

Mechatronics Competency Model

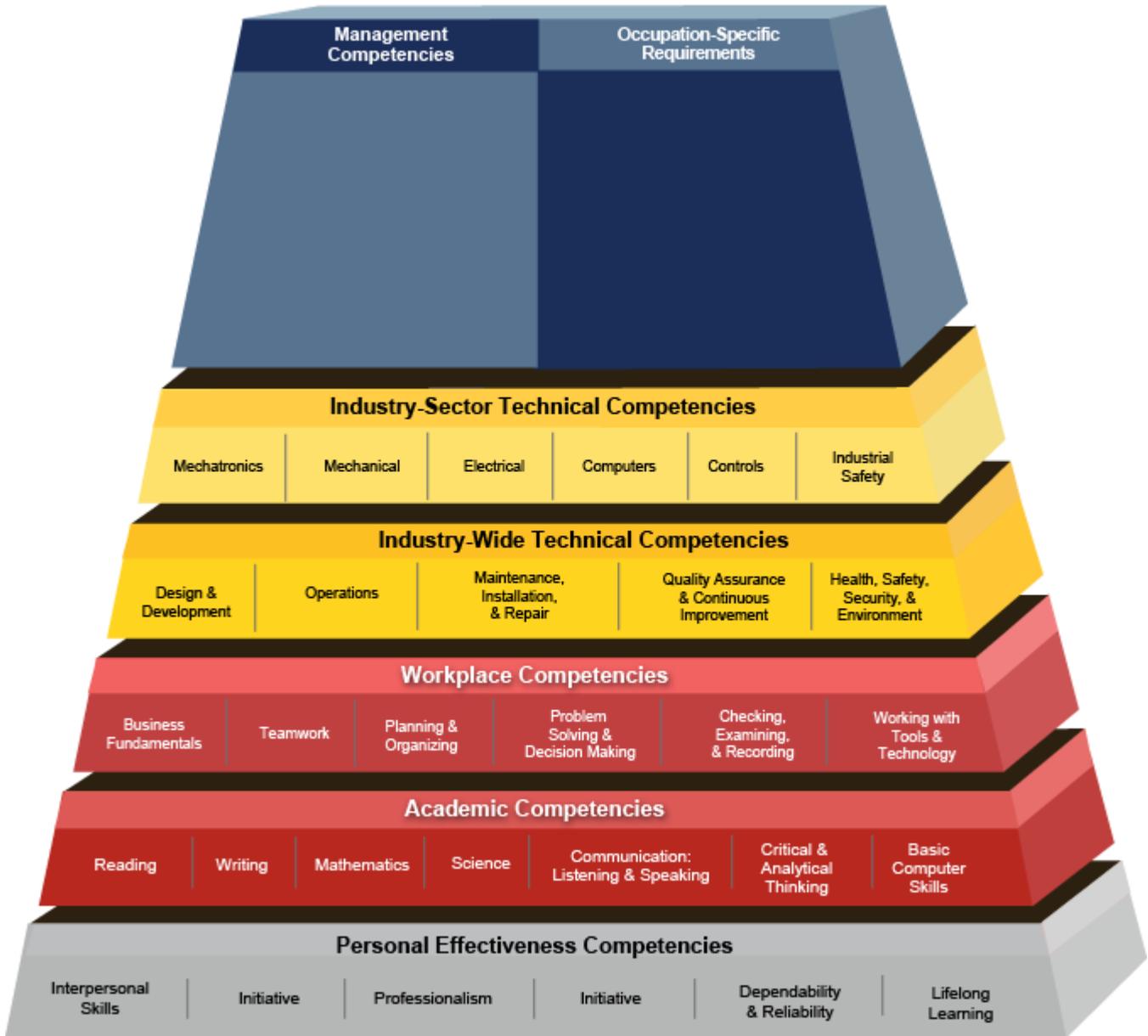


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ABOUT THE MODEL

The Mechatronics Competency Model is depicted in a pyramid graphic with nine tiers. This shape illustrates how occupational and industry competencies build on a foundation of personal effectiveness, academic, and workplace competencies. Each tier is comprised of blocks representing the skills, knowledge, and abilities essential for successful performance in the industry or occupation represented by the model. At the base of the model, the competencies apply to a large number of occupations and industries. As a user moves up the model, the competencies become industry and occupation specific. However, the graphic is not intended to represent a sequence of competency attainment or suggest that certain competencies are of greater value or higher skill than others. The graphic is accompanied by a table which contains definitions and associated key behaviors for each competency block.

COMPETENCY MODEL TIERS

Tiers 1 through 3, called Foundation Competencies, form the foundation needed to be ready to enter the workplace.

Tier 1 – Personal Effectiveness Competencies are shown as hovering below the pyramid because they represent personal attributes or “soft skills” that may present some challenges to teach or assess. Essential for all life roles, personal effectiveness competencies generally are learned in the home or community and reinforced at school and in the workplace.

Tier 2 – Academic Competencies are critical competencies *primarily* learned in a school setting. They include cognitive functions and thinking styles, and are likely to apply to most industries and occupations.

Tier 3 – Workplace Competencies represent motives and traits, as well as interpersonal and self-management styles honed in the workplace. They generally are applicable to a large number of occupations and industries.

Tiers 4 and 5, called Industry Competencies, show competencies that are specific to the *industry or industry sector*. The cross-cutting industry-wide technical competencies make it possible to show career lattices within an industry wherein a worker can move easily across industry sub-sectors. As a result, this model supports the development of an agile workforce, rather than narrowly following a single occupational career ladder.

Tier 4 – Industry-Wide Technical Competencies represent the knowledge and skills that are common across the sectors within a broader industry. These technical competencies build on, but are more specific than, a competency represented on a lower tier.

Tier 5 – Industry-Sector Technical Competencies represent a sub-set of industry technical competencies that are specific to an industry sector, in this case Mechatronics.

Tiers 6 through 9 represent the specialization that occurs within specific *occupations* within an industry. Information on occupational competencies is available through O*NET OnLine (<http://online.onetcenter.org/>).

Tier 1—Personal Effectiveness Competencies

<p>1. <u>Interpersonal Skills</u>: Demonstrating the ability to work effectively with others.</p> <ul style="list-style-type: none"> ▪ Interact appropriately and respectfully with supervisors and coworkers ▪ Work effectively with people who have diverse personalities and backgrounds ▪ Respect the opinions, perspectives, customs, and individual differences of others ▪ Use appropriate strategies and solutions for dealing with conflicts and differences to maintain a smooth workflow ▪ Be flexible and open-minded when dealing with a wide range of people ▪ Listen to and consider others' viewpoints
<p>2. <u>Integrity</u>: Displaying accepted social and work behaviors.</p> <ul style="list-style-type: none"> ▪ Treat others with honesty, fairness, and respect ▪ Comply with ethical standards for your field ▪ Take responsibility for accomplishing work goals within accepted timeframes ▪ Accept responsibility for one's decisions and actions
<p>3. <u>Professionalism</u>: Maintaining a socially acceptable demeanor.</p> <ul style="list-style-type: none"> ▪ Demonstrate self-control by maintaining composure and dealing calmly with stressful situations ▪ Accept criticism and attempt to learn from mistakes ▪ Demonstrate a positive attitude towards work ▪ Follow rules and standards of dress ▪ Follow rules and standards of personal hygiene ▪ Refrain from substance abuse
<p>4. <u>Initiative</u>: Demonstrating a willingness to work.</p> <ul style="list-style-type: none"> ▪ Take initiative in seeking out new responsibilities and work challenges ▪ Pursue work with energy, drive, and effort to accomplish tasks ▪ Persist at a task despite interruptions, obstacles, or setbacks ▪ Establish and maintain personally challenging, but realistic work goals ▪ Strive to exceed standards and expectations
<p>5. <u>Dependability and Reliability</u>: Displaying responsible behaviors at work.</p> <ul style="list-style-type: none"> ▪ Behave consistently, predictably, and reliably ▪ Fulfill obligations, complete assignments, and meet deadlines ▪ Follow written and verbal directions ▪ Comply with organizational rules, policies, and procedures
<p>6. <u>Lifelong Learning</u>: Displaying a willingness to learn and apply new knowledge and skills.</p> <ul style="list-style-type: none"> ▪ Demonstrate an interest in personal and professional lifelong learning and development ▪ Treat unexpected circumstances as opportunities to learn and adopt new techniques ▪ Seek feedback, and modify behavior for improvement ▪ Broaden knowledge and skills through job shadowing and continuing education ▪ Use newly learned knowledge and skills to complete specific tasks ▪ Take charge of personal career development by identifying personal interests and career pathways ▪ Seek and maintain membership in professional associations ▪ Read technical publications to stay abreast of new developments in the industry ▪ Maintain certifications and continuing education credits

Tier 2—Academic Competencies

<p>1. <u>Reading</u>: Understanding written English sentences and paragraphs in work-related documents.</p> <ul style="list-style-type: none"> ▪ Locate, understand, and interpret written technical and non-technical information in documents such as manuals, reports, memos, graphs, charts, tables, schedules, signs, and regulations ▪ Identify relevant details, facts, specifications, and main ideas ▪ Understand the essential message and purpose of written materials ▪ Infer or locate meaning of unknown or technical vocabulary
<p>2. <u>Writing</u>: Using standard English to compile information and prepare written reports.</p> <p>Organization and development</p> <ul style="list-style-type: none"> ▪ Create documents such as letters, directions, manuals, reports, graphs, and flow charts ▪ Communicate thoughts, ideas, information, messages, and other written information, which may contain technical material, in a logical, organized, coherent, and persuasive manner ▪ Develop ideas with supporting information and examples <p>Mechanics</p> <ul style="list-style-type: none"> ▪ Use standard syntax and sentence structure ▪ Use correct spelling, punctuation, and capitalization; use appropriate grammar (e.g., correct tense, subject-verb agreement, no missing words) ▪ Write in a manner appropriate for business; use language appropriate for the target audience; use appropriate tone and word choice (e.g., writing is professional and courteous)
<p>3. <u>Mathematics</u>: Using principles of mathematics such as algebra, geometry, and trigonometry to solve problems.</p> <p>Know and apply mathematical principles:</p> <ul style="list-style-type: none"> ▪ Number Systems and Relationships - whole numbers, decimals, fractions, alternate base systems (e.g. binary, octal, and hexadecimal numbers) ▪ Arithmetic – arithmetic operations on numbers, percentages, square root, exponentiation, and logarithmic functions ▪ Plane and Solid Geometry – distance, perimeter, area, and volume, spatial coordinates, visualization, spatial reasoning, and geometric modeling ▪ Measurement – measurement of length, mass, time, systems of measurement, units, and conversion between systems (e.g. from English to metric) ▪ Mathematical Notation - the language of mathematics to express mathematical ideas ▪ Mathematical Reasoning and Problem Solving – inductive and deductive reasoning, conjectures, arguments, strategies, and interpretation of results ▪ Elementary Statistics and Laws of Probability – mean, median, and standard deviation ▪ Algebra and Functions – equations, patterns, and functions ▪ Elementary Trigonometry – triangles and trigonometric functions ▪ Elementary Calculus – exponential, logarithmic and trigonometric functions, vectors, complex numbers, conic sections, and analytic geometry
<p>4. <u>Science</u>: Knowing and applying scientific principles and methods to solve problems.</p> <p>Know and apply scientific principles:</p> <ul style="list-style-type: none"> ▪ Scientific Method – the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of a hypothesis ▪ Chemistry – the composition, structure, properties, and reactions of matter, especially of atomic and

molecular systems

- Physics – matter and energy and physical interactions
 - Ohm’s Laws
 - Kirchhoff’s Laws
 - Pascal’s Law and Delta–P
 - Boyle’s Laws
 - Bernoulli’s Law

5. Communication—Listening and Speaking: Giving full attention to what others are saying and speaking in English well enough to be understood by others.

Listening

- Receive, attend to, interpret, understand, and respond to verbal messages and other cues
- Apply active listening skills using reflection, restatement, questioning, and clarification
- Pick out important information in verbal messages
- Understand complex instructions

Speaking and Presenting

- Speak clearly and confidently using common English conventions including proper grammar, tone, and pace
- Express information to individuals or groups taking into account the audience and the nature of the information (e.g., explain technical concepts to non-technical audiences)
- Present ideas in a persuasive manner

6. Critical and Analytical Thinking: Using logic, reasoning, and analysis to address problems.

- Use logic and reasoning to identify strengths and weaknesses of alternative solutions, conclusions, or approaches to problems
- Use inductive and deductive reasoning to analyze, synthesize, compare, and interpret information
- Draw conclusions from relevant or missing information
- Understand the underlying relationship among facts and connections between issues
- Organize problems into manageable parts

7. Basic Computer Skills: Using a computer and related applications to input and retrieve information.

Navigation and File Management

- Use scroll bars, a mouse, and dialog boxes to work within the computer's operating system
- Access and switch between applications and files of interest

Internet and E-mail

- Navigate the Internet to find information
- Open and configure standard browsers
- Use searches, hypertext references, and transfer protocols
- Send and retrieve electronic mail (e-mail)
- Write e-mail with an appropriate tone

Word Processing

- Use a computer application to type text, insert pictures
- Format, edit, and print text
- Utilize tools to finalize a document such as spell check, thesaurus, and headers
- Save and retrieve word processing documents

Spreadsheets

- Use a computer application to enter, manipulate, and format text and numerical data
- Insert, delete, and manipulate cells, rows, and columns
- Modify spreadsheets with the use of formulas, functions, and formatting
- Create and save worksheets, charts, and graphs

Presentations

- Use a computer application to create, manipulate, edit, and show virtual slide presentations
- Enhance a presentation with clip art, animation and transitions

Databases

- Use a computer application to manage large amounts of information
- Create and edit simple databases
- Input data
- Query a database to retrieve certain records
- Create reports to communicate the information

Graphics

- Work with pictures in graphics programs or other applications
- Create simple graphics
- Manipulate the appearance of graphics
- Insert graphics into other files/programs

Tier 3—Workplace Competencies

1. **Business Fundamentals:** Knowledge of basic business principles, trends, and economics.

Economic/Business/Financial Principles

- Characteristics of Markets
- Cost and Pricing of Products
- Economic Terminology
- Fundamentals of Accounting
- Profit and Loss
- Supply/Demand

Economic System as a Framework for Decision-making

- Understand how one's performance can impact the success of the organization
- Consider the relative costs and benefits of potential actions to choose the most appropriate one

Business Ethics – Act in the best interests of the company, your co-workers, your community, other stakeholders, and the environment

- Legal/Financial
 - Comply with the letter and spirit of applicable laws
 - Use company property legitimately, minimizing loss and waste; report loss, waste, or theft of company property to appropriate personnel
 - Maintain privacy and confidentiality of company information, as well as that of customers and co-workers
 - Comply with intellectual property laws
 - Protect trade secrets
- Environmental/Health/Safety
 - Maintain a healthful and safe environment and report any violations/discrepancies
 - Ensure proper handling and disposal of toxic or hazardous materials
 - Ensure equipment and systems are designed to be environmentally friendly and strive to continually minimize the resulting carbon footprint
 - Practice sustainability by using processes that are non-polluting, conserving of energy and natural resources, economically efficient, and safe for workers, communities, and consumers
 - Safeguard the public interest
- Social
 - Emphasize quality, customer satisfaction, and fair pricing
 - Deal with customers in good faith, no bribes, kickbacks, or excessive hospitality

Marketing

- Demonstrate an understanding of market trends, company's position in the market place, and defined market segments
- Understand position of product/service in relation to market demand
- Uphold the company and product brand through building and maintaining customer relations
- Integrate internal and external customer demands and needs into manufacturing product and process development

2. Teamwork: Working cooperatively with others to complete work assignments.

- Accept membership in and commit to the goals of a team
- Work effectively with multi-disciplinary teams
- Identify roles of team members and effectively communicate with all members of the team
- Recognize one's own effects on team performance
- Collaborate with others to formulate team objectives and develop consensus for best outcome
- Use teamwork skills to achieve goals, solve problems, and manage conflict
- Give and receive feedback constructively
- Express opinions openly and respect others' right to do so
- Be open to new ideas, new ways of doing things, and the merits of new approaches to work

3. Planning and Organizing: Planning and prioritizing work to manage time effectively and accomplish assigned tasks.

Plan

- Approach work in a methodical manner
- Plan and schedule tasks so that work is completed on time
- Keep track of details to ensure work is performed accurately and completely

Prioritize

- Prioritize various competing tasks
- Perform tasks quickly and efficiently according to their urgency
- Find new ways of organizing work area or planning work to accomplish work more efficiently

Allocate Resources

- Estimate resources needed for project completion
- Allocate time and resources effectively
- Coordinate efforts with all affected parties
- Keep all parties informed of progress and all relevant changes to project timelines

Anticipate Obstacles

- Anticipate obstacles to project completion
- Develop contingency plans to address them
- Take necessary corrective action when projects go off track

4. Problem Solving and Decision Making: Applying critical-thinking skills to solve problems by generating, evaluating, and implementing solutions.

Identify the problem

- Anticipate or recognize the existence of a problem and define the problem
- Locate and obtain all information relevant to the problem
- Identify potential causes of the problem by analyzing its component parts
- Recall previously learned information that is relevant to the problem
- Communicate the problem to appropriate personnel

Generate innovative solutions

- Think creatively to generate a variety of approaches to the problem
- Integrate seemingly unrelated information to develop creative solutions
- Develop innovative methods of obtaining or using resources when insufficient resources are available
- Demonstrate innovative thinking by using new and existing technology in new ways
- Use logic and reasoning to evaluate the relative merits of the various solutions, conclusions, or

approaches

Choose a solution

- Decisively choose the best solution after contemplating available approaches to the problem
- Make difficult decisions even in highly ambiguous or ill-defined situations
- Quickly choose an effective solution without assistance when appropriate

Implement the solution

- Commit to a solution in a timely manner
- Develop a realistic approach for implementing the chosen solution
- Use strategies, tools, resources, and equipment to implement the solution
- Observe and evaluate the outcomes of implementing the solution to assess the need for alternative approaches and to identify lessons learned

5. Checking, Examining, and Recording: Entering, transcribing, recording, storing, or maintaining information in written or electronic/magnetic format.

- Record data in control system documentation
- Compile, code, categorize, calculate, inspect, or verify information or data
- Apply systematic techniques for observing and gathering data
- Detect and correct errors or inconsistencies, even under time pressure
- Organize records and files to maintain data

6. Working with Tools and Technology: Selecting, using, and maintaining tools and technology to facilitate work activity.

Selection and Application

- Identify, select, and apply appropriate and cost-effective tools or technological solutions
- Identify potential hazards related to the use of tools and equipment
- Operate tools and equipment in accordance with established operating procedures and safety standards
- Use information technology and computer applications as it supports the gathering, storage, manipulation, and transfer of data and information

Keeping Current

- Demonstrate an interest in learning about new and emerging tools and technologies
- Identify sources of information concerning state-of-the-art tools, equipment, materials, technologies and methodologies
- Seek out opportunities to improve knowledge of tools and technologies that may assist in streamlining work and improving productivity

Maintenance and Troubleshooting

- Perform routine maintenance on tools, technology, and equipment
- Determine causes of operating errors and decide what to do about it
- Troubleshoot maintenance problems in accordance with established procedures
- Perform work functions that require engaging in hands-on activity

Tier 4—Industry-Wide Technical Competencies

1. **Design and Development:** Research and design for the application of technology to monitor and control the production of goods and services.

Critical Work Functions:

- Design production and production support systems.
- Create and apply technology to control production and process functions.
- Develop functional specifications for the design and development of control systems.
- Communicate about and respond to requirements of internal and external customers.
- Interpret and clarify customer expectations and product specifications.

Technical Content Areas:

Design Concepts

- Design for Manufacturing and Design for Logistics
- Development of Prototype Processes and Products
- Support Systems Design and Development
- System Design, Development, Testing, and Costing

Engineering Concepts

- Chemical Engineering
- Computer Engineering
- Electrical Engineering
- Mechanical Engineering

Research & Development Fundamentals

- Intellectual Property Protection
- Human Subject Protection
- Market/Sales/Life Cycle Analysis
- Research and Design Procedures

Technical Drawings and Schematics

- CAD Drawing Fundamentals
- Geometric Dimensions and Tolerances
- Interpretation of Drawings and Schematics
- Print Reading

Testing/Troubleshooting

- Advanced Fault Finding Skills on Actual Equipment
- Data Analysis and Verification
- Data Interpretation and Corrective Action Implementation
- Statistical Process Control

Workflow Assessment

- Documentation Fault Finding Skills
- Ergonomic Simulation and Assessment of Tasks
- Manufacturing/Processing Concept Planning
- Mixed Model Line Balancing
- Plant Layout Planning and Analysis
 - Plant Design Optimization
 - Walk-Path Assembly Planning

- Work Flow Simulation
- Procedure Analysis and Verification
- Process Simulation Tools e.g. Die Press Lines, Manufacturing Lines
- Resource Planning
- Workloads on Multiple Stations

2. Operations: Set up, operate, monitor, control, and improve technology that supports production and process schedules to meet customer requirements.

Critical Work Functions:

- Develop industrial production/process plans and documentation.
- Support the operation and control of production/process equipment.
- Monitor industrial processes and systems.
- Manage continuous improvement process.
- Manage raw materials/consumables/outputs.
- Perform industrial process applications and operations.

Technical Content Areas:

Industrial Production and Process Basics (including but not limited to a knowledge of)

- Industrial Process (continuous or batch) – processing, transporting or conveying liquids, gases, or goods in pipes or on conveyers (e.g. chemicals, refining, brewing, smelting, utilities, pharmaceutical manufacturing).
 - Balancing
 - Continuous flow
 - Fermentation
 - Filtration
 - Mixing
 - Reaction
 - Recovery
 - Separation - Distillation etc.
- Discrete Manufacturing – the manufacture, assembly, or handling of individual parts (e.g. automotive, heavy equipment, aircraft, aerospace, consumer goods).
 - Assembly
 - Fabrication
 - Finishing
- Hybrid Manufacturing – the packaging or bottling of manufactured goods (e.g. food, beverage packaging, printing, consumer packaging, pharmaceutical packaging).
 - Bottling
 - Finished goods handling and storage
 - Packaging

Production/Process Monitoring

- Calibration
- Process Troubleshooting
- Controlling Process Flow
- Documentation and Reporting
- Environmental Parameters
- Instrumentation

- Performance of Analytical Tests
- Time, Materials, and Costs

Industry-wide Standards (including but not limited to)

- Documentation of Measurement and Control Instruments and Systems (ISA 5)
- Enterprise/Control Integration (ISA 95)
- Manufacturing and Control Systems Security (ISA 99)

Project Management and Execution

- Contracts
- Material and Resource Management
- Operator Training
- Personnel Management Methods
- Project Lifecycle
- Project Management Tools and Techniques

3. Maintenance, Installation, and Repair: Maintain and optimize technology in support of process or manufacturing equipment and systems.

Critical Work Functions:

- Support the installation, customization, or upgrading of equipment.
- Coordinate preventive maintenance to ensure production or industrial process runs smoothly.
- Identify, diagnose, and/or repair equipment problems.
- Communicate with others to ensure maintenance and repairs meet operational needs.
- Maintain hands-on knowledge of equipment operations.
- Maintain equipment, tools, and workstations.

Technical Content Areas:

General Skills

- Basic Disassembly/Assembly Skills
- Installation and Calibration of Instrumentation
- Equipment Troubleshooting
- Installation of Parts for Industrial Equipment
- Schematic Drawings and Control Documents
- Use of Hand Tools
- Machining Skills
 - Drilling
 - Cutting
 - Milling
 - Lathing

Maintenance, Installation, and Repair Skills (including but not limited to a basic knowledge of)

- Electrical/Electronic Systems
- Hydraulic/Pneumatic Systems
- Mechanical Power Transmission Systems
- Mechanical Systems
- Piping Operations

Reliability and Maintainability

- Analysis of Failure Data
- Basic Reliability Models

- Documentation Requirements
- Investigative Techniques

4. Quality Assurance and Continuous Improvement: Ensure product and process meets quality system requirements as defined by customer specifications.

Critical Work Functions:

- Understand and apply basic concepts associated with measuring quality.
- Implement controls to support quality management.
- Use process systems to ensure quality levels are maintained.
- Seek new approaches and techniques to improve quality levels.
- Employ audits and inspections to maintain the quality and continuous improvement process.
- Correct the product and process to meet quality standards.
- Suggest and/or implement continuous improvement actions.
- Support and maintain quality systems.

Technical Content Areas:

Continuous Improvement

- Benchmarking and Best Practice
- Business Process Reengineering
- Data Analysis
- Performance improvement strategies
- Systems Analysis

Corrective and Preventive Actions

- Documentation Creation
- Eliminating Non-Conformities
- Verification and Documentation

Improving Quality

- Problem Solving Tools
- Sampling and Charting
- Statistical Process Control

Quality Assurance

- Industry Standards
- Lean Manufacturing
- Meeting Customer Needs
- Quality Management Systems and Tools

Quality Assurance Audits

- Audit Procedures
- ISO 9000

Statistical Process Control Methods

- Acceptance Sampling
- Capability Analysis
- Factor Analysis
- Inspection/Test/Validation
- Reliability Analysis

5. Health, Safety, Security, and Environment: Equipment, practices, and procedures which promote a healthy, safe, and secure work environment.

Critical Work Functions:

- Understand and follow established personal safety, security, and environmental practices.
- Ensure that equipment is being used safely.
- Comply with local, federal and company health, safety, security, and environmental regulations.
- Identify unsafe or insecure conditions and take corrective action.
- Conduct health, safety, and/or environmental incident and hazard investigations.
- Conduct preventive health, safety, and/or environmental incident and hazard inspections.
- Implement continuous improvement in health, safety, security, and/or environmental practices.

Technical Content Areas:

Continuous Improvement in Health, Safety, Security, and Environment

- Analysis of Health/Safety/Security/Environmental Data
- Identification of Projects and Priorities
- Root Cause Analysis

Environmental Protection/Waste Management

- Chemical Hazard Assessment
- Design to Minimize Environmental Impact

Investigations for Health, Safety, Security, or Environmental Incidences/Hazards

- Developing Corrective Actions
- Documentation of Findings
- Follow-up Investigation
- Insurance (Property)
- Violations Reports to Proper Authorities
- Workers Compensation

Personal Safety

- Understanding and Following Established Safety Practices
- Safety Procedures for the Working Environment
- Use of Personal Protective Equipment and Clothing

Preventive Health, Safety, or Environmental Inspections

- Audit of Records and Documentation
- Conducting Inspections
- Documentation of Inspection Findings
- Emergency Response Preparedness
- Fire Protection and Control

Regulations

- Hazardous Material Communication (HAZCOM)
- Hazardous Material Handling and Disposal (HAZMAT)
- Hazardous Material Information System Labeling and Storage (HMIS)
- Office of Homeland Security System and Physical Security Regulations (US only)
- Regulations Governing Safe Use of Equipment
- Role of the Occupational Safety and Health Administration (OSHA), the Environmental Protection Administration (EPA), or Other Appropriate Regulatory Bodies in the Workplace (US only)
- Trade Compliance Department of Commerce (US only)

Standards

- International Environmental Management Guidance (ISO14001)
- International Information Security Management Guidance (ISO27001)

Safety Procedures

- Confined Spaces
- First Aid or First Response Procedures
- Assessing Material, Equipment, and Fixtures for Hazards
- Lock /Tag Out Practices
- Material Safety Data Sheets (MSDS)
- Response to Shop Emergencies
- Safe Evacuation of Facility
- Safe Moving of Materials
- Safe, Prescribed Operation of Equipment and Tools
- Use, Maintenance, and Inspection of Machine Safeguards
- Use of Safety Equipment

Tier 5—Mechatronics Technical Competencies

1. **Mechatronics: Systems, processes, and standards supporting the application of integrated manufacturing systems.**

Critical Work Functions:

- Understand the necessary steps to plan, execute, and control a mechatronic system.
- Program, calibrate, configure, test, start-up, and operate a mechatronic system.
- Understand mechatronics as the integration of multiple disciplines in industrial processes.
- Identify major application areas for mechatronics.
- Apply mechatronics in various manufacturing, scientific, and technical applications.
- Abide by mechatronics industry codes, standards, and regulations.
- Research and apply emerging and future mechatronics technologies.

Technical Content Areas:

Project Planning, Execution, & Control for a Mechatronic System

- Establish project objectives
- Show linkage between project, technical, and business objectives
- Develop a work plan, schedule, and budget
- Implement a work plan through teamwork and shared responsibility
- Demonstrate knowledge of each of the four areas of mechatronics
- Integrate the four areas of mechatronics to design a system
- Use oral, written and computer communication skills to communicate and document plans, actions, and results
- Design, construct, program, calibrate, configure, test, startup, operate, troubleshoot, and repair a mechatronic system
- Create documentation for a mechatronic system including maintenance procedures
- Complete a project audit to determine best practices and areas for improvement

Four Areas of Mechatronics

- Mechanical Engineering
- Electrical and Electronic Engineering
- Systems and Process Control Engineering
- Computer Science

Codes, Standards, and Regulations (as applicable)

- American National Standards Institute (ANSI)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Society of Automation (ISA)
- International Electro-technical Commission (IEC)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Underwriters Laboratories (UL)
- Other Industry-specific Codes, Standards, and Regulations
- Other International Codes, Standards, and Regulations

2. Mechanical: Principles and application of mechanical components used in manufacturing machinery and systems.

Critical Work Functions:

- Select, install, align, adjust, and repair mechanical components.
- Demonstrate troubleshooting, lubrication, preventive and reactive maintenance procedures for mechanical components.
- Calculate and measure speed, torque, power, pitch, ratio, mechanical efficiency, and motor current in both English and S.I. units for a variety of drive types and configurations.
- Use mechanical drawings and measuring devices to size, check tolerances, and assemble mechanical components.

Technical Content Areas:

Mechanical Components

- Frames
- Fasteners
- Shafts
- Bearings
- Keys
- Couplings
- Bushings
- Sheaves
- Idlers
- Speed Belt Systems – Conventional, Multiple, Wedge, Notched, and Variable
- V-Belt Drive Systems
- Sprockets
- Master Links
- Shafts
- Belts
- Chain Drives – Single Roller, Multiple Strand, and Silent
- Cams
- Followers
- Gears – Spur, Bevel, Helical, Worm, and Right Angle
- Electric Motors

Measurements

- Speed
- Torque
- Power
- Pitch
- Ratio
- Mechanical Efficiency
- Motor Current

Complex Components

- Clutches
- Brakes
- Gear Boxes
- Transmissions

- Ball Screws
- Linear Guides

Lubrication

- Lubricants
- Automatic Lubrication Systems

Pneumatics

- Components
- Schematics Symbols and Diagrams
- Maintenance and Troubleshooting Procedures

Hydraulics

- Components
- Schematic Symbols and Diagrams
- Speed, Flow, and Pressure Control
- Cylinder Synchronization and Regeneration
- Maintenance and Troubleshooting Procedures

Advanced Techniques

- Precision Measurement and Alignment Techniques
- Vibration Analysis
- Central Lubrication
- Conveyor Systems

3. Electrical: Principles and application of electrical systems in a manufacturing environment.

Critical Work Functions:

- Install, document, and maintain electrical components and systems.
- Troubleshoot, inspect, test, and repair electrical components and systems.
- Understand electrical control circuits to include components, and various input devices, output devices.
- Demonstrate knowledge of how to operate the proper electrical measurement instruments and interpret the electrical measurements taken to include voltage, current, and resistance measurements.
- Apply the basics of transformers to include operation, application, sizing, and various types.
- Apply the basics of circuit protection to include fuses, circuit breakers, disconnects, and other protection devices.
- Understand basic electrical control wiring to include electrical prints, electrical panels, wire color coding, and wiring fundamentals.
- Understand and apply knowledge of industrial power distribution including conduit basics, bending, conduit types, conductors, disconnects, overcurrent protection, and power distribution installations.

Technical Content Areas:

AC/DC Electricity

- Circuits
- Measurements – Voltage, Current, and Resistance
- Transformers – Operation, Application, Sizing, and Types
- Circuit Protection
- 3-Phase

Components

- Power Supplies

- Switches (NO and NC)
- Resistors
- Capacitors
- Inductors
- Motors
- Transformers
- Buzzers
- Solenoids
- Lights
- Fuses
- Circuit Breakers
- Rheostats
- 3- Phase Motors
- Motor Starters – Manual, Magnetic, and Reversing
- Motor Control Circuits

Logic Gates

- AND, OR, NOT, NOR and NAND Logic and Memory
- Ladder Diagrams
- Using a Transformer, Switches, Indicators, and Relays

Input and Output Devices

- Motor
- Pneumatic
- Hydraulic
- Combining with Relays, Timers, and Counters

Wiring

- Electrical Prints
- Electrical Panels
- Termination
- Color Coding
- Bundling
- Labeling

Power Distribution

- Conduits
- Bending
- Types
- Conductors
- Disconnects
- Overcurrent Protection
- Installations

Rotating Electrical Motors and Electronic Motor Drives

- DC Motors
- AC Motors
- Starting
- Braking
- DC Electronic Drives

- AC Variable Frequency and Vector Drives

Schematics Symbols

- Electrical Components
- Logic Gates
- Input and Output Devices
- Motors

4. Computers: Hardware, programmable logic controllers, databases, networks, and programming.

Critical Work Functions:

- Install and maintain computer hardware.
- Install, document, and support the integration of computer systems with other systems.
- Operate, troubleshoot, and maintain programmable logic controllers.
- Operate networks for manufacturing systems.
- Apply Manufacturing Operations Management Systems (MOM).

Technical Content Areas:

Installation and Maintenance of PC Hardware

- PC Video and Sound System Configuration
- Hard Drive Maintenance
- Event Viewer
- ROM/BIOS
- MMC and the Task Manager
- Power-On Self Test diagnostics
- Control Heat in the Computer
- SATA and SCSI Drive Interfaces
- Troubleshoot Hardware
- Manage Expansion Buses
- Maintain Laptop Computers
- USB and IEEE-1394 Technologies
- AC Power Quality and Protection
- Utilize TCP/IP
- Internet Connections
- Printers

Programmable Logic Controllers

- Principles, Function, and Operation
- Ladder Logic Programming
- Troubleshooting
- Input and Output Modules
- Visualization
 - Human Factors
 - Alarm Management
 - Machine Level Interfaces
 - Mobile/Portable
 - Operator Interface – Human Machine Interface (HMI)
 - Enterprise Interfaces – Plant-wide Displays, Dashboards

Network Configuration

- Cable (Wire and Fiber Optic) Networks
- Network Component Configuration
- Network Diagnostics
- Network Management
- Wireless Networks

Industrial Digital Networks (including but not limited to)

- Device Level Networks
 - DeviceNet
 - CAN Bus
 - Interbus
- Motion Networks
 - SERCOS
 - Profi-net
- Cell Level Networks
 - MODBus
 - ControlNet
 - Profibus
- Enterprise Level Networks
 - Ethernet – TCP/IP

Cyber Security of the System

- Security Programs, Plans, and Policies
- System and Network Security Techniques
- User Support

Data Management

- Data Documentation
- Data Quality Issues
- Data Security, Viruses, and Malware
- Data Storage and Retrieval
- Database Operations and Maintenance
- Database Software
- Database Structure and Types
- Special Requirements of Real -Time Process Databases

5. Controls: Using hardware and software to maintain consistent operation of processes, unit operations and systems of processes and unit operations.

Critical Work Functions:

- Specify, select, Install, troubleshoot, and maintain devices to measure physical properties.
- Select, specify, install, troubleshoot and maintain devices to manipulate flows, levels, temperatures, energy, positions, speeds, and other variables.
- Specify, select, Install, troubleshoot, and maintain wiring, fiber optics, radio frequency devices or other media to faithfully communicate information from these devices to and from control equipment.
- Specify, select, install, program, tune, troubleshoot and maintain controllers to control process variables, sequences, motion, and systems for single and multiple variable systems.
- Calibrate, troubleshoot, test, repair, and improve sensing, measurement, and actuation devices.
- Prepare, use and modify documentation related to all of the above components and systems.

- Perform all operations in strict regard for personal, product, equipment and facility quality and safety.

Technical Content Areas (including but not limited to):

Basic Process Control

- Control Loop Concepts (Theory may be with or without calculus)
- Processes
 - Flow
 - Level
 - Pressure
 - Temperature
 - Mass / Weight
- Physics (Associated with above)
 - Units—English and Metric
 - Calculations / conversions
- Sensors (As used in packaging machinery and hybrid industries)
 - Transmitters
 - Scaling
 - Analog to Digital Conversion
- Final Control Elements (As used in packaging machinery and hybrid industries)
 - Direct Acting / Reverse Acting
 - Digital to Analog Conversion
- Controllers – Single Loop
 - Manual
 - Proportional
 - Proportional / Integral
 - Proportional / Integral / Derivative
 - Time Proportional
 - PLC Integrated – Software Based
 - Tuning
 - Alarms
 - Modes
 - Resolution / Accuracy / Deadband

Batch Control

- Control Activity Management
- Recipe Management
- Equipment Hierarchy Model
- S-88, S-95

Control System Types

- Distributed Control Systems: Hardware
- Process Automation Controllers: Hardware, Architecture and Communications
- Programmable Logic Controllers: Hardware and Configuration
- Motion Controllers: Single Axis, Multi-axis Coordinated Motion
- Robot Controllers
- SCADA Systems: Hardware, Architecture, and Communications

- OMAC Line Types, Network Types, Controller Types
- Human / Machine Interface: Types (lights, displays, PCs, etc), Architectures (one to one, one to many, many to one, many to many)

Control System Documentation (Both US ISA and JIC standards and European IEC standards)

- Create, Use, and Modify
- Installation Details
- Instrument Lists
- Location Plans (Instrument Location Drawings)
- Logic Diagrams
- Loop Diagrams
- Operating Instructions
- Piping and Instrument Diagrams (P&ID)
- Process Flow Diagram (PFD)
- Specification Forms
- Standards and Regulations
- IEC 61131 Languages (5)
- Elementary Ladder Diagrams

General Purpose Multi-axis Motion Control

Components

- Servo and Stepper Motors
- Encoders and Resolvers
- Motion Controllers
- Motion Networks
- Motion Control System Types
- Motion Control Programming
- International Standards – IEC61131
 - IEC – 61131
 - Instruction List
 - Ladder Diagram
 - Function Block
 - Structured Text
 - Sequential Function Chart
 - PLC Open Motion Function Blocks
 - Other Motion Languages

Functions

- Electronic Caming
- Electronic Gearing
- Electronic Line Shafts
- Electronic Clutching and Braking
- Real and Virtual Axes
- Performance, Tuning, and Troubleshooting
- Application Examples Relevant to Packaging and Hybrid Manufacturing

Robotics

Robot Types

- Articulated
- Delta
- Gantry
- Selective Compliant Assembly Robot Arm (SCARA)

Robot Applications

- Material Handling
- Machine Tending
- Parts Inspection
- Packaging
- Collating
- Picking & Placing
- Cartoning
- Casing
- Palletizing
- Vision Guided
- Interfacing to Other Systems

Programming

- Coordinate Systems
- Teach Pendant Control and Programming
- Robot Command Language Programming
- Variable Names

Systems Integration (Of the following with hardware, software, wiring, troubleshooting)

- PLC's
- Robots
- Motion Controllers
- Programmable Automation Controllers
- PC's
- Bar Code Readers
- RFID Systems
- Vision Systems
- HMI Systems
- Cell Controllers
- Manufacturing Execution Systems (MES)
- Supervisory Control and Data Acquisition Systems SCADA
- Enterprise Resource Planning Systems ERP
- Computer Integrated Manufacturing

6. Industrial Safety: Mechatronic system safety and reliability.

Critical Work Functions:

- Apply safety rules for working with electrical equipment, electrical rotating machinery, mechanical and pneumatic equipment, industrial lubricants, conveyor systems, process systems, and robotics.

- Analyze and determine the need for changes or additional equipment to improve safety.
- Install, validate, periodically check, document, and maintain the safety equipment.
- Apply instrumentation procedures in hazardous areas safely.

Technical Content Areas:

Alarm Management

- Alarm Management System
- HMI Design for Alarm Systems
- Key Components of an Alarm Philosophy
- Performance Metrics for Alarm Systems
- Products of Alarm Rationalization

Reliability

- Common Cause and Its Impact on Reliability
- Concepts of
 - Mean Time to Repair (MTTR)
 - Mean Time to Failure (MTTF)
 - Mean Time Between Failures (MTBF)
- Safe and Dangerous Failure Modes
- Testing Intervals and Its Impact on Availability
- Types of Redundancy and How They Impact Dangerous and Safe Failure Modes

Machine and Process Guarding

- Concepts of Guarding
- Design Considerations
- Laws and Regulations
- Protection Levels
- Risk Analysis

Manufacturing Safety: Process, Discrete, and Hybrid

- Hazard and Risk Analysis including Hazard and Operability (HAZOP) Studies
- Safety Life Cycle
- Allocation of Safety Functions to Protective Layers
- Determination of Safety Integrity Levels
- Safety Requirements Specification
- Design and Engineering Issues and System Technologies
- Installation, Commissioning, and Validation
- Operations and Maintenance

Safe Use and Application of Electrical Apparatus

- Equipment for Use Where Explosive Concentrations of Gas, Vapor, or Dust Might be Present
- Installation Design for Hazardous Areas
- General Purpose Requirements

Safety Controller Equipment

- General Purpose Programmable Logic Controllers (PLCs)
- Safety PLCs
- Simplex, Duplex, and Quad Systems

- System Selection
- Diagnostic Annunciation
- Instrument Selection for Safety Systems
- Probabilistic Modeling of Sensors

Resources Reviewed

Mechatronics Engineering Technology Curriculum

Reading Area Community College

<http://www.racc.edu/Academic/programs/Mechatronics.aspx>

Certificate Program in Packaging Mechatronics

Packaging Machinery Manufacturers Institute

<http://www.pmmi.org/pmmiu/>

Industrial Maintenance Training Center of Pennsylvania

Lancaster County Workforce Investment Board

http://www.lancastercountywib.com/index.php?option=com_content&view=article&id=80:industrial-maintenance-training-center-of-pennsylvania&catid=48:industry-partnerships&Itemid=120

Mechatronic System Program

West Kentucky Community and Technical College

http://www.westkentucky.kctcs.edu/en/Academics/Academic_Divisions/at/Mechatronic_Systems.aspx