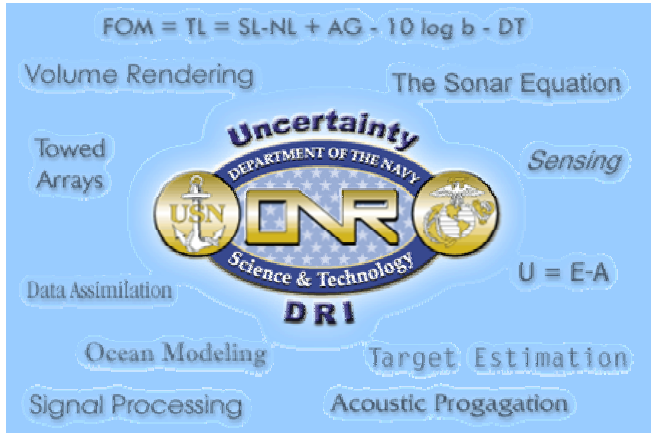

Modeling and Analyzing the Propagation of Uncertainty from the Environment through Sonar Performance Prediction

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Long Term Goals

- **Understand the propagation of uncertainty from the Ocean Environment to Performance Prediction**

- **For the purpose of studying Uncertainty: Develop a Simulation platform for the Ocean ==> Acoustics-==> Signal Processing ==> Performance Prediction**

- **Develop methodology to distill the complexity and uncertainty of the ocean/acoustic/system sensitivities to relevant situational awareness for the operator**

Objectives/Approach

- **Study physics of the interfaces of the uncertainty components (Simulation AND Theory)**
- **Model synthesis for Monte Carlo simulations**
- **Combination of above for test and evaluation**
- **Utilize data of opportunity**

Participants and Components

- **<u>SIO, MPL/PORD</u>: Initial acoustic/system modeling; Adjoint model studies, setup of Monte Carlo Platform, ocean/data objective mapping of SWellEx site and ROMS modeling, "platform" (Cornuelle, Gerstoft, Hodgkiss, Kim, Kuperman, Thode)**

- **<u>SAIC</u>: Adjoint methodology, fast propagation modeling for geo-acoustic Monte Carlo simulation, "platform" (Hursky, Porter, Siderius)**

- **<u>Orincon</u>: Geo-acoustic uncertainty as related to inversion methodology; Situational awareness/performance prediction (Cox, Heaney)**

- **<u>Duke</u>: Signal processing physics of uncertainty; Test and evaluation with data (Krolik, Nolte)**

Common Themes

- Adjoint methodology for both acoustics and oceanography
- Statistical analysis for inversion and signal processing uncertainty
- ROMS modeling and objective mapping providing a “data” platform for Monte Carlo simulations
- Rapid propagation modeling making sophisticated Monte Carlo possible
- Rapid inversion methods estimate bias in uncertainty as well as potential for reducing uncertainty
- Signal processing, uncertainty and sonar performance
- Uncertainty display issues

Presentations

- **Paul Husky: Acoustic adjoint method [10 min]**
- **Bruce Cornuelle: Sensitivity analysis for oceanography/acoustics with the adjoint methodology and data analysis [35 min]**
- **Michael Porter: Rapid 3D modeling and sensitivity analysis [15 min]**
- **Bill Hodgkiss: Inversion and uncertainty mapping [10 min]**
- **Kevin Heaney: Inversion, TL sensitivity and uncertainty display [20 min]**
- **Krolik/Nolte: Signal processing, uncertainty and performance prediction: Theory and data [30 min]**

Final Status

- Development of acoustic/pressure adjoint methodology.
- Development of Rapid 3D modeling/sensitivity Monte Carlo capability.
- Extension of adjoint theory beyond pressure to other observables.
- ROMS configured for 600 m nested grid in SwellEx region,
- Including tidal forcing; Realizations generated from ROMS.
- Pre-assimilation studies exploring ensemble generation and nonlinearity and information content of intensity data.
- Related striation inversion with TL uncertainty; combined geo and ocean acoustics uncertainty --> detection range uncertainty
- Fast, analytical methods for characterizing the performance of both optimum Bayesian and adaptive CFAR detectors have been derived.
- Analytical methods derived that approximate the ROC for optimum Bayesian detection for an uncertain ocean environment model in terms of the signal covariance matrix rank, SNR, and a signal-to-interference coefficient.
- Recent results for the multiple source SWellEx-96 S59 event using the AODS North horizontal array yields agreement between theory and real data detection performance when wavefront uncertainty and limited snapshot support are accounted for.

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• P. Hursky, M. B. Porter, B. D. Cornuelle, W. S. Hodgkiss, W. A. Kuperman, “Adjoint modeling for acoustic inversion,” J. Acoust. Soc. Am. **115**: 607-619 (2004).

• A. Thode and K. Kim, "An adjoint normal-mode approach for computing derivatives of pressure with respect to environmental parameters and frequency," J. Acoust. Soc. Am. (2003).

• A. Thode, "A normal-mode formula for the derivative of a waveguide pressure field with respect to three-dimensional sound speed perturbations,” J. Acoust. Soc. Am. (2004).

• Kevin Heaney, Henry Cox, “ A tactical approach to environmental uncertainty and sensitivity,” submitted IEEE J. Oceanic Engr., May 2004

Kevin Heaney, Henry Cox, “Estimating and reducing uncertainty in a tactical environment.” in *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance* Eds: N. Pace and F. Jensen, Boston: Kluwer Academic (2002).

• P. Gerstoft, C-F. Huang, and W.S. Hodgkiss, “Posterior estimation of transmission loss from ocean acoustic data ,” submitted IEEE J. Oceanic Engr., 2004.

Publications to Date (not including abstracts) cont'd

- P Gerstoft, C-F. Huang, and W.S. Hodgkiss: "A posterior transmisson loss from ocean acoustic data," 6th Euro. Conf. Und Ac. Delft 2004.

- Liewei Sha and Loren W. Nolte, "Detection performance prediction in uncertain ocean environments: Bayesian viewpoints", J. Acoust. Soc. Am., revision submitted April 2004.

- Liewei Sha and Loren W. Nolte, "Bayesian sonar detection performance prediction in the presence of interferences in uncertain environments", J. Acoust. Soc. Am., submitted December 2003.

- Liewei Sha and Loren W. Nolte, "Bayesian sonar detection performance prediction with SWellEX96 vertical array data", special issue on Capturing environmental uncertainty in sonar performance, IEEE J. Oceanic Engr., submitted February, 2004.

- Liewei Sha and Loren W. Nolte, "Localization performance prediction in uncertain ocean environments; Bayesian viewpoint and analytical approximations", special issue on Capturing environmental uncertainty in sonar performance, IEEE J. Oceanic Engr., submitted February, 2004.

Publications to Date (not including abstracts) cont'd

- Loren W. Nolte, Stacy L. Tantum, and Liewei Sha, (invited paper) "Bayesian Matched Field Tracking, Depth Classification, and Environmental Inversion in Ocean Acoustics", Sixth International Conference on Theoretical & Computational Acoustics, Honolulu, Hawaii, April 11-15, 2003.

- J. L. Krolik, P. Book, S. Kraut, "In situ detection performane assessment of a sonar array when the signal wavefront and noise covariance are uncertain", Proc. of Sensor Array and Multichannel Signal Processing Workshop, Barcelona, July 2004 (in press).
- J.L. Krolik, P. Book, and S. Kraut, "In Situ Adaptive CFAR Performance Assessment for Passive Sonar" in preparation for submission to the IEEE J. Oceanic Engr., 2004.