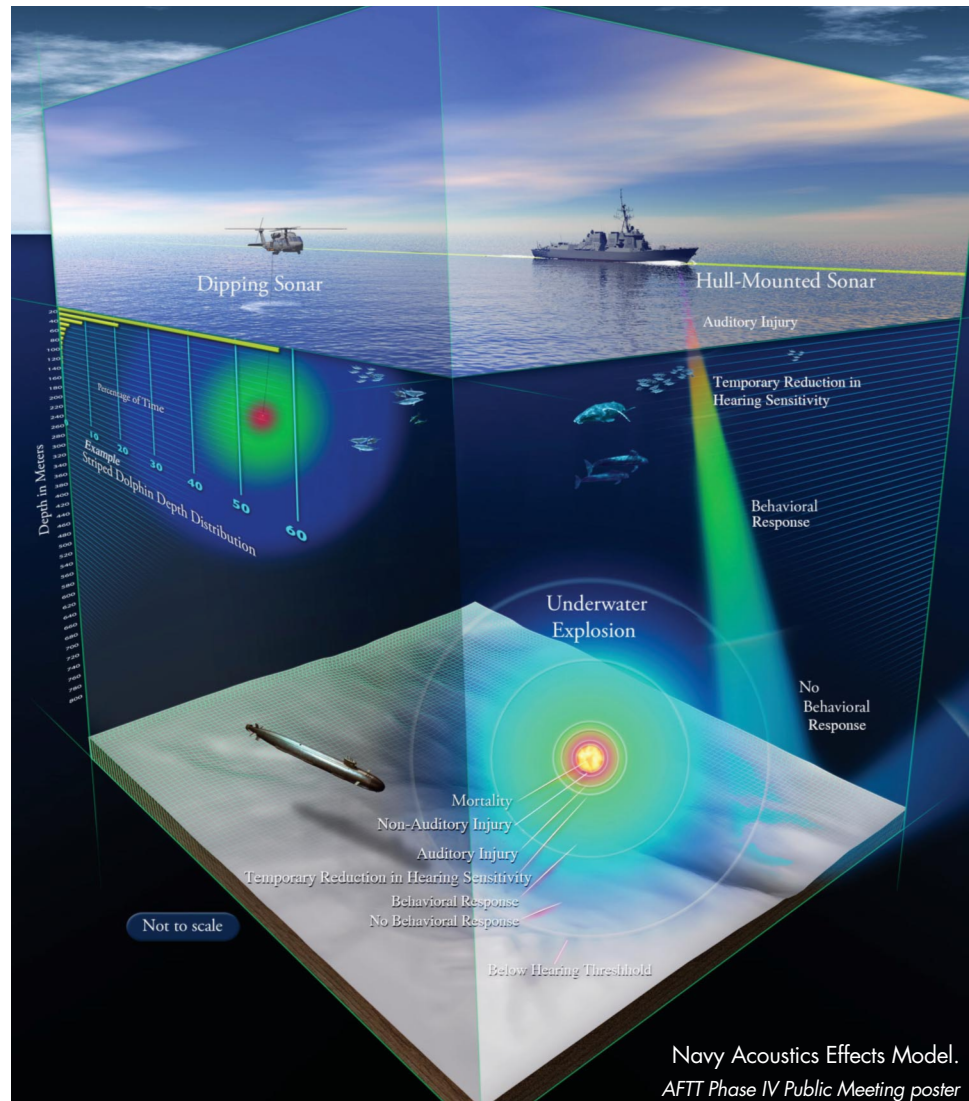# Advancing the Navy Acoustic Effects Model (NAEMO)

NEED

To assess the potential impacts of training and testing activities on protected marine species, the Navy uses the Navy Acoustic Effects Model (NAEMO). This acoustic modeling and simulation tool estimates potential impacts on protected and endangered marine mammals and sea turtles from underwater sound associated with Navy training and testing activities. Originally developed in the late 1990's, NAEMO has been updated periodically to reflect advancing technical and scientific knowledge. A recent scientific review and workshop identified several areas for needed improvements including further consideration of the sensitivity of the model to its inputs, the uncertainty and the overall robustness of the current modelling approach.

Navy Acoustics Effects Model.
AFTT Phase IV Public Meeting poster

SOLUTION

This project will conduct sensitivity analyses to consider which input parameters have the greatest influence on model outputs (and thus may be the subject of future research investment to improve estimates of effects). Uncertainty analyses will focus on how much the uncertainty in each input parameter influences uncertainty in the resulting model outputs. This also includes the estimation of a Monte Carlo error, which is an uncertainty that arises because it was computed using a finite number of simulated samples instead of the true, infinite distribution. Finally, robustness analyses, a type of sensitivity analysis, will be used to assess how sensitive model

outputs are to different possible model formulations (as opposed to differences in parameter values within a model formulation).

METHODOLOGY

This is a collaborative project between the principal investigators from St Andrews (led by SMRU Consulting) and the Marine Species Modeling Team (MSMT) from the Naval Undersea Warfare Center (NUWC) Division Newport. Each team will lead separate but closely related efforts. One will be primarily undertaken the team at NUWC with support and input from St. Andrews and one will be led by the St Andrews team, developed outside of the current NAEMO modeling processes but in consultation with MSMT NUWC. Within each effort, the project has identified specific work packages as summarized below.

- **Work package one (WP1): Monte Carlo error and sensitivity of NAEMO input parameters**

  Led by MSMT NUWC, the project team will work to understand the size of the expected Monte Carlo error (uncertainty) and how that error changes. They also will work to identify other potential error components. Results will contribute to other work packages, specifically work package three (animat seeding) and work package four (simulation studies).

- **Work package two (WP2): Simulator development**

  The St Andrews team will develop a simulator to understand which processes, and their formulation, are having the largest influence on estimated effects or on other metrics used to support compliance. The functional and efficient NAEMO simulator is intended to approximate the current NAEMO outputs but with increased flexibility to explore sensitivities of input parameters and processes within the model.

- **Work package three (WP3): Animat seeding**

  This work package will explore how within NAEMO virtual marine animals (animats) are introduced and distributed (i.e., seeded) and

when density is accounted for in the modeling processes. This will help to identify processes that could reduce simulation complexity, processing time and the size of the output file.

- **Work package four (WP4): Simulation studies**

  This will include two phases of simulation studies. The first (WP4a) will explore animat movement in multiple dimensions, sound propagation complexity and sound avoidance and how these factors change the estimated effects compared with current NAEMO outputs. A second phase (WP4b) will then be undertaken to understand if, and how, to implement context-specific animat responses and whether such inclusion would improve overall compliance.

SCHEDULE

With its August 2025 start, the project plans to have final products expected by the end of 2028. Work packages one and two deliverables are expected by mid-2026. Subsequent products are estimated by the close of 2027 (WP3) and 2028 (WP4). However, sequencing and schedule for each work package will be determined in coordination with the MSMT NUWC.

NAVY BENEFITS

Input parameters and modeling methods analyzed in WP1 will highlight those areas of NAEMO to be improved, ultimately providing more accurate results. Refined simulation capabilities will decrease processing/run times for future NAEMO simulations program runs. Additionally, improvements could increase responsiveness to new data and ensure use of best available science. Currently if new or corrected data are provided at the end of simulation runs, varying degrees of re-analysis are required depending on the change. Improved simulation tools could allow partial re-analysis, minimizing the additional level of effort and time demands of full re-analysis. Increased efficiency and reduction of processing time will provide cost savings to the Navy.

PRODUCT AND DELIVERABLES

A technical report from WP1 will characterize the Monte Carlo error and sensitivity of the input parameters. Related software code (in R) and supporting technical reports will be produced following each simulator development package completed under WP2. An additional technical report from WP3 will summarize the animat seeding approaches explored and any decisions made/implemented for analyses in future phases. The WP4 report will clearly indicate whether some of the processes coded in the simulator can be directly implemented or amended in NAEMO and what these processes should look like (e.g. 2D or 3D movement). A manuscript for peer-review publication will summarize the WP4 effort.

ABOUT THE PRINCIPAL INVESTIGATORS

Samantha Simmons is a principal scientist with SMRU Consulting and previously served as the Scientific Program Director with the U.S. Marine Mammal Commission. Dr. Simmons earned her Ph.D. in ecology and evolutionary biology at the University of California, Santa Cruz.

Magda Chudzińska is a senior researcher with SMRU Consulting investigating potential effect of marine developments on marine mammal species. Dr. Chudzińska earned her Ph.D. from Aarhus University.

Co-investigator: Len Thomas (Centre for Research into Ecological and Environmental Modelling (CREEM) and School of Mathematics and Statistics at the University of St Andrews).

About the LMR Program

The Living Marine Resources (LMR) program seeks to develop, demonstrate, and assess data and technology solutions to protect living marine resources by minimizing the environmental risks of Navy at-sea training and testing activities while preserving core Navy readiness capabilities. For more information, contact the LMR program manager at exwc_lmr_program@navy.mil or visit exwc.navfac.navy.mil/lmr.