Marine Engineering & Technology Training Programs in the US – Opportunities and Challenges

A.K. Verma,
Marine Engineering Technology Department
Texas A&M University at Galveston
Galveston, Texas-77553, USA
D. Pinisetty and D. L. Satterwhite
School of Engineering
California State University Maritime Academy
Vallejo, CA 94590
{Corresponding author's email: averma@tamug.edu}

Abstract - Maritime industry is crucial for global trade and economic development. Ninety percent of all goods are traded through oceans globally. Over the past few decades, electrical and electronics systems on seagoing ships have become highly sophisticated. The efficient operation of modern vessels depends upon the crew trained in these modern technologies and intelligent systems. New training programs must be developed to address the changing workforce skill requirements [1] [2]. Seven Maritime Academies in the US offer US Coast Guard-approved programs in Marine Engineering and Marine Engineering Technology.

The country's Marine Engineering and Technology programs must prepare for the shift towards ship automation, cybersecurity of marine systems, and the use of alternative fuels. This article is a collaboration between Texas A&M Maritime Academy and California State University Maritime Academy to present the ongoing efforts at these Academies to improve the workforce by developing new curricula to address future workforce needs. The article discusses the development and implementation of new courses, minors, and programs, including the development of laboratory facilities in support of the new curriculum.

Keywords: Training programs; Curriculum, Minors, Lab development; Workforce development.

INTRODUCTION

The global blue economy is expected to double in size to $3 trillion by 2030, according to an analysis by the Organization for Economic Co-operation and Development (OECD). This economy is defined by the World Bank as "the sustainable use of ocean resources for economic growth, enhanced livelihoods, jobs, and the health of ocean ecosystems"[4]. This growth will be driven by strong expansion in new industries like alternative energy, the digitalization and automation of port and transportation operations, food security, and coastal resilience.

Over the last few years, electrical systems on seagoing ships have undergone significant development and change. In addition, the complexity and number of electrical and electronic equipment have greatly expanded [3]. With the increasingly complex electromechanical systems, and the impact of global warming, the demand for marine engineers is expected to grow since the existing vessels must be retrofitted to comply with new pollution and emission standards regulations.

In light of these developments, The International Maritime Organization (IMO) amended STCW 95 (also known as the Manila Amendment) on June 25, 2010, to introduce the certified position of Electro-Technical Officer in place of Electrical Officers. This was enacted to make modern electrical engineers competent to understand the emerging more complex and sophisticated electrical systems [7]. An Electro-Technical Officer (ETO) is defined as a licensed member of the engine department of a merchant or passenger ship

and is a key position in the technical hierarchy of modern ships with automated and conventional electrical and electronic systems [8]. Under the direction of the Chief Engineer, Electro-Technical Officers are responsible for monitoring and repairing the ship's electrical and electronic equipment to ensure that it is operating as safely and efficiently as possible [8]. To prepare the future workforce for Blue Economy, the Marine Engineering Technology Department at Texas A&M University has decided to develop two minors and a state-of-the-art engine room simulator laboratory. ETO program to address industry needs. The first minor in Marine Engineering Technology is designed to increase awareness about marine engineering careers, and the second minor in Marine Electro-Technology is designed to provide foundational courses so students can obtain an ETR rating upon graduation.

FUTURE INDUSTRY NEEDS

The workforce will need to grow in tandem with the growth of the U.S. blue economy to satisfy the demands of new technologies and disciplines. With the rising use of automation on ships and shipping terminals, it is projected that skilled people would be required to support this expansion. The following five technological advancements play a key role in global trade growth and climate change's escalating effects: 1. Artificial intelligence 2. Sensor technology 3. Robotics and 3D printing 4. Big data and IoT 5. Autonomous control 6. Augmented reality 7. Ship propulsion systems 8. Advanced materials [9][10].

The advancements in intelligent, highly automated, and autonomous ships stand out among the eight growth areas. The rising usage of intelligent systems for ship management, operation, and propulsion is an example of this trend. The U.S. Coast Guard is expected to adopt this approach soon and mandate that an ETO man all ships in U.S. waters. No higher education institutions, not even the seven maritime academies in the U.S., currently provide a degree or a training course for ETOs.

In the future, the Marine Engineering Technology department at the Galveston campus of Texas A&M University plans to develop a new program in collaboration with the Multidisciplinary Engineering Technology Program from the main campus in College Station.

COLLABORATING INSTITUTIONS

Texas A&M University at Galveston, an ocean-focused branch campus of Texas A&M University, educates early 2,300 undergraduate and graduate students in a diverse range of marine and maritime programs, including majors in science, business, engineering, liberal arts, and transportation. With almost $10 million in research expenditures, it is an essential part of Texas A&M's unusual land-, sea-, and space-grant mission and is promoting the growth of the blue economy in the Gulf Coast Region.

The Texas A&M Marine Academy, one of seven in the nation and the only academy incorporated into a Tier 1 academic institution, is located at Texas A&M-Galveston and prepares more than 400 cadets yearly for maritime duty and employment worldwide. Texas A&M-Galveston is perfectly situated in Galveston, Texas, on the Gulf Coast, surrounded by the industry, environment, and programs necessary to carry out its unique mission.

Located on a scenic waterfront campus in Vallejo, CA, Cal Maritime is one of seven degree-granting maritime academies in the United States and the only one on the West Coast. The School of Engineering offers ABET-accredited programs in Mechanical Engineering, Facilities Engineering Technology, and Marine Engineering Technology. The mission of the School of Engineering is to provide each cadet with a world-class education and experiential training in engineering and applied technology. The School of Engineering prepares cadets for a lifetime of learning and successful careers in engineering and maritime-related fields while instilling

the values, vision, and skills to enable them to become future leaders and problem solvers to advance the engineering profession's science and technology.

EFFORTS AT TEXAS A&M UNIVERSITY AT GALVESTON

A. *Development of Minors*

1) *Minor in Marine Engineering Technology*

The growth of autonomous vessels and increased global trade have transformed the Merchant Marine's workforce needs. To meet this demand, the MARE department has begun two separate minors: a minor in Marine Engineering Technology and a minor in Marine Electro-Technology.

The first minor introduces maritime business and other engineering majors to marine engineering, ship's propulsion, and auxiliary systems. This minor program, once USCG approves it, will allow the student to test for their Designated Duty Engineer Coast Guard Certification, allowing them to work on smaller vessels such as tugboats and river barges. This curriculum includes the MARE 200 course, where the student will spend 60-75 days as a cadet on the training vessel, participating in class, standing watch, and performing maintenance. The classes for the MARE minor are listed below in Table 1.

Table 1 Marine Engineering Technology Minor Courses

Marine Engineering Technology Minor Courses	Cr. Hrs
MARE 100: Marine Engineering Fundamentals	3
MARE 103: Basic Safety and Lifeboatman Training	3
MARE 200: Basic Operations	4
MARE 401: Marine Auxiliary Systems	3
MARE 377: Engineering Risk Management in Maritime Construction and Shipbuilding -or- MARE 441: Engineering Economics and Project Management	3
Total Credit Hours	16

2) *Minor in Marine Electro- Technology*

The Marine Electro-Technology minor will introduce students to the cutting-edge technology now on vessels. Digital electronics will be covered with advanced topics in High Voltage operations, Battery Power supply management, and shipboard automation. Upon USCG approval, the student will graduate with an Electro-Technical Rating (ETR) and, with additional sea-time, will be allowed to test for their Electro-Technical Officer Endorsement. As ships become more automated and move to alternative propulsion to decarbonize, electrical expertise will be critical onboard the vessel. This minor will allow our students to fill the need in the modern merchant marine. This minor is not limited to our License Option students; we are encouraging all of our students to enroll, as the knowledge can be applicable in Port Engineer or Maintenance Mange positions. The Marine Electro-technology courses are listed below in Table 2.

Table 2 Marine Electro-Technology Minor Courses

Marine Electro-Technology Minor Courses	Cr. Hrs.
MARE 235: Digital Fundamentals for Marine Engineers	3
MARE 325: Shipboard Networking Systems	3
MARE 335: Power Electronics for Shipboard Applications	3
MARE 345: High Voltage Technology for Marine Engineers	3
MARE 445: Marine Navigation Systems	3
Total Credit Hours	15

B. *Development of Simulator Laboratory*

Department of Marine Engineering Technology (MARE) has recognized the need for simulation-based training and paired with Wärtsilä Simulation and Training Solutions to update their traditional ERS I lab to a fifteen-person multipurpose propulsion simulation and full mission simulator with virtual and 3D capabilities. This new facility can supplement workshops on the training ship and existing labs with fully rendered high-fidelity experiences on six different propulsion types.

- Dual Fuel Diesel Electric
- Dual Fuel Slow Speed
- Slow Speed Diesel
- Medium Speed RoPax
- Dual Fuel Steam
- Gas Turbine

Wärtsilä has continued to lead the simulation industry with new High Voltage training aids and multiple simulators in alternative fuel sources. MARE has implemented more electro-technical training and alternative fuel source training, research, and education into their programs. This has led to new classes, minors, and exercises utilizing the upgraded full mission simulator with its high voltage breaker and the collection of four LNG models.

Figure 1 TAMUG MARE ERS 1 Classroom

Beyond the use of the updated fifteen-person and full mission simulator, MARE plans to use modern virtual and augmented reality (AVR) exercises in high voltage and LNG propulsion as shown in Fig 2. This will allow students to gain a sense of scale and layout for the operation and design of these modern vessels. With AVR, the entire vessel can be simulated in the confines of a twenty-five-square-foot space.

C. Development of New Courses

MARE is developing four new courses to meet the challenges of a changing marine industry.

1) Marine Cyber Security
2) LNG as Marine Fuel
3) Shipboard Networking System
4) Nuclear Engineering

Figure 2 TAMUG MARE VR Machinery Space

EFFORTS AT CALIFORNIA STATE UNIVERSITY MARITIME ACADEMY

A. Development of Automation Engineering Major and Data Science Minor

1) Major in Automation Engineering

Automation technology is rapidly transforming the global marine industry, creating a growing demand for professionals equipped with specialized knowledge and skills in this field. As the shipping industry increasingly relies on automation to enhance efficiency, reduce costs, and improve processes, the need for a workforce proficient in automation systems, control engineering, and data analysis becomes more pressing. This proposed major aims to meet this demand by equipping students with the skills necessary for roles related to automation, autonomous vehicles, and robotics within the maritime sector.

The curriculum is being developed to emphasize emerging technologies in industrial automation and artificial intelligence, among others. There is also potential to incorporate an automation engineering technology program that includes a Merchant Marine license.

2) Minor in Data Science

Autonomous ships are expected to include a range of advanced technologies such as artificial intelligence, sensors, communication systems, navigation systems

etc. Such technologies generate a vast amount of data that must be analyzed to improve decision-making, enhance safety, optimize vessel operations, and reduce human errors.

The Data Science minor will introduce critical concepts in computer programming, statistical inference, algorithms for machine learning methods, data visualizations, data processing, statistical concepts for error measurement.

B. Remote Trouble Shooting in Marine Engineering Technology (MET) Curriculum

The rapid evolution of shipboard technology presents significant challenges in troubleshooting, especially concerning innovative electronic and automation systems on new or upgraded vessels. This issue is particularly relevant in sectors such as offshore wind turbine installation, vessels associated with the oil and gas industry, and offshore drilling rigs. Failures due to new equipment, improper installation, or incorrect use and maintenance often exacerbate the problems they were meant to solve. Therefore, the ability to perform remote troubleshooting is essential for the industry.

In the Marine Engineering Technology (MET) curriculum, students are trained to collaborate with shoreside support from vendors and engineers, gaining an understanding of the shoreside perspective. In this training, students act as port engineers tasked with troubleshooting shipboard technical problems remotely. They must resolve issues with limited information and poor-quality system drawings provided by onboard engineers, developing critical thinking skills essential for workforce development in shore-based control centers. These skills are crucial for controlling and troubleshooting autonomous ship equipment using real-time data and communication systems.

C. Simulator Training in MET Curriculum

Simulators create an interactive environment where students can collaboratively diagnose system and machinery faults, akin to real-world operations of steam and diesel plants. This training allows students to build a mental model of real-world scenarios and safely test solutions without risk of injury or equipment damage. The workforce development with these skills is paramount for the success of maritime industry with modern ships. Cal Maritime boasts four engine room simulators, including full-mission and part-task diesel and steam simulators as shown in Figure 3.

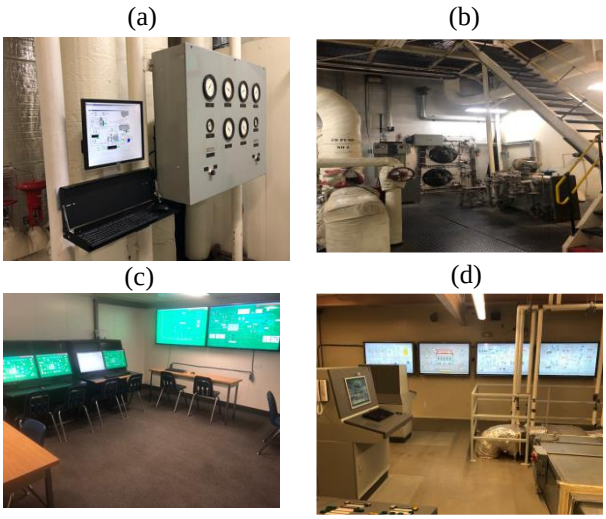

Figure 3 Cal Maritime's (a) Part-Task steam simulator; (b) Full-Mission steam simulator; (c) Part-Task diesel simulator; (d) Full-Mission diesel simulator.

Currently, Cal Maritime is upgrading its engine simulators with Wärtsilä to provide students with training on modern ship control and a plethora of virtual engine rooms and propulsion types. Additionally, high-voltage training modules will be acquired to prepare students for electrical plants both ashore and sea.

CONCLUSIONS

The growing maritime trade and an increasing number of highly automated ships require the presence of a skilled Electro Technical officer on board each vessel to manage and maintain these systems. The Marine Engineering Technology department at Texas A&M University's Galveston campus has developed an Electro Technology minor so that existing students in Marine

Engineering Technology can obtain the required technical background for the USCG endorsement as ETO. Four new courses are under development for the minor in Electro Technology, and one, the Marine Power Electronics for Shipboard Applications course, has been developed and offered. Another minor in Marine Engineering Technology was developed to increase awareness about the discipline among other majors. The ETO minor creates a pathway to highly sought-after and lucrative jobs in the marine sector.

The Automation Engineering major and Data Science minor at Cal Maritime are designed to educate the next generation of engineers for the maritime industry. With the rise of autonomous boats and the preparation for autonomous shipping [13], including the regulatory framework development by the International Maritime Organization, the need for such education is critical. Remote troubleshooting training in the MET curriculum is a key component of workforce development for modern ships equipped with advanced technologies. The planned simulator upgrades at Cal Maritime will incorporate high-voltage training, essential for modern shore side facilities and vessels. Additionally, like Texas A&M University's Galveston campus, Cal Maritime will consider developing an Electro-Technical Officer program and seek approval from the USCG.

REFERENCES

[1] Stuchtey, M., Adrien Vincent, Andreas Merkl, Maximilian Bucher, Peter M. Haugan, Jane Lubchenco, and Mari Elka Pangestu. (2020) "Ocean solutions that benefit people, nature and the economy." Washington, DC: World Resources Institute.

[2] NOAA (2020). *https://repository.library.noaa.gov/view/noaa/24933*

[3] Axel Rafoth, Jens Borchardt, (2021). New education tools for electro-technical officers (ETO)

[4] World Bank. (2017). What is the blue economy? *https://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy*

[5] National Oceanic and Atmospheric Administration NOAA (2021). *https://oceanservice.noaa.gov/economy*

[6] National Oceanic and Atmospheric Administration NOAA (2021). *https://oceanservice.noaa.gov/facts/population.html*

[7] Mindykowski, Janusz (2017). Towards safety improvement: implementation and assessment of new standards of competence for Electro-Technical Officers on ships. Maritime Policy & Management. 44 (3): 336–357

[8] Maritime Training and Education *https://www.edumaritime.net/stcw-code/stcw-iii-6-eto*

[8] Dominica Maritime Administration (2020) *https://dominica-registry.com/stcw-requirements-electro-technical-officer/*

[9] *https://www.cogoport.com/blogs/technologies-transforming-shipping-industry*

[10] *https://knowhow.distrelec.com/defence-aerospace-and-marine/8-technology-trends-transforming-the-maritime-industry/*

[11] *https://maritime.solent.ac.uk/maritime-industry/stcw-manila-amendments*

[12] International Maritime Organization. (2014). Electro-Technical Officer.

[13] Rudy R. Negenborn, Floris Goerlandt, Tor A. Johansen, Peter Slaets, Osiris A. Valdez Banda, Thierry Vanelslander, and Nikolaos P. Ventikos, (2023) "Autonomous ships are on the horizon: here's what we need to know." Nature, Vol. 615.