Naval Construction and Engineering

Ship Design and Technology Symposium

Wednesday, May 14, 2008

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

0800 – 0900	Registration and continental breakfast
0900 – 0910	Administrative information – Captain Patrick Keenan, USN
0910 – 0920	Welcome – Professor Rohan Abeyaratne, Department Head, Mechanical Engineering, MIT
0920 – 0930	Opening Remarks – Professor Nicholas Patrikalakis, Associate Department Head, Mechanical Engineering, MIT
0930 – 1000	Composite Materials and NDE – Professor James Williams, Jr., MIT
1000 – 1030	Alternative Selection through Pugh Analysis – Professor Daniel Frey, MIT
1030 – 1045	Break
1045 – 1105	DDG-51 to LCS Mission Module Carrier (Conversion) – LCDR Kevin Flood, USN, LCDR(s) Chris Peterson, USN, LCDR(s) Rocky Beaver, USN
1105 – 1125	LSD-41 to Ballistic Missile Test & Evaluation Platform (Conversion) – LCDR Greg Elkins, USN, LCDR Jeremy Leghorn, USN, LT Joe Darcy, USN
1125 – 1145	FFG-7 to LCS Mission Module Carrier (Conversion) – CDR Mitch Stubblefield, USN, LCDR Keith Douglas, USN, LCDR Joshua LaPenna, USN
1145 – 1205	LSD-41 to Hospital/Naval Construction Ship (Conversion) – LTJG Matt Smith, USCG, LT Simon Summers, CF, LTJG Alexandros Michelis, HN
1205 – 1315	Luncheon Buffet – Guest Speaker: Rear Admiral Mark Hugel, USN, Deputy Commander for Logistics, Maintenance and Industrial Operations, Naval Sea Systems Command
1215– 1235	Design of a Fast Catamaran Semi-Displacement Vessel – Julie Arsenault, Ashley Cantieny, Edward Huo, Morgan Laidlaw, Sebastian Sovero
1315 – 1345	MK-V S.O.C. Replacement Vessel – LT Colin Dunlop, USN, LT Will Hagan, USN, LT Ben Hawbaker, USN
1345 – 1415	Sub-Sahara: Security and Support Vessel – LCDR(s) Andrew Gillespy, USN, LT Perry Branch, USN, LT Ashley Fuller, USN
1415 – 1430	Break
1430 – 1445	Paramarine Introduction – LCDR Ethan Proper, USN, LCDR(s) Richard Jones, USN, LTJG Kyriakos Avgouleas, HN
1445 – 1515	Conventional Littoral Strike Submarine – LCDR Ethan Proper, USN, LCDR(s) Richard Jones, USN, LTJG Kyriakos Avgouleas, HN
1515 – 1530	Closing Remarks – Captain Patrick Keenan, USN
1530 – 1730	Reception with student thesis poster session

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 of 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 both a two-year program, which leads to a Master of Science degree in Naval Architecture and Marine Engineering, and 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, and 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, Singaporean, Taiwanese, Turkish and Canadian navies and U.S. Coast Guard in the program. Officer students are admitted, and Navy faculty members are appointed, through normal MIT procedures. The program is a model of voluntary collaboration for the mutual benefit of MIT and the Navy.

Rear Admiral Mark A. Hugel
Deputy Commander
Logistics, Maintenance and Industrial Operations
Naval Sea Systems Command

Rear Admiral Hugel is a native of Mansfield, Ohio. He was commissioned an Ensign in June 1977 after earning a Bachelor of Science degree in Systems Engineering from the United States Naval Academy. He was accepted into the Navy Nuclear Power Program and, following initial training, he was assigned to sea tours in *USS Enterprise* (CVN 65) and *USS Mississippi* (CGN 40).

During his tour as Damage Control Assistant in *USS Mississippi*, he was designated a Surface Warfare Officer. Later, he reported to the *Abraham Lincoln* (CVN 72) Precommissioning Unit as the first Main Propulsion Assistant, where he served until the ship's post shakedown availability. While assigned to *Lincoln*, he was accepted for lateral transfer into the Engineering Duty Officer Program.

In June 1992, Rear Adm. Hugel completed his graduate education at Massachusetts Institute of Technology, earning a Master of Science in Naval Architecture and Marine Engineering, and a Master of Science in Mechanical Engineering. He subsequently served as Carrier Project Officer and Aircraft Carrier Program Manager's Representative at Supervisor of Shipbuilding, Conversion and Repair, USN, Newport News, Virginia. During this tour, he directed both a complex overhaul of *USS Dwight D. Eisenhower* (CVN 69) and the new construction of *USS Harry S. Truman* (CVN 75).

Rear Adm. Hugel was later a branch head on the Chief of Naval Operations staff, where he directed the Navy's ship maintenance and industrial capability policy. He completed a third tour at Norfolk Naval Shipyard where he was the 100th Shipyard Commander, and most recently was Deputy Director for Fleet Readiness (OPNAV N43B). He is currently assigned as Deputy Commander, Logistics, Maintenance and Industrial Operations, Naval Sea Systems Command.

He has received numerous personal decorations and other service awards and ribbons.

Rohan Abeyaratne

Rohan Abeyaratne is the Department Head of Mechanical Engineering at MIT. He is also the Quentin Berg Professor of Mechanical Engineering

Professor Abeyaratne joined the Department as Associate Professor without tenure in 1986 leaving his position as a tenured Associate Professor at Michigan State University. Four years after arriving at MIT he was granted tenure in 1990. He was promoted to Full Professor in 1995. Prior to his joining the Michigan State University faculty in 1980, Professor Abeyaratne was a Research Associate at Brown University for one year. He received his M.S. and Ph.D. degrees from the California Institute of Technology in 1976 and 1979, respectively. He received his B.S. degree from University of Ceylon in 1975.

Professor Abeyaratne is an internationally renown theoretical applied mechanician who has had a significant impact on the applied mechanics community. He is well known for his mathematical rigor and precision in solving some of the most difficult engineering problems. He is also recognized as one of the best teachers in the Department; he won the Den Hartog Distinguished Educator Award in 1995; the MIT Graduate Student Council Teaching Award (1988) for excellence in teaching and is a member of the Editorial Board of the International Journal of Mechanical Engineering Education. He is a Fellow of ASME, 1998 and a Fellow of the American Academy of Mechanics, 1996.

Nicholas M. Patrikalakis

Dr. Patrikalakis is the Kawasaki Professor of Engineering, Professor of Mechanical and Ocean Engineering, and Associate Head of the Department of Mechanical Engineering at MIT. He has been a Faculty Member of the Department of Ocean Engineering (1985-2004) and a Postdoctoral Associate (1983-1985) at MIT. He holds a S.M. in Naval Architecture and Mechanical Engineering (1977) from the National Technical University of Athens, Greece, and a Ph.D. in Ocean Engineering (1983) from MIT. His current research focuses on shape similarity evaluation, marine robotics, and distributed information systems for multidisciplinary ocean simulation. He is co-director of the Design Laboratory. Seventeen Ph.D. and 35 S.B., M. Eng., S.M. and Engineer's theses have been completed under his direction. He has published over 140 papers, two textbooks and has edited 20 journal special issues or conference proceedings. He has received research funding from NSF, ONR, DARPA, NAVSEA, NOAA, USCG, USACE, NUWC, MMS, NRF (Singapore), NIRO (Japan), General Electric, Westinghouse, Chevron, Conoco, Doherty Foundation, Furukawa Electric and Toshiba (both of Japan). He is a member of ACM, ASME, CGS, IEEE, ISOPE, SIAM, SNAME and TCG. He serves as Co-Editor-in-Chief of Computer-Aided Design journal, and participates in the editorial boards of several other international journals. He has also served as program chair or chair of over 10 major international conferences..

James H. Williams, Jr.

James H. Williams, Jr. (S.B. and S.M. -- Massachusetts Institute of Technology; Ph.D. -- Trinity College, Cambridge University) is the School of Engineering Professor of Teaching Excellence, Charles F. Hopewell Faculty Fellow, and Professor of Applied Mechanics in the Mechanical Engineering Department at the Massachusetts Institute of Technology. He is also Professor of Writing and Humanistic Studies in the School of Humanities, Arts, and Social Sciences. He has received many awards and published numerous papers and reports in conjunction with his teaching, consulting, and research in the mechanical characterization of advanced fiber reinforced composites; wave propagation in large space structures; in-process and post-process quality control; reliability; dynamic fracture; nondestructive evaluation with emphasis on acoustic emission, thermal, and ultrasonic responses of composites; dynamic behavior of structures subjected to seismic excitation; and the development of computerized data base systems for composite materials selection. He has been interviewed, cited, or featured in hundreds of newspaper, magazine, and broadcast media pieces. Formerly, as a senior design engineer at the Newport News Shipbuilding and Dry Dock Company, he performed a broad range of mechanics calculations on both industrial and governmental systems including, for example, stress and dynamical analyses of catapults, turbines, and propulsion shafting on nuclear-powered aircraft carriers such as the USS Nimitz (CVN-68), as well as overall ship accelerations and turning radii under various loading conditions. He has also conducted dozens of major multi-year consultations for the US government and international corporations involving a multiplicity of structural systems on high-performance aircraft, automobiles, rockets, offshore oil platforms, and hydroelectric power generation stations. If unavailable at his office, he can likely be found *attempting* to hit a 200-yard three-iron to an elevated green somewhere in the Boston area.

Daniel D. Frey

Dr. Frey is Associate Professor of Mechanical Engineering and Engineering Systems at Massachusetts Institute of Technology

Dr. Frey's research concerns robust design of engineering systems. Robust design is a set of engineering practices whose aim is to ensure that engineering systems function despite variations due to manufacture, wear, deterioration, and environmental conditions. To advance the theory and practice of robust design, Dr. Frey is working to understand the role of adaptive behavior in experimentation, the ways that methods can exploit the structure of design problems, and the complementary role of experiments and simulations.

Dr. Frey's experiences include: designing prosthetic devices, flying aircraft in the U.S. Navy, content direction of children's television series.

Dr. Frey's honors include the MIT Department of Aeronautics and Astronautics Teaching Award, received in 2000; the Everett Moore Baker Memorial Award for Outstanding Undergraduate Teaching at MIT, received in 1999; the R&D 100 Award, received in 1997 (awarded by R&D magazine) and the Joint Service Commendation Medal in 1991. He is a member of the American Society of Mechanical Engineers, the American Statistical Association, and the American Society of Engineering Education.

Dr. Frey holds a Ph.D. in Mechanical Engineering from MIT, an MS in Mechanical Engineering from the University of Colorado and a BS in Aeronautical Engineering from Rensselaer Polytechnic Institute.

Captain Patrick J. Keenan, USN (P.E.)

CAPT Keenan, a Princeton, NJ native, is an Engineering Duty Officer with marine salvage, drydocking and ship repair specialties. He has served in engineering and deck/salvage capacities aboard ATF and ARS class salvage ships and as the Seventh Fleet Salvage Officer. Shore assignments have included hyperbaric maintenance officer at a diving research facility, drydocking and diving officer in a naval shipyard, aircraft carrier repair officer at a supervisor of shipbuilding, Officer in Charge of U.S. Navy Ship Repair Unit Bahrain and Commanding Officer of the Navy Experimental Diving Unit in Panama City, FL. CAPT Keenan is currently the Director of the Naval Construction and Engineering Program at the Massachusetts Institute of Technology. He is qualified in air, mixed gas and saturation diving systems and as a docking officer for both floating and graving drydocks.

A registered professional engineer and marine surveyor, CAPT Keenan received a BA in Chemistry from the University of Pennsylvania, an MS in Materials Engineering and a Naval Engineer Degree from the Massachusetts Institute of Technology. His research relating to waterborne ship repair has been published in the *Naval Engineers Journal*. He holds a U.S. patent for his invention *Method and Apparatus for Thermal Insulation of Wet Shielded Metal Arc Welds* and he was the 2000 American Society of Naval Engineers Claude A. Jones Award winner for excellence in the field of Naval Engineering.

CAPT Keenan is married to Jean Fiore of Pawcatuck, CT. They have two sons, Liam and Seamus.

Commander Joe P. Harbour, USN

CDR Harbour currently serves as the Academic Officer of the Naval Construction and Engineering Program at the Massachusetts Institute of Technology.

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. He completed the Navy's rigorous Nuclear Power School in Orlando, Florida and Prototype in Charleston, SC. Following Submarine Officer Basic School he reported to the USS Nevada, SSBN 733.

While on stationed on the Nevada, he served a number of junior officer billets and 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). In route to MIT, he reported to Puget Sound Naval Shipyard, Bremerton for a 4 month temporary duty assignment where he served as Zone Manager for Auxiliary systems on USS Carl Vinson (CVN 70).

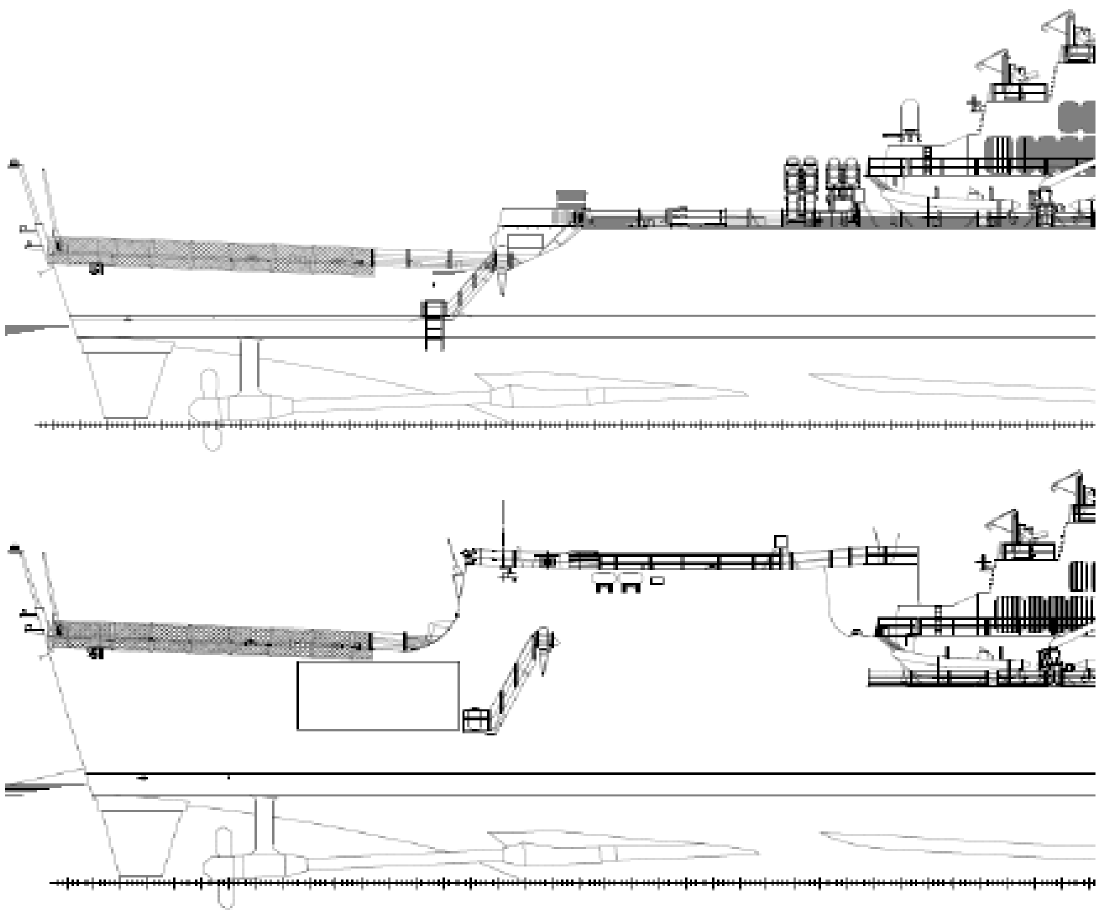
During his three year tour at MIT he received two masters degrees, Naval Engineer and a Masters of Science in EE, with an emphasis on large propulsion electric motors and electric power systems.

CDR Harbour was then transferred to Portsmouth Naval Shipyard (PNS) in Kittery, ME where he served as a Zone Manager for nuclear systems in the engine room for a SSN 688 class Depot Modernization Period (DMP) (USS Alexandria (SSN 757)). He then served as Assistant Project Supervisor for non nuclear systems on the USS Norfolk (SSN 714) Refueling overhaul. During which he held the collateral duty of Shipyard Docking Officer. He completed his three year tour at Portsmouth as the Assistant Operations Officer followed by Deputy, Test Engineering and Planning.

In June 2004 he reported to NAVSEASYSCOM WNY Arlington, Virginia where he served as the Ship Design Manager for the Submarine Rescue Diving and Recompression System (SRDRS) and worked in cooperation with Program Executive Office for deep submergence vehicles (PMS 394) to ensure SRDRS met all applicable operation and technical requirements. He was then selected to be the Executive Assistant for NAVSEA 05. He reported to his present duty in June 2006.

DDG-51 to LCS Mission Module Carrier (Conversion)

LCDR Kevin Flood, LCDR(s) John Beaver, LCDR(s) Chris Peterson



The Littoral Combat Ship (LCS) was envisioned to be a platform that would greatly enhance the war fighting capabilities of the US Navy. However, cost over-runs as well as significant construction delays resulted in the cancellation of ships 3 and 4. The Navy currently lacks the capability expected of LCS. Therefore, in the absence of building additional LCS type ships, this conversion project presents a conversion design in which the Flight I Arleigh Burke Class Destroyer would be able to carry the mission modules designed for the LCS and subsequently perform the missions intended for LCS. The Flight I DDG is an ideal candidate for this conversion, as most of the hulls are nearing mid life major overhaul.

The design requires the removal of the Aft VLS system, the 2 Quad Harpoon Missile Canisters and related systems, and the aft CIWS. This conversion also required the removal of the TACTAS room and the ship's laundry room. The laundry room was subsequently relocated to the space vacated by the Aft VLS. Two berthing rooms were also added into the space vacated by the aft VLS in order to provide sufficient berthing space for additional Mission Package support personnel. This conversion required the addition of a hangar onto the existing ship's superstructure as well as the addition of a large mission bay. The mission bay is a vertical extension of the aft boundaries of the ship, raising the flight deck by 16 feet.

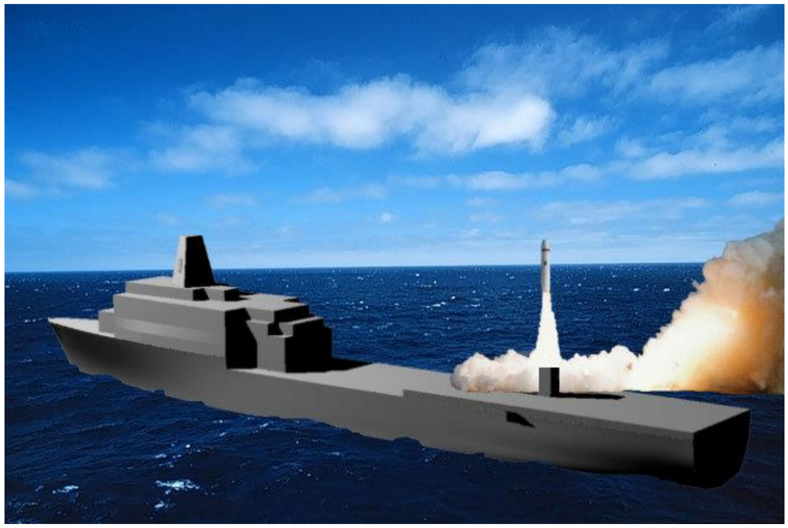
The design project resulted in a ship capable of housing all seventeen possible LCS mission modules currently existing for the ASW, SUW, and MIW mission packages. Furthermore, there was no significant effect on the draft, displacement, list, or trim of the baseline ship. The converted ship will have the ability to execute missions that are currently intended for the LCS, as well as have the modularity to adapt to future mission packages while maintaining the seakeeping and stability characteristics of the original ship.

		DDG (Flt 1)	**Conversion Design**			**Max**
		Class Avg	MIW	ASW	SUW	**Difference**
Disp	**(LT)**	8956	8961	8963	8921	0.39%
KG	**(ft)**	25.17	25.57	25.55	25.47	-1.59%
GM	**(ft)**	4.65	4.25	4.27	4.36	8.60%
LCG	**(ft-FP)**	234.24	235.58	235.76	235.05	-0.33%
Avg Draft	**(ft)**	21.35	21.32	21.32	21.28	0.33%
Trim	**(ft)**	0.4 (A)	0.26 (A)	0.35 (A)	0.05 (A)	0.35 ft (4.2 in)
Heel	**(°)**	0	0.50 (P)	0.70 (P)	0.97 (P)	0.97º

The cost analysis, based on the MIT cost model, estimates a total conversion cost of $58.37M (FY2008$).

LSD-41 to Ballistic Missile Test & Evaluation Platform (Conversion)

LT Joseph Darcy, USN, LCDR Greg Elkins, USN, LCDR Jeremy Leghorn, USN



The Ballistic Missile Test and Evaluation (BMT&E) ship conversion study provides a practical method of testing our nation's current and future Ballistic Missile Defense (BMD) capabilities. BMD consists of layers of overlapping defenses that protect against incoming ballistic missiles in the boost, midcourse, and terminal phases of flight. Defensive measures are currently executed from land based, sea based, and airborne platforms each having a specific phase of flight that can be defended against. As testing progresses it is imperative to be able to launch test missiles from different geographic areas to ensure acceptable defensive effectiveness no matter where a potential ballistic missile may be launched from. The BMT&E platform will be able to accomplish test missile launches from differing geographic areas and allow all current and future BMD systems to assess their kill effectiveness.

An emphasis will be placed on the US Navy's role in BMD. Currently, the Navy has 10 Destroyers and Cruisers participating in BMD. These ships are AEGIS equipped with Standard Missile-3 Interceptors (SM-3) and have the capability to provide short to intermediate range defense in the midcourse phase. Current ships are S-band capable which allows early warning and Long Range Surveillance and Tracking (LRS&T) capabilities for Inter-Continental Ballistic Missiles (ICBM). The tracking data is transmitted to ground based defense systems to allow for ICBM defense. The next generation of Destroyers will also have X-Band capabilities and will ideally provide a sea based BMD system that can defend against any ballistic missile in the ascent/boost or midcourse phase. The BMT&E platform will have a dual band radar (X and S band) as well as AEGIS systems to allow for testing of future BMD systems. This will ensure the effectiveness of the next generation of Destroyers and Cruisers in their BMD roles.

The main focus of the conversion is to ensure the capability exists to test any phase of BMD systems for the next 10 years. The addition of electrical generating capacity will allow for a dual band radar as well as ensuring electrical capacity for systems to be tested in the future. AEGIS upgrades in the control room will ensure the BMT&E ship will have the same capabilities as the next generations of US Naval warships. The missile launch platforms will be built with a focus towards modularity as well as safety to allow for efficient testing. The ship's geometry is unchanged from that of the LSD 41. The BMT&E ship was found to be stable for all loading conditions. The MIT math model along with NAVSEA-05C cost data estimates a BMT&E ship conversion cost of $104M (FY 2008$).

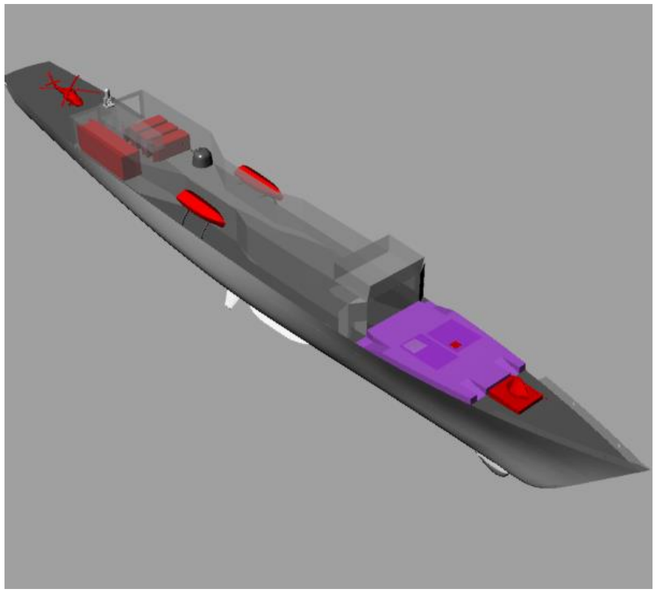
Principal Characteristics	
LBP (ft)	580
Hull LOA (ft)	608.7
Beam, DWL (ft)	84
Depth at STA 10 (ft)	53
Draft to Keel, DWL (ft)	19.5
GMt (ft)	8.1
Cp	0.604
Cx	0.946

Loading Comparison		
	LSD 41	BMT&E
Lightship Displacement (LT)	11041	11104
Full Load Displacement (LT)	15855	16127
Deadweight (LT)	4814	5023

Cost	
Conversion Cost	$104.1M
Annual Operating Cost (over 10 years)	$241.0M
Total Life Cycle Cost (2008)	$345.1M

FFG-7 to LCS Mission Module Carrier (Conversion)

LCDR Keith Douglas, USN, LCDR Josh LaPenna, USN,
CDR Mitch Stubblefield, USN



Due to cost over runs and contract disputes, the LCS program has experienced major delays in its full integration into the Fleet. Because of this anticipated delay, it is prudent for the Navy to consider other options for filling the existing capability gaps. Pre-existing modular mission packages (MMP), which are the keystone to the LCS program have already been well defined and are nearing completion. Given the current state of the LCS program and the maturity of the packages, placing an MMP on an existing host platform is worthy of serious consideration. A team of three individuals at Massachusetts Institute of Technology (MIT) was tasked with determining a strategy and the modifications required to enable an FFG 7 hull to effectively employ an LCS MMP.

The team's strategy involved determining a sound overall approach to address issues such as MMP selection and reconfigurability. The modification portion involved the engineering required for the conversion and the analysis of the results. Deliverables from this study include the conversion strategy, applicable drawings, stability, strength, and sea keeping analysis, as well as a cost estimate.

The design team determined that the focus of this study was on converting the FFG 7 to accept the LCS Surface Warfare (SUW) mission package. The mission package must be able to be installed and removed relatively quickly. The only modification of any type to the package was that only one of the two 30mm guns was accommodated. The existing CIWS Block 1B organic to the FFG 7 substitutes as the other 30mm gun.

Results of this study indicated that the LMP frigate is fully capable of executing the SUW mission in littoral waters with high success in a low to medium threat environment scenario. Although the FFG 7 can be modified to employ the SUW mission package, other missions such as the mine warfare (MIW) and anti-submarine warfare (ASW) would be more challenging. Although not performed during this study, future concept explorations could include modified ASW and MIW packages.

Characteristic	**Converted FFG 7**	**Littoral Combat Ship**	
		Threshold	Goal
Speed	29 kts	40 kts	50 kts
Endurance Range	4100 nm	3500 nm	4300 nm
MP Payload	185 MT	180 MT	210 MT
MP Type	SUW	SUW, MIW, ASW	
Draft (navigation)	26 ft	20 ft	10 FT
Manning	217	100	75
Helo/UAV Ops	SS5	SS4	SS5
Watercraft Ops	SS4	SS3	SS4
Provisions	28 days	14 days	21 days
MP Change out	2 days	4 days	1 day
Procurement Cost	$25.6M	$220M	$150M

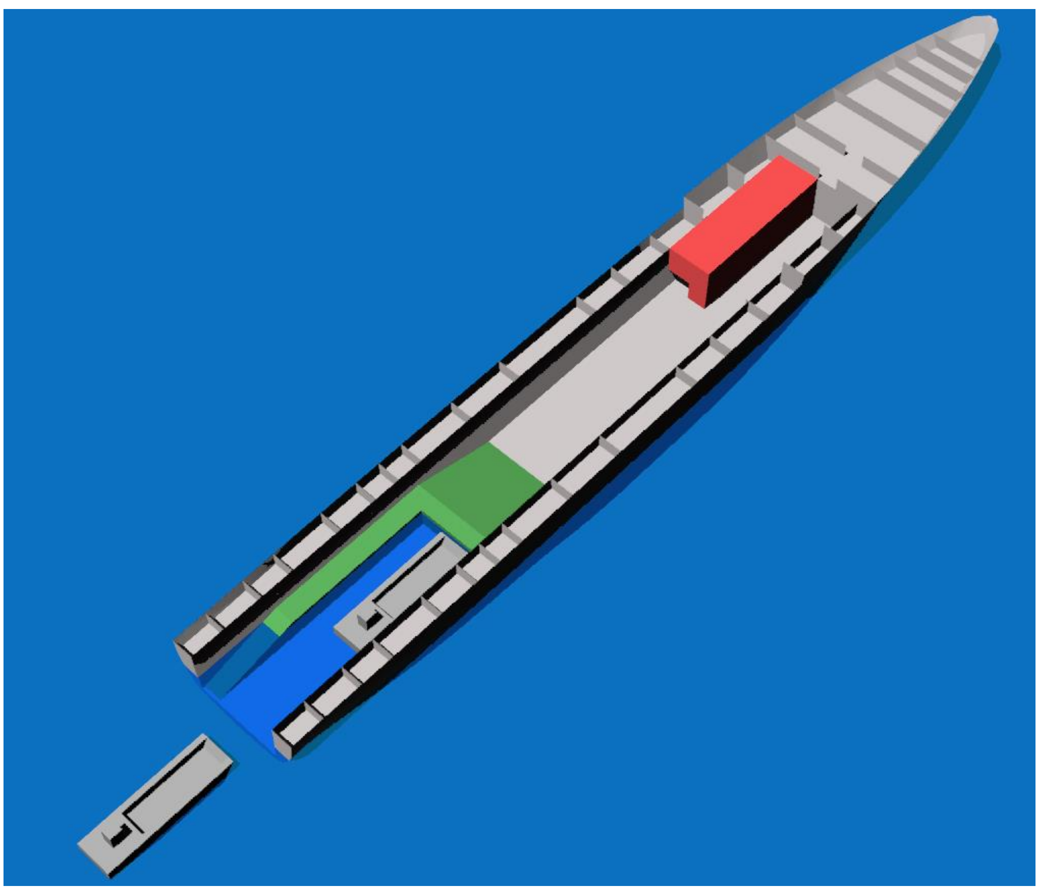
LSD-41 to Hospital/Naval Construction Ship (Conversion)

LTJG Alexandros Michelis, HN, LTJG Matthew Smith, USCG, Lt(N) Simon Summers, CF

The MERCY class hospital ships of the United States Navy (USN) are nearing decommissioning, and a number of replacement concepts are being considered. A proposed replacement plan is to convert currently serving amphibious ships that are also nearing decommissioning, but which have significant serviceable life remaining. This would result in a low replacement cost while providing the amphibious capability that is considered highly beneficial when transporting casualties. Further to this, the concept of operations for hospital ships is being considerably revised. Whereas the purpose of the existing ships is to act as a floating hospital providing relatively long-term care for a large number of patients, it is recognized that these ships are seldom, if ever, employed in this capacity. During future combat operations, it is anticipated that hospital ships will serve as short-term facilities for the stabilization of casualties before transport by air to more extensive facilities removed from the operational theatre. The result is a reduction in the capacity and capability required of future hospital ships relative to the MERCY class ships. Also, it is recognized that these hospital ships are likely to be deployed on humanitarian missions in order to assist in the response to foreign and domestic crises while enhancing the image of the United States and of the USN. As such, it has been proposed that future hospital ships carry a Naval Construction Force detachment in order to give the ability to rebuild infrastructure in situations of humanitarian crisis.

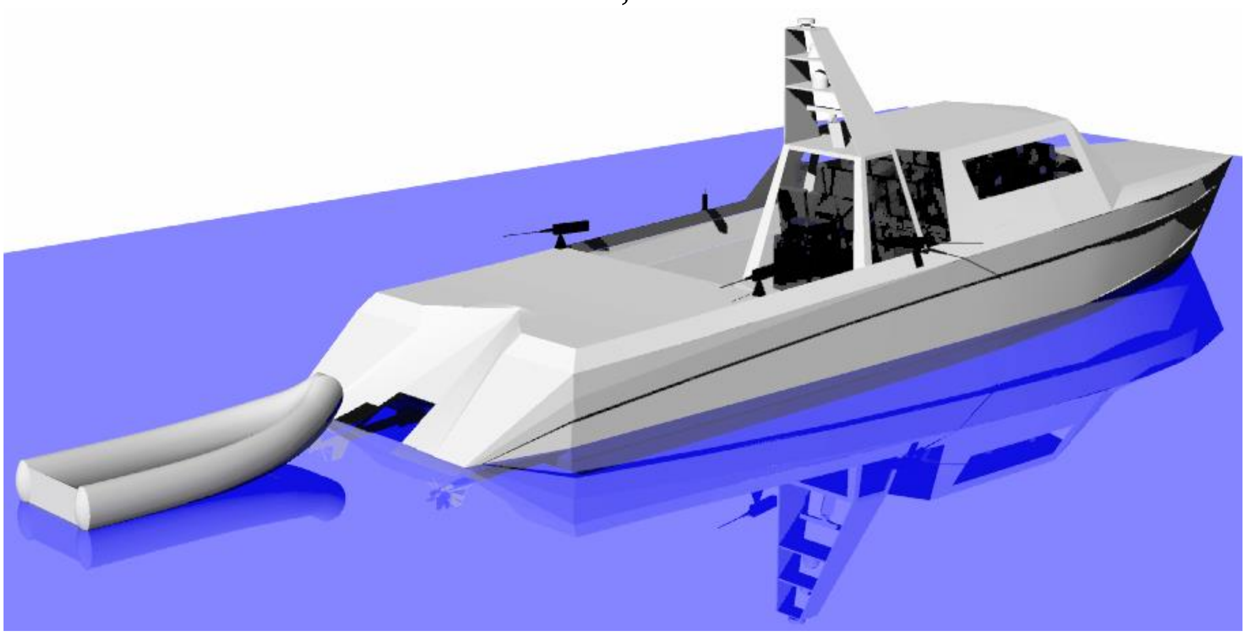
This conversion builds on a prior design in which the LSD-41 class ship was converted to a hospital ship. The current design incorporates a smaller ship-borne medical facility, a small mobile medical facility, and a significant Naval Construction Force detachment, as well as accommodations for a large contingent of command, civilian, and host-nation personnel. The design was considered broadly feasible, with at least the minimum values of all requirements achieved. However, in order to prove the design, more detailed analysis of a number of issues would be required, particularly concerning both weight and structural strength. The table below summarizes the characteristics and capabilities of the converted ship.

SHIP CHARACTERISTICS	
Displacement, Full Load	15929 lt
Length Between Perpendiculars (LBP)	580 ft
Length Overall (LOA)	610 ft
Beam	84 ft
Draft, Full Load	19.95 ft
MISSION CAPABILITIES	
Hospital Beds	133
Operating Rooms	4
Isolation Ward Beds	19
Mobile Medical Facility Beds	25
Naval Construction Force	19 items
ORGANIC VEHICLES	
CH-53E Helicopter	1
LCM-8 Amphibious Boat	2
Medical Tender	2
COST	
Total Conversion Cost, FY08 $	128.7M



MK-V S.O.C. Replacement Vessel

LT WILLIAM L. HAGAN III, USN; LT COLIN DUNLOP, USN; LT BENJAMIN HAWBAKER, USN



Events over the past seven years have produced a new breed of enemy, capable of unconventional operations in more restrictive waters. This new mode of operation requires the U.S. Navy to shift towards designs and a shipbuilding posture capable of fulfilling operations in the littoral areas rather than on the open ocean. To that effect, the Navy must build smaller, faster, and more versatile vessels to accomplish the mission of larger ships.

Over the past fifteen years the MK-V Special Operations Craft has proved to be a lethal component in the U.S. Navy's arsenal. However, the MK-V was originally designed with a fifteen year service life and in desperate need of replacement due to increasing maintenance cost and operator injuries. Programs launched in recent months illustrate the government's recognition of this issue; 1) a $10 million contract to rebuild the MK-V power plants and 2) a Maine shipyards bid to build a replacement including their launch of a new carbon fiber composite hull.

This study addresses new technologies and applications available to fulfill the current need as well as completing the current MK-V's mission with increased reliability, speed, and efficiency. The study considered different hull forms, engine configurations, propulsion systems, and armament in order to construct a vessel that meets or exceeds the needs of today's special operation forces with room for future expansion.

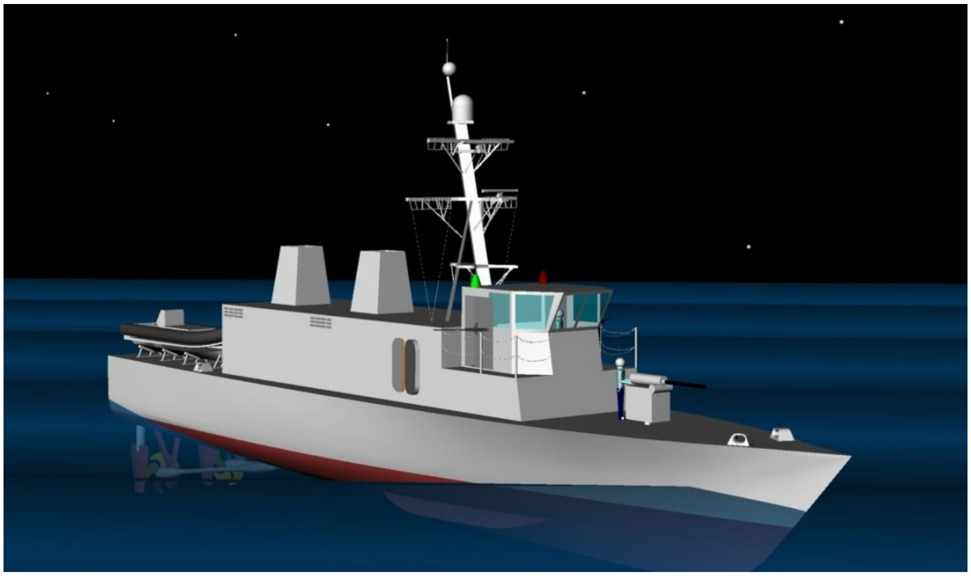
The final MK-V Replacement Craft design is built on a 70.3 feet long catamaran hull that is C-17 Globemaster transportable with a maximum draft of 3.1 feet allowing it to operate in even the most restrictive waters. The vessel is capable of a 500 nautical mile range and a top speed in excess of 55 knots in sea state two. The MTU 8V396 engines are coupled to Arneson Surface Drives for increased maneuverability, reduced appendage drag, and better fuel efficiency.

This design is expected to save the Navy thousands of dollars each year in operating and maintenance expenses, while eliminating shock injuries to the operators and providing special operations forces with a more capable and stable platform.

Design Dimensions		
Full Load Weight	94985	lbs
Light Ship Weight	83755	lbs
Length Overall	70	ft
Waterline Length	64	ft
Demi-hull Separation	4.5	ft
Demi-hull Beam	6.5	ft
Engine Selection (2x)		
MTU 8V396	1501	hp
Fuel Required (Diesel)	11,230	lbs
Arneson Surface Drive (ASD-14)	8,500	ft-lbs
Weapons Outfit		
M 60	7.62	cal gun
M 240	7.62	cal gun
M 2	0.50	cal gun
MK 19	40	mm Grenade
FIM-962	MANPAD	Missile
M 224	60	mm Mortar
Performance		
Top Speed	57	knots
Cruise	35	knots
Design Cruise Sea State	3	
Manning		
Crew (minimum)	3	
Special Forces Personnel	16	
Additional Seating	2	
Equipment / Furnishing		
Hospital bunks	2	
Payload Margin	7,000	lbs
Combat River Raiding Craft	4	

Sub-Sahara: Security and Support Vessel

LT Perry Branch, USN, LT Ashley Fuller, USN, LT Andrew Gillespy, USN



The Sub-Sahara security platform (Waterborne Patrol Craft Security or WPCS) will fill an emerging gap in the security of coastal African nations and be instrumental in the continued success in long-term prosecution of the Global War on Terror. Multiple sources, including the *Seafarers Assistance Program* and *The Standard,* report that over 150 hostages were taken from the Sub-Saharan region in the first half of 2006. Statistics like these highlight one of many security deficiencies in this region. The WPCS will fill this growing security gap by enhancing maritime security and combating terrorism. Additionally, this platform will address coastal natural resource security, official coastal replenishment needs and humanitarian evolutions such as non-combat evacuation, coastal interdiction and rescue. The Concept of Operations (CONOPS) for this platform is unique in the fact that the ship will cover an unconventionally wide spectrum of operations and support a multinational array of stakeholders. The platform will also strike a balance between technical flexibility and maintainability. Therefore, the WPCS will weight operational robustness over advanced technology employment. The target date for integration, training and employment in the Sub-Sahara region is FY-10.

Through detailed gathering of customer needs and directly mapping those needs to missions, the design team was able to build a ship that fulfilled the requirements of customers throughout the life cycle. The mission statements were further mapped to engineering requirements for the ship design. The WPCS was then designed using a combination of the Pugh Concept Selection Methodology and Design of Experiments. Pugh was used to narrow down the larger concepts such as hull type, screw arrangement and prime mover type. Once the larger concept decisions were set the team used design of experiments (DOE) to establish clarity on the final design variables. DOE provided the team with functional descriptions of how the control variables affected the response variables of performance, cost and complexity.

Most importantly, the process resulted in a ship that has the ability to meet the original stakeholder needs and the likely complex array of required employment scenarios in the region. The design team conducted a thorough review of all the missions for the WPCS and determined that the ship was satisfactory in each one. In addition, because of the thorough design approach, the design team is confident that the resultant ship provides the customer true value for their purchase. The ship is an optimized package designed to meet the customer needs affordably and efficiently.

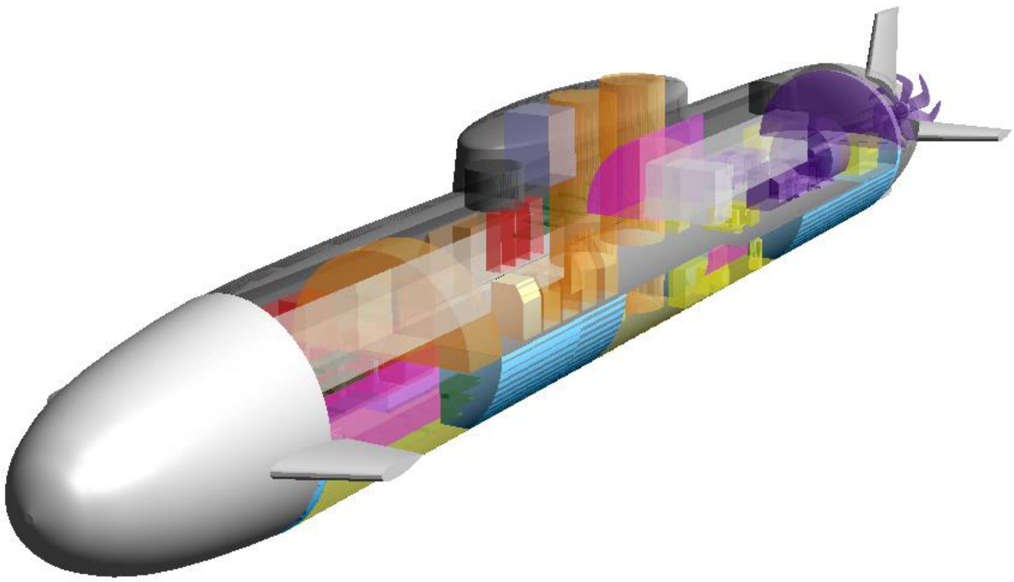
Principle Characteristics	
Full Load Displacement	201 LT
Design Draft	7.7 ft
Length Overall	116.4 ft
Hull Form	NPL High Speed Round Bilge
Performance Characteristics	
Maximum Speed	23 knots
Mission Endurance	7.3 days
Range	878 nm
Powering and Electrical	
Propulsion Engines	(2) Niigata FX 12V16 – 2240 BHP
Electrical Engines	(2) MTU 6V331 – 400kW
Mission Outfitting	
Primary Weapons	Mk 38 25mm gun
Secondary Weapons	(6) 0.50 caliber mounts
Armor	0.25" steel hull plus additional 0.25" above waterline
Environmental Cleanup	250m of boom, capability to clean up 95% of 3000 gal oil spill contained within boom, can deploy biological agent to breakdown oil
Passenger Area	Carry up to 10 passengers
Radar	Bridgemaster E Series X and S band
C4I System	GCCS-M to TADIL integration equivalent
Communications	IFF, IMARSAT, AN/WSC-3, AN/URT 23E R2368(A)
Cost	
Acquisition Cost	$27.9M

Conventional Littoral Strike Submarine

Through Paramarine™ -aided Design

LTJG Kyriakos Avgouleas, HN, LCDR(s) Richard Jones, USN,

LCDR Ethan Proper, USN



Future submarine operations will require a submarine with strike capability beyond that of the submarines in the current inventory. The Littoral Strike Submarine (SSL) will fill the gap between the Virginia class submarines, which are limited in the strike role to carrying Tomahawk cruise missiles and the deep draft SSGNs. The SSL will operate primarily in littoral waters providing rapid strike capabilities to forces on shore. The SSL will also provide NATO allies with strike capabilities as well as enhanced covert troop delivery.

Design Goals and Thresholds

Design Parameter	Threshold	Goal
Operating Depth	200m	300m
Speed	12 kts	21 kts
Range (@ 10 kts)	3000 nm	5000 nm
Endurance	10 days	14 days
Crew (Off/Enl)	6 / 24	6 / 31

The top level architecture was determined by a Pugh analysis. The key parameters for the SSL were large diameter, vertical payload tubes located centrally in the submarine, and a body of revolution hull form with parallel mid-body. Paramarine™ was chosen as the design tool for this project and was used to perform the design and analysis of the submarine.

Final Design Summary

Design Parameter	Final Value
LOA	57.4 m (188.2 ft)
Beam	6.72 m (22 ft)
Submerged Displacement	1894 LT
Surface Displacement	1684 LT
Max. Submerged Speed	22.1 knots
Operating Depth	200m
Crew Size	6 officers / 25 enlisted
Endurance	12 days without snorkeling
Cost	$471.7 Million

The SSL incorporates design features which are unconventional in traditional designs. The first of these is a removable composite sail which allows the sail to be removed during extended maintenance availabilities, greatly improving access to equipment in the sail and for preservation of the area within the sail. Another was the high level of automation incorporated in the operating systems to allow a reduction in the crew size while enhancing mission capability. Lastly, large diameter payload tubes are included in a non-nuclear submarine allowing a wide variety of payloads to be carried.

The analysis conducted on the SSL indicates that the SSL will meet all design thresholds and satisfies the requirements of the Initial Capabilities Document.

Optimal Ship Routing

LTJG Kyriakos Avgouleas, HN

Prof. Paul D. Sclavounos
Thesis Supervisor

Fuel savings in ship navigation has always been a popular subject in the maritime industry as well as the world's largest Navies. Oil prices and environmental considerations drive the effort for more fuel-efficient navigation. This thesis addresses the problem of deterministic minimum fuel routing by applying optimal control theory in conjunction with state of the art hydrodynamic and weather forecasting tools.

A fictitious cross-Atlantic route is defined and the optimal combination of speed and heading is determined, so that fuel consumption is minimized while certain safety constraints are met. The safety constraints are postulated as the probabilities of slamming and deck wetness, both of which are not allowed to exceed prescribed limiting values. The problem formulation adopted in the thesis lies in the framework of Dynamic Programming, which is most suitable for computer implementation.

The hydrodynamic performance of the ship is computed through the use of SWAN1, an advanced frequency domain CFD code. With the aid of SWAN1, ship motions and resistance can be accurately calculated. The latter includes the estimation of mean added resistance in waves, which has a major effect on the fuel consumption of ships sailing in rough seas. Wave and swell forecasts are provided in a deterministic setting by a third generation numerical wave model, the WAM cycle 4, developed at the European Center for Medium-Range Weather Forecasts (ECMWF). Utilizing the hydrodynamic results and the output of the wave model a computer program was developed in MATLAB®, which employs the Iterative Dynamic Programming algorithm to solve the optimal control problem.

Development of Real Time Non-Intrusive Load Monitor for Shipboard Fluid Systems

LT Perry L. Branch, USN

Prof. Steven B. Leeb	.Robert W. Cox	Patrick Hale
Thesis Supervisor	Thesis Supervisor	Thesis Reader

Since the year 2000, the United States Navy has spent an average of half a billion dollars over the congressionally approved budget for shipbuilding. Additionally, most experts project that in order to meet the Chief of Naval Operation's goal of a 313 ship Navy, the annual ship building budget will have to increase by about two thirds. Exacerbating this problem is the rising cost of maintaining the current inventory of ships. The U.S. Navy has long used a requirements driven maintenance program to reduce the number of total system failures by conducting routine maintenance and inspections whether they are needed or not. In order to combat this problem the Navy will inevitable have to turn to a condition based maintenance system. The Non-Intrusive Load Monitor (NILM) is a system that can greatly enhance the ability to monitor the health of engineering systems while incurring a low acquisition cost and low technology risk.

This research focuses on the development of a real time user interface for the current NILM architecture in order to provide useful system information to an operator. Additionally, this research has shown that the NILM can be used effectively and reliably, to monitor equipment health, recognize and indicate abnormal operating conditions and casualties and provide invaluable information for the training operators, diagnosing problems and troubleshooting. The NILM is a cheap and proven method of monitoring equipment and reducing maintenance costs.

Modeling Magnetic Core Loss for Sinusoidal Waveforms

LT Colin J. Dunlop, USN

Prof. David J. Perreault	Prof. Charles R. Sullivan
Thesis Supervisor	Thesis Reader

Among the challenging unsolved technical problems that have plagued the minds of scientist and engineers throughout the 20th and 21st century is the development of a quantifiable model to accurately estimate or explain Core Power Losses (CPL). CPL is the input power that is consumed by the magnetic material used in a magnetic circuit. These losses reduce the end users usable power and must be accounted for in system design. To compensate for these losses, large safety factors must be incorporated which result in over-designed systems (motors, generators). If the losses can be accurately modeled, these safety factors could be reduced. As the safety factor decreases, so does the size, weight, and cost of the system.

The outcome of an open-literature review of CPL found that there are many CPL estimation equations, but very little work has been reported that compared these models to actual Power Ferrite data. So, this thesis described and then compared several current CPL models using experimental collected data and then validated the use of several of the terms used in these models. Specifically, the accuracy of the low frequency use of the Hysteresis Loss Equation was investigated and the validity of the use of two independent variables, core area and conductivity, commonly found in many CPL empirical equations, was analyzed.

Spectral Approaches to Non-Intrusive Load Monitoring

LT Ashley Fuller, USN

Prof. Steven Leeb	Pat Hale
Thesis Supervisor	Thesis Reader

The Non-Intrusive Load Monitor (NILM) is a system that monitors, records and processes voltage and current measurements to establish the operating characteristics of individual loads. The NILM can also be used to actively monitor degradation or diagnose specific system failures. Current NILM research conducted at Massachusetts Institute of Technology's Laboratory for Electromagnetic and Electronic Systems (LEES) is exploring the application and expansion of NILM technology for the use of monitoring a myriad of electromechanical loads. This thesis presents a fundamental NILM operation explanation using an "Ideal Machine," concept and demonstrates its potential to detect an array of electric machine failures before they become catastrophic. The NILM's ability to the monitor the current spectrum of electric machines can be used to immediately diagnose multiple common system casualties and detect unusual system operation.

Current versions of the NILM identify loads simply by looking at transient patterns and steady-state power changes. This may not be enough when you're looking at multiple systems. One option that will be investigated is the use of system spectral information. Analogous to the mechanical vibration monitoring, the electrical spectral information presents a greater potential for multi-system remote monitoring and overall cost savings. Measurements and experimentation were conducted in the LEES laboratory and the Industrial Support Center electric shop, Boston.

Integrated Patrol Craft Design

LCDR(s) Andrew J. Gillespy, USN

Richard W. Kimball
Thesis Supervisor

Early stage ship design and assessment continues to be a challenge for naval architects and ocean engineers. The complex and multifaceted interactions between the different components of the ship and the broad spectrum of disciplines required in ship design make it difficult to fully realize the effects of any one change on the entire system. The initial design of smaller patrol craft is especially difficult due to the lack of design tools able to deal with ships of small size operating the semi-planing region. This paper puts forth a method for narrowing the design space for patrol craft design. Using a systems approach, a program was created and tested to aide designers in the initial design and assessment of patrol craft.

Nondestructive Evaluation and Underwater Repair of Composite Structures

LT William L. Hagan III, USN

Prof. James H. Williams, Jr.	Captain Patrick J. Keenan, USN
Thesis Supervisor	Thesis Reader

Composite materials are gaining popularity in U.S. Naval applications because of their unparalleled strength, stiffness, and manufacturing simplicity. A better understanding of the structural integrity of these materials has the potential to reduce overdesign, decrease manufacturing cost, and simplify repairs.

Though underwater nondestructive evaluation of composites has not been well documented, this thesis illustrates the available technologies for underwater evaluation and repair of laminated composite structures, similar to those currently used in marine applications. Dependent on accuracy and reliability of underwater evaluation, the decision to pursue temporary or permanent repairs may be made based on available information regarding the structural integrity of the effected repairs.

Discussion of the environmental effects on composite laminates and their repairs is included to provide insight into the detrimental effects of contaminates such as saltwater and petroleum products. The effect of the environment has a profound impact on the quality of composite repairs using currently available repair materials.

Underwater repairs, whether permanent or temporary, are suggested for future U.S. Navy components such as the DDG-1000 composite twisted rudder. Furthermore, a suggestion is made to eliminate the use of cofferdams on U.S. Navy shaft covering repairs in order to reduce both cost and the risk of injury associated with a cofferdam.

Analyzing the Effects of Component Reliability on Naval Integrated Power System Quality of Service

LT Benjamin F. Hawbaker, USN

Prof. Joel P. Harbour	Pat Hale
Thesis Supervisor	Thesis Reader

The Integrated Power System (IPS) is a key enabling technology for future naval vessels and their advanced weapon systems. While conventional warship designs utilize separate power systems for propulsion and shipboard electrical service, the IPS combines these functions. This allows greater optimization of engineering plant design and operations and leads to significant potential lifecycle cost savings through reduced fuel consumption and maintenance. Traditionally the focus of power system design has been survivability, with the assumption that service continuity was inherently provided. A new probabilistic metric, Quality of Service (QOS), now allows the power continuity and quality delivered to loads to be addressed explicitly during the design of IPS vessels. This metric is based both on the reliability of the power system components and the system architecture employed.

This thesis describes and implements a method for modeling and evaluating the effects of component reliability on the QOS performance delivered by a current generation IPS architecture. First a representative "ship" is created, based largely on the U.S. Navy's *ZUMWALT* class destroyer (DDG-1000), including electrical loads, an operating profile, and Integrated Fight Through Power system architecture. This simulated ship is then run through a reliability analysis model employing Monte Carlo Simulation techniques to evaluate the QOS performance of the power system. By treating the reliability of power system components as a variable, the model gives insight into the role component reliability plays within the given system architecture. A method is then proposed for extending this analysis to comparative studies between future IPS architectures or components, with the ultimate goal of allowing research and development efforts to better focus precious funding and resources on areas with the greatest potential for high-value improvement.

Improving Shipboard Applications of Non-Intrusive Load Monitoring

LCDR(s) Richard Jones, USN

Prof. Steven Leeb	Pat Hale
Thesis Supervisor	Thesis Supervisor

The Non-Intrusive Load Monitor (NILM) measures equipment performance by measuring and analyzing the source power to the equipment at a single point in the electrical system. Previous studies have proven the usefulness of the NILM system in characterizing the state of mechanical systems onboard U.S. Coast Guard vessels and at the U.S. Navy's Land Based Engineering Site (LBES) in Philadelphia, Pennsylvania.

This thesis seeks to improve the NILM system by exploring a more user friendly Graphical User Interface (GUI) to allow shipboard crews to utilize the NILM while in operation. Previous applications of NILM required post-event data analysis in the laboratory. An additional NILM was installed on the Low Pressure Air Compressor (LPAC) #1 at the LBES facility to investigate abnormalities detected in the operation of LPAC #2 by previous research. The ability of the NILM to function at the highest levels of the electrical distribution system was also explored at the LBES facility with the installation of two additional NILM systems on the main switchboards supplying power to the auxiliary system loads. Finally, a brief overview of the analysis software of the Multi-Function Monitor (MFM), a key component in modern ship's Zonal Electrical Distribution Systems (ZEDS), is presented to explore the possibility of the NILM and MFM systems operating in conjunction to improve the operation of future ZEDS.

Minimum Pressure Envelope Cavitation Analysis Using Two-Dimensional Panel Method

LCDR(s) Christopher J. Peterson, USN

Prof Patrick Keenan	Richard W. Kimball
Thesis Supervisor	Thesis Supervisor

An analysis tool for calculating minimum pressure envelopes was developed using XFOIL. This thesis presents MATLAB® executables that interface with a modified version of XFOIL for determining the minimum pressure of a foil operating in an inviscid fluid. The code creates minimum pressure envelopes, similar to those published by Brockett (1965). XFOIL, developed by Mark Drela in 1986, is a design system for Low Reynolds Number Airfoils that combines the speed and accuracy of high-order panel methods with fully-coupled viscous/inviscid interaction. XFOIL was altered such that it reads in command line arguments that provide operating instructions, rather than from the operator via menu options. In addition, all screen output and plotting functions were removed. These modifications removed XFOIL's user interface, and created a "black box" version of XFOIL that would perform the desired calculations and write the output to a file. These modifications allow rapid execution and interface by an external program, such as MATLAB®. In addition, XFOIL's algorithms provide a significant improvement in the accuracy of minimum pressure prediction over the method published by Brockett.

Development of the modified XFOIL and MATLAB® interface contained in this thesis is intended for future interface with *Open-source Propeller Design and Analysis Program* (OpenProp). OpenProp is an open source MATLAB®-based suite of propeller design tools. Currently, OpenProp performs parametric analysis and single propeller design, but does not perform cavitation analysis. Minimum pressure envelopes provide the propeller designer information about operating conditions encountered by propellers. The code developed in this thesis allows the designer to rapidly assess cavitation conditions while in the design phase, and make modifications to propeller blade design in order to optimize cavitation performance.

Automated Classification of Power Signals

LCDR Ethan Proper, USN

Prof. Steven B. Leeb	Robert W. Cox	Patrick Hale
Thesis Supervisor	Thesis Supervisor	Thesis Reader

The Non-Intrusive Load Monitor (NILM) is a device that utilizes voltage and current measurements to monitor an entire system from a single reference point. The NILM and associated software convert the incoming signal into a spectral power envelope which can then be searched to determine if and when an electrical transient has occurred. The identification of this transient can then be determined by an expert classifier, and a series of these classifications can be used to diagnose system failures or improper operation. Current NILM research conducted at Massachusetts Institute of Technology's Laboratory for Electromagnetic and Electronic Systems (LEES) is exploring the application of NILM technology to ship system diagnostics.

This thesis presents the *ginzu* application which implements a detect-classify-verify loop that locates the indexes of transients, identifies them using a decision-tree based expert classifier, and generates a small descriptive *event file*. The *ginzu* application provides a command-line interface between streaming pre-processed power data (PREP) and a separate graphical user interface. This software was developed using thousands of hours of archived data from the Coast Guard Cutters ESCANABA (WMEC-907) and SENECA (WMEC-906). A validation of software effectiveness was conducted through the real-time application of the NILM system onboard USCGC ESCANABA.

Numerically-Based Ducted Propeller Design Using Vortex Lattice Lifting Line Theory

CDR John M. Stubblefield, USN

Richard W. Kimball	Prof. Patrick J. Keenan
Thesis Supervisor	Thesis Supervisor

This thesis used vortex lattice lifting line theory to model an axisymmetrical-ducted propeller with no gap between the duct and the propeller. The theory required to model the duct and its interaction with the propeller were discussed and implemented in *Open-source Propeller Design and Analysis Program* (OpenProp). Two routines for determining the optimum circulation distribution were considered, and a method based on calculus of variations was selected. The results of this model were compared with the MIT Propeller Lifting Line Program (PLL) output for the purpose of validation.

Ducted propellers are prevalent in modern marine propulsion systems, and the application of this technology continues to expand. The theory associated with ducted propellers applies to a wide-range of devices which include azimuth thrusters, pumpjets, and tidal turbines. Regardless of the application, engineers need tools such as OpenProp to design these devices for their expected operating conditions. OpenProp is an open source MATLAB®-based suite of propeller numerical design tools. Previously, the program only designed open propellers. The code developed in this thesis extended OpenProp's capability to be able to design a propeller within an axisymmetrical duct.

Redesign and Shock Analysis of HALIFAX Class Frigate Gas Turbine Uptake Structure"

Lt(N) Simon Summers, CF

Prof. Thmasz Wierzbicki
Thesis Supervisor

The gas turbine exhaust uptakes of the HALIFAX class frigates of the Canadian Navy have experienced thermally-induced fatigue cracking since soon after the commissioning of these ships. The uptake structure is heavily stiffened in order to meet shock resistance requirements. Unfortunately, the result has been that thermal expansion of the uptake shell is constrained, thus every flash-up and shut-down of a gas turbine results in a fatigue cycle of its uptake with extremely high stresses. Among the methods proposed to address the problem is the structural redesign of the uptakes within the constraints of the original mounting arrangements. Any such redesign would be required to reduce thermal stresses while still meeting the shock resistance requirements. This work presents the redesign of the uptakes such that they continue to meet shock requirements while incorporating design aspects, developed in the literature, which are anticipated to reduce thermal stresses. The original intention was to use the modal-based design response spectrum method to assess shock resistance. However, due to excessive stresses in the original model and in all subsequent modifications using this method, the less-rigorous base acceleration method was primarily used.

Notes: