

Competencies Related to Marine Mechatronics Education

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Abstract

With the needs of the military changing in recent years, the U.S. Navy has been required to spend more time out to sea. Longer deployments limit the ability for the Navy to perform ship maintenance and to train their technicians. Recent trends also include reduced numbers of sailors, who typically aid with more efficient naval operations. This leads to the demand for sailors with multidisciplinary skills, in this case, electrical technician and mechanical technician skills. Mechatronics has long been an occupation that integrates different disciplines, including mechanical, electrical, and computer technology. This paper will present an overview of competencies related to the career, as well as provide an overview of the relationship between mechatronics engineering and marine engineering.

Introduction

The Navy is steadily reducing the number of sailors manning each vessel. Since crews have made up the largest fraction of the through-life cost of ships over the years, this personnel reduction requires more automated systems to keep the ships at sea and in total readiness, (Arciszewski, de Greef, & van Delft, 2009; Donaldson, 2013). To meet this need, industrial automation systems are being investigated as replacements and upgrades for the military systems that have been used for years in warship designs. This will require ship repair partners, both military and civilian, to work with unfamiliar equipment (in the current trades mix) that was not designed for installation in such a harsh environment. One such project, titled “Reduced Ship’s Crew by Virtual Presence (RSVP),” was funded by the Office of Naval Research in 1998 (Seman, 2006). This project focused on the development of a wireless sensor network that can be used for naval ships, and included government engineers, who wanted to change the deck plate wrench turning system. Industry engineers researched where to embed sensors, radios, networking, and power components; academics on the team wanted to validate data acquisition and analysis methods to use for their own research (Seman, 2006).

Marine Mechatronics Applications

Recent naval combatant innovations have led to the development of Autonomous Surface Vehicles (ASVs), for the purpose of more enduring, reliable, and autonomous missions (Huntsberger & Woodward, 2011). Swarm boats are a recent development in ASVs. They serve as auxiliary protective mobile boats that can help the main vessel navigate ocean systems in a safer way. These “drone boats” function to swarm a vessel that would attack the main boat. They have appropriate technology, such as Control Architecture for Robotic Agent Command and Sensing (CARACaS). This includes sensors and accompanying software that react if the approaching vessel is identified as a threat (Huntsberger & Woodward, 2011). This software, developed by the Jet Propulsion Laboratory (JPL), originates from NASA’s Mars rovers, but has recently been adapted for use on small boats. Figure 1 shows an example of applying this technology.

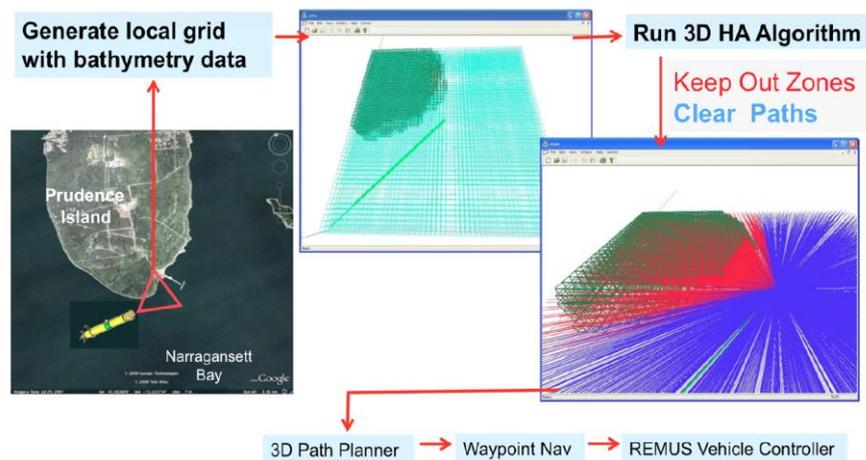


Figure 1: 3D trajectory planning under CARACaS - AUV (Huntsberger & Woodward, 2011).

Ship design in the U.S. Navy starts with concept design, then moves to engineering design, and then to production design, as shown in Figure 2. The concept phase defines the way the ship is supposed to function. During this phase, a concept of operation (CONOPS) is developed (Chalfant, 2015). In the Analysis of Alternatives (AoA) phase, ship designers define major equipment. Based on the Expanded Ship Work Breakdown Structure (ESWBS), along with the basic structure, other ship modules include: electric plant, propulsion plant, command and surveillance, auxiliary systems, and outfit and furnishings, and armament (Chalfant, 2015).

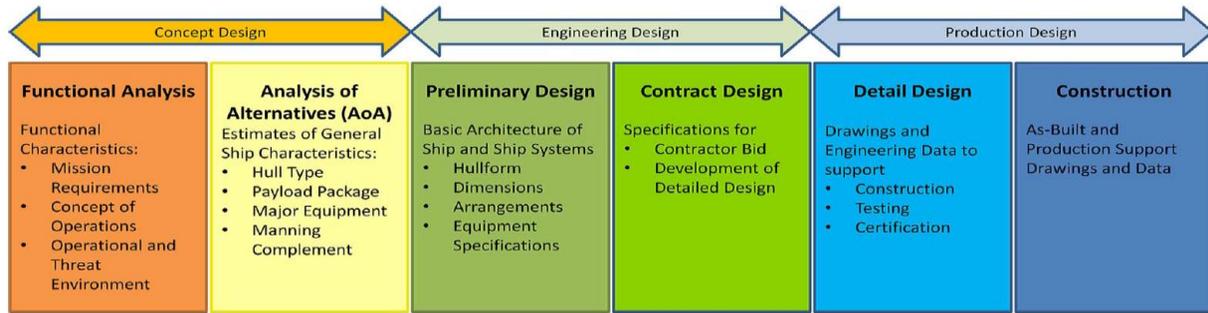


Figure 2: Ship design stages (Chalfant, 2015)

Ships are designed using two main approaches: traditional and inside out. Traditional ship design starts from requirements and moves to the defining of payload equipment (weapons, sensors, self-defense, communication systems, aircrafts, submersibles or smaller boats to be carried); then moves to the hull design; spaces allocated for specific functions; calculation of hydromechanics design features; calculation of powered needed to propel the ship; wave analysis, propulsion design and selection; electrical generation, distribution and auxiliary machinery selection, and then cost estimate. Inside out ship approach starts with selecting equipment and sub-systems and then focuses on warping out the structure and the hull around the chosen sub-systems (Chalfant, 2015).

The Office of Naval Research's funded project designed the smart ship system design (S3D) concept for early stage design, simulation, and analysis (Chalfant, 2015). This method defines the template for mechatronic subsystems, such as mechanical, electrical, piping and HVAC (cooling HVAC system is shown in Figure 3). The main purpose of this system is to investigate influences among different subsystems that create a specific ship function and provide simulation tools in order to avoid future problems in development and design. It requires coupling together simulations that focus on heat dissipation analysis with 3D visualizations of the used space for ship sub-systems (Ferrante, Chalfant, Chryssostomidis, Langland, & Dougal, 2015). The cooling system, shown in Figure 3, includes requirements data (about the ship, about the load, about the energy source), ship design templates (for topology, connectivity strategies, isolation strategies, arrangement tips), and further tools for design and analysis of distribution systems. The same design methodology can be applied to various distribution systems, such as those for power distribution, communication network, and water management systems (Chalfant et al., 2012).

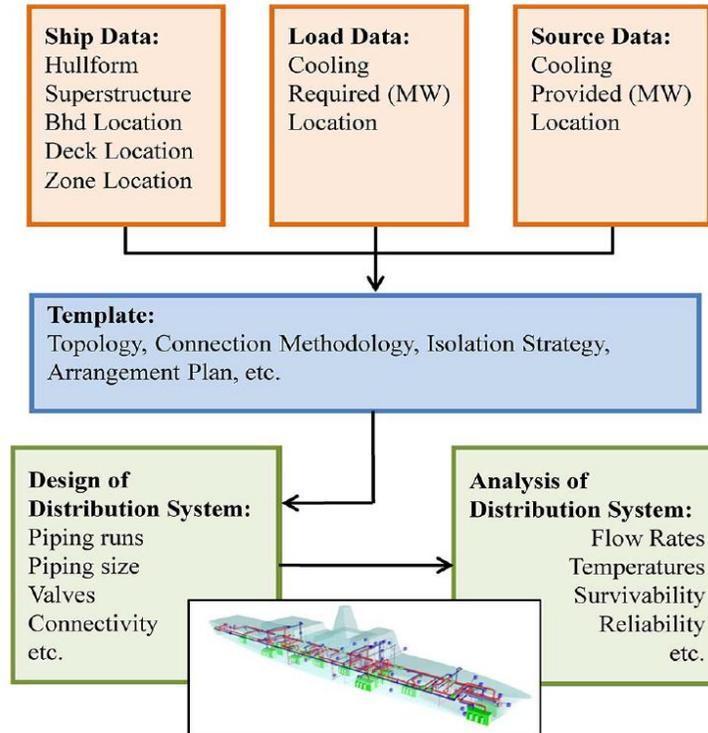


Figure 3: Systems engineering framework as HVAC design template (Chalfant, 2015)

Other notable developments within the last century include autonomous naval systems, autonomous undersea vehicles, and high precision shipborne rail guns, where GPS guided shells can approach targets hundreds of miles away (Buderi, 2013). As well, various technological innovations in the area of electronics have driven design changes in naval systems, like in the application of offshore patrol vessels (Waters, 2014). Automations have widely been used in weapon systems but are now being used in areas of operation, monitoring, and maintenance (Donaldson, 2013). Automation is found in many hazardous and confined spaces in industry, as well as in warships. It has been used in weapon and payload systems, as well as for weapons delivery. Mechatronics methodologies are used for adaptive fuzzy control of the ship steering mechanism, intelligent ship autopilots, routing detection, adaptive automation, and anti-ship missile seekers (Arciszewski et al., 2009; Gauf & Lejune, 2015; Gu, Wei, Xiao, Wu, & Wu, 2002; Liang, Wang, & Ji, 2012; Qi, 2007; Rigatos & Tzafestas, 2006). Figure 4 shows an example of an integrated bridge and navigation system. It is a fully automated Navy ship system (MarineLink.com, 2013). This system includes solid state and conventional radars, an electronic chart display, an information system, a multifunctional workstation, and an adaptive track pilot and navigation sensors.



Figure 4. Raytheon IBNS used for Italian Coast Guard ships (MarineLink.com, 2013)

Other examples are related to marine robotic vehicles (Toal, Omerdic, Riordan, & Nolan, 2010). The manufacturing of ship structures also includes mechatronics and robotics applications, including automatic welding systems for large hulls (Arregi et al., 2012). Welding processes usually account for 40% of the overall manufacturing time in shipbuilding. Hence, automation and adequate control of these systems can improve and streamline manufacturing processes, especially for the welding processes that are performed outdoors. These are usually not automated but, instead, are performed by multiple welding operators, especially for the welding of hulls, which are the common cause of quality problems. Since the position of the electrode has to be at an adequate angle and controlled in three dimensions, seam tracking is a major problem (Arregi et al., 2012).

Advanced Manufacturing Careers and Mechatronics

President Obama, who launched the Advanced Manufacturing Partnership to support these initiatives, identified advanced manufacturing as one of the areas that can support economic growth (Hemphill, 2014). Various reports cited a current gap in the educational system in the United States, alongside the need for additional advanced manufacturing skills and training of skilled workers (Baumann et al., 2015; Baumann et al., 2014). There are various ways in which different institutions are trying to address the skills gap for this industry, such as Stackable Credentials and Credits or Massive Open Online Courses (MOOCs) (Spak, 2013). Others ways include modernizing existing manufacturing courses (Ngaile, Wang, & Gau, 2015).

Mechatronics was initially introduced in electronics packaging and assembly courses, in relation to adaptive control and intelligent manufacturing systems (Jovanovic, Verma, & Tomovic, 2013). It has also been introduced as a program in various Engineering Technology departments across the United States. Figure 5 shows the Department of Labor’s recognition of the following competencies for the area of mechatronics, defined by the Association for Packaging and Process Technologies’ Mechatronic competency model (PMMI, 2015).

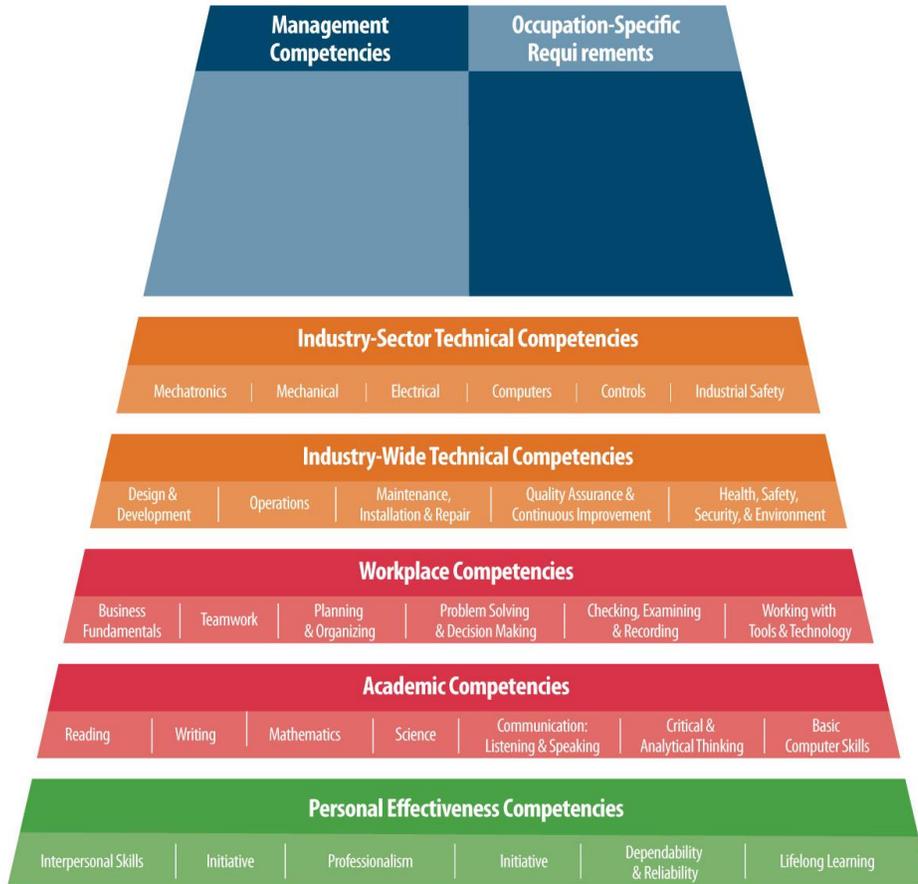


Figure 9: Mechatronic competency model (PMMI, 2015)

Conclusion

Although, there is a shortage of technicians in the maritime industry that understand mechatronics systems, the industrial automation industry has been using these systems for years. Hence, there is a need to better prepare technicians to install and repair these systems, since it involves a complete change to the previous design of warship systems. As well, the nature of advanced manufacturing jobs has changed with technology innovations, since computing capabilities are driving advances in data management and cyber-physical system capabilities.

Acknowledgments

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