

## The Education of Naval Ship Designers in the U.S.A.

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*Abstract:* - The U.S. Navy is the source of most ship design and shipbuilding employment (direct and indirect) in the U.S. and it has been active in ensuring that sufficient and appropriately trained professionals are available to support its future ship design and shipbuilding needs. This has been achieved in a number of ways. Since 1901 MIT has maintained a graduate program in Naval Construction and Marine Engineering, MIT has also been the location of the Professional Summer Program consisting of a series of classified and unclassified professional courses. The Naval Postgraduate School offers Masters level education in warship related systems engineering and operations research. Even with all this activity the results are not meeting today's needs. To correct this problem the U.S. Navy along with the University of Michigan and other participating academic institutions augmented the available education in naval ship design by introducing a new intensive seven week summer naval surface ship design program. The above programs offered in the U.S. that augment education in warship design supporting the goals of skill set development, refreshment, and maintenance are described in this paper.

*Key-Words:* - Naval surface ship design education, training, professional concentrated courses

### 1 Introduction

The U.S. Navy provides continuing education to its engineers in a number of ways including their own in-house education division that provides short courses, through the MIT graduate program in Naval Construction and Marine Engineering and the MIT Professional Summer Program, and most recently by sponsoring a new intensive seven week summer naval surface ship design program. Each of the programs will be briefly reviewed in the paper.

There has been a drive in recent years to provide graduate level distance learning courses in naval architecture for practicing engineers who do not have an undergraduate degree in naval architecture. Virginia Polytechnic Institute (VT) has had a distance learning program in naval architecture for some years. The United States Merchant Marine Academy (USMMA) has a distance learning program (Global Marine Institute) covering marine engineering subjects.

The U.S. Navy hires its engineers from diverse

educational and experiential backgrounds. Engineers that specialize in ship design have an undergraduate degree in naval architecture, an undergraduate engineering degree with a Masters degree in Naval Architecture, or both undergraduate and a Masters degree in Naval Architecture. There are a number of engineers that have no education in naval architecture who desire to follow the ship design manager career path and they need additional education in ship design.

Special "summer" concentrated courses have been provided by the Massachusetts Institute of Technology (MIT) for many years, namely the Design of Naval Submarines Summer Course. The University of Michigan, now offers the Summer Naval Surface Ship Design Program started in 2005.

### 2 Universities

Seven universities and two marine academies offer degrees in naval architecture and/or marine engineering in the U.S. A further five universities

and marine academies offer courses in naval architecture and marine engineering but the degree earned is in another discipline such as Ocean or Civil Engineering.

Only the U.S. Naval Academy has an undergraduate naval architecture program that focuses on naval ships. Virginia Polytechnic Institute has a strong naval ship design focus due to its experience of its professors, some of whom served in the U.S. Navy and in their design group. The University of Michigan plans to offer a one semester Surface Naval Ship Design course based on their summer course. MIT offers a graduate level Naval Construction and Engineering Program (Course 2N) within the Mechanical Engineering Department.

### 3 MIT Naval Construction and Engineering Program (2N) [1]

Since 1901, MIT has maintained a graduate program in Naval Construction and Marine Engineering, in close cooperation with the United States Navy. This program prepares Navy, Coast Guard, foreign naval officers, and other graduate students for careers in ship design and construction. The course of study consists of both a two-year program, which leads to a Master's of Science degree in Naval Architecture and Marine Engineering and a three-year program, which leads to the degree of Naval Engineer.

The curriculum leading to a Master of Science in Naval Architecture and Marine Engineering is based on a broad working knowledge of all the basic engineering skills. As a part of the more general field of ocean engineering, naval architecture and marine engineering are concerned with all aspects of waterborne vehicles operating on, below, and just above the sea surface. The Master of Science in Naval Architecture and Marine Engineering is intended to develop an individual who plans to concentrate in areas related to waterborne vehicles and/or their subsystems.

The program leading to the Naval Engineer's degree requires a higher level and significantly broader range of professional competence in engineering than that required for the M.S.M. degree. The program for an engineer's degree ordinarily includes subjects in the areas of economics, industrial management, and public policy or law, and at least 12 units of comprehensive design.

Student working toward the simultaneous award of the engineer's and master's degree are offered the opportunity of working on a single thesis appropriate to the specifications of both degrees and

demonstrates the educational maturity expected of candidates for the higher degree.

### 4 Professional Summer at MIT [2]

Massachusetts Institute of Technology and The Charles Stark Draper Laboratory, Inc. sponsor a series of classified and unclassified professional courses organized and developed by the Professional Summer Program at MIT. The courses are intended for officers and civilian personnel in government and industry working in ship systems design, analysis and production, and in specific technologies important to the U.S. Navy.

The Professional Summer Program was developed to meet the needs of Navy graduate students in the Naval Construction and Engineering Program in MIT's Department of Mechanical Engineering and to provide others with an opportunity to study and discuss technical issues important to the U.S. Navy. Lecturers in the Program have been selected to present conceptual frameworks, up to date information, and perspectives for the future. Lecturers come from a variety of technical sources, including the U.S. Navy, industry, and academia.

This is the thirty-fifth year of the Professional Summer Program. The program of previous years has launched what has become an important and continuing forum for education and information exchange among the leaders of the military technical communities. All courses meet the "Continuous Learning Points" (CLP) requirements of the Defense Acquisition Workforce Improvements Act (DAWIA). The year 2007 curriculum included:

- Submarine Combat Systems
- Surface Ship Combat System Design Integration
- Ship and Submarine Signatures
- Submarine Concept Design
- Shipbuilding Operations and Technology
- Weapons Effects and Ship/Submarine Survivability

### 5 Naval Post Graduate School [3]

The Naval Postgraduate School offers both on campus and distance learning opportunities supporting aspects of warship design in the following areas:

- MS in Systems Engineering
- MS in Electronic Systems Engineering
- MS in Engineering Science
- Electrical and Computer Engineering
- Reactors/Mechanical Engineering
- Engineering Acoustics-Physics

Two of the curricula areas providing education in naval ship design competency areas are the systems engineering and reactors/mechanical engineering programs.

### 5.1 MS in Systems Engineering

The Master of Science in Systems Engineering distance learning degree program is designed for DoD organizations involved in a wide range of systems engineering and integration challenges. These commands can now partner with NPS to educate and train engineers with tools and technologies relevant to their work, resulting in employees with greater knowledge and expertise to enable them to better meet the needs of their customers.

### 5.2 Reactors/Mechanical Engineering

The department of Mechanical Engineering provides a strong academic program which spans the disciplines of the thermal-fluid sciences, structural mechanics, dynamic systems and control, materials science and engineering and total ship systems engineering. These disciplines are blended together with a strong emphasis on naval engineering applications such as may be experienced on surface vessels and in submarines.

The NPS programs are designed to help Department of Defense engineering organizations become more responsive to the changing nature of engineering tasking in support of research, development and acquisition. Another objective of is to enhance the professional standing of employees through academic accomplishment.

## 6 National Naval Responsibility for Naval Engineering

In October 2001, the Office of Naval Research (ONR) established the National Naval Responsibility for Naval Engineering (NNRNE) in response to conclusions and recommendations from several studies and reports [4-12]. These reports highlighted the significant role the Department of Defense must play in leading the R&D investment stimulus for the cooperative development of innovative, cost and labor saving technologies by the U.S. shipbuilding industry and the supporting academic institutions. Additionally, each subsequent report continued to identify the areas of education, innovation and competitiveness as problematic in the U.S. shipbuilding industry.

The Office of Naval Research created a program initiative aimed at starting and nurturing partnerships among the pertinent stakeholders

(government agencies, industry, academia, non-profit organizations, etc.) to address the shipbuilding industry weaknesses identified. The goals of the NNRNE will be achieved by such actions as:

- Investing and stabilizing sufficient resources in the relevant programs
- Formulating and maintaining investments in seven key S&T areas in naval engineering
  - 1) Ship design tools
  - 2) Ship structural materials
  - 3) Hydromechanics
  - 4) Advanced hull designs
  - 5) Ship propulsion
  - 6) Ship automation
  - 7) Ship systems integration
- Sustaining, in conjunction with industry, an infrastructure for innovative shipbuilding concepts
- Issuing Broad Agency Announcements for graduate fellowships and post-doctorates
- Conducting major field experiments that integrate various technologies into innovative concepts
- Augmenting S&T programs with investments in infrastructure such as students, facilities, and equipment.

Research projects are undertaken aimed at providing for the education and training of students who will make up the next generation of naval engineering workforce and foster development of design tools. Most of the projects are being performed by multi university teams thus ensuring collaboration and supporting a distribution of knowledge and experience among them.

## 7 Naval Acquisition Intern Program

The Naval Sea Systems Command (NAVSEA) is a primary participant in a Department of the Navy-wide career development program called the Naval Acquisition Intern Program (NAIP). This program is centrally administered by the Navy, providing employment opportunities in the following six career fields:

- Systems Planning, Research, Development and Engineering
- Business/Cost Estimating and Financial Management
- Contracting
- Communications/Computer Systems
- Acquisition Logistics
- Manufacturing, Production and Quality Assurance.

NAVSEA has employees in all six career fields, with the bulk of our NAIP participants in the Systems Planning, Research, Development and Engineering and Business/Cost Estimating and Financial Management fields. It is structured to last two years if the engineer has a masters degree or two and a half years if they have a bachelors degree.

The NAIP offers professionalism, rapid advancement, mobility, travel and the opportunity to be associated with a specialized field that is vital to our nation and to the support of our Naval Forces. Individuals who are enrolled in the program are integrated into ship acquisition project ship design teams supporting Program Executive or NAVSEA offices. The NAIP employees will support NAVSEA competencies that encompass oversight and management of:

- Research,
- Development,
- Systems integration,
- Design,
- Construction,
- Testing,
- Fleet introduction,
- Lifetime support,
- Disposal ,
- Foreign military transfer of current and future surface combatant, amphibious and auxiliary ships, and submarines.

Key to this program is a planned series of rotational assignments, developed in coordination with a career field advisor and whenever possible mentors from NAVSEA's ranks of senior scientists, engineers, or executives. Rotational assignments will expose interns to a wide range of Navy activities and allow him/her to gain experience regarding how the various parts of the Navy, Office of the Secretary of Defense, and Federal Government interact with each other and industry, regulatory bodies and research organizations. Rotations also provide the engineer with an opportunity to experience program management issues and challenges.

The external rotations provide the interns with the opportunity to work at another Government Agency or Field Activity within the United States for up to eight months to enhance their practical experience and industry understanding. Interns have the flexibility and opportunity to experience work environments normally inaccessible to entry level engineers including, but not limited to:

- Fleet operations at sea
- Fleet maintenance activities ashore

- All public and private shipyards involved in US Navy shipbuilding
- Naval Surface and Undersea Warfare Centers
- Office of the Chief of Naval Operations
- Office of the Secretary of Defense
- Naval Air Systems Command
- Program Executive Offices
- All NAVSEA technical codes

Experience has shown that interns are only limited by their personal desires and abilities. Successful interns have found themselves working at sea underway on a carrier strike group's flag staff, participating on builder's sea trials of some of our newest shipbuilding programs, briefing three-star admirals on a weekly basis, or independently representing the Navy's position to working groups at the Office of the Secretary of Defense and Joint Staff level. In short, the NAIP provides the flexibility and opportunity for the Navy's future leadership to shine early in their careers.

The NAIP also facilitates graduate school tuition assistance for those who wish to pursue an advanced degree in engineering, engineering management, or business administration. Funding is provided by the Navy's centralized Acquisition Workforce Tuition Assistance Program (AWTAP). Additionally, the program provides opportunities to attend dedicated engineering and management training programs, as well as ensuring certification as certification in the Defense Acquisition workforce in their respective career field through the Defense Acquisition University.

Finally, interns are guaranteed full-time placement at their Host Command (NAVSEA Headquarters or a Warfare Center) after completion of the intern program granted that performance has been deemed satisfactory.

## 8 University of Michigan Summer Naval Ship Design Program

All the above programs have not provided the necessary number of naval ship design educated engineers. There is still a significant gap between what is required and what is available. To help close this gap ONR organized a Naval Ship Designer Education Conference at University College London (UCL) in 2003 [2], which concluded that Naval Ship Design was too specialized for any single university to develop and sustain an ongoing program focusing on naval ship design on their own. Thus it was concluded that it is essential that such education be sponsored by Naval

Authorities and/or Government.

The idea for the summer program was born in August 2004. NAVSEA believed that the program was a necessary addition to the existing programs in order to ensure the future capability of the U.S. to:

- Develop cost effective and innovative naval ship designs
- Effectively meet defense and commercial market human capital needs for personnel development and career skills refreshment.

Significant participation, constant support and encouragement from NAVSEA's Future Concepts and Surface Ship Design Group, NAVSEA Code 05D, personnel was and is the critical success factor. A program development team in place November 2004 consisting of representatives from:

- University of Michigan
- University of New Orleans
- Virginia Tech
- Naval Post Graduate School
- NAVSEA

As a basis for the design of the program, the development team was tasked to:

- Identify unique aspects and best practices of Naval Ship Design
- Review the current state of education in Naval Ship Design and prepare a recommended curriculum outline for a modularized Naval Ship Design Course
- Determination of ship design best practice in both naval and commercial industry.
- Identification of naval ship unique design areas, compared to commercial ship design.

Based on the success of the 2005 through 2007 programs, the University of Michigan is continuing to offer a naval surface ship design program of unclassified professional courses organized. The program was developed by the University of Michigan's Department of Naval Architecture & Marine Engineering and a team from the Naval Postgraduate School, Virginia Tech, and NAVSEA. The program is endorsed by the Future Concepts and Surface Ship Design Group of the Naval Sea Systems Command (NAVSEA). Industry has requested that the Michigan program be made available for presentation at company locations and NAVSEA had requested that the program be provided in the Washington DC area so that many of their employees and those of the design agents that support NAVSEA could attend. So the 2007 program was held in Washington DC..

The Summer Naval Surface Ship Design Program was developed to meet the rapidly evolving needs of practicing professionals, graduate students planning to enter the profession of naval ship design and other professionals who desire an opportunity to study and discuss technical issues important to the U.S. Navy. Lecturers in the Program are from Academia government and industry.

They present the latest advances in design technologies such as naval ship design, naval marine systems design, systems architecting, systems engineering, design of experiments (DOE), and multi-disciplinary design optimization (MDO). The program encompasses both theory and practice, including current knowledge of product development best practices, lessons learned experience, current and future challenges in naval ship design, and a hands-on capstone design. Participants will also learn how to work concurrently in a multi-disciplinary, collaborative, collocated team environment producing winning ship designs and successful ship acquisitions. All courses will provide University of Michigan CEUs, and meet the "Continuous Learning Points" (CLP) requirements for Defense Acquisition Workforce Improvements Act (DAWIA). The complete program will be offered to final year undergraduate and graduate students as an elective 4 credit course.

Participants in the programs so far have been from NAVSEA, U.S. Design Agents, U.S. shipyards, naval officers from Turkey, Korea, and Columbia, and students from University of Michigan. The curriculum was developed to build skill-sets sequentially leading to a Capstone concept design class. The program is flexible, however, and permits students to enroll in the entire program or for individual courses, albeit with pre-requisites for select courses if taken separately. Also to better prepare non-naval architect students for the courses there are recommended pre-program Naval Architecture Overview books.

Details of the program, including course contents by day and registration, can be accessed on the program website:

**Website:** <http://www.umich.edu/~snssdp>

Table 1 lists the courses and major contents for 2007 program.

## 9 Conclusions

The U.S. Navy has been active in ensuring that sufficient and appropriately trained professionals are available to support its future ship design and shipbuilding needs by providing continuing

education to its engineers for skill set development, refreshment, and maintenance in a number of ways for over 100 years.

The MIT graduate program in Naval Construction and Engineering, and the MIT Professional Summer Program have been longstanding education opportunities for naval ship designers. The Naval Postgraduate School offers Masters level education in warship related systems engineering and operations research. Education in naval ship design has most recently been augmented by a new intensive seven week Summer Naval Surface Ship Design Program run through the University of Michigan Naval Architecture department. This program has been both a technical and financial success in its first 3 years, and looks set to increase its success both at the University of Michigan and other locations. It was also used to develop a new, one-semester Naval Surface Ship Design course at the University of Michigan, which may be offered in the future as a part of their distance learning program.

The U.S. navy is now reaching down to the undergraduate level providing input to curriculum and projects that will be used to support the human infrastructure needs of today's navy and the navy of the future. The Naval Acquisition Intern Program is the demonstrated successful path integrating naval ship designers into NAVSEA.

The third Summer Naval Surface Ship Design Program has just completed with increased level of attendance, and lessons learned from attendee feedback are being reviewed to improve it for a continuing successful program.

The approaches briefly discussed in this paper have proven effective for more than 100 years in providing the U.S. Navy with the educated and trained ship designers and support engineers. However the challenge remains to interest and motivate sufficient numbers of people to avail themselves of these learning opportunities.

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However, the statements and opinions presented in the paper are those of the authors, and they do not necessarily represent the collective or individual position of any university or the United States Navy or Department of Defense.

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- [10] U.S. Department of Commerce's May 2001 "National Security Assessment of the U.S. Shipbuilding and Repair Industry"
- [11] National Research Council Marine Board's proposed and funded "Naval Engineering Cooperative Research" study dated July 2001
- [12] ONR Workshop on Teaching Future Warship Designers – 2004 (at University College London)

**TABLE 1: 2007 SNSSDP COURSES AND CONTENTS**

- 1. NAVAL SHIP DESIGN (5 days)**
  - Sea Power 21
  - DOD 5000.2
  - Naval Ship Acquisition
  - Naval Ship Acquisition - differences between countries
  - Cost Estimating
  - Toward Successful Warship Design
  - Naval Ship Design Standards and Practices
  - Naval Ship Production Practices, Naval Ship Design for Production
  - Total Ship Certification: Design Approval, Validation
  
- 2. SHIP MOBILITY AND SUPPORT SYSTEMS (5 DAYS)**
  - Zonal Design and Zonal Distribution Design
  - Manpower Estimation
  - Propulsion Plant Design and Integrated power Systems
  - Machinery Arrangement Design
  - Mobility and Survivability Effectiveness
  
- 3. WARFARE SYSTEMS (5 days)**
  - Mission Definitions, Required Operational Capabilities
  - Naval Science/Combat Systems&C4ISR Integration
  - Survivability, Vulnerability, Other Unique Warship Features
  
- 4. NAVAL SYSTEM ARCHITECTING/ENGINEERING (5 days)**
  - System Architecting and Engineering Processes; System Architecture Definition
  - Architecture Frameworks; Systems Engineering Standards and Practices
  - Requirements Definition Process; Needs Analysis; Preference Modeling
  - Objective Hierarchies; Decomposition; Analytic Hierarchy Process
  - Metrics Definition; Quality Function Deployment; Functional Analysis and Allocation
  - Concept Generation Methods; Creative Thinking Techniques
  - Concept Selection Methods; Decision Analysis; Multiple Criteria Decision Making; Pareto Optimality
  - Cost – Effectiveness - Risk Trade-off Methods; Design of Experiments; Response Surface Methods
  - Technology and Cost Uncertainty; Risk Management and Analysis
  
- 5. CONCEPT AND REQUIREMENTS EXPLORATION (5 Days)**
  - Measures of Effectiveness/Performance/Risk (MOE/MOP/MOR)
  - Current Tools for Naval Ship Concept Design & Selection
  - Naval Ship Synthesis and Analysis
  - Requirements Determination/CE-note: spell out “CE”
  - Multi-objective Design Optimization (MDO)
  
- 6. CAPSTONE NAVAL SURFACE SHIP DESIGN (10 days)**
  - Team Based Design – Design Best Practice