Naval Construction and Engineering
Ship Design and Technology Symposium

Wednesday, May 13, 2009

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

0800 – 0900 Registration and continental breakfast

0900 – 0915 Welcome and Opening Remarks
- CAPT Mark Welsh, MIT Naval Construction and Engineering Program Director
- Professor Michael Triantafyllou, Associate Head and Director of Center for Ocean Engineering, Department of Mechanical Engineering, MIT

0915 – 1015 Research Briefs – *Non-Intrusive Load Monitoring*
- Professor Steven Leeb, MIT
- LCDR Jeremy Leghorn, USN
- LCDR Keith Douglas, USN

1015 – 1100 Break and Poster Sessions (Ship Conversion Design Projects and Theses)

1100 – 1200 Year-long Design Project Brief and Discussion – *Tug and Salvage Ship Replacement*
- LCDR Joshua LaPenna, LCDR Keith Douglas, LCDR Jeremy Leghorn, LT Joseph Darcy

1200 – 1330 Lunch Buffet and Keynote Address
- Mr. Jeffrey Geiger, President, Bath Iron Works Corporation

1330 – 1430 Research Briefs – *Strength and Failure of Stiffened Plates and Cylinders*
- Professor Tomasz Wierzbicki, MIT
- LTJG Matthew Mothander, USCG
- LCDR Joshua LaPenna, USN

1430 – 1530 Break and Poster Sessions (Ship Conversion Design Projects and Theses)

1530 – 1630 Year-long Design Project Brief and Discussion – *Littoral Combat Ship and Coastal Patrol Craft*
- LCDR Kevin Flood, LCDR Rocky Beaver, LCDR Greg Elkins, LT Alexandros Michelis (Hellenic Navy)

1630 – 1700 Endnote Address and Closing Remarks
- Visiting USN Flag Officer (TBD)
- CAPT Mark Welsh, MIT Naval Construction and Engineering Program Director

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, Chilean, Israeli, Turkish and Canadian navies and U.S. Coast Guard in the program. Officer students are admitted, and Navy faculty members are appointed, through normal MIT procedures. The program is a model of voluntary collaboration for the mutual benefit of MIT and the Navy.

Jeffrey S. Geiger

President General Dynamics Bath Iron Works

Jeffrey S. Geiger became president of General Dynamics Bath Iron Works on April 1, 2009 after being elected by the General Dynamics Board of Directors as a vice president of the corporation on March 4, 2009. He is the 13th president of Bath Iron Works.

Mr. Geiger received a B.S.E. Degree in Naval Architecture and Marine Engineering from the University of Michigan in 1983 and was awarded an M.S.E. in Naval Architecture and Marine Engineering, Ship Production Specialization, at the University of Michigan in 1984.

Mr. Geiger joined Bath Iron Works in 1984. He has held a number of positions with increasing responsibility since beginning as a Production Planner.

Following participation in a company-sponsored, two-year management development program, he was appointed to the position of Manager, Production Engineering.

He later moved into the position of Assistant Director, Production Control, where he managed facility plans, production product scheduling and statusing, manpower planning and analysis.

Mr. Geiger then became Foreman of the Sheet Metal Department, managing all trade personnel, trade planning, and installation functions for AEGIS Cruisers and Destroyers.

Further progression took him to the position of Director, Manufacturing Engineering.

In March of 1993, Mr. Geiger assumed the position of Vice President of Engineering with responsibility for all engineering, design, and logistic support functions. In 1995, he assumed additional responsibility for the Material Procurement organization.

In 2000, Mr. Geiger assumed the position of Vice President of Operations. In this capacity, he had responsibility for all Manufacturing and Facilities functions. In 2004, he assumed additional responsibility for the Planning and Quality Control organizations. This included administrative responsibility for approximately 5,000 employees.

In 2007, he was appointed Senior Vice President of Operations assuming additional responsibility for the Strategic Planning, Communications, and Business Development organizations.

In March of 2008, he assumed additional responsibility as Senior Vice President of Operations and Vice President of Engineering, including the detailed design development for DDG 1000. In January 2009, he was named Senior Vice President of Operations and Engineering.

Mr. Geiger is presently a member of the Executive Control Board of the National Shipbuilding Research Program and has served as a National Advisory Board member for the Naval Architecture & Marine Engineering Department of the University of Michigan. He is also on the Board of the United Way of MidCoast Maine.

Mr. Geiger lives in Bath with his wife, Margie, and their two children, Carlie and Colin.

Mary C. Boyce

Gail E. Kendall Professor of Mechanical Engineering
Head of Department

Professor Mary C. Boyce is the Gail E. Kendall (1978) Professor 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 18 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, and Fellow of the American Academy of Arts and Sciences.

Michael S. Triantafyllou

Currently William I. Koch Professor of Marine Technology, Associate Head and Director of the Center for Ocean Engineering, Department of Mechanical 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. 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, 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).

Tomasz Wierzbicki

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-orientated 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*.

Steven B. Leeb

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. A major thrust in his current research is the development of power electronic drives and supplies for servomechanical and industrial applications, including medical drug delivery devices, battery chargers, motion controllers and fluorescent lamp ballasts. Another research interest related to power quality issues and on-line machine diagnostics involves the development of a Nonintrusive Load Monitor (NILM). The NILM determines the operating schedule of the major electrical loads in a commercial or industrial building from measurements made solely at the electrical utility service entry. He is currently working to develop the NILM into a virtually sensorless platform to determine power quality, perform critical load diagnostics, and monitor manufacturing processes and actuator performance on ships, aircraft, automobiles, and satellites. He is the author or co-author of over 70 publications and 13 US Patents in the fields of electromechanics and power electronics

Captain Mark S. Welsh, USN

Captain Welsh was appointed Professor of the Practice of Naval Construction and Engineering at Massachusetts Institute of Technology in July 2008. He is the Director of the Naval Construction and Engineering program, commonly called the 2N program, within the Mechanical Engineering Department at MIT.

Captain Welsh was born in East St. Louis and raised in Keyesport, Illinois. He enlisted in 1978 in the U.S. Navy nuclear power program. As a second-class Electrician's Mate (EM2), he was selected for the two-year NROTC program and attended the University of Missouri-Columbia. He received a Bachelor of Science in Electrical Engineering and was commissioned an Ensign in the Engineering Duty Submarine Option program.

He completed Submarine Officer Basic School and served on USS SNOOK (SSN 592). After completing Submarine Warfare qualifications, he transferred to the Engineering Duty community and reported to Massachusetts Institute of Technology. Captain Welsh graduated from MIT earning the degrees of Naval Engineer and Master of Science in Electrical Engineering and Computer Science.

Captain Welsh completed his Engineering Duty qualification at Portsmouth Naval Shipyard where he served as Ship Superintendent for the overhaul of USS SAND LANCE (SSN 660), Senior Ship Superintendent for the refueling overhaul of USS L. MENDEL RIVERS (SSN 686), and Docking Officer.

His subsequent assignments include: Deputy R&D Manager for the VIRGINIA class Submarine Program Office; Associate Professor of Naval Construction & Engineering in the Ocean Engineering Department at MIT; Deputy Director, Naval Sea Systems Command Submarine Advanced Development Division; Program Manager for the Navy’s next generation large-scale research vehicle, CUTTHROAT (LSV 2); Ohio Class SSGN Program Technical Director; and Director, Engineering Duty Officer Assignment Branch and Engineering Duty Officer Community Manager at the Naval Personnel Command. Prior to his appointment at MIT, he served four years as Commander, Naval Surface Warfare Center, Crane Division in Crane, Indiana.

Captain Welsh is a member of several professional societies. His personal awards include the Legion of Merit, the Meritorious Service Medal (3 awards), the Navy Commendation Medal (2 awards), and the Navy Achievement Medal (4 awards).

Captain Welsh married Katherine Sue Stack of Edwardsville, Illinois in 1978 and they currently reside in Clinton, MA. They have two daughters; Heather, a Registered Nurse and graduate of George Mason University and Holly, an Environmental Scientist and graduate of Virginia Tech. They also have six grandchildren.

Commander Trent R. Gooding, USN

Commander Gooding was appointed Associate Professor of the Practice of Naval Construction and Engineering at the Massachusetts Institute of Technology in September 2008. He serves as the Academic Officer for the Naval Construction and Engineering program (Course 2N) within the Mechanical Engineering Department at MIT.

Born in Owosso, Michigan, and raised in central Michigan, he entered the United States Naval Academy in 1990. He graduated with distinction in 1994, receiving a Bachelor of Science in Ocean Engineering, and was commissioned an Ensign in the Special Operations community.

Following Surface Warfare Officers School in Newport, Rhode Island, he completed the Basic Diving and Salvage Officer courses in Panama City, Florida. Next, he was assigned to USS BEAUFORT (ATS 2), homeported in Sasebo, Japan, where he served as Assistant Operations Officer until decommissioning in March of 1996. He transferred to USS PATRIOT (MCM 7), also homeported in Sasebo, and served as Combat Information Center Officer, Damage Control Assistant, and Operations Officer from May 1996 to May 1998.

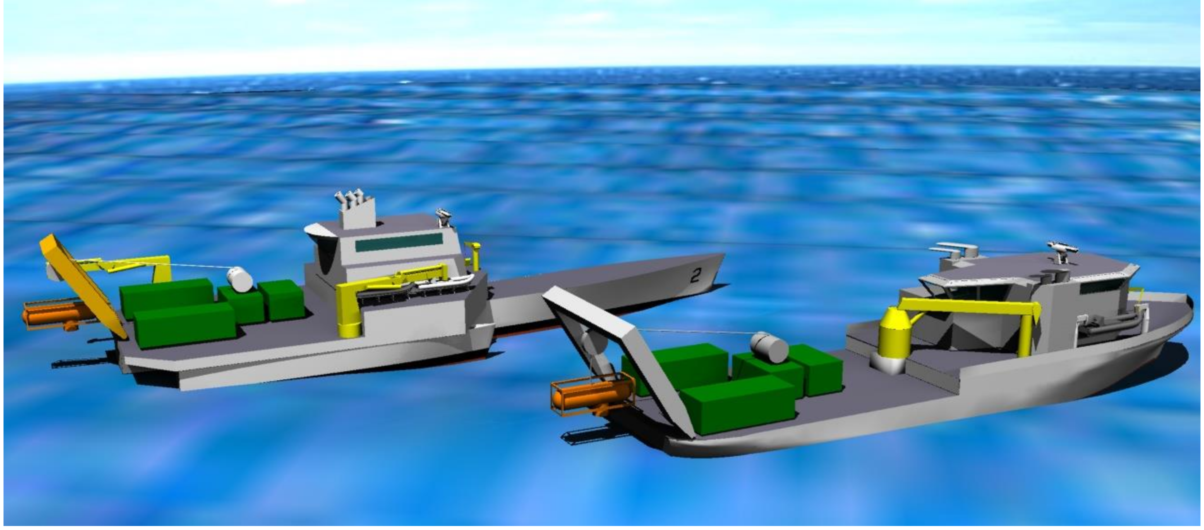
After completing Surface Warfare and Special Operations qualifications, he was accepted for lateral transfer to the Engineering Duty community and, subsequently, was accepted to the Naval Construction and Engineering program at MIT. He graduated from MIT in January 2001 with degrees in Naval Construction and Engineering and Ocean Systems Management. During his next assignment at Puget Sound Naval Shipyard in Bremerton, Washington, he managed nuclear submarine overhauls, served as shipyard docking and diving officer, and completed the Engineering Duty Officer Qualification Program to become a fully qualified EDO (1440).

From September 2003 to October 2004 he served as 5th Fleet Salvage Officer and AOIC Ship Repair Unit Bahrain, gaining experience in ship voyage repair, diving and salvage during OIF, OEF, and the GWOT. Beginning in November 2004, he worked as Ship Concept Manager and Deputy Ship Design Manager in the Future Concepts and Surface Ship Design Group at the Naval Sea Systems Command (NAVSEA 05D) in Washington, D.C., until assuming his current duties at MIT in June 2008.

Commander Gooding is married to Stacey Marie Pennington of Carson City, Michigan. They have three girls, Alyssa, Leah, and Remi, and reside at Hanscom Air Force Base near Bedford, Massachusetts.

T-ATS(X) Tug and Salvage Replacement Ship Concept Design

LCDR Joshua LaPenna, USN, LCDR Keith Douglas, USN
LCDR Jeremy Leghorn, USN, LT Joseph Darcy, USN



As the useful service life of the Safeguard Class Salvage and Rescue Ship (T-ARS) and Powhatan Class Fleet Ocean Tug (T-ATF) comes to an end, a single, combined towing and salvage ship is being considered as a replacement (T-ATS(X)). An assessment by the United States Fleet Forces Command and the Center for Naval Analyses suggests the procurement of 7-9 additional ships with an initial delivery date of 2019 at a rate of one ship per year to sustain the nation's current salvage and towing capabilities. Both new design and commercial procurement options are being considered.

To meet this challenge, four students enrolled in the 2N Program at the Massachusetts Institute of Technology developed two competing designs to fulfill the T-ATS(X) mission. Employing both traditional and modern age concepts, monohull and trimaran variants were optimized based on cost and mission effectiveness. Technical analyses conducted include: structural integrity, intact and damaged stability, powering, arrangements and seakeeping. Both qualitative and quantitative assessments of risk, cost and effectiveness were also considered. A direct comparison between the two designs revealed the monohull variant as the more favorable ship, meeting or exceeding all Initial Capabilities Document threshold requirements. The low technological risk of a traditional hull form proved to be the dominant factor in selecting the monohull over the trimaran.

T-ATS(X) GENERAL CHARACTERISTICS		
	TRIMARAN	**MONOHULL**
LBP (FT)	263	230
Beam (FT)	93	61
Draft (FT)	15.6	16.7
Displacement (LT)	3021	4041
Sustained Speed (KTS)	20	18
Endurance Speed (KTS)	10	10
Endurance Range (KTS)	12000	12000
Manning	60	60
Bollard Pull (LT)	175	152
Lead Ship Cost ($M)	347	373

Littoral Combat Ship and Coastal Patrol Craft

LCDR Rocky Beaver, USN, LCDR Kevin Flood, USN
LCDR Greg Elkins, USN, LT Alexandros Michelis, HN

For the past several years, the US Navy has been discussing the Littoral Combat Ship or LCS. The Littoral Combat Ship (LCS) is intended to assure sea based access for joint operations by satisfying capability gaps in littoral Mine Countermeasures (MCM), littoral Surface Warfare (SUW) and littoral Anti-Submarine Warfare (ASW), while the in-service Fleet of multi-mission surface combatants continues to dominate in deep water and power projection operations. In addition to these three separate missions, the core capabilities of the ship will be mobility; special operations force; intelligence, surveillance, reconnaissance; maritime interdiction operations; homeland defense; and anti-terrorism force protection. The importance of the LCS to today's Navy cannot be overstated, as it is the center piece of our "313 Ship Navy" that we hope to get to. However, the LCS has been plagued with construction problems and cost over-runs. With the cost of the Navy's current littoral combat ship skyrocketing and its funding in peril of repercussions from Congress, some say the sea service ought to give serious consideration to acquiring cheaper boats that could complement a reduced fleet of larger surface combatants. As a result of the need to fill the Navy's capability gap in non-traditional roles, especially required in the littoral regions, it is the intent of this project to do a complete, from the ground up, design of a Littoral Combat Ship that will be cheaper than the current LCS, as well as design a smaller patrol type vessel based off the baseline LCS that is developed.

This study employed a very unique design methodology. The new LCS was designed around the current LCS Initial Capabilities Document (ICD) with a few modifications. It followed a very traditional design methodology. However, the Coastal Patrol Craft (CPC) was designed without an ICD. It utilized certain modules (main machinery module, auxiliary machinery module, etc.) from the LCS. The hypothesis was that this could lead to significant benefits in engineering, production, and maintenance costs. The downside is that the second ship is somewhat fixed based on the optimization of the LCS. The principle characteristics of each ship are shown in the table below.

The costs associated with this project were calculated in two separate ways. The first way was to use the MIT Cost Model for each ship independently, as if each ship was to be a separate class by itself. The second way was to modify the MIT Cost Model in a manner that would capture the unique design methodology that was employed in for this project. These two different costs were then compared so that the actual savings could be determined. The analysis performed shows that there will exist a 10% procurement cost savings for LCS and that the CPC will cost approximately 15% less than if its design had not leveraged the LCS design. It is envisioned that there will also be savings associated with the lifecycle costs. By having two ship classes that have common types of mechanical equipment, there is likely huge savings in the supply chain, training arena, and shore support. These areas are not easily quantified in our cost model, but they nevertheless will provide a net savings in terms of the lifecycle costs of these two classes of ship.

	Littoral Combat Ship	**Coastal Patrol Craft**
Displacement	2776 LT	1162 LT
Arrangeable Area	34334 ft^2	16998 ft^2
LBP	350 ft	225 ft
Beam	41 ft	34 ft
Draft	12.3 ft	10 ft

Arleigh Burke Class DDG Flight IIA Integrated Topside (INTOP) Conversion

LCDR Jerod Ketcham, USN, LT Matthew Frye, USN, LT Douglas Kroll, USN

With the current number of topside apertures aboard naval platforms, and the rate at which this number is increasing, there is a clear need to focus on the joint development of combined sensor packages. In conjunction with the Office of Naval Research (ONR) and Naval Research Laboratories (NRL), the Integrated Topside (INTOP) Program intends to accomplish this goal through the development of multifunction arrays (MFA). These arrays maximize ship war fighting capability and topside system flexibility, while lowering the overall size, weight, radar cross section (RCS) and cost of topside RF systems. After showing the feasibility of INTOP installation aboard a single class of ship, these organizations can then expend effort in standardizing the conversion process to allow for broad adoption within the Navy.

This conversion study examines the effects of replacing the SPY-1D radar and SHF/EHF communication antennas with three MFAs and two 3-axis gimbals aboard a DDG-51 Flight IIA Arleigh Burke Class Guided Missile Destroyer. The INTOP variant selected for implementation provides the greatest performance value, while minimizing the overall impact to the baseline design. Although a significant alteration to the forward deckhouse is necessary for housing a larger sized array and the additional cooling equipment, the ship's hull shape and equipment configuration below decks does not require direct alteration. Conducting a ship modification in this manner is a technically feasible concept once ship designers develop a practical method for installing the additional electric power necessary to operate the MFAs. As integrating topside radar suites which perform at a high level will remain a priority into the future, follow on research should focus on developing the best method for delivering a higher level of installed power. Once this hurdle is overcome, the INTOP conversion could give the destroyer advantages provided by the INTOP program, as well as supply a good platform for future radar implementation studies.

Ship Characteristics:

Displacement (Full Load): 9276 LT
Displacement (Lightship): 7195 LT
Length Overall: 497 ft
LBP: 471ft GM_t: 2.7 ft
Beam: 59 ft   Draft: 20.7 ft
Cp: 0.615   Cx: 0.822

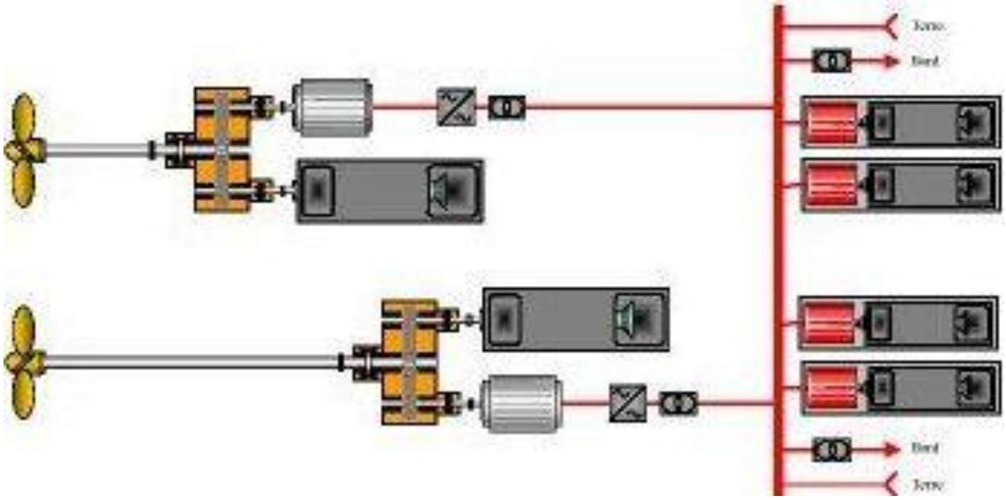
DDG 51 Modified repeat with a Hybrid Power and Propulsion System

LT Chad N. Tidd, USN, LTjg Dimitrios Laskos, HN

Executive Summary

Future high energy weapon systems will require electric power beyond what is currently generated on U.S. Navy warships. Future ships will also need to be more energy efficient and cost less to operate than current ships in the fleet. This paper is a study of one option for generating greater electric power at higher efficiency while reducing overall operational costs on a DDG-51 Class destroyer.

The strategy used in this study to improve power generation performance was to combine electric power generation and mechanical propulsion into a hybrid system. This allows the propulsion plant to be configured in a way that maximizes the benefit of both technologies. Combinations of four different electric propulsion motors and eight different gas turbines were considered in two different hybrid configurations: COGLOG (**CO**mbined **G**as turbine e**L**ectric **O**r **G**as turbine) and COGLAG (**CO**mbined **G**as turbine e**L**ectric **A**nd **G**as turbine). A figure of merit analysis of the variants resulted in the selection of a COGLAG configuration using two 3.7MW LHD-8 Alstom electric propulsion motors, two Roles Royce MT30 Gas Turbine Motors (GTM) as dedicated propulsion turbines and four General Electric LM500 Gas Turbine Generators (GTG).



A summary table which compares significant attributes of the original DDG-51 CLASS Flight IIA ship and the converted ship (Flight IIB) is shown below:

Attribute	**Flight IIA**	**Flight IIB**
Full Load Displacement (MT)	9,433	9,674
Light Ship Displacement (MT)	7,226	7,466
Sustained Speed (kts)	29.9	29.3
Maximum Electric Power (MW)	6.75	15.1
Maximum BHP (MW)	78.3	72.6
GTG SFC (kg/KWh) (100% BHP)	0.31	0.28
GTM SFC (kg/KWh) (100% BHP)	0.23	0.20

This study concludes that a COGLAG configuration is a technically feasible option to power DDG-51 Class ships and recommends its use to provide sufficient power at greater efficiency for current and future weapon systems.

T-AKE to AS(R) Submarine Tender (Modified Repeat)

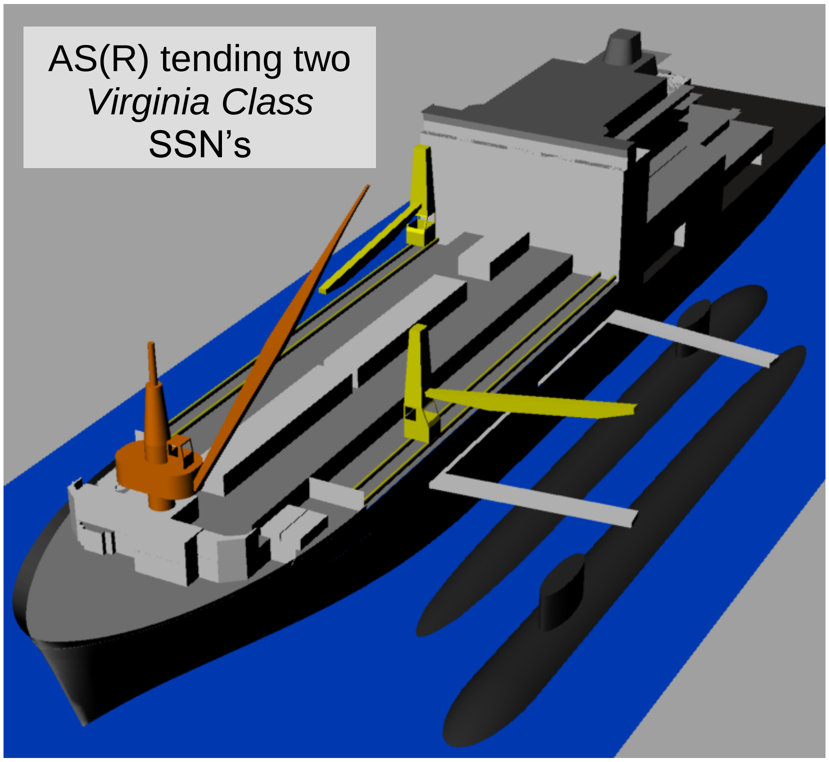
LT Jonathan Gibbs, USN, LT Kristopher Netemeyer, USN

Current fleet submarine tender assets include USS Emory S. Land (AS-39) (commissioned 1979) and USS Frank Cable (AS-40) (commissioned 1980). These ships are nearly 30 years old and close to the end of their useful service lives. The propulsion plants lack the reliability needed to execute frequent upkeeps and provide continuous utility services to tended submarines at geographically disparate and distant locations. Further, they are manpower-intensive and fuel-inefficient to operate. Lack of modular design and increasing difficulty of obtaining parts make maintenance expensive and time consuming. These deficiencies are inherent to the ships' design and could not be improved much by overhaul. Accordingly, a new class of submarine tender is needed to provide improved capability to repair submarine battle damage, provide in-theater maintenance support for forward-deployed units in peacetime and provide mobile remote-site logistics support.

This design study evaluated using the ongoing T-AKE 1 class production line as a basis for a modified repeat or minimum-modification / minimum cost ship configured for the submarine tender role. The study focused on using current T-AKE data, arrangements, weights, and drawings as a starting point. From there several design variants were analyzed and the most capable and cost effective model was chosen. Using this data, modifications were made as necessary to the arrangements, structure, and weights of the original T-AKE to transform her into the chosen AS(R) variant. The variant was put through a series of structural and stability analyses along with various seakeeping scenarios to determine the AS(R)'s sea worthiness and mission effectiveness. A simplified cost analysis based on SWBS weight groups was also performed comparing the costs of the AS(R) to those of the baseline T-AKE.

The outcomes from this study verify that using the T-AKE as a basis for a new submarine tender is a feasible solution from both an economic and capability perspective. The results demonstrate that the T-AKE can perform the mission of a submarine tender with minimal modifications and design alterations.

SHIP CHARACTERISTICS	
Displacement, Full Load	38,139 LT
Length Between Perpendiculars (LBP)	659.1 ft
Length Overall (LOA)	688.6 ft
Beam	105.6 ft
Draft, Full Load	28.9 ft
Sustained Speed	20 kts
Range (18+ kts)	13,061 NM
Service Life	40 years
Accommodations	1849
MISSION CAPABILITIES	
Repair Shop Area	50,000 ft^2 +
Submarine Ordnance Stowage	360 Stows
Repair Stock Stowage	2000 LT
1 – 35 LT Heavy Lift Crane (150 ft Boom)	
2 – 12 LT Side Repair Cranes (80 ft Booms)	
4 Hotel Service Booms (85 ft)	
1600 Amps at 450 VAC to 6 Tended Units	
COST	
Acquisition (% over base ship)	18%
Life Cycle (% over base ship)	12%


AS(R) tending two *Virginia Class* SSN's

LPD-17 to Hospital/Naval Construction Ship (Modification Repeat)

LT David Hanthorn, USN, LT Eli Sewell, USN, LT Nadia Tepper, USN

The MERCY class hospital ships of the United States Navy (USN) are nearing decommissioning, and a number of replacement concepts are being considered. A modification repeat of the current LPD-17 will allow the savings of reusing the existing design, while providing the future hospital ship the mobility and reliability of the LPD-17. The goal is to design a more capable, maneuverable and sustainable medical platform than currently exists, equipped with the latest medical technology.

The LPD-17 Hospital Variant (HV) will provide the capacity to expand medical capabilities within the sea base to support joint force operations ashore. Joint sea-basing is defined by the CNO Seabasing Joint Integrating Concept (2005) as “the rapid deployment, assembly, command, projection, reconstitution, and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary joint forces without reliance on land bases within the Joint Operations Area.” In an anti-access or austere environment, the LPD-17 HV will support joint operations ashore by serving as a medical sea base, providing emergency MEDEVAC, administering emergency treatment, and stabilizing patients for subsequent transfer to medical facilities at supporting advanced bases.

This modification repeat was designed with an efficient medical treatment facility layout in mind. The facility encompasses an entire deck allowing easy passage of patients from triage, pre-op, op, post-op and ICU. Additionally, this variant retains the existing medical facility separate from the additional hospital variant medical spaces. This feature facilitates isolation during instances where foreign nationals, POWs or biological contaminants are of concern. The variant also provides accommodations for a significant Naval Construction Force detachment. The LPD-17 HV has the unique ability to transport either patients or construction force assets by air and by sea. The table below summarizes the characteristics and capabilities of the modified ship.

SHIP CHARACTERISTICS	
Displacement, Full Load	20736.4 Lt
Length Between Perpendiculars (LBP)	656.2 ft
Length Overall (LOA)	683.9 ft
Beam @ DWL	96.8 ft
Draft @ DWL	23.0 ft
MISSION CAPABILITIES	
Medical/Dental Operating Rooms	10/6
Intensive Care Beds	55
Ward Beds	200
Water Production	323K GPD
Naval Construction Force	140 tons
ORGANIC VEHICLES	
Helicopter	1 CH-53 or 2 V-22
Amphibious Boat	1 LCAC
COST	
Total Procurement Cost, FY08 $	695-810M

An Early Conceptual Design and Feasibility Analysis of a Nuclear-Powered Cargo Vessel

LCDR John L. Beaver III, USN

Prof. Henry S. Marcus	**Prof. Richard K. Lester**
Thesis Supervisor	Thesis Reader

Economic globalization has resulted in the tremendous growth of worldwide trade. Much of this trade is carried out via the various waterways of the world. The bulk of these trade goods are transported by merchant ships that burn diesel fuel to propel them through the water. With the cost of crude oil rising to record highs, the costs associated with operating these ships has been skyrocketing as well, indicating the need for the development of alternative sources of propulsion power.

This thesis focuses on the development of an early stage conceptual design for a nuclear-powered commercial cargo ship and the subsequent economic analysis of that ship in comparison to its conventionally-powered predecessor ship. In addition, this thesis will also analyze and propose solutions to the various non-technical issues that currently stand in the way of building and operating a nuclear-powered cargo vessel. The end result of this research clearly shows that a nuclear-powered commercial cargo ship, while being technically feasible, is still economically inferior to a conventionally-powered cargo ship.

Naval Engineer and Master of Science in Nuclear Engineering

Short Sea Shipping:
Barriers, Incentives and Feasibility of Truck Ferry

LT Joseph Darcy, USN

Prof. Henry S. Marcus	**Prof. Mark S, Welsh**
Thesis Supervisor	Thesis Supervisor

Many problems plague the United States' transportation infrastructure; congestion, poor roadway conditions, obsolescence and maintenance cost not the least among these. In recent years, the Department of Transportation, through its Maritime Administration (MARAD), has begun a program for partial solution to this complex transportation issue. MARAD, acting on tasks assigned to it in the Energy Independence and Security Act of 2007, has established the Marine Highways Initiative to spur development of alternative and supplemental transportation modes that utilize inland waterways and coastlines of the United States. At the same time, the U.S. Department of Defense is investigating ways to fulfill its sealift requirements, while at the same time reducing its inventory of government owned vessels that do not trade.

This paper explores the issues surrounding the current state of transportation and transportation infrastructure. It also seeks to determine the feasibility of a truck ferry that would accomplish both MARAD's Marine Highway as well as the Department of Defense's sealift goals. The feasibility study examines the hypothetical business' profitability through different funding and operating scenarios. The analysis also sets a framework for other studies by using open-source data to determine freight flows, potential costs and market share.

Naval Engineer and Master of Science in Mechanical Engineering

Structural Analysis and Design of Floating Wind Turbine Systems

LT Joshua Di Pietro, USCG

Prof. Paul D. Sclavounos	**Prof. Trent R. Gooding**
Thesis Supervisor	Thesis Reader

As oil supply rates approach potential maximums and the global detrimental affects of carbon emitting energy technology are becoming more comprehensively understood, the world is searching for environmentally benign energy technology which can be reliably and economically harvested. Deep water offshore wind is a vast, reliable and potentially economical energy sources which remains globally untapped. In order to harvest this resource, potential floating turbine systems must be analyzed and designed for; economic production and deployment, reliable operation, and adequate service life.

The Laboratory of Ship and Platform Flow (LSPF) has created trusted hydrodynamic modeling software used to perform a Pareto Optimization which resulted in an optimized Floating Wind Turbine (FWT) design; hereto called MIT TLP1. This thesis details the structural design aspects of Floating Wind Turbines (FWT) in a rationally based optimization approach for incorporation into existing LSPF hydrodynamic optimizations. A steel structural design is created based on the geometry and loading of the MIT TLP1 for a 10m significant wave height. The design is based on similar system analysis, classic linear structural theory, American Bureau of Shipping rules and American Petroleum Institute recommended practices. The design is verified using Finite Element Analysis (FEA). The results of this work show that the MIT TLP1 design is technically feasible from a structural integrity, performance and produce-ability standpoint.

Master of Science in Naval Architecture and Marine Engineering, Master of Science in Mechanical Engineering

Shipboard Aggregate Power Monitoring

LCDR Keith Douglas, USN

Prof. Steven B. Leeb	**Prof. Robert W. Cox**
Thesis Supervisor	Thesis Supervisor

Modern naval warships rely on vast arrays of sensor networks to evaluate the performance of mission critical systems. Although these sensor networks enable increased levels of automation, they are costly to install and to maintain. The power distribution network offers an alternative solution for tracking the performance of mission critical systems. Research conducted at Massachusetts Institute of Technology's Laboratory for Electromagnetic and Electronic Systems (LEES) has proven that the power distribution network contains vital information that can provide performance monitoring and automatic diagnostic functions.

This thesis will address the issue of sensor-count reduction through the application of Non-Intrusive Load Monitoring (NILM) technology. Theoretical studies and field experiments will be presented in order to demonstrate the NILM's ability to correlate load activity with power measured from an aggregate level in the distribution system. Additionally, a critical evaluation is conducted on the current NILM configuration's ability to perform automated classification. Findings will be supported using data collected from NILMs monitoring power flow on board the U.S. Coast Guard Cutter ESCANABA (WMEC-907).

Naval Engineer and Master of Science in Mechanical Engineering

Hardware Model of a Shipboard Generator

LCDR Gregory L. Elkins, USN

Prof. Steven B. Leeb	**Prof. Robert W. Cox**
Thesis Supervisor	Thesis Reader

A hardware model of the Gas Turbine Generator (GTG) in use on the US Navy's DDG-51 Class Destroyer is constructed for use as a lab apparatus at the Massachusetts Institute of Technology's Laboratory for Electromagnetic and Electronic Systems (LEES). A numerical Simulink model of the GTG is developed that provides speed response to a change in electrical loading. The Simulink model takes into account basic physical characteristics of gas turbine generators and is tuned to provide a speed response that meets the destroyer's Allison 501-K34 Gas Turbine Specification.

The basic construction of the hardware model consists of a relatively inexpensive 5 kilowatt three-phase generator; lab inventory DC motors and power supplies utilized to provide the mechanical input; an input-output interface board; and computer software to implement speed control. An empirical open loop model of the prime mover's measured response to a change in the generator's electrical loading is developed in Simulink. Closed loop feedback control is then included in the model and tuned in Simulink to provide a response similar to the GTG.

Proportional and Integral (PI) control of the hardware model is implemented utilizing controller gains identified by the Simulink closed loop model and the resulting hardware model's response is compared with that of the numerical Simulink model of the destroyer's GTG. A control loop for voltage control is included following the establishment of adequate speed control.

Naval Engineer and Master of Science in Mechanical Engineering

Propeller Performance Analysis
Using Lifting Line Theory

LCDR Kevin M. Flood, USN

Richard W. Kimball	**Prof. Mark S. Welsh**
Thesis Supervisor	Thesis Supervisor

Propellers are typically optimized to provide the maximum thrust for the minimum torque at a specific number of revolutions per minute (RPM) at a particular ship speed. This process allows ships to efficiently travel at their design speed. However, it is useful to know how the propeller performs during off-design conditions. This is especially true for Naval warships whose missions require them to perform at a wide range of speeds. Currently the *Open-source Propeller Design and Analysis Program* can design and analyze a propeller only at a given operating condition (i.e. a given propeller RPM and thrust). If these values are varied, the program will design a new optimal propeller for the given inputs. The purpose of this thesis is to take a propeller that is designed for a given case and analyze how it will behave in off-design conditions.

Propeller performance is analyzed using non-dimensional curves that depict thrust, torque, and efficiency as functions of the propeller speed of advance. The first step in producing the open water diagram is to use lifting line theory to characterize the propeller blades. The bound circulation on the lifting line is a function of the blade geometry along with the blade velocity (both rotational and axial). Lerbs provided a method to evaluate the circulation for a given set of these conditions. This thesis implements Lerbs method using MATLAB® code to allow for fast and accurate modeling of circulation distributions and induced velocities for a wide range of operating conditions. These values are then used to calculate the forces and efficiency of the propeller. The program shows good agreement with experimental data.

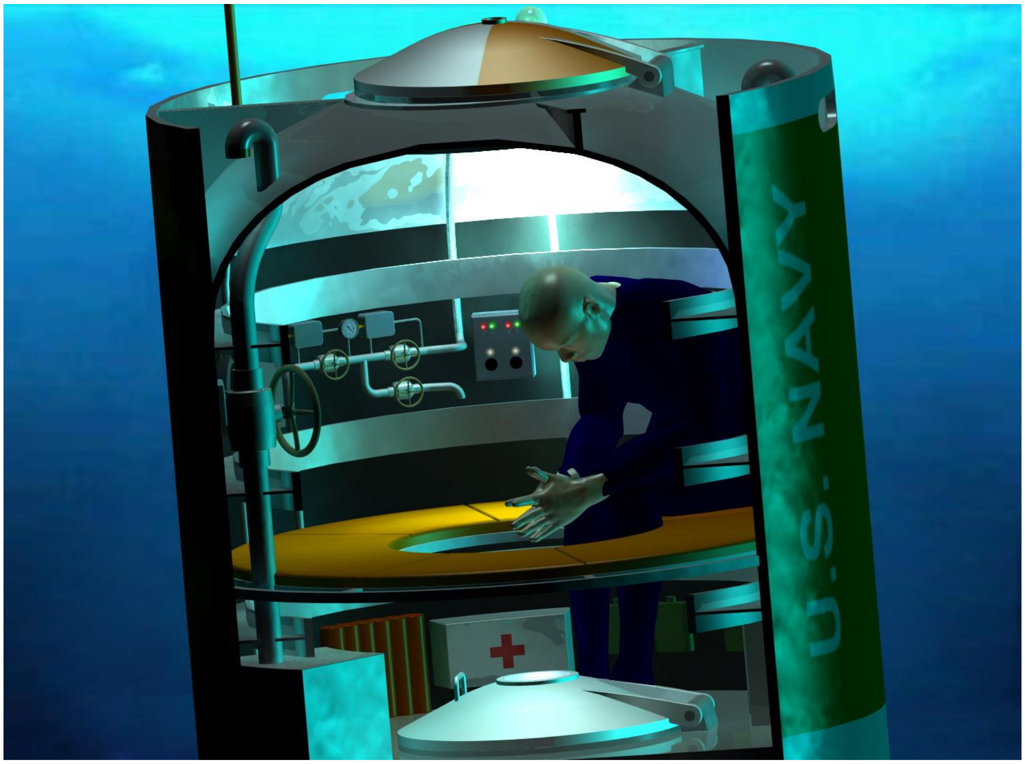
Naval Engineer and Master of Science in Mechanical Engineering

Surfacing Rescue Container Concept Design for Trident Submarines

LCDR Joshua Jonathan LaPenna, USN

Prof Tomasz Wierzbicki
Thesis Supervisor

In the wake of the KURSK tragedy, world navies have brought their full attention to the submarine rescue problem. While many rescue systems exist, none have been able to sufficiently address the gamut of scenarios that place submariners in peril. One rescue strategy utilizes a submarine escape capsule commonly referred to a Surfacing Rescue Container (SRC). Although SRCs have been employed in several submarine designs over the last four decades, the United States has never adopted the underlying strategy. This paper recognizes the SRC concept as the most reliable means of rescue, and proposes a modular SRC concept design (LSRC) which utilizes a modified Trident D-5 missile tube as its host. The design is intended for use on the U.S. Navy's next generation ballistic missile submarine (SSBN) but may be back-fitted on current U.S. Navy Ohio class and U.K. Royal Navy Vanguard Class submarines with significant alteration. Technical analyses include a minimum weight design approach for internally stiffened right circular cylinders exposed to external hydrostatic pressure, an analytical and numerical structural analysis of imperfect ring stiffened cylinders, and a seakeeping analysis for cylindrical spar buoys.



Naval Engineer and Master of Science in Mechanical Engineering

Modeling for Ship Power System Emulation

LCDR Jeremy T. Leghorn, USN

Prof. Steven B. Leeb	**Prof. Robert W. Cox**
Thesis Supervisor	Thesis Reader

With the U.S. Navy's continued focus on Integrated Fight Thru Power (IFTP) there has been an ever increasing effort to ensure an electrical distribution system that maintains maximum capabilities in the event of system faults. This is to ensure that the crew has the ability to complete real time tactical missions in the event of battle damage to any localized portions of the electrical distribution system. Fault isolation is a priority component of the U.S. Navy's Next Generation Integrated Power System (NGIPS) Roadmap, which lays out the framework as well as milestone dates for future development. Non-Intrusive Load Monitoring (NILM), which has been used extensively for condition based maintenance applications, could simultaneously be used to enhance the existing zonal protection system employed with Multi-Function Monitors (MFM). NILM may be able to, inexpensively, use the existing current and voltage sensors available from the MFM hardware to determine electrical loading which could allow for faster fault isolation capability.

A test platform with three 5000 watt synchronous generators is being constructed to emulate a U.S. Navy DDG 51 FLT IIA class ship electric plant. This is being accomplished in order to evaluate the feasibility of improving the fault isolation capabilities of the MFM with NILM implementation. The first step in this endeavor will be to electrically relate the test platform to the DDG electric plant. In order to accomplish this step, the fault simulation results from the test platform will be compared to simulated faults using U.S. Navy data from DDG 51 electric plants. This will allow for the fault isolation results from the test platform to be related to the DDG 51 electric plant.

Naval Engineer and Master of Science in Electrical Engineering

Relationship of Grain Boundary Structure and Mechanical Properties of Inconel 690

LT Joseph J. Marra, USN

Prof. Bilge Yildiz	Prof. Tomasz Wierzbicki	Prof. Krystyn Van Vliet
Thesis Supervisor	Thesis Reader	Thesis Reader

Stress corrosion cracking, the failure of a material due to environmentally assisted crack nucleation and propagation, is a serious metallurgical problem with impact on current and future designs of ship structural components and nuclear reactors. Stress corrosion cracking results from the combination of a material with known susceptibility, the presence of tensile stress and a corrosive environment. Initiation of stress corrosion cracking is difficult to detect and highly localized conditions that cause this phenomenon to occur can be difficult to control through the life of components in systems with long designed service lives in harsh environments. As a result, inhibition of stress corrosion cracking is a particularly challenging problem. Stress corrosion cracking occurs intergranularly, or along grain boundaries. The mechanism of stress corrosion cracking is thus considered to be highly dependent on microstructure and alloy composition. Therefore, inhibition can be achieved through a better fundamental understanding of the microstructural characteristics at the material's grain boundaries.

This thesis identifies the relationship between the microscale structural nature of grain boundaries and their mechanical properties in relation to their impact on the resistance to stress corrosion cracking in Inconel 690. The approach combines the use of nanoindentation, electron backscatter diffraction, and grain boundary engineering to study the properties of grain boundaries as a function of their structure. First, grain boundary engineering is accomplished on Inconel 690 through thermomechanical processing to produce samples with a variety of grain boundary structures. Next, grain boundaries of interest are identified using electron backscatter diffraction analysis. Finally, nanoindentation is used to extract mechanical properties at and near the selected grain boundaries, providing data for analysis of nanomechanical and structural properties in Inconel 690.

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

Plug Repairs of Marine Glass Fiber / Vinyl Ester Laminates Subjected to Uniaxial Tension

LT Alexandros Michelis, HN

Prof. J. H. Williams, Jr.	**Prof. Mark S. Welsh**
Thesis Supervisor	Thesis Supervisor

Glass fiber/vinyl ester composite laminates are currently being used and proposed for the hulls, bulkheads, and superstructures of large ships. This thesis examines the effectiveness of the repair of such laminates using glass fiber/vinyl ester chopped strand mat plugs to fill circular holes.

The stress distributions around circular holes in various glass fiber/vinyl ester woven roving laminates subjected to uniaxial tension are calculated before and after repairs using plug materials of different fiber volume fractions. The orthotropic laminates ranged from balanced to unidirectional woven rovings, and the chopped strand mat plug fiber volume fractions ranged from 0 to 0.40.

The effectiveness of the plug in reducing the laminate stresses increased monotonically with increasing fiber volume fraction, reducing the maximum laminate stress to about 60% of the unrepaired laminate stress at a plug fiber volume fraction of 0.40.

Naval Engineer and Master of Science in Mechanical Engineering

Applications and Analysis of Stiffened Side Shell Panel Failure for Naval Patrol Craft

LT(jg) Matthew K. Mothander, USCG

Prof. Tomasz Wierzbicki	**Prof. Trent R. Gooding**
Thesis Supervisor	Thesis Reader

Over their lifetime, naval patrol craft are subjected to many different types of loading scenarios, most of which are perfectly safe. In rare instances, through a variety of different reasons, these craft are loaded beyond their means, resulting in structural failure.

This thesis focuses on how side shell stiffened panel failure occurs from a global and local perspective. It incorporates aspects of basic ship structural design theory, detailing static and dynamic shipboard loads, progressive collapse behavior, and global causes of hull strength reduction. Locally, it examines stiffened panel failure modes due to axial loading through a comparison analysis with consideration for sources of panel strength loss. Finally, this thesis discusses methods for avoidance and mitigation of failure in the future at the design, construction, and operational levels.

Globally, this thesis draws from two incidents in the last decade where U.S. Navy and U.S. Coast Guard patrol craft have had class-wide incidents of structural failure. These failures have ranged from buckling, to yield, to fracture. Each ship's background is discussed, and primary stress calculations are presented with design margins based on Classification Societies, along with an engineering analysis of the failures that occurred on each vessel. Internal and external factors for overall hull strength reduction are examined and applied to each case, including considerations for slamming and saltwater corrosion.

Using the failure incident that took place on the U.S. Coast Guard 123', local failure modes are examined across several analysis methods for axially loaded stiffened panels. Buckling and ultimate load values are calculated through a parametric design space, while boundary conditions and geometric properties are varied. Finite element analysis and proven analytical methods are used, including those developed by Von Karman. A comparison analysis is completed using experimental data, where local causes for strength reduction in panels are considered, including construction imperfections, shearing, residual stresses, cracking, and initial deflection.

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

Notes: