Naval Construction and Engineering
Ship Design and Technology Symposium

Thursday, May 3, 2012

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

0800 – 0900	Registration and continental breakfast
0900 – 0920	Welcome and Opening Remarks
0920 – 1000	Research Briefs
1000 – 1030	Break and Poster Sessions (featuring student theses and projects)
1030 – 1200	Student Design Project Briefs
1200 – 1230	Break and Poster Sessions (featuring student theses and projects)
1230 – 1330	Lunch Buffet and Keynote Address
1330 – 1430	Research Briefs
1430 – 1500	Student Design Project Briefs
1500 – 1530	Break and Poster Sessions (featuring student theses and projects)
1530 – 1620	Research Briefs
1620 – 1630	Closing Remarks

History

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

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

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

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

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

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

MIT Naval Construction and Engineering Program Description

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

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

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

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

Rear Admiral Thomas J. Eccles

Chief Engineer and Deputy Commander for Naval Systems Engineering, Naval Sea Systems Command

Rear Admiral Eccles was born on Johnson Air Force base in Japan and raised in Wallingford, Conn. He graduated from the Massachusetts Institute of Technology in 1981.

Eccles served at sea aboard USS Richard B. Russell (SSN 687) and USS Gurnard (SSN 662). As an engineering duty officer, he held positions at Mare Island Naval Shipyard, in the Navy's Deep Submergence Systems Program, and he had two tours in the Virginia Class Submarine Program, directing design and construction. He was executive assistant to the commander, Naval Sea Systems Command.

Eccles was Seawolf program manager through the delivery of USS Jimmy Carter (SSN 23), where his team was awarded the Meritorious Unit Commendation, then program manager for Advanced Undersea Systems, responsible for research and development submarines, submarine escape and rescue systems, and atmospheric diving systems. As a commander he was program manager for the design and construction of the unmanned autonomous submarine Cutthroat (LSV 2).

Eccles' previous flag officer assignments included deputy commander for Undersea Warfare and Undersea Technology in NAVSEA, and commander of the Naval Undersea Warfare Center, before becoming NAVSEA's chief engineer in September 2008.

In 2010 Eccles led the U.S. technical team supporting the Republic of Korea joint international investigation into the loss of the warship Cheonan. Also in 2010, he was appointed to the National Academy of Engineering committee examining the Deepwater Horizon explosion and oil spill in the Gulf of Mexico.

Eccles' education includes four degrees from MIT including a bachelor's in Electrical Engineering, a master's in Mechanical Engineering, the professional degree of Naval Engineer, and a master's in Management of Technology from MIT's Sloan School. He serves on the Visiting Committee in MIT's Department of Mechanical Engineering. He is a graduate of the Naval War College, the Defense Systems Management College, and the foreign policy program Seminar XXI, and was elected to the Society of Sigma Xi. He is qualified in submarines, and as a deep sea diver and salvage officer. His decorations include the Legion of Merit (3), the Meritorious Service Medal (4), and other individual and unit awards.

Mary C. Boyce

Gail E. Kendall Professor of Mechanical Engineering
Head of Department

Professor Boyce earned her B.S. degree in Engineering Science and Mechanics from Virginia Tech; and her S.M. and Ph.D. degrees in Mechanical Engineering from the Massachusetts Institute of Technology. She joined the M.I.T. faculty in 1987. Professor Boyce teaches in the areas of mechanics and materials. Her research areas focus primarily on the mechanics of elastomers, polymers, polymeric-based micro- and nano-composite materials, lattice- structured materials, natural materials, and biological macromolecular networks, with emphasis on identifying connections among microstructure, deformation mechanisms, and mechanical properties. She has published over 100 journal papers in the field of mechanics and materials; and has mentored 36 SM Thesis students and 20 PhD students.

Professor Boyce has been the recipient of several awards and honors recognizing her research and teaching efforts, including the MIT MacVicar Faculty Fellow, the Department of Mechanical Engineering Keenan Award for Teaching, the Spira Award for Teaching, the NSF Presidential Young Investigator Award, the ASME Applied Mechanics Young Investigator Award, Member-at-Large of the USNCTAM, Chair of the ASME Applied Mechanics Division, Fellow of the American Academy of Mechanics, Fellow of the ASME, Fellow of the American Academy of Arts and Sciences, and Member of the National Academy of Engineering.

Michael S. Triantafyllou
William I. Koch Professor of Marine Technology,
Director of the Center for Ocean Engineering

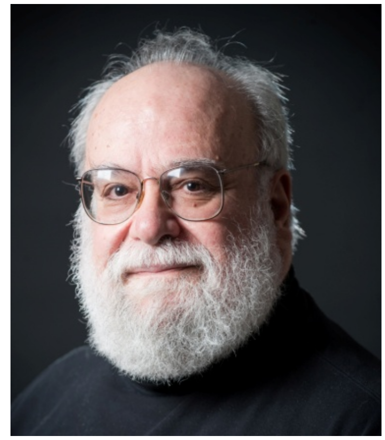
Undergraduate studies (1969-1974) in Naval Architecture & Marine Engineering at the National Technical University of Athens, graduate studies in Ocean Engineering at MIT (SM Ocean Engineering, SM Mechanical Engineering 1977, ScD 1979).

Assistant Professor (1979-83), Associate Professor (1983-90), Professor (1990-2004), Department of Ocean Engineering, MIT; Professor of Mechanical and Ocean Engineering (since 2004). He has published in the areas of dynamics and control of marine systems, experimental fluid mechanics, and biomimetics: M.S. Triantafyllou & G.S. Triantafyllou, 1995, "An Efficient Swimming Machine", *Scientific American*, 272, 64-70. M.S. Triantafyllou, G.S. Triantafyllou, D.K.P. Yue, 2000, "Hydrodynamics of Fish Swimming", *Annual Review of Fluid Mechanics*, 32, 33-53. J.C. Liao, D.N. Beal, G.V. Lauder, & M.S. Triantafyllou, 2003, "Fish exploiting vortices use less muscle", *Science*, 302 (5650), 1461-1608, November 28, 2003.

Prof. Triantafyllou is a member of the Society of Naval Architects & Marine Engineers, the American Physical Society, the American Society of Mechanical Engineers, and the Intern. Society for Offshore & Polar Engineers. Honors and Awards include: William I Koch Professorhip in Marine Technology (since 2008), Cover of *Science* (2003), RoboTuna on permanent exhibit at the Museum of Science, London (since 1998); prototype *RoboTuna* in national traveling exhibit on robots, Science Museum of Minnesota (2003-2004). Visiting Professor, ETH Zurich (1999), NTU Athens (1994, 2000), NTH Norway (1993), Kyushu U. (1986). *Discover Magazine* Awards for Technological Innovation (1998). ABS/Linnard Prize for best paper in the *Transactions of SNAME* (1997). Highlight Paper of 1995 *Scientific American*. H. L. Doherty Professorship in Ocean Utilization (1983-1985).

Chryssostomos Chryssostomidis

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



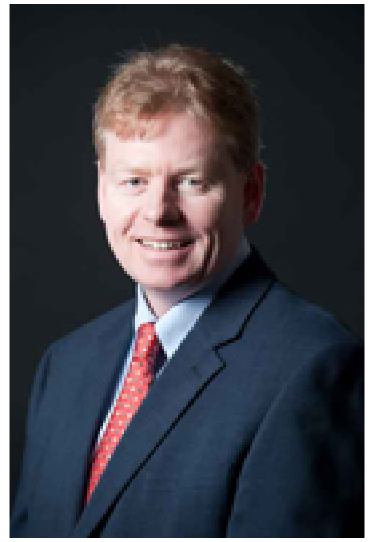
Educated at MIT and at the University of Newcastle-upon-Tyne in naval architecture, Professor Chryssostomidis was appointed to the MIT faculty in 1970 and became a full professor in the Department of Ocean Engineering in 1982. That same year he was appointed director of the MIT Sea Grant College Program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

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

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

John Leonard

Professor of Mechanical and Ocean Engineering



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

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

Tomasz Wierzbicki

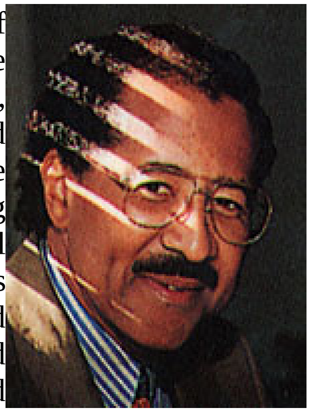
Professor of Applied Mechanics
Director, Impact and Crashworthiness Laboratory

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

In 1983, he was appointed as a full professor at MIT, where he is currently directing the Impact and Crashworthiness Lab. He is the author of over 150 papers published in major international journals. In 1986, he received the Alexander von Humboldt senior US scientist award. Professor Wierzbicki spent over three years working in the BMW R&D Department in Munich. He directed a number of large industry-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*.

James H. Williams, Jr.

Professor of Mechanical Engineering, Writing and Humanistic Studies
School of Engineering Professor of Teaching Excellence, Emeritus



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, Emeritus, 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.

Captain Mark W. Thomas, USN

Professor of the Practice of Naval Construction and Engineering

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

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

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

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

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

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

Commander Pete Small, USN

Associate Professor of the Practice of Naval Construction and Engineering

Commander Peter D. Small was commissioned in 1995 from the NROTC at the University of Virginia where he earned a Bachelor of Science Degree in Mechanical Engineering. He has also earned a Master of Science Degree in Operations Research in 2002 from Columbia University and a Master of Science Degree in Mechanical Engineering and a Naval Engineer Degree in 2005 from the Massachusetts Institute of Technology. He is a licensed Professional Engineer in the Commonwealth of Virginia.

Upon completion of Navy nuclear propulsion training, Commander Small reported to USS L. MENDEL RIVERS (SSN 686) where he served as Chemical and Radiological Control Assistant, Damage Control Assistant, and Communications Officer and conducted dry-deck shelter operations on two deployments to the Mediterranean Sea and Arabian Gulf. He then served as Assistant Professor of Naval Science and Nuclear Programs Officer at the State University of New York (SUNY) Maritime College and Fordham University. In 2005, Commander Small reported to the Supervisor of Shipbuilding, Conversion and Repair, Newport News, Virginia where he was the Project Officer for the Pre-Commissioning Units (PCU) NORTH CAROLINA (PCU 777) and NEW MEXICO (PCU 779) new construction, USS OKLAHOMA CITY (SSN 723) Docking Selected Restricted Availability (DSRA), and the USS TOLEDO (SSN 769) Depot Modernization Period (DMP). From 2008 to 2010 he served as Deputy Ship Design Manager and Aft Project Officer in NAVSEA PMS397, the OHIO Replacement program office.

In September of 2010 Commander Small was appointed Associate Professor of the Practice in the Mechanical Engineering Department at the Massachusetts Institute of Technology and currently serves as the Academic Officer of the graduate Naval Construction and Engineering (Course 2N) curriculum.

Commander Small's decorations include the Meritorious Service Medal, Joint Service Commendation Medal, Navy Commendation Medal (three awards), Navy and Marine Corps Achievement Medal (four awards), Navy Unit Commendation, National Defense Service Medal (two awards), Armed Forces Expeditionary Medal, and Sea Service Deployment Ribbon (two awards).

He is married to the former Stacy McLaurin of Burke, Virginia. They have two daughters, Clara and Elena, and reside in Belmont, Massachusetts.

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Arctic Combat Ship (ACS)

LT Dave Cope, USN; LT Tim Emge, USN; LT Christopher MacLean, USN

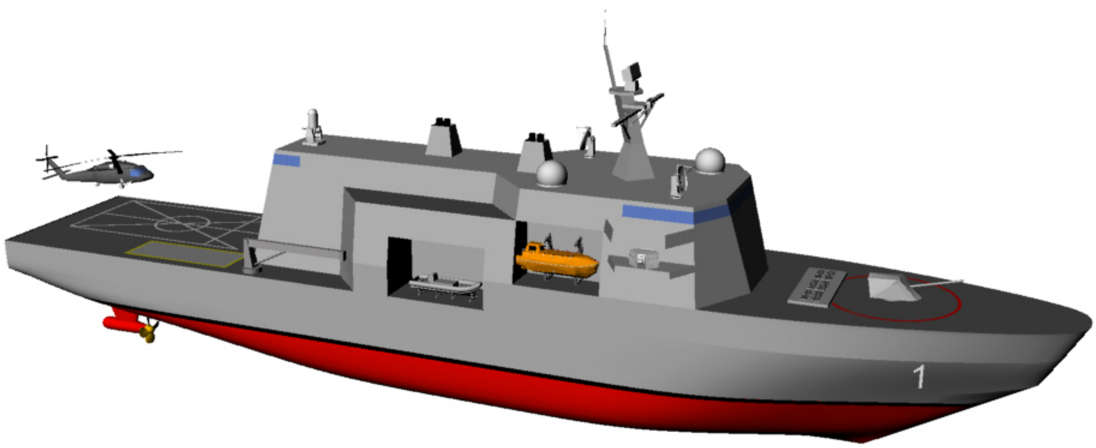
The effects of climate change are slowly opening Arctic sea lanes that have previously only been accessible by specialized marine cargo and research vessels. Scientists predict that by 2030 the region will experience ice-diminished summers and expect an increase in commercial shipping, resource development, research, tourism, and strategic focus. The 2009 *U.S. Navy Arctic Roadmap* outlines the Navy's action items from FY10-14, one of which is the investment in weapons, platforms, sensors, command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR). This can only be achieved by acquiring the right capability at the right cost and right time to meet combatant commander requirements for the region. The goal of this project was to develop an Arctic capable surface combatant to meet the Navy's future mission requirements.

The ACS will be a CONUS based platform and conduct extended, independent operations in the opening Arctic waters. Its overarching objective will be to provide a U.S. Navy presence in the region to secure vital national interests. The vessel's operational profile was determined from climatic conditions and emerging concerns of the Navy. It is assumed that the ACS's operations will be primarily conducted during the summer and fall when ice conditions allow for increased maritime traffic.

The ACS will be the U.S. Navy's looking glass into a currently opaque region and with organic assets, increase the awareness of the maritime domain. Major mission areas will include C4ISR, Surface Warfare (SUW), Search and Rescue (SAR), and Humanitarian Assistance and Disaster Relief (HADR). To accomplish these missions, the ACS hull was designed to the American Bureau of Shipping (ABS) Polar Class 4 rules and guidelines, enabling the vessel to operate independently in the Arctic year-round. The design incorporates a flexible Mission Bay capable of housing up to 10 twenty foot equivalent units (TEU) and either a hovercraft or landing craft. A 30 ton boom crane and cargo elevator on the starboard side loads and unloads the Mission Bay. The diesel Integrated Power System (IPS) and Zonal Electrical Distribution System (ZEDS) provides an efficient and redundant shipboard power architecture, enabling a range of over 17,500 nautical miles. Azipod propulsion has become standard in polar capable ships and was selected for the design because of its reliability and superior maneuvering characteristics. The ACS, while providing persistent ISR, can also project power through its MK 110 57mm main gun, 24 MK 41 Vertical Launch Cells, and embarked MH-60R helicopters. Extra weight and space margin leave open the possibility of installing a higher power 3D air radar and a sonar suite. Due to the harsh Arctic environment, three enclosed polar lifeboats were placed onboard, providing adequate capacity for all crew and embarked personnel.

As a class of six ships, the ACS will persistently monitor commercial and military traffic in the Arctic, direct humanitarian and disaster response operations, project offensive power when necessary and adapt to the changing environment. The ACS will be a flexible surface combatant designed to fulfill the Navy's emerging requirements for an Arctic presence.

Ship Characteristics	
Parameter	**Value**
LBP	345.5 ft
Beam	65.5 ft
Draft	20 ft
Depth (Station 10)	50 ft
Prismatic Coefficient	0.625
Lightship Displacement	5,357 LT
Full Load Displacement	7,046 LT
GM_t/B	0.141
Range	17,560 nm
Maximum Speed	19.7 kts
Sustained Speed	18.0 kts
Lead Ship Cost	$1.27B FY11
Follow Ship Cost	$977M FY11
Crew	124
Accommodations	156



Unmanned Vehicle Carrier

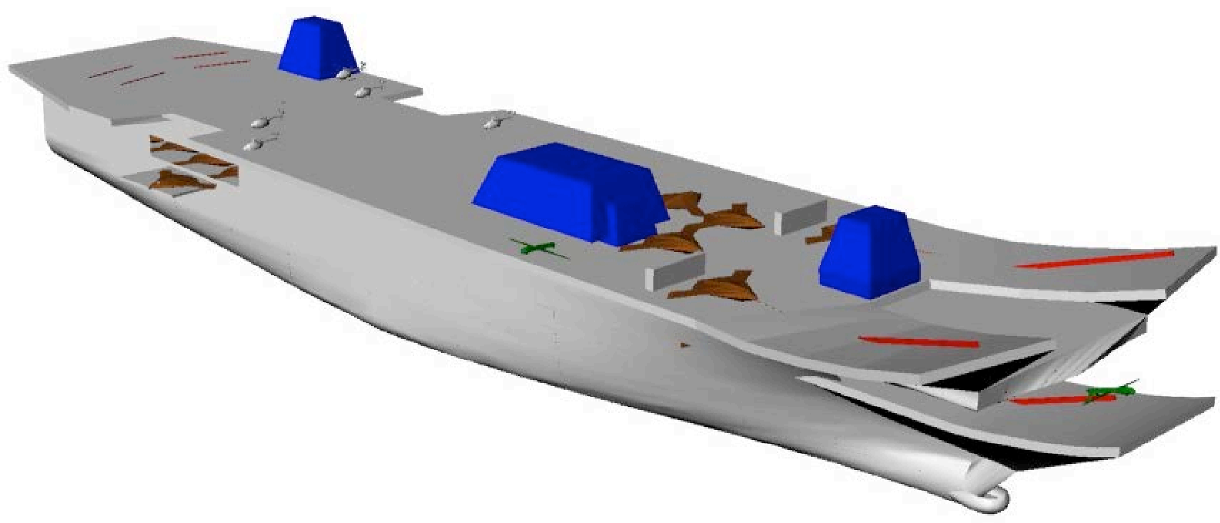
LT Evangelos Koutsolelos, HN; LT Andrew Privette, USN
LT Petros Voxakis, HN; LT James Wilkins, USN

Modern combat environments have a high demand for the development and employment of unmanned systems. Numerous recent technological developments make it feasible to build military systems to perform without human intervention. These unmanned systems are being used more and more for missions such as mine countermeasures, anti-submarine and anti-surface warfare, coastal security, exclusive economic zone protection, and intelligence, surveillance and reconnaissance (ISR). More than a decade ago, military operations using Unmanned Aerial Vehicles (UAVs) in Kosovo demonstrated the potential for accomplishing warfare missions more efficiently, with less human risk, and lower cost than had historically been accomplished with manned vehicles. Today, UAVs fly above Iraq and Afghanistan providing America's military forces with a significant advantage over enemy forces. While there are many pilot programs to provide for Unmanned Vehicle (UV) deployment from existing ships, all serve as added, secondary roles to current primary missions and require integration into and disruption of current operational routines. The Navy lacks a dedicated platform that would take full advantage of the exploding world of opportunities provided by unmanned systems which have been clearly demonstrated to be the way of the future.

In order to fill this capability gap, an Unmanned Vehicle Carrier (UVC) to deploy, recover, maintain, and store unmanned systems is proposed. The UVC is equipped with modern mission bays that have sufficient internal arrangeable space to carry a wide variety in number and type of UVs. It is capable of launching and recovering air, surface and undersea UVs in every geostrategic environment. Conventional and innovative developmental technologies are incorporated to effectively meet the technological challenges of current and future UV systems. Unmanned Surface Vehicles (USV) and Unmanned Undersea Vehicles (UUV) can be launched singly by crane or in large sorties via well deck launch. UAV launch operations are enabled by combining Electro-Magnetic Aircraft Launch System (EMALS) technology with “ski-jump” type ramps to shorten flight deck length requirements. A second flight deck, located beneath the main flight deck, for launching UAVs, provides a significant advantage by increasing the air sortie rate and allowing either increased launch rate or simultaneous launch and recovery operations. Equipped with a high level of vehicle handling automation, UVC maximizes available flight deck space by removing the need for a large control tower/island. Using an integrated mast and a simple pilothouse for navigation, UVC has more topside space available, with all command and control facilities located in the internal decks. To allow the UVC more autonomy and nearly unlimited range, a nuclear plant is used to power an advanced Integrated Power System (IPS). Advanced vehicle control options allow for control handoff to offsite locations or for maintaining organic mission control. In this way the UVC can operate as a mobile headquarters platform, acting as a force multiplier in a rapidly changing and demanding theater of operations.

The UVC has the ability to perform many of the existing aircraft carrier missions with a comparative reduction in the procurement and life cycle costs as well as manning requirements. Thus, the UVC is a forward leaning and affordable solution to address the issues raised by new generations of UVs. With a projected life cycle of 50 years beginning in 2030, the UVC will enhance the application of U.S. military force and global power projection through unmanned systems.

Ship Characteristics	
Parameter	**Value**
LBP	750 ft
Beam	124 ft
Draft	29.11 ft
Depth (Station 10)	90 ft
Prismatic Coefficient	0.62
Lightship Displacement	37,072 LT
Full Load Displacement	48,489 LT
GM_t/B	0.155
Maximum Speed	25.3 kts
Sustained Speed	24.1 kts
Lead Ship Cost	$6.5B
Follow Ship Cost	$4.6B



Strike Littoral Intelligence Surveillance and Reconnaissance Submarine (SLĪSR)

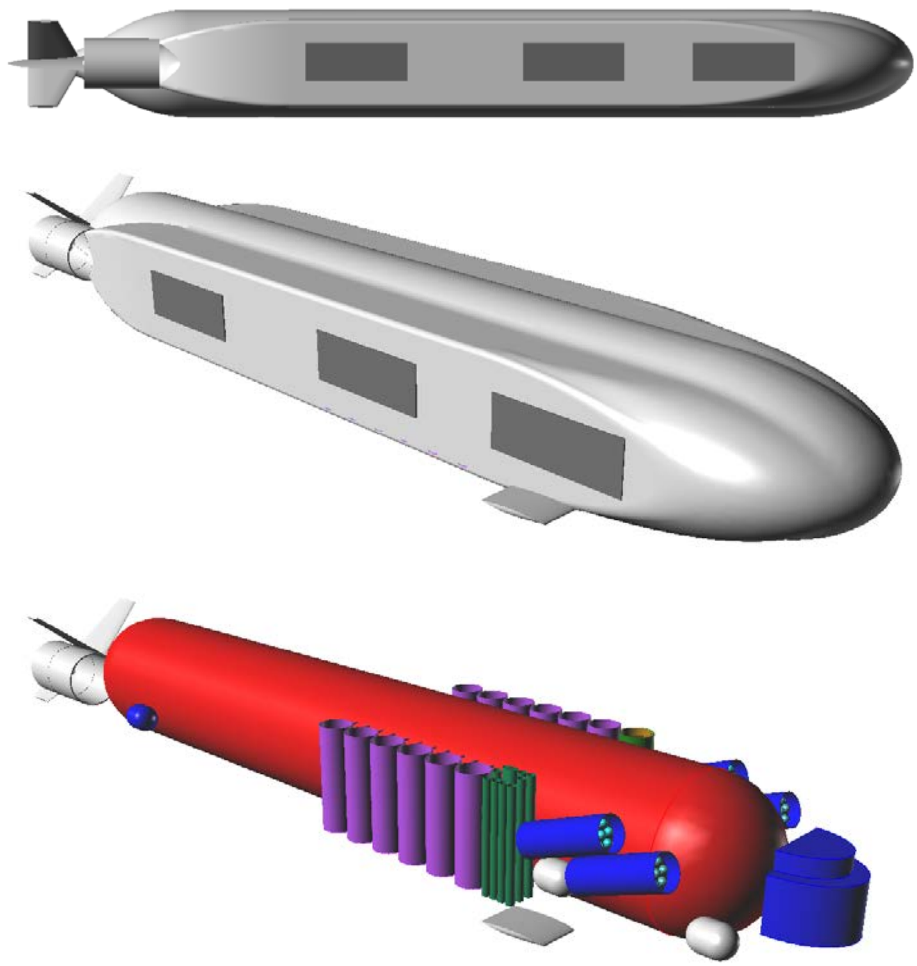
CDR John Campbell, USN; LCDR Greg Crawford, USN; LT Eric Thurkins, USN

The final LOS ANGELES Class Fast Attack submarine will be decommissioned in fiscal year (FY) 2030, and the US Fast Attack Submarine Fleet will consist entirely of VIRGINA Class Submarines. The OHIO Class SSGN's will have been decommissioned over the previous five fiscal years by current plans; and given current attitudes about those ships and their utility, the perceived and real loss of capability to the fleet will be significant. Initially projected as a class of 30 submarines, the VIRGINIA will have been in production for just over 30 years, and by 2032 (FY), the last of the final block of originally projected VIRGINIAs will have been delivered. Without a change in the number of VIRGINIAs built, design and construction of a replacement class of submarines for the VIRGINIA should begin around FY 2018 to allow adequate time for design and a smooth transition from construction of VIRGINIA to the replacement class.

The SLĪSR concept design process explored innovative ideas as well as current techniques including external weapons, sail-less design, IPS systems, modular construction, and double-hull design. A modified version of the MIT submarine MATHCAD model was developed to accommodate a non-body-of–revolution design. This MATHCAD model was used in conjunction with Rhinoceros 3D to develop the necessary balanced volumes and weights in an iterative fashion. Additionally, the model was imported into Paramarine to conduct seakeeping and stability analyses. Finally, a simplified cost model was used within MATHCAD to estimate the acquisition cost of the SLĪSR submarine.

The study produced a highly capable and innovative submarine that is stable, meets all customer design requirements, and is cost effective as a replacement to the VIRGINIA Class Submarine.

SLĪSR Characteristics	
Parameter	**Value**
LBP	286 ft
Beam	50.2 ft
Draft	26.6 ft
Lead Fraction (% A-1)	574 LT (9.7%)
Reserve Buoyancy	17%
Submerged Displacement	8333 LT
NSC	7122 LT
Endurance	90 days
Maximum Speed	31 kts
Max Operating Depth	130% VIRGINIA Class
Lead Ship Cost	$2.44B (FY12)
Crew Size/ Accommodations	147



Commercial Offshore Supply Vessel (OSV) To Arctic Capable T-ATS(X) Replacement

LT Arthur Anderson, USN; LT Amiel B. Sanfiorenzo, USN; Mr. David Jurkiewicz

The Military Sealift Command (MSC) currently has four active tug ships, the T-ATF 166 Class, and four active salvage ships, the T-ARS 50 Class, which are scheduled to begin phased retirement in 2020. To ensure there is not a gap in tug and salvage capability, the US Navy is investigating the development of a common hull T-ATS(X) to replace the missions of the T-ATF and T-ARS Class ships. The primary mission of the common hull T-ATS(X) will be to serve as a combat logistics support force providing salvage, repair, towing, diving, and rescue services to the fleet at sea effectively merging the high-level mission capabilities of the T-ATF and T-ARS Class ships. This study investigated the validity of using a commercial OSV, the UT-722L, as a candidate for conversion into the common hull T-ATS(X) Class ship. The UT-722L design is licensed by Rolls-Royce Marine with licenses for production worldwide.

Additionally, vessel traffic in the arctic region is increasing as polar ice continues to recede. As a result, special focus within this study was placed on incorporating the American Bureau of Shipping (ABS) C0 Ice Classification into the T-ATS(X).

An analytical hierarchy process was used to guide concept exploration and selection of the T-ATS(X) design. The design space included 24 variants based on crane selection, crane location, and arctic capability. Seven Measures of Performance (MOPs) were used to measure the effectiveness of each T-ATS(X) variant. The Overall Measure of Effectiveness (OMOE) vs. modification cost was plotted for each variant, and a final variant was selected to maximize OMOE and minimize cost.

The final T-ATS(X) variant incorporated a number of modifications from the UT-722L to meet the thresholds and objectives set by the customer requirements. Those modifications included: strengthening the hull structure to satisfy ABS Ice Class C0 requirements, adding extra heating capacity for arctic conditions, installing a 52-LT capacity crane, increasing electrical generation capacity, and creating additional accommodation spaces.

To verify the feasibility and performance of the T-ATS(X) several analyses were conducted. These included: an intact stability analysis, a powering and resistance analysis, and seakeeping analyses for normal and VERTREP operations. Furthermore, a topside icing model was developed to analyze the stability of the vessel in arctic conditions with external asymmetrical topside ice accumulation.

In conclusion, the results of this study demonstrate the UT-722L can meet the Navy’s requirements for the T-ATS(X) with low-risk modification at comparatively low cost. The estimated lead ship cost of this T-ATS(X) conversion design is $152 million (FY12), which is significantly lower than the projected cost of a 2008 MIT clean sheet T-ATS(X) design study.

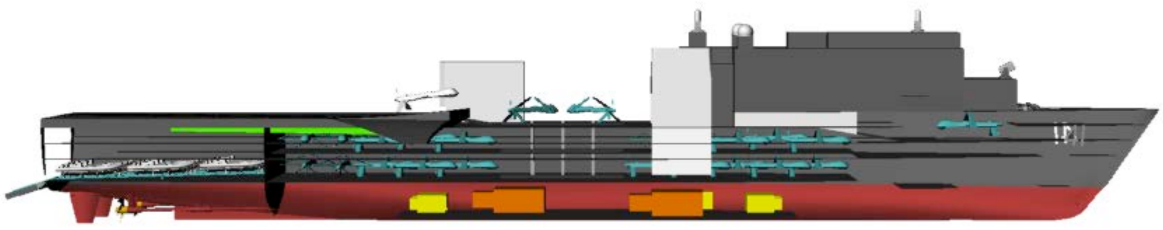
T-ATS(X) PRINCIPAL CHARACTERISTICS	
Parameter	**Value**
Displacement	5,644 LT
LOA	262 ft
LWL	249 ft
Beam	59 ft
Draft	20 ft
Max Speed	17 kts
Sustained Speed	16.3 kts
Endurance Speed	12 kts
Endurance Range	13,000 nm
Brake Power	12,370 kW
Electric Capacity	6,790 kW
Bollard Pull	194 LT
Crane Capacity	1 x 52 LT at 35 ft 1 x 3.2 LT at 26 ft 1 x 2.0 LT at 32 ft
Firefighting Capability	FiFi Lvl 1 w/ AFFF
VERTREP Capability	VERTREP Level III Class 5
Submarine Rescue Capability	US Navy SRDRS and NATO SRS

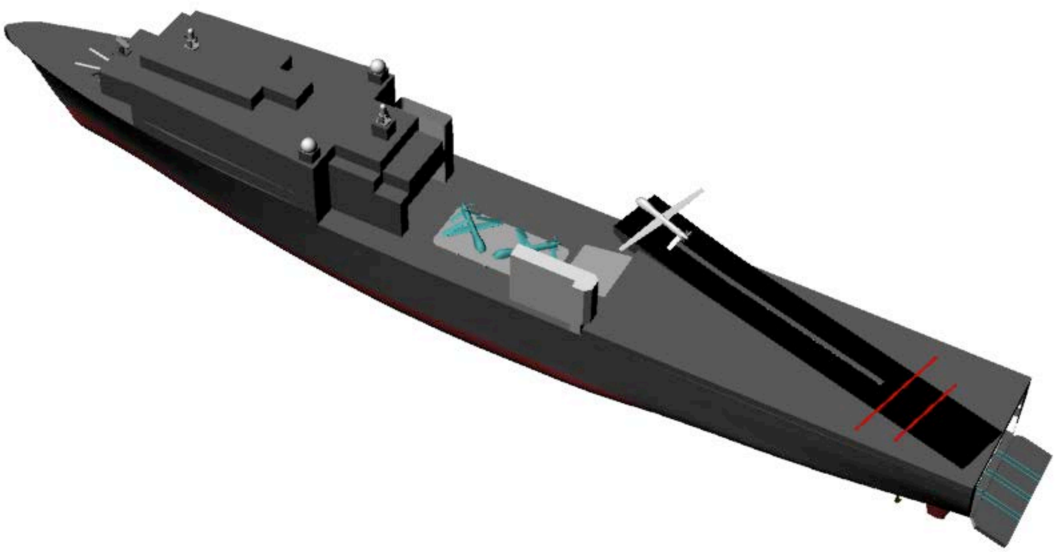
Conversion of the LSD 41 to an Unmanned Aerial and Surface Vehicle Carrier (CVU)

LT Katie Gerhard, USN; LT Carl Bodin, USN; LTJG Kostantinos Nestoras, HN

Unmanned Aerial Vehicle and Unmanned Surface Vehicle technology continues to rapidly advance and many current Navy missions can now be conducted using unmanned vehicles. As payload, endurance, and range grow, the Navy must capitalize on this technology. Since many Whidbey Island class LSDs face mid-life overhaul, this project proposes converting the current flight deck to a catapult equipped, angled flight deck for launching Predator size UAVs. Multiple analytical tools were used to explore the design space and determine the optimal flight deck design, UAV/USV type and quantity. The conversion design focuses on topside redesign, incorporation of a scaled down EMALS catapult, the rearrangement of spaces to support UAV/USV missions and payloads, and cost feasibility.

CVU Characteristics	
Parameter	**Value**
LOA	610 ft
Beam	84 ft
Draft	17.6 ft
Installed Power	6500 kW
Prismatic Coefficient	0.604
Lightship Displacement	11,041 LT
Full Load Displacement	14,255 LT
Sustained Speed	23 kts
Maximum Speed	25 kts
Endurance	8000 nm
Number of UAV	20
Type of UAV	MQ-9 Reaper
Number of USV	9
Type of USV	Spartan Scout RHIB





National Security Cutter-Based Navy Small Patrol Combatant

LT Travis Anderson, USN; LT Michael Bahr, USN; LT Bart Sievenpiper, USN

The US Navy budget is facing a severe squeeze in the coming years that may force a second look at the force size and structure. This is already evident in the FY 2013 Department of Defense budget proposal that recommended the early retirement of 7 Ticonderoga-class cruisers. The retirement of the cruisers, along with the planned retirement of the Perry-class frigates and the ever-increasing requirement for ballistic missile defense, is placing an enormous operational requirement on the Arleigh Burke-class destroyers. While the Littoral Combat Ship (LCS) will alleviate some of these stresses, these vessels are not optimized for blue water operations. By leveraging the US Coast Guard's investment in the Legend-class National Security Cutter (NSC), an affordable option may be available to better meet fleet needs.

This study evaluated the technical feasibility and cost of performing a modified repeat of the NSC into a Small Patrol Combatant (SPC). The NSC is designed to operate in blue water for extended periods and is designed with modern control features that allow the vessel to be operated with a relatively small crew. Adding an Aegis combat systems suite, AAW missiles, passive and active sonar arrays, and increased armament make the SPC capable of performing a relevant set of Navy missions. A combination of improved sensors and weapons systems, built in survivability features, and assessment of missions and standards can ensure adequate survivability for the Coast Guard-based SPC.

Results of this study confirm the SPC provides a robust platform capable of operating in a wide variety of mission areas. The ship has greater organic warfighting capability than current LCS or Perry-class. With an estimated cost of $900M (FY11), this vessel could be produced at approximately half the cost of a current Burke-class destroyer, making it an affordable blue water option for the fleet.

SPC Characteristics	
Parameter	**Value**
LBP	127.5 m
Beam	16.46 m
Draft	6.86 m
Depth (Station 10)	11.8 m
Prismatic Coefficient	0.62
Lightship Displacement	4,255 Mton
Full Load Displacement	4,550 Mton
GM_t/B	0.053
Range	5,000 nm
Maximum Speed	29 kts
Sustained Speed	28 kts
Lead Ship Cost	50% DDG-51
Accommodations	148

LPD-17 Humanitarian Assistance and Disaster Relief (HADR) Variant

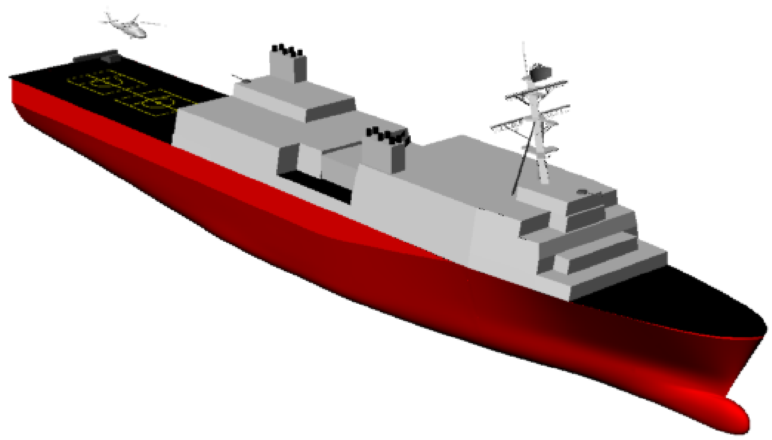
LT Dominic Alvarran, USN; LCDR Joseph Meier, USN; Lt(N) Eric Poulin Royal, RCN

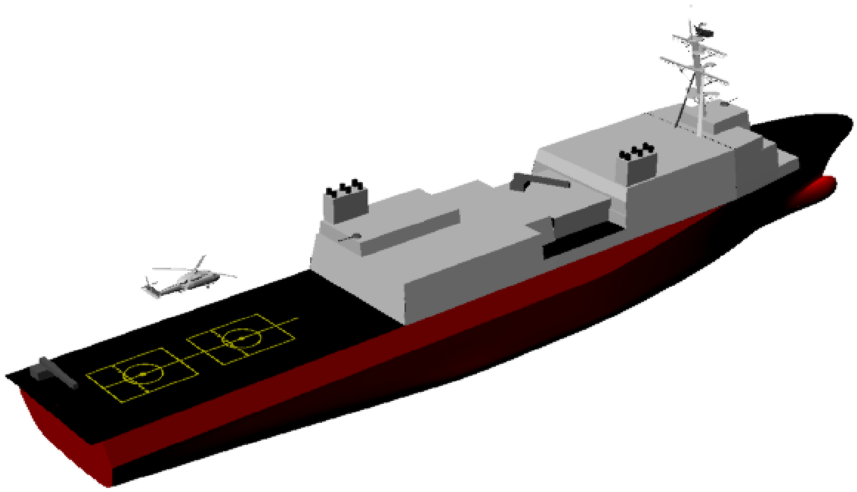
In recent years, the United States has seen a sharp rise in the frequency and level of involvement in Humanitarian Assistance and Disaster Relief (HADR) missions. As the world population continues to rise, only increases in the number of future relief missions are forecast, yet the US does not maintain any ships designed to effectively carry out such missions. The current doctrine for disaster relief response is to deploy the closest available ships to assist, with little regard to how capable the ships are to meet the needs of the mission. In many cases, ships are ill-equipped to provide meaningful support and lack personnel trained in standardized disaster relief methods.

To overcome this deficiency, this paper proposes a conversion design utilizing the highly flexible LPD-17 platform as the basis of a purpose-built HADR ship, capable of providing fresh water, food, shelter, and medical care to a population of 50,000 displaced persons for 30 days. The design leverages the useful attributes of LPD-17 such as her heavy lift helicopter and LCU capability, and eliminates unneeded and costly features such as high-tech weapons systems and sensors. By replacing the unneeded equipment with additional potable water production capability, fuel stores, medical facilities, cargo handling capabilities and surge bunking, an LPD-Disaster Relief (DR) variant is possible.

To test the viability of the concept, several analyses were conducted. Stability and seakeeping computer models were developed to verify the design meets Navy standards, and arrangement drawings were developed in order to prove the ship met needed space requirements. Finally, a comprehensive “maximum load-out” cargo manifest was generated and used in the stability analysis to ensure the ship would not fail under worst-case conditions. The conclusion drawn was that a vessel capable of conducting large-scale HADR missions could be created with minimal structural modifications to the existing LPD-17 platform.

LPD-DR Characteristics	
Parameter	**Value**
Length Overall	208.5 m
LBP	200 m
Beam	31.9 m
Full Load Draft	7.2 m
Sustained Speed	23 kts
Installed Power	41600 SHP
Range @ 23 kts	9000 nm
Lightship Weight	19919 MTon
Full Loads	2050 MTon
Full Load Weight	21969 MTon





2012 2N Student Theses

High-Voltage Lithium-Ion Battery Models for Crashworthiness Analysis

CDR John Campbell, USN

Prof. Tomasz Wierzbicki	**Dr. Elham Sahraei**
Thesis Supervisor	Thesis Reader

Computational models for evaluating performance of Li-Ion cells are necessary to reduce costs of testing and to accurately predict failure under abuse conditions. Detailed constitutive and computational models capable of predicting failure, to date, have not been published in the open literature for Li-Ion cells, modules, and battery packs. The present work is concerned with studying behavior of Li-Ion pouch cells. Such cells have a very complex internal structure with multiple layers of various materials, similar to a composite laminate. The objective of this work is to detect and model the onset of short-circuit under conditions of mechanical abuse. In this study, a homogenized model of the interior structure was developed and calibrated through a set of carefully planned experiments. A set of punch indentation tests was conducted using rigid hemispherical punches while monitoring load, displacement, temperature and voltage output of the individual cells. The previously developed model was calibrated against physical test results by choosing the proper tensile cutoff value for the average tensile strength of the electrode/separator assembly. The FE simulation perfectly represents the overall results seen in physical testing. The model of a single cell is a starting point in the development of more complex systems such as modules and battery packs. Ultimately the battery pack can be coupled with FE models of whole vehicles and would be useful in evaluating damage to the packs in the event of a vehicular crash. Such a model can be used to ensure properly engineered battery packs for hybrid and electric vehicles, potentially minimizing weight and production cost while maximizing safety.

Naval Engineer
Master of Science in Mechanical Engineering

Electrical Discharge Machining of Highly Doped Silicon

LCDR Greg Crawford, USN

Prof. David Hardt	**Dr. Chris DiBiasio**
Thesis Supervisor	Research Advisor (Draper Lab)

Electrical Discharge Machining (EDM) is an advanced machining process that removes material via thermal erosion through a plasma arc. This machining process is accomplished through the application of a high frequency current (typically through a fine wire or other electrode) to a conductive workpiece. The electrode is physically separated from the workpiece by some small distance and the potential difference is typically discharged through an insulating dielectric material. This short duration application of current produces a spark across the gap between the electrode and workpiece, causing vaporization and melting of local material in both the electrode and workpiece. Typically this process is used for conductive substrates (i.e. metals), however, recent research has shown that this process may be used on semiconductor substrates such as doped silicon wafers. The purpose of this research will be to optimize the EDM process on doped silicon wafer workpieces individually for both material removal rate (MRR) and surface roughness (R_a) for both Wire EDM and Die-sinker EDM machines utilized in the machine shop at Draper Laboratory. Once process optimization is completed, minimum obtainable feature size for various features and evaluation of various effects on the optimized process will be conducted.

EDM is a complex process with numerous inputs to the process that have the potential to directly or indirectly influence the output product. As such, it this research characterized the process for both WEDM and Die-Sinker EDM utilizing statistical Design of Experiments (DOE) methods to minimize the number of input variables varied during testing and model the process mathematically using only those inputs of statistical relevance. The research was conducted at Draper Laboratory for potential in use for Microelectromechanical systems (MEMS).

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Naval Engineer
Master of Science in Mechanical Engineering

Design of a Free-running, 1/30th Froude Scaled Model Destroyer for In-situ Hydrodynamic Flow Visualization

LT Dave Cope, USN

Prof. Chryssostomos Chryssostomidis
Thesis Supervisor

Hydrodynamic flow visualization techniques of scaled hull forms and propellers are typically limited to isolating certain operating conditions in a tow tank, circulation tunnel or large maneuvering basin. Although cost effective, these tests provide a limited perspective on the interactions of the entire system. Full scale testing, other the other hand, provides real world data but is costly. In between, a Froude scaled, free-running model of an existing hull form controls costs but also provides superior hydrodynamic data that can be translated more accurately to full scale. For this purpose, a $1/30^{th}$ scale free-running model of the David Taylor Model Basin 5415 hull, the precursor to the ubiquitous Arleigh Burke Guided Missile Destroyer class hull, was designed and constructed.

The propeller crashback, a core propulsion plant test for both the U.S. Navy and commercial vessels, imparts significant unsteady loads both mechanically, and with the advent of the Integrated Propulsion System, electrically to the engineering plant. Each of these is respectively of interest to propeller designers and the Electric Ship Research and Development Consortium (ESRDC). The $1/30^{th}$ scale model provides unsteady, time-resolved, accurate 3D flow visualization and propeller loading data as well as measurements of the effects on the electrical propulsion motors. Testing conducted with the model provides the real world effects of the propeller flow interaction with the hull, appendages, and, in this case, the other propeller. The second area of research concerns the high inefficiencies of slender hull forms while maneuvering. During a turn, a significant amount of power is lost to the low pressure region developed on the inside of the turn from shedding vortices that originate along the keel. This increases the tactical diameter of the turn and reduces the turning efficiency of the vessel. Research is currently being conducted around controlling the shedding of vortices and keeping them attached to the hull thereby increasing the turning efficiency and decreasing the turning radius of the vessel. The final area of interest is in forward mounted podded propulsors for use on large vessels. The model provides a reconfigurable platform for measuring the maneuverability characteristics due to the introduction of such machinery.

Naval Engineer
Master of Science in Mechanical Engineering

Nondestructive Evaluation of Composite-Steel Interface by Acoustic Laser Vibrometry

LT Timothy J. Emge II, USN

Prof. Oral Buyukozturk	**Prof. James H. Williams, Jr.**
Thesis Supervisor	Thesis Reader

Composite materials are increasingly being used in both civil and ship structures. In particular, fiber reinforced polymer (FRP) composites are being utilized. FRP materials are most often employed to reinforce aging or damaged portions of civil structures. On naval vessels, FRP materials are incorporated to reduce weight, particularly up high, and to reduce radar cross section, thereby increasing stealth capability. In both cases of FRP use, it is usually in conjunction with some other material, oftentimes steel. It is beneficial when using FRP and steel to adhesively bond them together. When these materials are joined adhesively, the most common failure mode is debonding or delamination at the interface of the adhesive with the steel and composite materials. These defects are often difficult to discern without the aid of some form of nondestructive testing (NDT). Acoustic laser vibrometry is a relatively new method of NDT that shows a lot of promise in analysis of this interface. In this approach, an airborne acoustic wave is utilized to excite the location of the damage underneath the FRP sheets/plates and the target vibration is measured using a laser vibrometer. To study the acoustic laser method, a defect specimen was created from a plate of AL6XN stainless steel and a plate of glass FRP adhesively bonded on their faces with a purposely placed elliptical debonding defect. A number of parameters of the acoustic laser vibrometry system were varied and trends were found. Additionally, grid data was collected from the defect specimen and a defect mapping was created. Theoretical and finite element models were produced and compared to measured results. The close correlation of the results from these three methods validated them all.

Naval Engineer
Master of Science in Civil and Environmental Engineering

Modular Machinery Arrangement and Its Impact in Early-Stage Naval Electric Ship Design

Mr. David Jurkiewicz

Prof. Chryssostomos Chryssostomidis
Thesis Supervisor

Electrical power demands for naval surface combatants are projected to rise with the development of increasingly complex and power intensive combat systems. This trend also coincides with the need of achieving maximum fuel efficiency at both high and low hull speeds. A proposed solution to meet current and future energy needs of conventionally powered naval surface combatants is through the use of an Integrated Power System (IPS), which is seen as the next evolution in naval ship design. Unfortunately, historically-based ship design process models and parametrics cannot accommodate new-concept designs that are not incremental changes to previous practice. Additionally, integrating IPS with the next generation of ship designs is also synonymous with the desire of conducting system-level tradeoffs early within the ship design process. In an effort to enhance the relationship between new-concept designs and historically-based ship design processes, this thesis focuses on a novel approach of incorporating IPS at the earliest stage of the design process as part of assessing system-level tradeoffs early.

This thesis describes a methodology for the system design and arrangement of an IPS machinery plant based on an objective of meeting a desired power generation level, effectively introducing a power constraint at the start of the design process. In conjunction with the methodology development, a hierarchical process and design tool for integration with Graphics Research Corporation's (GRC) naval architecture software suite, Paramarine, is also produced to assist in rapid development and evaluation of various IPS arrangements. The result of this process, through several case studies, provides insight into equipment selection philosophy, the initial sizing of the ship's machinery box, and the initial definition of electrical zones. Lastly, the developed tool is also used to aid in the creation of "design banks," allowing the naval architect to manage weight, power, and volume at the beginning of the ship design process; therefore, supporting early system-level tradeoffs for new-concept designs.

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

Numerical Analysis of a Shear Ram and Experimental Determination of Fracture Parameters

LT Evangelos Koutsolelos, HN

Prof. Tomasz Wierzbicki
Thesis Supervisor

The human, economic and environmental disaster that followed the Deepwater Horizon catastrophe at the Gulf of Mexico in April 2010 revealed how much the offshore drilling industry relies on the Blowout Preventer (BOP) as the primary means of controlling a ‘well kick’ or ‘blowout’. One of the most important components of the BOP are the shear rams which are tasked with cutting the drilling string in case of an emergency, allowing the blind rams and the annular type blowout preventer to seal the wellbore and generally prevent things from becoming unmanageable. The increased drill pipe material strength, the fact that their diameter and wall thickness are eventually optimized (larger and heavier pipe sizes) and the greater water depths in combination with the high drilling fluid density, affect the BOP’s ability to shear. This study investigates all stages of the shearing process and attempts to optimize the geometry of the shear blades. In order to do that, simulations are conducted with Finite Element Models (FEM) by utilizing the Impact and Crashworthiness Lab’s (ICL) fracture methodology, the backbone of which is the Modified Mohr-Coulomb (MMC) fracture criterion. Nine cases involving three different angles defining the sharpness (cutting angle) and three angles characterizing the shape of the blade are evaluated. The optimum configurations for the shear blades are investigated based on the maximum required cutting force and the sealing capability. The simulations are performed for TRIP 690 steel as well as the X70 grade. The fracture and plasticity parameters for X70 grade of steel were experimentally determined in the ICL lab as part of this research. Finally, recommendations for shearing the tool joints, the connections of the drill pipes, are made based on the Finite Element (FE) simulations.

Naval Engineer
Master of Science in Mechanical Engineering

Fracture and Plasticity Characterization of DH-36 Navy Steel

LT Christopher MacLean, USN

Prof. Tomasz Wierzbicki
Thesis Supervisor

Multi-layered plates consisting of DH-36 steel coated by a thick layer of polyurea, for increased blast and impact protection, are of increasing importance to the Department of Defense. A hybrid approach of experiments and simulation was performed to characterize fracture and plasticity of DH-36 Navy steel, which is the first step in creating an accurate model of the composite material. The performance limit to this material during an impact is ductile fracture. The prediction follows that the onset of fracture occurs when a certain critical value of plastic strain is reached. This value is highly dependent on the state of stress. Seven different types of tests were performed, including tensile tests on dog-bone and notched specimens and punch indentation tests on circular blanks. Also, tensile and shear tests were performed on butterfly specimens using the dual actuator loading frame. Fracture surface strains were measured using digital image correlation. Local fracture strains were obtained by using an inverse engineering method of matching measured displacement to fracture with computer simulations. The results are used to calibrate the Modified Mohr Coulomb fracture model which is expressed by the stress state invariants of load angle and triaxiality.

Naval Engineer
Master of Science in Mechanical Engineering

Concept Design of a Long Range AUV Propulsion System with an Onboard Electrical Generator

Lt(N) Eric Poulin

Royal Canadian Navy

Prof. Chryssostomos Chryssostomidis
Thesis Supervisor

Automated Underwater Vehicle (AUV) Technology has come a long way in the past decade. Due to advances in batteries and telecommunications, unmanned underwater vehicles no longer require a tether to a mother ship for power, command and control; however, AUV endurance and range are still limited by the size and capacity of the onboard batteries. Attempts to overcome this limitation, with studies utilizing fuel and solar cells were developed to augment the stored energy onboard. This thesis examines the viability of utilizing an internal combustion engine as an onboard generator to recharge the batteries during the mission in order to increase both range and endurance. Working in conjunction with the MIT Rapid Development Group, an onboard generating system was developed utilizing a gasoline generator. This system was incorporated into a long range AUV propulsion system. Maximum efficiency of all components was stressed at every point in the design process in order to decrease the propulsion system power requirements. Advanced lithium-ion battery systems were also investigated in order to find a system that balanced maximal energy storage with low recharge time. The study resulted in a theoretical AUV propulsion system that could traverse distances that span the Atlantic Ocean at a speed of 2 knots. It is believed that this type of AUV would be ideal for both scientific research and military applications.

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

Autonomous Adaptation and Collaboration of Unmanned Vehicles for Tracking Submerged Targets

LT Andrew Privette, USN

Prof. John J. Leonard	**Michael R. Benjamin**
Thesis Supervisor	Thesis Reader

In this thesis, we address the problem of harbor and sea-lane security against submerged threats. One method in which security can be achieved is through the development and deployment of unmanned autonomous vehicles. This thesis will examine, develop, and implement algorithms and behaviors that will help aid in harbor security. To do this we will employ an Autonomous Surface Vehicle (ASV) to local and track stationary and mobile underwater targets in littoral environments using a particle filter that is based on gathering range only information. The next step will be to use that information and create behaviors for the ASV to make decisions about maneuvering with the goal of tracking and intercepting the contact of interest. The last step of the thesis is to investigate the use of multiple ASV that collaborate in order to localize, track, and investigate threats at a faster rate.

Naval Engineer
Master of Science in Electrical Engineering and Computer Science

Development of an Early Stage Ship Design Tool for Rapid Modeling in Paramarine

LT Eric Thurkins Jr., USN

Prof. Chryssostomos Chryssostomidis
Thesis Supervisor

In early-stage ship design, it is helpful to perform preliminary design and analysis on many configurations to assist in developing and narrowing the trade space. This process is further complicated with the increasing interest in concepts that are breaks from previous practice, such as Integrated Power System (IPS) designs, which require initial development to go deeper than historically based parametrics can provide. Paramarine is a ship design and analysis tool which can be used in this early-stage design; however, as with many early-stage design tools, the fleshing out of diverse ideas in Paramarine can be time and resource consuming. In an effort to enable a developer to create early-stage designs with depth significant enough to be meaningful but still general enough to allow the level of flexibility in design required in the early stages of development, this project seeks to develop an Early Stage Ship Design Tool (ESSDT). This ESSDT is a novel interface with which a designer can rapidly develop and alter basic, major design components of a ship from a compiled database of components and gain a rendered model for analysis within the naval design tool Paramarine. By making use of many early-stage parametric and developed calculations and leveraging the use of IPS, this ESSDT automates many of the initial ship's estimates and minutia of design. Utilizing both Excel and Paramarine software, the ESSDT rapidly creates a visual model of a basic naval vessel with primary systems and equipment from relatively few initial user inputs while embodying a depth of user-changeable default settings for more complex and non-standard design efforts.

Several case studies were run to show the capability and flexibility of the tool, as well as showing how new powering and mechnical systems can affect the parameters of the ship as a system of systems.

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Naval Engineer
Master of Science in Mechanical Engineering

Ship Hull Resistance Calculations using CFD methods

LT Petros Voxakis, HN

Prof. Chryssostomos Chryssostomidis	**Prof. Stefano Brizzolara**
Thesis Supervisor	Research Advisor

In past years, the computational power and run-time required by Computational Fluid Dynamics (CFD) codes restricted their use in ship design-space exploration. Increases in computational power available to design agents, in addition to more efficient codes, have made CFD a valuable tool for early stage design and trade studies.

In this work an existing physical model (DTMB #5415, similar to the US Navy DDG-51 combatant) is replicated in STAR-CCM+, initially without appendages, then with the addition of the appendages. Towed resistance is calculated at various speeds. The model is unconstrained in heave and pitch, thus allowing the simulation to achieve steady dynamic attitude for each speed run. The effect of dynamic attitude on the resistance is considered to be significant and requires accurate prediction. Results are validated by comparison to available data from tow tank tests of the physical model.

The corresponding self-propelled, full scale ship is then modeled in the same CFD package. Self-propelled simulation allows for the estimation of the thrust deduction. .

The results demonstrate the accuracy of the CFD package and the potential for increasing use of CFD as an effective tool in design space exploration. This will significantly reduce the time and cost of studies that previously depended solely on physical model testing during preliminary ship design efforts.

Naval Engineer
Master of Science in Mechanical Engineering

Propeller Design Optimization for Tunnel Bow Thrusters in the Bollard Pull Condition

LT James Wilkins IV, USN

Prof. Chryssostomos Chryssostomidis
Thesis Supervisor

Tunnel bow thrusters are often used by large ships to provide low-speed lateral maneuverability when docking. Required to provide high thrust while essentially at a standstill, the design point for these thrusters is the bollard pull condition. Traditionally, the term bollard pull refers to the amount of force a tug can apply to a bollard when secured to a pier. Here, the bollard pull condition is used to describe a propeller with no flow over it except for that induced by its own rotation. Conventional propeller design is primarily performed for an optimal vessel speed or range of speeds. OpenProp, a propeller design code based on lifting line theory, is a numerical model capable of design and analysis of such propellers. It has been experimentally validated for standard design conditions in an external flow, but until now has been incapable of design with no external fluid velocity component applied. Recent updates to the model now allow for bollard pull design work. This project is the first application of the OpenProp model update. Propellers are designed for both open water and ducted (tunnel) applications in OpenProp. The initial designs are then refined by coupling MTFLOW, a Reynolds-Averaged Navier-Stokes (RANS) viscous flow solver, with PBD-14, a lifting surface design program for marine propulsors. An experimental apparatus is constructed to test the propeller designs and validate the OpenProp model. A range of off-design operating conditions are analyzed and results are presented.

Naval Engineer
Master of Science in Mechanical Engineering