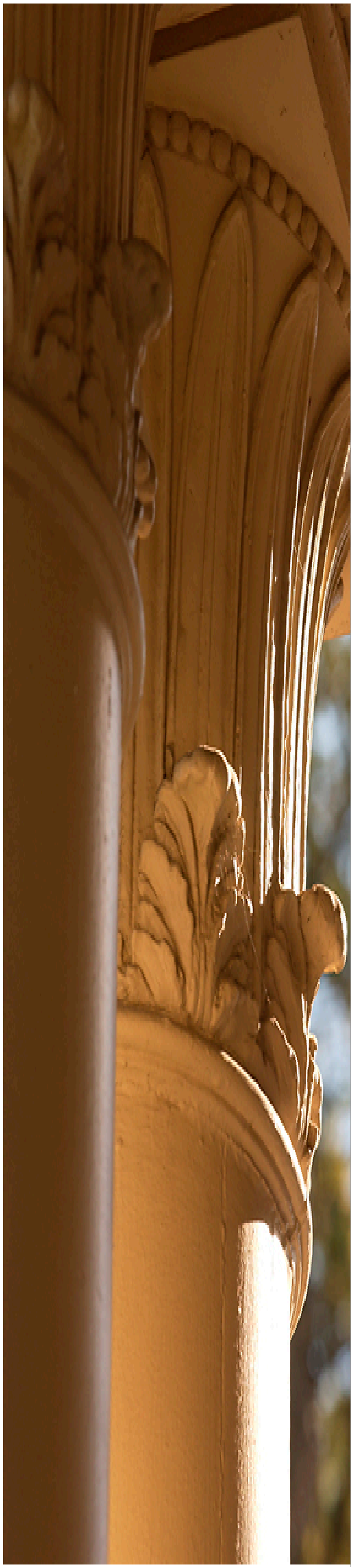

Mechatronics in Washington State:
Manufacturing, Energy and Marine Sectors

June 2016

Submitted by:

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Mechatronics refers to the integration of engineering design, technologies and work processes that also have implications for the knowledge, skills and abilities required of employees in most modern industrial settings.

A number of colleges and industry-education partnerships have sought to enhance and upgrade their manufacturing curricula and extend mechatronics concepts to other sectors because many of the technologies, work processes, skill and knowledge requirements cut across occupational categories and industries.

This research summary provides a brief history of mechatronics, including the technology, workplace and labor context for its application. It also summarizes the evolution of mechatronics in manufacturing, and its extension to two other industry sectors in in Washington State: Energy, and Marine Technology. Conclusions and a set of potential next steps for future research and action are provided for consideration by industry, postsecondary education and state Centers of Excellence.

Conclusions

Mechatronics concepts and practices have continued to evolve with the advent of new technologies and work practices, and their use has extended to other industry sectors and work environments. Mechatronics principles and applications are especially relevant to technically-oriented occupations (engineering, technicians, and maintenance personnel), and their relevance is growing as the need increases for employees who can design, install and support increasingly-complex technical systems and components that are required to interact. Greater complexity has, in turn, required higher levels of knowledge and skill among employees in some occupations.

Current national, state and regional research and program development projects for mechatronics--including those supported by government sponsors, industry associations, and employer-education partnerships—have expanded in recent years. Gaps in the availability of qualified technical personnel in industry and the advent of new technologies are among the key reasons for an increased emphasis on mechatronics. The need for employees with mechatronics-related knowledge and skills is real, and the evidence suggests that this trend will continue.

Education and Training Programs: Mechatronics degree and certificate programs appear to be increasing in number, especially at two-year technical colleges, primarily in response to employer interest and demand. The growing number of mechatronics competency and curriculum development projects provides further evidence of the importance attached to mechatronics concepts and practices. In most cases, two-year technical colleges are incorporating mechatronics content into current programs or courses, such as general manufacturing or industrial maintenance programs or certificates. In Washington, a few mechatronics degree and certificate programs exist, and more are being developed or proposed.

Considerations

Confirm Demand: Working to identify industry and employer demand for mechatronics is a critical first step. Engaging with industry sector partners, employers and subject matter experts in a structured manner (i.e., DACUMs, focus groups, skill standards projects) helps confirm the specific jobs, competencies and skills employers expect, their level of support for mechatronics degrees and certificates, and the kinds of individuals for whom mechatronics skills are most appropriate.

Take an Incremental Approach: In most cases mechatronics appears to more closely represent a growing *functional area* rather than a discreet *occupation*. Efforts to incorporate mechatronics into existing technical programs, apprenticeships, and through certificates is a logical first step to meeting demand and exploring future growth opportunities and market for stand-alone mechatronics degree programs and certificates in the economic region.

Collaboration Imperative: Input about mechatronics program needs from employers is critical, but workers and labor organizations should also be consulted. Because it cuts across disciplines and technology platforms, there is a natural link between mechatronics and the growing trend toward employee multi-skilling. Future technology applications are likely to streamline technician and preventive maintenance functions further. When used mainly to reduce costs—even when multi-skilling is justified by technology changes—its use can evoke strong reactions and resistance from workers and labor unions. It is unclear whether the growth of mechatronics has raised similar concerns, however it is important to consider the factors that may enhance or detract from its acceptance among employees.

Energy Sector Mechatronics: Currently there does not appear to be an organized effort in the energy sector to develop or market mechatronics as a stand-alone program, even though it is clear that mechatronics concepts and practices are widely applied across the energy sector. It may be useful to explore the application of mechatronics with industry partners to determine whether increasing the mechatronics-related content within existing technician and skilled trades programs and apprenticeships is warranted, and to gauge employer support for new programs or certificates.

Marine Industry Mechatronics: Mechatronics content is evident in the marine industry, and organized efforts are underway to further identify and integrate mechatronics competencies into marine-sector education and training programs. Similar to the energy sector, the application of mechatronics concepts and practices is not new, but they are becoming more widespread due to continued technology advances, new production methods, and the regulatory environment. Past efforts to establish competencies through DACUM and skill standards development processes in in Washington (including marine, energy, manufacturing, construction and others) offer an opportunity to leverage established work in this area, and new work by the NSF-funded SMART Center and MATE offer additional opportunities to connect mechatronics to marine occupations and training nation-wide.

INTRODUCTION

The manufacturing sector is the birthplace of modern mechatronics. What is not clear is how broadly mechatronics concepts and practices have diffused to other industry sectors, such as energy and marine technology. If mechatronics proves to be an enduring concept and trend that cuts across industry sectors and is valued by employers, how can the education and training programs that support those industries incorporate and support mechatronics principles and practices most effectively?

This research summary provides a brief history of mechatronics and examines its application and evolution as it is applied nationally and across the energy and marine technology industry sectors in Washington State. The findings offer some initial observations and action steps that COE stakeholders and partners should consider as they work to generate, update and improve workforce education and training programs, especially at public two-year colleges. The ultimate goal of this work is to ensure that relevant mechatronics concepts, content and practices are understood and applied effectively to improve program responsiveness and student success.

This summary leverages and builds upon prior work by the NSF-funded Automotive Manufacturing Technology Education Consortium which in 2008 established competencies and skill standards for the automotive industry. Those competencies and standards were subsequently adapted for mechatronics, and they are now being reviewed and verified by national and Washington businesses and colleges for use in other industries.

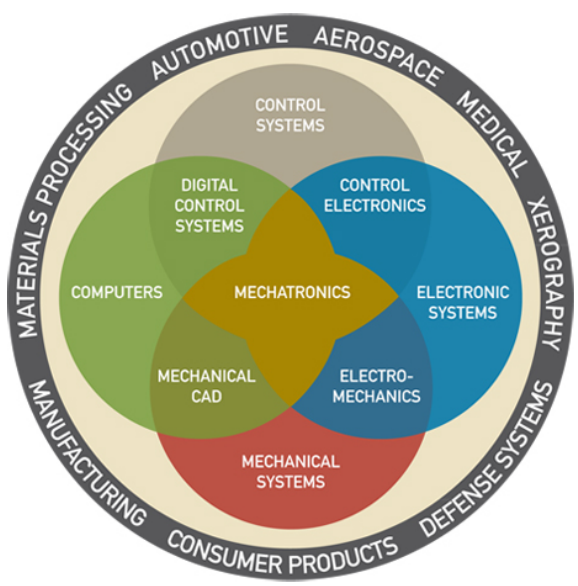
HISTORY AND CONTEXT FOR MECHATRONICS

History

The term mechatronics was coined over 40 years ago, when engineer Tetsuro Mori combined the words "mechanical" and "electronic" to describe the electronic control systems that Japan's Yaskawa Electric Corporation was building for mechanical factory equipment. Since that time, mechatronics has continued to evolve with the advent of new technologies and applications. More recently, mechatronics has been defined as:

…a multidisciplinary field of engineering that combines mechanical, electronic, computer, software, control and systems design engineering in order to design and manufacture useful products.[1]

An Industrial robot is one example of a product designed and used in manufacturing that integrates mechanical, electronic and software systems. As applied to products, processes and industries, mechatronics has been described as a central feature of modern engineering design and production (see below).[2]



[1] AMTEC, 2016: http://autoworkforce.org/?s=mechatronics
[2] https://www.asme.org/engineering-topics/articles/mechatronics/mechatronics-and-the-role-of-engineers

A Changing Workplace

All modern industrial firms rely on automation technologies to ensure greater worker safety, product quality and productivity. While automation may replace some jobs and functions, as the structure of work continues to become more complex, knowledge and skill requirements change and often increase.[3] In turn, employers, workers and job seekers will attach greater value to postsecondary education and training similar to the description of mechatronics: higher levels of interdisciplinary technical knowledge and skill, understanding system dynamics, and systems integration. A stronger foundation in non-technical "new basics" is also expected, including skills in team-based work, structured problem solving, critical thinking, and interpersonal communications. Continued emphasis on STEM (science, technology, engineering and math) competencies in education and the workplace also provide opportunities to incorporate mechatronics principles. Thus, the emphasis on mechatronics appears to be consistent with, and in response to, broader technological and organizational trends and adaptations in education for the modern industrial workplace.

Population and Labor Market Shifts

The distinction based on type of work and educational qualifications is important because they also pertain to postsecondary education and training options. The state's demographics and labor marked is shifting: in Washington state, and the nation as a whole, smaller cohorts of new high school graduates are projected through 2030, and the average age of the large baby boomer population is increasing.[4] As more individuals move into retirement, competition will grow for a smaller pool of qualified labor, and skill gaps will increase. Demographic shifts mean that the growth market for postsecondary education will be older adults who are already working and want to complete their degrees, upgrade their skills or change careers. The future workforce will also become more ethnically and culturally-diverse, and there will continue to be challenges to opportunity and completion for these populations.[5] Many high school students may already be learning mechatronics concepts through existing STEM courses and internship experiences, while the needs of working adults for mechatronics training at all levels may expand considerably.

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[3] Carnevale, A.P., Smith, N., and J. Strohl. (2013) *Recovery: Job Growth and Education Requirements through 2020.* Georgetown University Center on Education and the Workforce, Washington, DC.

[4] Washington State Office of Financial Management, Forecasting and Research Division (2015). *Preliminary State Population Forecast 2010-2040.* Supplemental presentation, November 4. Retrieved from http://www.ofm.wa.gov/pop/stfc/.

[5] Washington Student Achievement Council (2015). *2015 Roadmap Report: Measuring our Progress*. (December): http://www.wsac.wa.gov/2015-roadmap-update

Mechatronics in Education and Work

Mechatronics is typically associated with two occupational levels: the first relates expressly to engineering design and technology systems integration. Here, the emphasis is on design and the process of creating, integrating or improving products, components and processes. Occupations at this level are typically filled by professional engineers who hold baccalaureate-level degrees (or higher) and advanced certifications. Interdisciplinary knowledge (engineering, technology and computer science, in particular) and technology applications are emphasized, and pathways into technical management are common. Mechatronics programs, certificate or course options exist at many leading research universities, colleges and technical institutes. The mechanical engineering department at the University of Washington, for example, has offered a series of high level mechatronics-focused courses and curriculum since 1996.[6] Engineering faculty and many students are engaged in specific projects where mechatronics is central to applied research and product development in affiliated areas including robotics, nanotechnology, bio-medical and bio-mechanical systems, instrumentation and manufacturing.[7]

In contrast, mechatronics is also relevant to sub-baccalaureate, technician-level professions, education and craft training programs. Two-year technical degrees, technical certificates, and also apprenticeships have been developed to prepare individuals for mechatronics-related work functions and tasks. Here, the emphasis is typically on the installation, maintenance, and repair of mechatronics-based products, systems and components. In technician-level and craft training programs, it is common to see traditional academic instruction combined with some level of integrated hands-on experience; on-the-job training, cross-training in different functional areas and jobs, the incorporation of automation technologies, and the general use of applied learning strategies. Engineering technicians, maintenance and repair workers, and related craft generalists and specialists—such as electronics technicians, mechanics/millwrights, or industrial electricians—are typical job titles of individuals who perform mechatronics-related tasks. Most often, mechatronics is not specifically identified in these job descriptions; installing, repairing and maintaining modern integrated system components and platforms follows as a natural extension of those technological innovations.

Automotive Manufacturing and Mechatronics

The automobile industry was among the early proponents of mechatronics education and training for technicians and engineers, and the industry continues to provide leadership in this area. The national Automotive Manufacturing Technical Education Collaborative (AMTEC), which began in 2005, is a collaboration of community and technical colleges and industry partners that has actively promoted development of mechatronics education and training curriculum, competency and diagnostic assessments (offered through Nocti Business Solutions), simulation equipment and workforce

[6]See: https://www.me.washington.edu/files/prospective/grad/docs/SD_courseflow.pdf
[7]See: https://www.me.washington.edu/files/research/areas/mechatronics.pdf

development services.[8] With funding from the National Science Foundation, AMTEC became a national Center for Excellence in Advanced Automotive Manufacturing in 2009.[9] AMTEC has continued to develop curriculum, assessment and certificate offerings, and is now working with cross-industry employer partners, Centers of Excellence, and some community and technical colleges in Washington state to formalize mechatronics education and training programs in other industrial sectors including aerospace, high tech, and food processing (described later).

STEM Connections

Growing national interest in boosting Science, Technology, Engineering and Mathematics (STEM) education has also sparked increased emphasis on mechatronics by industry and all levels of education. The National STEM Consortium (NSC), for example, has provided leadership for development of mechatronics education and training.[10] NSC and its employer and college partners have developed five one-year STEM certificate programs in several high-demand fields, one of which is mechatronics. The program leverages the Siemens Mechatronics Certification, which is a nationally recognized industry certification.[11] NSC notes the growing need for mechatronics skills across a wide spectrum of industry sectors, both within and outside of manufacturing. Six founding two-year college partners currently offer some version of the mechatronics certification.[12]

One of the key strategies developed by NSF was creation of a two-part STEM "Bridge" program that integrates basic skills, workforce, computer and job readiness skills training embedded into the technical curriculum rather than relying on separate pre-program courses. A STEM Foundations course integrates online modules that enable students to focus on targeting specific areas of weakness so they can maximize their participation in the technical curriculum.

Mechatronics Competency Model

Curriculum and assessment development initiated by AMTEC and other partnerships are notable because of the emphasis on demonstrated competencies as the primary indicator of achievement. Competency-based learning has a long history in professional-technical education, and it is especially suitable for modular-based curriculum designs in which mastery of learning modules are additive, and assessments enable students to rapidly acquire certification in specific skill areas.

The U.S. Department of Labor has invested heavily in development of competency models for several leading industry sectors over the past decade, and these are offered for us as part of a Competency

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[8] See: http://autoworkforce.org/

[9] AMTEC is affiliated with the Kentucky Community and Technical College System, which is its base, but serves the broader regional partnership of 21 community and technical colleges and 12 automotive manufacturers and suppliers.

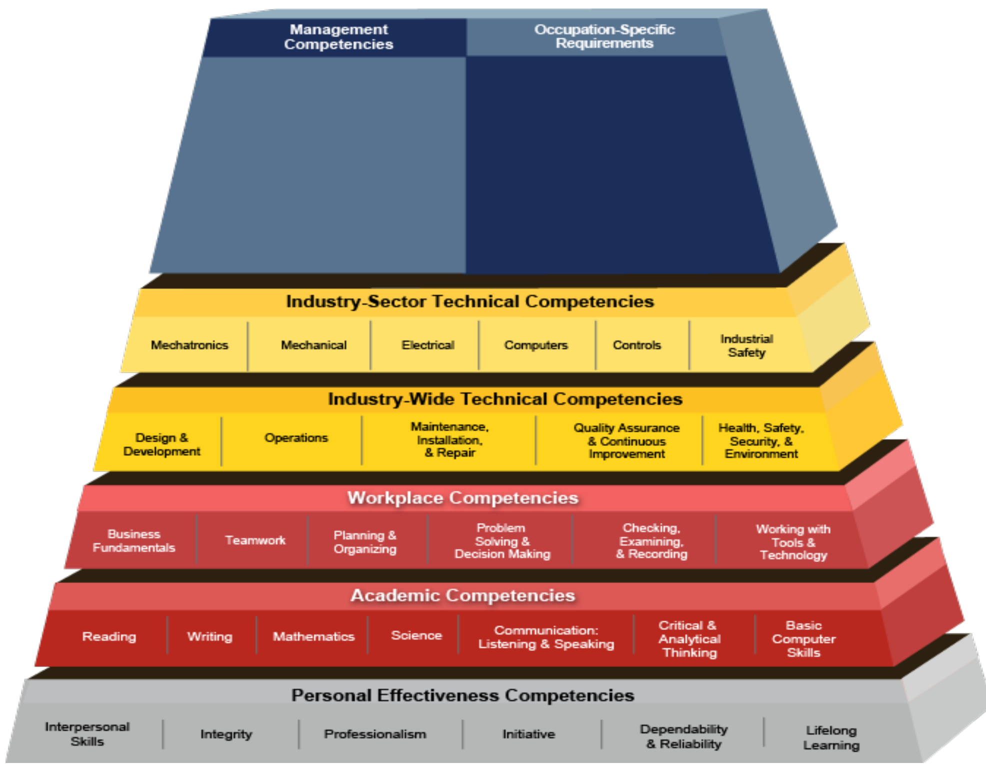
[10] See: http://www.nationalstem.org/home/mech/

[11] See: http://www.siemens-certifications.com/content/0/9131/9147/

[12] See: http://www.nationalstem.org/contact/#m_anchor

Model Clearinghouse. This work has included establishing four different models for manufacturing, one of which is a specific set of technical competencies for mechatronics.[13] The model stems from a partnership project of two-year colleges and workforce investment boards, which collaborated with the DOL's Employment and Training Administration (ETA) and the Association for Packaging and Processing Technologies (PMMI) to formalize a version of the mechatronics competency model that defines skill standards, curriculum and career paths for mechatronics that is built upon a foundation of personal effectiveness, academic, workplace and industry-wide technical competencies.[14] A graphic depiction of the mechatronics competency model is shown below.

Mechatronics Competency Model[15]



[13] See: http://www.careeronestop.org/CompetencyModel/competency-models/pyramid-home.aspx
[14] See: http://www.careeronestop.org/CompetencyModel/competency-models/mechatronics.aspx
[15] See: http://www.careeronestop.org/CompetencyModel/competency-models/pyramid-download.aspx?industry=mechatronics

It is worth noting that competency models often serve as the technical and general basis for skill standards, which specify the level of knowledge, skills, and abilities required for success in the workplace, and provide the basis for measurement criteria to assess competency attainment. A competency model differs from a set of skill standards in that skill standards define levels of skills (or competencies) required in a given job or role, while competency models typically do not.

Because they are more broadly-defined than occupation-specific skill standards, the competency model includes multiple levels of technical and non-technical competencies from which occupation-specific analyses can be conducted. The PMMI's mechatronics competency model, for instance, includes five different tiers of competencies. The detailed content for each of these five tiers is described in a 27-page document that accompanies the graphic model.

Mechatronics and Apprenticeship

PMMI and the Industrial Maintenance Training Center of North America (IMTC), in cooperation with the Employment and Training Administration of the DOL, have created National Apprenticeship guidelines for the occupation of "mechatronics technician." These guidelines have been recognized by DOL's Office of Apprenticeship since November 2014.[16] In its adaptation for mechatronics, PMMI chose to develop the guidelines and program around demonstration of skills and competencies above time ('seat time') for participants, a feature that PMMI says makes the program unique: "Unlike typical, time-based apprenticeships, the competency-based mechatronics apprenticeship program is structured around achieving competency in specific skills." Of course, virtually all apprenticeship programs also 'test' for competencies at some point, and students must demonstrate they have gained the required skills in structured ways. For most apprenticeships, time on the job (or through an instructional program) continues to be a key requirement for program completion.

PMMI further described the program as beneficial to participants because of the portable nature of the program, which maximizes career options for job seekers. PMMI reports that their Mechatronics certification tests are nationally portable, industry-accepted, third-party credentials endorsed by the National Association of Manufacturers' Skills Certification System. Employers can use the new apprenticeship guidelines to help establish a formal, DOL-registered apprenticeship program for their industry, or as a structure for establishing or updating internal training programs.

Mechatronics Curriculum

A review of existing and some proposed national and state mechatronics curriculum by two-year technical colleges and partnerships shows a fairly high degree of consistency regarding technical content. Most associates-level degree programs cover industrial technology basics as it relates to the installation, repair and maintenance of industry automation, systems and components, and there are some variations in the emphasis on integration and systems knowledge. Depending on the program

[16] See: http://www.pmmi.org/Education/content.cfm?ItemNumber=19525

goals, there may be considerable variation in the scope and depth of non-technical content, such as basic communications, human relations skills, problem solving strategies and teamwork. On the whole, however, curriculum and program descriptions show far more similarities than differences (see below).

Mechatronics – Common Curriculum/Training Content Areas[17]

Mechanical Systems, Mechanical Drives, Power Transmission	Fluid Power, Electrohydraulics, Pneumatics	General Preventive and Predictive Maintenance	Programmable Logic Controllers (Siemens, Allen-Bradley)
Blue Print Reading/Schematics	Controls & Instrumentation	Robotics	Basic Electricity & Electronics
Computer Literacy	Welding & Fabrication	Machine Tool Operations	Safety

The AMTEC curriculum, for instance, identifies 13 different core topical categories that are the basis for their program design, where each topical area contains multiple learning modules that incorporate a mix of lecture and laboratory experiences (see Appendix A). The categories and themes cut across the major technical content areas typically represented in other course descriptions and curriculum guides that have already been created for technician and craft-level programs (mechanical, electrical, computer and control technologies). The defined technical competencies form the platform for assessments, which can be purchased for use to certify attainment of mechatronics competencies in automotive and general manufacturing.[18]

Because the need for individuals with mechatronics knowledge and skills cuts across multiple industrial sectors, many colleges have initiated degree programs with the implicit goal of equipping students for careers in several different industries, and at multiple levels (see Appendix B). Certification programs can also be diverse, and range from a generalist certificate (targeting incumbent workers or current degree-holders) to certification with an emphasis in specific technical areas (PLCs, controls or robotics, for instance). As might be expected, the structure, content and student market for mechatronics degree and certificate programs are heavily influenced by research on local and regional industry demand, which colleges routinely require as a pre-condition for new programs. In its mechatronics AAS degree feasibility study, for instance, Arizona's Northland Pioneer College cited local demand as well as national

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[17] Adapted from the AMTEC basic mechatronics curriculum model: http://autoworkforce.org/wp-content/uploads/2014/03/Products.pdf
[18] See: http://autoworkforce.org

and regional labor market data on job growth, hiring projections and wages for energy occupations including engineers, line workers, technicians, and plant/field operators.[19]

Mechatronics in Washington

Several two-year college associate-level mechatronics degree and certificate programs exist in Washington, and more are being proposed to meet growing labor market demand, especially in aerospace manufacturing and related industry sectors.[20] Clover Park and Bellingham Technical Colleges, and Clark College, have already implemented technical two-year degree programs in mechatronics, and Everett and Centralia Colleges intend to implement their two-year programs by the end of 2016.[21] Green River College, which offers an AAS degree in mechatronics, has established short-term stackable certificates in machine maintenance that can be applied toward the mechatronics AAS.[22] It is also working with the Kent School District under a separate NSF-funded project to develop a mechatronics pathway for underserved populations leading to an AAS degree and careers in maintenance mechatronics.[23]

As noted earlier, AMTEC has been working to extend its established auto industry competencies, curriculum, assessments and certifications to other industry sectors. Using standards it developed in 2008 as the base, AMTEC leadership and research staff conducted a detailed validation process beginning in 2015 that engaged employer and education (mainly two-year college) partners in two rounds of ratings exercises (known as a Delphi process) to establish comparative scores across a wide range of 26 technical functions and 170 tasks that together comprise the AMTEC standards for mechatronics technicians. The 51 business and industry participants who submitted validation ratings included national automotive manufacturers and suppliers, aerospace manufacturers (led by Boeing Commercial Airplanes) and several aerospace suppliers. Companies from other manufacturing and non-manufacturing sectors (such as Amazon and Darigold) were also included. Input from 22 colleges was also collected, including Clover Park Technical College, Everett Community College, Centralia College and the Kent school district.

With support and leadership from Boeing and the Center of Excellence for Advanced Manufacturing and Aerospace (Everett Community College), the Washington partnership has established a Mechatronics Charter and is working to develop additional partnerships with Washington colleges and K-12 schools. Products will include mechatronics curriculum, assessments and experiential learning experiences that will be informed and shaped by the Delphi results. The first phase of this work is to establish the

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[19] Source: Energy Workforce Demand Report-West Region (2012). Prepared by EMSI for the Center for Energy Workforce Development (May). See: http://www.cewd.org/Workforce/DemandReports2012/West.pdf

[20] http://www.bizjournals.com/seattle/news/2016/03/30/boeing-cuts-wont-stop-colleges-from-expanding.html

[21] See: http://www.btc.edu/DegreesClasses/Programs/ProgramDetails.aspx?ID=92. Also: http://www.centralia.edu/academics/IA/index.html

[22] See: http://www.greenriver.edu/academics/areas-of-study/details/maintenance-mechatronics.htm.

[23] See: http://www.kent.k12.wa.us/site/default.aspx?PageType=3&ModuleInstanceID=458&ViewID=7b97f7ed-8e5e-4120-848f-a8b4987d588f&RenderLoc=0&FlexDataID=10366&PageID=595

programs and begin implementation using the modified curriculum modules, assessments and certification tools as the base. Boeing and other regional companies will contribute as anchor implementation partners, with the goal of expanding the pipeline of qualified workers for the aerospace industry and other industrial sectors throughout the Puget Sound region. Phase II will include expanding the range of partners and educational institutions (K-12, two-year college and universities), to measure and report student success, employer feedback and program modifications, and to develop and implement an effective sustainability/transition plan to ensure continuation of the work. Everett and the Center of Excellence were recently awarded a $3.9 million Department of Labor TECH-Hire grant in a partnership with Boeing and the City of Seattle (MechaWA) to introduce unemployed young adults to opportunities in the Aerospace industry, which will leverage the mechatronics curriculum and assessment work now underway.

Everett Community College, which is a primary education and training feeder to Boeing and other advanced manufacturing companies, is expanding its current 37,000 sq. ft. Advanced Manufacturing Training and Education Center facility and is adding a mechatronics certificate program through specialty options in Robotics Foundations and Mechatronics Systems.[24] While the program is primarily aimed at developing skills used in plant assembly sites, warehouse and service operations that use complex mechatronics systems, it is also being cast as relevant to the needs of employers across a range of industry sectors: "The foundational skill set for these integrated systems are interrelated in a variety of industries – aerospace, automotive, farming, mining, pharmaceuticals, power and energy, and food processing."

Identifying employer and industry demand beyond manufacturing is also a strategic advantage for colleges because it provides them with a broader market for mechatronics degrees and certificates, which in turn also provide additional career options and pathways for students and incumbent workers. Being responsive to the needs of industry is the most important first step. In establishing its program, Clark College also invested considerable time and energy to solicit industry support and input regarding the need for a mechatronics program in their service area. The resulting program is primarily aimed at manufacturing, but it also targets industrial maintenance generally, and other sectors that rely on automation and process technology. For the past five years Clark College has operated a mechatronics technology program and added multiple degree and certificate options (primarily mechanical or electronics) aimed at technician-level careers in manufacturing and high tech.[25] The program was initially developed by a faculty member who was on a one-year teaching sabbatical, who worked closely with regional industry partners during that time to define the program content based on employer

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[24] See: https://www.everettcc.edu/programs/aamc/mechatronics. The program is being described as a stand-alone credential for people seeking to enter the manufacturing field, or as part of a stackable set of certificates in the EvCC Advanced Manufacturing degree pathway. See also: http://www.theheraldbusinessjournal.com/article/20160205/BIZ/160209600/1005/EvCC-adds-new-program-to-train-new-kind-of-workforce-

[25] See: http://www.clark.edu/academics/programs/mechatronics/

needs. As the program developed, more employers came on board, and industry support for the program, which has its own employer advisory committee, is reported to be strong. Many underemployed workers, career changers and dislocated individuals enroll in the program, and students have reportedly experienced good employment outcomes.[26] Enrollment has grown and Clark plans to build a new advanced manufacturing center, where all manufacturing-related programs, including mechatronics, will be housed.

[26] Personal communication with Genevieve Howard, Dean of Workforce, Career & Technical Education, Clark College, May 4, 2016.

ENERGY INDUSTRY MECHATRONICS

In the energy sector, the application of mechatronics concepts and work processes do not appear to be designated by employers as a separate occupation, job function or task set. This is not to say that mechatronics concepts and applications are absent; on the contrary, designing and adapting new technology and systems integration is ubiquitous and crosses each of the traditional energy generation, transmission and distribution sectors.

Evidence of industry's reliance on mechatronics skills and standards are embedded in many of the technical standards required by the industry, as well as in the competencies and skill standards used as the basis for postsecondary education and training.[27] This is also true for renewable technologies, which rely heavily on integrated design engineering and new technologies. Renewables also require skilled technicians and maintenance personnel to install, maintain and repair renewable energy systems. As might be expected, virtually all energy-sector technologies, whether traditional or renewable, incorporate multi-platform technologies, systems and operating protocols that require skills and knowledge of mechatronics-based concepts and principles.

Wind turbines are a prime example of a technology that requires varying degrees of systems knowledge, problem solving skills, and the electrical, mechanical and computer and controls-based foundations that are central to mechatronics programming. The wind technician program at Walla Walla Community College, for instance, incorporates coursework in virtually all of the core curriculum/topic areas noted earlier, including a separate robotics-mechatronics class.[28]

Modernization of the electrical grid to a 'smarter' grid is another area in which mechatronics knowledge and skills are required in order to upgrade existing energy systems, technologies and components that are designed to improve overall grid performance and system flexibility. At the same time, just as smart grid systems and technologies have become more innovative, they have also become more complex, and elements of the new electrical grid are highly interdependent.[29] Automated metering and enhanced control systems with advanced user (customer) interfaces have a clear basis in the design and engineering of advanced technologies, but optimizing grid performance also relies on the knowledge and skills of employees who install and maintain these systems. Indeed, the level of interdependence between the technical and social (human) systems in the workplace, also known as socio-technical

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[27] Energy sector skill standards produced in Washington were sponsored and coordinated through the Pacific Northwest Center of Excellence for Clean Energy and its industry, labor and education partners. See: http://cleanenergyexcellence.org/

[28] See: http://www.wwcc.edu/cat/course_listing.cfm?CC=200&DC=EST&CCN

[29] Hardcastle, A. (2013). *Smart Grid Skills for the Energy Workforce*. Washington State University Energy Program, for the Pacific Northwest Center of Excellence for Clean Energy.

systems, is shifting and generally increasing as technology becomes more sophisticated.[30] Ideally, employees at all levels should understand how these systems work together and impact their work and the organization. Employees who have a broad knowledge of different subject matter and the ability to relate that knowledge and experience to their work are highly valued in a smart grid environment.

As with other industry sectors, specialists with deep subject knowledge continue to be important in the energy sector, but the ability to draw from many disciplines and experiences enables employees to grasp the complexities of grid modernization and to contribute in unique ways. For many of the same reasons, mechatronics concepts and principles are central to the energy industry, whether or not they are identified or codified by the term.

[30] Verbong, G.; Geels, F. (2012). Future Electricity Systems: Visions, Scenario's and Transition. In *Governing the Energy Transition: Reality, Illusion or Necessity?* Verbong, G., Loorbach, D., Eds.; Routledge: London, UK; pp. 400–434. Also: Kostyk, T.; Herkert, J. (2012). Societal implications of the emerging smart grid. *Communications of the Association for Computing Machinery*, *55*, pp. 34–36.

MARINE INDUSTRY MECHATRONICS

The prevalence of mechatronics in the marine sector appears to be similar to that found in the energy industry: the concepts, technologies and skills are evident in industry work practices, but is rarely identified as a singular function or occupation. Like the energy industry, which is highly regulated, the marine sector is also subject to myriad technical regulations and standards that pertain specifically to the design, construction, installation and repair of marine systems and components. These standards typically identify and define the technical requirements, however, and not the knowledge, skills, education and training required of employees to meet the standards. The American Boat and Yacht Council (ABYC), for instance, offers study guides to prepare individuals for certification exams, which are linked to the technical standards for that certification, but historically they have not served as a major education or training organization.[31]

But industry and trade associations have become more involved in sponsoring and supporting standards-based research activities for educational institutions that include mechatronics. The ABYC has focused more directly on marine industry education and training content, for instance, by developing and hosting the Marine League of Schools, a national consortium of marine technology postsecondary education providers that adhere to industry standards-based education and training.[32] Each member college has adopted technical standards into their programming, and this content covers many of the mechatronics competencies being discussed nationally. Through the League, the ABYC assists these institutions in the areas of curriculum development and instructor training/certification to help ensure that the training provided is relevant and up-to-date. The Northwest Center of Excellence for Marine Manufacturing and Technology (Skagit Valley College) is currently serving as the League chair and is working with several schools in Washington to embed standards-based curriculum that includes mechatronics content.

There are other industry groups that focus specifically on education and training programming. The National Marine Electronics Association (NMEA) is an international organization that provides training and certification for installers and technicians, and some of their trainings are offered in partnership with ABYC.[33] Several colleges that offer marine technology programs (including Skagit Valley College) incorporate NMEA standards into their curriculum, and NMEC trainings include many of the content categories that align with mechatronics concepts and applications. Another national organization, the National Maritime Education Council (NMEC), also serves as a leading national workforce development arm for the industry. It has developed standardized curricula, written and produced fee-based, performance-based assessments for use by employers and other parties. It also issues industry-

[31] See: http://abycinc.org/?page=StandardsIndex
[32] See: http://abycinc.org/?page=leagueofschools
[33] See: https://www.nmea.org/content/Traincert/Traincert.asp

recognized credentials that document completion of assessments and performance verifications regarding individual knowledge and skill levels.[34]

In partnership with the National Center for Construction Education and Research (NCCER), NMEC is now leading an effort to develop the first nationally recognized, standardized Maritime curricula for the industry. Early analyses of production craft skills led by NMEC and NCCER with industry partners revealed that there is relatively little variation among the skills sets for specific production crafts between the construction and maritime industries. This finding generated interest in aligning the knowledge and skill requirements for production crafts and adapting them for the maritime sector. NMEC is contracting with NCCER to develop formal written and performance-based assessments for maritime production crafts to certify the competencies of maritime craft employees. The project will leverage and adapt existing assessments, performance verifications and credentials developed by NCCER for the construction industry, leveraging postsecondary mechatronics competencies initially established by the South Carolina Department of Education as an enhancement to its manufacturing course standards.[35]

While mechatronics concepts are well represented in some of the curriculum and assessment resources, despite its growing role as a functional area NMEC has not seen broad-based industry support for establishing mechatronics as a distinct occupation, at least for now. NMEC staff noted that despite growing interest in the topic, mechatronics-specific standards and training curriculum for craft workers in the marine industry is still not yet very prevalent, probably because the focus of most skilled trades remains organized around specific, established occupations in the industry.[36] And, as with the energy sector, while more multi-skilling across occupations is happening, it appears that mechatronics concepts are probably being embedded within the existing standards, curriculum and work practices, rather than formally identified. For now, these concepts and practices are more evident in some occupations (i.e., design engineering) than in others (i.e., marine carpenter). What does seem to be emerging is that multi-skilling the technical and craft workforce is a fairly widespread practice among marine sector employers, and there is a growing recognition that employees at all levels are expected to be able to adapt to new technologies—if not directly oversee and support systems integration—as a routine aspect of their work.

Foundational work defining the knowledge, skills and abilities (KSAs) of marine industry occupations, especially for technical occupations (such as marine electrician, and composite technician, for instance) has helped to identify the prevalence of mechatronics competencies needed for the marine industry. Some of this work has been sponsored by the Northwest Center of Excellence for Marine Manufacturing and Technology and its industry and education partners, and has been used to establish and enhance

[34] See: http://maritimeeducationcouncil.org/
[35] See: http://ed.sc.gov/instruction/career-and-technology-education/programs-and-courses/career-clusters/manufacturing/
[36] Personal communications with Audrey Kennedy, NMSC, and Danielle Dixon, NCCER, May 2016.

technical programs though other marine education networks, including the Southeast Maritime and Transportation (SMART) Center. A National Science Foundation-sponsored (NSF) Advanced Technological Education (ATE) Center in the maritime and transportation industry, the SMART Center is hosted at Tidewater Community College in Virginia and is one of over 40 ATE Centers across the country focused on improving STEM (science, technology, engineering, and mathematics) education to meet the technician workforce needs of advanced technological industries in the U.S. [37]

Tidewater Community College hosts a mechatronics technology AAS degree (66 credits) and a career studies certificates (29 credits).[38] These programs evolved from their mechanical and industrial technology program, and was in response to employer demand for technicians could work across several technical areas, and who were able to support the integration of technology systems and components in industrial work environments.[39] The programs, which complement their new marine technologies AAS degree and certificate programs, are geared for students who seek related career opportunities in marine shipyards, but also in advanced manufacturing and other industrial settings.

The SMART Center is now working to build apprenticeship that incorporates mechatronics courses and that will align traditional apprenticeship with degree programs in the maritime and transportation fields. The Center is reaching out to other NSF partners and industry leaders to identify common interests, resources and leverage to develop an industry-wide consensus on standards for mechatronics through surveys and discussions with industry and education partners.

The Marine Advanced Technology Education (MATE) Center at Monterey Peninsula College in Monterey, California is another NSF ATE Center that is working to align marine technical education with mechatronics concepts and practices.[40] Supported by NSF since 1997, MATE has a long history of working to improve marine technical education nationally, to promote and enhance STEM education generally, and to help prepare the future workforce for ocean occupations. Among MATE's many activities has been its leadership for an international Remotely Operated Vehicle (ROVs, or underwater robotics) curriculum.[41] The ROV curriculum project, which began in 2014, defines competences for a year-long foundational curriculum in electronics, mechanics, hydraulics, robotics and computer controlled systems. A ROV Technology certificate /degree program serves as the next-level technical training for students or technical professionals seeking promotion or a career transition; international articulations of ROV degrees with 4-year marine technology degree programs are also underway. MATE has already developed a set of occupational Knowledge and Skill guidelines (KSGs) for technical marine occupations, as well as myriad curriculum products, curriculum resources, coordination for student internships, and it hosts highly-structured regional and international ROV competitions annually.

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[37] See: http://www.maritime-technology.org/about/
[38] See: http://www.tcc.edu/academics/mechanical-industrial/programs/mechatronics-degree
[39] Personal Communication with Barbara Murray, Executive Director, SMART Center, May 2016.
[40] See: http://www.marinetech.org/home/

[41] See: http://www.marinetech.org/international-rov-curriculum-project/

In designing its foundational curriculum, MATE purposely sought to also align the ROV competencies with mechatronics, electrical, and engineering technology competencies. Although the foundational curriculum and degree program is geared primarily for careers in the marine field, MATE leadership recognized that incorporating mechatronics concepts, principles and activities, along with core technical subjects, provides students with the skills needed to pursue careers in other industries that also rely on these technologies: from factory automation, manufacturing, robotics, to renewable energy generation, industrial maintenance, testing, and other technical fields. The MATE Center, in collaboration with the SMART Center, Washington's Northwest Center of Excellence for Marine Manufacturing and Technology (Skagit Valley College) and other partners, is now compiling existing research on mechatronics and is working to bring industry partners and subject matter experts together to conduct a national marine technology DACUM (Developing a Curriculum) project to establish the core competencies for mechatronics and related functions and tasks, from which additional occupational standards, curriculum and assessment products can be established.[42]

[42] Personal communication with Deidre Sullivan, Executive Director, MATE Center, April 2016, and Ann Avary, Executive Director, Northwest Center of Excellence for Marine Manufacturing and Technology, June 28, 2016.

CONCLUSIONS

Current national, state and regional research and program development projects for mechatronics--including those supported by government sponsors, industry associations, and employer-education partnerships—have expanded in recent years. Growing employer demand and gaps in the availability of qualified technical personnel in industry is also driving new activity among colleges to develop or adapt technical education and training programs that will equip students and incumbent workers with mechatronics knowledge and skills. In these respects, it appears that mechatronics—by whatever name it is described or applied—reflects an established and evolving set of concepts and practices; it is not a passing fad. The need for employees with mechatronics-related knowledge and skills is real, and the evidence suggests that this trend will continue. Several of Washington's Centers of Excellence, individual colleges and their industry and education partners are providing leadership to establish competencies, curriculum and assessment tools. This foundational work has enabled the identification of mechatronics content that is responsive to the changing needs of industry and maximizes the preparation and career options available to students and incumbent workers.

Characterizing Mechatronics

Mechatronics describes an integration of technologies, systems, work functions and skill requirements that are well established and specifically identified in some industry sectors, especially manufacturing. Mechatronics concepts and practices have continued to evolve with the advent of new technologies and work practices, and their use has extended to other industry sectors and work environments. As an organizing concept, mechatronics emphasizes the bringing together of different yet complementary technologies and systems that are commonly integrated in virtually all industrial workplaces, whether or not they are defined or identified by the term.

Mechatronics principles and applications are especially relevant to technically-oriented occupations (engineering, technicians, and maintenance personnel). It is especially evident and pervasive in descriptions of engineering design, and for projects that emphasize technology development and technology integration. Technician and maintenance-level employees are primarily engaged via installation, repair and preventative maintenance activities. Technology-driven, mechatronics is growing in response to increasingly-complex technical systems and components that are required to interact. Greater complexity has, in turn, required higher levels of knowledge and skill among employees in some occupations. Both depth and breadth in technology areas and their integration are required and valued. Mechatronics concepts are also relevant to many non-technical functions and occupations, where some basic understanding and knowledge of systems and technology integration is important in leadership and general support functions (general management, finance, sales, customer service, etc.).

Education and Training Program Development

All modern industrial environments incorporate and rely on mechatronics concepts and principles. Mechatronics degree and certificate programs appear to be growing in number especially at two-year technical colleges, primarily in response to employer interest and demand. Its prevalence in some university engineering programs is well-established, and the growing interest in mechatronics across two-year college professional technical programs are usually tied to manufacturing and industrial maintenance. The growth in certificate options offers students and incumbent workers avenues for skill upgrading and enhancing qualifications beyond existing degree programs, including into technical management careers.

The growing number of mechatronics competency and curriculum development projects provides further evidence of the importance attached to the development of new programs or upgrading existing technical education and training to incorporate mechatronics concepts and practices. New and ongoing investments by governmental sponsors and industry and education partners to identify industry needs and trends, as well as develop new programming or to upgrade existing offerings, also suggests that the emphasis on mechatronics is well established and growing. It seems unlikely that it represents a passing trend that will soon disappear.

Greater emphasis on technology integration directly affects the knowledge and skill requirements of technicians, craft workers and maintenance personnel who install, service and repair these complex systems, components and processes. Mechatronics principles and concepts are rooted in technical content, but they also call for foundational non-technical knowledge and skills needed to function in modern industrial environments: understanding systems and systems integration concepts, structured problem solving, working in teams, and interdisciplinary learning that cuts across multiple academic and technical areas. A solid foundation in mathematics, written communications and science are also identified as essential 'basics' for student success in mechatronics education and training programs.

In most cases, it appears that two-year technical colleges are incorporating mechatronics content into current programs or courses, such as general manufacturing or industrial maintenance programs or certificates. This is a prudent strategy since it enables colleges to bundle existing courses and technology areas together, while integrating a mechatronics overlay in ways that complement their existing programs, courses and employer markets. At the same time, most colleges are also marketing these programs as relevant to the needs of multiple industry sectors. This is also a wise strategy because designing and marketing programs to appeal to multiple industry sectors and employers can help expand a college's potential market base, and reduce the risks due to shifting economic cycles that invariably occur among industrial markets. The same benefits accrue for students, who have more employment options and the advantage of acquiring skill sets that are relevant and transferrable across different industry sectors and employers.

Considerations

Confirm Demand: Working to identify industry and employer demand for mechatronics is a critical first step. Engaging with industry sector partners, employers and subject matter experts in a structured manner (i.e., DACUMs, focus groups, skill standards projects) helps confirm the specific jobs, competencies and skills employers expect, their level of support for mechatronics degrees and certificates, and the kinds of individuals for whom mechatronics skills are most appropriate (i.e., entry-level employees, incumbent workers, etc.). For new students with little or no industry experience, mechatronics training could lead to generalist skills, but they may lack the benefit of depth gained through experience in a specific technical field. Many programs incorporate some combination of lecture/lab/internship experiences, which help compensate for the lack of industry experience, however incumbent workers with applied experience may be in a better position to achieve the most benefit from mechatronics training. For their part, employers may be more willing to support the career development of an established employee, and more quickly see the benefits of training investments through increased productivity and performance. This type of information and input from employers, in addition to other research on industry and technology trends and labor market demand, is central to determining accurate program viability, design options and investment priorities.

Take an Incremental Approach: Since in most cases mechatronics appears to more closely represent a growing *functional area* rather than a discreet *occupation*, efforts to incorporate mechatronics into existing technical programs, apprenticeships, and through certificates is a logical first step. Several Washington two-year colleges now offer associate-level degrees and certifications in mechatronics, and Washington's two-year colleges are also able to offer Applied Baccalaureate degrees (aka Bachelor of Applied Science, or BAS) in various high-demand fields. For students who have already earned a two-year technical degree (typically 'terminal' degrees that are not transferrable for credit in most university-level programs) the availability of an applied bachelor's degree in mechatronics could be an attractive option that may also be popular among employers. To date, a few BAS degrees incorporate mechatronics content, but none currently offers a BAS specifically in mechatronics.[43] Again, careful exploration of the market for a BAS-Mechatronics with employers should be conducted, and geographic economic considerations should also be explored: rural areas with limited industry opportunities may

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[43] Some colleges with AS-level degrees and certifications in mechatronics offer BAS degrees in related areas, yet no stand-alone BAS degree specifically in mechatronics currently exists: Bellingham Technical College, for instance, will soon offer a BAS in Operations Management, which include some training in mechatronics-related areas and technologies. The primary focus of that program, which launches in Fall, 2016, is on supervision, overall operations management and information technology in industrial settings: http://www.btc.edu/General/Publications/Press/BAS_OpsManag_FinalPressRelease2016.pdf. Clover Park Technical College offers a BAS in Manufacturing Operations, which also emphasizes operations and business management for students who have a manufacturing-related associate's degree in a technical or business discipline: http://www.cptc.edu/sites/default/files/files/14-03-24%20B%20Basmo.pdf. South Seattle College offers a BAS in Sustainable Building Science Technology, which emphasizes the integration of technology and systems: http://www.southseattle.edu/programs/bas/sustainable-building-science-technology/

not be able to support a specialty BAS within the local labor market, compared to more economically-diversified regions, metropolitan areas and cities, for instance.

Collaboration Imperative: In addition to gaining input and building support for mechatronics programming from employers, workers and labor organizations should also be consulted, where appropriate. Because it cuts across disciplines and technology platforms, there is a natural link between mechatronics and the growing trend toward employee multi-skilling. There is some concern that as a separate occupation mechatronics engineers or technicians may become "Jacks of all trades" and lacking in the depth of experience that may be required to solve specific technical problems or make repairs.[44] For all the advantages multi-skilling can confer on employees and companies, it can be viewed by workers and organized labor as a vehicle aimed mainly at cutting established job classes and labor costs. Multi-skilling has become a common practice in most production-oriented work environments, and is viewed as a partial solution to ongoing labor shortages in the skilled trades.

Looking ahead, new technology applications are likely to streamline preventive maintenance functions further across many industries.[45] Thoughtfully applied, employees and labor unions are receptive to, and may even promote, internal efforts to multi-skill the workforce. When used mainly to reduce costs—even when multi-skilling is justified by technology changes—its use can evoke strong reactions and resistance from workers and labor unions.[46] It is unclear whether the growth of mechatronics has raised similar concerns, however it is important to consider the factors that may enhance or detract from its acceptance among workers.

Energy Sector Mechatronics: Currently there does not appear to be an organized effort in the energy sector to develop or market mechatronics as a stand-alone program, even though it is clear that the functions, tasks and skills that underlie mechatronics are relevant and widely applied across the energy sector. For the energy sector, foundational work to establish skill standards for technical and affiliated occupations sponsored by the Pacific Northwest Center of Excellence for Clean Energy established the core competencies required by industry and used for college programs. This work identified mechatronics content, thus codifying the term may be less important than confirming the value of mechatronics as a contributor to the knowledge, skills and abilities required in the workplace, and as a method for ensuring that employees meet the highly-structured regulatory requirements for the industry.

The energy sector is not immune to the adaptations that are required by new technology advancements, and mechatronics principles are already central to this sector, and for that reason alone an effort to conduct focused conversations with industry leaders about future programming enhancements for mechatronics is advised. It may be useful, for instance, to determine whether

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[44] For an extreme perspective, see: *http://bin95.com/mechatronics-engineer-technician.htm*
[45] See: https://www.maintenanceassistant.com/blog/mechatronics-manufacturing-and-assessment-growing-demand-for-preventative-maintenance-systems/
[46] See: Campbell, J. and Reyes-Picknell, J. (2016). *Uptime: Strategies for excellence in maintenance management.* (3rd Ed.). New York: CRC Press.

increasing the mechatronics-related content within existing technician and skilled trades programs and apprenticeships is warranted, and how much support employers might give to establishing specific mechatronics degree programs or certificates that are customized for the energy industry.

Marine Industry Mechatronics: The prevalence of mechatronics content is evident in in the marine industry, and organized efforts are underway to further identify and integrate mechatronics competencies into marine-sector education and training programs. Similar to the energy sector, the application of mechatronics concepts and practices is not new, but they are becoming more widespread due to continued technology advances, new production methods, and changes in the regulatory environment. Past efforts to establish competencies through DACUM and skill standards development processes in various industry sectors in Washington (including marine, energy, manufacturing, construction and several others) offer an opportunity to leverage established work in this area, and new work by the NSF-funded SMART Center and MATE offer additional opportunities to connect mechatronics to marine occupations and training nation-wide.

Evidence from the survey of marine employers sponsored by the Northwest Center of Excellence for Marine Technology shows that some employees are expected to perform duties across two or more occupations or skill areas, which also infers the need for knowledge of multiple technology applications and integration that is a central tenet of mechatronics. The developmental work underway by the SMART Center, MATE and the Center of Excellence may provide a ready platform, resources and materials that could serve as the basis for in-depth discussions with local and regional marine employers about future trends and their priorities for mechatronics content and program options.

APPENDIX A: AMTEC MECHATRONICS CURRICULUM OVERVIEW

COURSE	TITLE	PURPOSE	TOPICS
AMT 101	Fluid Power/Electrohydraulics/ Pneumatics	Fundamental Concepts of Fluid Power	• Fundamentals of fluid power & electrohydraulics/ pneumatics • Flow/directional, pressure control valves • Reservoirs, fluids, & filters • Hose, Piping, & tubing • Electrohydraulics/Pneumatics • Systems and system troubleshooting
AMT 102	General PM & Predictive Maintenance	Routine to keep Equip in good working order	• Basic PM • Advanced technologies
AMT 103s	PLC (Siemans)	Intro to various elements of Siemens PLCs	• Intro to Siemens PLCs • Siemens hardware and software (I/O) • Programming Siemens PLCs • Siemens PLC communication
AMT 103ab	PLC (Allen-Bradley/Rockwell)	Intro to elements of Allen-Bradley PLCs	• Intro to Allen-Bradley PLCs • Allen-Bradley hardware and software (I/O) • Programming Allen-Bradley PLCs • Allen-Bradley PLC Communication
AMT 104	Blue Print Reading/Schematics	Drafting fundamentals (read, interpret, manipulate, and understand a mechanical part print.	• Drafting Fundamentals • Orthographic Interpretation
AMT 105	Robotics	Intro to robotics, safety, types, applications components terms and definitions	• Intro to Robotics • Programming/editing • Maintenance and PM • Troubleshooting (TS) using error codes • Integration of PLC with Robotics
AMT 106	Controls & Instrumentation	How to troubleshoot/replace/install circuit boards	• Fundamentals • Sensors & photoeyes • Calibration and loop tuning • Final control elements (control valves)
AMT 107	Basic Electricity & Electronics	Intro to various elements of basic electricity, symbols, terms, schematics, tracing circuits, function charts, line drawings and time charts	• Introduction to basic electricity • Instruments • Components & circuits • Solid state devices

AMT 108	Mechanical Systems/Mech Drives Power Transmissions	Intro to basic concepts of mechanical power transmission	• Basic mech. power transmission • Flexible drives • Couplings and alignment • Bearings, shafts, & seals • Brakes & clutches • Gears & cams
AMT 109	Safety	Basic OSHA Safety	• Basic OSHA safety • Hoists & cranes • Rigging awareness & fundamentals • First aid, CPR, & AED
AMT 100 LL	Computer Literacy	Intro to typical computer systems and components.	• Orientation to computer systems • Operating systems • Computer applications • Internet/Intranet
AMT 110	Welding & Fabrication	Intro to arc welding	• Introduction to welding • AMAW • GMAW • Oxy/fuel cutting and joining
AMT 120	Machine Tool Operations	Intro to machine operations	• Introduction to machining operations • Measuring & layout tools • Hand & power tools • Saws

Source: AMTEC. See: http://autoworkforce.org/

APPENDIX B: SAMPLE OF MECHATRONICS PROGRAMS IN THE U.S.

- American Institute of Mechatronics Engineers (and California State University, Chico): http://www.chicoaime.org/
- University of Waterloo, Ontario: https://uwaterloo.ca/mechanical-mechatronics-engineering/future-undergraduate-students/mechatronics-engineering
- Simon Fraser University, Mechatronics Systems Engineering Program : https://www.sfu.ca/mechatronics/about-mse.html
- Rochester Institute of Technology, Certificate program in Mechatronics: https://www.rit.edu/kgcoe/mechanical/program/certificate-program-mechatronics/certificate-program-mechatronics
- Mechatronics Technology Program by LabVolt: https://webcache.googleusercontent.com/search?q=cache:hV7DWlDJI8oJ:https://www.labvolt.com/downloads/89804_00.pdf+&cd=6&hl=en&ct=clnk&gl=us
- Tennessee College of Applied Technology: http://www.tcatnashville.edu/manufacturing/mechatronics
- Tidewater Community College, Norfolk, VA, Certificate in Mechatronics (29 credits, 14 months): https://apollo.tcc.edu/pls/apex/f?p=122:32:0::::P32_CUR_GUIDE_ID:98
- West Kentucky Community and Technical College, Certificate in Mechatronics Systems Operations Technician (16 credit hours.): http://westkentucky.kctcs.edu/en/Academics/Academic_Divisions/at/Mechatronic_Systems.aspx
- University of Hawaii-Leeward Community College, programs tied to Mechatronics: http://www.ocewd.org/industrial-technology
- Delta College, Mechatronics Technology AAS degree (2016): https://public.delta.edu/catalog/Pages/ProgramDetail.aspx?ProgramID=2975
- Professional development (2-day) for ME & EE engineers in vehicle (aerospace, automotive, commercial vehicle) design and engineering, by SAE International: http://training.sae.org/seminars/c0949/
- Lenawee Intermediate School District, Adrian, MI, Mechatronics - New Program for 2015-16: : http://www.lisd.us/wp-content/uploads/downloads/_acct_/00/00/01/48/mechatronics_flyer_1-2015_20150122_095100_1.pdf

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