Energy producing buoy for strategic applications: Design Trade Study – Q1 Report

Grant No. HR0011-09-1-0032

Lead Organization: Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039

Technical points of contact: Andrew Hamilton, Ph.D.
Jim Bellingham, Ph.D.
Tel: 831-775-1861/831-775-1731
Fax: 831-775-1646
Email: hamilton@mbari.org; jgb@mbari.org

Administrative points of contact:
Patrice Carroll
Susan Lantis
Grants Office – MBARI
Tel: 831-775-1803/831-775-1788
Fax: 831-775-1620
Email: grants@mbari.org

Project Period: 2/9/2009-6/8/2009

Report Period: 2/9/2009-5/8/2009

Summary

In the first quarter of this project, we've succeeded in establishing a team for this project and have gotten a good start on the technical work. In addition to the PI's, this team includes one existing MBARI research technician, a new MBARI engineering hire and three contractors. Because the main effort of this project is to perform a performance analysis and trade study related to the problem of wave-energy conversion for a station-keeping buoy platform, the team selected has strong representation in the fields of marine hydrodynamics, numerical modeling, and computational fluid mechanics. On March 11, 2009, the technical team met as a group at MBARI to introduce the project, discuss the project plans, and determine how the various contractors will work together to achieve the stated goals. This meeting was successful in establishing the options for the contractor interaction, and led to the subsequent consideration of several important technical details. Work has been ongoing at MBARI through the quarter to formulate the computational modeling framework needed to analyze the range of wave-energy extraction concepts identified. This framework is written in the Matlab programming language and forms the base of the analysis planned for this project. Concurrent with the development of this tool, analysis of global wind, wave, and solar data has been performed to characterize the environment the station-keeping buoy will need to operate in. This analysis is important to allow the modeling results to be used to establish long-term performance predications for specific concept designs. On April 16, 2009, a project kick-off meeting was held at MBARI with DARPA personnel and support staff. As of the end of Q1, 41% of the budget allocated for this effort has been spent. Plans for the next quarter include the use of the computational tools developed so far to establish some initial results for the various concepts under consideration. Additionally, in the next quarter the computational contributions of the contractors will be included in the modeling effort to refine the initial results.

Activities

1. Hired an engineer that will be dedicated to the project. (Sreeram Radhakrishnan, CV attached)
2. Hired consultant William Webster as a technical advisor to the project. (CV attached)
3. Held a technical meeting at MBARI with subcontractors Airflow Sciences, Marine Innovation and Technology, and consultant William Webster: March 11, 2009.
4. Held a project kick-off meeting with DARPA personnel: April 16, 2009.
5. Began development of software toolbox to perform numerical modeling relevant to the project.
6. Completed a global environmental-condition analysis.
7. Visited Roy Kornbluh at Stanford Research Institute (SRI) to discuss the applicability of their "artificial muscle" technology to this project.
8. Visited Sid Chao at CIIIS to evaluate the applicability of the "ferro-fluid" linear generator system to this project.

Technical Status and Results

The main technical work performed during this quarter involves the development of the computational framework needed to perform time-domain simulations of the various concepts under consideration for a station-keeping wave-energy conversion device. These concepts all require very similar modeling capabilities to analyze; all devices involve a floating body in waves and a device to harness energy from the relative motion of two or more bodies. The framework developed effectively solves for the motion of one or more bodies that are acted on by outside forces such as the wave field, currents wind, and any wave-energy extraction devices included in the system. This computational toolbox that is being developed is modular enough to allow various elements such as floating buoys, submerged foils, linear power take-off generators, submerged turbines, and wind turbines to be combined in nearly any arrangement. Adding new elements to the system requires only defining the forces that act on that element as a function of the elements position history throughout the time-domain simulation.

The analysis of such systems is fundamentally straightforward and involves the solution of Newton's equations of motion (force = mass times acceleration). Although the solution of this type equation is straightforward, the evaluation of the forces acting on the various parts of the system can be complicated.

For instance, the forces acting on a body floating in waves depends on the hydrodynamic behavior of the particular shape and size of the body. Further complicating this is the fact that as existing waves cause a floating body to move, this motion then causes the body itself to generate waves which add an additional force that acts on the body, further modifying it's motion. This feedback causes a "memory effect" in which the forces acting on the body at the current time depend not only on the bodies current velocity, but also on the velocity history of the body. Fortunately, systems this complicated problem has been solved by previous researchers (at least for linearized systems, which is an assumption made throughout this projects wave-body interaction numerical analysis and is one reason that subsequent validation of the simulation results via prototype or model testing is important). As of the end of the first quarter of this project, the work to include wave-body interactions of this type has been completed and the simulation framework has the capability to model the motion of a floating body in waves. Additional validation of this work via comparison with standard solutions and other simulation codes is ongoing.

To test and demonstrate the coupling of the floating body solution to submerged elements, the simple case of a submerged flat plate connected by an idealized linear generator to a floating buoy has been analyzed. In this simulation, an existing wave-field causes the buoy to move (heave, pitch and surge), this motion is coupled to a submerged flat plate via a spring/damper system that represents a linear generator. As expected, significant wave energy is converted but dissipated due to the viscous drag forces experienced by the submerged plate moving perpendicularly through the water. Nevertheless, some energy is being dissipated by the generator element. Simulations to characterize the exact performance of such a system concept are on-going.

In addition to the submerged flat plate, a simplified analysis of the behavior of a submerged foil has also been developed. The submerged foil hydrodynamics *may* also suffer from the complication of being a time-dependent phenomenon that has important memory effects. Due to the relatively long periods of the wave exciting forces, it is not yet clear if a quasi-static analysis of the foil behavior will be sufficient. To address this unknown, two approaches will be taken, one is based upon the theoretical behavior of linearized lifting flows, which will provide some guidance but may not be sufficient because of the large angles of attack experienced by a submerged foil in this application. The final evaluation of the need to include the time-dependent flow behaviors will likely require CFD (computational fluid dynamics) of this case, with and without the time-dependant effects. Fortunately, there is no fundamental reason that the time-dependent effects can't be included in the analysis, but it may increase the computation cost of the CFD work required.

Work to date on the submerged foil case has assumed that quasi-static behavior is valid and utilizes standard lift-drag behaviors of hydrofoils. The coupling of this simplified foil model to a floating body in an incoming wave-field has indeed shown that the submerged foil is capable of propelling at a slow rate of speed by converting wave energy. These results are very preliminary and quantitative estimates of the performance of such systems can not yet be stated. Nevertheless, this simplified foil model will be useful in designing and sizing the systems that will be analyzed by more sophisticated CFD techniques.

In addition to the simulation work performed, the environmental condition analysis that was started as part of the original trade study has been completed. This analysis collects global observations of wind, wave, and solar power levels, analyzes the correlations between different sources, and ground truths the global satellite observations with buoy observations at a few locations. The intention of this work is to allow a prediction of a given concept designs performance at any specified location based upon the combination of the global condition statistics and the simulation based performance predictions.

On April 15th, a visit to Roy Kornbluh at Stanford Research Institute (SRI) was made to evaluate the possible application of SRI's "Artificial Muscle" technology to this energy buoy project. This technology is interesting and may have an application if the analysis performed as part of this project requires a linear generator device. Linear generators are typically very inefficient and if such a device is to be included in the prototype and demonstration platforms, specific technology for this element must be identified. The SRI project is primarily related to the development of the artificial muscle components, their understanding of wave-dynamics and ocean engineering is less developed. There may be a good opportunity to collaborate with this group to provide the analysis capability they need to determine a

suitable application of their technology. Unfortunately, their statements about the efficiency of their technology were not clear, but it was discussed that if we provided a force and motion range estimate, they'd be able to characterize their system suitably for inclusion into our modeling.

On April 29th, a visit to CIIIS in southern California was made to evaluate the suitability of the ferro-fluid linear generator technology under development there. Like the SRI technology, this could be a solution if a linear generator element is required by our designs. Unfortunately, the technical knowledge and ability of this group seemed very rudimentary and it's difficult to imagine them producing a useable technology without significant help. They were completely unable to provide efficiency and performances estimates and were using highly suspect extrapolation techniques to estimate the power production capabilities of their system.

Budget and Spending

As of 5/8/2009, $118,166.40 has been spent out a budgeted $287.829.00. Attached to this report is the MBARI budget status report for this project. Because the spending rate is not sufficient to utilize the allocated funds within the original four month project period of performance, a non-cost extension request was made on 5/13/2009.

Plans

In the next quarter of this project, the tools that have been developed so far will begin to be used to perform design studies on the various concept designs that are being considered for the energy buoy. As initial results become available, the contractor involvement will increase as refined models that include the CFD analysis of the submerged foil case are analyzed. Additionally in the next quarter, plans for model testing of certain elements of the proposed system will be made.

Attachments

1. MBARI Grant Status Report
2. William Webster CV
3. Sreeram Radhakrishnan CV

Grant Status Report

Month of Apr 2009

Project: 707956
Project Name: EPBuoy:Design Trade Study
Agency Name: DARPA
Prime Contract: HR0011-09-1-0032
Start Date: 2/9/2009 End Date: 6/9/2009

Active?: Y
Project Manager: Hamilton, John A
Project Total Value: $287,829

Account / Pool ID	Name	Total Budget	Ptd Billed	Ytd Billed	Itd Billed	Funds Remaining**	Open PO's w/o Overhd
Details for Grant 707956.00	*EP Buoy:DesignTrade Study*						
6000-000	Direct Labor	106,873.00	27,657.57	49,014.41	49,014.41	57,858.59	0.00
Total Labor		**106,873.00**	**27,657.57**	**49,014.41**	**49,014.41**	**57,858.59**	**0.00**
001	Fringe - Full	56,643.00	14,658.51	25,977.64	25,977.64	30,665.36	0.00
Total Fringe		**56,643.00**	**14,658.51**	**25,977.64**	**25,977.64**	**30,665.36**	**0.00**
5130-000	OS - General	20,500.00	0.00	1,710.00	1,710.00	18,790.00	0.00
5310-000	Supplies - Cmptr/Sftwr	0.00	0.00	2,102.11	2,102.11	(2,102.11)	0.00
5360-000	Supplies - General	0.00	0.00	161.72	161.72	(161.72)	0.00
5500-000	Travel - Domestic	6,600.00	0.00	0.00	0.00	6,600.00	0.00
Total Direct Costs		**27,100.00**	**0.00**	**3,973.83**	**3,973.83**	**23,126.17**	**0.00**
015	Indirect Cost Rate	97,213.00	21,581.20	39,200.52	39,200.52	58,012.48	0.00
Total Indirects		**97,213.00**	**21,581.20**	**39,200.52**	**39,200.52**	**58,012.48**	**0.00**
Totals for Grant 707956.00 EP Buoy:DesignTrade Study		*287,829.00*	*63,897.28*	*118,166.40*	*118,166.40*	*169,662.60*	*0.00*
Grant Totals		**287,829.00**	**63,897.28**	**118,166.40**	**118,166.40**	**169,662.60**	**0.00**

** Balance Excludes Open PO's

William C. Webster
Professional Biography

Personal

Birthdate: August 30, 1937 Citizenship: United States
Birthplace: New York, USA

Education

B.S. Naval Architecture and Marine Engineering,
Webb Institute of Naval Architecture, Glen Cove, New York, July 1959.

M.S. Engineering, Science/Naval Architecture,
University of California, Berkeley, California, June 1961.

Ph.D. Engineering Science/Naval Architecture,
University of California, September 1966.

Current Activities

President, Ship Research Incorporated. Software development and support in Offshore Engineering: Technip Offhore Inc., John Halkyard and Associates, American Bureau of Shipping.

Master, Deepwater Ocean Engineering Center, Harbin Engineering University, Harbin China

Chairman, International Advisory Board, Chulalongkorn University, Bangkok, Thailand

Memberm International Advisory Board, Asian Institute of Technology, Bangkok, Thailand

Member, Governing Board, Jaypee Institute of Information Technology, India (campuses in Dehli, Shimla and Kana)

Positions Held

2004 – 2006 Acting Vice-Chancellor for Budget & Finance
University of California, Berkeley.

2004 Acting Vice-Provost for Academic Planning & Facilities
University of California, Berkeley.

2003 – Present Emeritus Professor of Naval Architecture & Offshore Engineering

2000 – 2003 Vice Provost for Academic Planning and Facilities
University of California, Berkeley.

1969 - 2003 Professor of Naval Architecture and Offshore Engineering,
University of California, Berkeley.

1999 – 2003	James Fife Chair, Department of Civil & Environmental Engineering
1991 - 1999	Associate Dean of Engineering, University of California, Berkeley.
1980-85	Chairman, Department of Naval Architecture and Offshore Engineering, University of California, Berkeley.
1970-Present	President & Founder, Ship Research Inc., Kensington, CA
1968-69	Senior Research Engineer, Lockheed Missiles & Space Co., Sunnyvale, CA
1963-68	Principal Research Scientist, Hydronautics, Inc., Laurel, MD

Affiliations

Member, National Academy of Engineering

Fellow & Life Member, Society of Naval Architects & Marine Engineers.

Member, American Association of Engineering Education.

Commissioner, Commission on Engineering & Technical Systems,
National Research Council (1991-1996)

Member, Marine Board, National Research Council, 1984-1988
(Vice-Chair, 1986; Chair, 1987-88)

Secretary, The International Towing Tank Conference 1990-1993

Member, California Sea Grant Advisory Board, 1974 - 1995

External Advisory Boards for NSF (Division of Biological & Critical Systems), ONR (ocean Engineering Division), Texas A&M (Offshore Technology Research Center)

Awards

Elected to the National Academy of Engineering	1998
The Davidson Medal, for excellence in Ship Hydrodynamics, The Society of Naval Architects & Marine Engineers	1992
Elected Chairman, Marine Board, National Research Council	1986-88
Stipendiat, Alexander von Humboldt-Stiftung during residence in Hamburg, Germany.	1976
Lincoln Arc Welding Award (for being the thesis adviser to Mr. Farrokh Mistree, whose thesis won a national award).	1974
Graduate Student Paper Prize, Society of Naval Architects and Marine Engineers.	1960
Stevenson Taylor Prize (for Marine Engineering Thesis), Webb Institute of Naval Architecture.	1959

American Bureau of Shipping Prize (for highest grades), Webb Institute of Naval Architecture. 1959

Professional Societies

The Society of Naval Architects and Marine Engineers.
The Society of Sigma Xi.
American Society of Engineering Education

Languages

French (reading), German (reading, writing & some speaking), Thai (fluent)

Publications

1. "A Preliminary to the Investigation of the Torsion Loading of a Ship", SNAME Student Paper, San Francisco Section, 1960. (Awarded local and national SNAME graduate student paper prize.) 36 pp.

2. "The Static Stability of Ground Effect Vehicles--Thin Jet Theory", HYDRONAUTICS, Incorporated, Technical Report 011-1, December 1960, 37 pp. + 15 fig.

3. "Dynamic Heaving Motion of Ground Effect Machines", HYDRONAUTICS, Incorporated, Technical Report 011-3, March 1962 (with J.D. Lin), 18 pp. + 8 fig.

4. "Schiffe geringsten Wellenwiderstandes mit vorgegebenem Hinterschiff", Schiffstechnik, April 1962 (with J.V. Wehausen), Bd. 9 pp. 62-68.

5. "An Application of Linear Programming to the Fairing of Ships' Lines", A Symposium on Mathematical Programming, P. Wolfe (editor) McGraw-Hill, 1963 (with S.A. Berger), pp. 241-254.

6. "Ships of Minimum Total Resistance", The International Seminar on Theoretical Wave Resistance, University of Michigan, August 1963. Proceedings published October 1964 (with J.V. Wehausen, W.C. Lin), Vol. III, pp. 909-948.

7. "An Experimental Investigation of a Coanda Nozzle", HYDRONAUTICS, Incorporated, Technical Report 461-1, October 1964 (with T.T. Huang), 20 pp. + 13 fig.

8. "The Effect of Surface Tension on Ship Wave Resistance", Doctoral Thesis, The Institute of Engineering Research, University of California, Berkeley, Report No. NA 66-6, July 1966, 114 pp. + 6 fig.

9. "Mathematical Ship Lofting", Journal of Ship Research, December 1966, (with R.A. Tapia and D.A. Atkins), Vol. 10, pp. 203-222.

10. "The Analysis of the Control of Activated Anti-Roll Tanks", HYDRONAUTICS, Incorporated, Technical Report 490-2, December 1966 (with P. Dogan), 125 pp. + 127 fig.

11. "Rough Water Mating of Roll-on/Roll-off Ships with Beach Discharge Lighters", HYDRONAUTICS, Incorporated, Technical Report 636-1, July 1967 (with T. Hsieh, C.C. Hsu, D.P. Roseman), 68 pp. + 24 fig.

12. "The Design of Tanks for Use in an Active Tank System", HYDRONAUTICS, Incorporated, Technical Report 490-3, July 1967, 35 pp. +22 fig.

13. "An Analysis of Large Object Lift Systems", presented at the ASME Underwater Technology Division National Conference, 1967 (with E.R. Miller, Jr.), 42 pp. + 22 fig.

14. "The Design of Pumps for Use in an Active Anti-Roll Tank System", HYDRONAUTICS, Incorporated, Technical Report 490-1, October 1967 (with J. Dunne and S. Gyves), 37 pp. + 25 fig.

15. "Analysis of the Control of Activated Anti-Roll Tanks", presented at the Annual Meeting of the Society of Naval Architects and Marine Engineers, November 1967. Published in 1967 Annual Tranactions, Vol. 75, pp. 296-331.

16. "On the flow Field Beneath a Moving Pressure Distribution Over the Sea", HYDRONAUTICS, Incorporated, Technical Report 709-1, December 1967 (with T.T. Huang and K.K. Wong), 33 pp. + 10 fig.

17. "Study of the Boundary Layer on Ship Forms", HYDRONAUTICS, Incorporated, Technical Report 608-1, January 1968 (with T.T. Huang), 22 pp. + 12 fig.

18. "Vehicles for Ocean Engineering", presented at the Diamond Jubilee Meeting of the Society of Naval Architects and Marine Engineers, June 1968 (with D. Rosemand and V. Johnson), published in Diamond Jubilee Proceedings, pp. 8-2 to 8-27.

19. "Computations of Ship Boundary Layers", presented at the 7th Naval Hydrodynamics Symposium, Rome 1968 (with T.T. Huang), 5 pp.

20. "Study of the Boundary Layer on Ship Forms", (with T.T. Huang), Journal of Ship Research, Sept. 1970, Vol. 14, No. 3, pp. 153-167.

21. "An Experimental Study to Determine the Motions and Mooring Tensions of Three Buoys", Lockheed Missiles and Space Co., Report LMSC/DO 22460, Dec. 1968, 88 pp. + 17 fig.

22. "Monte Carlo Methods in Ship Design" (17 pp.) and "Container Ship Loading: A Container Allocation Model" (65 pp.) (with P. Van Dyke). Proceedings of Seminar on Computer-Aided Ship Design, University of Michigan, June 1970.

23. "Automated Procedures for the Allocation of Containers on Shipboard" (with P. Van Dyke and P. Cojeen), presented at Washington Section SNAME, Sept. 1968, 35 pp.

24. "The Prediction of Sinkage and Trim for Ships" (with O. Sibul, R. Yeung and C. Scragg), Dept. of Naval Architecture, U.C. Berkeley Report No. 74-1, January 1974, 26 pp.

25. "When is Collision Unavoidable?" presented at the 10th Symposium of Naval Hydrodynamics, Massachusetts Institute of Technology, June 1974, pp. 277-293.

26. "Phase I Report on the Development of Technical Practice for Roll Stabilization System Selection" (with E. Miller and J. Slager), HYDRONAUTICS, Incorporated, Technical Report No. 7401.06-1, October 1974.

27. "Development of Technical Practices for Selection of Roll Stabilization Systems--Phase II--Roll Tanks" (with R. Barr and V. Ankudinov), HYDRONAUTICS, Incorporated, Technical Report 7401.26-1, January 1975, 67 pp. + Appendices + 40 figs.

28. "The Flow About Arbitrary, Three-Dimensional, Smooth Bodies", Journal of Ship Research, Vol. 19, No. 4, December 1975, pp. 206-218.

29. "Basic Naval Architectural Considerations for Concrete Ships and Vessels", presented at the Symposium on Concrete Ships, University of California, September 1975, 19 pp.

30. "Structural Tests of SL-7 Ship Model" (with H.G. Payer), under publication by the Ship Structural Committee, 100 pp. + 150 fig.

31. "The Computation of the Hydrodynamic Forces Induced by General Vibration of Cylinders", Institut fur Schiffbau, Report No. 346, August 1976, 49 pp.

32. "A Water-Turbine-Driven Propeller for High Performance Craft Propulsion", (with I. Shacham), January 1977, the AIAA Journal of Hydronautics.

33. "Transient-Maneuver Testing and the Equations of Maneuvering" (with J.V. Wehausen, C. Scragg, T. Frank, D. Loeser and O. Sibul), 11th Symposium of Naval Hydrodynamics, London, March 1976.

34. "Some Aspects of Ship Maneuverability as Applied to the Problem of Collision Avoidance" (with J.T. Dillingham), presented at the Symposium on Aspects of Navigability, Delft Hydraulics Laboratory, 16 pp., May 1978.

35. "Computation of the Hydrodynamic Forces Induced by General Vibration of Cylinders", Journal of Ship Research, Vol. 23, No. 4, March 1979, pp. 9-19.

36. " A Phenomenon Observed in Transient Testing", (with J.V. Wehausen and O.J. Sibul), Schiffstechnik, Vol. 26, Nov. 1979, pp. 179-200.

37. "Mooring Loads", Recent Developments in Ocean Engineering, collection of preprints, from U.C. Extension's intensive four-day course, 24-27 Feb. 1981.

38. "The Statistical Description of the Local Motions Onboard a Ship Proceeding into a Short-crested Seaway", (with R.W. Trudell), American Society of Civil Engineers, Directional Wave Spectra Applications Symposium, U.C. Berkeley, 14-16 Sept. 1981.

39. "The Determination of the Directional Seaway from the Motions of a Ship", (with J.T. Dillingham), American Society of Civil Engineers, Directional Wave Spectra Applications Symposium, U.C. Berkeley, 14-16 Sept. 1981.

40. "Ships Moving in the Transcritical Range", (with D.B. Huang, O.J. Sibul, J.V. Wehausen, D.M. Wu, T.Y.Wu), Proceedings of the 11th Methodological Seminar on Ship Hydrohynamics, Vol. 2, Varna, Bulgaria, Nov. 1982.

41. "Wave Energy Absorption by a Permeable Ship" (with G. Nihous). Proc. Int'l. Workshop on Ship and Platform Motions, UCB, Oct. 1983.

42. "Ship Collisions with Bridges: The Nature of Accidents, Their Prevention and Mitigation", (co-author), Nat'l. Research Council, Marine Board, Nov. 1983.

43. "Ship Generated Solitons", (with R.C. Ertekin and J.V. Wehausen) 15th Symposium on Naval Hydrodynamics, National Academy of Sciences, Hamburg, West Germany, Sept. 1984.

44. "Waves Caused by a Moving Disturbance in a Shallow Channel of Finite Width", (with R.C. Ertekin and J.V. Wehausen) J. Fluid Mech., vol. 169, pp. 275-292, August 1986.

45. "A Consistent, Large-Amplitude Analysis of the Coupled Response of a TLP and Tendon System" (with J. R. Paulling), Proceedings of the Fifth OMAE Conference, Tokyo, April 1986.

46. "Measurement of the Forces on a Slightly Submerged Cylinder", (with S.B. Hodges), American Towing Tank Conference, New Orleans, August 1986.

47. Annual Report, Marine Board (W.C. Webster, editor), National Academy Press, Feb. 1987.

48. Sixteenth Symposium on Naval Hydrodynamics, Proceedings of Conference held in Berkeley, 1986. National Academy Press, pp. 613, June 1987.

49. Ocean Engineering Research Needs, (with R.J. Seymour), Institute of Marine Resources Report 87-5, September 1987.

50. Annual Report, Marine Board (W.C. Webster, editor), National Acad. Press, Feb. 1988.

51. "A Use of Graphics Workstations in Marine Container Terminals", Proceedings of United States/Japan Natural Resources Conference, May 1988.

52. "Consequence Analysis of TLP Tether Failure", (with T. Moan), Proceedings, BOSS'88, Tapir Publishers, Tronheim, Norway, June 1988.

53. "Prediction and Measurement of the Performance of Free Flooding Ship Antirolling Tanks", (with J.F. Dalzell and R.F. Barr), SNAME Transactions, vol. 96, New York, 1988.

54. "On Direct Methods in Water Wave Theory", (with J.J. Shields), J. Fluid Mech., vol. 197, pp. 171-199, Dec. 1988.

55. "Conservation Of Mechanical Energy And Circulation In The Theory Of Inviscid Fluid Sheets", (with J.J. Shields), J. Engg. Math. 23, 1-15, January 1989.

56. "Motions in Waves", (with R.F. Beck, W. F. Cummins, J.F. Dalzell, P. Mandel) Principles of Naval Architecture, Volume III, SNAME, N.Y., pp 1-188, November 1989.

57. "Applications of High-Level, Green-Naghdi theory to Fluid Flow Problems" (with J.J. Shields),. IUTAM Symposium on Marine Dynamics, Brunel University, London, June 1990.

58. "The Dispersion of Large Amplitude Gravity Waves in Deep Water" (with D.-Y. Kim),. 18th Symposium on Naval Hydrodynamics, Ann Arbor MI, August 1990.

59. "The Health of the U. S. Skill and Technology Base in Maritime Transportation", Marine Technical Society Annual Meeting, September 1990.

60. "The Motions of Large Floating Flexible Structures" (with M. ben Hamida), The First Symposium on Large Floating Structures, VLFS'91, Honolulu, HI, April 1991.

61. “Considerations for the Design of Floating Airports”, United States - Japan Natural Resources Marine Facilities Panel Conference, Tokyo, Japan, May 1991.

62. “Shiphandling Simulation for Waterway Design” (Chairman of NRC Marine Board panel which produced this report and editor of the report), National Academy Press, 1992 (Library of Congress Catalog Card Number 92-60999).

63. “Application of the Green-Naghdi Theory of Fluid Sheets to Shallow-Water Wave Problems” (with Z. Demirbilek). U.S. Army Corps of Engineers, Vicksburg, Mississippi, Technical Report CERC-92-11, 45 pp., Sept. 1992.

64. “Users Manual and Examples for GNWAVE” (with Z. Demirbilek). U.S. Army Corps of Engineers, Vicksburg, Mississippi, Technical Report CERC-92-13, 23 pp. + Appendix, 32 pp., Sept. 1992.

65. “Evolution of Time-Dependent Nonlinear Shallow-Water Waves” (with Z. Demirbilek). Advances in Hydro-Science and -Engineering, Vol. I, Part B (S. S.-Y. Wang editor), The University of Mississippi, pp. 1536-1544, June 1993.

66. "Marine Board Shiphandling Research" (with Cdr. Wayne Young). MARSIM '93, Institute of Marine Dynamics, National Research Council of Canada, St. Johns, Newfoundland, September 1993.

67. “The Proceedings of the 20th International Towing Tank, Vols. I & II” (editor), The University of California, Vol. I - June 1993, Vol II - March 1994.

68. “A Preliminary to the Physical Modeling of a Floating Airport” (with S.-W. Lee), Hydroelasticity "94, Trondheim, Norway, May 1994.

69. “The Motions Performance of a Mat-Like Floating Airport” (with P. Mamidipudi), Hydroelasticity "94, Trondheim, Norway, May 1994.

70. “Bragg Scattering of Water Waves by Green-Naghdi Theory” (with J. V. Wehausen), Z. angew. Math Phys 46 Special Issue (1995).

71. “Mooring-Induced Damping”, Ocean Engineering, Vol. 22, No. 6, pp.571-591, 1995.

72. “A numerical computation of capillary-gravity waves in deep water” (with J.-W. Kim). Workshop on Water Waves and Floating Bodies, Hamburg, Germany, 1996.

73. “GTS-Evaluation Report for Danish Maritime Institute” (Chair of committee and principal author), prepared for the Danish Agency for Development of trade and Industry, Ministry of Business and Industry, August 1996, 66pp. (Confidential)

74. “The drag of an airplane taking off from a floating runway” (with J.-W. Kim). 2nd International Symposium on Very Large Floating Structures, Yokohama, Japan, Nov. 1996. (Accepted for publication in the Journal of Marine Science).

75. “The dynamics of falling marine chain: a continuum model”, Journal of Offshore Mechanics and Arctic Engineering, Vol. 120, No. 1, February 1998, Published by ASME.

76. “The dynamics of falling chain: a rigid link model” (with W. Ma). OMAE Symposium, Yokohama, Japan, April 1997.

77. "A Waterfall Springing from Unsteady Flow over an Uneven Bottom" (with X. Zhang).Workshop on Water Waves and Floating Bodies, Alphen aan den Rijn, The Netherlands, April 1998.

78. "Optimal Structure for Large-Scale Floating Runways". Hydroelasticity '98 Conference in Fukuoka, Japan, Dec 1-3, 1998.

79. "Optimal Thruster Allocation" (with J. Sousa). ISOPE Conference, Brest, France. May 29 – June 4, 1999.

80. "Design and Characterization of a Small-Scale Azimuthing Thruster for a M.O.B. Module" (with S. Spry and D. Empey), VLFS '99 Conference, Honolulu, HI, Sept. 1999.

81. "Optimization of the Strength Distribution of a Model of a Large-Scale Floating Runway" (with J. Ma), VLFS '99 Conference, Honolulu, HI, Sept. 1999

82. "Mobile Offshore Base (MOB), Some Structural Considerations" Invited Lecture, International Ship Structures Congress Symposium, Tokyo, Japan, October 2000

83. "Hydroelastic Analysis of a Floating Runway with Inhomogeneous Structural Properties", Workshop on Water Waves & Floating Bodies, Hiroshima, Japan, April 2001

84. "A Ship Maneuvering Control Framework" (with J. Sousa, A. Girard, K. Hedrick), 20th International Conference on Offshore Mechanics & Arctic Engineering, Rio de Janiero, June, 2001.

85. "Simulation Environment Design and Implementation, An Application to the Mobile Offshore Base" (with A. Girard, J. Sousa, K. Hedrick), 20th International Conference on Offshore Mechanics & Arctic Engineering, Rio de Janiero, June, 2001.

86. "The Computation of the Motions of Large, Barge-Like Floating Structures Using Flat, Fifth-Order Source Panels" (with J. Ma), 4th Very Large Floating Structures Symposium, Tokyo, Japan, Jan 2003.

87. "A Strongly Nonlinear Model for Water Waves in Water of Variable Depth – The Irrotational Green-Naghdi Model" (with J.W. Kim, K. J. Bai, and R.C. Ertekin). Journal of Offshore Mechanics & Arctic Engineering, February 2003, Vol. 125, pp. 25-32, Feb. 2003

88. "Simulation of Characteristics of Tuned Liquid Column Damper Using a Potential-flow Method"(with P. Chaiviriyawong, T. Pinkaew and P. Lukkunaprasit). Accepted for publication in the Journal of Engineering Structures, 2006.

SREERAM RADHAKRISHNAN

The Center for Maritime Systems
Stevens Institute of Technology
711 Hudson Street, Hoboken, NJ 07030
(973) 767 8611
sradhakr@stevens.edu
http://personal.stevens.edu/~sradhakr

PROFESSIONAL OBJECTIVE

A full-time research and developmental position employing my skills in the area of acoustical oceanography, underwater acoustic propagation modeling and data analysis

EDUCATION

STEVENS INSTITUTE OF TECHNOLOGY, Hoboken, NJ

Jan 2005 – Present **Doctor of Philosophy in Ocean Engineering**
Dissertation: Real-time assessment and prediction of sound propagation in a highly variable urban estuarine environment with application to underwater detection.
Advisor: Dr. Alexander Sutin.

Sept 2003 – Dec 2004 **Master of Engineering in Ocean Engineering**
Thesis: Theoretical and experimental analysis of tethered spherical buoy instability in gravity waves.
Advisors: Dr. Raju Datla & Dr. Richard I. Hires

Relevant Coursework
Dynamic Oceanography**,** Stochastic Analysis of Ocean Waves, Estuarine Oceanography, Advanced Hydrodynamics Lab, Coastal Ocean Dynamics, Mixing of Inland & Coastal Waters, Sediment Transport, Introduction to Dynamic Meteorology, Coastal Engineering, Special Problems in Ocean Engineering - Remote Sensing of New York Harbor.

INDIAN INSTITUTE OF TECHNOLOGY (IIT) MADRAS, India

Aug 1999 - Aug 2003 **Bachelor of Technology in Naval Architecture and Ocean Engineering**
Minor: Operations Research
Senior Project: System Identification in Linear Ship Maneuvering using MATLAB.

Relevant Coursework
Fluid Mechanics**,** Introduction to Ocean Engineering & Oceanography, Marine Engineering, Ocean Wave Hydrodynamics, Computer Simulation, Vibration of Marine Structures and Acoustics, Offshore Structural Design, Physical Modeling and Instrumentation, FEM applied to Ocean Engineering.

RESEARCH EXPERIENCE

Graduate Research Assistant — **The Center for Maritime Systems**
July 2004 – Present — Stevens Institute of Technology, Hoboken, NJ

Key Contributions:

- Conducted underwater sound transmission experiments in the Hudson River estuary with a focus on transmission loss, noise level and the water column characteristics that affect propagating acoustic fields. Developed signal-processing algorithms to determine impulse response function of shallow water acoustic channels.

- Validated acoustic model predictions with experimental data and improved model predictions by incorporating realistic loss mechanisms. Analyzed model simulation results to understand the impact of variable sound speed field on the propagation of sound in an estuary. Integrated hydrodynamic and acoustic models to forecast acoustic field due to a sound source with ocean information feeding to the acoustic model.

- Utilized the BELLHOP Gaussian beam tracing model to generate eigenray plots and selectively display the multipath propagation from the source to the receiver. Analyzed channel impulse response measurements for different source-receiver spatial configurations in shallow water and obtain statistics of pulse-to-pulse acoustic fluctuations.

- Processed underwater sound recordings to develop an algorithm for the automatic detection of soniferous entities in passive acoustic signals. The algorithm was applied to identify the presence of cusk-eels in hydrophone measurements taken during acoustic surveys. The passive acoustic detection algorithm was also applied to the problem of automatically recognizing the presence of SCUBA divers in a noisy urban estuary.

- Participated as a diver in the SCUBA diver acoustic signature characterization experiment conducted in the Davidson laboratory towing tank. Gained considerable diving experience by participating in research as well as recreational dives with experienced SCUBA divers at Stevens. Currently certified as an Open-water Diver by PADI and NAUI.

- Assisted Research Engineers in carrying out hydrographic surveys and conducting field experiments in the Hudson River and New York harbor area. Worked as a deckhand on board research vessels and helped in deploying, operating and retrieving oceanographic instruments.

- Performed physical model testing of various marine crafts, coastal and offshore structures. Evaluated the stability of a spherical buoy in surface gravity waves in Davidson Laboratory towing tank as a part of master's thesis research. Analyzed the data from hydrodynamic experiments for publication.

TEACHING EXPERIENCE

Teaching Assistant — **Dept. of Civil, Environmental and Ocean Engineering**
Sept 2003 - June 2004 — Stevens Institute of Technology, Hoboken, NJ

- Taught two recitations a week for E 243 Probability and Statistics class. Administered exams, handled grades and supervised course graders. Topics included random variables, probability distributions, hypothesis testing and statistical data analysis.

- Managed Online Instructions tool (WebCT) to post assignments, solutions and grades. Held daily office hours and established individual tutoring sessions for students in need of extra help.

INTERNSHIPS

Western India Shipyard Ltd.
Goa, India
Dec 2001 - Jan 2002

- Gained extensive hands-on experience working as part of a team of technicians responsible for testing and troubleshooting shipboard mechanical systems and components.

Cochin Shipyard Ltd.
Kerala, India
May 2000 - June 2000

- Identified the various processes involved in building an entire ship from the ground up as part of the curricular industrial training at a ship building and repair yard.

INSTRUMENT SKILLS

I'm skilled in the use and installation of the following instruments:

ITC Wideband hydrophone ITC 6050C
RESON Broad Band Hydrophone TC4014
RESON Projector TC4034
Acoustic Doppler Current Profiler (ADCP) - RDI
CTD –YSI, Sea-Bird and Applied Microsystems

COMPUTER SKILLS

Programming Languages: MATLAB, FORTRAN, PASCAL
Operating Systems: Windows, DOS, UNIX (AIX, Linux, Solaris)
Software Packages: LabView, SpectraLab, AutoCAD, STAAD, Microsoft Office

SCHOLARSHIPS & AWARDS

The Center for Maritime Systems — **Research Assistantship**
Stevens Institute of Technology, Hoboken, NJ — July 2004 - Present

Civil, Environmental and Ocean Engineering — **Teaching Assistantship**
Stevens Institute of Technology**,** Hoboken, NJ — Sept 2003 - June 2004

ASCE Stevens Student Chapter Outstanding Teaching Assistant Award — May 2005

AFFILIATIONS

PADI and NAUI Certified Open Water Diver
Acoustical Society of America (ASA)
American Society of Civil Engineers (ASCE)

PUBLICATIONS

Sreeram Radhakrishnan, Alexander Sutin, "Impulse-response and acoustic fluctuation of high-frequency signals in a shallow water estuary", 156th Meeting of the **Acoustical Society of America**, Miami, Florida, November 2008 (accepted).

Sreeram Radhakrishnan, Raju Datla, Richard I. Hires (2007), "Theoretical and experimental analysis of tethered spherical buoy instability in gravity waves", **Ocean Engineering**, Elsevier, Vol. 34, pp. 261-274.

Sreeram Radhakrishnan, Alexander Sutin, Alan F. Blumberg, "Tidal time-scale variations of sound propagation in the Hudson River Estuary," **J. Acoust. Soc. Am.**, 122, 3005 (2007).

R. Stolkin, **S. Radhakrishnan**, A. Sutin, R. Rountree, "Passive acoustic detection of modulated underwater sounds from biological and anthropogenic sources," **OCEANS 2007 MTS/IEEE** Conference Proceedings, Vancouver, CA, Sep. 2007.

R. Stolkin, A. Sutin, **S. Radhakrishnan**, M. Bruno, B. Fullerton, A. Ekimov, M. Raftery, "Feature based passive acoustic detection of underwater threats," Proceedings of **SPIE** Volume 6204, 620408, Photonics for Port and Harbor Security II, May 2006.

REFERENCES

Dr. Alexander Sutin
Senior Scientist, Center for Maritime Systems
Stevens Institute of Technology,
Hoboken, NJ 07030
E-mail: Alexander.Sutin@stevens.edu
Phone: (201) 216-5339

Dr. Alan F. Blumberg
Director, Center for Maritime Systems
Stevens Institute of Technology,
Hoboken, NJ 07030
E-mail: Alan.Blumberg@stevens.edu
Phone: (201) 216-5289

Other references available upon request