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A New Course in Defense Manufacturing – An Introduction to Shipbuilding

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A New Course in Defense Manufacturing – An Introduction to Shipbuilding

Abstract: This paper discusses the development and deployment of a new course in DMEI (Defense Manufacturing Engineering Innovation) titled, "Introduction to Shipbuilding." This course has been taught using Zoom since 2021. After a brief literature review, an outline of the course is presented with topics including the maritime market for shipbuilding, economics of shipbuilding, the classification agencies, metallurgy and welding processes, ship structure and assembly, shipyard layout, accuracy control, and shipbuilding planning and scheduling. Difficulties in obtaining an appropriate textbook and the use of guest lecturers are discussed. Student survey data is presented, and conclusions are drawn about this course.

Key words: Shipbuilding, Defense Manufacturing

Introduction

The building of military vehicles includes the building of tracked and wheeled vehicles, aircraft and ships. Ships are the largest, most expensive and arguably most complex of the three types of military vehicles. Shipbuilders include both public (government owned) and private shipyards. The U. S. private shipbuilding and repairing industry is comprised of establishments that are primarily engaged in operating shipyards, which are fixed facilities with drydocks and fabrication equipment. Activities in the shipyards include ship construction, repair, and conversion and alteration, as well as production of prefabricated ship and barge sections and other specialized services. The industry also includes manufacturing and other facilities outside of the shipyard, which provide parts or services for shipbuilding activities within a shipyard. This segment of the US economy contributes 42 billion dollars to the annual Gross Domestic Product (GDP) [1].

Currently, there are 154 private shipyards in the United States spread across 29 states and the U. S. Virgin Islands. In addition, there are more than 300 shipyards engaged in ship repairs or capable of building ships but not actively engaged in shipbuilding [2]. Public shipyards include Portsmouth, NH, Norfolk, VA, Pearl Harbor, HI and Pudge Sound, WA. Further, the Coast Guard Yard near Baltimore also preforms construction and repair activities on Coast Guard Ships [3]. With this activity, the shipbuilding and repair segment of the US economy is a major employer of engineers and naval architects.

Although an important segment of the US economy, the US shipbuilding industry has been in decline since the 1981 disestablishment of industry subsidies [3]. Japan led the world in shipbuilding for three decades, and Korea took leadership of the Shipbuilding Industry in the 1990's. China has grown its shipbuilding markets most recently [4]. Further, European countries have come to dominate the production of passenger ships, while Korean, Japan, and China produce major percentages of various ship non-military cargo carriers [5]. For security

reasons, US military ships are produced by US shipbuilders. So, the Federal Government including the U.S. Navy, U.S. Army, and U.S. Coast Guard are the customers for private shipbuilders. For example, 16 of the 308 vessels delivered in 2020 were delivered to the U.S. Government [1].

Although not world dominant, the US shipbuilding and repair industry is an important segment of the US economy. Further, the shipbuilding industry focuses in large part of military ships with which the United States defends its self and provides for the national well being through the projection of sea power. These facts argue for courses in manufacturing engineering education that focus on shipbuilding for this national segment of the economy. This paper discusses one such course.

This paper continues by providing a brief literature review. It then discusses the substance of the course, followed by a discussion of a textbook on shipbuilding, repair and conversion. The use of guest lecturers is discussed, and student survey data is reviewed. Finally, conclusions are drawn, and acknowledgements are made.

Literature Review

The author completed a diligent attempt to review the literature on engineering education in shipbuilding. The google scholar tool was used with search terms including "shipbuilding" and "teaching" or "learning" or "education." Only a limited number of relevant articles resulted, with most focusing on teaching a single topic or using a specific method.

Examples in published information includes [6] report on teaching shipbuilding courses using MS-Project, MS-Access, and FORAN, and. The MarineTech project which taught high school students with Project Based Learning [7]. Others, reported on the use of distance learning during the COVID-19 pandemic with games for an undergraduate marine engineering curriculum [8]. In an ASEE Peer paper, Verma and Hughes [9] discuss the teaching of Lean Manufacturing at the Apprentice School at Northrop Grumman, Newport News. Other publications involve the National Shipbuilding Research Program such as the September 1992 report on the "Shipbuilder's Classroom of the Future" in which outputs of PC graphics and text, videodisc, audio tape and linear programs are used to meet the needs of the trainee from an instructor's smart lectern or remote [10]. Or, a Quality Function Deployment (QFD) short course is documented for use by shipbuilders [11]. It should be noted that this brief review does not discuss a paper or report on an undergraduate or graduate course in shipbuilding such as this paper. Therefore, the author states that he is unaware of the existence of such a paper.

Substance of the Course

The Introduction to Shipbuilding course is taught as a dual level course, undergraduate senior technical elective and masters level elective. Graduate students are required to do a term project which the undergraduates avoid. Otherwise, graduate students and undergraduate students experience the same course. The course is taught using Zoom to deliver lectures because of the need to accommodate multiple campuses and guest lecturers. Midterm and final exams are proctored at the various sites, and four homework assignments are given.

The Introduction to Shipbuilding course begins with an introduction lecture, follows with discussion of the world market for civilian shipbuilding, and then there is a discussion of the US military market for shipbuilding. The design and contracting process for ships is covered next, followed by the role of classification societies and the International Maritime Organization (IMO) as well as the Naval Sea Systems Command (NAVSEA). Metal materials and associated manufacturing processes are then discussed. An emphasis on welding and non-destructive testing (NDT) occurs in the lectures because of the predominance of this joining process in shipbuilding. Shipyard layout is then discussed with a focus on product flow and logical adjacencies motivated by the manufacture process. Ship structure and assembly is then covered. Outfitting discussions then occur, and this topic is followed by lectures on accuracy control and management methods. A brief review of project management techniques is then undertaken, and scheduling processes are discussed. Exams and homework are arranged to keep pace with the lecture schedule. The schedule for the Spring 2022 course is given as Table 1 to further illustrate the lecture sequence and exam schedule.

Table 1 – Course Schedule from Spring 2022

Week	**Date**	**Subject**	**Reading**
1	1/18	Course Syllabus, Introduction of Course	Syllabus, PPT
2	1/25	Maritime Industry Summary	Handout
3	2/1	Design of Ships and Ship Types	Ch 1-3, 12
4	2/8	International Maritime Organization & Classification Societies	Ch 4 & 29
5	2/15	Metal and Metal Manufacturing Processes	Ch 5-10
6	2/22	Metals and Manufacturing	Ch 5-10
7	3/1	Welding and NDT	Ch 5-10
8	3/8	Exam 1	
	3/15	Spring Break, March 14 - 19	
9	3/22	Shipyard Layout	Ch 11-13
10	3/29	Ship Structure & Assembly	Ch 14, 16-21
11	4/5	Outfitting	Ch 26-28
12	4/12	Accuracy Control	Notes, PPT
13	4/19	Management Methods	Notes, PPT
14	4/26	Project Management & Scheduling	Notes, PPT
15	5/3	Project Presentations	Notes, PPT

16	5/10	Exam 2 (5:45 pm to 9:15 pm)	

As a point of significant emphasis in the course, the fabrication of piece parts into sub-subassemblies is covered. The piece parts can be pipe segments, vent segments, structural and hull segments. The fabrication of piece parts is followed by the development of sub-assemblies, followed by the fabrication of modules (or blocks or units, terminology depending on the shipyard). The modules (or blocks or units) are then assembled to form the ship. Figures 1 through 7 represent this module (or block or unit) assembly process that forms the ship as the final product.

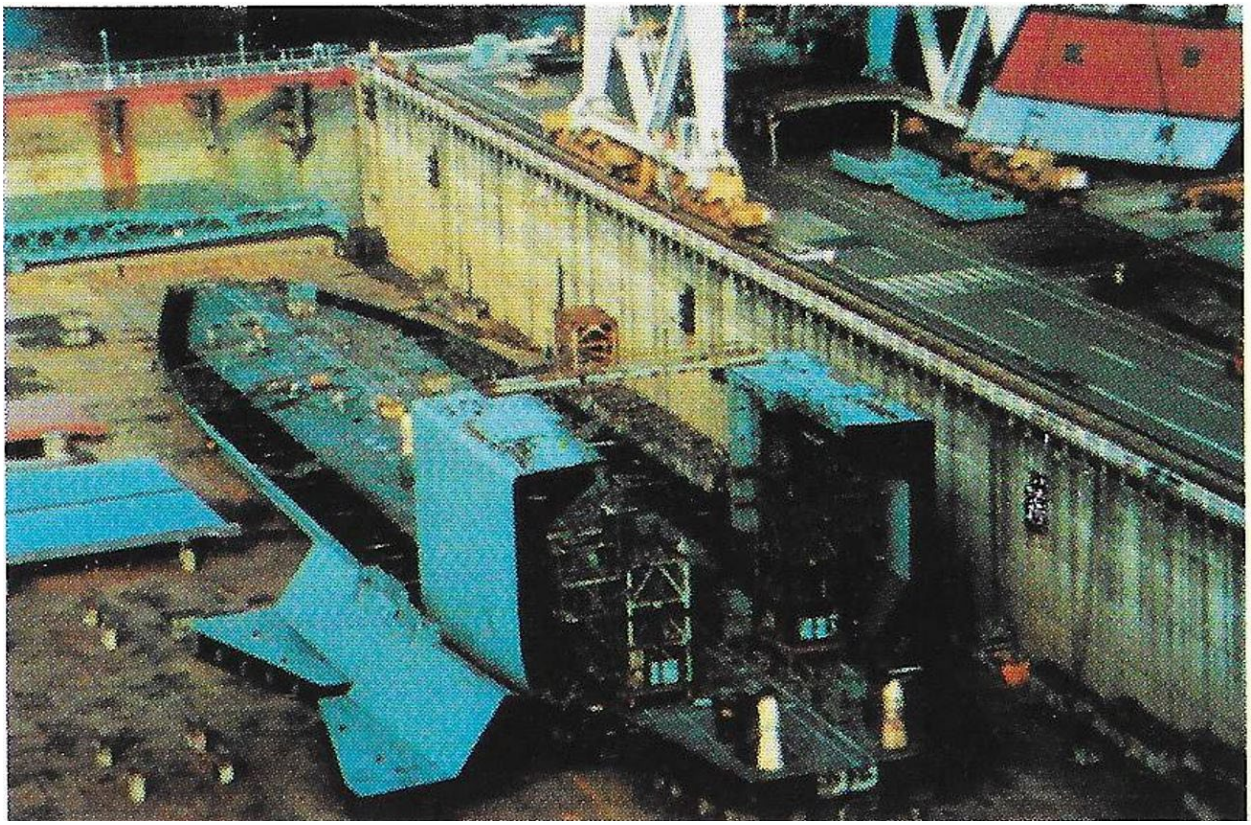

Figure 1 – Assembly of a Few Modules (or Units or Blocks) [12]

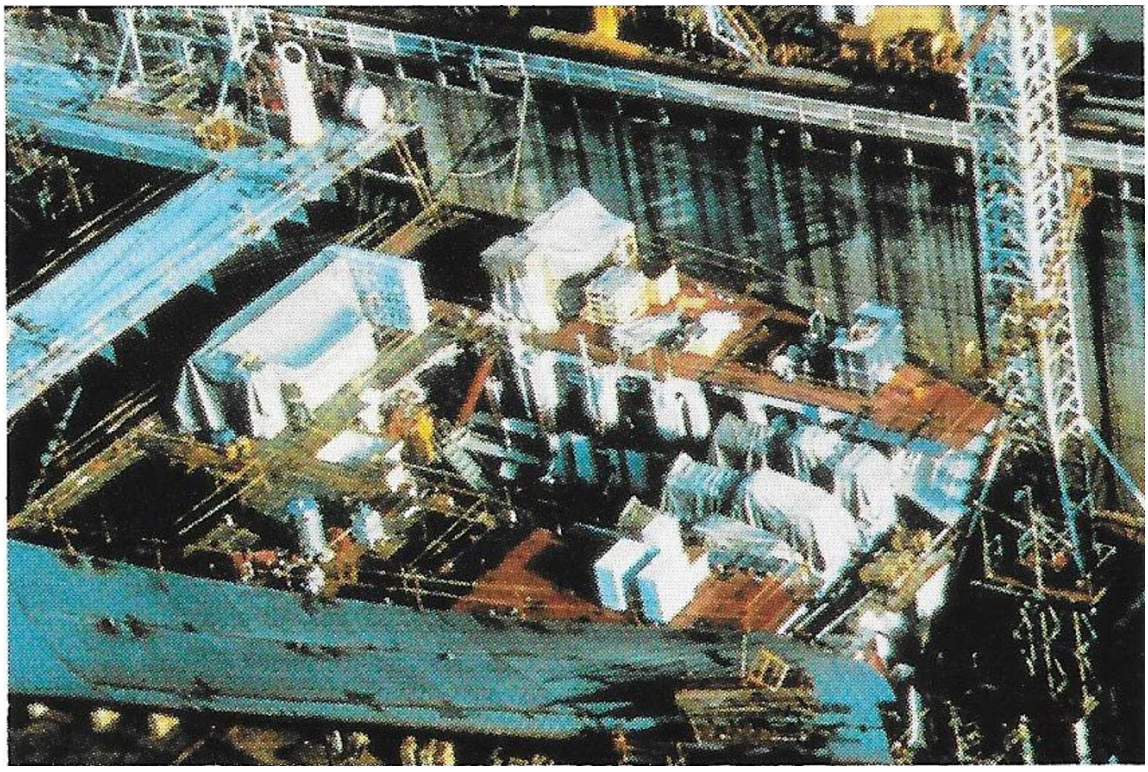

Figure 2 – Assembly of Machinery Modules (or Units or Blocks) [12]

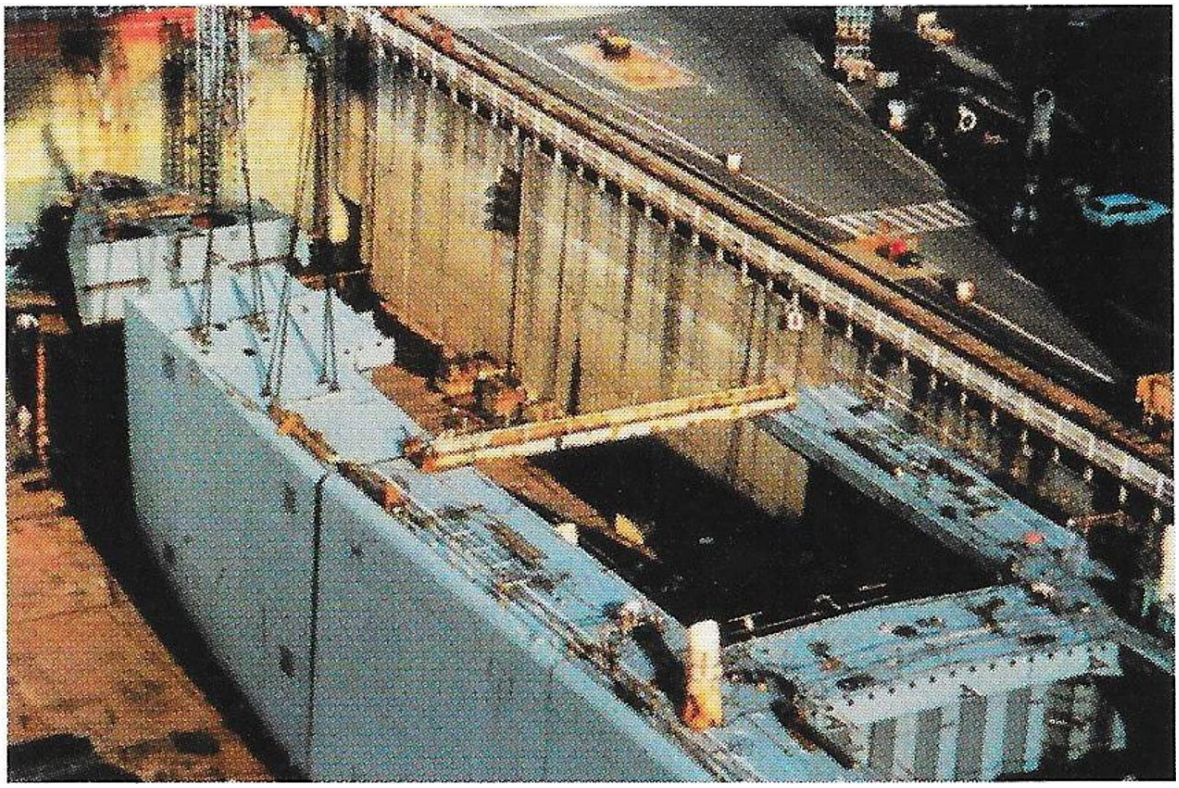

Figure 3 – Assemble of More Cargo Modules (or Units or Blocks) [12]

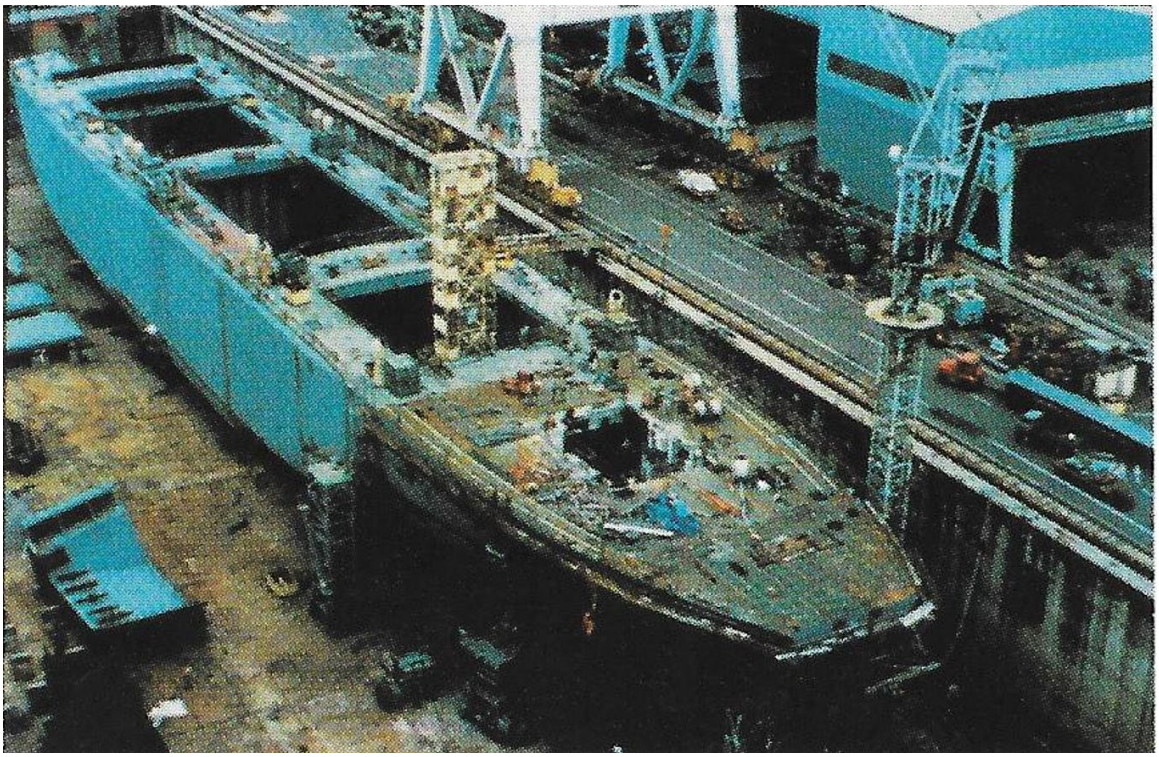

Figure 4 – Assembly of Even More Cargo Modules (or Units or Blocks) [12]

Figure 5 – Assemble of Forward Deckhouse Module (or Unit or Block) [12]

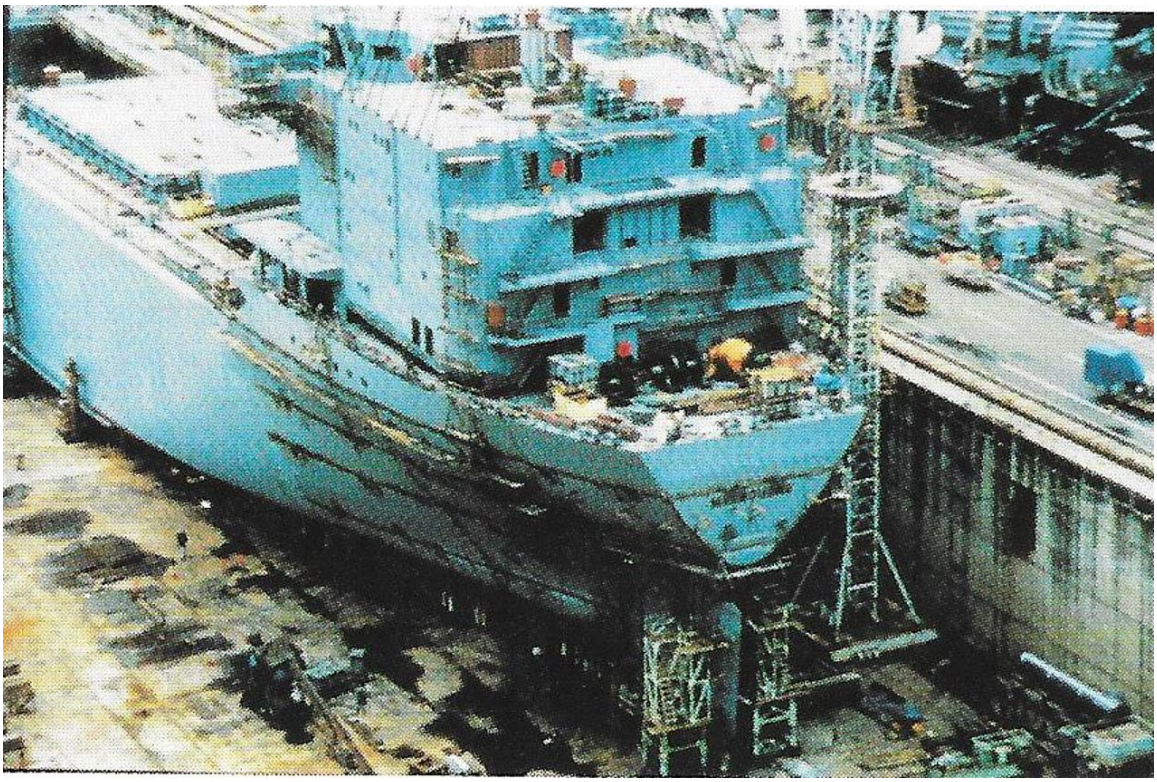

Figure 6 – Insertion of the After Deckhouse Module (or Unit or Block) [12]

Figure 7 – A Completed Ship [12]

Textbook

There are two textbooks that are used in the Introduction to Shipbuilding course. They are:

Eyres, D. J. and G. J. Bruce, *Ship Construction, 7th Edition*, Elsevier, Amsterdam, 2012, ISBN 978-0-08-097239-8

and

Storch, R. L., C. P. Hannon, H. M. Bunch, and R. C. Moore, *Ship Production Second Edition*, Cornell Maritime Press, Centreville, MD., 1995, ISBN 0-87033-461-1.

The text by Eyres and Bruce [13] is written with a focus on Naval Architecture, and the author views this textbook as limited in its use by undergraduate and graduate engineering students. For this reason, the text by Storch et al. [12] is also used. The text by Storch et al. is significantly dated but the material is still relevant. Further, the textbook by Storch et al. is available on the internet at no cost.

Although a more comprehensive, focused and updated textbook for the Introduction to Shipbuilding course is desired, it is recognized that there is a limited audience for this course. Therefore, the economics of the situation do not argue for the desired more focused and modern text.

Guest Lectures

Guest Lectures have been provided by the American Bureau of Shipping (ABS), by Huntington Industries – Ingalls Shipbuilding, and by personnel from the Naval Sea Systems Command (NAVSEA). Each presentation is about thirty minutes to approximately an hour in length with a questions segment.

The American Bureau of Shipping is the US Classification Society for ships in the United States. As such, ABS publishes design rules and ensures that ships and marine vessels are constructed to conform to these rules. This classification action ensures ship safety and provides input to those organizations that insure the ships operated by various companies. This “quality control” action represents an important part of the shipbuilding process.

The guest lecture from Ingalls Shipbuilding is always engaging and popular with the students. Video and slides are presented of actual shipbuilding progress at one of America’s premier private shipyards. In addition, Ingalls provides some recruitment information providing information on what it is like to work at a shipyard.

The guest lecture from the Naval Sea Systems Command (NAVSEA) provides information on the Federal Government’s role in military shipbuilding and naval systems. NAVSEA includes subordinate commands which include Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP) which has a role similar to ABS as it relates to the design and construction of military ships. So, the role and activities at SUPSHIP is covered in this guest lecture. Further,

the role of the Navy research and technology development laboratories is discussed as well as the activities at the NAVSEA Headquarters office at the Washington D. C. Navy Yard. Some recruiting information is also provided to allow students to learn what it is like to work at NAVSEA commands.

The guest lecturers represent valuable information provided to the students giving enrichment to the curriculum. As such, they are a valuable part of the course.

Student Survey Data

Student survey data is managed by the university administration and is considered mandatory for each student. Despite the advertisement as a mandatory for each student, not all students participate. There are five statements made on the survey with a five point Likert scale with 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The five statements made are:

The instructor clearly defined and explained the course objectives and expectations.
The instructor was prepared to teach for each instructional activity.
The instructor communicated information effectively.
The instructor encouraged me to take an active role in my own learning.
The instructor was available either electronically or in person.

Data is available for class surveys for the Spring 2021 and Spring 2022 administration of the course.

In the Spring 2021 administration of the course provided scores of 3.98 for the undergraduate version of the course with 10 students responding out of a class of 12 students. The graduate section had 3 students of 6 responding with a score of 5.0. Therefore, the weighted average score was 4.3 out of a 5 point scale.

The following year, Spring 2022, the student evaluation was 4.35 our of 5.0 for 4 out of 5 students responding in the undergraduate section. The graduate section had too few students for a survey. The result is that scores improved on the second administration of the course, and this is to be expected.

In addition to the quantitative feedback there is anecdotal evidence from students. One student wrote, “The Introduction to Shipbuilding course offered by Dr. Butler, gave me a good overview of the shipbuilding industry. This course helped me understand what primarily drives the industry and how the future looks for shipbuilders, while also showing me the general process of building a ship.” Another wrote, “The shipbuilding course not only enriched my knowledge of the shipbuilding industry but also provided real world examples of management tools. I was introduced to the ship classifications where I learned the different types and uses for different ships in the world and the US. As someone who started with no knowledge on this industry, I felt I finished the course with a better concept of the shipbuilding industry… Apart from learning about ship organization internationally, I learned about some tools that I had seen in theory in courses previously taken. This course showed how these tools are used to schedule, manufacture, and supervise shipbuilding. Overall, I felt this course to be helpful in both, providing a good context of shipbuilding for anyone interested in pursuing careers related to it and in explaining

how management tools are used to prepare anyone interested in pursuing other management careers." Although anecdotal in nature these student comments provide additional feedback on the Introduction to Shipbuilding Course.

Conclusions

The author argues for the following conclusions:

1. Shipbuilding and ship repair is an important United States industry necessary for the construction and repair of ships for the defense of the United States.
2. There has been little reported work on the development of courses supporting the shipbuilding and repair industry.
3. There should be more courses taught on the processes used to build and repair ships
4. A good, current textbook does not exist for the "Introduction to Shipbuilding" course, but it is unlikely that a new, up to date textbook could be forthcoming because to the limited market for such a book.
5. Guest lectures appear to be an excellent way to provide more information to students and convey knowledge about shipbuilding and repair.
6. Survey data does not provide an important insight into the quality of the course.
7. More efforts to support the Defense Manufacturing Industries should be undertaken by qualified engineering faculty.

In essence, this paper describes and argues for courses which support one of the primary Defense Manufacturing Industries – shipbuilding and repair. By supporting this industry, engineering faculty support the US Maritime branches, US Navy and US Coast Guard, in the protection of our shores and the projection of sea power in the national interest.

Acknowledgement

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References

[1] Maritime Administration (MARAD) (March 30, 2021) "The Economic Importance of the U.S. Private Shipbuilding and Repairing Industry," U.S. Department of Transportation, https://www.maritime.dot.gov/sites/marad.dot.gov/files/2021-06/Economic%20Contributions%20of%20U.S.%20Shipbuilding%20and%20Repairing%20Industry.pdf

[2] Colton, Tim, (Accessed January 2023) www.shipbuildinghistory.com

[3] Bauer, Keith, Pete Blackledge, Yunhyok Chang, Mieczslaw Cieniuch, Denny Fields, Harry Flammang, William Harrison, Stephen Malter, Carlos Moreira, Roger Oetjen, David Rorthery, Michael Brown, and Mark Montroll, (2000) "Industry Studies, Shipbuilding," Industrial College of the Armed Forces, http://www.ndu.edu/icaf/industry/2000/shipbuilding/shipbuilding.htm

[4] Islam, Md. Khodadad, Md. Akramuzzaman Shaikh, and Dr. Md. Mamun Habib (2017) "An Overview of the Shipbuilding Industry: A Literature Review," *Proceedings of the 1st International Conference on Business and Management*, pp. 185-190, ISBN 978-984-34-2360-3.

[5] Bactiar, Aziz Ikhsan, Marimin, Luky Adrianto, and Romie Oktovaianus Bura (2021) "Determinants of Shipbuilding Industry Competitive Factors and Institutional Model Analysis," *Decision Science Letters*, Vol. 10, pp. 151-162.

[6] Souto-Iglesias, Antonio, Israel Martinez-Barrios, Mirko Toman, Aaron Fernandez-Coracho, and Rafael Guadalupe-Garcia (2013) "Integrated Learning of Production Engineering Software Applications in a Shipbuilding Context," *International Journal of Engineering Education*, Vol. 29, No. 6, pp. 1400-1409.

[7] Verma, Alok, Daniel Dickerson, and Sue McKinney (September 2011) "Engaging Students in STEM Careers with Project-Based Learning – MarineTech Project," *Technology and Engineering Teacher*, pp. 25-31.

[8] Leon, Alejandro and Marta Pena, (2022) "Gamification Tools in the Learning of Shipbuilding in the Undergraduate Marine Engineering Education," Computer Applicatins in Engineering Education, Vol. 30, pp. 458-471.

[9] Hughes, J. and Verma, A. (June 2004) "Enhancing Instruction in Lean Manufacturing the the Development of Simulation Activities in Shipbuilding Operations, *Proceeding of the 2004 ASEE Annual Conference*, Salt Lake City, Utah. 10.18260/1-2—13225.

[10] Boutwell, Richard, C. and Hugh M. Davis, Jr., The National Shipbuilding Research Program Report 0383, (September 2-4, 1992), "Paper No. 9A-1: Training Shipbuilders with the Classroom of the Future," *Proceedings of the 1992 Ship Production Symposium*, New Orleans, LA.

[11] University of Michigan Transportation Research Institute (UMTRI), Marine Systems Division for the National Shipbuilding Research Program Document 0396, (November, 1993), "Short Course on Quality Function Deployment for the US Shipbuilding Industry," Sponsor: U.S. Department of the Navy, Naval Surface Warfare Center – Carderock Division.

[12] Storch, R. L., C. P. Hannon, H. M. Bunch, and R. C. Moore, Ship Production Second Edition, Cornell Maritime Press, Centreville, MD., 1995, ISBN 0-87033-461-1.

[13] Eyres, D. J. and G. J. Bruce, Ship Construction, 7th Edition, Elsevier, Amsterdam, 2012, ISBN 978-0-08-097239-8