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Code of Practice for the Performance of Mechatronic Engineering Work

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ECSA

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DEFINITIONS

In this Code of Practice, any word or expression that is defined in the Act retains that meaning unless the context otherwise dictates.

Act: The Engineering Profession Act, No. 46 of 2000.

Candidate: A person who is registered in terms of Section 19(2)(b) of the Act.

Category of registration: The categories of registration that are provided for in Section 18(1)(a) of the Act (i.e. Professional Engineers, Professional Engineering Technologists, Professional Certificated Engineers, and Professional Engineering Technicians).

Code of Conduct: The Code of Conduct for Registered Persons in terms of the Act.

Council: The Engineering Council of South Africa established in terms of Section 2 of the Act.

Designer: The person undertaking work in relation to any structure, including drawings, calculations, design details, and specifications.

Engineering work: The work identified in terms of Section 26 of the Act and clarified in the Identification of Engineering Work as gazetted.

Enterprise Resource Planning: A type of software that organisations use to manage day-to-day business activities such as accounting, procurement, project management, risk management and compliance, and supply chain operations.

ISA 95: An international standard of the International Society of Automation for developing an automated interface between enterprise and control systems. More commonly referred to as ANSI/ISA-95 or ISA-95, this standard has been developed for global manufacturers.

ISA 95 Level 0: The process.

ISA 95 Level 1: Intelligent devices.

ISA 95 Level 2: Control systems (e.g. programmable logic controllers [PLCs], distributed control systems [DCSs]).

ISA 95 Level 3: Manufacturing operations systems (e.g. Manufacturing Execution System [MES]).

ISA 95 Level 4: Business logistics systems.

Mechatronic Engineer: A Professional Engineer registered in terms of 18(1)(a)(i) of the Act who has specific required qualifications and demonstrated experience in the sub-discipline of Mechatronic Engineering at a complex level.

Mechatronic Engineering Technologist: A Professional Engineering Technologist registered in terms of 18(1)(a)(i) of the Act who has specific required qualifications and demonstrated experience in the sub-discipline of Mechatronic Engineering at a broadly defined level.

Mechatronic Engineering Technician: A Professional Engineering Technician registered in terms of 18(1)(a)(i) of the Act who has specific required qualifications and demonstrated experience in the sub-discipline of Mechatronic Engineering at a well-defined level.

Mechatronic engineering work: Engineering work identified specifically in the discipline of Mechatronic Engineering.

Project Engineer: A Registered Person responsible for the management of the engineering work within a project and its technical aspects.

Registered Person: A person registered with the Engineering Council of South Africa in terms of the Act under one of the categories referred to in sections 18 and 19.

Risk: The effect of uncertainty on the objectives of a design; it is expressed in terms of a combination of the consequences of an event and the likelihood of occurrence.

Specialist work: Mechatronic engineering work that requires training, knowledge, and experience outside the normal education curriculum and beyond that obtained in the general practice of the profession.

The Code: This Code of Practice document.

ABBREVIATIONS

CAD	Computer-aided design
CoP	Code of Practice
DCS	Distributed control system
ECSA	Engineering Council of South Africa
ERP	Enterprise Resource Planning
FAT	Factory Acceptance Test
HMI	Human Machine Interface
ISA 95	ISA 95, ANSI/ISA-95 or ISA-95
MES	Manufacturing Execution System
MOM	Manufacturing Operations Management
NQF	National Quality Framework
PC	Personal computer
PLC	Programmable logic controller
Pr Cert Eng	Professional Certificated Engineer
Pr Eng	Professional Engineer
Pr Tech Eng	Professional Engineering Technologist
Pr Techni Eng	Professional Engineering Technician
QCP	Quality Control Plan
SAT	Site Acceptance Test
SCADA	Supervisory control and data acquisition

1. INTRODUCTION

In terms of Section 27(1) of the Engineering Profession Act, No. 46 of 2000 (the Act), the Council must draw up a Code of Conduct for Registered Persons and may draw up a Code of Practice (CoP) in consultation with the Built Environment, Voluntary Associations, and Registered Persons. Furthermore, the Council is responsible for administering the Code of Conduct and the Code of Practice and ensuring that these codes are available to all members of the public at all reasonable times. The *Overarching Code of Practice for the Performance of Engineering Work* was, therefore, developed and published in the *Government Gazette* ~~dated~~ ~~26 March 2021~~ (Republic of South Africa, 2021b). In this document, this is referred to as the Overarching Code of Practice' for brevity. The Overarching Code of Practice applies to all engineering disciplines.

Respective disciplines and sub-disciplines may develop their own CoPs to complement this Code; this Mechatronic Engineering CoP is an example of this. The Mechatronic Engineering CoP should be read in conjunction with the Overarching Code of Practice; it is not intended to duplicate the requirements thereof.

2. SCOPE AND APPLICATION

Regarding scope and application, the Code

- applies to the discipline of Mechatronic Engineering and its sub-disciplines;
- identifies specific engineering work within the Mechatronic Engineering field;
- classifies mechatronic engineering work according to the complexity of the work and its sensitivity with respect to public safety and environmental stewardship. It must be acknowledged that all mechatronic engineering work involves risk due to the nature of the discipline. ~~of the product (electricity) and the impact of its incorrect control;~~

- sets out the level of competence required by persons registered in any of the categories of registration provided for in Section 18.1 of the Act for the performance of mechatronic engineering work of varying complexity; and
- stipulates requirements for the practice of mechatronic engineering work and provides a statement of recognised good practice.

Where a Code or Act is referenced in this document, the latest version thereof shall apply.

3. PURPOSE

In terms of the Standards Act, No 8 of 2008 (Republic of South Africa, 2008), "a code of practice" is a description of:

a) the terminology to be used.

b) the method to be applied or the procedure to be followed.

c) the material to be used.

any other requirements to be met (e.g. competency) in connection with the execution in an orderly, systematic, practical, efficient, safe and effective manner.

This document defines a set of guidelines that outlines the following accepted practices and standards for the mechatronics engineering discipline:

- Establishes a set of ethical and professional standards that define acceptable conduct, behavior and practices in mechatronics engineering.
- It serves as a benchmark for mechatronic engineering practitioners
- It provides a way to ensure that all members are held accountable to the same standards of conduct. Refer to the ECSA Codes of Conduct.

- It provides a framework for members to adhere to and enables stakeholders, including clients, customers, and the public, to have confidence that the profession or industry is ethically and responsibly managed.

4. LEGAL FRAMEWORK

This CoP shall be read in conjunction with the Engineering Profession Act, No. 46 of 2000, the Code of Conduct, the Occupational Health and Safety Act, No. 85 of 1993 and all other relevant legislation.

5. MECHATRONIC ENGINEERING WORK

5.1 Identification and Classification of Mechatronic Engineering Work

Engineering work can be identified from the gazetted identification of engineering work regulations. In addition, the development of new technologies has created the opportunity for measurement devices, control mechanisms, and automation models to expand beyond the sphere of the already known.

Automation has infiltrated all fields of engineering just as mathematics did many years ago. Specialisations include the following:

- **Mechatronic Devices:** A mechatronics system is composed of mechanical parts, electric devices, electronics components, sensors, and hardware and is operated and controlled under the supervisions and commands that are programmed through suitable software. Manufacturers and resellers of mechatronic devices make a clear distinction between mechatronic devices and its sub-systems including electronics, mechanics, and computing. Any specialist in the afore-mentioned sub-systems can be brought in the design, implementation, and maintenance of a mechatronic device

- **Factory Automation:** Factory automation is the incorporation of automation from end-to-end manufacturing processes. In manufacturing environments, automation often employs technologies such as pneumatic systems, nuclear measurement devices, hydraulic systems, computer systems, and robotic arms to create a more complex system. This leads to the integration of all four levels of the ISA 95 model, from the process to the Enterprise Resource Planning (ERP) system to the actual measuring devices. This is often called the 'smart factory'.

- **Process Automation:** Process automation is the use of advanced technology to automate and streamline industrial continuous processes to increase safety, efficiency, reduce costs, and improve the quality of products. It involves the use of various technologies such as programmable logic controllers (PLCs), sensors, robotics, machine learning, and artificial intelligence. These technologies work together to monitor and control various aspects of the production process, such as temperature, pressure, speed, and flow rate, etc.

A high-level summary of the mechatronics engineering work is presented below:

5.1.1 Characteristics

Mechatronic engineering is multi - disciplinary, involving aspects of electrical engineering, mechanical engineering, chemical engineering, industrial engineering, etc.

Mechatronic engineering work involves, among other things:

- **Advice and Design:** Advising and designing systems which generate, transmit and distribute industrial communication of control - and automation systems

- **Analysis and Design:** Analysis and design solutions to meet specific objectives. Designing, specifying and implementing Control and Instrumentation of plant and processes, and safety integrated systems in plants and factories

- **Investigations and Problem Solving:** Theoretical experimental investigation and problem solving

- **Knowledge Application:** Application of knowledge and engineering technology, based on mathematics, basic sciences, information technology as well as specialist and contextual knowledge
- **Management:** Management of Mechatronic engineering works
- **Research:** Conducting research and developing new or improved theories and methods related to the measurement techniques, control algorithms and automation philosophies of Mechatronic devices, factory automation and process automation.
- **Responsibility and Judgement:** Exercising judgment and taking responsibility for engineering work
- **Safety and Environment:** Addressing the safety and environmental consequences and other impacts of engineering work
- **Standards:** Establishing control standards and procedures to ensure efficient functioning and safety of the Mechatronic device, plant or process
- **Supervision:** Supervising, controlling, developing and monitoring the operation and maintenance of automation systems, control systems and measurement devices

5.1.2 Functions

Mechatronic Engineering consists of any or a combination of various types of work within Mechatronic Devices, Factory Automation, Process Automation, and General Automation. More detail can be found in the Discipline Specific Training Guidelines.

Below is a list of some of the functions and what each one means:

- **Audits**: An audit of an automation system is an important process of reviews that ensures that the system is functioning as intended and that all aspects of the system are compliant with applicable regulations and standards.

- **Build**: The Build of a Mechatronic system involves a series of steps that can be broadly divided into different phases while having a clear understanding of the Mechatronic system's goals and objectives, as well as the organization's needs and constraints:

- **Calibration**: Calibration of an Mechatronic system involves the process of verifying and adjusting the accuracy and performance of the sensors, instruments, and control devices used in the system

- **Commissioning**, on the other hand, is the process of verifying that the implemented product or system meets the client's requirements and is fully operational. It involves testing the functionality, performance, and reliability of the product or system, as well as ensuring that all safety and regulatory standards have been met.

- **Consulting**: Consulting is the professional service in which a person provides advice and expertise to individuals or organizations seeking solutions to automation related problems or challenges based on their specialized knowledge and experience in a particular industry or field. Mechatronic systems could comprise of various sub systems like Electrical, Chemical, Industrial, Mechanical etc., therefore these Consultants need not be specialists within Mechatronic, but could have expertise in other related fields.

- **Development**: Development of a Mechatronic system involves several steps, from identifying the requirements of the system to the eventual commissioning and maintenance of the system.

- **Education**: Education within Mechatronic engineering involves providing individuals with the knowledge and skills needed to design, develop, implement, and maintain automated systems. Mechatronic Education provides the learner with knowledge from a wide range of engineering disciplines such as Electrical and Electronic Engineering, Computer Engineering, Mechanical Engineering, Chemical Engineering and Industrial Engineering, etc.

- **Feasibility studies**: This involves an assessment of the practicality and potential of a proposed Mechatronic project or venture. The purpose of a feasibility study is to determine whether the proposed solution is viable, considering its economic, technical, legal, and operational aspects.

- **Implementation** refers to the process of putting a plan or design into action by developing and building the necessary components, systems, or software. It involves tasks such as coding, testing, integration, and deployment.

- **Installation**: Installation refers to the process of physically setting up and configuring a Mechatronic device, system or equipment in a specific location.

- **Maintenance**: Maintaining a Mechatronic system involves performing routine inspections, preventive maintenance, and corrective maintenance to ensure that the system functions correctly and meets its intended operational objectives.

- **Optimization**: In the context of Mechatronic engineering, optimization typically involves the use of advanced data analytics, machine learning, and artificial intelligence techniques to analyze data and improve system performance via feasibility studies and prototyping.

- **Production and plant operation**: Mechatronic, as per the Identification of Engineering Work, consists of Mechatronic Devices, Process Automation and Factory Automation. By Production and Plant operation, in the Mechatronic context, refers to the management and maintenance of automation systems within industrial plants or factories that produce goods or provide services. It involves overseeing the daily operations of the plant to ensure the smooth and efficient functioning of equipment and processes.

- **Programming**: Programming a Mechatronic system involves creating or configuring software that controls the behavior of the system. This software typically runs on a programmable logic controller (PLC) or a similar control device.

- **Project, budget, and team management**: Mechatronic project management is the process of planning, organizing, and coordinating the resources and activities required to complete a mechatronic project on time, within budget, and to the required quality standards. It involves managing a team of Mechatronic practitioners who are responsible for designing, developing, and implementing Mechatronic systems.

- **Prototyping**: Prototyping Mechatronic systems is the process of developing a working model of a Mechatronic system for testing and validation purposes before moving on to full-scale production. Mechatronic systems combine mechanical, electrical, industrial, and computer engineering principles to create intelligent and automated systems that perform specific functions.
- **Quality Management:** Quality Management Systems cover all aspects of the work and are appropriate to the nature of the work and the size of the organisation. Quality Management Systems are reviewed on a regular basis. Compliance with the system should be audited at least annually. Organisations undertaking engineering work should consider external certification such as ISO 9001 and ISO 14001.
- **Research**: It is a systematic process of investigation that aims to discover new knowledge, insights, and understanding about Mechatronic Devices, Factory - and Process Control algorithms.
- **Retirement / end of life replacement**: Mechatronic equipment and - systems end of life (EOL) refers to the point at which a piece of equipment or technology is no longer functional, repairable, or economically viable to continue using. At this stage, the equipment is typically retired, discarded, or recycled.
- **Risk Management:** Risk and impact mitigation includes probability and impact assessments of all the risks connected to the system or project. Risks include risks to the environment, risks to the project schedule, technical risks, etc. Risk Management systems are reviewed continuously.
- **Specifications**: Mechatronic specifications refer to the technical requirements and performance characteristics of a mechatronic system, which is an integrated system that combines mechanical, electrical, and software components. These specifications

are essential for ensuring that the system meets the desired functional requirements and performance objectives.

- **Testing and commissioning**: Testing and commissioning of Mechatronic devices and systems are critical processes that ensure that a Mechatronic system is functioning properly and meets its performance specifications before it is put into operation.

- **Troubleshooting & debugging**: Mechatronic troubleshooting and debugging are important processes that are used to identify and resolve problems with Mechatronic systems. Debugging mechatronic systems requires a multidisciplinary approach that combines mechanical, electrical, and software engineering. It also requires patience, persistence, and attention to detail. With the right tools and approach, however, it is possible to diagnose and solve problems in mechatronic systems.

5.1.3 Technologies

The Mechatronic Engineering technologies include the following:

- **Analytics:** Databases and data analytics such as Original Equipment Effectiveness (OEE)

- **Artificial intelligence (machine learning):** Employs computers and machines to mimic the problem-solving and decision-making capabilities of the human mind such as those used in machine monitoring and process control in which the technology captures and maintains data during process upsets and makes automatic adjustments with the normal warnings to operators.

- **Augmented reality**: An enhanced, interactive version of a real-world environment achieved through digital visual elements, sounds, and other sensory stimuli via holographic technology. This is also used during training exercises.

- **Autonomous instances:** Autonomous processes, systems and operations are designed, operated and maintained.

- **Big data:** Primarily refers to data sets that are too large or too complex to be dealt with by traditional data-processing application software. Data with many fields offers greater statistical power while data with higher complexity may lead to a higher false discovery rate. As technology develops (as in the case of 5G), the gathering of measurement points and process parameters increases.
- **Biometrics:** The mechatronic professional uses biometrics (body measurements and calculations related to human characteristics) as a form of identification and access control. Biometrics are also used to identify individuals in groups who require updated certification to handle sensitive material in certain environments (e.g. nuclear) and to use products such as Unilab and other laboratory instruments.
- **Computer Aided Designs:** Computer-aided design and simulation software: Mechanical, Mechatronic, Network, Hydraulic, Pneumatic, etc
- **Computerized Control:** Computerized control technologies such as SCADA, HMI, PLC, Industrial PC's, and Embedded controllers (incl. Microcontrollers)
- **Connectivity:** Interconnected network of machines, communication mechanisms and computing power to create or maintain "Smart factories" and "Smart devices."
- **Cyber Security:** Cyber security since companies started using cloud based systems
- **Digital twins:** Using computer-based software to duplicate a mechatronic device, factory, or process that includes a database with the parameters and specifications of every element in the design. This is used when there is a requirement to change one of the parameters of the process and to determine the effect that this change will have on the complete system.
- **Energy Efficiency:** Monitoring and optimizing energy efficiency and renewable systems.
- **Industrial Internet of Things:** Industrial Internet of Things and cloud systems to obtain the data the business requires.

- **Industrial Network Topologies:** Industrial network topologies such as Profinet, Industrial Ethernet, Profibus, Foundation Fieldbus, and others
- **Industrial software engineering:** Applying the principles of software engineering to design, develop, maintain, test, evaluate, and implement computer software from advanced automation algorithms to the automation of the ISA 95 stack.
- **Manufacturing:** Additive and subtractive manufacturing
- **Measuring Devices:** Sensors, transducers, and measurement systems
- **Numerical analysis methods:** Numerical analysis is a branch of mathematics that deals with the development and implementation of numerical algorithms and computational techniques to solve mathematical problems that cannot be solved analytically. It involves the use of mathematical models and algorithms to approximate solutions to complex problems that arise in engineering, science, economics, and other fields.
- **Philosophies:** Optimization of industrial processes, automation and control philosophies
- **Programming:** Programming languages – C#, Python, C, MATLAB, C++, R, etc
- **Robotics:** Involves the conception, design, manufacture, and operation of robots (mechatronic devices). The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways.
- **Safety and Best Practices:** Automation safety and best practices from an automation perspective
- **Safety Systems:** Safety systems design, implementation and maintenance in classified areas
- **Single board computers:** Single board computers (SBCs) are complete computers built on a single circuit board, which integrates all the essential components of a

computer system, such as a processor, memory, storage, and input/output interfaces. These computers are small and compact, making them ideal for embedded systems, small projects, and prototyping.

- **Solutions architecture:** Working mainly in the field of industrial information technology, designing and implementing complex technical solutions during the entire lifecycle of a solution.
- **Vision Systems:** Vision systems refer to a set of technologies that enable machines to perceive and interpret visual information from the environment. These systems are designed to replicate human vision and perception capabilities using advanced hardware and software technologies such as cameras, sensors, image processing algorithms, and machine learning.

5.1.4 Industries

The mechatronics engineering field includes the following industries:

Aerospace: Mechatronic engineering plays a crucial role in the aerospace industry, where it is used to design and develop intelligent systems that optimize the performance, safety, and reliability of aircraft and spacecraft. Mechatronic engineering combines mechanical, electronic, and computer engineering to create innovative solutions that enhance the efficiency and functionality of aerospace systems. Some of the key applications of Mechatronic engineering in the aerospace industry include:

- Flight Control Systems: Mechatronic engineering is used to develop flight control systems that optimize the performance and safety of aircraft. This includes the development of sensors, control algorithms, and actuators that can adjust flight control surfaces to stabilize the aircraft and respond to changes in flight conditions.
- Navigation Systems: Mechatronic engineering is used to develop navigation systems that enable precise navigation of aircraft and spacecraft. This includes the

development of inertial measurement units, GPS systems, and computer vision systems that can provide accurate position and velocity information.

- Propulsion Systems: Mechatronic engineering is used to develop propulsion systems that optimize the performance and efficiency of aircraft and spacecraft. This includes the development of fuel injection systems, turbofan engines, and rocket motors that provide high thrust and precise control.

- Environmental Control Systems: Mechatronic engineering is used to develop environmental control systems that optimize the comfort and safety of passengers and crew. This includes the development of systems for heating, ventilation, and air conditioning, as well as systems for cabin pressurization and air purification.

Overall, Mechatronic engineering is an essential technology in the aerospace industry, driving innovation and creating intelligent systems that optimize the performance, safety, and reliability of aircraft and spacecraft.

- **Agriculture:** Mechatronics has the potential to revolutionize the agriculture industry by increasing efficiency, productivity, and sustainability. Some examples of how mechatronics is being used in agriculture are:

    - Autonomous agricultural machines: Mechatronic systems are used in the development of autonomous agricultural machines such as tractors, harvesters, and drones. These machines can perform tasks such as planting, spraying, and harvesting crops with high accuracy and efficiency.

    - Precision agriculture: Mechatronic systems are used to develop precision agriculture technologies that allow farmers to optimize crop yields and reduce waste. This includes technologies such as GPS-guided equipment, precision irrigation systems, and sensors that monitor soil moisture and nutrient levels.

    - Livestock management: Mechatronic systems are used to develop technologies that improve livestock management, including automated feeding systems, milking machines, and sensors that monitor animal health.

- Climate control systems: Mechatronic systems are used to develop climate control systems for greenhouse farming, which can help to optimize growing conditions and reduce energy consumption.
- Food processing and packaging: Mechatronic systems are used in food processing and packaging to automate tasks such as sorting, grading, and packaging. This can help to reduce labour costs and increase efficiency.

- **Communication:** Mechatronics plays a crucial role in the communication industry, where it is used to design and develop intelligent systems that optimize the performance of communication devices and networks. Mechatronics combines mechanical, electronic, and computer engineering to create innovative solutions that enhance the efficiency, reliability, and security of communication systems. Some of the key applications of mechatronics in the communication industry include:
  - Signal Processing: Mechatronics is used to develop signal processing algorithms that enhance the performance of communication devices and networks. This includes the development of error correction techniques, modulation schemes, and compression algorithms that optimize signal quality and bandwidth. Examples are Profibus, Profinet, Foundation Fieldbus, Ethernet APL, etc.
  - Network Management: Mechatronics is used to design and develop intelligent systems that manage communication networks. This includes the development of network control systems that optimize the routing of data, as well as the development of security systems that protect against cyber threats.
  - Smart Devices: Mechatronics is used to develop smart devices, such as surgery robots, co-bots, autonomous drones, prosthetics, etc. that integrate multiple communication, mechanical and other technologies. This includes the development of sensors, processors, and communication interfaces that enable these devices to communicate with other devices and networks.

- Overall, mechatronics is an essential technology in the communication industry, driving innovation and creating intelligent systems that enhance the efficiency, reliability, and security of communication devices and networks.

- **Construction**: Mechatronics has a growing role in the construction industry, with applications ranging from heavy equipment automation to building control systems. Some examples of how mechatronics is being used in construction include:

  - Heavy equipment automation: Mechatronic systems are used to automate heavy construction equipment, such as bulldozers, excavators, and cranes. These systems can improve safety and increase efficiency by allowing machines to operate autonomously or with minimal human intervention.

  - Building control systems: Mechatronic systems are used to develop building control systems that manage heating, ventilation, and air conditioning (HVAC) systems, lighting, and security systems. These systems can improve energy efficiency and reduce operating costs.

  - Automated material handling: Mechatronic systems are used to automate material handling processes in construction, such as transporting building materials and equipment around the job site. This can improve efficiency and reduce the risk of injuries.

  - Structural health monitoring: Mechatronic systems are used to monitor the health of structures during construction and throughout their lifespan. This includes technologies such as sensors that detect structural damage and control systems that adjust building elements in response to changing conditions.

  - Prefabrication and modular construction: Mechatronic systems are used to automate the prefabrication and assembly of building components, such as walls and floors. This can reduce construction time and costs and improve quality control.

- Overall, mechatronics has the potential to improve safety, efficiency, and sustainability in the construction industry. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for the construction industry.

- **Custody transfer and gauging:** Custody transfer and gauging refers to the transfer of ownership of a product, such as oil or gas, from one party to another. Mechatronics has an important role in custody transfer applications, especially in the measurement and control of the quantity and quality of the product being transferred. Some examples of how mechatronics is used in custody transfer include:

    - **Calibration:** Mechatronic systems are used to calibrate measurement devices, such as flow meters and tank gauges, to ensure that they are providing accurate measurements. This is important in custody transfer as any inaccuracies can result in financial losses for the parties involved.

    - **Control systems:** Mechatronic systems are used to develop control systems that regulate the flow of product during custody transfer. This includes the use of valves and pumps that can be controlled remotely and automated to ensure that the transfer process is efficient and accurate.

    - **Data management:** Mechatronic systems are used to manage and analyse the data generated during custody transfer. This includes data related to flow rates, tank levels, and product quality, which can be used to optimize the transfer process and improve efficiency.

    - **Flow measurement:** Mechatronic systems are used to accurately measure the flow rate of the product being transferred, such as oil or gas. This involves the use of flow meters that can provide precise measurements, even in challenging operating conditions.

    - **Tank gauging:** Mechatronic systems are used to monitor the level and temperature of product in storage tanks. This is important in custody transfer as it ensures that the correct quantity and quality of product is being transferred.

Overall, mechatronics plays a critical role in custody transfer applications by ensuring that the correct quantity and quality of product is being transferred between parties. The use of mechatronic systems can help to improve accuracy, efficiency, and safety during custody transfer processes.

- **Energy (including renewable energy and 'green technologies'):** Mechatronics plays a critical role in the energy sector, from the generation and distribution of electricity to the extraction and refinement of oil and gas. Some examples of how mechatronics is being used in the energy industry include:

  - Renewable energy generation: Mechatronic systems are used in the monitoring and control of renewable energy generation, such as wind turbines and solar panels. These systems help to optimize energy production and improve efficiency.

  - Power generation and distribution: Mechatronic systems are used to control and monitor power generation and distribution networks, including power plants, transmission lines, and substations. This helps to ensure that energy is delivered safely and efficiently to consumers.

  - Oil and gas extraction: Mechatronic systems are used in the extraction of oil and gas, including drilling and production processes. These systems help to improve safety and efficiency in the extraction process.

  - Refining and processing: Mechatronic systems are used in the refining and processing of oil and gas, including control systems that regulate the flow of raw materials and automated equipment that reduces labour costs.

  - Energy storage: Mechatronic systems are used in energy storage systems, such as batteries and capacitors. These systems help to store energy generated from renewable sources and distribute it during times of peak demand.

- Overall, mechatronics is critical to the energy sector, as it helps to improve efficiency, reduce costs, and increase safety in energy production and distribution processes. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for the energy industry.

- **Finance:** Mechatronics, as a field of engineering, are indirectly contributing to the finance sector and their impact is ever increasing. Some areas where mechatronics contributes to the finance sector include:
  - Robotics and automation: Mechatronic systems are used in the development of robots and automation systems that can perform financial tasks, such as managing investment portfolios or executing trades. These systems can help to increase efficiency and reduce errors in financial transactions.
  - Cybersecurity: Mechatronic systems are used to develop cybersecurity solutions that protect financial institutions from cyber-attacks. For example, to create secure data encryption and authentication protocols.
  - Data analysis and processing: Mechatronic systems can be used to develop algorithms and data processing systems that can analyse large volumes of financial data. These systems can help financial institutions make more informed investment decisions and manage risk.
  - Smart banking: Mechatronic systems can be used to develop smart banking solutions, such as mobile banking apps and digital payment systems. These systems can help to improve customer experience and make financial transactions more convenient.
  - Overall, it indirectly contributes to the industry by improving efficiency, security, and data processing capabilities.

- **Food and beverage:** Mechatronics play an important role in the food and beverage industry, where automation and precision are critical to ensuring high-quality products and efficient processes. Some examples of how mechatronics is used in the food and beverage industry:

- Food processing: Mechatronic systems are used in food processing equipment, such as mixers, conveyors, and packaging machines. These systems help to automate the processing of food products and improve efficiency.
- Quality control: Mechatronic systems are used in quality control processes, such as checking the weight, size, and colour of food products. These systems help to ensure that products meet quality standards and reduce waste.
- Packaging and labelling: Mechatronic systems are used in packaging and labelling equipment, such as filling machines and labelling machines. These systems help to automate the packaging and labelling of products and reduce labour costs.
- Agricultural automation: Mechatronic systems are used in agricultural automation, such as the automated planting and harvesting of crops. These systems help to improve efficiency and reduce labour costs in the agricultural sector.
- Food safety: Mechatronic systems are used in food safety processes, such as detecting contaminants and pathogens in food products. These systems help to ensure that food products are safe for consumption and reduce the risk of foodborne illness.
- Overall, mechatronics is critical to the food and beverage industry, as it helps to improve efficiency, reduce labour costs, and ensure product quality and safety. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for the food and beverage industry, especially in the areas of automation and quality control.

- **Fracking and shale gas operations:** Mechatronics plays a crucial role in shale gas operations, which involve extracting natural gas from shale rock formations using hydraulic fracturing or "fracking". Some examples of how mechatronics is used in shale gas operations include:

  - Drilling equipment: Mechatronic systems are used in the drilling equipment used to extract shale gas, such as the drill bit and rig. These systems help to automate the drilling process and improve efficiency.

  - Hydraulic fracturing: Mechatronic systems are used in the hydraulic fracturing equipment, such as the pumps and valves, that inject a high-pressure mixture of water, sand, and chemicals into the shale rock to release the trapped natural gas. These systems help to control the pressure and flow rate of the fracturing fluid and optimize the extraction process.

  - Control systems: Mechatronic systems are used to develop control systems that monitor and regulate the various processes involved in shale gas operations, such as drilling, fracturing, and well production. These systems help to improve safety and efficiency and reduce the risk of accidents.

  - Data analysis: Mechatronic systems are used to analyze and process data from sensors and other monitoring equipment used in shale gas operations. This data can help operators make informed decisions about the extraction process and optimize production.

  - Overall, mechatronics is critical to the shale gas industry, as it helps to improve efficiency, reduce costs, and ensure safety in the extraction process. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for shale gas operations, especially in the areas of automation and data analysis.

- **Healthcare:** Mechatronics has a growing role in the healthcare industry, where it is used to develop innovative medical devices, improve patient care, and enhance the efficiency of healthcare operations. Some examples of how mechatronics is used in healthcare include:

- Medical devices: Mechatronic systems are used in the development of medical devices such as surgical robots, drug delivery systems, and prosthetics. These systems help to automate medical procedures and improve precision, accuracy, and safety.
- Diagnostic equipment: Mechatronic systems are used in diagnostic equipment such as MRI machines, CT scanners, and ultrasound machines. These systems help to produce high-quality images and improve diagnostic accuracy.
- Rehabilitation: Mechatronic systems are used in rehabilitation equipment such as exoskeletons and prosthetics. These systems help to improve mobility and quality of life for patients with mobility impairments.
- Assistive technology: Mechatronic systems are used in assistive technology such as hearing aids, cochlear implants, and vision aids. These systems help to improve the quality of life for patients with sensory impairments.
- Healthcare operations: Mechatronic systems are used in healthcare operations such as medication dispensing systems and patient monitoring systems. These systems help to automate healthcare processes and improve efficiency.
- Overall, mechatronics is critical to the healthcare industry, as it helps to improve patient care, enhance medical procedures, and increase efficiency. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for healthcare, especially in the areas of medical device development and assistive technology.

- **Manufacturing (e.g. automotive, chemicals, metals, textiles, electronics):** Mechatronics plays a critical role in manufacturing, where it is used to automate production processes, improve efficiency, and enhance product quality. Here are some examples of how mechatronics is used in manufacturing:

- Robotics: Mechatronic systems are used in industrial robotics, which are used to automate a variety of manufacturing tasks such as welding, assembly, and packaging. These systems help to increase production efficiency and reduce labour costs.
- Automated production lines: Mechatronic systems are used in automated production lines, which are used to manufacture products such as cars, electronics, and household appliances. These systems help to increase production efficiency and reduce errors and waste.
- Quality control: Mechatronic systems are used in quality control processes, such as inspecting products for defects and ensuring product consistency. These systems help to improve product quality and reduce waste.
- Material handling: Mechatronic systems are used in material handling equipment, such as conveyors and robots, which are used to transport raw materials and finished products throughout the manufacturing process. These systems help to improve efficiency and reduce labour costs.
- Process control: Mechatronic systems are used in process control equipment, such as sensors and control systems, which are used to monitor and regulate manufacturing processes such as temperature, pressure, and speed. These systems help to improve efficiency and ensure product quality.
- Overall, mechatronics is critical to the manufacturing industry, as it helps to automate processes, increase efficiency, and improve product quality. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for manufacturing, especially in the areas of automation and process control.

- **Maritime:** Mechatronics plays an important role in the maritime industry, where it is used to develop innovative solutions for ships, ports, and offshore structures. Some examples of how mechatronics is used in maritime applications are:

- Navigation and control systems: Mechatronic systems are used to develop advanced navigation and control systems for ships and other vessels. These systems help to improve safety, efficiency, and environmental performance.
- Autonomous vessels: Mechatronic systems are used to develop autonomous vessels, which are capable of operating without human intervention. These systems help to improve efficiency, reduce costs, and increase safety.
- Cargo handling: Mechatronic systems are used in cargo handling equipment, such as cranes and hoists, which are used to load and unload cargo from ships. These systems help to improve efficiency and reduce labour costs.
- Offshore structures: Mechatronic systems are used to develop offshore structures, such as oil rigs and wind turbines, which are used in the extraction of natural resources and the generation of renewable energy. These systems help to improve efficiency and reduce costs.
- Port automation: Mechatronic systems are used to automate port operations, such as container handling and logistics. These systems help to improve efficiency and reduce labour costs.
- Overall, mechatronics is critical to the maritime industry, as it helps to improve safety, efficiency, and environmental performance. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for maritime applications, especially in the areas of navigation, automation, and cargo handling.

- **Mining:** Mechatronics has a growing role in the mining industry, where it is used to improve safety, increase efficiency, and reduce costs. Here are some examples of how mechatronics is used in mining:
  - Autonomous vehicles: Mechatronic systems are used to develop autonomous vehicles, such as trucks and loaders, which are used to transport materials and

equipment. These systems help to improve safety, reduce costs, and increase efficiency.

- Mining equipment: Mechatronic systems are used in mining equipment, such as drilling machines and excavators. These systems help to improve precision and accuracy, reduce wear and tear, and increase efficiency.
- Safety systems: Mechatronic systems are used to develop safety systems, such as collision avoidance and proximity detection systems, which help to reduce accidents and injuries.
- Data analysis: Mechatronic systems are used to analyse data from mining operations, such as equipment performance and environmental conditions. This data helps to improve efficiency, reduce costs, and optimize mining processes.
- Environmental monitoring: Mechatronic systems are used to monitor environmental conditions in and around mining operations, such as air quality and water levels. These systems help to reduce the impact of mining on the environment and improve sustainability.
- Overall, mechatronics is critical to the mining industry, as it helps to improve safety, increase efficiency, and reduce costs. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for mining applications, especially in the areas of automation, safety, and data analysis.

- **Personal services:** Mechatronics is also being used in personal services to enhance customer experience, automate processes, and improve efficiency. Here are some examples of how mechatronics is used in personal services:
  - Robotics in hospitality: Mechatronic systems are used to develop robots for hotels and restaurants, which can perform tasks such as cleaning, room

service, and food preparation. These systems help to reduce labour costs and improve customer experience.

- Automated vending machines: Mechatronic systems are used in vending machines, which can dispense a variety of products such as food, drinks, and personal care items. These systems help to improve convenience and reduce labour costs.
- Personalized customer service: Mechatronic systems are used to develop systems that can personalize customer service, such as chatbots and virtual assistants. These systems can provide customized recommendations, answer customer questions, and help to improve the overall customer experience.
- Wearable devices: Mechatronic systems are used to develop wearable devices, such as fitness trackers and smart watches, which can monitor health and wellness metrics. These systems help to improve personal health and wellness and provide valuable data for healthcare providers.
- Smart home systems: Mechatronic systems are used to develop smart home systems, which can automate tasks such as temperature control, lighting, and security. These systems help to improve convenience, reduce energy costs, and enhance home security.
- Overall, mechatronics is playing an increasingly important role in personal services, as it helps to improve customer experience, automate processes, and increase efficiency. As technology continues to evolve, we can expect to see more mechatronic solutions being developed for personal services applications, especially in the areas of robotics, personalization, and wearable devices.

- **Petrochemical (e.g. gas to liquids):** Mechatronics plays an important role in the petrochemical industry. Petrochemical plants use a variety of complex equipment and systems that require advanced automation and control technologies to operate efficiently and safely. Mechatronics, which integrates mechanical engineering, electrical engineering, and computer science, provides the necessary tools and techniques to design, build, and operate these systems.

- One important application of mechatronics in the petrochemical industry is in process control systems. These systems use sensors, actuators, and control algorithms to monitor and adjust the various parameters of the production process, such as temperature, pressure, flow rate, and composition. Mechatronics technologies such as PLCs (Programmable Logic Controllers), SCADA (Supervisory Control and Data Acquisition), and DCS (Distributed Control Systems) are commonly used to automate these processes.

- Another important application of mechatronics in the petrochemical industry is in the design and control of robotic systems. Robots can be used to perform a variety of tasks in the production process, including inspection, maintenance, and material handling. Mechatronics technologies such as machine vision, motion control, and artificial intelligence are commonly used to design and control these systems.

- In addition, mechatronics can also be used in the design and control of safety systems in the petrochemical industry. These systems use sensors, alarms, and interlocks to detect and respond to potentially hazardous conditions, such as leaks, fires, and explosions. Mechatronics technologies such as fault diagnosis, fault-tolerant control, and safety-critical systems engineering are commonly used to design and control these systems.

- Overall, mechatronics plays a critical role in the petrochemical industry, helping to ensure efficient and safe production processes and reducing the risk of accidents and downtime.

- **Pipeline operation and monitoring**: Mechatronics is an important technology in pipeline operations. Pipeline systems require sophisticated control and monitoring systems to ensure efficient and safe operation, as well as to detect and respond to any potential problems. Mechatronics provides the necessary tools and techniques to design, build, and operate these systems.

- An important application of mechatronics in pipeline operations is in the design and control of pipeline monitoring systems. These systems use sensors and data analysis techniques to monitor various parameters of the pipeline, such as flow rate, pressure, temperature, and corrosion. Mechatronics technologies such as wireless sensor networks, distributed data processing, and data visualization are commonly used to design and control these systems.
- Another important application of mechatronics in pipeline operations is in the design and control of pipeline inspection systems. These systems use robots, drones, and other autonomous vehicles to inspect the pipeline for damage, leaks, or other issues. Mechatronics technologies such as machine vision, motion control, and artificial intelligence are commonly used to design and control these systems.
- In addition, mechatronics is used in the design and control of pipeline maintenance systems. These systems use robots and other automated equipment to perform maintenance tasks, such as cleaning, coating, and repairing the pipeline. Mechatronics technologies such as motion control, force feedback, and haptic interfaces are commonly used to design and control these systems.
- Overall, mechatronics plays a critical role in pipeline operations, helping to ensure efficient and safe transportation of oil, gas, and other products. Mechatronics technologies are used to design and control various systems, including monitoring, inspection, and maintenance systems, to ensure the pipeline operates safely and effectively.

- **Power generation automation:** Mechatronics plays an important role in power generation automation, which involves the use of advanced automation and control technologies to monitor and manage the generation, transmission, and distribution of electrical power. Mechatronics, which integrates mechanical engineering, electrical engineering, and computer science, provides the necessary tools and techniques to design, build, and operate these systems.

- One important application of mechatronics in power generation automation is in the design and control of power generation systems. Power generation systems include various types of generators, such as gas turbines, steam turbines, and hydroelectric generators. Mechatronics technologies such as PLCs, SCADA, and DCS are commonly used to automate these systems and ensure efficient and safe operation.

- Another important application of mechatronics in power generation automation is in the design and control of power transmission and distribution systems. These systems include power transformers, switchgear, and other equipment used to transmit and distribute electrical power. Mechatronics technologies such as real-time monitoring, fault diagnosis, and condition-based maintenance are commonly used to design and control these systems and ensure reliable and efficient power transmission and distribution.

- In addition, mechatronics can also be used in the design and control of renewable energy systems, such as wind turbines and solar panels. These systems require advanced control and monitoring systems to ensure efficient and reliable operation. Mechatronics technologies such as power electronics, energy storage systems, and smart grids are commonly used to design and control these systems and ensure efficient and sustainable power generation.

- Overall, mechatronics plays a critical role in power generation automation, helping to ensure reliable, efficient, and sustainable power generation, transmission, and distribution. Mechatronics technologies are used to design and control various systems, including power generation, transmission, and distribution systems, as well as renewable energy systems.

- **Refinery automation:** Mechatronics is a crucial technology in the automation of refinery operations. Refineries are complex facilities that require advanced automation and control technologies to operate safely, efficiently, and cost-effectively. Mechatronics, which integrates mechanical engineering, electrical engineering, and computer science, provides the necessary tools and techniques to design, build, and operate these systems.

  - One important application of mechatronics in refinery automation is in the design and control of process control systems. These systems use sensors, actuators, and control algorithms to monitor and adjust various parameters of the refining process, such as temperature, pressure, flow rate, and composition. Mechatronics technologies such as PLCs, SCADA, and DCS are commonly used to automate these systems and ensure safe and efficient operation.

  - Another important application of mechatronics in refinery automation is in the design and control of safety systems. Refineries operate with hazardous chemicals and processes, and safety systems are critical to protect personnel, equipment, and the environment from harm. Mechatronics technologies such as fault diagnosis, fault-tolerant control, and safety-critical systems engineering are commonly used to design and control these systems and ensure safe and reliable operation.

  - In addition, mechatronics can also be used in the design and control of maintenance and inspection systems. These systems use robots and other automated equipment to perform maintenance tasks, such as cleaning, inspecting, and repairing equipment. Mechatronics technologies such as machine vision, motion control, and haptic interfaces are commonly used to design and control these systems and ensure efficient and effective maintenance.

  - Overall, mechatronics plays a critical role in refinery automation, helping to ensure safe, efficient, and cost-effective refining operations. Mechatronics technologies are used to design and control various systems, including process control, safety, and maintenance systems, to ensure reliable and efficient refining operations.

- **Security:** Mechatronics plays a crucial role in the security industry, where it is used to design and develop intelligent systems that enhance the safety, security, and reliability of security operations. Mechatronics combines mechanical, electronic, and computer engineering to create innovative solutions that improve the effectiveness of security systems. Some of the key applications of mechatronics in the security industry include:
    - Surveillance Systems: Mechatronics is used to develop surveillance systems that can monitor and analyse security footage in real-time. This includes the development of high-resolution cameras, image processing algorithms, and automated tracking systems that can detect and track suspicious activity.
    - Access Control Systems: Mechatronics is used to develop access control systems that restrict access to secure areas. This includes the development of biometric authentication systems, RFID systems, and facial recognition systems that can accurately identify authorized personnel.
    - Alarm Systems: Mechatronics is used to develop alarm systems that can detect and respond to security threats. This includes the development of motion sensors, glass break sensors, and perimeter sensors that can trigger alarms and alert security personnel.
    - Robot Security Systems: Mechatronics is used to develop robotic security systems that can patrol and monitor large areas. This includes the development of autonomous robots that can navigate complex environments, detect and respond to threats, and communicate with human security personnel.
    - Overall, mechatronics is an essential technology in the security industry, driving innovation and creating intelligent systems that enhance the safety, security, and reliability of security operations.

- **Supply chain (warehousing and distribution):** Mechatronics has a significant role in supply chain management, which involves the planning, coordination, and execution of goods and services from the point of origin to the point of consumption. Mechatronics technologies are used to design and control various systems, including transportation, logistics, and warehousing systems, to ensure efficient and effective supply chain operations.
  - One important application of mechatronics in the supply chain is in the design and control of automated transportation systems. These systems use autonomous vehicles, such as drones and self-driving trucks, to transport goods
- **Terminal automation and storage:** Mechatronics plays a significant role in terminal automation, which is the process of managing and controlling the movement of containers, vehicles, and other equipment within a port or terminal. Mechatronics combines mechanical, electronic, and computer engineering to design and develop automated systems that can efficiently manage the various tasks involved in terminal automation. Some of the key applications of mechatronics in terminal automation include:
  - Automated Container Handling: Mechatronics is used to design and develop automated systems that can handle containers without human intervention. These systems can move, stack, and transport containers within the terminal, improving efficiency and reducing the risk of accidents.
  - Vehicle Tracking and Management: Mechatronics is used to design and develop systems that can track the movement of vehicles within the terminal. This helps in managing traffic flow and reducing congestion within the terminal.
  - Safety and Security Systems: Mechatronics is used to design and develop safety and security systems that can monitor the movement of containers and vehicles within the terminal. These systems can detect potential safety hazards and alert terminal operators to take necessary action.

- Data Analytics: Mechatronics is used to develop data analytics systems that can analyze the vast amounts of data generated by terminal automation systems. This helps terminal operators to identify trends, improve efficiency, and optimize operations.

- Overall, mechatronics plays a crucial role in terminal automation, enabling the development of automated systems that can improve efficiency, safety, and security within terminals.

- **Transport:** Mechatronics plays a crucial role in the transportation industry, where it is used to design and develop intelligent systems that can improve the efficiency, safety, and comfort of transportation vehicles. Mechatronics combines mechanical, electronic, and computer engineering to create innovative solutions that optimize the performance of transportation systems. Some of the key applications of mechatronics in transport include:

  - Autonomous Vehicles: Mechatronics is used to develop the sensors, controllers, and software required for autonomous vehicles. These systems use sensors, such as lidar and radar, to detect and interpret the environment, allowing the vehicle to make decisions and navigate without human intervention.

  - Electric Vehicles: Mechatronics is used to design and develop the powertrain systems for electric vehicles. These systems include electric motors, battery management systems, and power electronics that optimize the performance and efficiency of electric vehicles.

  - Advanced Driver Assistance Systems: Mechatronics is used to develop advanced driver assistance systems (ADAS) that can improve the safety of transportation vehicles. These systems include features such as lane departure warning, automatic emergency braking, and adaptive cruise control, which help to prevent accidents and reduce the risk of injury.

- Connected Vehicles: Mechatronics is used to develop systems that allow vehicles to communicate with each other and with the infrastructure. These systems can improve traffic flow, reduce congestion, and enhance safety by providing real-time information about road conditions, traffic patterns, and weather.

- Overall, mechatronics is an essential technology in the transport industry, driving innovation and creating intelligent systems that improve the efficiency, safety, and comfort of transportation vehicles.

- **Wholesale and retail trade:** Mechatronics plays an increasingly important role in the wholesale and retail industries, where it is used to design and develop automated systems that improve efficiency, accuracy, and customer experience. Mechatronics combines mechanical, electronic, and computer engineering to create innovative solutions that optimize the performance of wholesale and retail operations. Some of the key applications of mechatronics in wholesale and retail include:

    - Warehouse Automation: Mechatronics is used to develop automated systems that can manage and optimize warehouse operations. This includes the development of automated storage and retrieval systems, conveyor systems, and robotic picking systems that can handle large volumes of products efficiently.

    - Point-of-Sale Systems: Mechatronics is used to design and develop point-of-sale systems that optimize the checkout process. This includes the development of barcode scanners, cash registers, and payment terminals that improve the speed and accuracy of transactions.

    - Inventory Management: Mechatronics is used to develop inventory management systems that optimize the tracking and control of stock. This includes the development of automated stock management systems, as well as the use of sensors and data analytics to monitor stock levels and demand.

- Customer Experience: Mechatronics is used to develop systems that enhance the customer experience in wholesale and retail operations. This includes the development of interactive displays, smart fitting rooms, and personalized recommendations based on customer data.
- Overall, mechatronics is an essential technology in the wholesale and retail industries, driving innovation and creating automated systems that improve efficiency, accuracy, and customer experience.

6 MECHATRONIC ENGINEERING COMPETENCIES

6.1 Work within area of competency

Depending on their tertiary education, training, experience, category of registration, and recognition by the profession, mechatronic engineering practitioners function at one of two distinct levels as indicated in Table 1 below.

Mechatronic Engineering Practitioners shall perform duties within the professional category limitations specified in the Identification of Engineering Work (*Government Gazette,* No. 44333) (Republic of South Africa, 2021a) as updated from time to time.

Table 1: Competence levels of mechatronic engineering practice

Level	Designation	Typical characteristic of practitioner	Risk associated with work done
1	Candidate	Person who has a tertiary education qualification in Mechatronic Engineering and works under supervision and mentorship of person(s) who meet the requirements stated in document **R-04-T&M-GUIDE-PC/SC**	Low risk
2	Registered professional in Mechatronic Engineering	Person registered with the Engineering Council of South Africa as a Professional Engineer, Professional Engineering Technologist, or Professional Engineering Technician in the Mechatronic Engineering discipline as stated in document **R-05-TRONIC-PN/PT/PE**	Medium to High risk

It is accepted that because of the varying nature of mechatronic engineering services, rigid boundaries are not applicable, but the experienced mechatronic engineering practitioner can recognise the appropriate competence level that is required.

6.2 Category of work for competency

In addition to the complexity of the work, the level of the practitioner assuming responsibility for the mechatronics work is also linked to the category of risk defined in Table 2 below.

Table 2: Risk Categories

Category of mechatronic work	Level of risk	Illustrative nature of mechatronic engineering work
1	Low	Simple mechatronic engineering solutions with low mechatronic safety and serviceability performance requirements where the analysis requires a simple application of design rules or direct interpretation of reference guidelines
2	Medium	Mechatronic engineering solutions with moderate to challenging mechatronic safety and serviceability performance requirements where the design approach involves either a process of • reasoning and calculation based on the application of standards, or • reasoning, calculation, and consideration of accepted analytical principles based on a combination of deductions from available information, research and data, appropriate testing, and service experience
3	High	Mechatronic engineering solutions with challenging mechatronic safety and serviceability performance requirements that require specialist skills, recognised expertise, and knowledge beyond that required for Category 2

6.3 Overlaps

a) Persons registered in a particular discipline may perform Engineering Work in a different discipline if their knowledge, training, experience and applicable qualifications specifically render them competent to perform such work and subject to the expressed permission of ECSA.

b) Persons registered as professionals under a Professions' Act other than the Engineering Profession Act may not perform Engineering Work even if their knowledge, training, experience and applicable qualifications specifically render them competent to perform such work without the expressed permission of ECSA.

c) Mechatronic engineering has a bearing on many activities of industry and even commerce and hence there may be no clearly defined boundaries. In such cases the experienced and appropriately registered engineer would recognize the competencies required and hence act appropriately.

The Overarching Code of Practice for Engineering Work must be consulted when any overlap occurs.

6.4 Levels of Competency

The levels of competence required for Mechatronic engineering practitioners and a career path to achieving these levels are indicated in Figure 1.

Levels of Competency depends on the qualification and the experience of the mechatronic professional as defined by the Engineering Council of South Africa (ECSA) regarding the Professional Engineering Technician, the Professional Engineering Technologist, and the Professional Engineer.

Candidates work under the supervision of registered professionals until they are able to register with the ECSA in the relevant category.

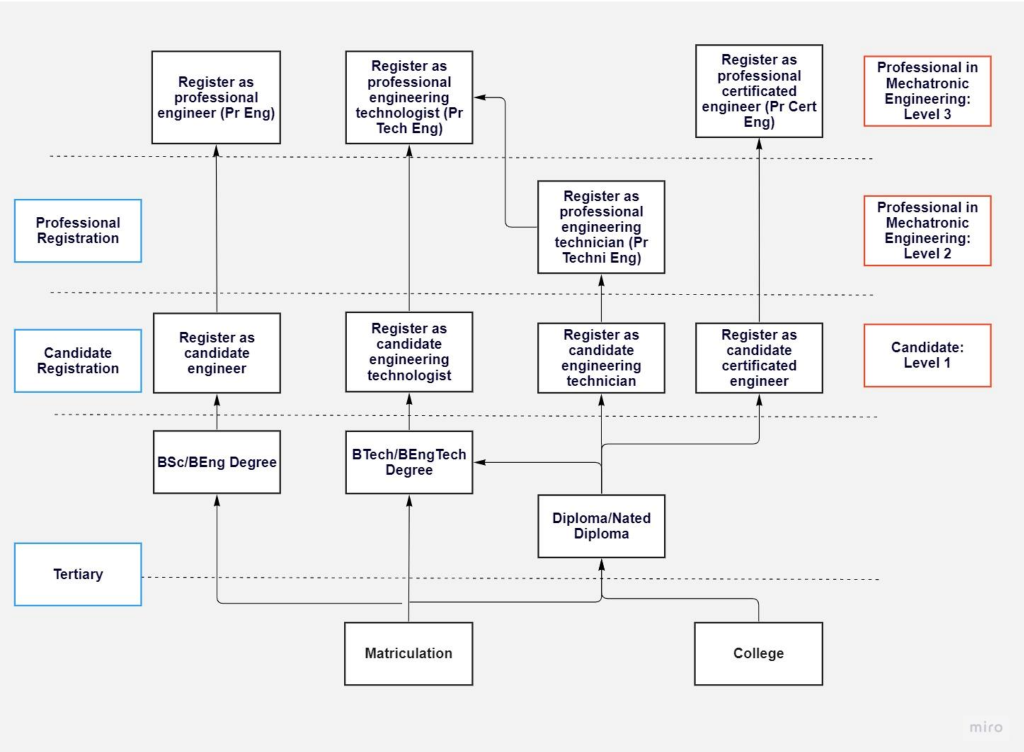

Figure 1: Levels of competence required to practise Mechatronic Engineering

6.5 Competencies required for identified critical mechatronic engineering systems

The following mechatronic engineering systems are designated as critical mechatronic engineering systems, that is, those that may have high risk and high consequences for the public, the environment, and health:

- Control systems within dangerous environments: these include nuclear reactor control and protection, anti-surge controllers on oxygen compressors, and the like.
- Control systems of mechatronic devices that interact with humans

- Measurement and control devices in dangerous classified areas such as Ex classification
- Confidential or restricted data of the system process and/or stores
- The system is essential for the continuous safe operation of the people, process, or device.
- The system provides a critical or campus-wide service.
- It is very difficult to detect the event before it happens or escalates.
- The incident will have serious consequences.
- Risk Analysis must consider the sensitivity of the data that is processed and stored by the system and the likelihood and impact of potential threat events.

6.6 Ethical requirements

Mechatronic engineering practitioners shall execute mechatronic engineering work in accordance with the provisions of the ECSA's Code of Conduct. They shall conduct work within their area of competence.

6.7 Development of Knowledge, Skill, and Expertise

Mechatronic engineering practitioners shall continue to develop knowledge, skill, and expertise in accordance with ECSA's Standard for Continuing Professional Development (see document **ECPD-01-STA**).

7 MECHATRONIC ENGINEERING GOOD PRACTICE

Mechatronic engineering is a complex field that requires a combination of mechanical, electronic, and computer engineering knowledge to design and develop advanced systems. Some examples of good practices for mechatronic engineering include:

7.1 Behavioural Characteristics

Mechatronic engineering practitioners require a specific skillset due to its multi disciplinary nature. Mechatronic engineering practitioners require a combination of technical skills, collaboration, and continuous learning to design, develop and maintain advanced systems that meet the needs of various industries. It also means knowing when to ask specialists in various fields such as electrical, mechanical, programming, etc. for assistance when required.

7.1.2 Systems thinking

- Mechatronic engineers must have a systems thinking approach that considers the entire system, including its interactions and dependencies, rather than just individual components. This approach ensures that the system is optimized for performance, reliability, and cost-effectiveness

7.1.3 Multi-disciplinary collaboration

- Mechatronic practitioners must work collaboratively with other engineers, technicians, and stakeholders from different fields. Collaboration helps to integrate various subsystems, identify issues, and optimize the system design.

7.1.4 Continuous learning

- Mechatronic engineers must stay up to date with the latest advances in mechatronic engineering, including new technologies, tools, and practices. Continuous learning helps to improve skills and knowledge and facilitates innovation and creativity.

7.2 Problem analysis

Defining a Mechatronic problem involves identifying a specific issue or challenge that requires a mechatronic solution. Some steps that can help define a Mechatronic problem include:

- **Identify the problem**: The first step is to identify the problem or challenge that needs to be addressed. This may involve observing a system or process and identifying inefficiencies, limitations, or safety concerns. A Formal Problem Analysis methodology is recommended.
- **Define the Objective**: Once the problem has been identified, it's important to define the objective of the Mechatronic solution. This may include improving system performance, increasing efficiency, reducing costs, or enhancing safety.
- **Identify the Constraints**: The next step is to identify any constraints or limitations that may impact the design of the mechatronic solution. This may include budget constraints, space limitations, safety regulations, or environmental constraints.
- **Analyse the System**: It's important to analyse the system or process that the mechatronic solution will be integrated into. This may include identifying subsystems, components, and interfaces that need to be considered.
- **Brainstorm Solutions**: Brainstorming potential solutions is an important step in defining a Mechatronic problem. This involves considering various design approaches and evaluating their feasibility, effectiveness, and potential benefits and drawbacks.
- **Refine the Problem Definition**: Once potential solutions have been identified, it may be necessary to refine the problem definition to ensure that the mechatronic solution addresses the identified problem and meets the defined objectives and constraints.

Overall, defining a Mechatronic problem involves a systematic approach to identifying a specific issue or challenge, defining the objectives and constraints of the solution, and evaluating potential design approaches to ensure that the solution meets the intended requirements and objectives.

7.3 Design

Overall, mechatronic engineering requires a combination of technical skills, collaboration, and continuous learning to design and develop advanced systems that meet the needs of various industries.

Model-based design tools such as MATLAB/Simulink, LabVIEW etc., including digital twins are often used to simulate, analyse, and optimize the performance of the system before building a physical prototype. This approach saves time and resources and ensures that the system meets the design specifications.

Standardizing practices as far as possible ensures that system designs are consistent, reliable, and interoperable. Standardization includes using common hardware and software interfaces, following coding standards, and adhering to safety and environmental regulations.

Good practice in mechatronic engineering design includes the following:

7.3.2 Design Requirements

The design of mechatronic engineering solutions shall be performed by, or under the direction, control and supervision of a Registered Person who needs to accept responsibility for the design. The full scope of the client requirements shall be agreed and documented as part of the design package and alternative solutions considered.

The selected solution shall clearly demonstrate meeting of client requirements in a safe, effective, and cost-efficient way to ensure adherence to reliability, availability, maintainability and safety requirements.

Mechatronic design requirements are essential for ensuring that the mechatronic system meets the intended functionality and performance goals. Some good practices for mechatronic design requirements include:

Mechatronic design requirements are essential for ensuring that the mechatronic system meets the intended functionality and performance goals. Some good practices for Mechatronic design requirements include:

- **Clearly defined objectives**: Clearly define the objectives and requirements of the mechatronic system before starting the design process. This includes, among others, specifying the system's intended use, functionality, performance goals, environmental constraints, and safety requirements.
- **Systematic Analysis:** Conduct a systematic analysis of the Mechatronic system, including its functional requirements, interfaces, subsystems, and interactions. This analysis helps to identify potential problems, risks, and design constraints that may impact the system's performance and reliability.
- **Modular Design:** Use a modular design approach that breaks down the Mechatronic system into smaller, more manageable subsystems. This approach simplifies the process of determining the design requirements, promotes reusability, and facilitates maintenance and repair once the solution is presented.
- **Testing and Verification:** Develop a testing and verification plan that ensures the Mechatronic system meets the design requirements and objectives. This plan should include unit testing, integration testing, and system testing to verify the performance, reliability, and safety of the system.
- **Documentation and Traceability:** Document all aspects of the Mechatronic system design, including requirements, design specifications, test plans, and verification results. This documentation facilitates traceability and ensures that the design meets the intended requirements and objectives.

Overall, following these good practices for Mechatronic design requirements can help ensure the successful design and development of Mechatronic systems that meet the intended functionality and performance goals.

7.3.3 Design Process

The engineering design process is a series of steps that is followed by most engineering disciplines. For Mechatronics engineering practitioners, many of the functions identified in paragraph Functions, needs to be followed by mechatronic engineering practitioners in creating functional products and processes and in solving problems. It usually consists of inputs from various other engineering disciplines due to the multi-disciplinary nature of Mechatronic engineering.

These steps could include the following and is normally preceded by the Determine Design Requirements phase:

These steps include the following:

- **Requirements Analysis:** The first stage involves defining the system requirements and objectives, including the intended functionality, performance goals, and constraints. This stage may also involve identifying potential risks and challenges associated with the system.

- **Conceptual Design:** In this stage, engineers develop initial design concepts and evaluate different approaches to meet the requirements and objectives identified in the previous stage. This stage may involve brainstorming, prototyping, and feasibility studies.

- **Detailed Design:** Once a concept has been chosen, engineers begin the detailed design process. This stage includes designing individual subsystems, selecting components and materials, and specifying interfaces and control systems.

- **Implementation**: During this stage, engineers build and test prototypes of the mechatronic system. This may involve manufacturing and assembling the various subsystems, testing individual components, and verifying that the system meets the design requirements and objectives.

- **Testing and Validation:** After the prototype has been built, engineers conduct extensive testing to validate the design and ensure that it meets the performance goals and safety requirements. This stage may involve unit testing, integration testing, and system testing.
- **Deployment and Maintenance**: Once the design has been validated and tested, the system can be deployed in the field. Engineers may also provide ongoing maintenance and support to ensure that the system continues to perform reliably and effectively over time.
- **Design Calculations and Simulations:** Formal calculations shall be prepared for all Mechatronic engineering solutions. Calculations shall be recorded on calculation sheets or downloaded from a computer simulation tool to form part of a design report. For manual analysis, all analysis calculations shall be shown together with the results of the analysis, e.g. response times, alarm and trip levels, etc.
- **Documentation and Traceability:** Document all aspects of the Mechatronic system design, including requirements, design specifications, test plans, and verification results. This documentation facilitates traceability and ensures that the design meets the intended requirements and objectives.

Overall, the mechatronics design process is often iterative and may involve several cycles of design, testing, and refinement before a final product is produced. Effective collaboration and communication among multidisciplinary teams is critical to ensure that the design meets the intended requirements and objectives.

7.3.4 Design Calculations

Mechatronics is a multi-disciplinary field. Therefore, Mechatronics design involves the integration of mechanical, electrical, and software components to create complex systems.

The design calculations for mechatronics systems vary depending on the specific application and system requirements, such as:

- **Coding:** Coding refers to the process of writing code, which is a set of instructions that a computer can understand and execute. It involves writing the code in a specific programming language, which is a formal language designed to communicate with computers. The code is typically written using a text editor or an integrated development environment (IDE).

- **Component Sizing Calculations:** Component sizing calculations involve determining the size and capacity of various components in the mechatronics system. These calculations include motor size, battery capacity, and capacitor size.

- **Control System Calculations:** Calculations for control systems in mechatronics involve determining the process characteristics such as response times, pressures, flows, temperatures, alarms and absolute limits. This is used to design trip systems, alarm levels, equipment safety specifications in hazardous environments. It is also used to determine the required sensor resolutions, control algorithms, signal bandwidth, and controller bandwidth. These calculations help to ensure the accuracy and precision of the mechatronics system and the process being controlled.

- **Cost Analysis:** Cost analysis is a critical aspect of mechatronics design. It involves determining the total cost of the system, including materials, labour, and maintenance. Cost analysis helps to ensure that the mechatronics system is cost-effective and meets the requirements of the application.

- **Force and Torque Calculations:** Force and torque calculations are critical in designing the mechanical components of a mechatronics system. These calculations help determine the required motor size and gear ratios for a particular application.

- **Heat Transfer Calculations:** Heat transfer calculations are critical in mechatronics design to ensure that the system operates within safe temperature limits. These calculations help to determine the cooling requirements for the system.

- **Kinematic Calculations:** Kinematic calculations help to determine the position, velocity, and acceleration of mechanical components in a mechatronics system. These calculations are used in motion control systems, robotic arms, and other applications.

- **Programming:** This is a broader concept of coding that includes coding as well as other activities such as problem-solving, design, testing, and debugging. Programming involves not only writing code but also understanding the problem that the code is trying to solve, designing a solution that meets the requirements, and testing the code to ensure that it works as intended.

- **Power Calculations:** Power calculations are used to determine the amount of power required to drive a mechatronics system. This calculation includes the power required to move mechanical components, power needed for electronic components, and power required for control systems.

These are just some of the common calculations used in mechatronics design. The specific calculations required for a particular application will depend on the system requirements and design specifications and may involve the input from various other specialization disciplines such as Mechanical, Electrical, Chemical, Computer and Industrial engineering.

Use technologies, engineering knowledge, or systematic approaches to develop new and improved techniques and methods to design or optimise mechatronics systems:

- Develop commissioning scope of work and input into the planning process.

- Develop and improve commissioning procedures.

- Develop and improve quality and maintenance plans.

Formal calculations shall be prepared for all mechatronic engineering solutions. Calculations shall be recorded on calculation sheets or downloaded from a computer simulation tool to form part of a design report. For manual analysis, all analysis calculations shall be shown together with the results of the analysis (e.g., response times, alarm, and trip levels). Systems engineering plays a critical role in this regard.

Sufficient information and data must be indicated on calculations and simulations for audit, investigation, checking etc. purposes.

7.3.5 Simulations

Mechatronic simulations are often computer-based models that simulate the behaviour and performance of Mechatronic systems. Mechatronic simulations are used to test and validate designs, analyse system behaviour, optimize performance, and reduce development costs and time. Simulations are also used in the control of industrial plant processes by using say water to test control systems rather than the actual product.

There are several simulation methodologies that are used to model and analyse mechatronic systems. Here are a few examples:

- **Discrete event simulation:** In this methodology, the events that occur in a system are modelled as discrete events occurring at specific points in time. The simulation tracks the flow of system entities through different stages and processes, and the impact of various events on the system's overall behaviour.
- **System dynamics:** System dynamics models describe the behaviour of complex systems by representing the interactions between different components of the system.
- **Monte Carlo simulation:** This methodology involves using random sampling techniques to model the behaviour of a system.
- **Continuous simulation:** Continuous simulations involve modelling the behaviour of a system over a continuous time period, using differential equations to describe the behaviour of system components.
- **Multi-domain system simulation (MDS):** MDS is a methodology used to model and analyse complex systems that are composed of multiple interconnected domains or subsystems. These domains can be physical systems such as mechanical, electrical,

hydraulic, thermal, and others or non-physical systems such as control and signal processing systems.

7.3.6 Quality and sign-Off of designs

- **Quality of design**: The designer shall take all reasonable steps for quality control, to generally ascertain that the Mechatronic engineering solutions implemented or installed on site comply with the design. It is recommended that a quality control plan (QCP) be instituted by the contractor and approved by the designer; this QCP must conform not only to all the requirements of the design but also to the requirements of the codes and/or relevant specifications that the contractor is expected to satisfy.

- **Design Testing:** Any tests required for the purpose of mechatronic systems design (including Prototype, Functional Tests, or Factory Acceptance Test [FAT] where required) shall be stated and communicated to the contractor and/or client for execution. Test results and other relevant data shall be filed with the calculations or overall design package.

- **Quality Concerns:** Should the designer not be satisfied with the arrangements regarding quality control instituted on site, this shall be raised with the contract manager (if work is external) and, where applicable and necessary, with the client.

- **Design documentation approval:** Approval of designs means that the design is complete, is fit for the intended purpose, and complies with the required standards, specifications and legislation in terms of safe operation, loading adequacy, and fault level withstand. Approval of a design drawing/illustrative model means that the drawing/model is complete, that the drawing/model conforms to the design, and that the mechatronic content of the drawing/model is correct.

- **Sign - Off**: The steps shall be signed off by the contractor as having been correctly completed and overseen by the engineer for important issues. Should the quality control on site remain unsatisfactory, the designer shall not sign off any work.

- **Certification:** The designer, if satisfied that the Mechatronic engineering solutions have been implemented and installed in accordance with the requirements of the design, shall certify that the Mechatronic engineering solutions have been commissioned according to relevant standards and a certification of completed works issued

- **Maintenance**: Maintenance requirements shall be defined and clarified by designer and client. This refers to both preventative and corrective maintenance types. As per Regulations issued in terms of the Occupational Health and Safety Act, an obligation is placed on all plant owners to ensure that the Mechatronic engineering solutions are safe for continued use and are inspected regularly.

- **Quality Control Post Design**: This quality control is not limited to the actual site only, but also needs to include any manufacture / pre-assembly and assembly work completed.

7.3.7 Design drawings:

Design drawings shall show all information required for implementation, application, and/or installation and shall be checked prior to issuing. Appropriate requirements (temperatures, pressures, intrinsic safety requirements use cases, etc.) shall be included.

General information or data to be indicated includes the following:

- Name of the responsible Mechatronic engineering practitioner.

- Name and address of the consulting firm responsible for the mechatronic design.

- All symbols and units shall be consistent with those used in the CoP or standard that is employed.

7.3.8 Retention Period

Irrespective of client requirements regarding the retention of design information, all design drawings, calculations, computer print-outs, test results, and test certificates, etc. shall be retained in a form that is easily retrievable.

In South Africa, the retention period for mechatronic design records depends on the type of record and the industry in which the record was created.

For example, according to the South African Companies Act of 2008, companies are required to keep proper accounting records for a period of seven years. These records would include financial documents related to the mechatronic design process such as invoices, receipts, and bank statements.

In addition, certain industries in South Africa may have specific regulations that dictate the retention period for mechatronic design records. For example, the National Health Act of 2003 requires health facilities to maintain patient records for a period of six years after the patient's last visit.

It's important to note that these retention periods are minimum requirements, and in some cases, it may be advisable to retain records for a longer period. For example, if a mechatronic design project is related to a legal matter, it may be necessary to keep records for a longer period to comply with legal requirements.

In summary, the retention period for mechatronic design records in South Africa varies depending on the type of record and industry in which it was created. However, companies are generally required to keep proper accounting records for a period of seven years.

Should there be a need to review the approved documents, the designer shall adhere to the implemented process to ensure that all changes are done, accepted, and communicated to all relevant parties in good time.

7.3.9 Obligations to society

Any mechatronic engineering work carried out shall consider the ECSA Code of Conduct, the PAIA Act, the POPI Act and other relevant legislation.

The execution of engineering work shall adhere to legislation and recognised standards, which include the following Acts:

- Engineering Profession Act, No. 46 of 2000
- Occupational Health and Safety Act, No. 85 of 1993
- National Building Regulations and Building Standards Act, No. 103 of 1977
- National Environmental Management Act, No. 107 of 1998
- Employment Equity Act, No. 55 of 1998
- Basic Conditions of Employment Act, No. 7 of 2018

All engineering work must be carried out according to the norms of the profession.

Such norms are generally represented by national and international standards, industry standards, codes of practice, and best practice guidelines. A mechatronic engineering practitioner shall assess any deviation from the recognised standards or work beyond the scope of such standards in terms of sound engineering and scientific fundamentals.

7.4 System maintenance

Maintaining mechatronic systems is an important aspect of ensuring their continued operation and performance. The requirements for maintaining mechatronic designs may vary depending on the specific application and equipment involved

Some common requirements include:

- **Regular inspections:** Mechatronic designs should be inspected on a regular basis to ensure that all components are functioning properly and to identify any potential issues before they become major problems.
- **Preventive maintenance:** Preventive maintenance involves performing routine maintenance tasks, such as replacing worn components or lubricating moving parts, to prevent equipment failure and prolong the life of the mechatronic design.
- **Calibration:** Mechatronic designs often include sensors and other measurement devices that require calibration to ensure accurate and reliable operation. Calibration should be performed on a regular basis according to the manufacturer's guidelines.
- **Documentation:** Proper documentation is essential for maintaining mechatronic designs. Documentation should include design drawings, schematics, and operating manuals, as well as records of inspections, maintenance, and repairs.
- **Training:** Personnel responsible for maintaining mechatronic designs should receive proper training to ensure that they have the knowledge and skills needed to perform maintenance tasks safely and effectively.
- **Upgrades and modifications:** Mechatronic designs may need to be upgraded or modified over time to improve performance or address changing operational requirements. These upgrades and modifications should be carefully planned and executed to ensure that they do not compromise the safety or reliability of the equipment.

Overall, the requirements for maintaining mechatronic designs are multifaceted and require careful planning and execution to ensure the continued operation and performance of the equipment.

8 INTERPRETATION AND COMPLIANCE

8.1 Interpretation

The word ‘shall’ indicates a peremptory provision.

The word ‘should’ indicates a provision directive or informative in character requiring substantial compliance.

The word ‘they’ in its singular form or its derivative forms ‘their/them’ are pronouns used for gender neutrality.

8.2 Compliance

Failure to comply with a peremptory provision of this CoP constitutes improper conduct in terms of the Act.

Failure to comply with a directive or informative provision of this CoP may constitute improper conduct in terms of the Act if its consequences are significant.

9 ADMINISTRATION

The Council shall be responsible for the Administration of this CoP, including its publication, maintenance, and distribution.

The Council shall ensure that the CoP and all amendments thereto are available on the ECSA website and upon request, shall provide a copy thereof.

The Council shall take all reasonable steps to introduce the CoP to the general public.

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REVISION HISTORY

Revision Number	Revision Date	Revision Details	Approved By
Rev. 0 Draft A	26 September 2022	New document	RPS & Working Group
Rev. 0 Draft B	07 October 2023	Steering Committee Draft	Steering Committee
Rev. 0 Draft C	07 October 2022	Broader Consultation Draft	Working Group
Rev. 0 Draft D	05 December 2022	Incorporation of comments received from Broader Consultation	Working Group
Rev. 0 Draft E	26 January 2023	Steering Committee	Steering Committee
Rev. 0 Draft F	21 April 2023	Steering Committee recommendation to submit to RPSC for approval	Steering Committee
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The Code of Practice for

Performance of Mechatronics Engineering Work

Revision 0 dated 02 June 2023 and consisting of 64 pages reviewed for adequacy by the Business Unit Manager and approved by the Executive: Research, Policy, and Standards (**RPS**).

.... 25 March 2024

Business Unit Manager Date

.... 2024/04/05

Executive: **RPS** Date

This definitive version of this policy is available on our website.

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Structural Engineering Code of Practice

Geotechnical Engineering Code of Practice