Naval Construction and Engineering

Ship Design and Technology Symposium

Thursday, May 2, 2019

MIT Samberg Conference Center, 50 Memorial Drive
Building E52-Seventh Floor, Dining Rooms M & I

0800 - 0845	Registration and Continental Breakfast
0845 - 0900	Welcome and Opening Remarks - CAPT Joe Harbour, Director Naval Construction and Engineering - Prof Nicholas Makris, Director for the Center of Ocean Engineering
0900 – 0925	Student Design Project Brief - U-MaVeRIC: UxV Augmented Surface Combatant: LT Ioannis Dagres, LT Casey Strouse, LCDR Matt Washko
0925 – 0950	Student Conversion Project Brief - FREEDOM Class LCS Propulsion Plant Conversion: LT Charles Hasenbank, LT Tikhon Ruggles, LT Cody White
0950 – 1010	Poster Session
1010 – 1035	Research Brief: Prof Dick K. P. Yue - Design and Testing of an Autonomous Mothership for Surface Vehicle Swarm Docking: LCDR Andrew Freeman
1035 – 1100	Student Design Project Brief - Experimental Evaluation Vessel: LT Bill Hentschel, LCDR DP Johnsen, LCDR William Taft
1100 – 1120	Poster Session
1120 – 1145	Research Brief: Prof James Kirtley - Z-source Circuit Breaker Use in Naval Power Systems: LCDR William Taft
1145 – 1200	Break, lunch served
1200 - 1250	**Lunch Buffet and Keynote Address** **RADM Ronald A. Boxall, Director, Surface Warfare (N96)**
1250 – 1300	Break, transition
1300 – 1325	Student Design Project Brief - T-AH 21 Next Generation Hospital Ship: LT Aaron Sponseller, LT Travis Rapp, LT Robert Carelli
1325 – 1350	Student Conversion Project Brief - Halifax Class Frigate Laser Installation conversion: LT(N) Eric Jeunehomme, LT Austin Jolley
1350 – 1410	Poster Session
1410 – 1435	Student Conversion Project Brief - DDG 51 FLT IIA Roll Reduction Conversion: LT Thomas Deeter, LT Michael Liu
1435 – 1500	Student Conversion Project Brief - Autonomy of Opportunity: Kit for a Unmanned Platform: LT Jason Barker, LT David Baxter, LT Brian Stanfield
1500 – 1520	Poster Session
1520 – 1545	Student Design Project Brief - Project Smenos: Squadron of Optionally Manned Corvettes: LCDR Andrew Freeman, LT Udit Rathore
1545 – 1550	Wrap-Up and Concluding Remarks
1550	**Mission Complete**

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History

In August 1897, the Chief Naval Constructor, Commodore Hichborn requested Massachusetts Institute of Technology to develop and offer a three-year course of study for the professional training of naval constructors. MIT cordially responded to this request and a course of study was agreed upon. The three years of work were designated as the Junior, Senior, and Graduate years. Successful completion of the course led to the Master of Science degree. In 1901, three graduates of the U.S. Naval Academy, Ensigns Ferguson, McEntee and Spilman, began the course of study under the direction of Professor William Hovgaard.

An 1877 graduate of the Danish Naval Academy in Copenhagen, Hovgaard served in the Danish Royal Navy until 1883 when he was sent to the Royal Naval College in Greenwich, England, to study warship construction. He graduated from its three-year course in 1886 and the next year published his first naval book, "Submarine Boats." In 1901, as a Commander in the Danish Navy, he came to the United States to continue his study of the submarine and was induced by the Secretary of the Navy, John D. Long, to take charge of the new course for naval constructors at MIT. Professor Hovgaard resigned from the Danish Navy as a Captain in 1905. He was head of the new course, designated XIII-A, until 1933 when he retired as a Professor Emeritus. During his years as head of course XIII-A, Professor Hovgaard taught hundreds of naval officers and authored several widely-used textbooks.

The Naval Academy graduates sent to MIT for the course officially were attached to the Navy Yard in Charlestown and were registered as regular MIT students. The faculty maintained close relations with the chief constructor in Washington and with the constructors and top civilian staff at the Navy Yard and Fore River Ship and Engine Company in Quincy. This served two purposes: the instruction at MIT was being adapted to the needs of the service, and the faculty could use the work under construction at both yards to illustrate the classroom instruction. The course schedule was arranged to permit the students to spend one afternoon a week at the Navy Yard.

The course for naval constructors differed from the regular course XIII studies in that it was more intensive, more advanced, and was focused on warship design. A feature of the course, presented from the beginning, was that it fully immersed students in the various subjects not only with lectures, but with projects and practical assignments designed to provide hands-on experience in drawing, machine tool work, and laboratories.

Since 1910, instructors in the XIII-A curriculum have also been commissioned U.S. Navy officers. The first, Professor Henry H. W. Keith, with course XIII-A from 1910-1945, was commissioned a Lieutenant Commander in the Corps of Naval Constructors during WWI. Instructor Harold Larner (1916-1917) also held a naval commission and retired as a Captain. From 1910-1945, Course XIII-A relied on long-term instructors such as Professors Hovgaard (Captain, Danish Navy, 1901-1933), Keith (Captain, USN, 1910-1945), and Rossell (Captain, USN, 1931-1946) to lead the naval construction program. In 1945, the Navy's Bureau of Ships inaugurated the practice of detailing two active duty officers as professors for relatively short terms (2-3 years). At any given time, one officer would be a trained and experienced naval architect and the other a naval engineer.

In January of 2005, the Department of Ocean Engineering merged with the Department of Mechanical Engineering. The Naval Construction and Engineering Program, formerly called XIII-A, is now Course 2N in the Center for Ocean Engineering, Department of Mechanical Engineering

MIT Naval Construction and Engineering Program Description

The graduate program in Naval Construction and Engineering is intended for active duty officers in the U.S. Navy, U.S. Coast Guard and foreign navies who have been designated for specialization in the design, construction and repair of naval ships. The curriculum prepares Navy, Coast Guard and foreign officers for careers in ship design and construction and is sponsored by Commander, Naval Sea Systems Command. Besides providing the officers a comprehensive education in naval engineering, we emphasize their future roles as advocates for innovation in ship design and acquisition. All officers write a thesis and we endeavor to direct them toward research that supports the needs of the Navy or the Coast Guard. The course of study consists of either a two-year program, which leads to a Master of Science degree in Naval Architecture and Marine Engineering, or a three-year program, which leads to the degree of Naval Engineer.

The principal objective of both the two and three-year programs is to provide a broad, graduate level technical education for a career as a professional Naval Engineer with ship orientation. In addition to concentrating on hydrodynamics, structures and design, the curricula of both programs provide an appreciation for total ship engineering in a manner not covered in mechanical, electrical, structural, nor nuclear engineering. This approach provides an academic background for individuals who will later occupy positions of influence and actively participate in the concept formulation, acquisition, construction/modernization, design, maintenance, or industrial support of large-scale ship system programs.

The curriculum emphasizes ship design through a sequence of five subjects. "Projects in New Construction Naval Ship Design" is the last in the sequence of subjects in naval ship design at MIT. This ship design project, along with the graduate thesis, represents the culmination of the three-year Naval Construction and Engineering Program. The ship design project provides each student with the opportunity to develop an original concept design of a naval ship. The project begins during their third summer, continues through the Fall semester and Independent Activities Period and completes in their final Spring semester. The major objectives of the project include: (a) application of their naval architecture and ship design education in a complete concept design process; (b) application of their MIT technical education to at least one area of detailed engineering in this project (e. g., structures, hydrodynamics, signatures); (c) contribution to existing MIT Center for Ocean Engineering design tools; (d) application of at least one new technology and assistance in answering design questions for sponsors. These objectives are the basis for specifying requirements and planning individual projects.

There are two active-duty Engineering Duty Officer Faculty for the Naval Construction and Engineering program and officers from the U.S., Hellenic, Israeli, Turkish and Canadian navies, and U.S. Coast Guard in the program. Officer students are admitted, and Navy faculty members are appointed, through normal MIT procedures. The program is a model of voluntary collaboration for the mutual benefit of MIT and the Navy.

Rear Admiral Ronald A. Boxall

Director, Surface Warfare (N96)

Rear Adm. Ronald Boxall is a native of Holland Patent, New York. He attended The Pennsylvania State University, earning a Bachelor of Science in Science and was commissioned in 1984. He also attended the Naval Postgraduate School in Monterey, California, where he earned a Master of Science in Information Systems and later attended the Naval War College in Newport, Rhode Island, earning a Master of Arts in National Security and Strategic Studies.

Boxall's sea duty assignments include: commander, Carrier Strike Group 3 embarked in USS John C. Stennis (CVN 74); command of USS Lake Erie (CG 70) and USS Carney (DDG 64); executive officer of USS Hue City (CG 66); combat systems officer in USS Simpson (FFG 56) and USS Ramage (DDG 61); and division officer in USS Merrill (DD 976) and USS Kinkaid (DD 965). During his seagoing career, he has made numerous deployments around the world from the Western Pacific, Atlantic and Indian Oceans to the Baltic, Mediterranean and Caribbean Seas as well as combat operations in the Arabian Gulf and counter-narcotics operations off South America. A former Pacific Fleet Shiphandler of the Year, he was also fortunate to have been associated with four outstanding Battle "E" winning crews.

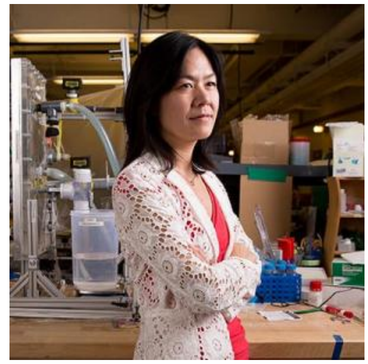
Ashore he served in numerous joint and staff billets to include: deputy director for Joint Strategic Planning (J-5) and deputy and chief of the Joint Staff Quadrennial Defense Review Office (J-8) on the Joint Staff, where he was selected as Action Officer of the Year; deputy director for Surface Warfare (N96B), executive assistant to the deputy chief of naval operations for Integration of Capabilities and Resources (N8), and executive assistant to the director of Navy Warfare Integration (N8F) on the Office of the Chief of Naval Operations (OPNAV) staff; and placement officer and deputy Surface Officer Distribution Division (PERS-41B) at Naval Personnel Command.

He is currently serving as the director, surface warfare, OPNAV N96 in the Pentagon.

Boxall's military awards include the Defense Superior Service Medal, Legion of Merit, Defense Meritorious Service Medal, Meritorious Service Medal, Joint Service Commendation Medal, Navy and Marine Corps Commendation Medal and the Navy and Marine Corps Achievement Medal, as well as various campaign and unit awards. Additionally, he was a recipient of the 2016 Penn State Eberly College of Science Outstanding Alumni Award.

Evelyn Wang

Department Head, Mechanical Engineering
Gail E. Kendall Professor



Evelyn N. Wang received her BS from MIT and MS and PhD from Stanford University. From 2006-2007, she was a postdoctoral researcher at Bell Laboratories, Alcatel-Lucent. Her research interests include fundamental studies of micro/nanoscale heat and mass transport and the development of efficient thermal management, water desalination and harvesting, and solar thermal energy systems. She has published over 100 archival journal papers her work has been honored with several awards including the 2012 ASME Bergles-Rohsenow Young Investigator Award and the 2017 ASME Gustus L. Larson Award. Her work on solar thermophotovoltaic energy conversion was selected as one of 10 breakthrough technologies in 2017 by MIT Technology Review and her work on water harvesting from air was selected as one of 10 emerging technologies in 2017 by Scientific American and World Economic Forum. She is an ASME fellow.

Dick K.P. Yue, Sc.D

Philip J. Solondz Professor of Engineering
Professor of Mechanical and Ocean Engineering

Dick K.P. Yue is the Philip J. Solondz Professor of Engineering, and Professor of Mechanical and Ocean Engineering, at MIT.

Professor Yue is a long-time MIT'er, having received all his degrees (S.B., S.M. and Sc.D.) in Civil Engineering from MIT. He has been a faculty member in the MIT School of Engineering since 1983. He is active in research and teaching in wave hydrodynamics, fluid mechanics and computational methods with applications to coastal and ocean engineering. Professor Yue is the Director of the Vortical Flow Research Laboratory and co-Director of the MIT Testing Tank facility, supervising an active research group of about 20 members. His main research focus is in theoretical and computational hydrodynamics, and he is internationally recognized for his expertise on ocean and coastal wave dynamics and for his extensive work in nonlinear wave mechanics, and large-amplitude motions and loads on offshore structures. Professor Yue has made seminal contributions in developing modern numerical methods for these problems, notably the development of the high-order spectral method for nonlinear wave-wave, wave-body, and wave-bottom interactions. Professor Yue has also made important contributions to the understanding of hydrodynamics of fish swimming, the complex mechanisms at the air-sea interface and their effects on interfacial processes. He has authored/co-authored some three hundred papers and a two-volume textbook on theory and applications of ocean wave hydrodynamics.

Professor Yue served as Associate Dean of Engineering from 1999-2007 (as the number two person in the MIT's Office of the Dean of Engineering), and was actively engaged in the overall administration of the School and in its pioneering educational and research initiatives. During that time, he was the originator of the MIT OpenCourseWare (OCW) concept and its formulation and played a major role in its adoption by MIT and then in its successful implementation. Since its launch in 2001, MIT OCW has transformed the global higher education landscape. Under OCW, MIT has published all its teaching materials, over 2,200 courses plus substantial additional learning materials, including resources for high school students. To date, MIT OCW has been translated into many major languages and has been accessed by over 100 million educators and learners worldwide, and has inspired and launched an international consortium (of more than 200 institutions of higher learning from 47 countries) devoted to open educational resources. As well, the introduction of OCW laid the foundation for a potentially even greater educational impact through today's Massive Open Online Courses (MOOCs). Professor Yue is also the Founding Faculty Director of the MIT Engineering Undergraduate Practice Opportunities Program (UPOP), a program that is revolutionizing engineering education by giving undergraduates special training and industry-based work experiences. It addresses the core issue of the lack of career readiness, on-the-job skills and leadership training in traditional engineering education, and thus promotes the future success of MIT's engineering graduates. Currently, UPOP enrolls over half of all engineering majors, with an objective to benefit effectively all of MIT's graduates in the foreseeable future. Professor Yue additionally helped to create and served as the Founding Faculty Director of MIT Engineering Professional Educational Programs (PEP) office, consolidating many of MIT's existing activities in this area under one organization, and creating a focal point for developing new professional and custom educational programs and offerings. Professor Yue was the Engineering School Director of International Programs 2007-2013, and the MIT Director of the Singapore-MIT Alliance (SMA). In 2008, in recognition of these and other wide-ranging activities benefiting MIT, Professor Yue received the prestigious Gordon Y. Billard Award for services of outstanding merit to the Institute

Nicholas Makris

Director of the Center for Ocean Engineering, Professor of Mechanical and Ocean Engineering, William I. Koch Professor of Marine Technology, Director of the Laboratory for Undersea Remote Sensing Secretary of the Navy/Chief of Naval Operations Scholar of Oceanographic Sciences

Professor Makris is an international leader in ocean science and engineering. After graduating from MIT with a SB in Physics and PhD in Ocean Engineering, he served at the Naval Research Laboratory in Washington DC where he conducted research with many of the US Navy's advanced undersea sensing tools, vessels, aircraft and facilities around the world at the end of the Cold War (1991-1997) before returning to MIT as a faculty member. He has published extensively on the physics of sensing and perception; wave propagation and scattering in random dispersive media; noise, scintillation and statistical estimation; undersea exploration; marine ecology; efficient and economical hurricane power quantification from underwater sound; and polar and icy satellite exploration. He served as Chief Scientist on numerous large international oceanographic expeditions around the world from the Nordic Seas to the Revillagigedo Islands of Central America. He has pioneered the use of ocean acoustic waveguide remote sensing to instantaneously image and continuously monitor oceanic fish and marine mammal populations over continental shelf scales. Professor Makris has presented his sensing methods on Capitol Hill at the US House of Representatives in the context of fisheries and at the House of Lords of the UK Parliament in the context of nuclear nonproliferation. He has worked with Senator John Kerry and the Massachusetts State Government to help resolve the New England Fisheries Crisis. He served on NASA's Science Definition Team for the Jupiter Icy Moons Orbiter, and is a Secretary of the Navy/Chief of Naval Operations Scholar of Oceanographic Sciences, Fellow of the Acoustical Society of America and recipient of the A B Wood Medal in Underwater Acoustics. He is a Bose Research Fellow.

His work has been featured by most major news organizations, including the BBC, New York Times, NPR, The Economist, Washington Post, Los Angeles Times, United Press International, and Telegraph.
Some examples of his publications include:

N.C. Makris, P. Ratilal, D. Symonds, S. Jagannathan, S. Lee, R. Nero, “Fish population and behavior revealed by instantaneous continental-shelf-scale imaging,” Science, Volume 311, 660-663 (February 3, 2006).

Nicholas C. Makris, Purnima Ratilal, Srinivasan Jagannathan, Zheng Gong, Mark Andrews, Ioannis Bertsatos, Olav Rune Godoe, Redwood W. Nero, J. Michael Jech, "Critical Population Density Triggers Rapid Formation of Vast Oceanic Fish Shoals", Science, Vol. 323, No. 5922, 1734-1737 (March 27, 2009).

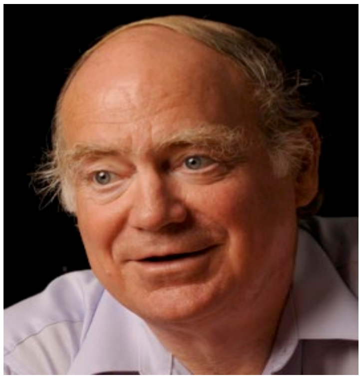
D. Wang, H.Garcia, W. Huang, D.D. Tran, A.D. Jain, D. H. Yi, Z. Gong, J. M. Jech, O. R. Godø, N. C. Makris, & P. Ratilal, "Vast assembly of vocal marine mammals from diverse species on fish spawning ground", Nature, doi:10.1038/nature16960, 02 March 2016.

P. Ratilal and N.C. Makris, “Mean and covariance of the forward field propagated through a stratified ocean waveguide with three-dimensional inhomogeneities,” J. Acoust. Soc. Am. 118, 3532-3559 (2005).

S. Lee, M. Zanolin, A. Thode, R. Pappalardo, N.C. Makris, “Probing Europa’s Interior with Natural Sound Sources,” Icarus 165, 144-167 (2003)

James L. Kirtley Jr.

Professor of Electrical Engineering, MIT



Professor Kirtley was with General Electric, Large Steam Turbine Generator Department, as an Electrical Engineer, for Satcon Technology Corporation as Vice President and General Manager of the Tech Center, as Chief Scientist and as Director. Dr. Kirtley was Gastdozent at the Swiss Federal Institute of Technology, Zürich (ETH).

Dr. Kirtley attended MIT as an undergraduate and received the degree of Ph.D. from MIT in 1971. Dr. Kirtley is a specialist in electric machinery and electric power systems. He served as Editor in Chief of the IEEE Transactions on Energy Conversion from 1998 to 2006. Dr. Kirtley was made a Fellow of IEEE in 1990. He was awarded the IEEE Third Millennium medal in 2000 and the Nikola Tesla prize in 2002. Dr. Kirtley was elected to the United States National Academy of Engineering in 2007. He is a Registered Professional Engineer in Massachusetts

Alexandra H. Techet

Associate Professor of Mechanical and Ocean Engineering

Prof. Alexandra (Alex) Techet is currently an Associate Professor of Mechanical and Ocean Engineering at MIT (with tenure). She first got the ocean bug as a kid growing up on the coast of North Carolina sailing and fixing boats. An avid sailor, SCUBA diver and water-polo player, Alex is drawn to water both in and out of the lab.

She received her B.S.E. in Mechanical and Aerospace Engineering in 1995 from Princeton University and then graduated from the MIT/WHOI Joint Program in Oceanographic Engineering with a M.S. in 1998 and a Ph.D. in 2001. In 2002, after a post-doc at Princeton University in the Mechanical and Aerospace Engineering Department, Prof. Techet returned to MIT as an Assistant Professor in the Dept. of Ocean Engineering. In 2005, Prof. Techet joined the Mechanical Engineering Dept. at MIT when the two departments merged. She also holds a guest appointment at the Woods Hole Oceanographic Institution and works with researchers there to develop oceangoing instrumentation. Professor Techet was a recipient of the 2004 ONR Young Investigators Award. Her imaging work has been recognized several times by the APS Gallery of Fluid Motion and has been featured on the cover of the Journal of Fluid Mechanics.

Professor Techet's research in experimental hydrodynamics has made important contributions to several key areas, including: 3D multi-phase flow imaging, spray hydrodynamics, water entry of spheres and projectiles, flow structure interactions, unsteady bio-inspired propulsion and maneuvering, and sensing at the air/sea interface. The goal of her research is to address long-standing hydrodynamics problems faced by the U. S. Navy and the ocean science and engineering communities through rigorous experimental investigation. Prof. Techet's work provides critical insights for the design and understanding of a wide range of systems that operate in the marine environment, including surface ships, submarines, undersea projectiles, offshore oil platforms, and ocean energy systems.

Themis Sapsis

Associate Professor of Ocean Engineering

Dr. Sapsis is the Doherty Associate Professor of Mechanical and Ocean Engineering at MIT, where he has been a faculty since 2013. He received a diploma in Ocean Engineering from Technical University of Athens, Greece and a Ph.D. in Mechanical Engineering from MIT. Before becoming a faculty at MIT, he was appointed Research Scientist at the Courant Institute of Mathematical Sciences at New York University where he worked on stochastic methods for turbulence.

Prof. Sapsis work lies on the interface of nonlinear dynamical systems, probabilistic modeling and data-driven methods. He has numerous contributions on the development of robust and efficient statistical prediction algorithms that take into account the challenges and constraints imposed by real world problems, primarily motivated by ocean engineering applications. He has published in the areas of uncertainty quantification for turbulent fluid flows in engineering and geophysical systems and his methods and algorithms have been extensively adopted and applied by others in fields such as data assimilation and filtering, CFD and optimization, probabilistic dynamical systems and others. A particular emphasis of his work is the formulation of mathematical methods for the prediction and statistical quantification of extreme events in complex engineering and physical systems such as extreme ship motions, extreme mechanical vibrations, rogue waves in the ocean, and hot-spots in turbulence.

His work has been featured by major news organizations, including the BBC and The Economist. He is the recipient of three Young Investigator Awards (Naval-, Army- and Air-Force- research office), as well as the Alfred P. Sloan Foundation Award for Ocean Sciences.

Some examples of his publications include:

M. Farazmand, T. Sapsis, A variational approach to probing extreme events in turbulent dynamical systems, Science Advances, 3:e1701533 (2017)

W. Cousins, T. Sapsis, Reduced order precursors of rare events in unidirectional nonlinear water waves, Journal of Fluid Mechanics, 790 (2016) 368-388

T. Sapsis, A. Majda, Statistically accurate low order models for uncertainty quantification in turbulent dynamical systems, Proceedings of the National Academy of Sciences, 110 (2013) 13705-13710

T. Sapsis, Attractor local dimensionality, nonlinear energy transfers, and finite-time instabilities in stochastic dynamical systems with applications to 2D fluid flows, Proceedings of the Royal Society A, 469 (2013) 20120550

A. John Hart

Associate Professor of Mechanical and Ocean Engineering
Director of the Laboratory for Manufacturing and Productivity

Prof. John Hart serves as an Associate Professor of Mechanical Engineering at MIT. He received his Bachelor of Science in Engineering from the University of Michigan, and S.M. and PhD from MIT in Mechanical Engineering. Following graduating, he returned to U of M as an Assistant Professor of Mechanical Engineering, Chemical Engineering, and Art/Design from 2007-2013. He returned to MIT in 2013 to take his current position in the faculty and received tenure in 2017.

John leads the large and diverse Mechanosynthesis research group which aims to accelerate the science and technology of advanced manufacturing in areas including additive manufacturing, nanostructured materials, and the integration of computation and automation in process discovery. He also teaches undergraduate and graduate courses in manufacturing processes, advanced materials, and research methods. John has published >125 papers in peer-reviewed journals, and is co-inventor on >50 patents, many of which have been licensed commercially. He has also co-founded of three advanced manufacturing startup companies, including Desktop Metal. John has been recognized by prestigious awards from NSF, ONR, AFOSR, DARPA, ASME, and SME, by two R&D 100 awards, by several best paper awards, and most recently by a 2017 MIT Ruth and Joel Spira Award for Distinguished Teaching

Thomas W. Eager

Professor of Materials Engineering and Engineering Management

Professor Eagar received his B.S. and Sc.D. degrees from the Massachusetts Institute of Technology (M.I.T.) in 1972 and 1975, respectively. Following graduation, he worked with the Homer Research Laboratories of Bethlehem Steel Corporation from 1974 to 1976, after which he returned to M.I.T. as a faculty member, where he rose through the ranks to his current position as Professor of Materials Engineering and Engineering Management. In 1984 and 1985, he served as a liaison scientist with the Office of Naval Research-Far East in Tokyo, Japan. Starting in 1995, he served for five years as the Head of the Department of Materials Science and Engineering at M.I.T.

Among his many citations, Dr. Eagar has received the Adams Memorial Membership Award of the American Welding Society (AWS) (1979), the Charles H. Jennings Memorial Medal Award of AWS (1983, 1991, 2003), the Champion H. Mathewson Gold Medal of AIME (1987), the Warren F. Savage Award of AWS (1990 and 1996), the William Spraragen Memorial Award of AWS (1990 and 1993), the Silver Quill Award of AWS in 2002, and the Henry Marion Howe Medal of ASM International (1992). He was the Henry Krumb Lecturer of AIME in 1987, and was elected an ASM Fellow in 1989, an AWS Fellow in 1994, and an AAAS Fellow in 2003. He received an Honorary Membership in AWS in 1999. In 1993, he received the William Irrgang Award of AWS. In 1990, he delivered the Houdremont Lecture at the International Institute of Welding, and in 1992 he delivered the AWS Comfort A. Adams Lecture. In 2008 he delivered the Plummer Lecture of AWS. In 1993, he presented the conference keynote address at the American Society for Nondestructive Testing. He delivered the Nelson W. Taylor Lecture at Penn State University in 1995 and the General Electric Distinguished Lecture at Rensselaer Polytechnic Institute in 2001. In 1997, he was elected a member of the National Academy of Engineering. In June 2003, he testified before Congress on manufacturing employment in the United States.

Professor Eagar is a member of a number of professional societies, including the National Academy of Engineering, AIME, ASM, ASME, SAE, ASTM, Tau Beta Pi and the American Academy for the Advancement of Science. He serves on the National Research Council, Board of Manufacturing and Engineering Design and is a former member of the National Materials Advisory Board. He is on the Editorial Board of the Science and Technology of Welding and Joining and is a Principal Reviewer for the Welding Journal. He has published over 220 papers and holds seventeen patents.

Daniel D. Frey

Professor of Mechanical Engineering
Faculty Research Director, MIT D-Lab

Frey's research concerns robust design of engineering systems. Robust design is a set of engineering practices whose aim is to ensure that engineering systems function despite variations due to manufacture, wear, deterioration, and environmental conditions. Frey is also actively involved in design of engineering devices for the developing world.

Professor Frey has worked intensively over the past two years with colleagues, administrators, and the Singapore Ministry of Education to establish a major new research center for engineering design. The Singapore-MIT International Design Center (IDC) is intended to be a source of new design theory, experimental evidence on effectiveness of design methods, improved teaching methods and equipment, and new technologically intensive designs. The IDC is also a nucleus for growth of the new Singapore University of Technology and Design (SUTD), which will begin teaching undergraduates in April 2012. The IDC will have active research and major facilities both at SUTD and at MIT.

Professor Frey has received numerous awards and honors. These include the Junior Bose Award for Excellence in Teaching in 2006, a best paper award from INCOSE in 2005, an NSF CAREER award in 2004; the MIT Department of Aeronautics and Astronautics Teaching Award in 2000; the Everett Moore Baker Memorial Award for Outstanding Undergraduate Teaching at MIT in 1999; and an R&D 100 Award in 1997 (for a virtual machining software he developed) and another R&D 100 Award in 2010 (for a new type of wheelchair he co-invented with a team led by Amos Winter).

Professor Frey is a member of the American Society of Mechanical Engineers (ASME), the American Statistical Association (ASA), the International Council on Systems Engineering (INCOSE), and the American Society of Engineering Education (ASEE). He holds a Ph.D. in Mechanical Engineering from MIT, an MS in Mechanical Engineering from the University of Colorado, and a BS in Aeronautical Engineering from Rensselaer Polytechnic Institute.

Steve Spear

Sr. Lecturer, MIT; Principal, HVE LLC

The speed and efficacy with which you innovate and improve has a huge effect on success—from upstream R&D to downstream operations. Spear's work focuses on accelerating this, so while rivals struggle in undifferentiated competition, you're enjoying a sustained competitive advantage with better offerings into the market offered in better ways.

At MIT, Spear teaches about this as a senior lecturer for over a decade, has advised dozens of graduate theses, and is principal investigator for research called "Making Critical Decisions When Faced with Hostile Data."

In an advisory capacity, Spear has worked with Alcoa, Intel, the Pittsburgh Regional Healthcare Initiative, the U.S. Army Rapid Equipping Force, GlaxoSmithKline, and many others to create a high velocity learning dynamic as a differentiating capability. He also has helped architect the U.S. Navy's learning strategy and was one of a few outside advisors to the Navy's internal review of Pacific Fleet collisions in 2017. Spear and his colleagues have created software—called See to Solve Gemba and See to Solve Real Time Alert System— to support accelerated learning.

Spear's writing has appeared in diverse settings – Academic Medicine, Annals of Internal Medicine, Harvard Business Review (where "Fixing Healthcare from the Inside Today" won a McKinsey Award and where "Decoding the DNA of the Toyota Production System" has been a top selling reprint and highly influential in the manufacturing community), US Naval Institute's Proceedings (forthcoming), Academic Administrator (aimed at public school superintendents), the New York Times, the Boston Globe, and USA Today. His book, The High Velocity Edge, received the Philip Crosby medal from the American Society for Quality.

Bryan R. Moser

Academic Director and Sr. Lecturer, System Design and Management (SDM)
Associate Director, Strategic Engineering Research Group

Bryan Moser is the Academic Director of MIT's System Design & Management (SDM) program. As Sr. Lecturer, his focus is on project management and design, integrating project management, system architecture, and systems engineering with an emphasis on the behavior and dynamics of teams solving complex problems across boundaries. In addition, Bryan leads multi-disciplinary research on complex sociotechnical systems as a Project Associate Professor and Director of the Global Teamwork Lab (GTL) using sociotechnical models, interactive visualization, simulations, and experiments.

Warren Seering

Weber-Shaughness Professor of Mechanical Engineering and Engineering Systems

Professor Warren Seering is the Weber/Shaughness Professor of Mechanical Engineering and Engineering Systems at the Massachusetts Institute of Technology. Professor Seering earned his B.S. and S.M. degrees in Mechanical Engineering from the University of Missouri and his Ph.D. degree in Mechanical Engineering from Stanford University. He joined the MIT faculty in 1978. His work at MIT has focused on product design and development, dynamic systems, robotics, and the role of computation in machine performance. He has taught courses in design, product development, applied mechanics, system dynamics, and computer programming and numerical methods. He is a Registered Professional Engineer in the State of Massachusetts.

Michael S. Triantafyllou

Director, MIT Sea Grant
The Henry L. and Grace Doherty Professor in Ocean Science and Engineering

Undergraduate studies (1969-1974) in Naval Architecture & Marine Engineering at the National Technical University of Athens, graduate studies in Ocean Engineering at MIT (SM Ocean Engineering, SM Mechanical Engineering 1977, ScD 1979), Assistant Professor (1979-83), Associate Professor (1983-90), Professor (1990-2004), Department of Ocean Engineering, MIT; Professor of Mechanical and Ocean Engineering (since 2004). He has published in the areas of dynamics and control of marine systems, experimental fluid mechanics, and biomimetics: M.S. Triantafyllou & G.S. Triantafyllou, 1995, "An Efficient Swimming Machine," *Scientific American*, 272, 64-70. M.S. Triantafyllou, G. Weymouth, J. Miao, 2016, "Biomimetic Survival Hydrodynamics and Flow Sensing," *Annual Review of Fluid Mechanics*, 48, 1-24. M.S. Triantafyllou, 2017, "Tuna hydraulics inspire aquatic robots," *Science*, 357 (6348), 251-252. Prof. Triantafyllou is a Fellow of the Society of Naval Architects & Marine Engineers, a Fellow of the American Physical Society, a member of the American Society of Mechanical Engineers, and a member of the Intern. Society for Offshore & Polar Engineers. Honors and Awards include: William I Koch Professorship in Marine Technology (2008-2017), A. Stodola Medal, ETH Zurich 2014, Cover of *Science* (2003), RoboTuna on permanent exhibit at the Museum of Science, London (since 1998); prototype *RoboTuna* in the MIT Museum since 2004. Visiting Professor, ETH Zurich (1999), NTU Athens (1994, 2000), NTH Norway (1993), Kyushu U. (1986). *Discover Magazine*Awards for Technological Innovation (1998). ABS/Linnard Prize for best paper in the *Transactions of SNAME* (1997). Highlight Paper of 1995 *Scientific American*. H. L. Doherty Professorship in Ocean Utilization (1983-1985).

CAPT Joe P. Harbour, USN

Professor of the Practice of Naval Construction and Engineering

Born in Ft. Collins, Colorado and raised in Wyoming, he received a Bachelor of Science in Electrical Engineering from the University of Wyoming and received his commission, through the Nuclear Propulsion Officer Candidate (NUPOC) program, at OCS on 01 MAY 1992.

He served as Sonar Officer, Reactor Controls Assistant, Main Propulsion Assistant, Strategic Missile Officer and Tactical Systems Officer on USS Nevada (SSBN 733 (GOLD)), completed seven deterrent patrols, completed his Submarine Warfare qualifications, qualified Engineer for Naval Nuclear Propulsion plants and completed his Strategic Weapons Officer (SD2) qualifications. He was then selected for lateral transfer to the Engineering Duty Officer Community and graduate studies at Massachusetts Institute of Technology (MIT) and was awarded two masters degrees, Naval Engineer and masters in EE, with emphasis on large propulsion electric motors and electric power systems in 2001.

His engineering duty officer tours include service as nuclear and non-nuclear Project Supervisor on submarine and CVN CNO availabilities, Shipyard Docking Officer, Deputy for Test Engineering & Planning and Business & Strategic Planning and as Operations Officer at Portsmouth and Norfolk Naval Shipyards (PNSY & NNSY). Between shipyard tours, he served at NAVSEA HQ WNY as the Ship Design Manager for the Submarine Rescue Diving and Recompression System (SRDRS), ensuring SRDRS met all applicable operation and technical requirements, and completed his tour at HQ as Executive Assistant for NAVSEA 05; Additionally he returned to MIT, as Academic Officer for course 2N, Naval Construction and Engineering Program, where he advised and instructed Naval Construction and Engineering curriculum to some 40 U.S. and foreign naval officers annually. CAPT Harbour also served TDY as an IA to Iraq - serving as the Director of Engineering and Fielding for JCCS-1 conducting counter RCIED Missions. In 2011 he was stationed on U.S. Fleet Forces staff as the Submarine Maintenance Branch Head where he managed Atlantic Fleet submarine maintenance. In 2012, after selection to captain, he transferred to NNSY as the Business and Strategic Planning Officer, where he led forecasting and budgeting for $1.2B annual budget and 10,000 combined civilian and military workforce. He reported to MIT in July of 2014 as the Curriculum Officer for the Navy's 2N program.

His awards include the Meritorious Service Medal (three awards), Navy and Marine Corps Commendation medal (three awards), Army Commendation Medal and the Meritorious Unit Commendation, and various others. He is a member of the Acquisition Professional Community (APC), Society of Naval Architects and Marine Engineers (SNAME), the American Society of Naval Engineers (ASNE) and the academic society Tau Beta Pi.

Commander Andrew Gillespy, USN

Associate Professor of the Practice of Naval Construction and Engineering

Commander Andrew Gillespy is a native of Grand Prairie TX. He graduated from Vanderbilt University in 1998 with a Bachelor of Engineering in Electrical Engineering and was commissioned through the NROTC program.

Upon completing his nuclear and submarine training, Gillespy served aboard USS PENNSYLVANIA (SSBN 735) (BLUE) where he completed four strategic deterrent patrols in both the Pacific and Atlantic Fleet and the first Extended Refit Period in Kings Bay. On the PENNSYLVANIA he earned his dolphins and qualified as an Engineer. After serving at Recruiting Command as the Enlisted Nuclear and Submarine Branch Head, he was accepted for lateral transfer into the Engineering Duty Community.

Gillespy qualified as an Engineering Duty Officer at SUPSHIP Groton where he completed numerous repair and new construction availabilities. He also served as the waterfront coordinator in both the repair and new construction departments. While at SUPSHIP Groton, he completed an Individual Augmentation (IA) tour as the Joint Engineering Department Head for US Forces Afghanistan detachment South/Southwest in Kandahar, Afghanistan. In Team Sub, Gillespy held positions in the COLUMBIA Program Office as the Affordability Assistant Program Manager (APM) and as the Aft Project Officer, in the VIRGINIA Program Office as the APM for Construction and Test, and in the Advanced Undersea Systems Office as the APM for Acquisition. Gillespy currently serves as the Academic Officer at the Naval Construction and Engineering Program at MIT.

Gillespy has received LY Spear Award as the top graduate in the Submarine Officer Basic Course, the Naval Sea Systems Award for scholarship and professionalism at the Massachusetts Institute of Technology, and The Vice Admiral C.R. (Russ) Bryan Award for academic excellence at Engineering Duty Officer School.

Gillespy's education includes three degrees from MIT including the professional degree of Naval Engineer, a doctorate in Ocean Engineering, and a masters in Engineering and Management from MIT's Sloan School of Business. His decorations include the Defense Meritorious Service Medal, Meritorious Service Medal (2) and other individual and unit awards.

Freedom (LCS 1) Class Ship Propulsion Plant Conversion

LT Charles Hasenbank, USN; LT Tikhon Ruggles, USN; LT Cody White, USN

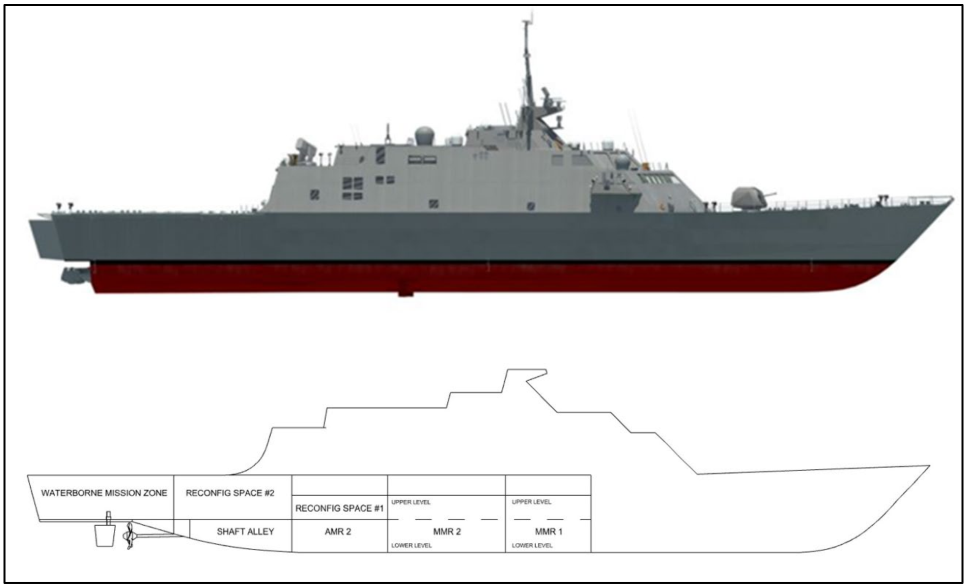
This conversion project developed a concept design for an engineering plant revision of FREEDOM (LCS 1) Class ships from waterjet propulsion to a propellers. Design metrics for the FREEDOM Class were utilized as a benchmark to perform an analysis of alternatives, aimed at designing a replacement propulsion plant that aligned with the proposed speed and endurance profile of the Frigate (FFG(X)) program while also improving engineering plant efficiency, simplicity and fleet commonality. The converted FREEDOM Class ship was expected to complete similar missions to its predecessor but with a reduced speed profile. These missions include littoral surface, mine and anti-submarine warfare. Maintaining the small size, agility, light weight and shallow draft were key characteristics for performing these littoral missions.

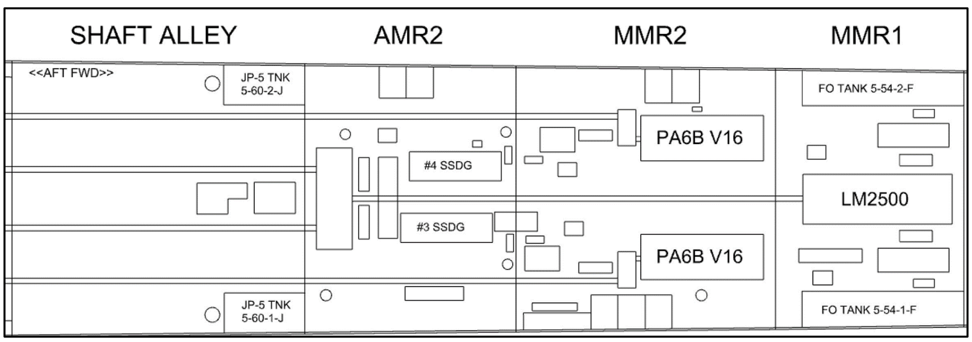
The starting point for the study was a FREEDOM Class match model containing the baseline load list and spatial arrangement. This model was utilized as the project benchmark in order to minimize the impact of the conversion to ship structure and existing ship systems outside of the engineering plant. Alterations to crew habitability and mission support spaces were also minimized during the engineering plant conversion.

The design philosophy for this project was to provide an updated engineering plant that better fit the restructured speed and range profile requirements without affecting the ships littoral capabilities. Additionally, the conversion team aimed to provide a design that increased efficiency, decreased acquisition costs, decreased complexity, and increased fleet commonality.

The design space for this conversion project focused on mechanical propulsion configurations. The updated hull design removed the waterjet housing step and faired that portion of the hull in order to provide sufficient inflow for the propellers. The waterjet propulsion system was replaced with controllable pitch propellers and rudders. The final engineering plant layout was selected by first determining the number of shafts based on propeller size and then developing potential plant configurations. The optimal engineering plant layout was selected using an overall measure of effectiveness analysis based upon the design philosophy.

The existing two diesel, two gas turbine and waterjet configuration was replaced with a more moderately powered engineering plant consisting of two diesel, one gas turbine, and four controllable pitch propellers. This plant configuration provided sufficient power to achieve the 28 knot sustained speed requirement as well as exceed the 3500 nm endurance objective. The transition from waterjets to a propeller driven engineering plant, in conjunction with the revised speed profile, assisted in providing a design with increased endurance range, operating efficiencies, and fleet commonality as well as a decreased displacement, complexity and acquisition cost.


WATERBORNE MISSION ZONE
RECONFIG SPACE #2
RECONFIG SPACE #1
UPPER LEVEL
UPPER LEVEL
SHAFT ALLEY
AMR 2
MMR 2
MMR 1
LOWER LEVEL
LOWER LEVEL


SHAFT ALLEY
AMR2
MMR2
MMR1
<<AFT FWD>>
JP-5 TNK
5-60-2-J
FO TANK 5-54-2-F
PA6B V16
#4 SSDG
LM2500
#3 SSDG
PA6B V16
JP-5 TNK
5-60-1-J
FO TANK 5-54-1-F

Halifax Class Frigate Laser Installation

Lt(N) E Jeunehomme, RCN; LT Austin Jolley, USN

More and more, directed energy weapons are escaping the imaginary of science fiction and entering the real world. In order to remain ahead of the rapidly developing threat environment, state military have to remain on the fore front of technological advancement. Lasers will have their role to play in augmenting offensive and defensive capabilities of warships. In this optic, the team was asked to investigate laser weapons with the intention to replace the 57mm gun on Halifax Class Frigates of the Royal Canadian Navy.

The process used to evaluate the feasibility of the design change started with the evaluation of current weapon technology and the characterization of multiple system given sponsor requirements. Each theoretical system was evaluated and the 50kW version was chosen for its operational capabilities, technological relevancy, and because it met all of the stated and assumed requirements. Next, auxiliary systems were specified and arranged within the freed space left by removal of the 57mm gun. This strengthen our assumption that enough space is available on the platform for the change. Finally, the ship was modelled in MaxSurf. The new system weight is significantly less than the old. A plan to correct the ship trim was developed using the platform's ballast tanks.

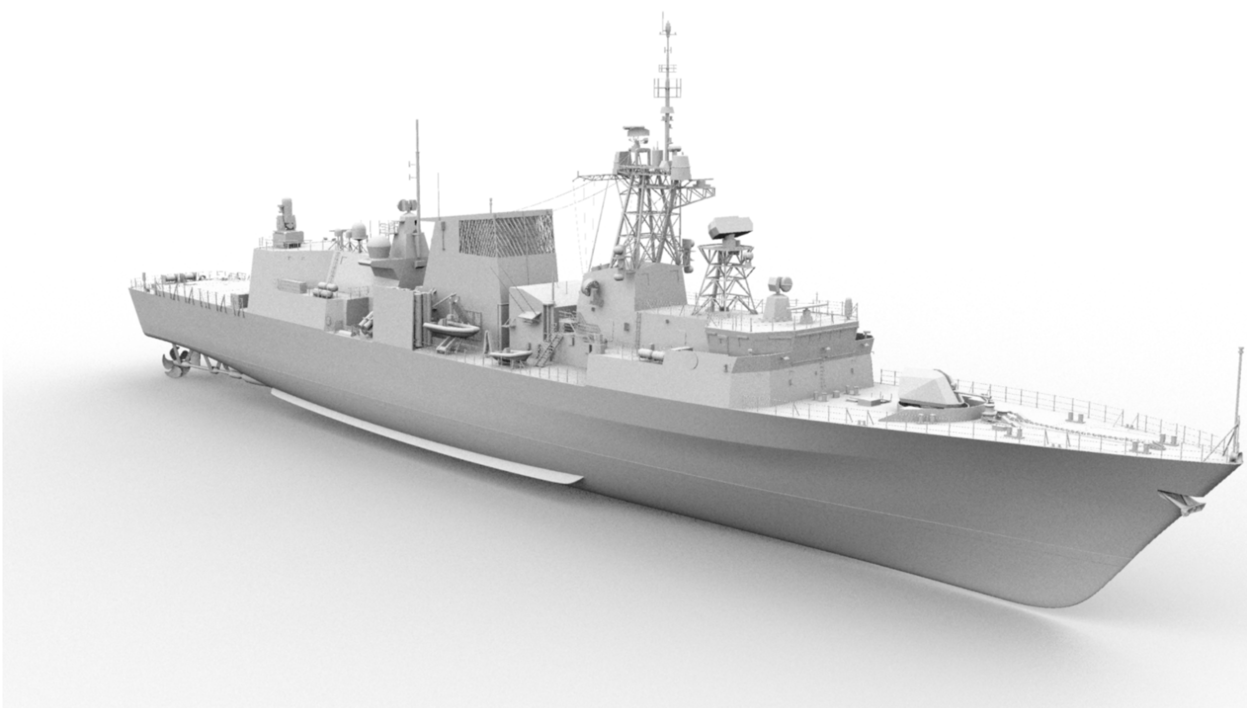


Figure 1: Rendered image of a Canadian Patrol Frigate

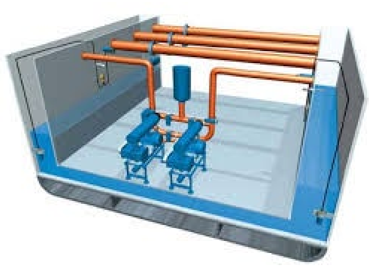
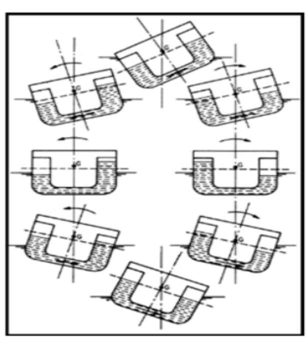
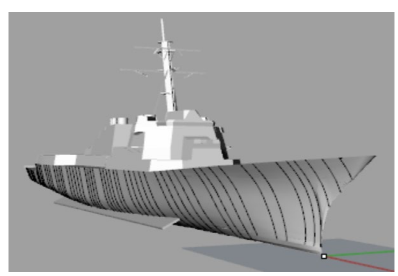
DDG-51 FLT IIA SS6 Roll Reduction

LT Thomas Deeter, USN; LT Michael Liu, USN

An increase in sea states across the globe has started to affect the areas in which U.S. warships may operate. U.S. warships are designed to structurally withstand sea state six, but the crew effectiveness drops in high sea states as safety mishaps become more likely. We reviewed the effects the addition of roll mitigation tanks and larger bilge keels had on the existing DDG-51 FLT IIA hullform roll acceleration and safety mishaps caused by excessive roll.

Five separate models (active roll mitigation tank, passive roll mitigation tank, small bilge keel, medium bilge keel, large bilge keel) were created and analyzed for effects on top speed, maximum stress, Motion Induced Interruptions (MII), Motion Sickness Index (MSI), and RMS Roll Angle. The model results were compared to baseline values via a normalized performance value. Cost estimates for each model were generated from the MIT 2N cost model. Performance to cost comparison led to the conclusion that the small bilge keel option was the optimal conversion.

Type	Top Speed (knots)	Max Stress (psi)	MII (case/ minute)	MSI (% in 2 hrs)	RMS Roll Angle	Cost of Conversion
Baseline	30.00	17260	0.34	18.40	4.06°	NA
Small Bilge Keel 6922487	28.23	15888	0.22	19.15	2.25°	$6,922,487
Medium Bilge Keel	27.33	15001	0.19	19.28	2.09°	$9,521,281
Large Bilge Keel	26.47	14401	0.17	19.40	1.97°	$12,121,614
Active Roll Mitigation Tank	30.63	17905	0.14	19.78	1.88°	$68,122,464
Passive Roll Mitigation Tank	30.63	17905	0.12	19.70	1.76°	$71,323,397

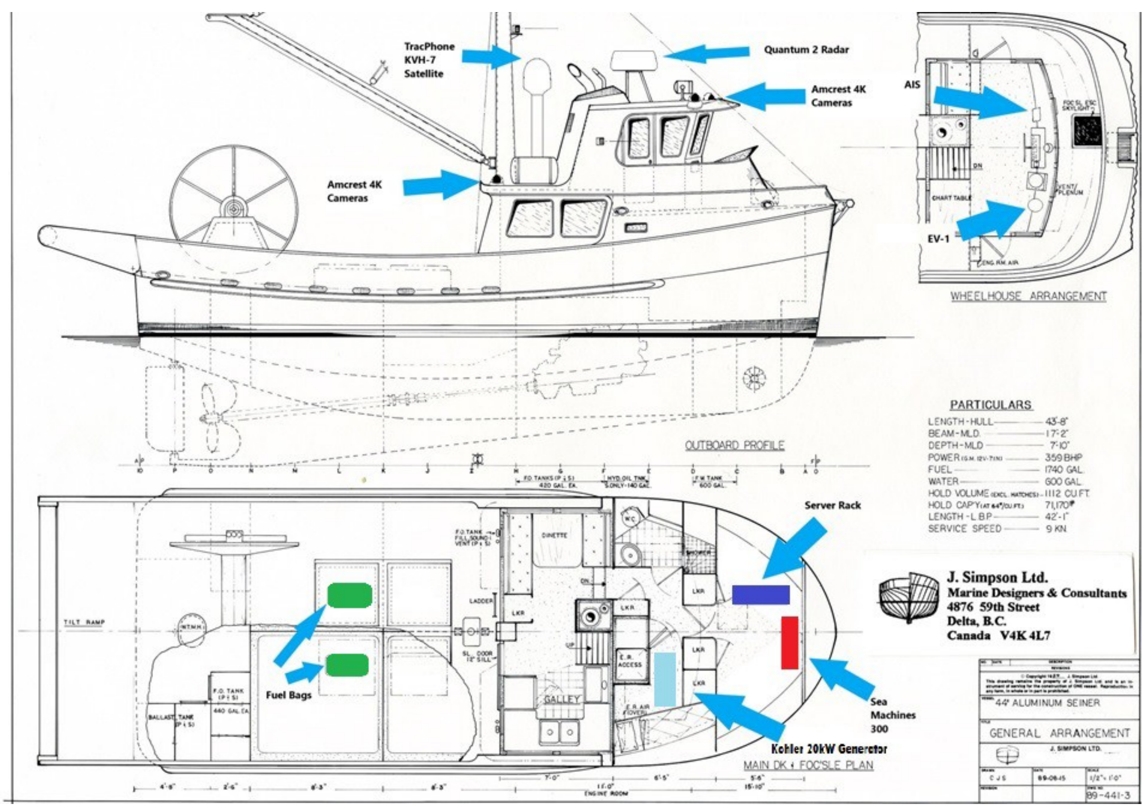




Autonomy of Opportunity (A/O) Kit for Conversion of a Fishing Vessel into a Low Cost Unmanned Platform

LT Jason Barker, USN; LT David Baxter, USN; LT Brian Stanfield, USN

Autonomous technology is now successfully implemented in the civilian maritime market. The purpose of this study was to understand the feasibility of obtaining fishing vessels from friendly fishing ports and deploying them to areas of interest for increased acoustic detection and tracking. The relatively low cost of the vessel makes potential loss of the vessel less significant from a strategic and financial sense and enables the Navy to potentially add lots of ISR vessels to the fleet in a short amount of time. The Navy's increased interest in autonomy, the growing threat of area denial and acoustic monitoring by other countries, and an abundance of fishing vessels organically patrolling areas of interest motivate equipping a vessel of opportunity to perform autonomous acoustic search.

The outcome of this study converted a 44 ft Drum Seiner using current autonomous technology, such as the Sea Machines 300, into a low cost unmanned platform. We explored arrangements of the masts and antennas, topside deck, living quarters, and fishing cargo hold for conversion into our autonomous vessel. We designed additional fuel storage and transfer capabilities into the vessel to increase endurance range and addressed interfacing with existing systems. Summarized below are the arrangements of the modified vessel, estimated cost for autonomy, and the change in endurance range of the modified vessel at rated speed of 9.5 knots.



Item	Units	Unit Cost	Total Cost
Sensors & Comms			
Quantum 2 RADAR	1	$1,899.99	$1,899.99
AIS700	1	$999.99	$999.99
Amcrest UltraHD 4K Camera	5	$129.98	$649.90
KVH Tracphone V7-HTS Satellite	1	$29,995.00	$29,995.00
Sensors & Comms Total			**$33,544.88**
Sea Machines and Steering			
SM300	1	$98,500.00	$98,500.00
EV-200	2	$1,999.99	$2,899.99
Sea Machines and Steering Total			**$101,399.99**
Fuel Injection System			
Fuel Bags	2	$3,065	$6,130
Fuel Pipe	100 ft	$0.81/ft	$81.00
Fuel Pump	2	$380.00	$760
Fuel Injection System Total			**$6,971**
Auxiliary System			
Bilge Pump	3	$62.30	$186.60
Auxiliary System Total			**$186.60**
Electrical Generator			
Kohler 20EOZD-3 Generator	1	$18,245.00	$18,245.00
Electrical Generator Total			**$18,245.00**
		OVERALL	**$160,347.47**

U-MaVeRIC: UxV Augmented Surface Combatant

LT Ioannis Dagres, HN; LT Casey Strouse, USN; LCDR Matthew Washko, USN

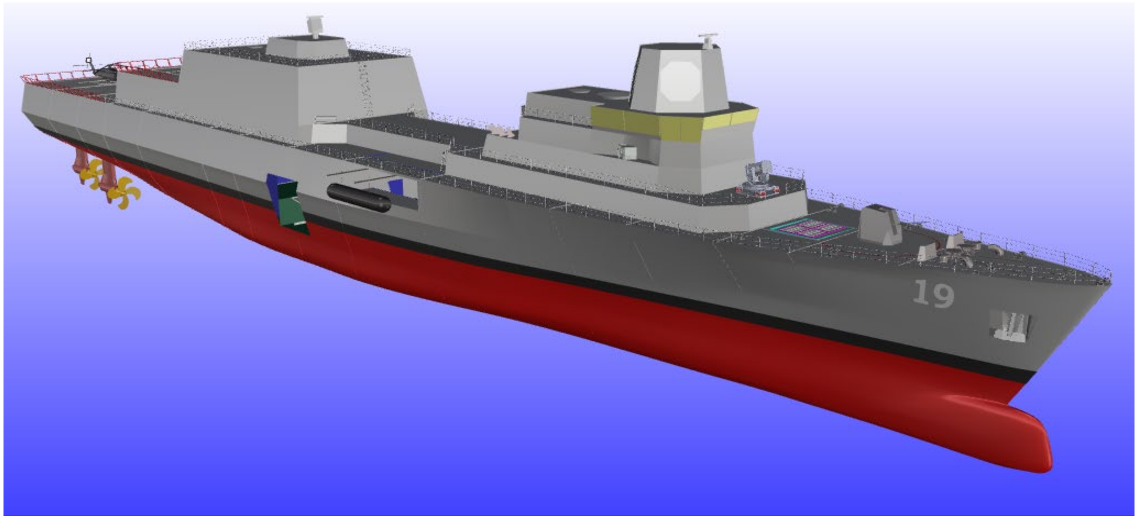
Throughout the last decade, the United States Navy has invested significant resources in the advancement of unmanned technologies in the air, surface, and undersea domains. Unmanned vehicles (UxVs) are rapidly evolving across all domains, and a robust future exists for military applications of Unmanned Air Vehicles (UAVs), Unmanned Surface Vehicles (USVs), and Unmanned Underwater Vehicles (UUVs). UxVs are already operating on many vessels within the Navy, but no surface combatant has been designed from the initial concept stage to support UxV operations as the central focus of their concept of operations.

This study evaluated a concept design for a surface combatant with the primary mission of launching, operating, recovering, supporting, and maintaining unmanned vehicles across the broad spectrum of both current and future unmanned vehicles. The team created a large design space based on sponsor and derived requirements, and then used set based design (SBD) to select several final variants. Incorporating the best elements from each of these final variants, the team generated a preferred variant outside the original design space. This preferred variant is named the UnManned Vehicle Rapid Insertion Combatant (U-MaVeRIC). A detailed design of the preferred variant, including outfitting, mission capabilities, and future flexibility, are also included.

The U-MaVeRIC is a modern surface combatant with a robust combat system similar to FFG(X), a vertical launch system, SeaRam, a 57mm gun, and a flexible arrangement for employment of UxVs across all domains. Manned and unmanned aircraft can embark and conduct operations from one of two flight decks and hangars. USVs and UUVs each have large storage areas with multiple options for launch and recovery. A stern ramp for USVs, port and starboard side-launch telescoping cranes for UUVs, and a new concept garage in the center of the vessel, designed to launch USVs and UUVs by opening a ballasted compartment, complete with an elevator and turntable, to the sea to allow launch and recovery at the waterline.

The U-MaVeRIC is a technically feasible and highly mission-capable design with a unique combination of surface combatant and unmanned vehicle carrier capabilities. The capabilities and concepts developed within this study will provide the Navy with the most technologically advanced, multi-mission surface combatant in the world. Augmented by the highest concentration of UxVs in the world, U-MaVeRIC brings an unlimited future potential due to the substantial incorporation of flexibility, commonality, and robustness of design.

U-MaVeRIC Characteristics	
Parameter	**Value**
LBP (ft)	668
Beam (ft)	93
Draft (ft)	29
Full Load Displacement (ton)	26428
Endurance Range (nm)	8000
Maximum Speed (kt)	30
USV Loadout (no./size)	6 Mk5
UUV Loadout (no./size)	6 LDUUV
UAV Loadout (no./size)	12 Fire Scout
Manned Aviation Loadout (no.)	2 MH-60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U-MAVERIC

Experimental Evaluation Vessel (EEV)

LT Bill Hentschel, USN; LCDR DP Johnsen, USN; LCDR William Taft, USN

Between laboratory testing and the installation of technologies aboard the U.S. Navy's warships lies Technology Readiness Levels five through seven, which entail testing in a relevant environment. Currently, the Navy does not have a dedicated seagoing asset that can test emerging technologies in this range of technology maturation. To satisfy this need, the Experimental Evaluation Vessel (EEV) provides a testbed to facilitate this technological progression using a low-cost, high-flexibility design. To account for the numerous developing technologies that will require rapid and frequent shipboard changes to support testing requirements, the vessel provides modular configurations through allocation of space margin in the test spaces and the associated transfer paths throughout the ship.

With sufficient space, weight, area, power, and cooling (SWAP-C) to test a range of systems, EEV was designed to be operated by civilian mariners, who will be accompanied by test teams for each at-sea evaluation period. Due to EEV's unconventional operational nature, reduced manning and the test environment provided an opportunity to apply practices not normally used in traditional U.S. warship design. Though prudent marine engineering practices still applied, U.S. Navy standards of survivability, habitability, and shock were relaxed when justified to improve affordability, flexibility, and modularity.

EEV's design portrays the priority placed on modular testing configurations and the rapid interchange of systems during in-port availabilities. The ship's Operations Deck (second deck) and Corridor Deck (seventh deck) are incorporated to facilitate rapid transfer of equipment throughout the ship and to distribute the primary and auxiliary services for test systems, respectively. The vessel provides multiple loading methods, including a stern ramp, removable decking, and pre-determined shipping paths. EEV's primary testing areas incorporate modular concepts, such as flexible infrastructure (FI) and common interfaces, to facilitate the rapid interchanging of test components.

The propulsion plant houses three Main Machinery Rooms (MMRs), which accommodate the ship's seven GE LM2500+ gas turbine generators and baseline propulsion equipment, and EEV's Engineering Test space, designed to allow interchanging test equipment and demonstrating modular engine room options provided for engineering plant testing. Due to the complexity of modular design for larger engine room components, additional focus was placed on equipment removal paths and the use of modular skids to facilitate the interchanging of test equipment.

Similarly, the Combat Systems Test area contains the Variable Payload Space, Modular Weapons Space, and Adaptable Testing Space, which provide SWAP-C to test various weapon system technologies and incorporate different types of modularity into the design. The ship's Railgun SWAP-C requirements drove the design team's sizing of EEV and provide the footprint for other combat systems during in-port weapon interchanges. Initial detection for at-sea test system engagements is provided by an AN/SPY-6 Air and Missile Defense Radar. Future opportunities for UxV stowage, handling, and launch-and-recovery operations ensure EEV's value for decades to come.

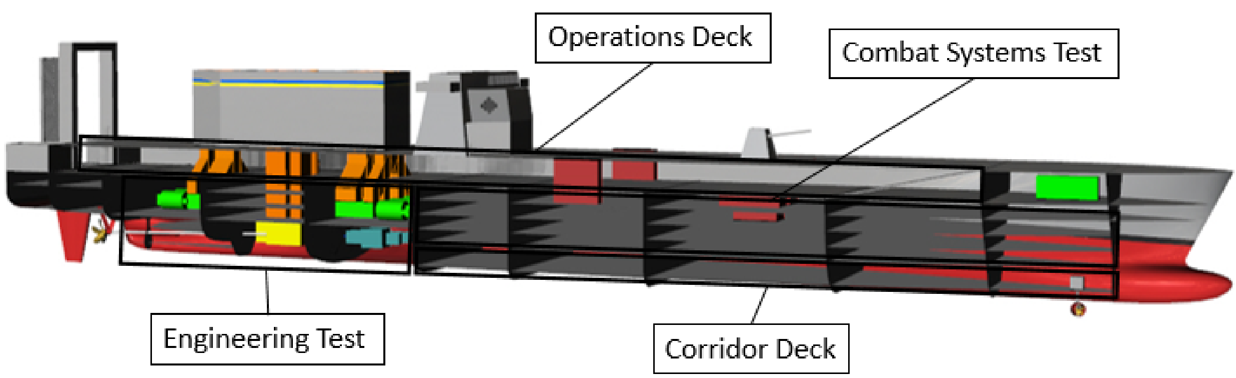
Connecting everything throughout EEV is its electric plant, a key enabler of the ship's testing flexibility. The electric plant was designed with three core principles: (i) capability to segregate vital and test-system loads, (ii) allowance for ship-wide system-interaction characterizations through testing, and (iii) ship-service accommodation for increased reliability configurations during split-plant and restricted-maneuvering situations. With 168 MW installed capacity, the 13.8 kVAC, 60 Hz system is distributed via five ship service and five test system zones to supply power to EEV's baseline ship and test plant loads. Since the vessel's distribution system cannot provide power at every possible voltage, test system interfaces are standardized at 4160 VAC and 450 VAC three phase, 120 VAC single phase, and 1000 VDC.

A reduction to the three main cost-drivers for MSC vessels – personnel, fuel, and maintenance – were fundamental to EEV's cost-conscious design. Technical risks were mitigated through the use of fielded equipment and a modular infrastructure in the design of an asset that satisfies a Fleet need for testing in a relevant environment.

EEV Characteristics	
$\Delta_{Full\text{-}Load}$	39200 LT
$\Delta_{Lightship}$	25896 LT
LOA	783 ft
LBP	766 ft
Beam	105.36 ft
Draft	26.48 ft
Molded Depth	74.08 ft
KG	34.42 ft
GMT	19.45 ft

Sponsor Requirement	**Value / Description**
Endurance	30 days
Test System Capacity	SWAP-C for ≥ 40-MJ Railgun system
Navigation	existing fleet concentration areas

Ship Selection Process	**Scope / Result**
System-Level Evaluation	cargo-handling options, eng. plant architecture
Ship-Level Evaluation	parametric analysis of 20 vessels
Tradespace Analysis	3000 variants (eight baseline models, 375 each)
Selected Variant	shaft-driven, IPS, size ≈ MSC dry-cargo vessel



T-AH 21 Next Generation Hospital Ship

LT Robert Beltri Carelli, USN; LT Travis Rapp, USN; LT Aaron Sponseller, USN

Future force structures envision ships and amphibious forces operating in distributed operations with disaggregated forces, while specifying a need for medical support afloat near the point of injury in the event of casualty sustainment. Current Afloat Theater Hospitalization is provided by two *Mercy*-Class hospital ships (T-AH) that have reached the end of their service life. When operationalized, their size and inflexible design precludes the ability to support Group-level transit or distributed operations.

In the Next Generation Hospital Ship (T-AH 21), an agile, scalable, surgical capability afloat meets this need by receiving, triaging, and allowing for surgery and stabilization care prior to preparing patients for transport to another location for more advanced treatment. Following the push towards distributed care, our design was for a smaller ship which allowed for a more expansive network of ships providing high quality care in remote locations.

Rendering of T-AH 21 alongside USNS Mercy

A robust trade space entails a variety of inputs to the maximum extent possible consisting of feasible ships or characteristics of ships that meet the project's objectives. Practical experience and familiarity with naval vessels proved essential in order to provide a useful group. The specific hull offsets were not identified, but rather their unique features associated with the hullform itself. For example, when looking at interoperability, a ship that has a well deck will score higher than a monohull without one. Once a hullform was chosen, the Rapid Ship Development Environment was used in order to perform a trade-off analysis for various independent parameters such as length, beam, stores, engine type, etc. A final, non-dominated, and cost-efficient option was chosen and further optimized during the outfitting design work.

A greater number of hospital ship points of care allowed the design to be scaled down to an operating suite of six larger reconfigurable rooms. Prior user feedback and operational lessons learned necessitated an increase and reconfiguring of the Intensive Care Unit capability, expanding the capacity beyond that of the *Mercy*-Class by almost 20%, accompanied by a corresponding reduction in the previously under-utilized limited care facilities. Under the design philosophy of flexibility and multi-mission capability, the T-AH 21 electrical plant is a high-capacity Integrated Power System for electric-drive propulsion and power distribution. The power network accommodates medical technological increases in power consumption, while providing a high-speed transit operational capability. A major reconceptualization of the patient and passenger transfer was performed, facilitated by space for up to four boat davits, with two per side located near the waterline for expanded boat operations in heavier seas. Additionally, a primary flight deck aft with hangar space for an embarked MV-22 Osprey tilt-rotor aircraft was designed with the real option of space provisions forward for a secondary flight deck on the ship's forecastle. Pierside care is facilitated by a "roll on-roll off" ramp capable of easily receiving high volumes of ambulatory patients or multiple ambulance vehicles.

	Mercy-Class (T-AH 19)	Next Generation Hospital Ship (T-AH 21)
LOA	894 ft	535 ft
Beam	100 ft	99 ft
Full Load Draft	33 ft	25.5 ft
Speed	14 kts	26.5
Range	9,000 nm	10,000 nm
Endurance	30 days	30 days
Electrical Load Capacity	1,750 KW	37.5 MW Integrated Propulsion System
Embarkation Type	Limited rotary, surface, and walk-on	Pier vehicle, rotary, tilt-rotor, 4-boat surface transfer davits
Operating Rooms	12	6
Total Bed Capacity	1,000	497
CASREC Capacity	33	35
ICU Capacity	88	112
Intermed. Care	480	200
Limited Care Capacity	399	150

Comparison between USNS Mercy and T-AH 21 class

As the Navy's mission for maritime superiority calls for increases in distributed operations, the role and capacity that a hospital ship provides will change accordingly. The Next Generation Hospital Ship (T-AH 21) provides a fresh perspective for the new direction of Navy Medicine's afloat care mission and delivers an affordable, producible, and effective solution for the Fleet.

Project Smenos: Squadron of Optionally Manned Corvettes

LCDR Andrew Freeman, USN; LT Udit Rathore, USN

As the U.S. Navy continues to feel pressure from constrained budgets and the rise of near-peer competitors, solutions must be found to increase fleet capacity while maintaining the capability edge. Project Smenos, named after the Greek word for 'swarm,' developed a design and examined the technical feasibility of a corvette-sized combatant to fill this gap. By leveraging autonomous systems and a distributed mission system paradigm, the smaller vessel provides significant capability.

Smenos' primary mission is ASW, with ISR, MIW and ASuW as secondary missions. The vessels were designed to operate independently or in squadrons, surface action groups or strike groups. DDG-51's Flight IIA ASW capability provided the benchmark for the systems fielded on Smenos. Additional capabilities included expanded offensive ASW capability and UxV launch and recovery to improve the fleet's ASW and undersea ISR.

To facilitate this robust capability on a small ship, two key concepts were foundational to the design. First, the ships included an autonomous control structure that provided automation of the HM&E systems as well as a large portion of the navigation and steering systems. Given the state of automation technology, these systems were deemed to be feasible for naval use when combined with the presence of a small cadre of onboard personnel. Rather than execute their duties as traditional watchstanders, the automation systems would allow the personnel to act more in a duty capacity, able to respond to unexpected or complex situations. In addition to those systems, however, the control structure provides the backbone for further automation of the ship as the risk-reward balance changes with different mission scenarios. This Risk-Driven Manning concept allows operators and fleet commanders to adjust the crew size and capability to fit the mission needs. For instance, the unmanned Smenos could traverse a minefield, eliminating unnecessary risk to sailors while a manned vessel of the same squadron could conduct helicopter operations or torpedo engagements. Due to the combined manned and autonomous structures, this control structure also provides an excellent transition platform for the U.S. Navy to move from the completely manned platforms of today to the unmanned platforms envisioned for the future.

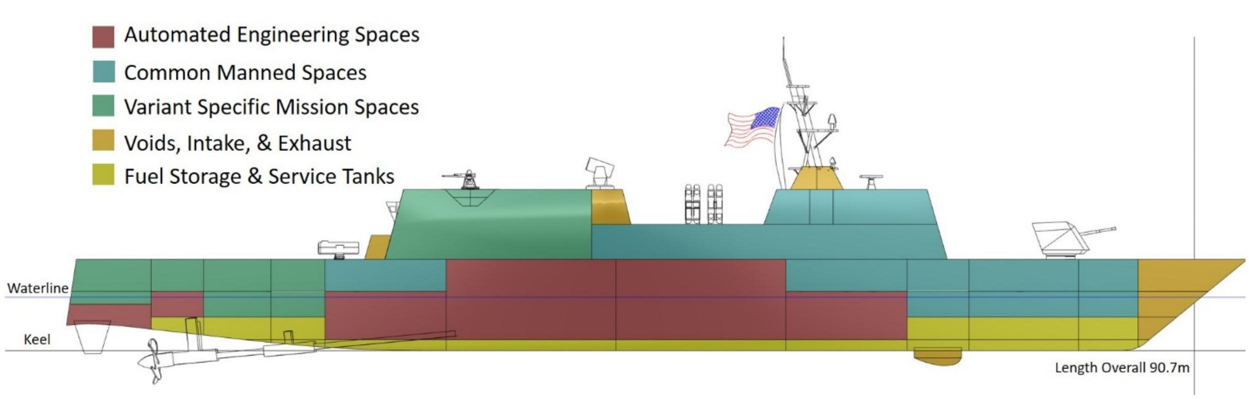


Figure 1: Common, Automated, and Distributed System Arrangement Zones

The second novel cornerstone of the design is the distribution of mission capability amongst the squadron vessels. Smenos corvettes are designed to include three different variants which each provide a unique and valuable contribution to the group. Although all variants were designed with the exact same hull structure, engineering plant, C4I and self-defense systems, the internals of aft and superstructure mission bays were different. The first variant included a hangar and associated maintenance area in the superstructure to host a MH-60R or similarly-sized ASW helicopter. This allowed the squadron to leverage air assets for logistics support as well as in the detection, identification, and prosecution of undersea threats. The second variant provided UxV host capabilities via a launch & recovery stern bay as well as telescoping davits to side launch an 11-meter boat from either side of the superstructure. Finally, the last variant was equipped with a 16-cell VLS to provide ASROC capabilities and provided the additional stores to extend the operational endurance of the squadron. All variants included a flight deck and hull-mounted sonar. Variable depth sonars are included on the first and third variants.

To develop Smenos, the project team leveraged tenets of set-based design to explore a large design space. This was essential to fully understand the implications of driving for a much smaller ship than currently exists in the fleet. The design process generated 2550 unique permutations that reduced to 19 design options through the analytical hierarchy process, feasibility criteria, and sensitivity analysis. We selected the final design that was closest to the utopia point which offered the greatest performance for the smallest increase in cost and risk. We validated the final concept design through technical analyses in the areas of stability, resistance, seakeeping, strength, general arrangements and cost. The result was a corvette which was technically feasible and surpassed the sponsor's cost target, ensuring the design was programmatically palatable given the current budget environment.

Smenos bridges the gap between existing surface combatants both in terms of size and in its hybrid configuration of autonomous and manned control structures. The vessel fills essential capacity shortfalls in the U.S. fleet and provides an immediately relevant ASW platform using currently available ASW mission systems. Finally, this platform provides a useful stepping stone for bringing the prototype unmanned platforms under development to fruition by incorporating the automated systems alongside manned systems in a way that provides for technology development and risk reduction.

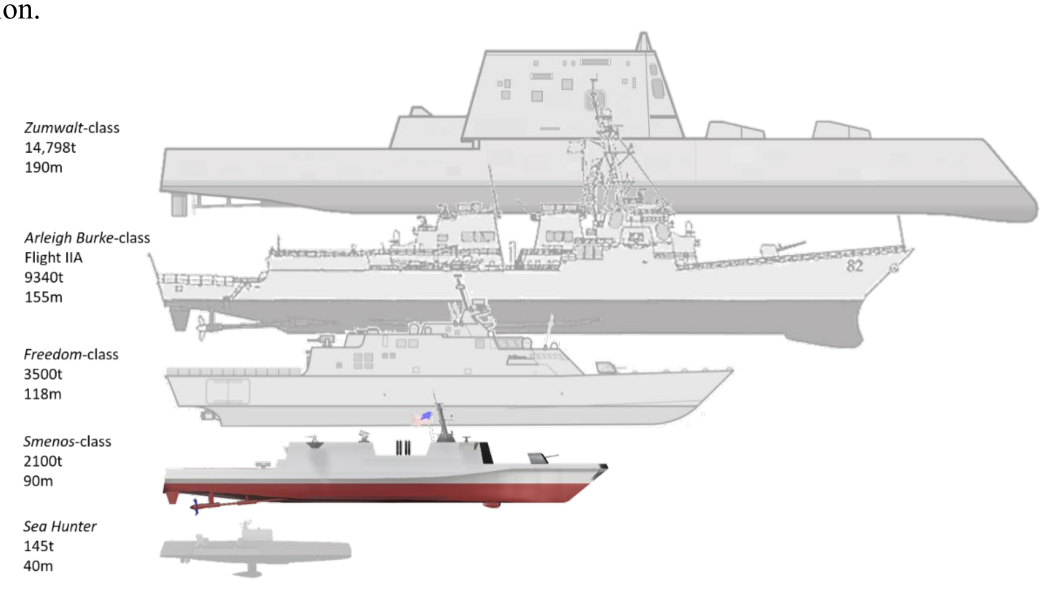


Figure 2: Bridging the Gap

Design and Testing of an Autonomous Mothership for Surface Vehicle Swarm Docking

LCDR Andrew Freeman, USN

Prof. Dick K. P. Yue
Thesis Supervisor

The field of marine autonomous systems has blossomed over the past several decades yet much remains to be explored. One important focus area gaining increased attention in this domain is the understanding and development of cooperative groups of vessels, known as swarms. Using simple behavioral rule sets, these systems of marine vehicles can work together in many ways including traveling in a "flock" or forming a perimeter around an area of interest. In many cases, however, the vehicles encounter limitations with respect to their capacity to carry a certain resource. This can manifest itself in the form of finite electrical energy, cargo-carrying capacity, or the need to replenish a swarm vehicle's deployable payloads. In all of these situations, there are many useful scenarios where the addition of a "mothership" can improve overall system performance.

This thesis elucidates the essential parameters for the design of such a mothership and considerations for docking the two vehicles together autonomously. Focus is placed on maintaining the mothership lightweight, compact, and low cost to ensure the results are usable by a broad audience and that the principles are shown to apply to the widest array of designs. A methodology and tools are presented herein to prepare future designers for creating similar systems. These include a theoretical analysis of the finite resource problem and how to leverage parameter relationships to determine design specifications for the mothership. A computational analysis of mother-daughter relative motions in waves follows which validates that the hullform characteristics support reduced complexity at the docking bay. Finally, a prototype developed by the author using the proposed methodology is detailed and experimental results are presented which highlight important considerations contributing to the success of autonomous mothership docking.

Naval Engineer

Master of Science in Mechanical Engineering

Z-source Circuit Breaker Use in Naval Power Systems

LCDR William Taft, USN

Prof. James Kirtley
Thesis Supervisor

The integration of the z-source circuit breaker into future naval medium voltage direct current power systems is investigated. Values for a “typical” naval medium voltage direct current system are determined for the development of an electrically-scaled model z-source circuit breaker. The scale model is used to determine the maximum time rate of change of voltage across the thyristor within the circuit breaker to aid in full-scale design. The turn-on transient behavior of the z-source circuit breaker is explored and fault cases that occur during this transient for which protection cannot be shown are discussed. Potential solutions to provide protection in these cases are explored, including circuit modifications, power system layouts, and operational restrictions.

Naval Engineer

Master of Science in Mechanical Engineering

Use of an Asymmetric Propeller for Unmanned Underwater Vehicles

LT Robert Beltri Carelli, USN

Prof. Alexandra Techet
Thesis Supervisor

This thesis describes the development and execution of a test program to determine the suitability of an asymmetric propeller for unmanned underwater vehicles (UUV). The idea to utilize a single blade propeller had been pioneered in the past for aviation as an attempt to generate greater thrust, but was quickly abandoned. Recently, Woods Hole Oceanographic Institute reevaluated the concept for use on a UUV, but for two different objectives. The first was a possible improvement in propulsive efficiency. For UUVs meant to operate for long periods without recharging, any increase in propeller efficiency can result in more time on station. The second object was to allow for an alternate method of steering the UUV. By controlling the speed of the propeller through each revolution, the thrust at any given point can be controlled. This allows for a non-uniformly distributed thrust about the longitudinal axis of the UUV which can be used to steer the UUV.

This thesis evaluated the efficiency of using such a propeller as well as the control authority it provides along a variety of speeds. This data was used to determine the suitability for UUVs and in which use cases an asymmetric propeller used for propulsion and steering could outperform a traditional propeller with a rudder.

Naval Engineer

Master of Science in Mechanical Engineering

Simulation-Guided Lattice Geometry Optimization of Metal Marine Propeller for Additive Manufacturing

LT Ioannis Dagres, HN

Prof. Themistoklis P. Sapsis	**Prof. A. John Hart**
Thesis Supervisor	Thesis Supervisor

One of the most promising emerging technologies is additive manufacturing (AM), which offers major advantages in manufacturing of complex components, enhanced performance, material savings, and process control, when compared to conventional processes.This thesis focuses on the design of an exemplary marine propeller to leverage the advantages of AM, specifically via simulation-guided design of an internal lattice structure.

For this purpose a B-series Wageningen three-blade propeller model, provided by NSWC Carderock, was used as a baseline. Its open water loading conditions were calculated numerically using OpenFOAM® Computational Fluid Dynamics (CFD) software. The CFD results were verified using the provided test data, which showed a conformity of 97%. The derived loads were introduced to the Finite Element Analysis (FEA) based optimization utility of Autodesk ® Netfabb Ultimate, in order to identify the optimum lattice geometry for this application. The design limitations were dictated by the material (316SL stainless steel), the metal additive manufacturing process, and the propeller outer geometry.

The design with the best performance was a hexagonal grid lattice with 1mm wall thickness, which was prescribed as a manufacturing constraint (thinnest wall. The material volume was reduced by 57%, while exhibiting a safety factor 7.5 based on the material properties and the simulated loads.

Naval Engineer

Master of Science in Mechanical Engineering

Design and Construction of a Propeller Open Water Testing Apparatus and Testing of a Stereolithography 3D Printed Model Propeller

LT William Ryan Hentschel, USN

Prof. Alexandra Techet
Thesis Supervisor

This thesis describes the design and construction of a propeller open water testing apparatus for educational and experimental use at MIT. This test apparatus was built as an inexpensive alternative to conducted in-house model scale marine propeller testing. A complimentary study was conducted to explore the process of manufacturing a model propeller using additive manufacturing. A propeller open water test apparatus, commonly referred to as a test boat, is used to measure the performance of marine propellers in uniform flow. The test boats performance was validated using a Wageningen B-series aluminum propeller as a benchmark. The test boat measured the open water performance of this benchmark within a small percentage of error. The practicality of using additive manufacturing to produce a model propeller was explored by manufacturing and testing a 3D printed replica of the benchmark propeller. The replica propeller was manufactured using a benchtop stereolithography 3D printer. The open water characteristics of the replica were measured and compared to the benchmark propeller. Results of this testing revealed some limitation of 3D printed model propellers, such as inadequate blade strength and imprecision of leading and trailing edge geometry. This research has provided MIT students with an inexpensive method to conduct preliminary marine propeller testing and offers in-sight into the use of additively manufactured model propellers.

Naval Engineer

Master of Science in Mechanical Engineering

Experimental Analysis of Foil on Foil Interaction for Flexible Flapping Fins

LT(N) Eric Jeunehomme, RCN

Prof. Alexandra Techet
Thesis Supervisor

In this thesis, I designed and fabricated robots leveraging additive manufacturing. This had two overarching purposes. One to make a testing apparatus that would allow the measurements of the influence of a flexible flapping foil onto a subsequent, in-line, foil with the optic of researching optimized propulsion solutions for under water vehicles. The second was to show that filament deposition modeling has advanced enough to produce bio-mimetic flexible robots of academic relevance that would allow, for a low price, the making of a number of experimental setup with specific measurements in mind. In order to reach those goals, two versions of a bio-mimetic archer fish of the genus *Toxotes* were modeled using various software. The models were modified to accept actuator assemblies and interface to the electronics and built using a modified hobby grade 3D printer.

Naval Engineer

Master of Science in Mechanical Engineering

Naval Additive Manufacturing: Bridging the Gap Between Research and Implementation

LT David P. Johnsen, USN

Prof. Thomas W. Eager
Thesis Supervisor

Additive manufacturing (AM), commonly known as three-dimensional printing, presents numerous advantages over traditional production methods, including design-to-end-use process reduction and on-demand generation of needed parts. While new companies have recently been founded with AM as their focus, many established large organizations are striving to find ways that the technology facilitates strategy execution in the existing structure. With its manufacturing base and requisite supply infrastructure, the military branches pose a significant opportunity for AM implementation. In particular, the U.S. Navy's continual pursuit to enhance operational readiness and advance unit self-sustainability provides a ripe environment for AM.

This research sought to advance the Navy's AM implementation initiatives through the identification of candidate applications, bridging the detected gap between ashore AM research developments and the cognizance of its front-line personnel. The resultant coordination of multiple exercises involving the Navy's operational units and field activities, culminating in two Naval AM Part-Identification Exercises, led to the discovery of over 600 AM applications that have established the Fleet's demand for AM and expedited the branch's adoption of the technology. Numerous Navy-wide efforts have stemmed from the exercises' findings, including affordability initiatives, technical data package developments, and an accelerated timeline for shipboard AM equipment installation. In addition, multiple avenues for the expansion of identified applications are recommended, leveraging the Fleet's existing methods of tracking material condition.

An examination of the Navy's existing guidance and many of its leading AM organizations provides the context for the research efforts. Seeking to inform these key stakeholders of considerations that must be understood prior to widespread AM utilization, an evaluation of product quality using digitally-shared print files and shipboard material distribution analyses are incorporated, providing opportunities for future development.

Naval Engineer

Master of Science in Mechanical Engineering

Resilient Acquisition: Unlocking High-Velocity Learning with Model-Based Engineering to Deliver Capability to the Fleet Faster

LT Travis Rapp, USN

Prof. Daniel Frey	Dr. Steven Spear
Thesis Supervisor	Thesis Supervisor

As the nation's security needs call for a growing naval fleet, the public-private industrial base will be stressed to perform at a high level of operational excellence. While reaching the required fleet size is a major challenge, ships are the delivery vehicles for complex weapons systems whose design and production is equally critical to deliver capability that the Fleet needs. Underperformance in defense acquisitions is found to be caused by complexity, uncertainty, and risk manifested through poor requirements that are unadaptable to the changing reality of the global security landscape.

This thesis hypothesizes that use of model-based engineering (MBE) will enable the needed efficiency and responsiveness. MBE consists of digital tools motivated by the principles of traceability and high-velocity design iteration that collectively connect requirements to technical specifications in a model-centric format in contrast to the document-based form prevalent today. Given the problem of disengagement between the request for proposal and the finished product, prior case examples of using MBE elsewhere in the defense and industrial establishment show a bridge for the divide between capability requirements and technical realization.

An original process-based shipbuilding production model further demonstrates how understanding effects of component changes affects overall system production. Changes in a ship's required operational capabilities, translated to technical design parameters, are mapped to production steps. Simulation results demonstrate that applying MBE contributes to increased early requirement fidelity, decreases in rework through missed changes, and more rapid design iteration when the models used are properly verified and validated.

Verification and validation (V&V) must be performed in a very specific environment to engender confidence in model usage through a systemic framework. The domain of MBE can be expanded to include definition of cybersecurity requirements for a new weapon system to illustrate an iteration of model-based system design. The modeling of these requirements contributes to validated resilience upon delivery, decreasing the likelihood that cyber-physical systems will be forced to rely on time-consuming updates that delay the capability delivery.

Naval Engineer

Master of Science in Mechanical Engineering

Quantification of Extreme Event Statistics in Ship Design

LT Udit Rathore, USN

Prof. Themistoklis P. Sapsis	**Prof. Bryan R. Moser**
Thesis Supervisor	Thesis Supervisor

Increased operational demands on Navy vessels extend both their time at sea as well as their service life, making the accurate prediction of a catastrophic failure increasingly challenging. The high value of these capital assets puts greater pressure on designers and decision makers to prevent such failures while balancing engineering and material cost. The current method for the quantification of extreme events is direct Monte Carlo simulation supplemented by complex mathematical models. When used alone these models fall prey to statistical uncertainty when predicting rare events. High fidelity computational tools have increased engineer's capacity to explore a wider range of operating conditions but ultimately cannot capture all the physical phenomenon of model or full-scale testing. Even with advances in computers, the quantification of rare events remains an expensive endeavor.

This thesis builds on previous work at the MIT Stochastic Analysis and Non- Linear Dynamics (SAND) lab that identified improved approaches for the quantification of extreme events using wave groups. This approach combines statistics with physics models to more accurately captures rare events in ship motion and loading conditions for modest computational cost. Improvements to the wave groups methodology ensured the slope and amplitude of the incident wave set reflected the waves encountered in a given wave spectrum. The remaining discussion emphasizes the value of an improved understanding of risk and decision analysis approach to ship design, ship operations, and ongoing science. The aim is no only to reduce design and operational cost for Naval vessels, but also provides a technological pathway to realizing a near-real-time risk evaluation tool that opens the operational window for operators and ship owners.

Naval Engineer

Master of Science in Mechanical Engineering

New Approaches to the Integration of Organizational Maintenance and Failure Data During Submarine Maintenance Planning

LT Aaron Sponseller, USN

Prof. Warren Seering
Thesis Supervisor

Planning for maintenance periods for U.S. Navy submarines is difficult due to schedule and cost constraints, operating cycles, and logistical concerns. Organizational maintenance and failure data is vital to understanding trends of failures among the various classes of submarines.

This thesis investigates the processes by which maintenance and failure data is collected, analyzed, and administered throughout the planning process. First, the relationship between organizational and depot level repair work is investigated with respect to how each level impacts the other. An original, multiple linear regression is used with little success to describe how maintenance completion rates affect failures of equipment; thus invalidating this process. Additionally, an improvement in depot level completion of maintenance and how it affects equipment start-up is described. Next, the Navy's maintenance improvement process, known as Reliability Centered Maintenance (RCM), is reviewed in order to suggest improvements to their use of organizational data. This process utilizes a variety of experts in maintenance, and submarine operations and their knowledge can be better fused with data sources for greater planning efficiency. Finally, the failure data collection process, while electronic, is cumbersome for engineers to use effectively during their planning process. Higher quality content and more standard fields will allow engineers to better understand the root causes for failure which creates more informed planning for future maintenance periods.

Naval Engineer

Master of Science in Mechanical Engineering

A Launch and Recovery System for Integrating Unmanned Ocean Vehicles onto Surface Platforms

LT Casey Strouse, USN

Prof. Michael S. Triantafyllou
Thesis Supervisor

Unmanned vehicles (UxVs) are becoming more prevalent across all domains. As UxV technology improves and their operations become more essential to mission success, the challenge of integrating these vehicles onto current surface platforms becomes increasingly more important to solve. Surface ships are designed to be adaptive and meet the changing requirements of their operational environment over their 25-plus year life. However, the majority of the current surface fleet was not designed from the beginning for launch and recovery of unmanned ocean vehicles and must be retrofitted to support unmanned vehicle operations. While integration of UxVs will be limited by the size of the host platform, their integration should not be limited due to the inability to safely launch and recover them.

This paper will analyze current manned launch and recovery systems across all naval surface platforms and present recommendations for improving these systems to be more adaptive to launching both manned and unmanned ocean vehicles. Specifically, this research will focus on minimizing the heave motions exhibited by the vehicle during launch and recovery. To achieve minimized heave motions and improve operational performance, an analysis was conducted to determine the feasibility, performance, and safety benefits of integrating an active heave compensating winch into the system.

Naval Engineer

Master of Science in Mechanical Engineering

Risk Based Decision Making for the Deferment of U.S. Navy Submarine Maintenance

LCDR Matt Washko, USN

Prof. Themistoklis P. Sapsis
Thesis Supervisor

Maintenance of United States Navy submarines is a complex set of operations comprised of scheduling, budgeting, and executing a continuous stream of work across multiple vessels in the same maintenance facility year after year. Local personnel are involved in the details of the day to day operations and focus deeply on today and tomorrow, with little bandwidth to focus on larger, systemic issues with impacts far removed from today. The addition of fluctuating annual funding levels, a younger workforce, and the pressures to meet national defense requirements add complexity and compound the pressure to mortgage tomorrow for today by deferring work without regards to its later impact. Recently, the maintenance community has begun to invest time and resources in these larger, systemic issues. This thesis investigates the impacts of deferred maintenance actions on the timely completion of submarine maintenance periods by analyzing data from 50 refits executed over a decade at Trident Refit Facility in King's Bay, Georgia.

The results of this thesis are best understood in three parts: the impact of deferred maintenance actions on submarine refit on-time completions, the development of a technical, risk-based deferment decision tool, and the possible application of deferring or canceling certain maintenance items as a way to reduce the maintenance workload across the fleet. The first part shows the quantitative analysis of the data demonstrating that deferred maintenance actions are not having any negative impacts to on-time schedule execution. The second part shows how through technical analysis and application of a probability and consequence risk framework, deferment decisions can be analyzed to ensure that only low-risk work is being deferred. And finally, an application of that same framework can be made across the fleet to reduce the maintenance backlog.

Naval Engineer

Master of Science in Mechanical Engineering

Optical Coordination of Surface and Subsurface Autonomous Vehicles

LT Cody White, USN

Prof. Dick K. P. Yue
Thesis Supervisor

Much work has been done in the development of autonomous systems for use at sea. They provide a useful way of carrying out a variety of task, from exploration to data collection. The vast expanse of the ocean has naturally led to interest in networks of independent, autonomous vehicles that can act in a coordinated manner known as a swarm.

Current swarm technology has focused on the surface of the water. However, it is desirable to be able to perform measurements at varying depths. In order to expand swarm capabilities, this work investigates using low cost cameras and lights to provide navigation for a subsurface vehicle, by allowing it to follow a surface vehicle. This would allow for data collection at various depths, expanding the capability of the existing swarm, while maintaining the coordination of the swarm on the water's surface. This leverages the benefits of wireless communication and GPS.

This work focused on developing an understanding of the potential capabilities that could be expected as a result of utilizing low cost cameras for guidance. Testing was performed to examine tracking algorithm performance in both relatively clear testing tank water as well as turbid pond water. Using a low-cost, 5.0 Megapixel USB camera, testing showed reliable tracking performance out to a maximum range of 50 feet, in clear water.

Additionally, this work focused on creating an underwater platform to facilitate testing of various tracking algorithms. The platform utilizes a vertically facing USB camera. This camera was incorporated into the guidance and propulsion system of the vehicle. This platform allows further testing of tracking schemes as well as environmental effects, such as wave and target motion, water clarity, and ambient light.

Naval Engineer

Master of Science in Mechanical Engineering

Notes: