Navy plans to operate is to conduct a survey of the animals 1 week before the operation and 1 week after the operation. Such a pre- and post-operation study would provide another way of monitoring the possible effects of their operations on marine mammals.

The SAIC model distributed animals in a uniform manner throughout the operational area. This is one way to examine effects, but if a species is known to have a clumped distribution in an operational area, simulations could be run with that distribution instead.

B. Animal Movements and Behavior

The available literature on the behavior of marine mammals shows significant variation among species, by time of day, by season, and by individuals, so the task of incorporating this variation into a model is complicated. Marine mammal responses to noise can be variable, i.e., ignore the sound and continue typical behavior, temporary startle response but remain in the same area, significant startle response leading to abandonment of behavior and leaving the area, acclimation to the sound over time, and even attraction to the sounds source. Data presented by Southall et al. (2008) summarized all these various responses and even provided examples of the same species reacting differently based on their previous experience with noise. Furthermore, an animal's willingness to tolerate noise may be largely based on whether it is engaged in biologically important behaviors, such as feeding or breeding.

A significant problem is that an animal could change its behavior after exposure to noise and those changes could range from avoidance to acclimation. The SAIC model does not incorporate changes in behavioral response after the first exposure to noise. This changed behavior could affect the number of estimated takes.

Currently, the potentially impacted water volume calculated by the SAIC model extends out to the 120 dB received level; however, recent data indicate that beaked whale reacted to playbacks of sounds from killer at a received level of 110 dB. Based on these new data, should the model be extended out to the 110 dB level?

Depth of the animal and time of day are important in assessing the potential impact. The SAIC model applies a risk function to examine behavioral takes. The risk function should be applied to preferred depths of a given species at specific times of day and in specific seasons that a species typically occurs, rather than the whole potentially impacted water volume.

C. Seasonal and temporal differences in distributions and densities of marine mammals

The SAIC model does not incorporate the presence of plankton in the water column, which can vary seasonally in a local area. Especially for mysticetes, knowing the distribution of plankton in the area at a time of operation could greatly affect the animal's movement, distribution, density and behavior. SAIC should consider incorporating plankton locations in the output of their model.

The SAIC model output provided data for the summer and winter estimated takes is useful and based on Trial Run 1, it seems that summer take is typically higher than winter takes, which is biologically sensible. Thus, the SAIC model has the ability to modify the number of hours of operation in summer and in winter to reduce take.

The SAIC model could incorporate known diel behavioral patterns in marine mammals. Several species of dolphins are known to feed at night and rest during the day, thus the hours of operation could affect the animal's behavior differently. The model could be adapted to incorporate different animal densities based on whether the operation is conducted during the day or night, when data are available for a particular species. Currently data are not available to predict whether noise would have a more significant effect if disturbing animals that were resting or feeding.

Many pinnipeds species haul out at predictable times of day. If a given pinnipeds species typically is not in the water during the hours of operation that should reduce the take estimate. Again, adding a day/night option to the model might better reflect the needed number of takes for pinnipeds.

D. Age and sex differences in marine mammals

The SAIC model uses two risk curves: one for odontocetes/pinnipeds and one for mysticetes. However, for some species of marine mammals there are enough data on behavioural differences by age and sex of individuals to refine the risk curves. Where data are available, the SAIC model could incorporate age and sex differences in animal densities. This may be especially important for species in which males and females are only together for a short breeding period then feed and live in different areas outside the mating time, i.e., elephant seals, humpback whales, gray whales. If operations are in a breeding area, these animals are together for only a short time and the potential for noise impacts could be higher. If operations are in the areas comprised of a particular sex, there might be a disproportion effect on the males or females.

In some marine mammals, different age classes exhibit different distributions, densities, and behaviours. It is unknown whether young individuals in a species would be more susceptible to noise impacts than more experienced adults.

Adding information on densities of different age and sex classes to the SAIC inputs might produce very different numbers of takes in some species.

E. Factors affecting sound propagation

As stated in the Terms of Reference, the review panel was not required nor given access to the particulars of the oceanographic and sound propagation models used as inputs to the SAIC. I can only assume that because these data are of great importance to Navy operations that they are the best available. However, in discussions at the review there seemed to be situations where bottom features, i.e. rocky versus sandy bottom, even assuming a flat bottom, resulted in received levels that varied by as much as 20 dB. I defer to Dr. Erbe, the propagation specialist on the review panel, on this point.

The original model provided to the Navy by SAIC designated 36 provinces (based on bathymetry, bottom types etc.) in warm and in cold season, in the Gulf of Mexico and along the Atlantic Coast, all had a flat bottom, but were limited to a range of 100 km from the sound source. However, because of noted responses by harbor porpoise at the 120-dB received level; the area was extended out to 150 km. The SAIC model identifies provinces within an operational area, which can then be divided into subareas. These provinces are defined based on bathymetry. However, these provinces may or may not appropriately reflect ecological/habitat differences, which are most important to the abundance and distribution of animals over the operation area. SAIC should adapt their model to identify habitat types or ecological zones important to marine mammals.

It was noted in the presentation that the CASS model will only accept one sound velocity profile at a time, resulting in the need to rerun the SAIC model at different distances from the source and for different species.

Each province had a single sound velocity profile, single bottom type, and single frequency from the sound source for the winter and for the summer. Is this sufficient to represent the typical variation in sound propagation in areas as large as a province, especially considering a province could be composed of several subareas?

SAIC presenters indicated that the important variables to the model for examining propagation are range and depth of the source, water depth, bottom type, and identification of interference patterns such surface ducts. The SAIC model incorporates all these variables.

The speed of the sound source is probably much more influential than animal movements, so the SAIC model does not include movement of the animals, just movement of the sound sources.

2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the SAIC models.

The SAIC model had the following assumptions:

A. The expected number of takes does not depend on the initial distribution of animals (i.e., uniform, Poisson).
This assumption simplifies the calculation, but for some species in some provinces and at some times of year their distribution may be clumped.

B. The expected number of takes does not depend on group size (single or clumped).
This may not be a valid assumption and could greatly affect the number of takes. There needs to be a way of transforming an animal take to a group size typical of the species.

C. The expected number of takes is not dependent on animal motion in an x-y plane.
The SAIC modelers stated that the number of takes with a fixed sound source and moving animals would be the same as for a moving source and fixed animals.

I believe this is a valid assumption.

D. The expected number of takes may depend on depth distributions (but not on detailed dive patterns)

This is a valid assumption.

E. The expected number of takes does not depend on details of sound propagation (only well-defined averages over ranges and depth).

SAIC presenter stated that typically to accurately use the model the user just needs the signal level averaged over the range and depth to estimate the number of takes.

F. Every animal has the same probability of a take if the original distribution is uniform in the operational area.

This is an assumption that simplifies calculations. The SAIC model does incorporate the idea that the probability of take is different among species. Incorporating age and sex differences into the SAIC model might help refine the fact that there may not be an equal probability of take in all animals of a species.

G. Sampling rate (range, depth, and season) provides the necessary resolution to estimate marine mammal takes.

The SAIC model uses oceanographic data from February for winter and August data for summer; whereas the NUWC model averages three months of data to obtain two values for the winter and summer seasons. Calculating propagation for a particular month in a particular location would better reflect the animal's environment, especially at critical breeding and feeding times of the year.

H. The SAIC model assumed a constant 20 km distance between the sound sources. SAIC presenters stated that distance between sources is not important.

   This distance seems large to me, but I can't evaluate Navy operations to know if this is a valid assumption.

I. The SAIC model assumed an animal can only be taken once in a 24-hour day.

   Using this assumption, the animal would automatically reset at the end of a 24-hour period. It could be taken twice on two consecutive days. The SAIC model incorporates the effects of several sources by modeling them separately and then summing the number of takes at the end. This would result in overestimating takes, because the model does not account for the fact that the same animal might be taken twice within 24h by two different sound sources.

   This is an easy calculation, but it does not address whether multiple sounds sources operating at the same time might cancel-out some of the noise or how complex sounds fields from different frequency sources might interact.

J. The model does not allow for recovery time between exposures. In the real world of exposures there may or may not be a recovery time if operations last more than 24 hours. Until more detailed data on TTS in marine mammals are available, I think it is a reasonable assumption.

K. SAIC made an *ad hoc* decision for behavioral takes, as one 24-h day or the length of an operation, whichever is shorter.
   This is a reasonable assumption.

L. The SAIC model assumes that each new day the same animal could be taken.

   This is a reasonable assumption.

M. The SAIC model assumes the hearing of marine mammals is omnidirectional.

   This is a reasonable assumption.

N. The SAIC model assumes sound energy accumulates over a 24-hour period.

   This assumption is valid. The 24-hour period is used as a time-frame to estimate human hearing damage.

O. The SAIC model assumes that near field propagation has little effect on the number of marine mammal takes.

This seems like a reasonable assumption.

P. The SAIC model assumes that often animal densities are more coarsely sampled than environmental factors.

For some species this may be true.

Q. The SAIC model assumes the speed of the source is not greater than the speed of the animal.

This assumption is reasonable.

R. The SAIC model assumes animal swims at 3 km/hour; therefore they can calculate the distance swam in a 4-hour operation.

If animals were foraging in a local area this might over estimate the distance traveled.

S. The SAIC model assumes a straight line of travel for the sound source.

This may not be a valid assumption for all Navy operations.

T. The SAIC model assumed a flat bottom to calculate propagation fields.

Flat rocky and flat sandy bottom could give different propagations.

U. The SAIC model assumed the density of animals remains the same throughout an operation, even when land is removed from province.

This simplifies the calculation, but does not address the real world situation of when an animal decides to leave the operational area or change its behavior during an operation.

V. The SAIC model considered operation length shadows from land play an insignificant role in number of takes.

The model removes land shadows before placing animals, so this keeps the animal density the same and uniform in the operational area.

W. The SAIC model assumes cetaceans and pinnipeds have their head under water 100% of the time.

This assumption is workable for cetaceans, but perhaps not for pinnipeds.

3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.

SAIC presenters stated that all post-processing features of the SAIC model were oriented to reduce take and become more conservative.

The SAIC model calculates take based on a 4-hour block, but if operations occurred for less than a 4-hour block the take was prorated to the duration of the operation.

A histogram of the percent of harassments by distance from the source was plotted. Up to 15 km from the source, 95% of all behavioral harassments have occurred.

Post-modeling correction calculations for multiple sound sources:

This post-modeling correction prevents over-counting the number of takes. It generally approximated that the number of ships = number of ships X probability of exposure to estimate the number of takes.

Post-modeling correction density dilution:

The SAIC model calculates the average number of marine mammal takes per ping. The SAIC presenters stated that there could be a problem to just add up the portion of a take for each ping because it might over estimate the take. This post-modeling is applicable to sonar pings, but what about to other more continuous types of military noise, such as a torpedo launch or helicopter noise?

Both post-modeling corrections are important to better refine the actual area of potential impact and better estimate the number of takes of marine mammals.

4. Assess whether the SAIC model meets the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

See comments below.

3. <u>SAIC Model Implementation</u>

Details relevant to the topics described below are given in the documents identified in Annex 1.

Does the SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? <u>Specifically, does the model:</u>

i. **accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within SAIC model***

The SAIC model used data bases and propagation models provided by the Navy, which are presumably the best available. The Review Panel was not allowed access to reviewing these propagation models, so I can only assume they are valid.

Each application of SAIC model is reviewed individually to make sure the appropriate propagation model and input data are used.

The SAIC model accurately implemented the propagation model. However, the time required to make a run is significant.

CASS/GRAB will only select a single frequency, so assumed all species will hear that frequency, this is figured-out in post-processing.

Why not calculate if a species could hear the signal initially from a lookup table, this would save a lot of processing time?

The data bases DBDBV, GDEM, HFBL, US Navy Marine Climatic Atlas of the World, and OMAL have been used by the Navy for years to generate sound propagation models. The presenter noted that the Office of Naval Research has studied the uncertainties of the CASS/GRAB model using these data bases and a report exists, but is not available to the Review panel. The areas of Navy operations are tested and extremely well known by Navy. Expertise by propagation modelers is very important in selecting the appropriate model and inputs to those models based on the area.

I question whether using a single bottom type, single frequency source, one of two seasons, and a single sound velocity profile per province appropriately accounted for the natural variability in sound fields that might occur during an operation; however, to make more detailed measurements of the sound field would be a huge computation, and is likely not practicable.

The SAIC model initially excludes land masses, then calculates the potentially impacted water volume and populates it with animals. This keeps the animal densities uniform and constant throughout the simulation. This is an important feature of the model, which likely reduces the number of animals that could be exposed in an operational area.

A set of model runs should be conducted to look for any peculiar results nearby islands, above sea mounts or near shore.

The SAIC model uses the typical oceanographic features for February to simulate the winter season and for August to simulate the summer season. Perhaps SAIC should start modeling a typical month's propagation and use these data as the input for a specific operational date.

The SAIC modelers did not want to miss details of the propagation field, such as a surface duct. SAIC model sampled transmission loss very often, especially in shallow water, where propagation models come up with false information. The SAIC model sampled depth extensively up to the maximum animal depth of 2 km, examining every 5 m in depths up to 1000 m, and every 10 m from depths of 1000-2000 m. The SAIC presenter stated that water depth and bottom loss mattered most in modeling.

ii. correctly handles the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

SAIC does analysis on classified computers and then generates spreadsheets of the results. SAIC has several computers that can calculate transmission loss, and so can examine many provinces in an operation area.

I question whether using a single frequency in the model adequately represents the animal's ability to hear the sound. How is this frequency selected? If the sound source is sonar, selecting a single frequency would be reasonable, but if the sound is a torpedo, helicopter, ship noise it is composed of a complex broadband signal. Is the frequency modeled at the most sensitive hearing in a given species or the frequency of the sound source with the highest amplitude? Is a different frequency used for the mysticetes, odontocetes, and pinnipeds or is the same frequency used for all runs, then interpreted after the fact based on the species hearing range?

SAIC should consider comparing outputs from runs of two identical sounds sources projecting at the same amplitude and the same frequency compared to the output of the same sound source at the same frequency and same amplitude. In other words, is the assumption that the influence of two sound sources can be modeled separately, and then added valid?

iii. correctly and efficiently extracts data from databases? If not, identify any errors. The SAIC model uses the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.

The attached Table 1 compares the NUWC and SAIC outputs for Test Run 1 during summer and winter for blue whales, fin whales, and Cuvier's beaked whales. Note the two models used different animal densities and different areas of operations, which might account for some of the differences in the number of takes. The NUWC model also used a much greater operation area for the beaked whale compared to the blue and fin whale. The NUWC model had greater takes than the SAIC model. I do not know if these differences are significant or how important the differences in operational area and original animal densities affected the differences in take.

A standard deviation around the number of takes can not be calculated from a single run. SAIC might consider providing the number of takes with ± SD by gathering data from multiple runs.

Does (or can) the SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar based on current scientific knowledge, such as:

i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference).

SAIC could stratify certain provinces as having a non-random distribution to better reflect the clumped distribution of some marine mammals. However, such detailed data may not be available for some species in some operational areas.

Biologists at SAIC provide animal densities for an operational area. For cetaceans species data are taken from marine resource guides, sometimes provided by the government, by contacting researchers to update data, from the best available published scientific data, or from NMFS Technical Reports. No one source provides animal density data.

Whenever there is the need to interpret densities among sources, SAIC uses the highest animal density available, which leads to a more conservative take.

ii. Marine mammal movement (horizontal and vertical)

The SAIC model does not include movement of animals in their model.

iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

The SAIC model does not distinguish individual animals from groups of animals.

Because the SAIC model does not incorporate movement of the animals it can not adapt to scenarios like avoidance of a sound source.

Instead, the dose response or risk function is intended to incorporate any data on avoidance or attraction to a sound source.

Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?

SAIC developed two risk curves: odontocetes/pinnipeds and mysticetes to help adjust takes for these general groups of species. SAIC should develop separate dose response curves for pinnipeds and not combine them with the odontocete dose response curve.

The model does not incorporate movement or behavioral data. The SAIC model does have the ability to divide operational areas into subareas where concentrations of animals could be placed, rather than the uniform distribution in other areas.

Trial run 2 conducted by the NUWC model had 3 noise sources. Although SAIC did not conduct the trial run 2, they would have just calculated three different sources independently and then added the number of takes for each sound source. However, in this Trial Run 2, the ship would have been the main sound source, with a torpedo producing a short-duration sound, and a submarine running as quiet as possible. So, three separate risk functions for each sound source would be essential.

The SAIC model assumes that all marine mammals hear the frequency used in the model. In fact, there is significant variation in hearing among mysticetes, odontocetes, and pinnipeds; both in frequency range and hearing sensitivity. For mysticete whales, the only available data are from anatomical, histological, and CT scans of the minke whale, a relatively small baleen whale (Ketten and Mountain, 2008; Mountain, 2008). Yet, the SAIC Trial Run 1 concentrated on fin and blue whales, for which very little is known about their hearing. In the future, the SAIC model should concentrate on minke whales to compare with the best available hearing data. However, I do not know if there is sufficient density and distribution data on the minke whale.

The hearing of several odontocetes has been anatomically, behaviorally, and physiologically measured. Southall et al. (2007) divided hearing in odontocetes into high-frequency and mid-frequency groups. The underwater hearing abilities of the California sea lion, harbor seal, and elephant seal have been examined behaviorally and physiologically. The underwater hearing of the ringed seal has only been measured behaviorally. Pinnipeds tested so far have a greater sensitivity in the best part of their hearing range than odontocetes, so should be of more concern relative to the impacts of noise. Yet, the SAIC model lumped pinnipeds with odontocetes in the same risk function. I recommend that SAIC develop a separate risk curve for pinnipeds and start modeling the effects on pinnipeds.

It is possible that with broadband sound sources, like a torpedo, ship noise, or helicopter noise, certain species would only hear part of the frequency content of the sound or that if the model frequency is not selected properly it would be examining a frequency either outside or at a reduced hearing sensitivity. SAIC should model the sound field for several frequencies within the frequency range of various military operations and within the hearing range of marine mammals.

The SAIC model only addresses the topic of harassment relative to noise exposure, it does not account for the visual presence of a tall ship, moving torpedo, or helicopter flying over head. Visual, moving objects may affect whether the noise from a source causes a reaction. They may be even more important in eliciting a response than the noise itself.

Does the SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?

The SAIC model appropriately uses SPL levels to calculate behavioral takes and SEL to calculate TTS and PTS takes. SPL is a sound pressure measurement with no time dimension. SEL is an energy measurement taken over a standard time, so it is comparable among studies and among model runs. SEL measurements also allow the accumulation of noise over the time of the operation and accumulation of noise with multiple sound sources.

Recent data by Finneran showed TTS in a bottlenose dolphin after only 15 sonar pings with an SEL of 214 dB, which translates to 5 min within 50 m of the source. This result calls into question whether the Level B (TTS) criteria should be less than 214 dB.

Comment on the strengths and weaknesses of the SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)

A. SAIC model strengths:

If operations are near a bathymetric boundary, the SAIC model can use the winnowing model to join adjacent provinces or divide a province into subareas.

If the animal has not accumulated enough energy over an operation to trigger a Level B (TTS) take, then the accumulated acoustic energy falls back into the behavioral category to examine a possible behavioral harassment take.

The SAIC model can accommodate more than one species in an operational area at a time.

All post-processing features of the SAIC model were oriented to reduce take and become more conservative.

A second exposure is the dose response that would have the same probability of risk as for the first exposure. To solve this, SAIC model uses the maximum exposure SPL level over a 24-hour period (or the end of the exercise period). This is very important in the model. Modeling exposure to exposure variations in dose response would be a massive calculation.

According to the SAIC presenter, their model has two differences from other models:

1. The SAIC model uses the worst case regarding TL and calculates TL at different depths.
2. The SAIC model only allows environmental parameters (and thus TL) to change within a grid. So each province gets a TL calculation that does not vary within the province.

B. SAIC model Weaknesses-

Because of the Navy's need to keep operational information restricted before an operation, the modelers using the SAIC model do not always know where and when the source(s) begin in the operational area and so cannot model that into the 24-hour window needed to calculate a take.

CASS has the limitation that it was compiled a long time ago and can only handle 16 bits, so the model can only output 32000 lines. Presenters at NUWC report that a new version of CASS is being developed.

Presenters reported that the SAIC model uses CASS/GRAB to create the propagation fields, but the models can "over-resolve" the transmission loss, TL, which can indicate takes that are not real.

Presenters noted that data on bottom type are difficult to find, however bottom type is not as important a factor as water depth in calculating propagation.

Currently, running the SAIC model takes about 1 week to process an operational area. The SAIC presenters reported they are developing a new model to replace the MATLAB program, which currently does post-modeling corrections to calculate the number of takes, so there are some inherent inefficiencies.

There is no interaction between species programmed into the SAIC model. Perhaps this should be done. There might be a greater effect at the interspecies level than at the individual level. Many dolphin species are known to congregate in mixed species herds in the wild and some species are known to have predator/prey relationships.

The SAIC model cannot predict a catastrophic event with a large cluster of animals, such as the beaked whale strandings in the Bahamas. The model could be improved to incorporate the probability of a catastrophic event. Catastrophic events are estimated by the tails of the distribution, not the mean. The review panel suggested that bathymetry may be the best indicator of the likelihood of a catastrophic event, like beaked whales in the Bahamas being confined to a local area with no escape route.

The SAIC model at least has two different risk functions: mysticete and odontocete/pinniped curves. However, there should be at least four curves: mysticete, mid-frequency odontocetes, high-frequency odontocetes, and pinnipeds (see Southall et al., 2007).

The dose response or risk function currently is based on only three actual studies. The SOCAL EIS discusses sources of data for risk functions: Nowacek data on wild right whales, data from SHOOP EIS, and data by Finneran on captive bottlenose dolphins, which was limited to single sonar exposures. The dose response or risk function is created with only a low value, midpoint value and a high value. Adding any new data could greatly change this risk function; however, currently these are the best available data to SAIC. This is a very weak link in the model, but until more data are available, it is the best approximation of behavioral responses.

C. SAIC model possible improvements:

The SAIC model should be adapted to include the typical amount of time spent in the water, in a given area, and during a given season for pinnipeds.

If a species is known to have a clumped distribution in an operational area, simulations could be run with that distribution instead of remaining uniform throughout the operational area.

The SAIC model should incorporate a way to determine takes for a single animal or for a group of marine mammals.

The SAIC model does not incorporate changes in behavioral response after the first exposure to noise.

The risk function should be applied to preferred depths of a given species at specific times of day and in specific seasons that a species typically occurs.

SAIC should consider incorporating plankton locations in the output of their model.

The SAIC model could incorporate known diel behavioral patterns in marine mammals with the corresponding hours of operation.

The SAIC model should incorporate interactions between species that would affect animal densities.

Adding a day/night option to the SAIC model might better reflect the animal density and number of takes for pinnipeds.

Where available, the SAIC model could incorporate age and sex differences in animal densities.

SAIC should adapt their model to identify habitat types or ecological zones important to marine mammals.

Calculating sound field for a particular month in a particular location would better reflect the animal's environment, especially at critical breeding and feeding times of the year.

SAIC might consider providing the number of takes with ± SD by gathering data from multiple runs.

SAIC could stratify certain provinces as having a non-random distribution to better reflect the clumped distribution of some marine mammals.

At minimum SAIC should develop separate risk curves for pinnipeds and odontocetes. Even better, SAIC should develop four dose response curves based on the four ear types of marine mammals identified by Southall et al. (2007): mysticete, mid-frequency odontocetes, high-frequency odontocetes, and pinnipeds.

Because the pinnipeds have more sensitive hearing, SAIC should start modeling the effects on pinnipeds.

In the future, the SAIC model should concentrate on minke whales as a representative mysticete because the best available hearing data are for this species.

SAIC should model the sound field for several frequencies within the frequency range of various military operations and within the hearing range of marine mammals.

Comment on whether any weaknesses in the SAIC model would likely result in over/underestimates of take (and the degree, if possible)

The SAIC model should use environmental/oceanographic data in a specified area to calculate the sound field each month, rather than a summer and winter sound field. Especially for marine mammals that migrate to feed or for seasonal breeders the effects of an exposure could greatly vary depending on the month of the year.

The SAIC model did not incorporate a recovery time between sound exposures. Such a recovery time would likely lead to a reduction in the number of takes.

The take numbers on Trial Run 1 using the NUWC model was slightly higher than from the SAIC model (see Table 1). Using the SAIC model, the summer take is always higher than winter take, reset time is 4 hours, and dose response harassment at 10 km is 0.95. The NUWC model also had higher number of takes during the summer.

I realize the 120-dB range was requested by NMFS, but have this question- if 90% to 95% of the takes occur at close ranges to the sound source (0 to 15 km), would running the model at only this close range be sufficient? This certainly would save computation time. Given the limited quality and quantity of animal density and distribution data on only a few species, is it necessary to examine the potentially impacted water volume out to the 120 dB range to estimate a possible 10% additional take?

The SAIC model should have a variance around that take number. However, this would likely result in needing to use the higher value of the standard deviation around the number of takes. SAIC presenters noted that to provide a variance around a take number might give the impression that they have data to input to the model that are more accurate than they really are.   Given the huge lack of data on animal densities a variance around a take number might be misleading.

In the SAIC model each source has a new risk function and newly exposed population, which might over estimate the number of takes. For example, if there were four sound sources, four independent take calculations could result in a higher number of takes than for one source repeated four times.

Because, of the long computational time for the SAIC model, they should consider minimizing the number of points sampled to save computation time. Currently, the dose response calculations extend out to 150 km from the source, at 5, 10, 100, 150 m etc. depths, and over a wide range of received levels, from 120 dB to the source level. Grid received levels are measurements in 5-m steps. These calculations are made by depth and distance, before the actually data on the animal density by depth for a given species are input to the model. Bracketing the typical swim depth and signal detection range, based on the abilities of a particular species to hear a particular frequency, could save computation time.

Currently, the histograms generated for the risk functions are in 0.5 dB intervals and out to 150 km, at different depths, and for different species. This fine detail ensures that no unexpected sound fields are encountered, but takes a great deal of time to compute. If SAIC used 5-dB steps, the curve would be smoother however, a 5-dB difference in the 125 dB to 120 dB range is a large difference in potentially impacted water volume.

With the SAIC model, the risk of behavioral take from 120 to 140 dB is less than 1 %. If calculations started at 140 dB, that would save much computation time. But, SAIC was mandated by NMFS to model out to the 120-dB level and the model is trying to be conservative in estimating the number of takes.

SAIC presenters stated that with straight line movements of the sound source (as in the current SAIC model) there is a higher rate of takes than if the model incorporated a random walk of the sound sources, which likely would result in fewer takes.

CREM Guidelines and the SAIC Model

The panel shall assess whether the SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

Have the principles of credible science been addressed during model development?

The Review Panel was told before the meeting that two trial runs would be presented by NUWC and by SAIC, so we could compare the outputs from the two models. However, SAIC did not conduct Trial Run2 because they were not given enough time before the review to conduct Trial run 2. Trial run 2 was complex with three different sounds (a surface ship and a submarine that launches a torpedo) so sources started and ended operations at different times. SAIC stated that a new dose-response curve for each source would take days to run, so they could not provide a demonstration of that output. The absence of this second run impaired the review panel's ability to evaluate the effectiveness of the SAIC model when using multiple sources and to compare with the output of the NUWC model.

SAIC has done detailed, 5-m area analysis of sound exposure because of possible criticism about the propagation models and mathematical computations. So, they believe the extra computational time is necessary to verify their model.

SAIC procedures were very transparent and efficiently used spreadsheet processing.

Is the choice of model supported given the quantity and quality of available data?

SAIC determines a density for each species by depth using the best available data. At the review, Janet Clarke, SAIC marine biologist, reported her detailed procedures on determining animal densities for a particular species. She obtains data for cetacean species out of marine resources guide, sometimes provided by government, and contacts researchers to verify or update data. She uses best available data from the literature, or from NMFS Tech Report. No one source is used to estimate animal densities.

For pinnipeds, there is little information on counts at sea; very few surveys for shipboard counts of pinnipeds, and most data are taken while pinnipeds are hauled out. She establishes the pinniped population level, haulout pattern, reproductive season, and migration from the literature, stock assessment reports. She tries to find data for specific age and sex classes. She adjusts estimates for time spent in the water and for summer and winter seasons.

For coastal cetaceans she assumes they are in coastal areas 100% of the time, but not for pinnipeds. Whenever SAIC needs to interpret several sources of animal density data, she uses the highest density, which leads to a more conservative take.

When absolutely no data are available, she uses information from other areas which are physically similar to the operational area.

These procedures are the best available, given the spotty nature and paucity of current data on marine mammal densities.

How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?

The SAIC model adequately simulates the sound field around the noise source using bathymetric data, bottom type, and sound velocity profiles to calculate the propagation of a signal. The use of provinces imitates different oceanographic environments; however, these may or may not reflect ecosystems of importance to marine mammals. Of course, different species use different habitats within the marine ecosystem.

How well does the model perform?

Output from Trial Run 1 indicated the model performed well, given its current configuration.

We were not able to evaluate the model performance for Trial Run 2.

Is the model capable of being updated with new data as it becomes available?

SAIC has several options to modify Navy activities to minimize the take level. SAIC uses the model for noise exposure in other scenarios, not just for the US Navy, and so has a great deal of experience with adapting the model. Using their model they can run simulations to give their client options on how to reduce the number of takes in a given operational area.

Literature Cited

Darlene Ketten and David Mountain—Minke whale hearing: micro to macro analyses: Part 1 cytoarchitecture and head anatomy. Abstract of presentation to Joint Industry Program, 28-29 October 2008.

David Mountain—Modeling mysticete hearing. Abstract of presentation to Joint Industry Program, 28-29 October 2008.

Brandon L. Southall, Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr., David Kastak, Darlene R. Ketten, James H. Miller, Paul E. Nachtigall, W. John Richardson, Jeanette A. Thomas, & Peter L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals*, Volume 33, Number 4.

Appendix 1: Statement of Work

Statement of Work for Dr. Jeanette Thomas

External Independent Peer Review by the Center for Independent Experts

Review of Naval Undersea Warfare Center (NUWC)
Marine Mammal Acoustics Exposure Analysis Model
and
Science Applications International Corporation (SAIC)
Marine Mammal Acoustics Exposure Analysis Model

Background and Scope of Work

The National Marine Fisheries Service (NMFS) requires an independent peer review of the Naval Undersea Warfare Center (NUWC) and Science Applications International Corporation (SAIC) marine mammal acoustics exposure effects analysis models (the processes these two groups use to perform the analyses described herein involve more than the use of single models, but will be broadly referred to as "models" for simplicity in this document) which shall assess whether they correctly implement the sub-models and data upon which it is based, whether they adequately assess all relevant physical and biological variables in assessing effects on local marine mammal populations, and whether they meet the Environmental Protection Agency's (EPA) Council for Regulatory Monitoring guidelines for models, which primarily involve scientific credibility. The review of the NUWC model will include an assessment of the current model (used for the Atlantic Fleet Active Sonar Training (AFAST) with additional analysis of the Effects of Sound on the Marine Environment (ESME) behavioral module, which the Navy intends to incorporate into the current model moving forward.

Minimizing and mitigating the potential effect of sound upon the environment is an increasing concern for many activities. Naval operations, seismic exploration, vessel and aircraft operations, certain construction activities, and scientific investigations now need to consider the potential effects underwater acoustic sources have on marine life. Marine mammals are usually the primary concern, due to their widespread distribution and excellent hearing ability, although impacts on fish are increasingly being considered as well. Predicting the exposure of marine mammals is complicated by several factors: a general lack of data to support a comprehensive understanding of density and distribution; horizontal and vertical movement patterns; any long-range migratory behavior; and a lack of understanding of exactly how potential sound avoidance behaviors may impact the levels of sound to which marine mammals are exposed.

Acoustic propagation and received sound levels are a function of water depth, range from the source, sound source characteristics, and a number of environmental variables. These issues, combined with the variable spatiotemporal distribution and movement of different species, contribute to a very complex problem. The NUWC and SAIC models address these specific complications in similar ways. The models predict a received level at range and depth in a 3-dimensional grid (x,y,z), then overlay the marine mammal density (animals/km^2) for each species on the 2-dimensional (x,y) grid. The third dimension (z) can be applied through the use of animal distribution in depth for a percentage of time if that data are available. Biological distribution and movement can be based on regional and seasonal behavioral data for each species evaluated. Acoustic sources are programmed to move through a virtual acoustic environment based on external environmental databases and radiated sound fields created from a selected propagation model (e.g., Comprehensive Acoustic Simulation System/Gaussian RAy Bundle (CASS/GRAB), or Range-dependent Acoustic Model (RAM)) The integration components of the NUWC and SAIC models make use of the high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation in MATLAB®. The end results of modeling represent estimated accumulated exposures above a specified criteria threshold (permanent threshold shift – PTS or temporary threshold shift – TTS) of animals for each source, scenario and marine mammal combination presented in a spreadsheet. The model also predicts received sound pressure levels that are then applied to a risk function curve to predict the probability of behavioral harassment.

For the SAIC model, the Navy developed several post-modeling corrections that *can* be applied to the output of the model to make it more realistic. These post-modeling applications quantitatively address the following factors, which are not accounted for in the models described above:

- Acoustic footprints for sonar sources do not account for land masses.
- Acoustic footprints for sonar sources are calculated independently, when the degree to which the footprints from multiple ships participating in the same exercise would typically overlap may be taken into consideration.
- Acoustic modeling does not account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

For the NUWC model, the Navy has developed the Effects of Sound on the Marine Environment (ESME) behavioral module that can be incorporated into the NUWC model to more accurately represent some of the biological variables of concern, such as animal movement and behavior. Reviewers will be asked to assess the NUWC model both with and without the inclusion of this module.

NUWC and SAIC both make use of Navy standard sub-models and databases that are housed at the Oceanographic and Atmospheric Master Library (OAML). The Chief of Naval Operations (CNO) established OAML in 1984. The OAML suite consists of Navy-standard core-models, algorithms and databases that support the Department of the Navy (DoN), Department of Defense (DoD), and research and development laboratories that support DoD and DoN and Joint and NATO activities. OAML also supports Task Force Web and Navy Enterprise Portal initiatives with state-of-the-art Navy-standard products. Some OAML databases, included sound speed profiles and the unclassified bathymetry database are available to the public.

The NUWC and SAIC models are not proprietary; however, several input data sources are either classified or restricted to the above-listed agencies and organizations. Nevertheless, the continued use of the models to provide acoustic exposure and impact predictions for regulatory assessment purposes requires that the models be reviewed independently, so that NOAA and other federal agencies can comply with the Data Quality Act.

Overview of CIE Peer Review Process:

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract for obtaining external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of stock assessments and various scientific research projects. The primary objective of the CIE peer review is to provide an impartial review, evaluation, and recommendations in accordance to the Statement of Work (SoW), including the Terms of Reference (ToR) herein, to ensure the best available science is utilized for the National Marine Fisheries Service management decisions.

The NMFS Office of Science and Technology serves as the liaison with the NMFS Project Contact to establish the SoW which includes the expertise requirements, ToR, statement of tasks for the CIE reviewers, and description of deliverable milestones with dates. The CIE, comprised of a Coordination Team and Steering Committee, reviews the SoW to ensure it meets the CIE standards and selects the most qualified CIE reviewers according to the expertise requirements in the SoW. The CIE selection process also requires that CIE reviewers can conduct an impartial and unbiased peer review without the influence from government managers, the fishing industry, or any other interest group resulting in conflict of interest concerns. Each CIE reviewer is required by the CIE selection process to complete a Lack of Conflict of Interest Statement ensuring no advocacy or funding concerns exist that may adversely affect the perception of impartiality of the CIE peer review. The CIE reviewers conduct the peer review, often participating as a member in a panel review or as a desk review, in accordance with the ToR producing a CIE independent peer review report as a deliverable. At times, the ToR may require a CIE reviewer to produce a CIE summary report. The Office of Science and Technology serves as the COTR for the CIE contract with the responsibilities to review and approve the deliverables for compliance with the SoW and ToR. When the deliverables are approved by the COTR, the Office of Science and Technology has the responsibility for the distribution of the CIE reports to the Project Contact.

Reviewer Requirements

The Center for Independent Experts (CIE) shall provide three panelists and a moderator for the review of each of the two models. The same individual will function as moderator for the review of both models. Preferably, the same three individuals would function as reviewers for both models, however, this may not be possible due to the required expertise and scheduling constraints.

CIE shall provide expertise in the scientific discipline of underwater acoustics, modeling, and marine mammalogy.

The underwater acoustician reviewer(s):

- shall have expertise and working experience with propagation loss models
- will preferably have working knowledge of the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB, which is the main propagation model incorporated in both the NUWC and SAIC models) and/or similar propagation models.

The modeling reviewer(s):

- shall have expertise with individual-based exposure assessment models
- will preferably have experience with the above type models dealing with the integration of multiple data streams (*e.g.*, multiple databases).
- shall be able to understand the dynamic interaction of databases.

The marine mammalogist reviewer(s):

- shall have experience in (primarily) marine mammal behavior of more than one species
- shall have experience in (secondarily) marine mammal physiology

The moderator:

- shall have expertise in marine mammalogy
- shall have expertise in either underwater acoustics or modeling

The CIE review shall be conducted during two panel review meetings organized around a three-day meeting at NUWC, Newport, RI and a three-day meeting at SAIC, McLean, VA according to the schedule stated herein. For each of the two reviews, each reviewer shall be required for a maximum of 15 days for reviewing pre-review documents, conducting the peer review during the NUWC/SAIC meeting, traveling, and completing the CIE reports. The moderator will need 17 days for each review.

Statement of Tasks for CIE Reviewers

Note: There are two sets of meetings (including teleconference, three days of on-site meeting, etc.), one set for review of the NUWC model and one set for review of the SAIC model. The organization of the two sets of meetings is identical, but on different dates.

For each set of meetings, the CIE reviewers and moderator shall review the pre-meeting documents in preparation for the peer review meetings, to be provided by the Project Contact in accordance with the schedule of milestones and deliverables herein (refer to listed in Annex I for preliminary list of documents). The CIE reviewers and moderator will participate during each three-day panel review meeting at (1) NUWC, 1176 Howell Street, Bldg 1346, Rm 407U, Newport, RI 02841, and (2) SAIC, 1710 SAIC Dr, McLean, VA 22102. After each meeting, the three CIE reviewers (of each model) shall complete independent peer review reports addressing all the Terms of Reference given below. The moderator(s) shall consolidate the individual reports into a summary report for each meeting. Details on the formats of the panelists' and moderator's reports are given in Annex II and III, respectively.

Teleconference Calls with CIE for NUWC and SAIC: The CIE panel and NUWC/SAIC teams will discuss via conference calls the details of the upcoming panel review meetings, providing an opportunity for the CIE reviewers to raise questions concerning background documents, specifications for trial runs, and other review-related material, including logistics. In preparation for these teleconference calls, the CIE reviewers shall review pre-meeting documents provided by the Project Contact in accordance with the scheduled milestones and deliverables herein.

Day 1 of panel review meetings for NUWC and SAIC Meetings: CIE reviewers shall participate during the NUWC and SAIC panel review meetings during the dates specified in the schedule of milestones and deliverables herein. During the meetings, the Term of References (ToR) will be reviewed and the NUWC/SAIC model presentations will be made by scientists from NUWC/SAIC, with questions and answer sessions as needed. Presentations shall include:

1) Introduction to the current NUWC/SAIC approaches (i.e., the ones used in the AFAST and HRC EISs) and the software, including data input requirements;
2) Explain incorporation of the ESME behavioral module into the NUWC model;
3) Review of results of internal testing of the software;
4) Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution and movement, (or other) behavior) from available data in order to estimate exposures on local marine mammal populations.
5) How these exposure estimates are interpreted relative to noise exposure thresholds and/or guidelines?
6) Review all relevant post-modeling correction factors for the SAIC model

7) Review all inherent, underlying assumptions in each model

The CIE reviewers and moderator shall meet to develop a set of test runs for during the panel review meeting. The purpose of this evaluation is to determine how the NUWC/SAIC model responds to a set of inputs designed to test the model. The CIE reviewers shall also acknowledge the differences and the roles of the external components (*e.g.*, animal input parameter values, propagation models) and the internal component of the model (e.g., ship movement) in regard to the functionality of the model The distinction is drawn here to emphasize that the values of animal placement parameters can and should change when new data are available, and that both models can utilize that new data. Navy staff will provide a comprehensive list of all of the parameters that can be input or changed by the users, versus those that are internal components. Example scenarios for devising these runs are provided in Annex IV.

Days 2-3 of the panel review meetings at NUWC and SAIC: CIE reviewers and the moderator shall work with NUWC/SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. For the NUWC model, the scenarios will be enacted both with and without the ESME behavioral module so that the reviewers can assess both. For the SAIC model – post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of NUWC/SAIC scientists as required, design simulations and request that the NUWC/SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because NUWC/SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, NUWC/SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, NUWC/SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

Terms of Reference

The CIE panel shall complete the following Term of Reference (ToR) for each meeting, and document their results in the individual panelist and summary reports.

1. Assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model implementation sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation).
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure conditions for animals within the NUWC/SAIC models.
3. Assess the validity of any post-modeling correction factors ("business rules") for the SAIC model.
4. Assess whether NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Monitoring (CREM) guidelines for model development.

1. NUWC/SAIC Model Implementation

Details relevant to the topics described below are given in the documents identified in Annex 1.

- Does the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:

  i. accurately and efficiently implement the propagation model? Identify any errors in the implementation. The propagation model implemented in the NUWC/SAIC models is CASS/GRAB. *The propagation model itself is not the subject of the CIE review, but rather the implementation of the model within NUWC/SAIC models*

  ii. correctly handle the input values to the models? If not, identify any errors. For example, are acoustic source level and frequency values properly transferred through the model components?

  iii. correctly and efficiently extract data from databases? If not, identify any errors. The NUWC/SAIC models use the GDEM (v 3.0) database for Sound Speed Profiles and DBDBV-5 Version 5.2 Level 0 for bathymetry.
- Does (or can) the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model correctly consider the biological parameters necessary to estimate effects on marine mammals from exposure to sonar or explosives based on current scientific knowledge, such as:
  i. Marine mammal distribution (including variation by species, season, and geographic areas within a given action area (habitat preference))
  ii. Marine mammal movement (horizontal and vertical)
  iii. Marine mammal behavior (patchiness/group size and likely avoidance of sound source)

- Does the model make appropriate assumptions to deal with uncertainty when biological data, such as distribution, movement and/or behavior, may not be available for a particular species?
- Does the NUWC/SAIC model consider the appropriate acoustic exposure metrics? Are the methods for accumulating SEL from multiple exposures consistent with standard scientific practice?
- Comment on the strengths and weaknesses of the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC model would likely result in over/underestimates of take (and the degree, if possible)

2. <u>CREM Guidelines</u>

The panel shall assess whether the NUWC (and separately, the NUWC model including the incorporation of the ESME behavioral model)/SAIC models meet the EPA's Council for Regulatory Environmental Monitoring (CREM) guidelines for model evaluation, which are summarized below. Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of

Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

Schedule of Milestones and Deliverables:
The CIE shall complete the milestones and deliverables in accordance with the schedule of activities provided in the following table.

Activity and Responsible Party	Date
NMFS Project Contact will provide pre-meeting background documents to CIE	17 October 08
CIE reviewers and moderator(s) shall participate in a teleconference call with NMFS, NUWC and SAIC to discuss technical and logistical details of the peer review meetings (depending on availability of participants).	27 October 08 1pm 866-620-3559 Passcode 6243699#
CIE reviewers and moderator shall participate in panel review meeting at NUWC to test models Address - 1176 Howell Street, Bldg. 1346, Rm 407U, Newport, RI 02841	**12-14 Nov 08**
CIE reviewers and moderator shall participate in panel review meeting at SAIC to test models Address - 1710 SAIC Dr, McLean, VA 22102	**17-19 Nov 08**
CIE reviewers shall submit their CIE independent peer review reports to CIE and the CIE moderator(s)	5 December 08
CIE moderator(s) shall submit their CIE summary report(s) to CIE	17 December 08
Upon CIE Steering Committee review and approval, CIE shall submit the CIE independent and summary reports to the NMFS COTR for review and approval in accordance with the ToR	24 December 08
CIE shall submit the final CIE reports in PDF format to the NMFS COTR	5 January 09
NMFS COTR will distribute the final CIE reports to the NMFS Project Contact for distribution	12 January 09

Acceptance of Deliverables:

Each CIE reviewer shall complete and submit an independent CIE peer review report in accordance with the ToR, which shall be formatted as specified in Annex 2, to Dr. David Sampson, CIE regional coordinator, at david.sampson@oregonstate.edu, and Mr. Manoj Shivlani, CIE lead coordinator, at shivlanim@bellsouth.net. Upon review and acceptance of the CIE reports by the CIE Coordination and Steering Committees, CIE shall send via e-mail the CIE reports to the COTR (William Michaels William.Michaels@noaa.gov at the NMFS Office of Science and Technology by the date in the Schedule of Milestones and Deliverables. The COTR will review the CIE reports to ensure compliance with the SoW and ToR herein, and have the responsibility of approval and acceptance of the deliverables. Upon notification of acceptance, CIE shall send via e-mail the final CIE report in *.PDF format to the COTR. The COTR at the Office of Science and Technology have the responsibility for the distribution of the final CIE reports to the Project Contacts.

Key Personnel:

Contracting Officer's Technical Representative (COTR):

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Request for SoW and ToR Changes:

The Statement of Work (SoW), Terms of Reference (ToR) and list of pre-review documents herein may be updated without contract modification as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToR are not adversely impacted. Any such requests for changes to the SoW and ToR shall be submitted to the COTR (Contracting Officer's Technical Representative) for approval no less than 15 working days prior to the CIE peer review meeting.

ANNEX I: Documents to be reviewed in preparation of the NUWC/SAIC model review. This is a tentative list and will be further refined and specified prior to the review time. Documents may be provided on an ftp site because of large size.

Document Titles
1. NUWC Marine Mammal Acoustic Effects Analysis
2. Numerical Simulation of Undersea Detonation Effects on Marine Species Life
3. NUWC Environmental Modeling for Marine Mammal Acoustic Effects Analysis
4. Oceanographic and Atmospheric Library (OAML) Summary
5. Insert PowerPoint presentation on SAIC model
6. Marine Resource Assessment for SOCAL
7. Source of density for SOCAL

Document	Document Type	Number of Pages	Degree of Difficulty
1. NUWC Acoustic Model	PDF		
2. NUWC Explosive Model	PDF		
3.NUWC Environmental			
4. OAML description	PDF	113	Low
5. SAIC Presentation	PowerPoint		
6. MRAs	CD/Hardcopy		
7. SOCAL Density			
8. Acoustic appendices from EISs for both the SAIC and NUWC models	PDF		

ANNEX II: Format and Contents of CIE Independent Reports

1. The report should be prefaced with an Executive Summary with concise summary of goals for the peer review, findings, conclusions, and recommendations.

2. The main body of the report should consist of an Introduction with
    a. Background
    b. Terms of Reference
    c. Panel Membership
    d. Description of Review Activities

3. Summary of Findings in accordance to the Term of Reference

4. Conclusions and Recommendations in accordance to the Term of Reference

5. Appendix for the Bibliography of Materials used prior and during the peer review.

6. Appendix for the Statement of Work

7. Appendix for the final panel review meeting agenda.

8. Appendix for other pertinent information for the CIE peer review.

ANNEX III: Moderator's Summary Report Generation and Process

1. The summary report shall include an overview of the review process.

2. The summary report shall provide a synopsis of the three panelist reports.

3. Points of agreement and disagreement among the panelists shall be documented.

4. The summary report shall also include as separate appendices copies of each of the panelists' report.

ANNEX IV: Example NUWC/SAIC Scenarios: The panel shall create their own scenarios to be sure that their questions are addressed and answered. Reviewers will develop the scenarios in close coordination with the modeling team to ensure that the scenarios are feasible. The examples below illustrate the type of scenarios that the NUWC/SAIC models can address. They cover two sources of anthropogenic noise from mid-frequency active sonar and underwater explosives. Development of scenarios (including identification of the necessary input parameters) will be addressed during the conference call and the first day of the meeting.

1. A vessel quipped with a mid-frequency (1-10 kHz) active sonar source operating in the Southern California Range Complex (SOCAL) in May. The vessel will be on the range for three days conducting sonar operations during daylight hours. The active sonar signals are one second long broadcast once a minute with a source level of 235 dB re 1 µPa at 1 meter. The active sonar can be operated in two modes; namely, search and track. The ship is moving at 10 kts randomly in a 40 km square operational area. The question to be addressed is how many bottlenose dolphins are modeled to be exposed to a received level that would lead to MMPA Level A (PTS) and Level B (TTS and behavioral) harassment if the operation goes forward? Alternatively, how would the acoustic exposure be altered if the exercise were conducted in January?

2. A similar scenario as above but instead of using mid-frequency active sonar, an explosive source will be used. Input parameters include (among others) the net explosive weight, the explosive depth, the average sediment depth and the seasonal sound speed profile.

Appendix 2: Meeting Agenda

Agenda for SAIC Meeting in Arlington (November 17-19)

4001 Fairfax Dr, Suite 175, Arlington, VA 22203, Navy POC – Hyrum Laney 703-907-2552

Day 1

9:00 – Introductions, Logistics, Security
9:15 - Review of ToRs (Moderator)
9:30 – Welcome aboard from SAIC Acoustic and Marine Systems Operation Manager
Presentations by SAIC Personnel
9:45 - Description of current SAIC approach (i.e., the one used in the SOCAL and HRC EIS) and the software, including data input requirements. Navy staff will have provided a comprehensive list of all the model parameters that can be input or changed by the users, versus those that are internal components.
10:45 - Break
11:00 - Review of post-modeling correction factors for the SAIC model.
11:45 - Review of results of internal testing of the software.
12:15 – Lunch
1:15 - Overview of the process used to derive and incorporate animal behavior parameters (marine mammal distribution, behavior) from available data in order to estimate exposures on local marine mammal populations.
2:15 - Discussion of how noise exposure thresholds and/or guidelines are applied to calculate exposure estimates.
2:45 - Review of all inherent, underlying assumptions of the model.
3:15 - Break
Development of Trial Runs
3:30 – Navy and moderator/reviewers continue discussion of trial runs begun on conference call and finalize scenarios to be run on days 2 and 3.
5:00 – Conclude Meeting

Days 2 and 3 (Navy Contacts will break this general description down into smaller pieces in advance of the meeting)

CIE reviewers and the moderator shall work with SAIC scientists to perform the model runs to obtain sufficient information on the input data, execution parameters, and model outputs for writing their CIE peer review reports. Post modeling calculations will be implemented for the example scenarios. The CIE panel shall, with the assistance of SAIC scientists as required, design simulations and request that the SAIC scientists create input files to represent these simulations during the course of the review. Projects can be created in a few minutes. Because SAIC models are working models (not simplified for public use), requiring expertise and familiarity with data input procedures and model execution techniques, SAIC scientists will perform the model runs under the oversight of the CIE panel. The number and complexity of simulations to be run during the evaluation period will have been discussed in the conference call and finalized on Day 1. To run the models, SAIC scientists will require sufficient time to research the values of the basic parameters (i.e., marine mammal parameters for different species, or beam pattern information for source). The input files will then be run, and the inputs and outputs will be provided to the CIE panel for their analyses and evaluation.

9:00 – Development of Input Data for Trial Run (HRC/SOCAL EIS Method)
11:00 – Trial Run (HRC/SOCAL EIS Method)
12:30 – Lunch
13:30 – Review of Results, or continue review of results to Day 3.
Day 3 continued

9:00 – Review of Report format, contents, and due dates (Moderator leads)
10:00 – Reviewer/Moderator discussion and resolution of outstanding questions/issues
11:30 – Wrap-up