Naval Construction and Engineering

Ship Design and Technology Symposium

Wednesday, May 6, 2015

Multi-Purpose Room, MIT Media Laboratory

Building E14, 6th floor

0800 - 0845	Registration and Continental Breakfast
0845 - 0920	Welcome and Opening Remarks
	- Prof. Gang Chen, Head of the Department of Mechanical Engineering
	- Prof. Dick Yue, Mechanical Engineering Area 5 Director
	- CAPT Joe Harbour, 2N Curriculum Officer
0920 - 1010	Research Brief: Prof. Henrik Schmidt
	- Evaluation of an L-Shaped Acoustic Array Composed of Multiple Autonomous Vehicles: LCDR(s) Kerry Bosché
	- The Effect of Array Orientation on the 3D Acoustic Picture for Sound Sources and the Vertical Ambient Noise Profile: LT Author Anderson
1010 - 1030	Break and Poster Sessions (featuring student theses and projects)
1030 - 1050	Research Briefs: Prof. Franz Hover
	- Shipboard Integrated Engineering Plant Survivable Network Optimization: CAPT Thomas Trapp
1050- 1140	Student Design Project Briefs - CG-47 Class Railgun Conversion: LCDR John Genta, LCDR Chris Wing, LCDR Johnathan Walker, LT Konstantinos Mentzelos
	- Naval Search and Rescue Craft SAR-1: LCDR(s) Matt Strother, LT Vanea Pharr, LT Matt Williams
1140 - 1200	Break and Poster Sessions (featuring student theses and projects)
1200 - 1300	**Lunch Buffet and Keynote Address**
	The Honorable Sean Stackley, ASN (RDA)
1300 - 1320	Research Briefs: Prof. Stefano Brizzolara
	- Effect of Inverted Bow on the Hydrodynamic Performance of Navy Combatant Hull Forms: LCDR(s) Jeff White
1320 – 1345	Student Design Project Briefs
	- Small Surface Combatant SSC: LCDR Brandy Dixon, LCDR(s) Kerry Bosché, LT Ryan Zachar
1345 - 1405	Research Brief: Prof. Steven Leeb
	- Utilization of Vibration Assessment During Rotor Spin-Down to Determine the Mechanical Health of Rotating Machines: LT Ryan Zachar
1405 - 1425	Break and Poster Sessions (featuring student theses and projects)
1425 – 1445	Research Brief: Dr. Eric Rebentisch
	- Contract Incentives for Shipbuilding: LCDR Kathleen McCoy
1445 - 1540	Student Design Projects
	- VA to UxV Mothership: LCDR Nate Mills, LCDR(s) Jim Colgary, LT Justin Stepanchick, LT Jake Gerlach
	- Arctic Frigate: LCDR Kathleen McCoy, LT Ian Campbell, LCDR(s) Jeff White
1540 – 1600	Wrap-up and Concluding Remarks
1600	**Mission Complete**

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.

A 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.

The Honorable Sean J. Stackley
Assistant Secretary of the Navy Research, Development, and Acquisition

Sean J. Stackley assumed the duties of assistant secretary of the Navy (ASN) (Research, Development & Acquisition (RDA)) following his confirmation by the Senate in July 2008. As the Navy's acquisition executive, Mr. Stackley is responsible for the research, development and acquisition of Navy and Marine Corps platforms and warfare systems which includes oversight of more than 100,000 people and an annual budget in excess of $50 billion.

Prior to his appointment to ASN (RDA), Mr. Stackley served as a professional staff member of the Senate Armed Services Committee. During his tenure with the Committee, he was responsible for overseeing Navy and Marine Corps programs, U.S. Transportation Command matters and related policy for the Seapower Subcommittee. He also advised on Navy and Marine Corps operations & maintenance, science & technology and acquisition policy.

Mr. Stackley began his career as a Navy surface warfare officer, serving in engineering and combat systems assignments aboard USS *John Young* (DD 973). Upon completing his warfare qualifications, he was designated as an engineering duty officer and served in a series of industrial, fleet, program office and headquarters assignments in ship design and construction, maintenance, logistics and acquisition policy.

From 2001 to 2005, Mr. Stackley served as the Navy's LPD 17 program manager, with responsibility for all aspects of procurement for this major ship program. Having served earlier in his career as production officer for the USS *Arleigh Burke* (DDG 51) and project Naval architect overseeing structural design for the Canadian Patrol Frigate, HMCS Halifax (FFH 330), he had the unique experience of having performed a principal role in the design, construction, test and delivery of three first-of-class warships.

Mr. Stackley was commissioned and graduated with distinction from the United States Naval Academy in 1979, with a Bachelor of Science in Mechanical Engineering. He holds the degrees of Ocean Engineer and Master of Science, Mechanical Engineering from the Massachusetts Institute of Technology. Mr. Stackley earned certification as professional engineer, Commonwealth of Virginia, in 1994.

Gang Chen

Carl Richard Soderberg Professor of Power Engineering,
Department Head,
Director, Pappalardo Micro and Nano Engineering Laboratories,
DOE EFRC: Solid-State Solar-Thermal Energy Conversion Center (S3TEC)

Gang Chen is currently the Head of the Department of Mechanical Engineering and Carl Richard Soderberg Professor of Power Engineering at Massachusetts Institute of Technology (MIT), and is the director of the "Solid-State Solar-Thermal Energy Conversion Center (S^3TEC Center)" - an Energy Frontier Research Center funded by the US Department of Energy.

He obtained his bachelor and master degrees from Huazhong University of Science and Technology, and his PhD degree from the Mechanical Engineering Department, UC Berkeley, in 1993. He was an assistant professor at Duke University, a tenured associate professor at UC Los Angeles, before moving to MIT. He is a recipient of a K.C. Wong Education Foundation fellowship and a John Simon Guggenheim Foundation fellowship. He received an NSF Young Investigator Award, an R&D 100 award, and an ASME Heat Transfer Memorial Award. He is a fellow of AAAS, APS, and ASME. In 2010, he was elected a member of the US National Academy of Engineering.

Dick K.P. Yue

Philip J. Solondz Professor of Engineering,
Skolkovo Foundation Professor or Mechanical Engineering,
Professor of Mechanical and Ocean Engineering

Dick K.P. Yue is the Philip J. Solondz Professor of Engineering, the Skolkovo Foundation Professor of Mechanical 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 more than two 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. 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.

Professor Yue is married to the former Miss Eva H. Wu. They have four children: Kevin Paul, Teresa Grace, Emily Joyce, and Brian John. The Yues reside in Weston, Massachusetts.

Henrik Schmidt

Professor of Mechanical and Ocean Engineering

Henrik Schmidt is Professor of Mechanical & Ocean Engineering at the Massachusetts Institute of Technology. He received his MS degree from The Technical University of Denmark in 1974, and his PhD. from the same institution in 1978. From 1978 to 1982 he worked as a Research Fellow at Risoe National Laboratory in Denmark. From 1982 to 1987 he worked as Scientist and Senior Scientist at the NATO SACLANT ASW Research Centre in Italy. He has been on the MIT faculty since 1987. He has served as Associate Director of Research at the MIT Sea Grant College Program from 1989-2002, and as Associate Department Head 1994-2002. He served as Acting Department Head of Ocean Engineering from 2002 - 2004. Professor Schmidt's research has focused on underwater acoustic propagation and signal processing, in particular on the interaction of sound in the ocean with seismic waves in the ocean bottom and the Arctic ice cover. His work has been of theoretical, numerical and experimental nature. He has been Principal Investigator in two Arctic ice station experiments, and Chief Scientist for several recent, major experiments in coastal environments. He has developed numerically efficient numerical algorithms for propagation of acoustic and seismic waves in the ocean and solid earth environment, including the SAFARI and OASES codes which are used as a reference propagation models in more than 100 institutions around the world, including all US Navy laboratories and most major universities involved in underwater acoustics and seismic research. In recent years Professor Schmidt has been pioneering the development of new underwater acoustic sensing concepts for networks of small Autonomous Underwater Vehicles (AUV) for distributed MCM and ASW. Prof. Schmidt was lead-PI for the multi-institutional PLUSNet team developing a distributed, autonomous acoustic sensing concept, under the ONR Undersea Persistent Surveillance Program. In addition to a long string of papers in the archival literature, Professor Schmidt has co-authored a textbook on computational ocean acoustics. He is a Fellow of the Acoustical Society of America (ASA), and he was the 2005 recipient of the ASA "Pioneer of Underwater Acoustics" medal.

Steven B. Leeb

Professor, EECS an Mechanical Engineering,
MacVicar Faculty Fellow

Steven B. Leeb received his doctoral degree from the Massachusetts Institute of Technology in 1993. He has served as a commissioned officer in the USAF reserves, and he has been a member on the M.I.T. faculty in the Department of Electrical Engineering and Computer Science since 1993. He also holds a joint appointment in MIT's Department of Mechanical Engineering. He currently serves as MacVicar Fellow and Professor of Electrical Engineering and Computer Science in the Laboratory for Electromagnetic and Electronic Systems. In his capacity as a Professor at M.I.T, he is concerned with the design, development, and maintenance processes for all kinds of machinery with electrical actuators, sensors, or power electronic drives. He is the author or co-author of over one hundred publications and fifteen US Patents in the fields of electromechanics and power electronics.

Franz S. Hover

Associate Professor of Mechanical Engineering

Franz S. Hover is Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology. He earned the B.S. degree in Mechanical Engineering at Ohio Northern University, and the S.M. and Sc.D. degrees from the Woods Hole Oceanographic Institution/Massachusetts Institute of Technology Joint Program in Oceanography/Applied Ocean Science and Engineering. Professor Hover teaches and conducts research in ocean systems, control and robotics.

Professor Hover was a consultant to industry and a Principal Research Engineer at MIT before joining the MechE faculty in 2007. Autonomous inspection of in-water ships has been a key area of work, driven by security concerns and maintenance necessity, and facilitated by state-of-the-art robotic underwater vehicles, sensors and algorithms. Professor Hover's long-term industry collaboration on the ship inspection problem has resulted in a major commercial product. His research also addresses design of ocean networks with emphasis on dynamic teams of communicating vehicles. The Hover group recently developed and implemented new methodologies in control over capacity-constrained acoustic channels underwater, and in adaptive positioning for high-quality acoustic performance. Work with the offshore industry is underway to pioneer the application of robotic systems to new tasks such as dismantling and decommissioning of rigs.

Professor Hover has authored or co-authored over one hundred refereed papers. He has supervised nineteen Master's and four Doctoral students, who are undertaking successful careers in research laboratories, industry and academia. Professor Hover has also supervised over 150 undergraduate research opportunity (UROP) projects, and served as mentor for the MIT Marine Robotics Team since 2004.

Eric Rebentisch

Sociotechnical Systems Research Center, Research Associate

Eric Rebentisch, Ph.D. is a research associate at the Massachusetts Institute of Technology's Sociotechnical Systems Research Center. There he leads and advises research projects, including "Creating High Performing Engineering Programs: Making Lean Thinking Part of the Program Management DNA", "Production in the Innovation Economy: How to Create Excellence Through Competition and Benchmarking in the U.S. Shipbuilding and Defense Industry", and "Skolkovo Institute of Science and Technology Enterprise Stakeholder Analysis".

He formerly headed LAI's Enterprise Product Development group and led its research, tools, and community development activities. He has advised dozens of graduate student theses at MIT on a range of topics. His research has focused primarily in aerospace, but also encompasses autos, medical devices, chemicals, and high- technology. It has addressed the development and management of enterprise technical competencies, including knowledge management and knowledge transfer, intellectual capital management, long-term institutional change, the "fuzzy front end" of product development, system architecting (including standardization, reusability, and commonality), and strategies for managing technical system development in an unstable environment.

He has also played a principal role in developing research findings into policy recommendations and deploying them to the US Government, and in facilitating high-level value-stream mapping and transformation events in complex enterprises such as the US Air Force, US Army, and the US Department of Defense (DoD). He led the facilitation of enterprise transformation initiatives with the US Army Materiel Enterprise and the US Army System of Systems Engineering office, and the office of the US DoD Deputy Chief Management Officer. He led the enterprise and stakeholder value research effort on the NASA Constellation Systems Study on the Draper Laboratory/MIT team studying future space exploration architectures and strategies.

He is co-author of the book *Lean Enterprise Value* and numerous other publications. At MIT he has taught courses in research methods and Lean/Six-sigma processes. He has been a principal in developing and deploying short courses at LAI and MIT, including the Lean Enterprise Value (LEV) and Lean Enterprise Product Development (LEPD). Both LEV and LEPD were developed with Dr. Hugh McManus and have been used widely in the aerospace industry to train managers and engineers lean enterprise principles and practices and to facilitate improvement initiatives.

He received a doctorate in the Management of Technological Innovation from the Sloan School of Management at the Massachusetts Institute of Technology, a Master's degree in Organizational Behavior from Brigham Young University, and a Bachelor of Science degree in Aerospace Engineering from the California State Polytechnic University, Pomona. Prior to academia, he worked in the aircraft industry as a propulsion engineer.

Stefano Brizzolara

Peabody Visiting Associate Professor, Mechanical Engineering
Assistant Director for Research, MIT Sea Grant

Stefano Brizzolara, MSc in Naval Architecture and Marine Engineering with honors at the University of Genova, Italy, PhD in numerical hydrodynamic for ship design, started his academic career in the Department of Naval Architecture of the University of Genova where he created the new course in Numerical Hydrodynamics for Ship Design in 2003 and founded the Marine CFD Group, a research team devoted to the development, validation and application to ship design of different Computational Fluid Dynamics Methods, including Boundary Element Methods (BEM), Reynolds Averaged Navier-Stokes Equations solvers and Smoothed Particle Hydrodynamics. His area of expertise is steady and unsteady hydrodynamics of fast marine vehicles, cavitation of propellers and hydrofoils and more recently coastal hydraulics.

In 2011 he has been Peabody Visiting Associate Professor in the Mechanical Engineering Department of the Massachusetts Institute of Technology (MIT) and since 2013 he joined MIT Sea Grant as Assistant Director for Research and continues to teach and research in the newly founded Innovative Ship Design Lab, MIT iShip which continues the research started with the Marine CFD group, extending it to the functional design of innovative high performance marine vehicles, fast ships and offshore technologies.

He has been (and is) working as principal investigator on several research projects funded by the Office of Naval Research, the European commission and the Maritime Industry. Some of them deal with the design of new unconventional silent propellers, design of the second generation autonomous surface drafts, design of ultra-high speed marine vehicles, such as unconventional super-cavitating surface-piercing hydrofoil-SWATHs, stepped planing hulls with stern hydrofoils and numerical techniques for the automatic parametric optimization of the hydrodynamic performance of ship hull forms.

Past experience includes: experimental research on propellers and hydrofoils at the cavitation tunnel of the Italian Navy in Rome; design of navy ships and propellers in the hydrodynamic design office of Fincantieri Navy Ship Business Unit (Genoa, Italy). He is author of more than 100 scientific papers and holder of four patents.

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 lead 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 Weston L. Gray, USN

Associate Professor of the Practice of Naval Construction and Engineering

Commander (CDR) Weston Gray is married to the former Melony Marie Benson. They have three sons: Frasher, Cason, and Evan.

Born and raised in rural Ohio, CDR Gray graduated from the University of Akron in 1999 with a degree in Electrical Engineering. After graduation, he was commissioned in the Navy and reported to Naval Nuclear Power Training Command (NNPTC) Charleston, South Carolina where he earned distinction as a Master Training Specialist.

CDR Gray lateral transferred to the Engineering Duty Officer (EDO) community in 2003. After the Submarine Officer Basic Course, he reported for duty aboard USS Maryland Gold to begin the EDO dolphin qualification. CDR Gray earned his EDO dolphins at Pearl Harbor Naval Shipyard while serving in various roles including Assistant Project Superintendent and Nuclear Project Engineer. In 2007, he deployed to Iraq in support of Operation Iraqi Freedom. To complete his Engineering Duty qualification, CDR Gray reported to the Massachusetts Institute of Technology (MIT) for graduate studies in 2008 where he took honors in his class and earned degrees in Naval and Electrical Engineering.

Following Graduate School, CDR Gray was assigned to NAVSEA 05 where he developed surface ship energy efficiency initiatives and led a project in PMS 320 to create electric supply systems to support high power radars on future surface combatants. In 2012, CDR Gray was assigned as the Project Officer for Next Generation Submarine Electronic Warfare in PMS 435.

CDR Gray is currently serving as Academic Officer and Associate Professor of the Practice for Naval Construction and Engineering at MIT.

Commander Gray has been awarded the Defense Meritorious Service Medal, two Navy Commendation Medals, two Navy Achievement Medals, and various unit and campaign awards.

2014 2N Student Projects

CG-47 as Test Platform for Electromagnetic Railgun (EMRG)

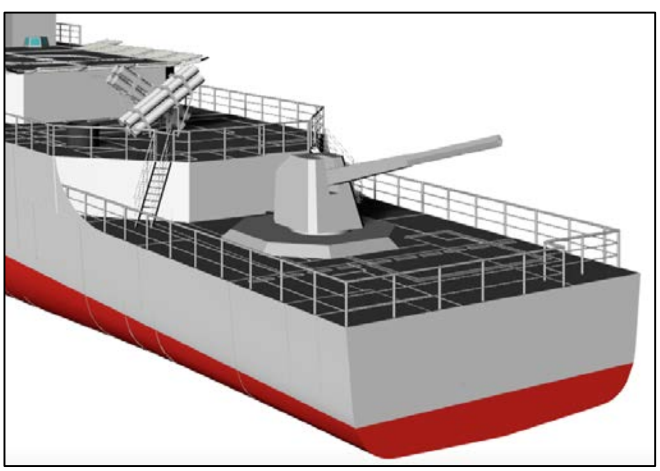
LCDR John Genta, USN; LCDR Chris Wing, USN;
LCDR Johnathan Walker, USN; LT Konstantinos Mentzelos, HN

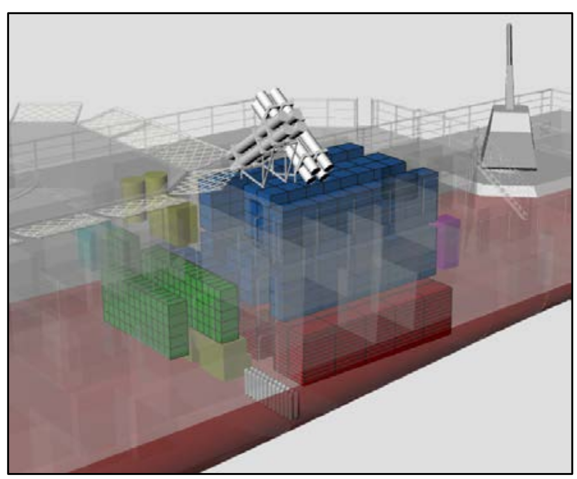
The core doctrine of the surface fleet's mission is to defend high-value units. Today's surface fleet faces the challenge of combating more sophisticated adversaries with longer-range weapons. The surface warfare enterprise is responding by shifting to a more offensive-minded concept of operations to affect an adversary's battlespace calculus by investing in weapons systems such as the Electromagnetic Railgun (EMRG). To support EMRG programmatic operational testing and evaluation a test ship needs to be identified.

This conversion design evaluated adding a 32MJ or 20 MJ Naval Surface Fire Support (NSFS) capable EMRG system to an existing CG-47 class cruiser. Evaluated EMRG systems were designed to have a battery, capacitor bank, and a pulse-forming network capable of providing all energy necessary for one 50 shot NSFS salvo. A hierarchal design process showed installing a 32MJ EMRG in the aft 5-inch gun space is feasible. Additionally, a weight-based labor cost estimate was performed.

Use of the aft 5-inch gun location and aft VLS spaces maximized retained mission capabilities. Because the heaviest components were arranged lower in ship, negligible changes to overall stability were predicted. Current CG-47 electric distribution plant capacity was shown to be able to meet EMRG system re-charging requirements and all static electric load conditions except 20 KW of winter battle load. An additional cooling system was designed and arranged that requires docking the ship to support the conversion design, although a trade space of alternatives was also presented.

	Disp. (LT)	Draft MS (ft)	KG (ft)	GMT (ft)	TRIM(ft)
Change Due to Conversion	22	0.02	-0.02	0.02	0.21 (less by BOW)





Small Surface Combatant

"State of the Art for 30 Years"

LT Kerry Bosché, USN **LCDR Brandy Dixon, USN** **LT Ryan Zachar, USN**

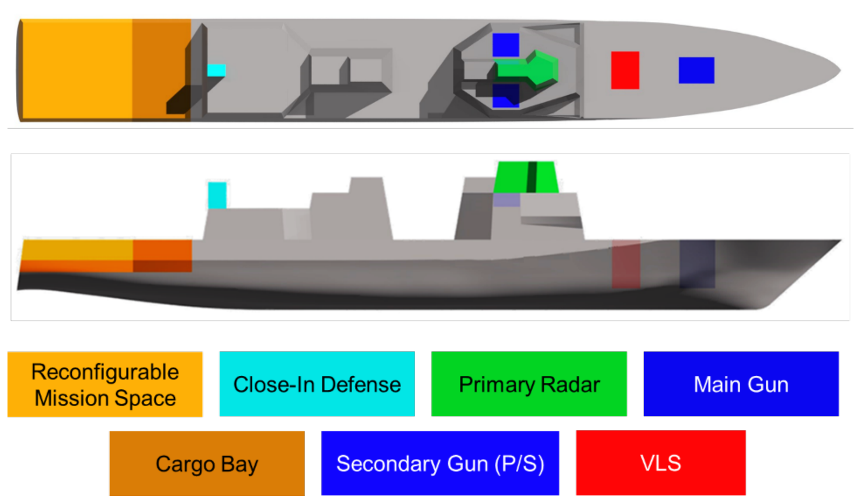
The Small Surface Combatant (SSC) is a frigate-sized warship for 2030-2060 and is capable of both independent and battle group operations. The SSC utilizes ***modularity for upgradeability*** to advance the concept of the Littoral Combat Ship (LCS), supporting the next generation of weapon and sensor systems. The SSC concept demonstrates that a frigate-sized combatant may be able to fill the US Navy's anticipated capability gaps as the current LCSs reach end of life, and be built with the capacity to support state-of-the-art systems over a 30-year lifetime.

Modularity for upgradeability is the ability of the design, as built, to meet threshold requirements while accepting the impacts of modularity in order to be able to grow to end-of-life desired capability. The primary impact of modularity is excess space, weight, and mechanical/electrical support capability when the ship is launched. Building this modularity into the ship shortens the upgrade timeline later in life and decreases the upgrade cost.

SSC accomplishes modularity for upgradeability through the use of ***module stations***, which

- Simplify the in-service upgrade process via careful structural and interface design.
- Accommodate all possibilities in a set of credible present and future systems by supporting the maximum physical dimension, weight, VCG, required power, and support connections found in the set.

SSC Module Stations



SSC Characteristics	
Primary Missons	ASW, ASuW, AAW
LBP	139.5 m
Beam	16.4 m
Draft (Full Load)	5.6 m
Weight (Full Load)	7900 MT
Power Plant (57 MW)	(2) GE LM2500 (2) GE LM500
Electrical Distribution	MVDC
Propulsion	(2) 19 MW AIM
Sustained Speed	27.1 kts

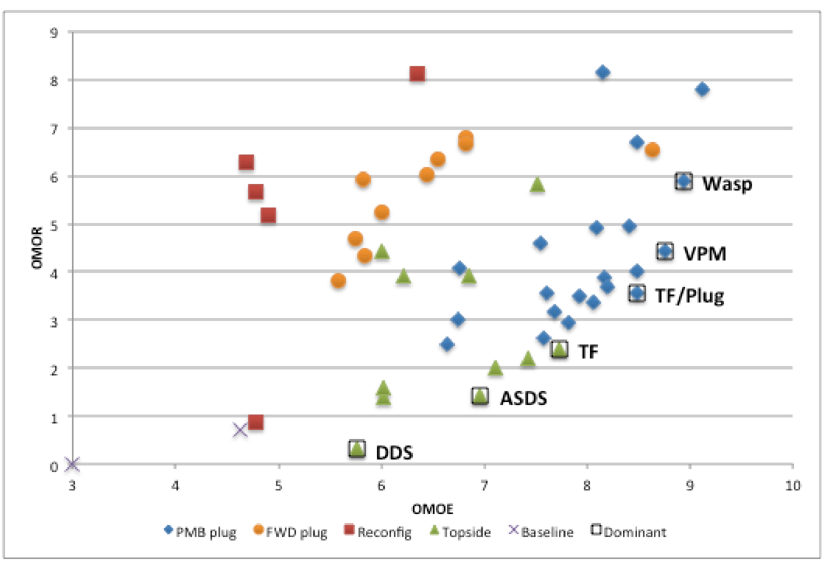
With the exception of the MVDC distribution system, all of the systems that would be built into SSC in 2030 are either technically mature or currently in development. The power requirements built into the module stations for future radar and weapons stations rely on current trends and reasonable assumptions about the requirements of future versions of these systems. However, two aspects of the SSC, the NSC based hullform and MVDC electrical distribution system, introduce risk into the design and create an overall risk assessment of medium-high.

The SSC does not represent or require a change from the CONOPS of current frigate-size through destroyer-size ships. In fact, the SSC represents an improvement in operational flexibility compared to the LCS. The module stations can accept legacy systems as built to keep cost down, yet the ship has the capacity to accept future weapons and sensors, including those requiring high energy. This provides the Navy with options to meet capability and cost requirements through the life of the vessel.

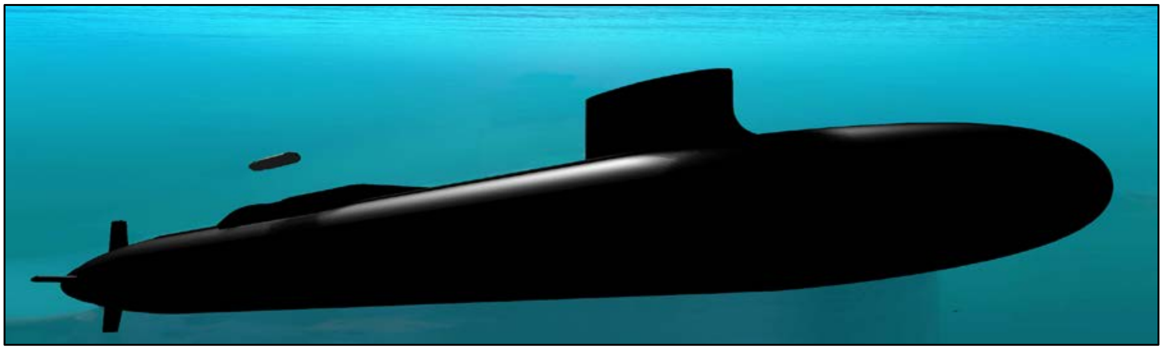
VIRGINIA Block M - The sUUVerine Project

LCDR Nathan Mills, USN; LT Jim Colgary, USN;
LT Justin Stepanchick, USN; LT Jacob Gerlach, USN

This study performed an analysis of alternatives to modify a VIRGINIA-like submarine to add unmanned vehicle (UxV) capability. Various designs were evaluated and ranked on risk, cost, and effectiveness in both UxV and typical submarine missions. One of the dominant designs was chosen for more detailed analysis. This option provides wet stowage of 4 Large UUVs underneath a topside fairing. The horizontal UUVs are launched and recovered through sliding doors at the top of the fairing. A 25 foot hull extension is added amidships to carry UxV support systems, berthing, and meet reserve buoyancy requirements. The converted submarine demonstrates a flexible, balanced UxV capable design at a lower cost than the Virginia Payload Module (VPM); however, further hydrodynamic analysis is required. For a better return on investment, the study recommends a smaller conversion of just a Large UUV launch and recovery system that attaches directly topside. This should be pursued to gain operational experience with Large UUV employment. Submarine employment tactics for all UUV sizes must be matured in time to inform the next SSN design.



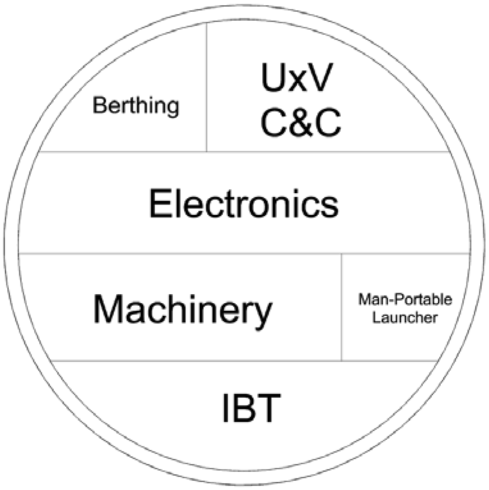
This study used an academic submarine model to evaluate the conversion of a VIRGINIA class submarine to a sea-based UxV host while understanding any baseline ship performance degradation. The conversion affords the host submarine the ability to transport, deploy, and recover various UxVs. The end result is a concept design, VIRGINIA Block M (VA-M), that achieves weight and volume balance while satisfying a set of requirements. The VA-M concept gives insights to the most effective ways to increase the submarine force UxV technology. Additionally, it revealed key the technology advancements that required to make the design viable.



The figures depict perspective and body views of the VA-M concept design. The 25 foot parallel midbody plug with a streamlined topside fairing allows for the launch and retrieval of four wet-stored Large UUVs. Additionally, the conversion includes a new ocean interface in the plug for launch of man-portable UxVs. Although a 7 foot maximum height topside fairing produced significant hydrodynamic concerns, this variant provided a feasible and flexible UxV capability at a competitive risk and cost.

	VA-M	Baseline
LBP [ft]	402	377
L/D	11.8	11.1
Mean Draft [ft]	28.2	28.0
Submerged Displacement [LT]	8490	7800
Weight Margin [LT]	550	380
Reserve Buoyancy	12%	12%
Baseline speed decrement [kt]	-1	0
Cost of Construction (lead ship)	$320 million	N/A

Principal Characteristics



Arctic Frigate (Arctic FFG)

LCDR Kathleen McCoy, USN; LCDR(s) Jeff White, USN; LT Ian Campbell, USN

As a result of polar ice melting, commercial, scientific and military activity is increasing in the Arctic region. As an Arctic nation, the United States has developed a national security strategy for peace and cooperation in the region. In support of this national strategy, the U.S. Navy has been tasked with the objectives of "ensuring security, supporting safety, promoting defense cooperation, and preparing for a wide range of challenges and contingencies" in the region. This design project addresses the need to have a constant naval presence in the Arctic region after 2030. The Arctic Frigate (Arctic FFG) is capable of deploying to the region for extended periods of time for the purpose of ensuring freedom of navigation, maintaining maritime security, conducting search and rescue missions, and rapidly responding to national security threats. Though not an icebreaker, the Arctic FFG can transit independently in medium first-year ice and satisfies all of the U.S. Navy and American Bureau of Shipping (ABS) Polar Class 5 requirements to operate in this environment.

Designing a warship for Arctic operations presented unique challenges. The ship's structure had to be stronger than that of a regular warship in order to withstand ice loads. Double-walled tanks were added to satisfy pollution prevention requirements. Machinery, air intakes and communications systems also required enhancements for operation in such an extreme environment. The ship was designed for a long endurance time and range (12,000 nm) to eliminate the need for underway replenishment while in the Arctic. The Arctic FFG uses an Integrated Power System (IPS) with two primary CAT 3616 5 MW and two secondary CAT 3612 3.8 MW diesel engines. Two 10 MW puller pods, hardened for ice conditions, provide propulsion. Retractable roll fins were installed to meet sea keeping performance requirements. The ship's armament consists of a 32-cell VLS, a Mk 110 57 mm gun, a 20 mm Phalanx CIWS and crew-served weapons. Major sensors consist of surface search radar, fire control radar and SEWIP. The helicopter hangar and flight deck can accommodate an aviation detachment with two MH-60R helicopters. The ship also carries two 7 m RHIBs and four 50-person Arctic lifeboats.

Ship Characteristics	
Parameter	**Value**
LBP	125.6 m
Beam	16.59 m
Full Load Draft	5.77 m
Full Load Displacement	6732 MT
GMT	1.71 m
GMT/B	0.103
Range	12,000 nm
Maximum Speed	19 kts
Endurance Speed	11 kts
Maximum Speed in Ice	5 kts
Crew	160
Lead Ship Cost	$1.48B (FY 15)
Follow Ship Cost	$1.25B (FY 15)

Conversion of FFG-7 to LCS Mission Package Test Platform

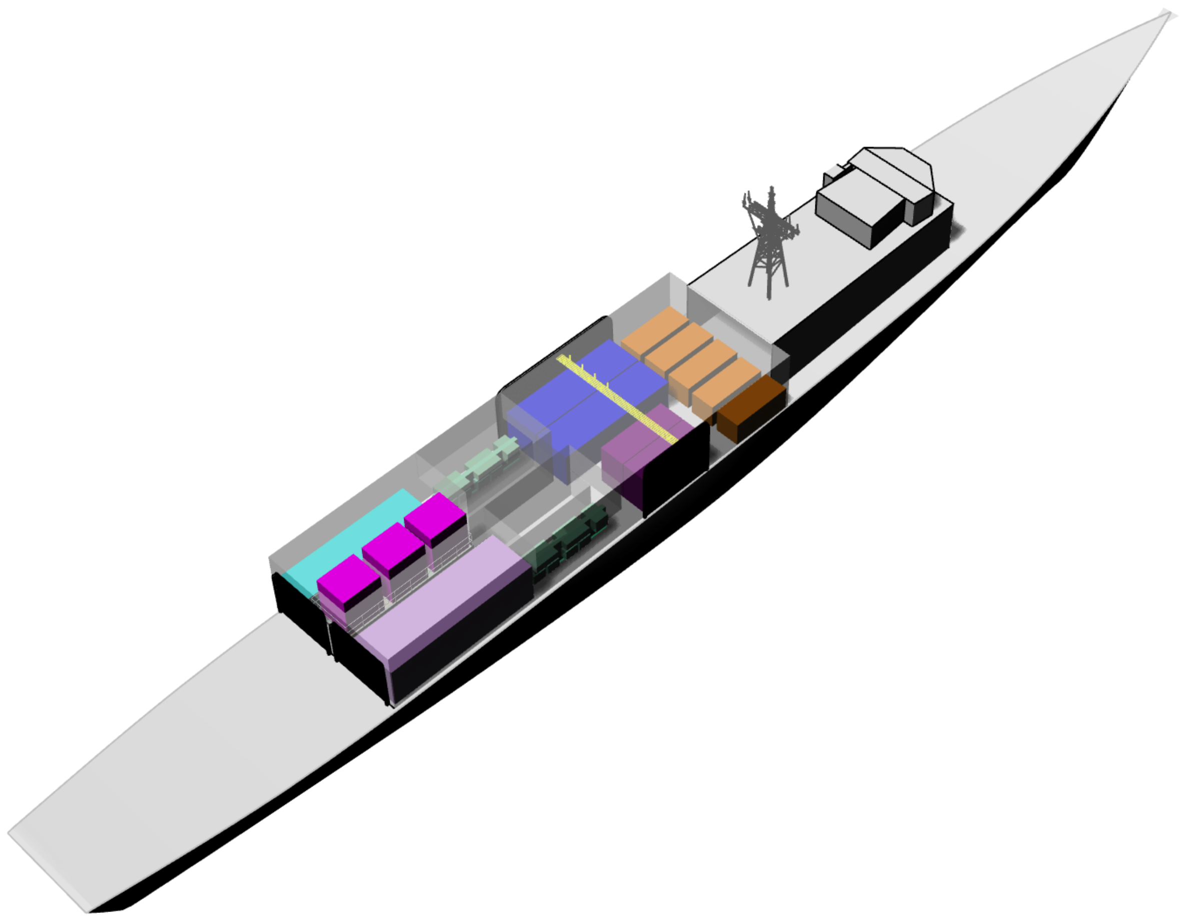
LT(N) Calley Gray, RCN; LT Chris Wilkins, USN; LTJG Mert Timur, TN

Due to cut backs to the total number of Littoral Combat Ships (LCS), the operational demand on the current LCS is very high, leaving little opportunity for the developmental testing and evaluation of the Mission Modules. This project examines the feasibility of converting a retiring FFG 7 to a Mission Module Test Platform capable of achieving high Technical Readiness Levels (TRLs).

A module layout was selected for examination that replaced the aft 2/3rds of the existing deckhouse with a large warehouse style mission bay. The layout closely resembled a mission bay on an LCS without comprising the structure of the hull.

Further analysis was performed using, RHINO, POSSE and Seakeeper. Deliverables from this study include a 3D RHINO model with the proposed Mission Module layout, a strength, stability and seakeeping analysis, as well as a cost estimate.

The results of this study showed that a converted FFG 7 would be a suitable test platform for LCS Mission Modules. Stability and seakeeping of the modified ship showed improvements from the original FFG 7 and without changing any of the power and propulsion systems, the FFG 7 is able to meet all interface requirements for the modules.



Riparian Support Boat (RSB)

LT Michael Rowles, USN; LT Roxane Powers, USN; LTJG Mert Gokdepe, TN

Naval Expeditionary Forces (NEF) currently use ad hoc shore basing and contracted local service providers for logistics support. This is expensive, operationally inefficient, and overly reliant on unpredictable contingency funding. Dedicated afloat support vessels would be operationally desirable, but are expensive. An effective compromise capability is the use of containerized mission support modules installed as needed on a mission utility landing craft (LCU).

The module host platforms is a modified LCU 1646 sub class craft that will be maintained by the existing Assault Craft Units (ACU), and will be available for general tasking when not needed for expeditionary support. Included in the modifications will be propulsion, electrical, auxiliary, and C4I system updates to extend service life of the final design.

The design approach of the Riparian Support Boat (RSB) consisted of a tradespace exploration focused on enhancing capabilities that would act as a force multiplier. Pertinent aspects of the RSB were analyzed using three separate paradigms: 1) the relative benefit of the RSB to each warfare customer, 2) the scope and occurrence of changes that can be applied to the conversion, and 3) the ranking of each improvement category's influence to the RSB's overall success. Analysis results showed that the design's performance benefited more from engineering and capacity changes than combat systems and capability improvements.

The final design included an Integrated Propulsion System, Foldable Knuckle Boom Crane, permanent RO Unit, and additional 3-man berthing compartment in the deckhouse.

The RSB final concept design is a capable and cost-effective craft inland connector, forward basing, and expeditionary mission support capabilities. The increased facilities engineering capabilities of the craft will enhance its functionality in expeditionary operations and increase the potency of these mission areas. The RSB provides vital operational support in the riparian environment where other platforms can't operate and without the use of costly "rented" solutions or dedicated acquisitions.

RSB Characteristics	
Parameter	**Value**
LOA	135.2 feet
LBP	134 feet
Beam	29.8 feet
Draft (Full Load)	6.6 feet
Depth	8 feet
Lightship Displacement	208.8 LT
Full Load Displacement	472 LT
Endurance Range	1,200 miles at 8 kts
Maximum Speed	11 kts
Military Lift	125 tons or 400 troops 2,185 sq. ft. cargo area (~10 TEU)
Propulsion and Electrical	2 STIAVELLI W22 High Efficiency IE2 electric motor @ 325kW (8poles) ea. 3 Hitachi SJ700B-1320 HFUF Power Conversion Modules @ 264 kW ea. 3 CAT C9 Diesel Generators @ 250 kW ea.
Crew	10 crew, 7 transient

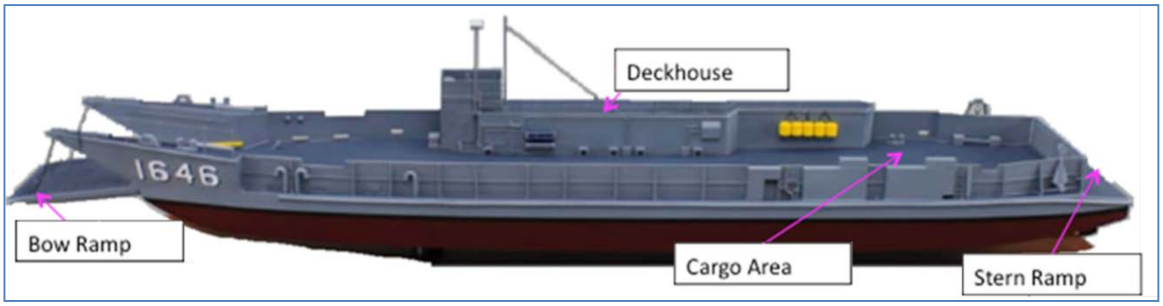


Figure 1: Original LCU 1646 sub class

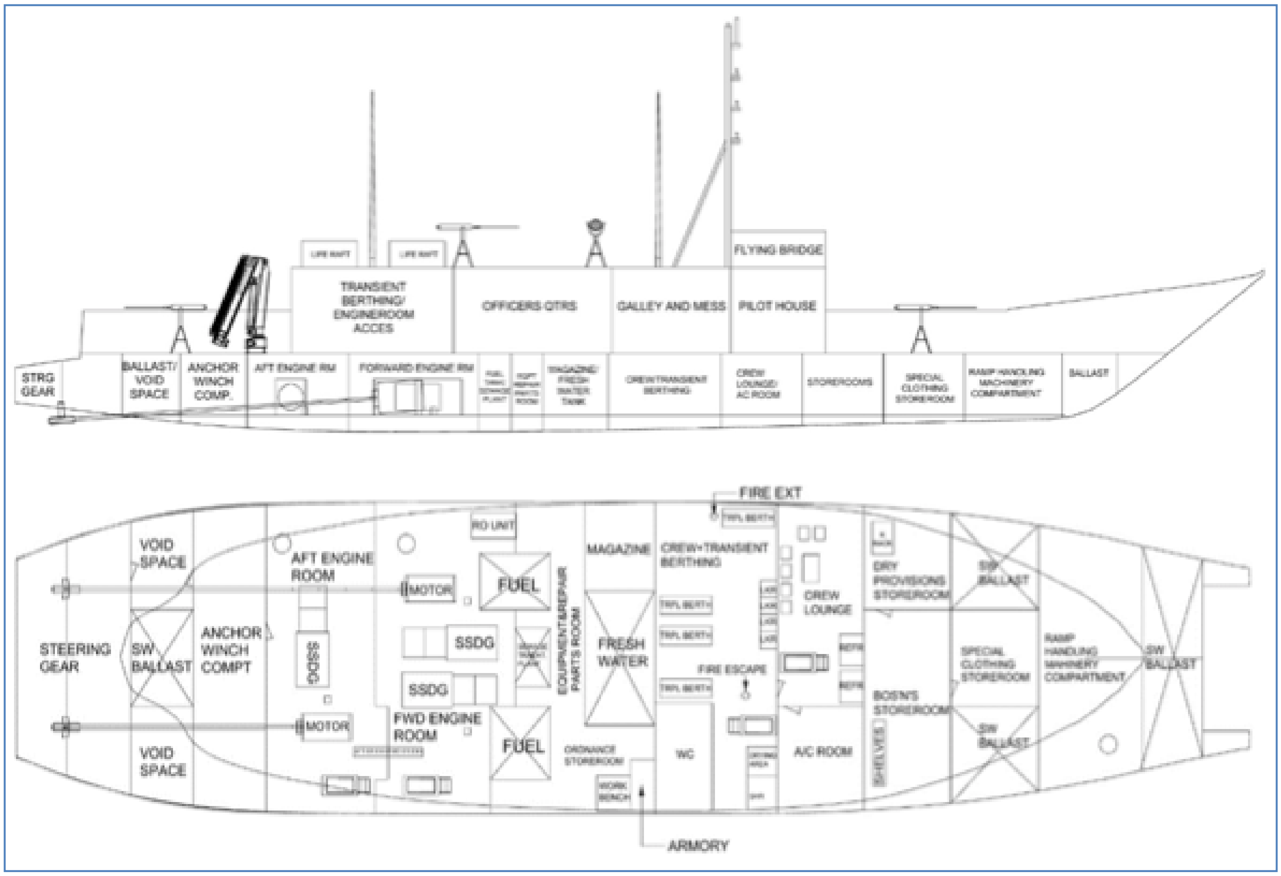


Figure 2: RSB

Search-and-Rescue Vessel (SRV)

LT Vanea Pharr, USN; LT Matthew Strother, USN; LT Matthew Williams, USN

Given the increasing frequency with which naval assets are tasked to assist in search-and-rescue missions following large-scale emergencies at sea, the absence of a capable asset specifically designed and tailored to this type of mission presents a fleet weakness. This study aims to assess the feasibility of designing and implementing a surface vessel specifically to address this weakness. The vessel is designed to be relatively small in size, fast, versatile, and agile. It is equipped to conduct and coordinate an extended search, and provide emergency medical care to a nominal number of incident survivors.

Due to the significant differences between this vessel and a typical surface combatant, a slightly different approach to the design process was employed. Initial hydrodynamics and volumetric Froude number calculations, as well as anticipated spatial constraints on the internal hull volume and the desired size and speed range, led to the selection of a fully planing monohull. Computational Fluid Dynamics (CFD) analysis of multiple hull variant designs was conducted as traditional design tools were simultaneously employed to make initial estimates of weights and internal space. In subsequent progressions through the design spiral, engine selections and estimated fuel requirements led to a significant increase in the predicted full load displacement, and alternative powering systems and construction materials were considered. The completed vessel employs a hybrid electric drive, driven by extremely efficient, power dense gas turbines, and is constructed from glass-reinforced plastic (GRP) to reduce structural weight.

The final conclusion of this study is that the Search and Rescue vessel is a fully feasible design. However, while the SRV is highly capable, the acquisition and maintenance costs for the class likely outweigh the value of successfully completing a mission that might be carried out “well enough” by existing aviation and surface assets.

Ship Characteristics	
Parameter	**Value**
LBP	60 meters
Beam	18 meters
Draft	8.5 meters
Depth (Station 10)	8.5 meters
Prismatic Coefficient	0.778
Lightship Displacement	1100 metric tons
Full Load Displacement	2200 metric tons
GM_t/B	0.36
Range	2160 nm
Maximum Speed	45 knots
Sustained Speed	45 knots
Lead Ship Cost	$637 million
Follow Ship Cost	$517 million
Accommodations	4 Officers, 2 CPOs, 15 Enlisted

2015 2N Student Theses

Shipboard Integrated Engineering Plant Survivable Network Optimization

CAPT Tom Trapp, USN

Prof. Franz Hover **Thesis Advisor**			
CAPT Joe Harbour	**Prof. Jim Kirtley**	**CAPT Mark Thomas**	**Prof. Ed Zivi, USNA**
Thesis Committee	Thesis Committee	Thesis Committee	Thesis Committee

Due to the complexity of the total ship system, and the iterative nature of the design process, the U.S. Navy has struggled to meet the spirit of the cost-as-an-independent variable (CAIV) policy. Selecting best-value concept variants in the Pareto optimal strategy does not guarantee cost optimality unless using cost-minimized variants. The method presented in this thesis is a systematic quantitative process for minimum cost survivable integrated engineering plant (IEP) design using mathematical optimization techniques that are ideal for early-stage design. There are three major contributions made by this work. First, is the application of ``designed-in'' survivability for high-level early-stage concepts that guarantees a minimum cost IEP design. The proposed method allows the systematic quantization of cost and performance early in the design process where cost savings are best realized. Second, is the accounting of the interdependence between the electrical generation and cooling domain. Mathematical constraints linking the domains ensure the effect of the failure of critical components is accounted for in the other domain(s). Finally, is a method for the integral design of minimum-cost shipboard stored energy is shown. The combined outcome provides the program manager assurance that the design selected is truly the best value, minimum cost IEP design.

PhD, Mechanical Engineering

Material Characterization of Lithium-ion Batteries for Crash Safety

LCDR Brandy Dixon, USN

Dr. Tomasz Wierzbicki
Thesis Supervisor

The safety of lithium-ion batteries is extremely important due to their widespread use in consumer products such as laptops and cell phones and more recently in vehicles. Several cases of thermal runaway in lithium ion batteries that resulted in fires have been reported recently. And in the case of vehicle batteries, deformation during a crash event could cause an internal short circuit, leading to thermal runaway, fires, or toxic gas release. While much is understood about lithium-ion batteries, no comprehensive computational models exist to test and optimize these batteries before manufacture.

The objective of this research is to characterize the mechanical properties of lithium-ion batteries to aid in the development of a comprehensive computational model. Prismatic, Elliptic, and Pouch cells, as well as their interior components, were obtained from Impact and Crashworthiness (ICL) sponsors and tested. The full cell tests included flat plate compression and hemispherical punch. Tests on interior component materials included uniaxial stress, biaxial punch, and compression tests. The results of these tests were used in the development of computational models that will be combined to fully describe the behavior of lithium-ion batteries in various crash scenarios and determine point of short circuit.

Naval Engineer

Master of Science in Mechanical Engineering

Design and Analysis of US Navy Shipbuilding Contract Architecture

LCDR Kathleen McCoy, USN

Dr. Eric Rebentisch	**CAPT Joe Harbour**
Thesis Supervisor	Thesis Reader

The US shipbuilding industry accounts for over 36 billion dollars annually, and US Navy shipbuilding is a large piece of that business. Contracting for US Navy ship procurement is complex due several factors such as budgetary and political concerns, sole or near sole source environments, and long lead-time construction. In the current climate of shrinking budgets, it is especially important to set programs up for financial success. One potential area for cost management improvement in acquisition programs is with the initial contract and incentive structure. If shipbuilding contracts could be described in engineering architectural terms, then perhaps that architecture could provide better clarity of contract options. Further, if contracting can be described as an engineering architecture, then perhaps that architecture could be optimized for a given result. These are the central questions of this thesis. To answer them, interviews were conducted with several experienced individuals from both industry and the government, including two former Commanders of Naval Sea Systems Command, the President of Irving Shipbuilding (Halifax, Nova Scotia) and a senior contracting expert from the Office of the Assistant Secretary of the Navy (Research, Development and Acquisition.) The successful Virginia Class Submarine (VCS) procurement strategy and program as well as Canada's new National Shipbuilding Procurement Strategy (NSPS) and recently signed build contract for the Arctic Offshore Patrol Ship (AOPS) were studied for insights into the contracting process. These insights were then used to form a contract architecture concept in accordance with the Tradespace engineering paradigm, first introduced by MIT's Adam Ross and Daniel Hastings in 2005. From the concept definition came the design vector definition. The design vector includes variables such as shareline definition, incentives, and contracted profit percentage. The tradespace was then populated by manipulating the design vector parameters. The Palisade tool @Risk was used to conduct the design vector manipulation and tradespace population. @Risk is an excel plug in that allows uncertain variables to be defined by probability distributions. The output values are then sampled at random from the input probability distributions. Each set of samples is an iteration, and many iterations are performed, resulting in output distributions and statistics. The tradespace of contract outcomes is then evaluated against utilities such as cost, profit, and risk. Although the factors affecting the contracting environment are complex, and not all are modeled, quantitative modeling allows the architect to roughly evaluate different approaches, vice just basing the contract on past models. It also gives the government the ability to check whether shipbuilder furnished predicted costs are reasonable for a given contract structure.

Naval Engineer

Master of Engineering and Management

Hydrophobic Coatings for Film Boiling Based Drag Reduction on a Torpedo Model

LT Ian Campbell, USN

Prof. Jacopo Buongiorno	**Dr. Thomas McKrell**
Thesis Supervisor	Thesis Advisor

Drag reduction for ships, submarines and other types of marine vehicles has been a focus of study for centuries and continues to be an important area of research today. Two of the most obvious benefits of drag reduction are increased speed and decreased fuel consumption. Many techniques for reducing drag exist, and some are more effective than others. One such technique is to establish and maintain a vapor layer around the object as it moves through the water.

Previous research has shown that porous, hydrophobic surfaces exhibit a dramatic reduction in critical heat flux (CHF), the heat flux required to transition from nucleate boiling to film boiling. Film boiling is characterized by the presence of a vapor layer which remains as long as the surface temperature remains above the Leidenfrost point. This vapor layer has poor heat transfer characteristics but has the potential to reduce drag by acting as a barrier between the solid surface and the liquid.

The goals of this research are to quantify the drag reduction due to film boiling, examine the durability of the hydrophobic coating and explore the feasibility of this concept for torpedo drag reduction. A torpedo was chosen due to its high speed and reduced emphasis on durability, since it is only used operationally once. A hydrophobic coating was created in the laboratory using a layer-by-layer (LBL) process and its performance was compared to a commercial hydrophobic coating. Drop tests of coated and uncoated torpedo models were conducted in a custom-built apparatus housing a water column and recorded with a high-speed video camera in order to measure velocity. Terminal velocity was extrapolated from instantaneous velocity measurements and used to calculate a drag coefficient for each model.

Naval Engineer

Master of Science in Mechanical Engineering

Characterizing Ash and Substrate Properties in Sintered Metal Fiber Diesel Particulate Filters using an Advanced Diagnostic Approach

LT Paul Folino, USCG

Dr. Victor Wong
Thesis Supervisor

In order to comply with strict air emissions regulations, applicable diesel engines are required to have an installed after-treatment device. A diesel particulate filter (DPF) is one of these after-treatment devices, and it is used to capture hazardous particulate matter (PM) from the engine exhaust stream. Over the lifetime of the DPF, incombustible materials such as lubricant-derived ash are deposited within the DPF. The presence of ash restricts the exhaust flow and thus causes an increase in the pressure drop across the filter. This increase in pressure drop due to ash accumulation has an adverse effect on engine performance, primarily a reduction in fuel economy.

The global effects of ash on engine performance are well researched and understood, however, the fundamental mechanisms of ash accumulation in the DPF require further understanding. Experimental data mainly addresses how ash reduces filter porosity and influences pressure drop across the filter, but an investigation of these properties reveals how other key sub-parameters, such as ash particle size and distribution and filter oxidation level, significantly contribute to an increase in pressure drop as well.

The focus of this work is to understand the behavior of ash particles in a sintered metal fiber (SMF) filter substrate and recognize the resultant effect on DPF pressure drop using an advanced diagnostic approach. Much of the work relies on the use of sophisticated imaging and software tools as well as basic computational fluid dynamics (CFD) simulations to quantify properties such as particle size, particle distribution, filter porosity, and pressure drop among others. Additionally, this research introduces and demonstrates the capabilities of these cutting-edge tools and how they can best be utilized to provide filter performance data to qualify existing and future experimental data for SMF or cordierite filters. An analysis of the data reveals a statistically significant dependence between pressure drop and the aforementioned sub-parameters.

Master of Science in Naval Architecture & Marine Engineering

Master of Science in Mechanical Engineering

Model Testing and Simulation Validation of High Speed Planing Hull

LT Matthew Williams, USN

Prof. Stefano Brizzolara	**Patrick Hale**
Thesis Supervisor	Thesis Reader

As part of a previous MIT thesis, a high-speed planing hull was designed with a cambered planing surface using methods established by Clement (Faison, 2014). Additionally, a cambered surface was designed using an in-house lifting surface program. The planing hull was stepped in a way to provide complete ventilation of the underhull aft of the step, with aft support provided by a set of supercavitating hydrofoils.

A model was constructed and subjected to a series of tests at the US Naval Academy hydrodynamics laboratory. Data was accumulated and analyzed by the author. Part of the analysis included statistical half and full factorial experimental designs to understand the physical parameters involved in model dynamic instabilities, and those parameters contributing the most to model drag. Additionally, computational fluid dynamic simulations were prepared and compared to physical testing data to establish a validation baseline with which to use CFD to aid in future model design.

Naval Engineer

Master of Science in Engineering and Management

Nondestructive Evaluation of Composite Rods Using Ultrasonic Wave Propagation

LT Vanea R. Pharr, USN

Prof. James H. Williams, Jr.
Thesis Supervisor

Nondestructive Evaluation (NDE) is a branch of applied science that is concerned with assessing the properties and serviceability of materials and structures without causing collateral damage or depreciation. This study presents a detailed analysis of advanced composite rods (comprised of two or more distinct axial sections of different materials) using theoretical ultrasonic NDE. In anticipation of the high elastic moduli of the rods (relative to many metals) along their longitudinal axes, a one-dimensional wave propagation analysis will be conducted. By analyzing the propagation of ultrasonic waves in non-dispersive media and the corresponding reflections and transmissions at structural interfaces, assessments of interfacial de-bonding will be explored and the presence of anomalous materials can be demonstrated. The resulting graphical presentations will be compiled and should provide the basis for easy material characterizations and assessments of structural integrity throughout the rods.

Naval Engineer

Master of Science in Mechanical Engineering

Effect of Inverted Bow on the Hydrodynamic Performance of Navy Combatant Hull Forms

LT Jeffrey White, USN

Prof. Stefano Brizzolara
Thesis Supervisor

The U.S. Navy is building a new surface combatant that has an unconventional inverted bow. Very little technical data has been published on the seakeeping effects of inverted bows, especially for military applications. Following the analogy of a ship as a classical damped spring-mass system, the inverted bow serves to soften the spring constant and reduce vertical accelerations. However, in the available literature the inverted bow is often accompanied by a tumblehome hull shape, leaving the source of any improvements unclear. In this study we isolate the effect of the inverted bow by experimentally and numerically comparing the motions of an existing combatant hull, the Oliver Hazard Perry class frigate (FFG-7), with a modified version of the same hull with an inverted bow. The bow of the FFG-7 was redesigned in the MIT-iShip lab by developing a set of basic curves that define the parametric surface of the new shape. The forward 30% of the hull is elongated with a very fine entry, extremely narrow V-shaped sections below the waterline and inverted flare and stem profile above the waterline. Two 1/80th scale models were built, one of the original and one of the inverted bow frigate, with the same material, machining and finishing standards. To ensure a meaningful comparison the displacement, draft and waterline length were held constant between models. Each model was dynamically ballasted to achieve a longitudinal radius of gyration equal 25% LBP. Model tests were conducted in the United States Naval Academy Hydromechanics Laboratory for resistance in calm water and seakeeping in both regular waves and irregular head seas. From the calm water tests a comparative performance prediction revealed that the inverted bow exhibited lower resistance across a range of speeds relevant to naval operations. Regular wave tests were conducted to experimentally determine the linear ship motion transfer functions for both models. The differences between the FFG-7 and the inverted bow responses are characterized in terms of the pitch, heave and bow acceleration transfer functions. Irregular head seas tests were conducted with both models in a side-by-side configuration, a novel approach to comparative seakeeping tests. This configuration allowed for a consistent time domain analysis of the non-linear responses. A numerical verification and experimental validation of the seakeeping code Aegir was conducted using the inverted bow.

Naval Engineer

Master of Science in Ocean Engineering

Utilization of Vibration Assessment during Rotor Spin-down to determine the Mechanical Health of Rotating Machines

LT Ryan Zachar, USN

Prof. Steven Leeb	**Patrick Hale**
Thesis Supervisor	Thesis Reader

Vibration analysis is a common method to assess the mechanical health of a machine and its associated hardware. Rotating machines such as engines and generators need to be properly balanced in order to function correctly, and excessive vibration can be an indicator of an abnormality. In certain applications the machines may also have special vibration arresting mounts to reduce noise levels. The US Navy's fleet of Mine Countermeasures Ships (MCMs) employ special mounts for their Ship Service Diesel Generators (SSDGs) in order to minimize the radiated noise from the SSDG to the hull and water. Vibration readings are currently taken above and below the mount periodically to try and determine the condition of the mount, however since the measurements are infrequent the condition is often not known until failure. This project seeks to develop a method for continuous monitoring by recording the generator's vibration only during spin-down. Rotor speed, which is derived by measuring the back EMF off of the generator phase lines, is combined with vibration to create a Frequency Response Function (FRF) for each spin-down which visualizes vibration levels at individual frequencies. These FRFs can be compared to a baseline to determine the relative health of the machine and its mounts. Each FRF features a resonant peak which changes in frequency and amplitude as the mount condition degrades or an imbalance develops. A test rig consisting of two motors coupled together to simulate a generator set was constructed in the Laboratory for Electromagnetic and Electronic Systems (LEES) in order to test the underlying theory that the vibrations in the FRF corresponded to levels obtained at actual frequencies during controlled tests. Tests were also conducted on in-service SSDGs aboard the USS CHAMPION during in-port and underway periods, with FRFs constructed for each spin-down. Results from these tests as well as experiments on other larger and smaller machines are presented.

Naval Engineer

Master of Science in Engineering and Management

Ash Impacts on Gasoline Particulate Filter Performance and Service Life

LT Nicholas Custer, USCG

Dr. Victor Wong
Thesis Supervisor

The increasing use of gasoline direct injection (GDI) engines, coupled with the implementation of more stringent particulate matter (PM) emissions regulations, requires new emissions control strategies for light-duty gasoline vehicles. Gasoline particulate filters (GPF) present one approach to reduce PM emissions below required levels. GPFs are proven effective at removing PM emissions from the exhaust stream, but they do create a backpressure on the exhaust system that reduces engine performance and fuel efficiency. Over the service life of the filter the accumulation of incombustible ash leads to a gradual increase in exhaust backpressure and reduction in engine efficiency.

This study utilized an accelerated aging system to study the impacts of lubricant derived ash, which is the leading source of ash in engine exhaust, on GPF performance over the filter's full service life. GPF samples were aged in the laboratory using a gasoline burner to generate a simulated exhaust stream. Lubricant oil was injected into the burner system to create elevated lubricant derived ash levels in the exhaust stream. GPFs were aged to a series of loading levels representing various stages of the filter life up to 150,000 miles.

The impact of ash deposits on the pressure drop sensitivity to soot accumulation was investigated at specific ash levels. The impact of ash deposits on three-way catalyst coating within the GPF was also studied by utilizing core samples on a reactor flow bench. Catalyst light off was determined through progressive temperature ramp experiments. The results highlight the importance of understanding ash impacts on the flow and catalyst performance of GPFs over the full useful life of the filter.

Master of Science in Mechanical Engineering

Naval Architecture and Marine Engineering

A Parametric Modelling Tool For High Speed Displacement Monohulls

LTJG Mert Timur, TN

Prof. Stefano Brizzolara
Thesis Supervisor

In ship design projects, it is of utmost importance to investigate a wide range of options during the concept design phase in order to determine which best suits to the requirements. Although, keeping the concept design phase shorter in order to be competitive in the market is as important. The chances for a shipyard to be awarded with a contract would surely increase with the number of its design alternatives with detailed evaluations. However, the number of the design alternatives is inversely proportional to the time span of concept design for each alternative. The detailed evaluations at this stage can only be performed with CFD (Computational Fluid Dynamics) and FE (Finite Element) tools, and both require a complete representation of the ship hull geometry. So, only having a faster hull form generation tool would enable the designer to evaluate more options.

It is possible to achieve rapid geometry generation through fully parametric modeling. Fully parametric hull modeling is the practice of creating the entire hull shape definition only from form parameters, without the need for offset data or predefined lines plan. In this thesis a fully parametric modeling tool, PHull, is developed using Java programming language for rapid geometry generation of high speed displacement monohulls, in order to be used in hydrodynamic optimization process. The results from the validation cases, FFG-7 and ATHENA Model 5365, are presented.

Master of Science in Naval Architecture and Marine Engineering

Hydrodynamic Performance of the Offshore Floating Nuclear Plant

LT Matthew Strother, USN

Prof. Jacopo Buongiorno	**Prof. Paul Sclavounos**	**Mr. Patrick Hale**
Thesis Supervisor	Thesis Reader	Thesis Reader

Nuclear power has the potential to produce electricity cheaply and cleanly throughout the world. However, it has several drawbacks, including large construction costs and susceptibility to natural disasters. The Offshore Floating Nuclear Plant (OFNP) overcomes these drawbacks by placing the plant safely a few miles offshore, removing the need for ground preparation and the dangers posed by earthquakes and tsunamis.

This project ensures the OFNP platforms are able to survive and operate safely in the ocean environment, even under the worst of conditions. Using WAMIT and Orcaflex, the hydrostatic characteristics and hydrodynamic performance of the two major OFNP models are evaluated. The platforms were exposed to monochromatic waves of a wide range of frequencies, and to ocean spectra simulating 100 year storms in both the Gulf of Mexico and the North Sea. The performance of the platforms were evaluated against standards first to ensure that the platform could safely weather the storms, and second to begin gaining an understanding of under what conditions the nuclear plant on the OFNP may continue to operate and under what conditions it should be shut down. Lastly the project designs a mooring system to ensure the OFNP will remain in place during 100 year storms, while minimizing capital and maintenance costs of the mooring system.

Naval Engineer

Master of Science in Engineering and Management

The Effect of Vertical Towed Array Orientation on the 3D Acoustic Picture for Sound Sources and Ambient Noise Fields

LT Arthur Anderson, USN

Prof. Henrik Schmidt	**Prof. John Leonard**	**Prof. Franz Hover**	**Dr. Michael Benjamin**
Thesis Supervisor	Committee Member	Committee Member	Committee Member

This research looks at towed-array data from an autonomous underwater vehicle (AUV) in a virtual environment to develop a 3-dimensional acoustic picture, which is the measured noise field in both the azimuthal and vertical direction. In this research a “yoyo” maneuver is used in which the vehicle moves up and down in the water column, as opposed to previous experiments where the AUV is kept at constant depth. The inspiration for this experiment is the upcoming ICEX planned for the Spring of 2016, in which the 3D acoustic picture produced by a Bluefin-21 with the DURIP towed array will be used in the array processing to gain insights into the Arctic environment for target tracking, seabed mapping using anthropomorphic ice cracking noise, passive target ranging, and the feasibility of using AUV's for persistent ice-edge surveillance. This thesis presents a method for quantifying and measuring the verticalness of an array for any maneuvers, conducts a number of virtual experiments to quantify the resolution of the picture, and draws general relationships between an array “vertical score" and the quality of a 3-dimensional acoustic noise pattern.

The verticalness of an array is measured by an inverse sine relationship, while the vertical score is calculated using an impulse response function, which tracks total verticalness over time. The vertical score is then tracked over a number of different experiments, and compared against the 3D noise field produced by an iterative algorithm that de-convolves the noise field from the beam response patterns for each run. The results conclude that within the vehicle maneuvering limits of the Bluefin-21, a fully pitched yoyo pattern vs. a constant depth pattern results in a relative increase in the maximum beam response of a source by approximately 8 dB, and also decreases the 3-dB down bandwidth in the vertical direction by approximately 16° without any significant losses for the bandwidth in the horizontal direction. This increase in vertical resolution allows measurements on range using simplified ray tracing calculations. When attempting to use a towed array to characterize a horizontally isotropic noise field, the results show that within the vehicle maneuvering limits of a towed array, the beam response patterns are not sufficient to produce an accurate acoustic picture, and that a vertical array is the most appropriate for measuring these types of noise fields.

Doctor of Philosophy in Mechanical Engineering

Evaluation by Simulation of an Acoustic Array Composed of Multiple Autonomous Vehicles

LT Kerry Bosché, USN

Prof. Henrik Schmidt
Thesis Supervisor

Ship-deployable (towed) arrays have been integral to Navy combatant operations for many decades. The continual advancement of towed array technology has been continually driven by the need for high sensitivity, low self-noise, and response across a wide range of frequencies. Robotic autonomy, as applied to acoustic sensors, is currently operationally limited to deployment of traditional arrays from semi-submersible tow vehicles. While such a configuration facilitates flexibility in array placement and a measure of stealth, it is an intermediate step toward fully-submerged, autonomous arrays.

In contrast to a traditional hard-wired acoustic array, a "virtual" array consists of multiple, untethered, hydrophone-equipped autonomous underwater vehicles (AUVs) sharing navigation data over an optical or acoustic connection. Due to the flexibility of its physical configuration, a virtual array can be both steered in angle and tuned (via element spacing) to optimize frequency response.

This research explores the performance of a simple acoustic underwater virtual array (AUVA). Basic software for controlling an AUVA is implemented and evaluated using computer simulation of array navigation. Simulation of a narrowband, beamforming sonar is used to assess AUVA performance under the control scheme. This research provides a basis for expanding the use of autonomous vehicles for acoustic sensing.

Naval Engineer

Master of Science in Mechanical Engineering

Design of a Dynaplane Stepped Planning Boat

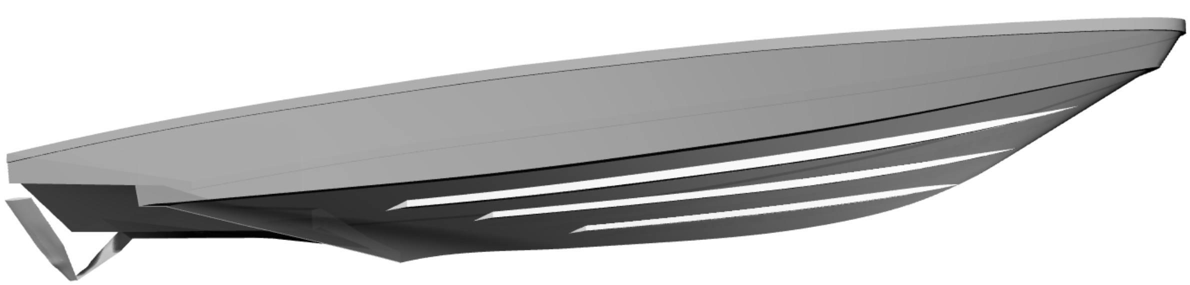
Lt(N) Calley Gray, RCN

Prof. Stefano Brizzolara
Thesis Supervisor

With emerging applications for high speed boats in commercial, military and off shore industries, there is a focus in the naval architecture community to improve the efficiency and performance characteristics of planing hulls. In the 1960's, Eugene Clement showed that considerable reductions in resistance at high speeds can be obtained by converting a conventional planing hull to a Dynaplane stepped planing hull. This refers to a hull configuration where the majority of lift is provided by a swept back cambered surface, while the remainder of the lift is provided by an aft lifting surface that also provides trim control and stability. The after-body is fully ventilated by use of a V-shaped step positioned at the trailing edge of the cambered surface. Clement’s semi-empirical conversion method was based off tests performed at the David Taylor Model Basin and is limited to boats with a deadrise of less than 15 degrees. Since the publication of his paper, advancements in CFD programs have made it possible to conduct accurate simulations of planing hulls with complex geometry, allowing for further development of Clement`s method. This thesis expands Clement`s method to high dead rise by applying it to a notional version of the Mark V Special Operations Craft used by the United States Navy with a design speed of 55kts. CFD Simulations with fixed trim were run in order to refine the cambered surface, design the step and after-body, to position the hydrofoil and to test the low speed performance of the interceptor. Once the hull design was finalized, simulations with two degrees of freedom were run to assess the dynamic stability of the hull. Through simulations, it was found that the configuration is dynamically stable and is able to reduce hull resistance at design speed by as much as 54% when compared with that of the original hull.

Master of Science in Mechanical Engineering

Naval Architecture and Marine Engineering



Turbulence Models for the Numerical Prediction of Transitional Flows with RANSE

LTJG Mert Gokdepe, TN

Prof. Stefano Brizzolara
Thesis Supervisor

Research on turbulence modelling has extensively increased of importance over the years and it is now considered one of the most important aspects to get the accurate computation of high Reynolds number flows with Reynolds Averaged Navier-Stokes Equations (RANSE) solvers. In naval architecture turbulence models are necessary to solve typical hydrodynamic problems both in model scale, where Re=O(10^6), and in full scale, typically Re=O(10^8), since direct numerical simulations are not possible in these cases. This thesis aims to study the performance of different turbulence models for the prediction of the laminar-turbulent transitional flow in the boundary layer of streamlined bodies of interest in naval architecture: starting with a systematic study on a flat plate and arriving to transitional flow airfoils like the NACA 65-213. The RANSE solver is built on the libraries of OpenFOAM(Open Field Operation and Manipulation) which is a free, open source CFD program which enables a large group of users such as engineers, scientists, academics and commerical organizations to solve broad range of problems including complex fluid flows, solid dynamics and electromagnetics. Turbulence models considered range from one equation models such Spalart-Allmaras, two-equation models such as k-epsilon, k-omegaSST, three-equation model kkl-omega as RANS solvers, LES solvers and DES Solvers. The validation of OpenFoam based solver and the different turbulence models is made on the prediction of the friction and pressure drag components as well as lift predictions and in particular on the capability of the turbulent models to capture the transition between laminar and turbulent regime. Four different turbulence models are used in this scope: k-epsilon, k-omegaSST, Spalart-Allmaras and kkl-omega in conjunction with different wall functions. The kkl-omega t.m. is one of the newest transition models and it was developed to superior to the other models since it provides the transition region information. Its current implementation in OpenFOAM significantly underestimates the skin friction and the onset of the transition point. We propose a series of modifications we implemented on model equations and empirical parameters to improve the accuracy of predictions of the frictional drag component of transitional flows of interest in naval architecture.

Master of Science in Mechanical Engineering

Naval Architecture and Marine Engineering

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