Naval Construction and Engineering
Ship Design and Technology Symposium

Wednesday, May 1, 2013

MIT Faculty Club, 50 Memorial Drive, Building E52-Sixth Floor

0800 - 0900	Registration and continental breakfast
0900 - 0920	Welcome and Opening Remarks - CAPT Mark Thomas, Curriculum Officer - Prof. Mary Boyce, Head, Department of Mechanical Engineering - Prof. Michael Triantafyllou, Director, Center for Ocean Engineering - Prof. John Leonard, Area Head, Ocean Science and Engineering
0920 - 1020	Student Design Project Briefs - T-AKE Modified Repeat to Canadian JSS LCDR Douglas Jonart, LT Leon Faison, Lt(N) Stephen Normore - Structural Feasibility of a DDG51 Flight IIA Conversion to D0 Ice Capability LT Aaron Dobson, LT Mark Ewachiw, LT Kyle Woerner - CSV Common Support Vessel and Submarine Tender Variant LCDR Bart Sievenpiper, LCDR Carl Bodin, LT Travis Anderson
1020 - 1035	Break and Poster Sessions (featuring student theses and projects)
1035 - 1105	Student Design Project Brief - MCS(X) Mine Countermeasures Support Ship LCDR Joe Meier, LT Arthur Anderson
1105 - 1200	Research Briefs - Prof. Alex Slocum LCDR Brian Heberley - Prof. Chrys Chryssostomidis LT Ben Sanfiorenzo
1200 - 1220	Break and Poster Sessions (featuring student theses and projects)
1220 - 1315	**Lunch Buffet and Keynote Address** **Vice Admiral Kevin McCoy, Commander, Naval Sea Systems Command**
1315 - 1445	Research Briefs - Prof. Tomasz Wierzbicki LCDR Joe Meier, CDR Andy Gish - Prof. Franz Hover - Prof. Steven Leeb LT Katie Gerhard, LT Travis Anderson, LCDR Bart Sievenpiper
1445 - 1500	Break and Poster Sessions (featuring student theses and projects)
1500 - 1600	Student Design Projects - AFSB(X) Afloat Forward Staging Base LT Katie Gerhard, LT Michael Bahr, LT Ben Sanfiorenzo - HaF "Half a Frigate" LT Dom Alvarran, LTJG Kostas Nestoras
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 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.

Vice Admiral Kevin M. McCoy

Commander, Naval Sea Systems Command

A native of Long Island, N.Y., Vice Admiral McCoy graduated from the State University of New York at Stony Brook in 1978, with a Bachelor of Science Degree in Mechanical Engineering.

At sea, McCoy served aboard USS Daniel Webster (SSBN 626) and as repair officer aboard USS L. Y. Spear (AS 36). In these assignments he earned his submarine engineering duty qualification and his surface warfare qualification. He was also awarded the Claud A. Jones Award from the American Society of Naval Engineers as "Fleet Engineer of the Year" during his tour onboard L. Y. Spear.

Ashore, McCoy served in numerous assignments in the Naval Shipyards, including assignment to Mare Island, Charleston, Norfolk, Puget Sound and Portsmouth Naval Shipyards. From 2001-2004, he served as the 80th commander of Portsmouth Naval Shipyard. McCoy earned a master's degree in Mechanical Engineering and an engineer's degree in Naval Engineering from the Massachusetts Institute of Technology. He also earned a Masters in Business Administration Degree from Emory University.

Upon selection to flag rank, McCoy served as assistant deputy commander of Industrial Operations of the Naval Sea Systems Command from 2004-2005. From 2005-2008, he served as the Naval Sea Systems Command’s chief engineer. In June 2008, he was confirmed by the U.S. Senate for promotion to the rank of vice admiral and was assigned as the 42nd Commander, Naval Sea Systems Command.

Mary C. Boyce

Ford Professor of Mechanical Engineering
Head of Department

Professor Mary C. Boyce is the Ford Professor of Engineering and Department Head of Mechanical Engineering at the Massachusetts Institute of Technology. Professor Boyce earned her B.S. degree in Engineering Science and Mechanics from Virginia Tech; and her S.M. and Ph.D. degrees in Mechanical Engineering from the Massachusetts Institute of Technology. She joined the M.I.T. faculty in 1987. Professor Boyce teaches in the areas of mechanics and materials. Her research areas focus primarily on the mechanics of elastomers, polymers, polymeric-based micro- and nano-composite materials, lattice- structured materials, natural materials, and biological macromolecular networks, with emphasis on identifying connections among microstructure, deformation mechanisms, and mechanical properties. She has published over 100 journal papers in the field of mechanics and materials; and has mentored 36 SM Thesis students and 20 PhD students. Professor Boyce has been the recipient of several awards and honors recognizing her research and teaching efforts, including the MIT MacVicar Faculty Fellow, the Department of Mechanical Engineering Keenan Award for Teaching, the Spira Award for Teaching, the NSF Presidential Young Investigator Award, the ASME Applied Mechanics Young Investigator Award, Member-at-Large of the USNCTAM, Chair of the ASME Applied Mechanics Division, Fellow of the American Academy of Mechanics, Fellow of the ASME, Fellow of the American Academy of Arts and Sciences, and Member of the National Academy of Engineering.

Michael S. Triantafyllou

William I. Koch Professor of Marine Technology,
Director of the Center for Ocean 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.S. Triantafyllou, D.K.P. Yue, 2000, "Hydrodynamics of Fish Swimming", *Annual Review of Fluid Mechanics*, 32, 33-53. J.C. Liao, D.N. Beal, G.V. Lauder, & M.S. Triantafyllou, 2003, "Fish exploiting vortices use less muscle", *Science*, 302 (5650), 1461-1608, November 28, 2003.

Prof. Triantafyllou is a member of the Society of Naval Architects & Marine Engineers, the American Physical Society, the American Society of Mechanical Engineers, and the Intern. Society for Offshore & Polar Engineers. Honors and Awards include: William I Koch Professorhip in Marine Technology (since 2008), Cover of *Science* (2003), RoboTuna on permanent exhibit at the Museum of Science, London (since 1998); prototype *RoboTuna* in national traveling exhibit on robots, Science Museum of Minnesota (2003-2004). 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).

John Leonard

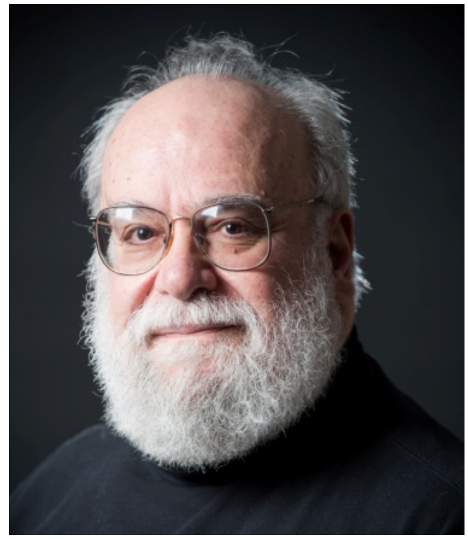
Professor of Mechanical and Ocean Engineering

Professor John Leonard is a member of the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL). His research addresses the problems of navigation and mapping for autonomous mobile robots. He holds the degrees of B.S.E.E. in Electrical Engineering and Science from the University of Pennsylvania (1987) and D.Phil. in Engineering Science from the University of Oxford (formally 1994). He studied at Oxford under a Thouron Fellowship and Research Assistantship funded by the ESPRIT program of the European Community.

Prof. Leonard joined the MIT faculty in 1996, after five years as a Post-Doctoral Fellow and Research Scientist in the MIT Sea Grant Autonomous Underwater Vehicle (AUV) Laboratory. He has participated in numerous field deployments of AUVs, including under-ice operations in the Arctic and several major experiments in the Mediterranean. He has served an associate editor of the IEEE *Journal of Oceanic Engineering* and of the IEEE *Transactions on Robotics and Automation*. He is the recipient of an NSF Career Award (1998), an E.T.S. Walton Visitor Award from Science Foundation Ireland (2004), and the King-Sun Fu Memorial Best Transactions on Robotics Paper Award (2006).

Chryssostomos Chryssostomidis

Doherty Professor of Ocean Science and Engineering
Professor of Mechanical and Ocean Engineering



Educated at MIT and at the University of Newcastle-upon-Tyne in naval architecture, Professor Chryssostomidis was appointed to the MIT faculty in 1970 and became a full professor in the Department of Ocean Engineering in 1982. That same year he was appointed director of the MIT Sea Grant College Program where in 1989 he established the MIT Sea Grant Autonomous Underwater Vehicles (AUV) Laboratory to develop technology and systems for advanced autonomous surface and underwater vehicles. He served as Department Head of the department of Ocean Engineering where he established the Ocean Engineering Teaching Laboratory from 1994 to 2002. He has been director of the MIT Ocean Engineering Department Design Laboratory since its inception in the early 1970s. In 2003, with MIT Sea Grant staff, he created the Sea Perch Program, funded by the Office of Naval Research. The Sea Perch program trains educators across the United States and around the world to build a simple, remotely operated underwater vehicle, or ROV, made from PVC pipe and other inexpensive, easily available materials.

Professor Chryssostomidis has received a number of acknowledgments of outstanding contributions to his field. Among them is his appointment as Naval Sea Systems Research Professor from l985 through l987. Prior to that in l975 and l976 he served as Von-Humboldt Scholar at Ruhr University, Bochum, Germany. Since January 1993 he has held a new professorship, the Henry L. and Grace Doherty Professor of Ocean Science and Engineering. In 1994 he was elected as Fellow of the Society of Naval Architects and Marine Engineering. In June 2001 he led the Nisyros, Greece scientific cruise and in August 2001 he was the team leader of the MIT AUV Laboratory expedition to Barati, Italy. He led the AUV Laboratory scientific cruises in Argentario Italy (2002), and Kythira Greece (2004).

His publications display his wide range of interests including design methodology for ships, vortex-induced response of flexible cylinders, underwater vehicle design, design issues in advanced shipbuilding including the all electric ship and T-Craft, conceptual study of a ship for sub-seabed nuclear waste disposal and abyssal ocean option for waste management. He receives research support from the Office of Naval Research, the National Science Foundation, the Naval Sea Systems Command, and the National Oceanic and Atmospheric Administration. Professor Chryssostomidis has served on several National Research Council Advisory committees focusing on shipbuilding and marine issues.

Tomasz Wierzbicki

Professor of Applied Mechanics
Director, Impact and Crashworthiness Laboratory

Professor Tomasz Wierzbicki received his MS degree from the Department of Mechanical Engineering of the Warsaw Technical University. He earned his PhD degree in 1965 from the Institute of Fundamental Technological Research under the supervision of Professor Piotr Perzena of the Polish Academy of Sciences. Soon after that, he went for a one year postdoctoral study at Stanford University and collaborated with Professor E. H. Lee. In 1981, he was promoted to a full professor at the Polish Academy of Sciences and in the same year, he left for the United States, which has become his home.

In 1983, he was appointed as a full professor at MIT, where he is currently directing the Impact and Crashworthiness Lab. He is the author of over 150 papers published in major international journals. In 1986, he received the Alexander von Humboldt senior US scientist award. Professor Wierzbicki spent over three years working in the BMW R&D Department in Munich. He directed a number of large industry oriented programs at MIT with the support of over 50 major automotive, aluminum and shipbuilding companies. Professor Wierzbicki's research and consulting interests are in the area of dynamic plasticity, structural failure, crashworthiness, ultralight material, and more recently ductile fracture. As of August 2007, he became an Associate Editor of the *International Journal of Impact Engineering*.

Franz S. Hover

Finmeccanica Career Development Professor of Engineering
Professor of Mechanical Engineering

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

Professor Hover was a consultant to industry and a Principal Research Engineer at MIT before joining the MechE faculty in 2007. He has broad engineering experience in systems and control, with applications in robotics and fluid mechanics. Professor Hover's current research centers on design methods for complex ocean systems. Autonomous inspection of in-water ships has been a major area of work, driven by security concerns and maintenance necessity, and challenges include poor water quality for cameras, the lack of an absolute navigation reference in the harbor environment, and efficient planning for coverage of large, complex structures such as propellers. Through a long-term industry collaboration, the platform technology has been recently commercialized. Professor Hover's research also addresses design of ocean networks, comprising groups of communicating vehicles as well as fluid and power systems. His group had developed new algorithms for high-quality approximate and relaxed solutions to canonical optimization problems in AC electrical distribution, and in capacity-constrained acoustic communication channels as used underwater. In flow control, Professor Hover has worked closely with offshore industry to develop and commercialize new safety equipment. He is advisor to the MIT Marine Robotics Team and heavily involved in undergraduate research.

Professor Hover has authored or co-authored over forty archival journal papers and fifty refereed conference papers. He has supervised sixteen Master's students and seven Doctoral students, who are undertaking successful careers in research laboratories, industry and academia.

Steven B. Leeb

Professor of Electrical and Mechanical Engineering

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 eighty publications and thirteen US Patents in the fields of electromechanics and power electronics.

Alexander Slocum

Pappalardo Professor of Mechanical Engineering

Alexander Slocum is the Pappalardo Professor of Mechanical Engineering at MIT, a MacVicar Faculty Teaching Fellow, and a Fellow of the ASME. He has seven dozen+ patents and has helped develop 12 products that have received R&D 100 awards for "one of the one hundred best new technical products of the year." Alex was the Massachusetts Professor of the Year in 2000 and is the recipient of the Society of Manufacturing Engineer's Frederick W. Taylor Research Medal, and the ASME Leonardo daVinci and Machine Design Awards.

Alex was instrumental in proposing and supporting with free-on-line analysis tools SEMI E57-1296 Kinematic Coupling Standard for locating 300 mm wafer cassettes. Alex also helped to start several successful companies and has a passion for working with industry to solve real problems and identify fundamental research topics. Alex also served on the DoE Science Team working with Energy Secretary Chu on the Deepwater Horizon Incident where he worked with team members to create new safety devices for deep water hydrocarbon exploration and production.

Alex's current interests focus on the development of precision machines from medical devices and instruments to energy harvesting and storage machines. He is presently involved in three startup companies where he helps develop the fundamental IP and also does detailed design and manufacturing reviews to help ensure machines are designed and built right the first time. He also does design consulting (reviews and detail design and analysis) for several other companies in industries ranging from energy to manufacturing.

Alex is most proud to have received the 1999 Martin Luther King Jr. Leadership Award, and works passionately to help teach people how to discover their creative abilities as a means for personal fulfillment and economic development. Since high school days, Alex has had a passion for furniture making, carpentry, and tinkering and believes hobbies and crafts are keys to the future of k-PhD education. Alex also loves sports from SCUBA to snowboarding to iron-distance triathlons and marathons. Endurance sports provide time during training runs and swims for deep thinking, and the extra blood flow is also good for the brain when not training; and Alex believes sports is a key to addressing many of the behavioral challenges many youth face. *Mens et Manus et Cor* is a credo that can be applied to help us all live better lives.

Captain Mark W. Thomas, USN

Professor of the Practice of Naval Construction and Engineering

Captain Mark Thomas graduated from Oklahoma State University in 1984 with a Bachelor's degree in Electrical Engineering, and received his Navy commission from Officer Candidate School in Newport, RI. Following commissioning, he served aboard *USS David R. Ray* (DD 971) as First Lieutenant, Auxiliary Officer, and Gunnery Officer.

Departing the ship in 1989, he served as Course Director for the DD 963 Engineering Officer of the Watch course in Coronado, CA and later as the Main Propulsion Inspector for gas turbine plants at the Pacific Board of Inspection and Survey (INSURV).

In 1993, he reported to Massachusetts Institute of Technology where he earned a Naval Engineer degree, a Master's degree in Electrical Engineering, and a PhD in Hydrodynamics. Upon graduation, he was assigned to the Supervisor of Shipbuilding, Pascagoula, MS, where he served as Test Officer, Repair Officer and Docking Officer.

Thomas reported to NAVSEA headquarters in 2000 as technical authority and project manager for advanced submarine propulsors. In 2002, he was detailed to the Office of Naval Research as Deputy Project Manager for the X-Craft project (later known as *Sea Fighter* FSF 1), and later assumed duties as the Project Manager, seeing the craft through delivery in 2005. He then reported back to NAVSEA headquarters, serving in the Program Office for LPD-17 (USS San Antonio) as Test and Requirements Officer.

In 2006, CAPT Thomas was selected to command the Carderock Division of the Naval Surface Warfare Center, and served in that capacity for three years. After stepping down in 2009, he returned to NAVSEA as the Technical Director for Surface Ship Design and Systems Engineering, NAVSEA 05DT. During this tour he was privileged to serve as a senior member of RADM Thomas Eccles' team investigating the sinking of the South Korean warship ROKS Cheonan. He reported to MIT in May of 2011 as the Curriculum Officer for the Navy's 2N program.

Captain Thomas' awards include the *Legion of Merit* (three awards), the *Defense Meritorious Service Medal*, the *Navy Meritorious Service Medal* (three awards), and the *Navy Commendation Medal* (two awards). He is a past recipient of the *NAVSEA Outstanding Performance Award* at MIT and the American Society of Naval Engineers *"Jimmie" Hamilton Award* for best original technical paper in the *Naval Engineers Journal*.

Commander Jerod W. Ketcham, USN

Associate Professor of the Practice of Naval Construction and Engineering

Commander Ketcham was commissioned in 1997 and began his naval career as an instructor at the Naval Nuclear Power Training Command where he taught Physics, Electrical Theory and Heat Transfer and Fluid Flow. He completed his Engineering Duty Officer (EDO) qualifications at the Supervisor of Shipbuilding Conversion and Repair (SUSHIP) Groton, CT where he was the lead ship coordinator for the delivery of USS VIRGINIA and USS TEXAS post shakedown availability (PSA). He supported Operation Iraqi Freedom (OIF) as a project officer for the United States Army Corps of Engineers (USACE) Baghdad, Iraq; in this role he assisted in the reconstruction of the Iraqi electrical generation infrastructure. CDR Ketcham completed his graduate studies at the Massachussetts Institute of Technology (MIT) and was assigned to Program Executive Office, Submarines (PEO SUBS) where he served as the Aft Project Officer for the OHIO Replacement design. In this role he led the engineering activities associated with the stern design of OHIO Replacement.

CDR Ketcham holds a Bachelor of Science in Mechanical Engineering from Wichita State University, a Naval Engineer's degree and a Master of Science in Materials Science and Engineering from MIT. He is a member of the Acquisition Professional Community (APC) and a licensed engineer in the state of Massachusetts.

CDR Ketcham's decorations include the *Joint Services Commendation Medal*, *Navy Commendation Medal* (two awards) and other individual and unit awards.

2013 2N Student Projects

T-AKE Modified Repeat to Canadian JSS (Conversion Project)

LCDR Douglas Jonart, USN; LT Leon Faison, USN; Lt(N) Stephen Normore, RCN

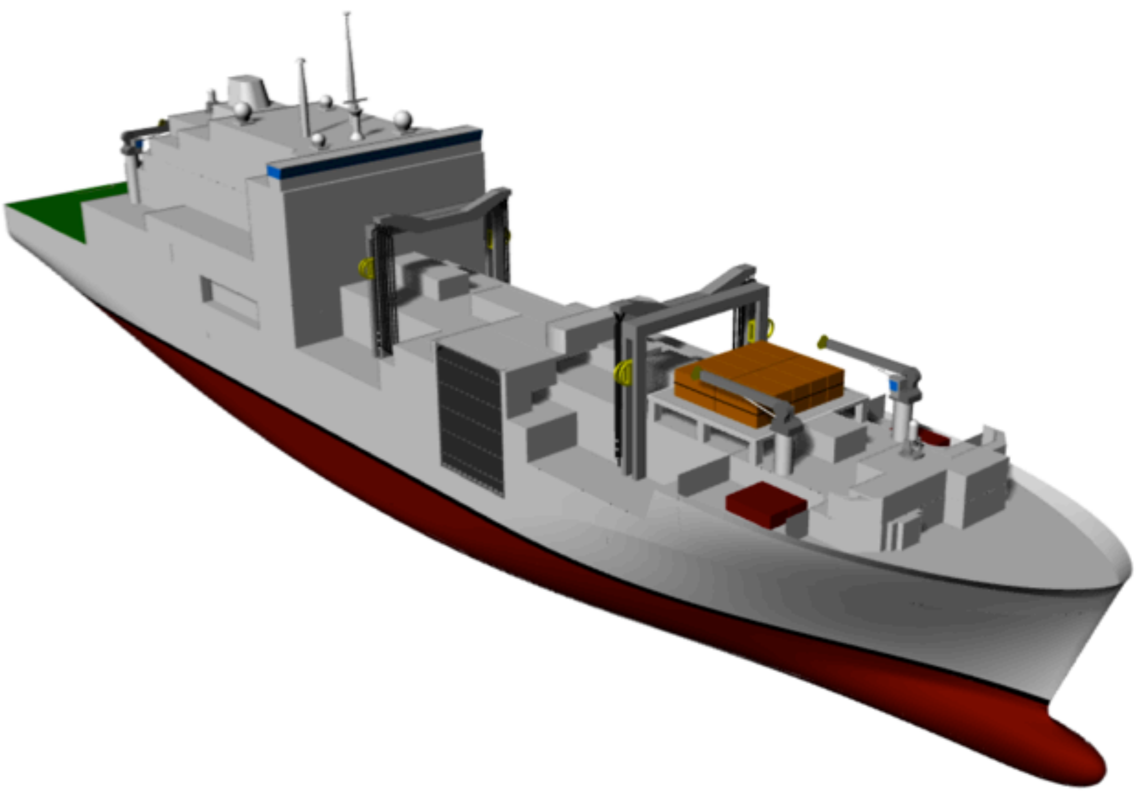
Canada's recently instituted National Shipbuilding Procurement Strategy aims to rebuild their shipbuilding industry while replacing all of the vessels in their fleet over the next three decades. The first vessels in need of replacement are the aging supply ships, the *Protecteur* class. The replacement, called the Joint Supply Ship (JSS), must fill the missions of both a traditional oiler and a dry cargo replenishment ship, as well as provide substantial sealift capability and several forms of task group support. A parametric study to identify an existing hull for modification to fill such diverse mission areas identified the U.S. Navy *Lewis and Clark* Class (T-AKE) as the most desirable candidate.

The T-AKE was built for the U.S. Navy to replenish dry stores and ammunition, supplemented with modest refueling capabilities. In converting the T-AKE design to meet the requirements for the Royal Canadian Navy's JSS, the design provided adequate propulsion and ice capabilities without modification. Aircraft, medical, fuel, and sealift capabilities all required upgrading to meet broader role of the JSS. Replenishment stations were simplified to a more robust and versatile set of 4 dual-purpose stations arranged in commonly supported port and starboard pairs. The hangar was upgraded to store a third helicopter and aviation maintenance facilities were expanded to provide greater fleet support services. Dry cargo areas were converted into fuel tanks deep within the ship and into Ro-Ro sealift on the upper decks. In accordance with MARPOL requirements, all fuel tanks were upgraded to double hull protection standards. Side and stern ramps provided access for Ro-Ro transfer. No existing landing craft were found to match the desires for the JSS, so space and cranes were included in the design to support either a larger craft that well exceeds requirements, like the U.S. Navy LCM-6, or a smaller craft with some capability short of desired levels, such as the LCVP currently in use in Canada.

The final design focused on simplicity and minimum cost, but engineering judgment in several spaces led the team to include more capacity than the minimum. Minimum thresholds were achieved for medical, joint task force headquarters facilities, aviation support, and container capacity. Capacities for ship fuel, cargo fuel, and aviation cargo fuel were all designed above minimum. Total accommodations and internal lane meters were all increased to maximum objective values.

Modifications to the design added 508 tons to the light ship condition. Major structural changes included transverse watertight doors for vehicle decks below the margin line, stern and side ramps for access to the main vehicle deck, and an internal fixed ramp with side-hinged cover to provide access to the lower vehicle deck. The inherent strength, stability, and seakeeping characteristics, as well as available reconfigurable space of the T-AKE allowed for a viable and capable baseline ship for the JSS. The final JSS variant improves upon the capabilities above the threshold requirements for a high return on investment for the Royal Canadian Navy.

Ship Characteristics	
Parameter	**Value**
LBP	210 meters
Beam	32.3 meters
Draft	9.42 meters
Full Load Displacement	42,692 MT
Speed	20 knots
Loads (MT):	
Dry Cargo	1494
Ammunition Cargo	600
Cargo Fuel	7456
Aviation Cargo Fuel	863
Accommodations	345
Internal Lane Meters	1500
Helicopter Hangars	3
Lead Ship Cost	$1,249 M



Structural Feasibility Assessment of a DDG51 Flight IIA Conversion to D0 Ice Capability (Conversion Project)

LT Aaron Dobson, USN; LT Mark Ewachiw, USN; LT Kyle Woerner, USN

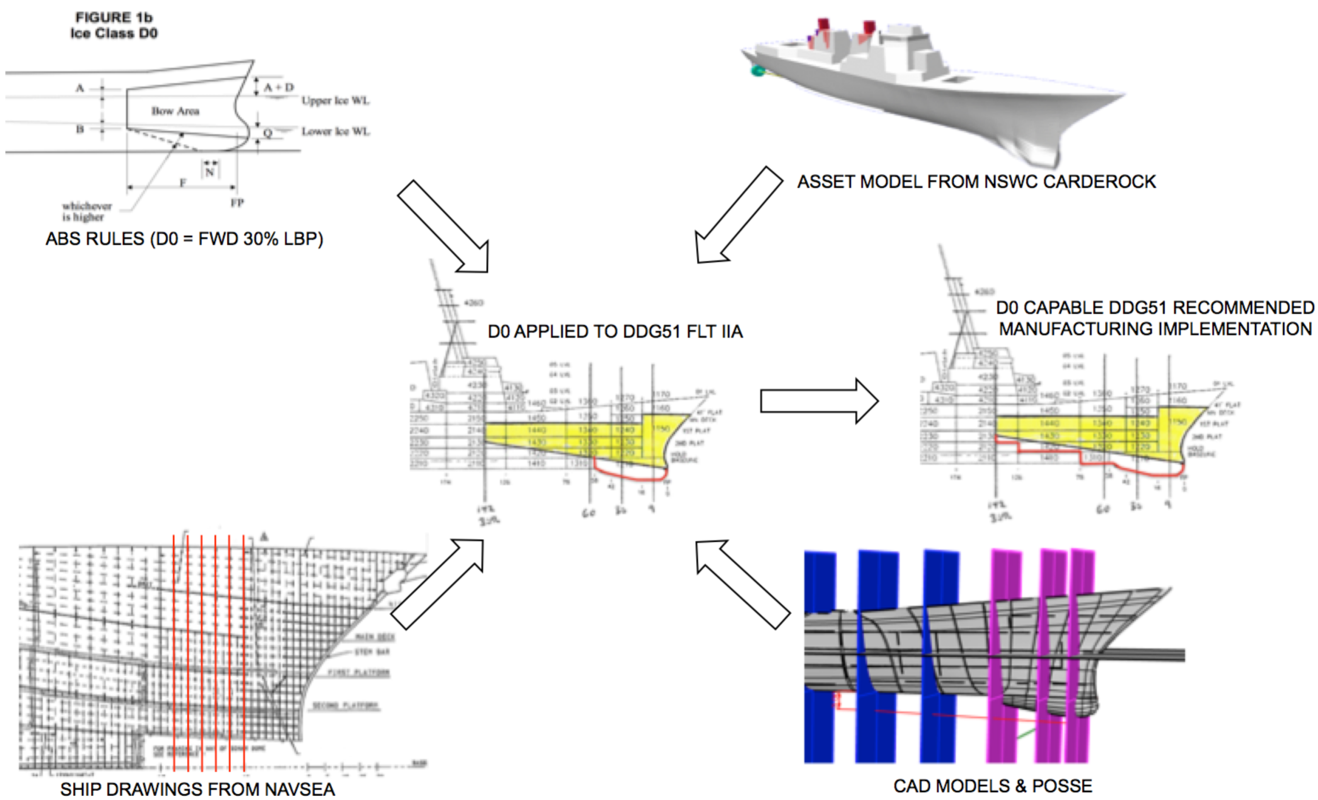
Global attention has increasingly focused on the Arctic as climate change opens more polar areas to navigation for longer periods of time each year. Oil reserves and other natural resources as well as significantly shorter transoceanic shipping routes have transformed the Arctic into a crucial region of heated international competition. While submarines maintain the capability to breach thin layers of ice in the Arctic, few surface combatant vessels possess the capability to transit the Arctic. Using the current DDG51 Flight IIA, this study provided the US Navy with a greater understanding of achievable and affordable ice capability for the selected hull.

The objective of this study was not to redefine the mission, concept of operations (CONOPS), or operational profile of the DDG51 Flight IIA. Rather, the objective was to expand the current capability set of the vessel to support a nominal level of ice capability required for associated Arctic missions. The goal of this study was to determine the minimal amount of change and cost required to make the DDG51 Flight IIA mission capable with D0 Arctic performance, as defined by the American Bureau of Shipping (ABS) Steel Vessel Rules (SVR), Part 6, Chapter 1, Section 5 (Requirements for Vessels Intended for Navigation in First-year Ice).

With the recommended changes, 100% mission capability was not achievable while operating this vessel in the presence of ice because of potential degradation to sonar capability. However mission capability was maximized to the greatest extent possible with available resources. Analysis will be required to determine if the vessel – after structural ice-hardening – is capable of deploying and using its various installed weapon systems and sensors reliably without risking damage and loss of the system altogether. Due to the structural changes of the ship being confined to the forward 30% of the ship, no impact to deployable systems was expected. Non-deployable systems of immediate concern included the flexible rubber sonar dome attached to the bulbous bow and the pitsword used for speed sensing below the keel. While solutions are presented to either increase mission capability or prevent damage to critical mission systems while operating in ice conditions, it was beyond the scope of this study to analyze their ice effects or design for their protection.

The DDG51 Flight IIA remains a versatile multi-mission platform. It is outfitted with an array of weapons, sensors, and armaments that provide for surface, sub-surface, and air warfare missions. Recent enhancements to the platform have added ballistic missile defense capability as well. Again, this study focused entirely on supplying the US Navy with the ability to use the DDG51 Flight IIA to a mission-limited extent in Arctic regions of immediate concern. It was undesirable to attempt to redefine how these vessels are currently deployed. The most likely mission-limiting factor was AN/SQS-53C performance after the addition of ice protection steel plating, though onboard assets such as TACTAS and dipping sonar were assumed to mitigate any performance losses.

The Flight IIA model was modified using ASSET, POSSE, and RHINOCEROS as well as a parametric model in MATLAB to achieve the desired ice capability. A parametric analysis was used in accordance with the guidance of ABS Steel Vessel Rules, Part 6, Chapter 1, Section 5 to determine compliance. Once compliance with ABS rules was achieved, the changes to the DDG ship design were analyzed with a weight-based cost model to determine the anticipated incremental cost to the ship delivery process for the desired ice capability. The end product was a comparison of ice capability to expected cost increase.



Common Support Vessel and Submarine Tender Variant

LT Travis Anderson, USN; LCDR Carl Bodin, USN; LCDR Bart Sievenpiper, USN

The necessary recapitalization of US Navy service support vessels in the coming decades will likely face severe cost restrictions due to the constrained fiscal environment. One possible solution to mitigate the cost of many classes of a few ships is to design a common support vessel (CSV) to function as the design basis for different variants. The CSV envisioned in this study provides a concept design consisting of a basic hull form with an engineering plant and some common ship arrangements complete. This hull form is intended for vessels displacing 17,000 to 27,000 LT and has sufficient arrangeable area to support many variants in a final design process. Variants envisioned for the CSV include a submarine or destroyer/LCS tender, a command ship, a hospital ship, and a humanitarian assistance/disaster relief vessel. Economies of scale can be achieved in material procurement and production by using a common vessel as the basis for several variants. This concept enables the savings normally only realized during long production runs of a single class to be achieved over multiple classes.

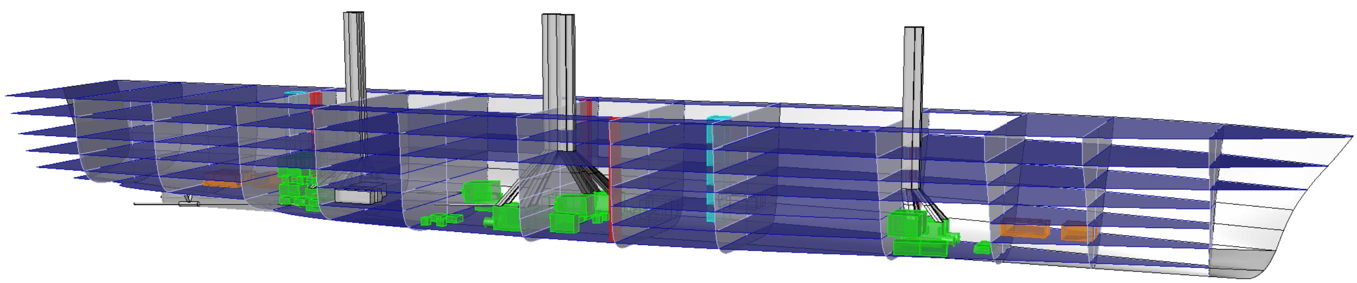
Analyses of intact and damaged stability, seakeeping, and strength were conducted through the entire range of design displacements to ensure the CSV is suitable for serving as a parent to the individual variants. One of the key aspects of these analyses was to find a region of acceptable KGs. A plot of displacement versus limiting KGs then provided a region of safe and feasible designs. Ultimately, this led to a hull that is suitable for many variants without redesign, but is likely to be sub-optimal for most variants.

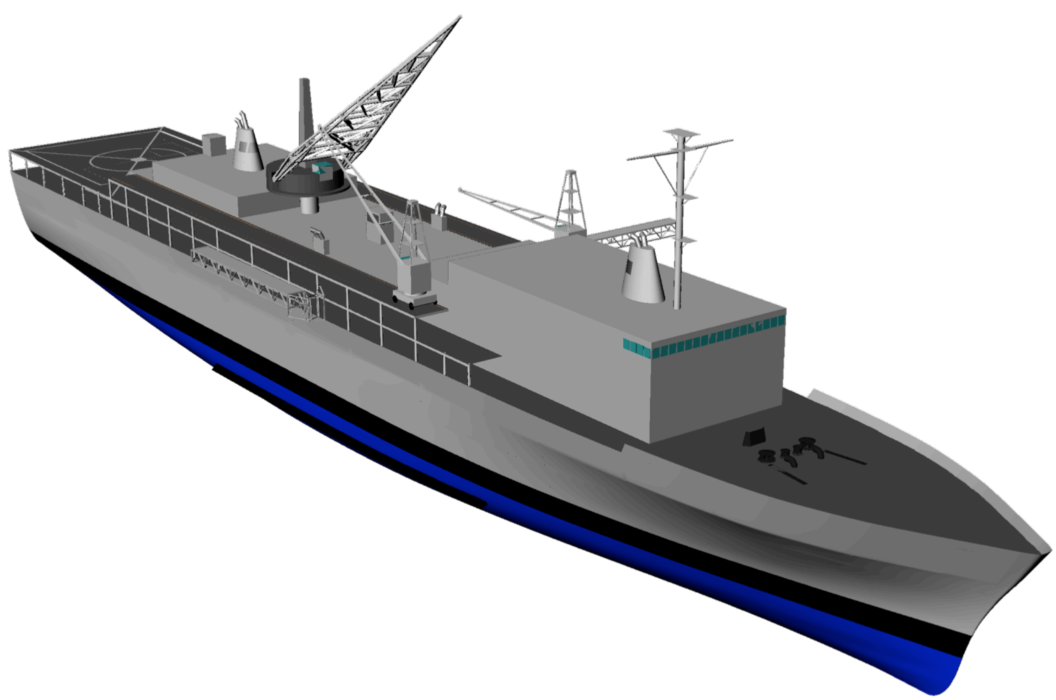
An analysis of requirements was conducted to determine areas of overlap between the proposed AS and LCC variants. For each of the design parameters the most limiting threshold value from the AS or LCC as set as the requirement for the CSV. From the areas of overlap portions of the ship were identified that would remain constant for all ship variants. These portions include engineering spaces, tankage, and areas such as medical and dental facilities and administrative support functions.

A complete variant design of the next generation submarine tender, AS(X), was performed to test the utility of the CSV concept. The AS(X) carries forward the capability of the AS-39 class submarine tenders in performing IMA level work and weapons transfers. Improvements were made to ensure the AS(X) remains fully capable of supporting Virginia-class submarines through Block V. A focus of the design was to provide efficient flow of work pieces and repair parts between various spaces onboard the ship and to the submarine.

The successful design of the AS(X) utilizing the CSV demonstrates the feasibility of this concept. Cost estimates for the tender, found using a weight-based model, are $820M for lead ship and $650M follow ship (FY12 dollars). The true cost benefit for the CSV would be realized when the design is used across multiple variants. This would promote lower construction costs through learning curve gains and lower life cycle costs through use of common components.

CSV Ship Characteristics	
Parameter	**Value**
LBP	592.5 feet
Beam	86.1 feet
Draft	18-27 feet
Depth (Station 10)	58.2 feet
Prismatic Coefficient	0.71
Displacement Range	17,000-27,000 long tons
GM_t/B	0.097
Range	10,000 nm
Maximum Speed	20.9 knots
Sustained Speed	19.5 knots
Accommodations	459-1054
AS(X) Lead Ship Cost	$820M (FY12)
AS(X) Follow Ship Cost	$650M (FY12)





Mine Countermeasures Support Ship MCS(X)

LT Arthur Anderson, USN; LCDR Joseph Meier, USN

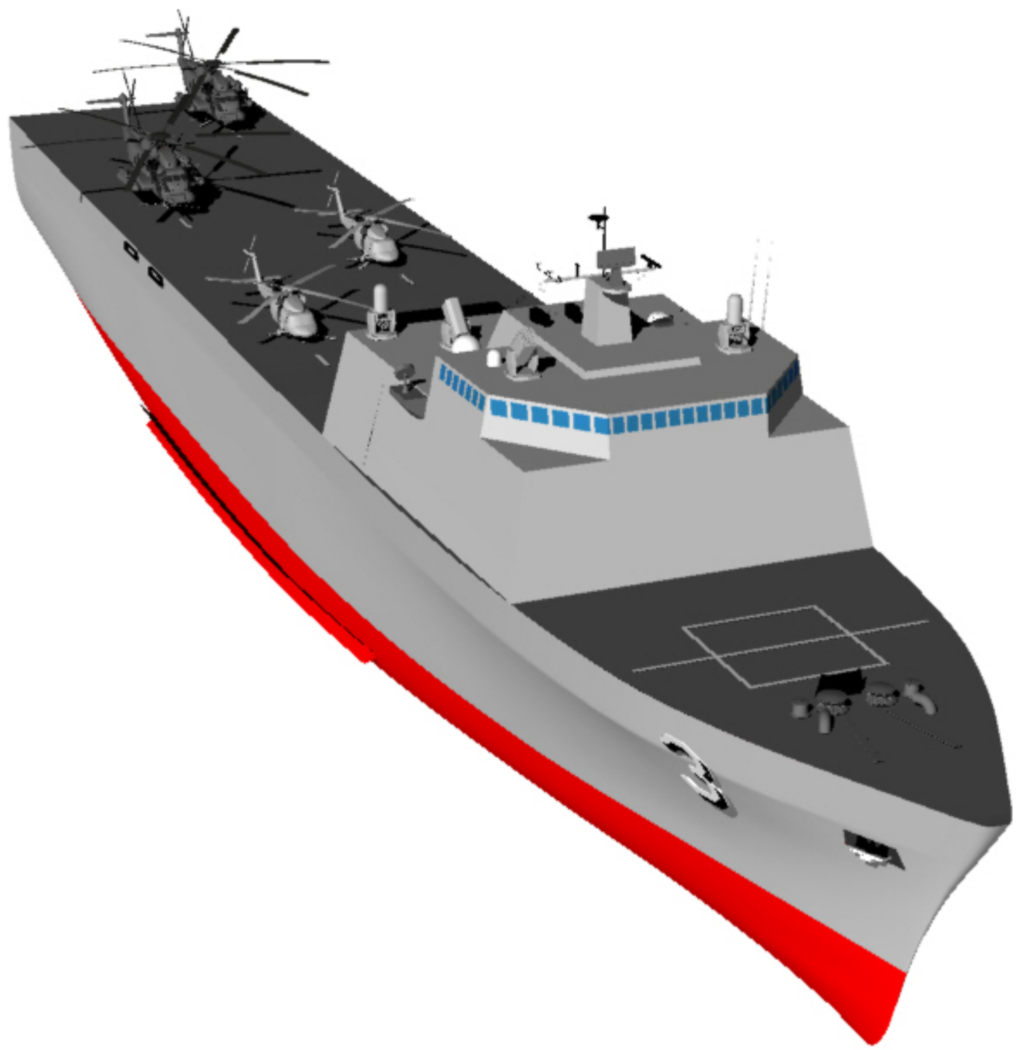
In an effort to maximize the utility of the Littoral Combat Ship (LCS), designers envisioned a ship capable of carrying modular, rapidly re-configurable payloads, which would allow commanders to quickly tailor the LCS to suit a wide range of fleet missions. One of several mission packages planned for the LCS was a Mine Warfare (MIW) suite, considered to be an adequate replacement solution for the aging Avenger Class Mine Countermeasures (MCM) fleet. As a part-time capability, this organic but very limited mine warfare package seemed a reasonable fit for the high speed, high cost LCS; however, now that the Navy is abandoning the idea of rapid ship reconfiguration and adopting a "stay as you are" doctrine for the LCS (Cavas, 2012.), it is easy to question why a 40 knot corvette like the LCS should be permanently relegated to mine sweeping duties – a mission that could be accomplished by a much slower, more economical asset.

While the Navy ponders the optimal (permanent) mission(s) for the LCS (Cavas, 2012.), it is clear that MIW should not be one of them. The LCS is an expensive ship due to her high speed, powerful gun, and state of the art engineering. Assigning such a ship permanent MCM duties would be a poor utilization of those capabilities. In addition, the LCS cannot carry adequate equipment to provide effective MIW services for a sizeable battle force, and cannot carry the MH-53K helicopter; the only asset presently capable of pulling Mk-105 sleds or towed SONARs in all weather conditions.

This project proposes a new design, the Mine Countermeasure Support Ship, MCS(X): a more economical platform capable of providing organic MCM capability to a battle force, such as an Amphibious Ready Group (ARG). The MCS(X) would carry out comprehensive mine search and sweep services, allowing the LCS to conduct other duties requiring her speed and armament. While more expensive per-unit than the LCS, the MCS(X) can carry MIW capability many times over that of the LCS, and can remain organic to the battle force, a capability not provided by the current Avenger Class sweeper ships. Successful MIW tactics continue to be a significant challenge to Navy war planners today; a challenge MCS(X) can meet.

This concept design illustrates how a relatively simple yet large ship with a large hangar and mission bay can effectively clear a carrier strike group (CSG) operating box at least three times faster than an LCS with MCM Mission Module, yet cost only 20% more than the LCS.

Dimensions and Performance		Mine Hunting Assets	
Displacement	20,600 MT	*Equipment*	
LOA	177 m	4x	MH-53 Sea Stallion Helicopters
LWL	169 m	4x	MH-60 Seahawk Helicopters
Beam	27 m	2x	Bell 407 Vertical Take-off UAVs
Draft	7 m	3x	MIW USV's
Max Speed	22.3 kts	12x	MIW UUV's
Sustained Speed	21.3 kts	3x	Mk-105 Mine-Hunting Sleds
Endurance Speed	20 kts	2x	11m RHIB
Endurance Range	12,000+ nm	*Personnel*	
Propulsion Power	27,144 kW	30x	Navy Special Clearance Team
Electrical Power	7,828 kW	400x	MIW Mission Planning Personnel



Afloat Forward Staging Base

LT Michael Bahr USN; LT Katie Gerhard USN; LT Ben Sanfiorenzo, USN

"There has been a long-standing request by the Central Command (CENTCOM) for an afloat forward-staging base, which is, effectively, a "mother ship" that supports smaller craft or aviation platforms."- Chief of Naval Operations

Throughout Naval history, when an at-sea platform is required for various missions, an older vessel is converted into a staging base to temporarily provide a solution to this capability gap. These ships are run hard into the ground until they are literally forced into decommission several years after being converted into the afloat staging base. Most recently, the USS PONCE, the exLPD 15, was converted into an interim afloat staging base and deployed to Fifth Fleet to serve as a floating, staging platform. The current front line has shifted from deep sea support to littoral combat. The 570-foot ship is limited in mission capability by the confines of the LPD 15 hull and is expected to last another four years when the fleet will again be in need of a forward deployed staging base to maintain front line presence. The US Central Command (USCENTCOM) has requested a clean-sheet design Afloat Forward Staging Base (AFSB) to replace the USS PONCE.

Currently there are no ships in the US Navy with the versatility to support operations ranging from minesweeping to SOF operations aside from CVNs and LHD/LHAs.

In order to fill this urgent request and mission void, an Afloat Forward Staging Base, AFSB(X), is proposed to efficiently meet the operational mission requirements of the US Military and maintain a dominant, command presence on the front line. The AFSB(X) platform is designed with the flexibility to meet both Mine Countermeasures mission parameters and the demands of the Special Operational Forces (SOF) as requested in a NAVSEA issued Request for Proposal. This ship is capable of launching and recovering four (4) MH-53 Sea Dragons in support of Aviation Mine Countermeasure missions. Within the same mission area, the AFSB(X) can launch four (4) MK-105 sleds to detect and detonate mines, two (2) MQ-8B Fire Scouts for aerial surveillance, and launch and recover RHIBS for support operations out of a boat ramp. Additionally, the AFSB(X) can be "flexed" into a floating base for SOF operations as well. The expansive flight deck can launch and recover an entire 160^{th} squadron made up of AH/MH-6 Helicopters and SH-60 Sea Hawk to maneuver SOF personnel onto or off the ship. The aft boat ramp can also launch and recover combatant crafts for the SOF detachment. Staging areas, armories, planning rooms, interrogation centers, triage rooms, and SCIFs are provided internally to support any and all SOF operations while in the AFSB(X) is in the SOF configuration.

The Initial Concept Design of the AFSB(X) is capable of meeting the mission requirements set out by NAVSEA and has the ability to replace the USS PONCE on time and on station. Thus, the AFSB(X) is a viable answer to the CNO and CENTCOM's cry for help. With a projected life cycle of 40 years, the AFSB(X) will enhance the application of U.S. military force and global power projection.

Hydrostatics		**Accommodations (With Margin)**	
Draft (Midships)	8.26 m	Officers	72
Length (L_{WL})	194.48 m	CPO	84
Beam	32.20 m	Crew	323
Wetted Surface Area (A_{WS})	7334.52 m^2	Total	479
Max. Section Area (A_X)	261.72 m^2	**Weapons**	
Waterplane Area (A_W)	5178.83 m^2	RAM	2
L/B	6.04	CIWS	2
B/T	3.90	Crew-Served Weapon	4
Displacement-to-length Ratio (DLR)	137.39	**AMCM**	
Prismatic Coefficient (C_P)	0.688	MH-53	4
Block Coefficient (C_B)	0.701	MQ-8B	2
Max Section Coefficient (C_X)	0.984	MK 105 Sled	4
Waterplane Coefficient (C_{WP})	0.827	RHIB	2
Speed		**SOF**	
Endurance Speed	18.13 kts	SH-60	4
Sustained Speed	20.14 kts	MH/AH-6	4
Max Speed	21.40 kts	MQ-8B	2
Propulsion- IPS		RHIB	2
Main Engines	2	CC-A	4
Secondary Engines	4	CC-M	2
Total Power from Main Engines	43310 kW	**Elevators**	
Total Power from Secondary Engines	10112 kW	External/Aviation Elevator	1
Overall Power Available	53422 kW	Internal Elevators	2

"Half a Frigate"

LT Dominic Alvarran, USN; LTJG Konstantinos Nestoras, HN

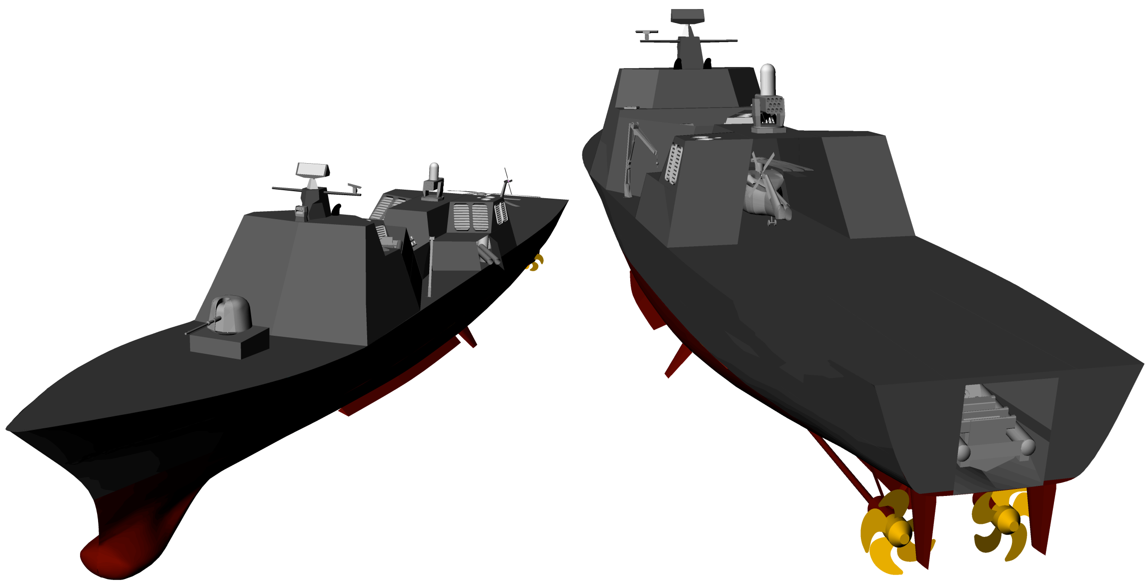
The Hellenic Navy (HN) currently conducts most national patrols of the Aegean Sea using patrol boats, gunboats, and fast attack missile boats. Additionally, the HN supports NATO in larger international missions in the Mediterranean and off the Somali coast. When in support of the international missions or when the sea state exceeds SS 5, the HN deploys frigates which are much more expensive to operate. This corvette allows the HN to deploy a much smaller ship consuming less fuel while maintaining a large amount of the frigate capabilities. Additionally, the corvette size allows for the incorporation of a helicopter for both national and international patrols.

The design of the ship focuses on minimizing cost by maintaining a small displacement thereby limiting lifetime operating costs through less fuel consumption and fewer required crewmembers as well as limiting construction costs. In order to maintain the small displacement along with the ability to operate in higher sea states, the Half a Frigate (HaF) is designed with a more appropriate architecture than the standard mono-hull.

A design analysis was conducted in order to choose the most cost effective variant along the hierarchy of system capabilities developed with the sponsor. The chosen variant's geometry was changed over several iterations in order to choose the most effective combination of length, beam, and GMT/Beam ratio that would provide the largest seakeeping envelope for conducting helicopter operations while maintaining speed requirements and a displacement below the threshold of 2500 tons. Several additional analyses were conducted including structural and stability analyses in order to verify feasibility of the resulting design.

It was found that geometry changes alone were insufficient in maintaining the balance between required seakeeping capability and cost limitation for a mono-hull. It is recommended that in a future study the Hellenic Navy could potentially consider a SWATH design or relax either the seakeeping or cost constraints. The use of active fin stabilizers is also discussed and was proven that big improvement in the seakeeping performance can be achieved. However, an additional study could potentially be done, in order to investigate the benefits of utilizing an active fin system over the additional cost and potential maintenance issues associated with it.

Design Parameter	Ship Characteristics	
	HaF	***MEKO 200HN***
Type	Corvette	Frigate
Max Speed [kts]	24	32
Max Range [nm]	3200	6000
Guided Missiles	8 anti-ship	8 anti-ship 16 anti-air
Anti-missile defense	SEARAM	CIWS
Deck Gun	76mm	127mm
Ship Launched Torpedoes	4 in the tubes	6 in the tubes 10 in storage
Helo Launched Torpedoes	6	Unknown
Radar Range	40nm	180nm
Torpedo Countermeasures	ADC	NIXIE
Electronic Warfare	ECM	ECM
Crew	75	200
LBP [m]	93.5	118
Beam [m]	12.96	14.8
Displacement [Mtons]	2473.8	3400
RHIBS	1 x 11m (stern boat bay) 1 x 7m	1 x 7m
Cost ($ USD)	300M	557M

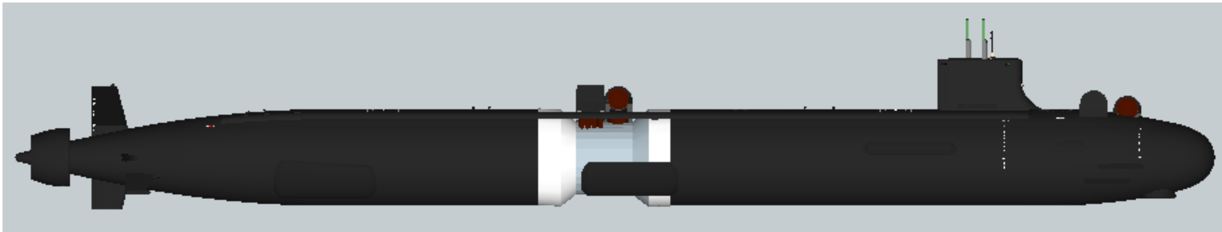


Stretch Virginia – an Alternative to the Virginia Payload Module (Conversion Project)

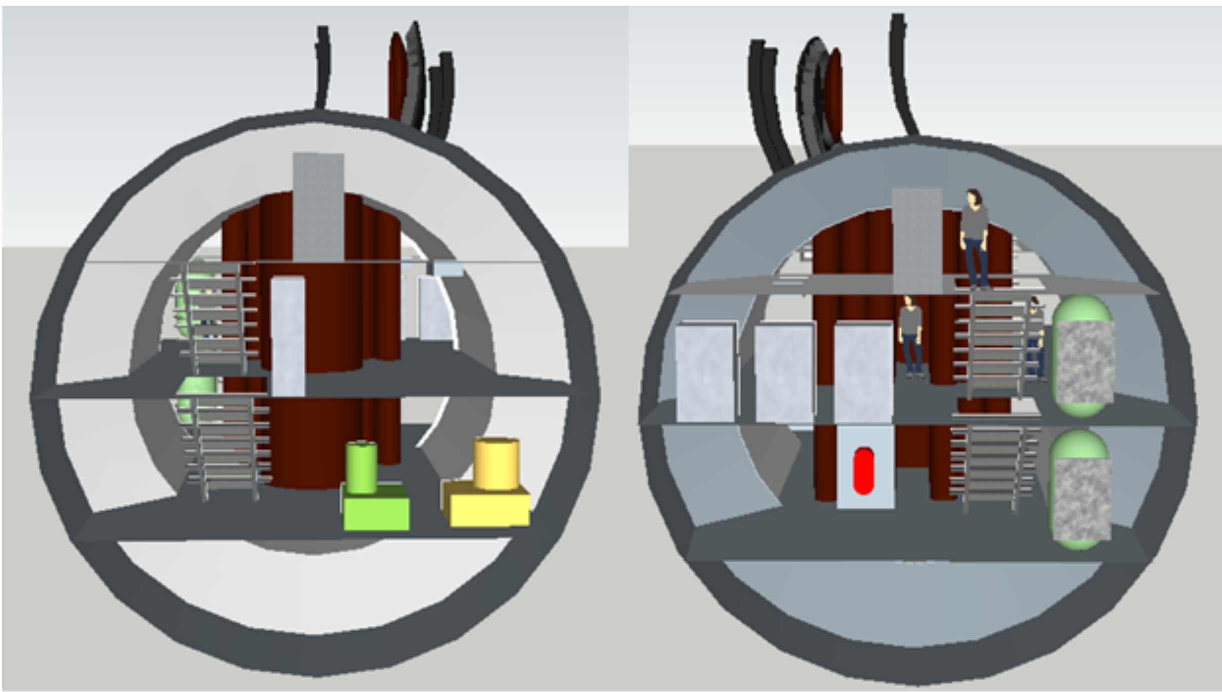
LT Adam Jones, USN; CDR Terry Nawara, USN; LT Damian Oslebo, USN

In 2011, Electric Boat revealed concept designs for a Virginia Payload Module (VPM). Electric Boat states the VPM will have "four additional large-diameter payload tubes in a module inserted amidship…extending the hull by 94 feet and increasing the fixed strike capacity by more than 230 percent per ship." Each large diameter tube can store seven Tomahawk missiles, support Special Operations Forces (SOF), or support prompt global strike missions. This paper will present an alternative to the VPM (termed "plug"). The goals in designing the plug were to minimize changes to the original Virginia class submarine, maintain the same mission capabilities as the VPM, and reduce its length to improve maneuverability and hydrodynamics while increasing the strike capability per foot added. The final result was a 47 foot plug with one large-diameter tube and 22 individual missile tubes that each contains one Tomahawk missile (or other possible 21 inch diameter payloads). By maintaining one large diameter tube, the plug can support the SOF and prompt global strike missions. The plug can be loaded with a total of 29 Tomahawk missiles, which is one more missile than the concept design for VPM.

Characteristic	**Value**
Length	424 feet (377 ft baseline plus 47 ft plug)
Additional Missile Tubes	29 Total (7 in MAC plus 22 VLS)
Cost	Less than 10.2% above baseline Virginia
Speed Reduction	Less than 5% from Virginia
Additional Personnel	None
Additional Systems	Cooling System (EAFW), Hydraulic System, Weapon Launch Console, Electric Switchboards, 2 Air Flasks, 2 Fans, Fire Hose
Technology Risk	Disposable VLS Pressure Caps



Profile View of Plug with Baseline Virginia (Plug's Hull Fairing Not Shown)



Forward Looking Aft Aft Looking Forward

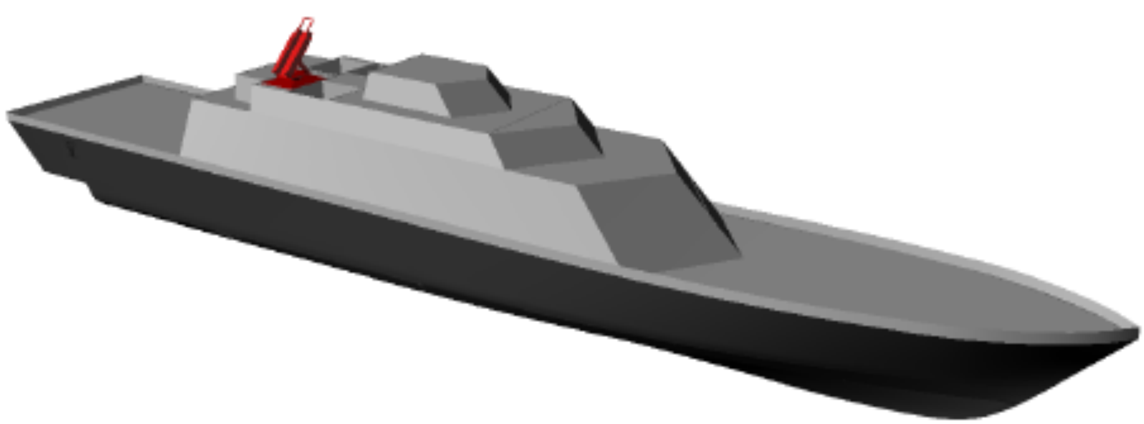
Feasibility Assessment of a Naval Surface Fire Support Capability for the Mono-Hull Variant of the Littoral Combat Ship (Conversion Project)

LT Kyle Miller, USN; LTJG Vasilis Georgiadis, HN; ENS Alexander Laun, USN

With the conclusion of major force deployments to Afghanistan, the Department of Defense (DoD) is refocusing on the vast Asia-Pacific region, increasing the likelihood of future expeditionary and amphibious operations. To improve its ability to operate in the congested littorals of this region, the United States Navy (USN) continues to develop and procure the Littoral Combat Ship (LCS), a high-speed, modular, multi-mission platform. Inevitably, future littoral operations will increase the necessity for effective Naval Surface Fire Support (NSFS), as provided by shipboard gun and missile systems.

This study was sponsored by Naval Sea Systems Command (NAVSEA) to assess the feasibility of providing a near-term NSFS capability for the mono-hull variant of the LCS. The proposed NSFS mission module includes components of the High Mobility Artillery Rocket System (HIMARS), a proven combat system that supports modern ground operations. The project team assessed the overall feasibility of the converted ship design by considering unique interface requirements, vessel stability, structural strength, seakeeping performance, design costs, and cumulative technical risk.

Ultimately, the project team determined that the mono-hull variant of the LCS could successfully support an NSFS capability. Successful integration of the proposed NSFS mission module would require modification of the LCS superstructure and additional development of control algorithms for the HIMARS Fire Control System (FCS).



2013 2N Student Theses

Advances in Hybrid Water-Lubricated Journal Bearings for Use in Ocean Vessels

LCDR Brian Heberley, USN

Prof. Alex Slocum	Prof. Doug Hart	Prof. Mark Thomas
Committee Chair	Committee Member	Committee Member

The outboard bearings that support shafts in naval ships and submarines present unique challenges to designers, shipbuilders, and operators. Such bearings must operate continuously and reliably in demanding environments at speeds that vary from below 1 rpm to well over 100 rpm. Water-lubricated bearings typically used for these applications operate hydrodynamically and are prone to adverse effects at lower speeds such as increased abrasive and adhesive wear as well as stick-slip shaft motion. This project focuses on developing a hybrid journal bearing capable of operating with hydrostatic pump pressure at lower rpm, while still maintaining the capability for hydrodynamic operation at higher rpm. Benefits of such a system include extending the periodicity between outboard bearing replacements, less abrasion and scoring damage to the propulsion shaft, and preventing stick-slip shaft motion.

To enable the in-water replacement of bearings without removal of the propulsion shaft, a partial arc (< 180 degree wrap) configuration is required. This partial arc constraint introduces several unique manufacturing difficulties. To address this, a novel manufacturing process has been developed that enables the rapid fabrication of high precision bearings with diameter and roundness errors of less than 0.001” (25.4 microns) on a nominal diameter of 3.24” as measured with a Coordinate Measuring Machine - greatly exceeding the published tolerances of conventional methods.

A unique experimental test rig was designed and built in order to measure the performance of 15 different prototype bearing designs. The rig is capable of submerged bearing testing in both hydrostatic and hydrodynamic modes of operation, with fundamental parameters such as speed, torque, loads, pressures, flow rates, and shaft position recorded. The operating characteristics of the bearings were then analyzed to identify key features and variables affecting bearing performance.

Certain bearing designs were found to be inherently stable for side loading conditions, without the use of compensation typically used in hydrostatic bearings. This finding led to bearings designed with simplified hydrostatic features and fluid supply systems. Such designs were found to have minimal degradation in hydrodynamic performance, making them particularly suitable for use as hybrid bearings. The key design drivers identified in this work are combined with ancillary factors to discuss the feasibility of hybrid bearings for use in marine applications.

PhD, Mechanical Engineering

Cooling System Design Tool for Rapid Modeling and Analysis of Chilled Water Systems Aboard US Navy Surface Ships

LT Amiel Ben Sanfiorenzo, USN

Prof. Chryssostomos Chryssostomidis	Dr. Julie Chalfant	Prof. Mark Thomas
Thesis Supervisor	Thesis Advisor	Thesis Advisor

In the past, chilled water systems have been relatively small and simple to design with the integration of the chilled water system taking place after other major design decisions have been made. However, Navy combatant ships are being designed with more powerful radars and combat system equipment with have greater power demands. These increased power demands result in larger heat loads and the need for larger, more complex cooling systems becomes evident. The design of these cooling systems is crucial and the need exists to begin integrating their design in the early stages of ship design. Although there are many tools at the disposal of the naval architect when it comes to seakeeping, strength analysis, intact and damaged stability, hydrostatics, and many other disciplines, there is not a tool for early-stage design of distributed thermal management systems such as the chilled water system. This project focuses on the development of an early-stage cooling system design tool (CSDT) for modeling and analyzing the chilled water (CW) system and auxiliary seawater (AUX SW) system. The CSDT provides rapid modeling and visualization of the two systems and has the capability to conduct several analyses on the modeled cooling system. The CSDT provides:

- 2-D and 3-D graphical representations of the CW and AUX SW systems
- a weight report with the calculated weight and center of gravity of the CW system
- an expansion tank sizing report
- steady-state temperatures calculated at various points within the system
- an A/C unit selection report which specifies which A/C units were incorporated into the design
- pressure distribution plots
- temperature response plots during transients
- temperature distribution plots during transients

It incorporates flow network analysis to determine the flow velocities within the piping system. In addition, a finite element approach was taken to allow for transient temperature analysis of the chilled water system. The transient temperature analysis was validated using a simple network which was solved analytically with good agreement between the CSDT and the analytic solution. Lastly, a simulation was conducted with 180 heat loads, demonstrating the usefulness of the tool and the potential tradeoffs which could be analyzed when utilizing the CSDT.

Naval Engineer
Nuclear Engineer

Material Characterization of High-Voltage Lithium-Ion Battery Models for Crashworthiness Analysis

LCDR Joseph D. Meier, USN

Prof. Tomasz Wierzbicki
Thesis Supervisor

A three-phased study of the material properties and post-impact behavior of prismatic pouch lithium-ion cells was conducted to refine computational finite element models and explore the mechanisms of thermal runaway caused by internal short circuit.

In phase one, medium and large sized cells at low state of charge (SOC) were impacted or compressed while measuring punch load, displacement, cell voltage, and surface temperature until an internal short circuit was detected, followed by a rise in surface temperature. Results were used to either refine the constitutive cell properties or validate the model refinements.

In phase two, an exploratory study into the behavior of lithium-ion prismatic pouch-type battery cells following surface impacts with hemispherical and conical punches (abuse testing) was conducted for the purpose of observing pouch behavior and adequacy of parameter measurement methods. Cells were impacted by steel punches to loads as high as 500 kN while recording load, punch displacement, and pouch surface temperatures, as well as normal and high-speed video footage. Comparisons of load, surface temperature, and thermal runaway for various States of Charge (SOC) and punch types are presented.

In the third and final phase of the study, material characterization of cell components was conducted to further refine computational models and draw conclusions regarding the interactions between impacted cell layers and the physical cause internal of short circuits. Results of uniaxial tension tests for coated and uncoated anode and cathode layers, as well as separator layers are presented, as well as conclusions about the use of digital image correlation (DIC) in such studies.

Much of the data generated in this study was used to further refine and validate prismatic pouch lithium-ion battery cell computational models developed by the MIT Impact and Crashworthiness Laboratory. Physical tests conducted in phase one of this study were plotted against model simulations for comparison, which showed that the models make close approximations for material displacement, and are good predictors of internal short circuit.

Naval Engineer
Master of Science in Mechanical Engineering

Analytic and Numerical Study of Underwater Implosion

CDR Andy Gish, USN

Prof. Tomasz Wierzbicki	**Prof. Mark Thomas**	**Dr. Yuming Liu**
Committee Chair	Committee Member	Committee Member

Underwater implosion, the rapid collapse of a structure caused by external pressure, generates a pressure pulse in the surrounding water that is potentially damaging to adjacent structures or personnel. Understanding the mechanics of implosion, specifically the energy transmitted in the pressure pulse, is critical to the safe and efficient design of underwater structures. Hydrostatically-induced implosion of unstiffened metallic cylinders was studied both analytically and numerically. An energy balance approach was used, based on the principle of virtual velocities. Semi-analytic solutions were developed for plastic energy dissipation of a symmetric mode 2 collapse; results agree with numerical simulations within 10%. A novel pseudo-coupled fluid-structure interaction method was developed to predict the energy transmitted in the implosion pulse; results agree with fully-coupled numerical simulations within 6%. The method provides a practical alternative to computationally-expensive simulations when a minimal reduction in accuracy is acceptable. Three design recommendations to reduce the severity of implosion are presented: (1) increase the structure's internal energy dissipation by triggering higher collapse modes, (2) initially pressurize the internals of the structure, and (3) line the cylinder with a flexible or energy absorbing material to cushion the impact between the structure's imploding walls. These recommendations may be used singly or in combination to reduce or completely eliminate the implosion pulse. However, any design efforts to reduce implosion severity must be part of the overall system design, since they may have detrimental effects on other performance areas like strength or survivability.

PhD, Ocean Engineering

Non-Intrusive Vibration Monitoring in US Naval and US Coast Guard Ships

LT Katherine Leigh Gerhard, USN

Prof. Steve Leeb	Mr. Pat Hale
Thesis Supervisor	Thesis Reader

In 2011, the Laboratory for Electromagnetic and Electronic Systems proposed a new type of vibration monitoring system, entitled vibration assessment monitoring point with integrated recovery of energy or VAMPIRE, in their work entitled *VAMPIRE: Accessing a Life-Blood of Information for Maintenance and Damage Assessmen*t [1]. The proposed monitoring system includes a self-power harvesting accelerometer installed in motors on US Navy and US Coast Guard vessels used to monitor equipment vibration and diagnose the source of the high vibrations.

Utilizing the observations and tools designed by the VAMPIRE project as a foundation, this thesis takes the LEES lab-designed CAPTCHA accelerometers to the US Navy and US Coast Guard fleets to test the lab-designed tool, collect ship equipment data, and verify the VAMPIRE concepts. The CAPTCHA's ability to the monitor the vibrations of these systems could be used to immediately diagnose system casualties, aid in parts repair, and ultimately, become a tool to promote Condition-Based Maintenance (CBM). Measurements and experimentation were conducted on two USCG ventilation fans in the lab as well as onboard the USCGC SENECA (WMEC-906), USCGC BERTHOLF (WMSL 750), USCGC STRATTON (WMSL 752), USS MICHAEL MURPHY (DDG 112), USS INDEPENDENCE (LCS 2), and USS SAN DIEGO (LPD 22).

Data was collected and analyzed using a developed MATLAB program to diagnose the types of vibrations seen in various experiments and observe high vibrations in the commissioned ships. The combined results of the CAPTCHA-recorded lab tests and ship testing corroborate the theories proposed in the VAMPIRE paper; however, additional studies could make the VAMPIRE proposal a robust solution to a fleet-wide vibration-induced maintenance problem.

Naval Engineer
Master of Science in Engineering and Management

Operational Profiling and Statistical Analysis of Arleigh Burke-Class Destroyers

LT Travis Anderson, USN

Prof. Franz Hover
Thesis Supervisor

Ship operational profiles are a valuable tool for ship designers and engineers when analyzing potential designs and ship system selections. The most common is the speed-time profile, normally depicted as a histogram showing the percent of time spent at each speed. Many shortcomings exist in the current Arleigh Burke (DDG 51)-class operational profiles. The current speed-time profile is out of date, based on another ship class, and does not depict the profile in one-knot increments. Additional profile data, such as how the engineering plant is operated and a mission profile, do not exist. A thorough analysis of recent DDG 51 operations was conducted and new and improved profiles were developed. These profiles indicate the ships tend to operate at slower speeds than was previously predicted with 46% of the time spent at 8 knots and below as compared to the previous profile with 28% for the same speeds. Additionally, profiles were developed to show the amount of time spent in each engineering plant line-up (69% trail shaft, 24% split plant, 7% full power) and the time spent in different mission types (69% operations, 27% transit, 4% restricted maneuvering doctrine). A detailed statistical analysis was then conducted to better understand the data used in profile development and to create a region of likely speed-time profiles rather than just a point solution that is presented in the composite speed-time profile. This was accomplished through studying the underlying distributions of the data as well as the variance.

Naval Engineer
Master of Science in Mechanical Engineering

Electrical Ship Demand Modeling for Future Generation Warships

LCDR Bart Sievenpiper, USN

Prof. Steven Leeb
Thesis Advisor

The design of future warships will require increased reliance on accurate prediction of electrical demand as shipboard power consumption continues to rise. Current US Navy policy, codified in design standards, dictates methods of calculating the average demand power. The research conducted for this thesis investigates the utility of current analysis techniques and examines possible improvements. To support this effort data analysis was first performed at a fleet level, using relevant information from ship's logs to update the speed-time profile for the DDG-51 class. Using an installed onboard sensing system, engineering plant data was analyzed to study the behavior of systems and components. The data from these sources was then used to develop a means for updating the loading profile for shipboard systems. The research then establishes one possible framework for behavioral modeling to support the development of an electrical loading design tool. Behavioral modeling introduces a means of simulating the shipboard loading based on global inputs and system responses, while remaining computationally efficient. Development of such a design tool would allow improved decision making at all stages of the design process.

Naval Engineer
Master of Science in Mechanical Engineering

Resource Constrained Project Scheduling at U.S. Naval Shipyards

CDR Terry Nawara, USN

Prof. Olivier L. de Weck	**Prof. Mark Thomas**
Thesis Supervisor	Thesis Advisor

Repairs of a nuclear U.S. submarine are resource constrained since resources are divided among approximately thirty shops (e.g. electricians, welders, and pipefitters). Submarine repair schedules are some of the most complex schedules seen in project management. The system complexity, the tight spaces, the operational nuclear reactor, the challenges inherent in repair, and resource competition all contribute to a dense integrated schedule. Minimizing the overall length of each project, the "makespan," is the primary objective function. This paper uses a commercially available simulation package, @Risk, to analyze a submarine repair schedule. Simulation is used to analyze uncertainty in the task durations and identify crucial tasks that highly impact the makespan. Finally, a genetic algorithm is tested to assign resources to minimize the makespan.

Naval Architecture and Marine Engineering
System Design and Management

Energy Storage and Dissipation in Polyurea Composites

LCDR Carl Bodin, USN

Prof. Mary Boyce
Thesis Supervisor

Polyurea composites have been of interest for a variety of engineering applications via their highly dissipative yet resilient behavior under deformation. Polyurea composites have been considered as a self-healing and anticorrosion coating in building applications, and more interestingly, as a lightweight addition to steel armor. In combination with a metal plate, a polyurea layer has been extensively studied under impact and blast loading. In this research, the tunable performance of polyurea sandwich armor composites is explored in modeling and experimentation. Cylindrical arrays comprised of polyurea, a resilient yet dissipative material, will enable improved load transmission by utilizing new dissipation and storage pathways due to geometry. Experimentation and computational modeling will be used to quantify the dissipation features of the polyurea composite. This research will combine new geometries and macroscopic interactions with the material properties of polyurea to improve its energy dissipation.

Naval Engineer
Master of Science in Mechanical Engineering

Cost Reduction of Polar Class Vessels: Structural Optimization that Includes Production Factors

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Prof. Dan Frey
Thesis Supervisor

Construction of ice-class vessels bring high cost on account of small structural clearances, e.g., frame spacing. In addition, the majority of design philosophies today are oriented towards reducing the weight of the hull structure to reduce the structural weight impact on displacement. As such, this thesis focused on the ability to reduce the cost of construction by accounting for production factors of a shipyard. In essences, there is a cost tradeoff between minimizing material and designing a ship that is easier to construct at the shipyard. This tradeoff is more apparent when constructing icebreakers and heavily ice-strengthen vessels for polar operation.

Research was conducted that revolved around North American shipyards and the American Bureau of Shipping's *Steel Vessel Rules* adoption of the recent *Unified Requirements for Polar Ships*. The most challenging aspect of data collection was determining proper production metrics to be included in the analysis, as majority of shipyards do not tack this information. However, guidance was provided by SPAR Associates, Inc. in determining how to overcome this issue and generate simple production costing relationships that most shipyards could utilize.

The production and material cost relationships developed were applied to an optimization program that was developed using MATLAB to determine the appropriate structural design that achieves a true minimum cost of production. The optimization problem was originally described as being a non-convex, mixed-integer problem with non-linear, bounded constraints. Engineering assumptions were implemented to remove the mix-integers from the problem and achieve a smooth function that could be easily computed using MATLAB's Global Search algorithm.

The program required the user to specify values for production and material factors that are representative of the shipyard intended to construct the vessel. As well, hull form geometry and lower/upper bounds of design variables, i.e. steel size limits, were required as inputs. The program would then compute the optimum solution that achieved minimum cost and output: frame scantlings, stringer/girder scantlings, plate thicknesses, frame spacing, and number of stringers/girders based on the steel sizes permitted for the various sections of the hull.

Initial results indicated that there is indeed a cost tradeoff between reducing production cost and minimizing structural weight for Polar Class vessels. Solutions identified overall cost savings when structural weight is increased resulting in larger frame spacing being achieved that allowed more accessibility when welding. Cost savings are found to be greater when examining higher Polar Class vessels in comparisons to the lower classes.

Master of Science in Naval Architecture and Marine Engineering
Master of Science in Engineering and Management

Passive Regeneration: Long-Term Effects on Ash Characteristics and Diesel Particulate Filter Performance

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Prof. Victor Wong
Thesis Supervisor

Diesel particulate filters (DPF) have seen widespread growth as an effective means for meeting increasingly rigorous particle emissions regulations. There is growing interest to exploit passive regeneration of DPFs to reduce fuel consumption accompanying traditional active regeneration. Incombustible material or ash, mainly derived from metallic additives in the engine lubricant, accumulates in the DPF over time. This ash accumulation increases flow restriction and rise in pressure drop across the DPF. The growth of pressure drop adversely impacts engine performance and fuel economy.

This study will build upon previous research to explore the different effects of regeneration strategy on ash packing and distribution within DPFs. Since passive regeneration relies on a catalyzed reaction, the interactions of ash with the catalyst will play an important role. Passive regeneration is specifically dependent on exhaust feed gas composition, exhaust conditions including temperature and flow rate, catalyst type and configuration, and the state of DPF loading during prior to passive regeneration. The goal of the study is to address the long-term effects of regeneration parameters on ash accumulations and the resulting impact of ash on the DPF catalyst performance.

These results, among few fundamental data of this kind, correlate changes in diesel particulate filter performance with exhaust conditions, regeneration strategy, and ash morphological characteristics. Outcomes are useful in optimizing the design of the combined engine-aftertreatment-lubricant system for future diesel engines, balancing the necessities of additives for adequate engine protection with the requirements for robust aftertreatment systems.

Naval Engineer
Master of Science in Mechanical Engineering

Realigning Contract Incentives for the Non-Competitive Environment of the US Shipbuilding Industry

LT Dominic Alvarran, USN

Prof. Olivier de Weck	Prof. Mark Thomas
Thesis Supervisor	Thesis Advisor

Currently, about $60B USD is spent annually by the Research, Development, and Acquisition portion of the Navy of which approximately one-third is spent on the acquisition of Navy ships and submarines. It is suspected that the lack of commercial shipbuilding available in the US, resulting in the consolidation of the US shipbuilding industry as a whole, limits the negotiating capacity for the US Navy and promotes suboptimal contracts that continuously produce major cost and production time overruns. Several incentives and contracting strategies are explored to improve, through formal and informal means, the best value for the Navy in the production of large ships.

MIT is currently working with the US Navy, as part of its Production in the Innovation Economy study, to produce a standalone module on US shipbuilding and defense manufacturing. The overall module focuses on several parts including:

1. Innovation in Bidding and Contracting
2. Project Management and Rework Dynamics
3. National and International Benchmarking of US Shipbuilding Performance
4. Supply Chain Management and Supplier Base
5. Prospects for US Commercial Shipbuilding.

This thesis focuses on the first part of that module: bidding and contract innovation. Different contract methodologies including some borrowed from other industries are evaluated for applicability and integration into the US shipbuilding industry.

The thesis looked at four current Navy contracts and their incentive structures. The analysis was done with incentives outside of monetary payoff in mind, but also included a look at the scale and alignment of the monetary payoffs with the intended performances. The recommendations given for each of the incentive types provided potential solutions to the misalignment of those incentives with the outcome for which the Navy hoped. However, those recommendations would potentially provide only a marginal improvement to the efficiency of shipbuilding contracts through an improvement in cost reduction, quality, and schedule adherence. Larger improvement would require a larger change in the contracting process and the industry as a whole. This change is possible through investment into the competitive base of the industry which could potentially take the form of search fund initially as a vehicle to grow a Tier 2 shipbuilder into a Tier 1 competitor.

Naval Engineer
Master of Business Administration

A Tool to Create Hydrodynamically Optimized Hull-Forms by Respecting Internal Arrangements

LTJG Konstantinos Nestoras, HN

Prof. Chryssostomos Cryssostomidis	**Prof. Stefano Brizzolara**	**Mr. Pat Hale**
Thesis Supervisor	Thesis Supervisor	Thesis Reader

For many years the design of ships has been based on the improvement of older designs with new requirements imposed on the design process. This was done primarily because generating new hull geometries had to be done manually and required the build of (physical) models, which was an expensive and time-consuming method. These models then had to be tested extensively in towing tanks, which again was a time consuming and expensive process. Fortunately, in recent years advancements in computer science and electrical engineering led to the creation of faster and more capable computers. This allowed the usage of very computationally intensive codes and algorithms, which drastically increased the accuracy of the carried calculation and thus limited the need for building numerous models and running multiple towing tank tests in the development of new hull geometries. At the same time the capability of geometric modeling of hull surfaces was increased and thus computers can now be used more easily in the design process. The tool created in this thesis allows the user to take advantage of those advancements by easily defining and altering the hull geometry. The resistance of the ship is calculated by a panel method potential flow solver, giving the user the ability to have more accurate resistance estimation than that taken from parametric models like Holtrop and Mennen. Further, the user can conduct optimization studies by using the Non Sorting Genetic Algorithm 2 (NSGA-II) and investigate what the optimal hull geometry should be for the given parameters and constraints. The tool is able to model internal arrangements such as engines and take them into consideration during the optimization, so that the generated hulls will guarantee that this equipment fits into the hull. This gives a higher flexibility to the designer, especially in the early stage design process. Finally, a more inside-out design approach can be utilized, which will lead to a better space usage in the hull, as the hull is fitted around the equipment, instead of trying to fit the equipment in the hull.

Naval Engineer
Master of Science in Engineering and Management

Cooperative Autonomous Tracking and Prosecution of Targets Using Range-Only Sensors

LT Arthur D. Anderson, USN

Prof. John Leonard	Dr. Michael Benjamin
Thesis Supervisor	Research Advisor

Autonomous platforms and systems, in both the military and the commercial worlds, are becoming ever more prevalent. They have become smaller, cheaper, have longer duration times, and now, more than ever, more capable of processing large amounts of information. Despite these significant technological advances, there is still a level of distrust for human operators in autonomous systems, as they are often seen as unreliable or incapable of making important decisions without human input. In marine and underwater vehicles, autonomy is particularly important since communications to and from those vehicles are limited, either due to the length of the mission, the distance from their human operators, the sheer number of vehicles being used, or the data transfer rate available from a remote operator to an underwater vehicle through acoustics.

The premise for this research is to use the MOOS-IvP code architecture, developed at MIT, to promote and advance marine vehicle autonomy collective knowledge through a project called the Hunter-Prey scenario. In this scenario, two or more surface vehicles attempt to track an evading underwater target using range-only sensors. These vehicles will work in a limited communication environment, attempting to cooperatively track the underwater target and ultimately maneuver into a position for a "kill" using a simulated depth charge. This scenario will be distributed to the public through academic institutions and interested parties, who will submit code for the vehicles to compete against one another. The goal for this project is to create and foster an open-source environment where many parties can compete and cooperate toward the common goal, the advancement of marine vehicle autonomy.

In this paper, the Hunter-Prey scenario is developed, a nominal solution is created, and the parameters for the scenario are analyzed using regression testing through simulation and statistical analysis.

Naval Engineer
Master of Science in Mechanical Engineering

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