MECHATRONICS I

UNDERSTAND SYSTEMS. BUILD AGENCY. SHAPE WHAT COMES NEXT.

Grace Hopper Center | VDOE Course 8554 | 36 Weeks | 2026–2027
Grades 10–12 | Recommended Prerequisites: IED and additional engineering coursework

Course Overview

Mechatronics is the design and study of systems in which mechanical structures, electronics, sensors, software, and people must work together. Robots are one visible example, but the same integration shapes automated laboratories, bionic prosthetics, semiconductor fabrication, advanced manufacturing, data-center infrastructure, and space exploration.

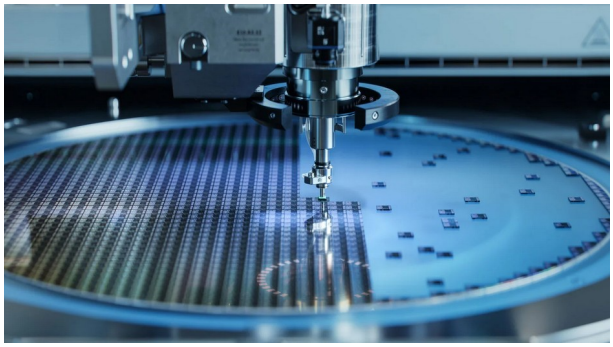
As sensing, computation, and AI become more capable, these technologies can appear increasingly opaque and complex. As Clarke's Third Law states: "Any sufficiently advanced technology is indistinguishable from magic." The physical world, however, still imposes constraints.

Physics still applies. Power must be delivered carefully. Parts must fit. Signals must be trustworthy. Systems must survive heat, wear, and uncertainty. Code that appears correct—or an AI agent that sounds confident—cannot replace human judgment, quality control, and the curiosity to keep exploring.

This course helps us move from using technology to understanding and shaping it. We build foundations in electronics, programming, fabrication, sensing, and control, then combine them into increasingly complex and open-ended systems. Along the way, we learn to trace problems across mechanical, electrical, and computational boundaries rather than treating each part in isolation.

More importantly, mechatronics gives us practice working in a world where the tools, technologies, and problems will continue to change. We learn how to approach unfamiliar systems, test ideas against evidence, persist when solutions are not fully apparent, and work alongside people whose strengths differ from our own.

Where We Are—and Where We Are Going



Modern electronics begin with semiconductors
Today's chips are built through lithography, deposition, etching, doping, and precision measurement, then combined into processors, memory, sensors, communications, and power electronics.

NEXT SYSTEM: Chiplets joined through advanced packaging, 3D-stacked memory, optical connections built beside processors, new material systems, and fabrication equipment that uses real-time data to control processes and catch defects.



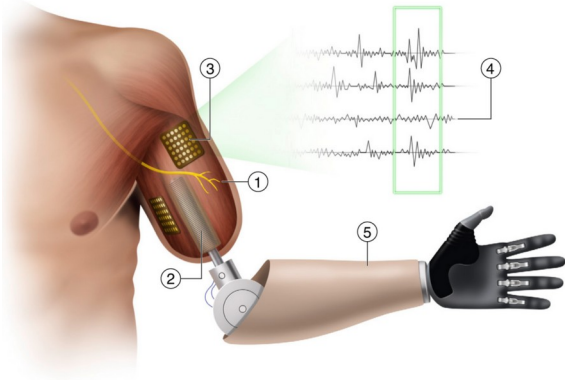
Computing has a physical body
AI and cloud services run on semiconductor processors and memory, high-speed networks, enormous power systems, cooling equipment, backup infrastructure, and the people who maintain them.

NEXT SYSTEM: Chips connected by light, cooling brought directly to processors, on-site generation and storage, grid-responsive data centers, and infrastructure that uses less water and energy while putting less strain on surrounding communities.



Robots are moving beyond fixed tasks
Industrial robots excel at repeated, carefully programmed work; collaborative and mobile robots are beginning to add vision, force sensing, and safer operation in shared spaces.

READ THE SYSTEM: Tactile hands that handle unfamiliar objects, robots taught through demonstration or spoken instructions, mobile machines that navigate and manipulate, and AI systems that transfer learning across many different tasks.



Machines are becoming extensions of the body
Advanced prosthetics use muscle signals, microprocessors, powered joints, and custom interfaces to translate a person's movement or intent into useful mechanical action.

READ THE SYSTEM: Interfaces that read signals directly from muscles and nerves, artificial touch and position sense, two-way communication with the nervous system, and devices that increasingly close the loop between intention, movement, and sensation.

How the Course Is Structured

Students build from prior experience toward deeper technical work, greater independence, and increasingly complex systems.

Each quarter follows a consistent learning cycle and assessment process while the complexity, uncertainty, and responsibility increase across the year. Students enter Mechatronics with different strengths and interests, but share a willingness to work hard, stay focused, contribute to a team, and struggle productively with problems that do not have immediate answers.

Quarter 1 begins with an intensive electromechanical boot camp that strengthens foundational skills through building, measurement, troubleshooting, and repeated practice. From there, students move into increasingly demanding work involving precise motion, system integration, autonomous operation, and one of the central challenges of modern robotics: managing uncertainty in the real world.

This is a course for students who want to dive deeply into technical work alongside teammates who are equally invested. That might include students drawn to mathematics, robotics, computation, biotechnology,

fabrication, assistive technology, or autonomous laboratories. The common thread is not a particular future career—it is the willingness to concentrate, experiment, troubleshoot, revise, and stay with difficult problems long enough to make meaningful progress.

As the year progresses, the teacher provides less of the path and students take greater responsibility for determining how systems should be built, tested, improved, and defended. By Quarter 4, teams draw on months of intensive labs, technical challenges, successes, and failures to pursue a culminating project that asks them to move beyond following directions and move the needle themselves.

Year at a Glance

Quarter	Focus	Culminating Evidence
Q1	Electronics foundations — safe prototyping, measurement, semiconductor switching, timing, PWM, and motor control	Safety exam; OSHA 10 coursework; verified PWM motor-control evidence; selected Q1 technical portfolio evidence; individual concept test and reflection
Q2	Precision motion and automation — ESP32 position control, servo/stepper motion, homing, calibration, sequencing, and repeatability	SCARA-style precision automation workcell; calibration and repeatability evidence; individual concept test/technical defense; brief industry connection
Q3	Autonomous systems integration — line sensing, mechanical transitions, state-based control, environmental measurement, telemetry, and reliability	Autonomous field mission; repeated mission/reliability evidence; individual concept test/technical defense; selected technical portfolio evidence
Q4	Team-directed capstone — a student-run design studio in teams of three to four	Public demonstration; capstone defense; completed technical portfolio; individual contribution evidence

Stage 1 — Desired Results

Transfer Goals

By the end of the course, students can independently:

- Work safely within a professional lab environment and complete required workplace safety credentials.
- Learn unfamiliar technical skills efficiently and apply them to meaningful problems.

- Design, build, test, and improve mechatronic systems in response to criteria and constraints.
- Apply foundational knowledge of electronics, programming, fabrication, materials, sensing, and control in unfamiliar situations, including selecting appropriate actuators and control strategies.
- Persist through ambiguous technical problems—individually and as teams—using evidence from data rather than guesswork to determine and apply next steps.
- Communicate technical reasoning through appropriate vocabulary, schematics, test data, meeting notes, and defensible design decisions.

Enduring Understandings

Students will understand that:

- Technology is created by people and reflects human decisions, assumptions, priorities, incentives, and tradeoffs—including which problems are selected, who benefits, cost, repairability, access, and resource use.
- Complex systems become understandable when they are separated into component functions and interfaces.
- Small electrical signals are used to control much larger forces, movements, and processes. Different actuators are suited to different motion and control problems.
- Reliable and precise systems emerge through homing, calibration, repeated prototyping, measurement, failure analysis, and feedback-driven revision.
- Autonomous systems depend on trustworthy sensing, calibrated thresholds, clear state transitions, and reliable interfaces; success requires the system to recognize changing conditions and respond without human control.
- Effective teamwork requires both shared responsibility and visible individual competence.
- AI can accelerate learning and technical work, but its outputs must be tested, interpreted, and defended by people.
- Human judgment remains necessary when systems produce uncertain, incomplete, or consequential information.

Essential Questions

Questions we revisit as systems become more complex

How should we design and build technology that responds to genuine needs?	**What can we do when the solution to a technical problem is not immediately apparent?**
How do individual components become integrated systems?	**What does it mean to be a good teammate?**
How can we learn unfamiliar tools and ideas without waiting for step-by-step instructions?	**How do actuator choice, geometry, sensing, and control determine whether motion is precise and repeatable?**
How can AI extend what we can solve without replacing our intuition and judgment?	**How does an autonomous system recognize changing conditions and decide what should happen next?**

How Students Participate in a Better Future

Increasingly powerful technologies make human judgment more important, not less. A better technological future depends on people who can understand the systems around them, question their outputs, and take responsibility for how those systems affect others.

- **Learn the fundamentals deeply enough to question technology.** Recognize when a confident answer, diagram, code sample, or AI suggestion does not match physical reality.
- **Replace confidence with evidence.** Measure, test, compare, and repeat rather than accepting the first explanation or successful trial.
- **Keep people at the center of design.** Begin with genuine human needs rather than adding technology simply because it is available.
- **Ask what should be built, not only what can be built.** Consider safety, reliability, repairability, accessibility, energy, materials, and unintended consequences.

- **Remain responsible for decisions.** AI and automation can assist with research, coding, analysis, and troubleshooting, but people must still evaluate the evidence and decide when a system can be trusted.

- **Become a producer, not merely a consumer.** Understanding how technological systems work gives us greater agency to question them, improve them, and help determine how they shape our communities and future.

Stage 2 — Evidence of Learning

Major performance tasks

Quarter 1 — Electronics Foundations	Quarter 2 — Precision Automation Workcell
Students repeatedly use a Predict → Simulate → Build → Measure → Explain → Troubleshoot cycle to develop deep understanding of breadboards, measurement, Ohm's law, KCL/KVL, electric power, AC/DC context, diodes, TIP122 switching, NO/NC motor-control wiring, 555 timing, PWM, flyback protection, and DC motor control. Tinkercad Circuit supports prediction and experimentation; measurements from real circuits provide the evidence.	Teams assemble and commission a teacher-designed SCARA-style workcell as a platform for learning position control and repeatability. Q1 DC motor control provides a useful contrast to the servo and stepper actuation used in Q2. Students command servo positions, home a stepper axis, establish safe motion limits, calibrate the workcell, sequence a fixed pick-and-place task, and use repeated trials to identify and reduce error. The mechanism is provided so students can focus on wiring, programming, calibration, testing, and troubleshooting rather than designing a robot arm from scratch. Formal inverse kinematics and broad actuator surveys are not required. Geometry is learned through HOME, joint position, reach, clearance, and work envelope. Individual checkouts and a concept test/technical defense establish accountability. Industry context is embedded through a brief connection between precision positioning and an authentic automated system.

Quarter 3 — Autonomous Field Mission	Quarter 4 — Team-Directed Capstone
Teams integrate a common robot into one fully autonomous field mission. The robot follows a black line, enters a standardized zipline interface, traverses and exits the zipline, reacquires the line, approaches a destination, stops at a specified distance using an ultrasonic sensor, deploys a temperature probe into a standardized medium, waits for a valid reading, retracts the probe, and transmits the measurement to a student computer. Once the mission begins, no human control is permitted. Depth comes from integration rather than from designing every subsystem from scratch. A common chassis/drivetrain, starter line-following code, standardized zipline hardware, known sensors, a simple servo probe mechanism, and the Bluetooth communication framework are provided. Students own calibration, threshold selection, state transitions, wiring and mechanical interfaces, troubleshooting, and reliability. The goal is not one lucky run; repeated trials must show that the subsystems function as one system.	Teams of three to four propose, prototype, test, and publicly defend a mechatronic system reflecting their interests and technical strengths. Quarter 4 begins with rapid proposal validation and risk reduction so teams can test the most consequential assumptions before committing to a final design. Teams then develop subsystems, integrate a minimum viable system, measure performance, revise from evidence, and prepare a public technical defense. A capstone may extend prior work or begin anew; an extension must demonstrate unmistakable technical advancement through new capability, deeper integration, stronger reliability, or substantially improved performance.

Collaboration and Individual Evidence

Students are encouraged to discuss approaches, compare results, and troubleshoot with classmates. Individual labs, prelabs, checkouts, and submitted evidence, however, must represent each student's own work and understanding; watching or copying another student's work does not demonstrate competence. When a peer contributes a useful idea or solution, students acknowledge that contribution. Team projects share a system goal, but individual understanding remains visible through named responsibilities, checkouts, documentation, technical defenses, and contribution evidence.

Competency Alignment and Recurring Evidence

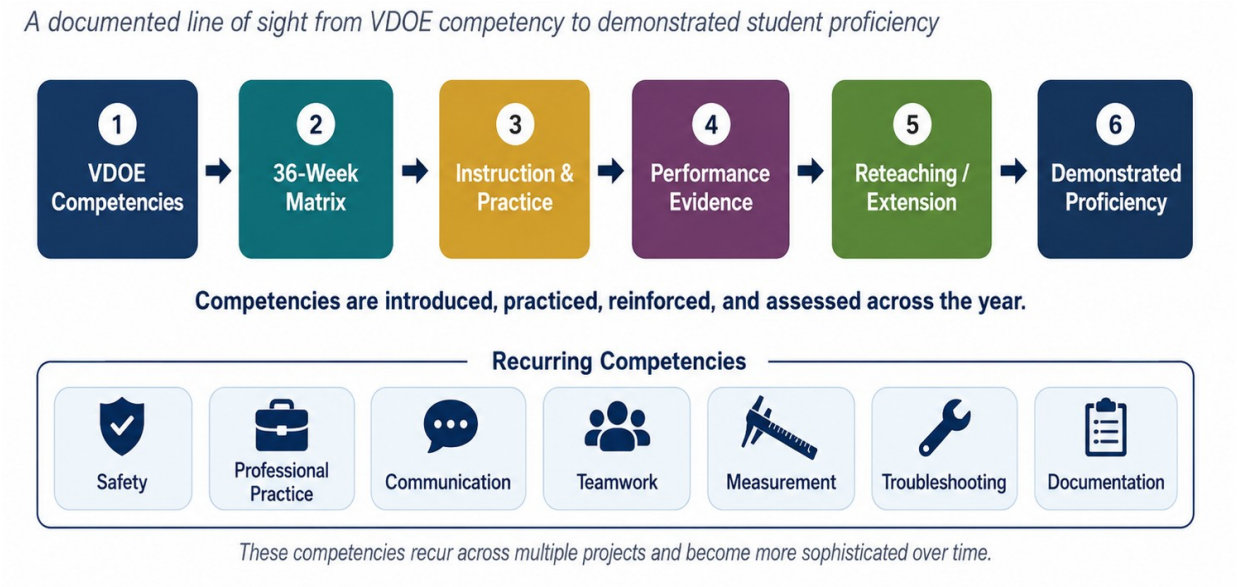
The framework is paired with the 36-week VDOE competency matrix

The course framework is paired with a 36-week VDOE competency matrix that maps all 97 required competencies to the weeks in which they are introduced, practiced, reinforced, or

assessed. Together, the framework and matrix connect state requirements to instruction, student performance, and evidence of learning.

Competencies are intentionally spiraled through authentic technical work rather than treated as isolated checklist items. Personal, interpersonal, and professional competencies recur through creativity and innovation; critical thinking and problem solving; initiative, integrity, and work ethic; conflict resolution; listening and speaking; respect for diversity; customer-service habits; collaboration; big-picture thinking; career- and life-management; continuous learning and adaptability; time and resource management; information literacy and security; maintaining working knowledge of current IT systems; occupational technologies, tools, and machines; job-specific mathematics; professionalism; technical reading and writing; and workplace safety. Evidence comes from lab practice, meeting notes, checkouts, technical writing, peer and stakeholder feedback, project records, and individual defenses.

State-required content that does not need a stand-alone unit is embedded deliberately: Q1 includes OSHA/safety procedures, circuit laws, electric power, AC/DC context, motor-control diagrams, and NO/NC switching; Q2 includes programmable-control systems, precision measurement, tools and fasteners, mechanical drawings/specifications, manufacturing foundations, and advanced-manufacturing context; Q3 reinforces sensors, Internet safety, information security, and acceptable-use practices; Q4 addresses materials, planning, management, finance, workforce and labor issues, community issues, health/safety/environmental issues, and stakeholder considerations. Career, student-organization, and work-based-learning competencies form a yearlong professional-practice strand: students learn the purpose and goals of the applicable CTE student organization; compare the benefits and responsibilities of student membership with later professional and civic organization membership; demonstrate leadership through participation in an appropriate student-organization meeting, program, or project; identify types of WBL opportunities; and, when a WBL experience is available and appropriate, participate in it, reflect on lessons learned, and connect it to related career opportunities. Major projects still integrate multiple competencies at once, while the matrix supports pacing, reteaching, differentiation, and documentation of growth.



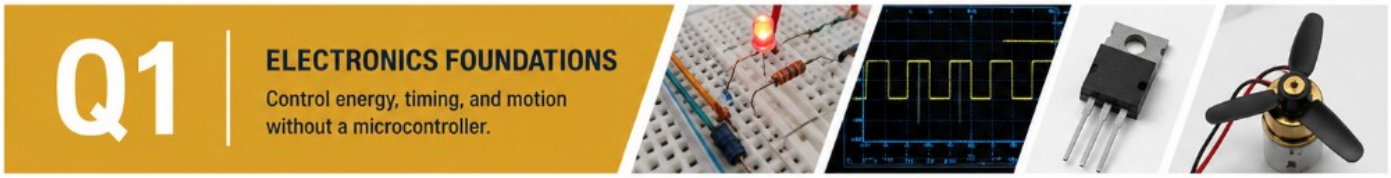
Stage 3 — Learning Plan

A 36-Week Progression from Foundations to Independent System Design

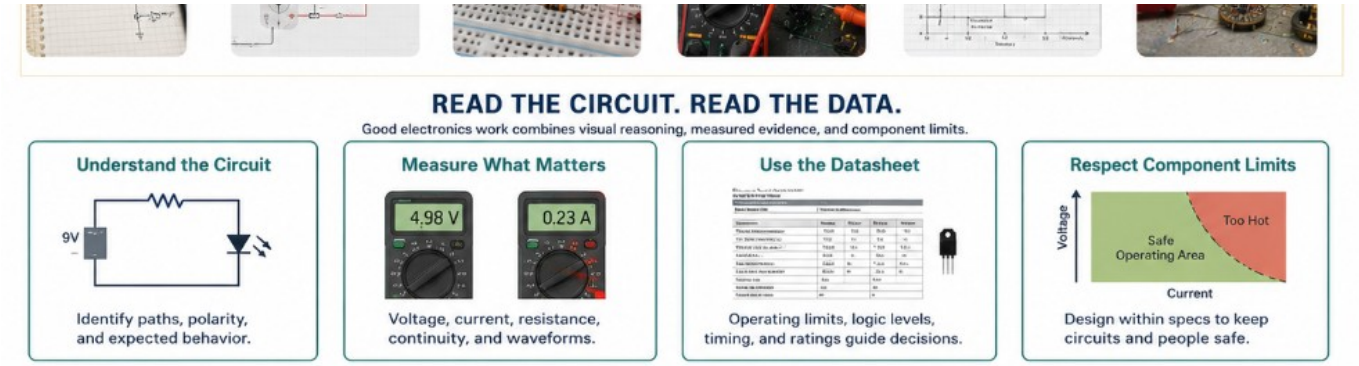
The same learning cycle repeats across the year: understand the system, verify subsystems, integrate interfaces, test under real conditions, revise from evidence, and explain and defend. What changes is who owns the decisions. Quarter 1 is strongly guided; Quarters 2 and 3 give students increasing responsibility for calibration, sequencing, troubleshooting, and reliability; Quarter 4 turns the cycle into a team-directed studio. The Student Visuals / Reference column identifies the few diagrams, examples, or models that should anchor a 10–15 minute weekly launch and remain available during independent work.

Four Quarter Throughline

Q1	Control energy and motion without a microcontroller	Electronics Foundations Portfolio
Q2	Control position and sequence work with repeatable automation	**Precision Automation Workcell**
Q3	Integrate sensing, state transitions, mechanisms, and communication into a reliable autonomous mission	**Autonomous Field Mission**
Q4	Direct a team studio and publicly defend a meaningful system	**Team Capstone**



Quarter 1 establishes a shared electronics foundation by going deeply into a small number of ideas rather than surveying many topics. Students repeatedly predict circuit behavior, simulate in software, build it physically, measure what actually happens, explain the evidence, and troubleshoot differences. The quarter moves from lab safety, into breadboard prototyping and measurement, then semiconductor behavior, TIP122 motor switching, 555 timing, PWM, soldering, and systematic troubleshooting. One integrated PWM motor controller from raw components becomes the technical destination for the quarter. OSHA 10 coursework runs in parallel.



Quarter 1 — Weekly Learning Plan

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **Course Launch, Safety, Mechatronic Systems, and First Circuits** **Purpose:** Establish professional lab safety, define the mechatronic system, and understand how energy moves through a complete circuit.	mechatronics; system; circuit; breadboard; schematic; source; load; voltage; current; resistance; polarity; PPE; OSHA; lockout/tagout; electrical hazard; ergonomics	**Teacher:** Launch the course with a mechatronic-system map, using a robot as one example, and required lab safety: legal requirements, OSHA 10, maintaining a safe work environment, electrical hazards, PPE requirements, lockout/tagout, inspection of hand and power tools for safety/usability, fire classes and extinguishing methods, first-aid response, ergonomics, and injury plus personal/environmental/equipment safety-violation reporting; then model bench power, breadboards, schematics, and a simple LED circuit. **Students:** Identify the components and interfaces of a mechatronic system and describe why a robot is a mechatronic system; complete safety stations and tool inspection; identify fire classes and appropriate extinguishing methods; demonstrate required LOTO and PASS fire-extinguisher procedures with an approved trainer; then troubleshoot and build the first circuit.	Safety exam/checkouts; OSHA 10 progress; LOTO/PPE/fire-response evidence; mechatronic system map; working LED circuit and schematic.	Mechatronic system block diagram; safety/LOTO/PPE/fire-response reference; bench-power setup; breadboard anatomy; schematic → breadboard example.
Week 2 **Measurement, Circuit Laws, Power, and Troubleshooting** **Purpose:** Use measurement and circuit laws to explain current, voltage, resistance, and power from evidence.	multimeter (DMM); continuity; voltage; current; resistance; Ohm's law; KCL; KVL; electric power; watt; series; parallel; voltage drop; tolerance; troubleshooting	**Teacher:** Identify common electrical measurement devices, then model safe DMM use, Ohm's law, Kirchhoff's current and voltage laws, electric power, resistor tolerance, series/parallel reasoning, and measurement-led troubleshooting. **Students:** Compute voltage, current, resistance, and power with Ohm's law and KCL/KVL; measure resistance, voltage, and current; compare predictions with measurements; and isolate seeded faults from evidence.	DMM checkout; Ohm/KCL/KVL/power calculations; predicted-versus-measured data; troubleshooting record.	DMM placement diagrams; Ohm's law relationship; KCL node and KVL loop; electric-power relationship; seeded fault.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 3 **Diodes, Semiconductor Behavior, and DC Motors** **Purpose:** Understand one-way semiconductor behavior, AC-to-DC context, and the electromagnetic behavior of a DC motor.	semiconductor; diode; rectifier diode; LED; anode; cathode; forward bias; reverse bias; forward voltage; datasheet; AC; DC; rectification; DC motor; electromagnetic field; torque; back EMF; polarity	**Teacher:** Introduce diode and LED semiconductor behavior, polarity, forward/reverse bias, diode-test mode, and datasheet use; compare AC and DC and show the rectifier diode's role in AC-to-DC power conversion; explain how current and magnetic fields create motor torque and back EMF. **Students:** Measure diode behavior, use key datasheet information, explain the rectification context, test how motor polarity changes direction, and describe the motor's electromagnetic behavior.	Diode/LED measurements; annotated schematic; datasheet evidence; AC/DC and motor-behavior explanation; DC-motor observation.	PN-junction/diode direction; AC vs. DC waveform; rectifier context; motor magnetic-field/torque diagram; motor-polarity diagram.
Week 4 **TIP122 Switching and Motor-Control Stations** **Purpose:** Use a small control signal, NO/NC switches, and a transistor to control a larger motor load safely.	transistor; TIP122; Darlington; base; collector; emitter; electronic switch; motor-control station; line diagram; normally open (NO); normally closed (NC); connector; common ground; flyback diode; back EMF	**Teacher:** Identify the parts of a motor-control system; describe connector purpose and selection; interpret a simple line diagram; model NO/NC pushbuttons with TIP122 low-side switching, the base resistor, control/load-current paths, common ground, and flyback protection. **Students:** Interpret the line diagram; assemble a motor-control station using NO and NC switches; identify and use the required connectors; label control and load-current paths; measure key points; orient the flyback diode; and troubleshoot faults.	Motor-control-station checkout; interpreted line diagram; annotated current paths; key measurements; flyback/troubleshooting evidence.	Motor-control line diagram; NO/NC symbols; TIP122 current-path schematic; control vs. load path; connector/common-ground and flyback-diode diagrams.
Week 5 **Capacitors, Timing, and the 555 Timer** **Purpose:** Understand how resistance and capacitance can create repeating electrical behavior without software.	capacitor; capacitance; charging; discharging; RC timing; 555 timer; astable; oscillator; frequency; period; duty cycle; potentiometer	**Teacher:** Introduce capacitance, qualitative RC timing, 555 astable operation, frequency, period, duty cycle, and potentiometer control. **Students:** Build a 555 oscillator, vary resistance or capacitance, predict the effect, and explain the observed timing change.	Working 555 oscillator; simulation evidence; timing comparison; explanation.	Capacitor charge/discharge curve; 555 pinout; astable timing loop; R/C cause-and-effect example.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 6 **PWM and Adjustable 555 Control** **Purpose:** Understand pulse-width modulation before using it to control a motor.	pulse-width modulation (PWM); duty cycle; pulse; switching; average power; potentiometer; control signal; waveform	**Teacher:** Connect 555 timing to PWM and make duty cycle visible through an LED and simulated waveform. **Students:** Build adjustable PWM, compare low/medium/high duty-cycle settings, and explain what the potentiometer changes.	Adjustable PWM circuit; three-setting comparison; annotated waveform; explanation.	PWM waveforms at three duty cycles; potentiometer connection; average-power visual.
Week 7 **Integrated PWM Motor Controller** **Purpose:** Combine verified subsystems into one understandable motor-control system and troubleshoot it from evidence.	PWM; duty cycle; subsystem; integration; control power; motor power; common ground; signal path; load-current path; flyback diode; troubleshooting	**Teacher:** Integrate the 555 and TIP122 stages; model separate control/motor power, common ground, and signal-versus-power troubleshooting. **Students:** Verify each stage, integrate the controller, test several settings, take targeted measurements, and diagnose faults.	Working PWM motor controller; labeled schematic; three-setting evidence; troubleshooting record.	555 → TIP122 → motor block diagram; separate power paths/common ground; troubleshooting flow.
Week 8 **Soldering and Durable Electronics** **Purpose:** Develop soldering skill or transfer the verified PWM controller into a durable form.	soldering; solder joint; tinning; continuity; strain relief; polarity; durable circuit; protoboard; serviceability; repair; inspection	**Teacher:** Teach soldering safety, joint quality, continuity testing, strain relief, organized layout, and rework. **Students:** Complete focused soldering practice or build a durable PWM controller, then inspect, repair, and verify the work.	Soldering checkout or durable controller; inspection, continuity, and repair evidence; OSHA 10 evidence.	Good/bad solder-joint photos; strain-relief examples; protoboard layout; continuity-check sequence.
Week 9 **Quarter 1 Review, Concept Test, and Reflection** **Purpose:** Show that understanding transfers beyond a memorized build sequence.	evidence; troubleshooting; fault; signal path; load-current path; subsystem; integration; PWM; transistor; 555 timer; diode; measurement	**Teacher:** Review with unfamiliar diagrams, measurements, and fault scenarios; assess reasoning rather than memorized build steps. **Students:** Defend selected portfolio evidence, reason through unfamiliar faults, complete the concept test, and reflect on growth.	Q1 concept test; selected technical portfolio; concise reflection.	Q1 integrated system map; fault-diagnosis flow; concise portfolio/evidence exemplar.

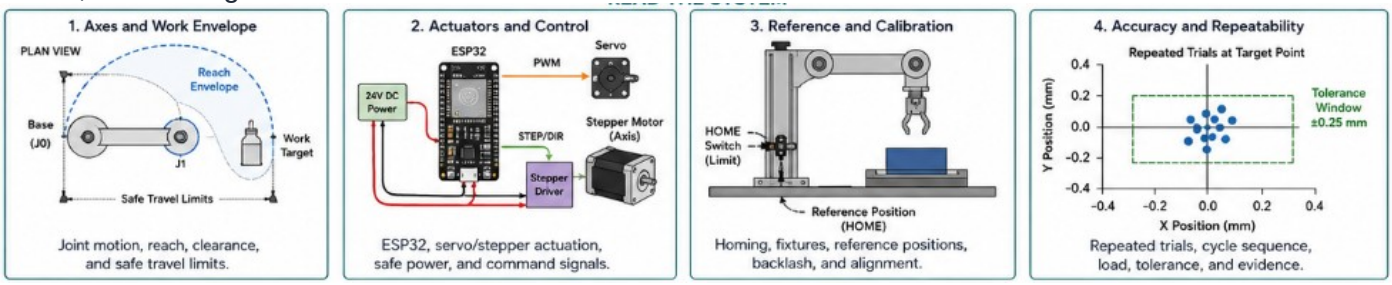


Quarter 2 asks one central question: How do we make physical motion predictable and repeatable?

Students replace Quarter 1's fixed timing and manual control with an ESP32 and use a teacher-designed SCARA-style workcell as a laboratory for position control. The mechanism is provided so time is spent on servo and stepper actuation, safe power, homing, calibration, sequencing, testing, and troubleshooting rather than CAD-designing a robot arm.

Quarter 1's DC motor becomes a useful contrast: it is well suited to continuous rotation but does not inherently know position. In Quarter 2, students use servos and a stepper because the workcell must establish HOME, move to known positions, respect a safe work envelope, and repeat a fixed task within tolerance. Geometry stays practical—joint position, reach, clearance, and work envelope—rather than becoming a formal kinematics unit.

Industry context remains fully embedded. Students connect the workcell to authentic applications where repeatable positioning matters, such as semiconductor manufacturing, laboratory automation, CNC machining, packaging, electronics assembly, and autonomous lab testing technology. The technical work remains the priority: establish a baseline, collect repeated evidence, identify the largest source of error, revise, and test again.



Quarter 2 — Weekly Learning Plan

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **ESP32, Programmable Control, and Servo Position** **Purpose:** Replace fixed electronic control with programmable position commands and identify the parts and types of programmable control systems.	programmable control; input; controller; output; ESP32; PLC; robot/CNC controller; actuator; DC motor; servo; position control; commanded position; safe range; common ground; current demand	**Teacher:** Map inputs → controller → outputs and compare common programmable-control systems such as microcontrollers, PLCs, CNC/robot controllers; compare actuator types including DC motors, servos, and steppers; connect Q1 DC-motor control to positional actuation; introduce ESP32 servo wiring, power, common ground, safe ranges, and position commands. **Students:** Identify programmable-control system components and examples; identify and justify appropriate actuator types; wire and command a servo; establish a safe range; and compare commanded and observed motion.	Programmable-control system map; servo-control checkout; safe-range table; commented code; actuator rationale.	Input → controller → output diagram; ESP32/PLC/CNC/robot-control comparison; DC motor vs. servo; servo signal/power wiring map.
Week 2 **Servo Calibration, Precision Measurement, and Repeatability** **Purpose:** Use precision measurement to show that a commanded position and a physical position are not always the same.	calibration; servo horn; datum; offset; accuracy; repeatability; tolerance; trial; variation; caliper; U.S. customary units; metric units	**Teacher:** Model servo-horn indexing, datums, calibration offsets, tolerance, repeated-position testing, and safe use of precision measurement tools in U.S. customary and metric units. **Students:** Measure repeated positions with appropriate precision tools, record and use both measurement systems, establish useful offsets and limits, and determine whether the servo returns consistently.	Precision-measurement checkout; repeatability data; U.S./metric measurement record; calibration/offset record; individual servo checkout.	Caliper/ruler measurement reference; U.S.–metric comparison; commanded vs. measured position plot; horn indexing; datum/offset diagram.
Week 3 **Stepper Motion and Homing** **Purpose:** Create controlled incremental motion and establish a repeatable reference position.	stepper motor; driver; A4988; step; direction; current limit; limit switch; homing; reference position; linear axis	**Teacher:** Introduce stepper/A4988 control, step/direction signals, current limiting, limit switches, homing, and separate actuator power. **Students:** Wire the stepper subsystem, set a safe current limit, home the axis, and verify repeated return to a reference position.	Stepper/A4988 checkout; homing demonstration; repeated-reference data; wiring diagram.	Stepper/A4988 wiring; step/direction concept; current-limit callout; homing/limit-switch sequence.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 4 **Assemble the SCARA Workcell and Read the Mechanical System** **Purpose:** Integrate verified motion subsystems while using drawings, specifications, tools, fasteners, and machine elements correctly.	SCARA; joint; axis; link; end effector; machine element; threaded fastener; non-threaded fastener; assembly drawing; specification; freehand sketch; manual drafting; CAD; alignment; cable routing; interference; interface	**Teacher:** Model assembly from mechanical drawings and written specifications; distinguish freehand sketching, manual drafting, and CAD; identify mechanical components, machine elements, and common hand tools; compare threaded and non-threaded fasteners and their applications; reinforce tool selection, inspection, care, alignment, cable routing, and interference checks. **Students:** Read the provided drawing/specification; identify mechanical components and machine elements; identify, select, use, and care for appropriate hand tools and fasteners; assemble and wire the workcell; verify each motion subsystem; and correct integration problems.	Assembled workcell; drawing/specification interpretation; fastener/tool checkout; axis checkouts; labeled system diagram; troubleshooting notes.	Exploded assembly and mechanical drawing; sketch vs. manual drafting vs. CAD; threaded/non-threaded fasteners; labeled machine elements; cable/interference examples.
Week 5 **HOME, Calibration, and Work Envelope** **Purpose:** Establish known reference positions and determine where the workcell can move safely and consistently.	HOME; calibration; offset; work envelope; reach; clearance; safe limit; pose; fixture; collision	**Teacher:** Model HOME, calibration offsets, safe limits, reach, clearance, work envelope, and fixed pickup/place positions. **Students:** Establish HOME, calibrate the axes, map safe and restricted regions, and verify repeatable fixed positions.	HOME/calibration table; work-envelope map; safe limits; fixed-position checkout.	HOME/reference diagram; work-envelope map; safe/restricted regions; fixed-position layout.
Week 6 **Sequence a Pick-and-Place Task** **Purpose:** Organize known positions into a safe, understandable automated sequence.	sequence; state; transition; pose; automation; safe state; program flow; pick; place	**Teacher:** Model a HOME → APPROACH → PICK → LIFT → PLACE → RETURN sequence and one-move-at-a-time testing. **Students:** Program and test each move separately, connect them into a complete cycle, and annotate the sequence clearly.	Sequence diagram; functioning pick-and-place cycle; annotated code.	Pick-and-place state flowchart; labeled poses; one-move-at-a-time test sequence.
Week 7 **Measure Repeatability and Failure** **Purpose:** Determine whether the workcell can repeat its task reliably rather than merely succeed once.	accuracy; repeatability; tolerance; placement error; trial; success rate; variation; failure mode; evidence	**Teacher:** Establish a consistent test protocol and distinguish accuracy, repeatability, tolerance, placement error, success rate, and failure mode. **Students:** Run repeated cycles, measure placement results, classify failures, and identify the largest source of variation.	Repeated-trial and placement data; success/failure record; prioritized failure analysis.	Accuracy vs. repeatability target graphic; placement scatter plot; failure-category example.

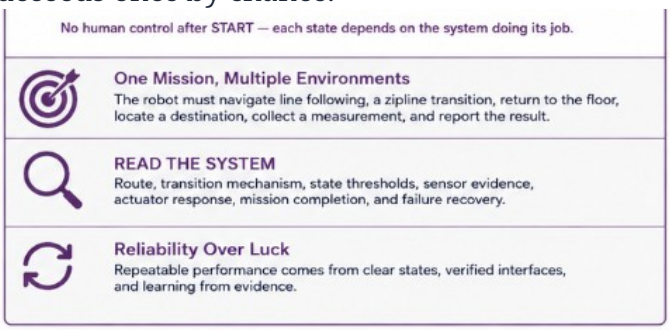
Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 8 **Improve the Weakest Part** **Purpose:** Revise the most consequential source of error and determine whether the change actually improves performance.	root cause; reliability; revision; validation; backlash; flex; drift; optimization; extension	**Teacher:** Coach root-cause analysis around alignment, backlash, flex, fixture stability, power, calibration, and code; hold extensions until the baseline is reliable. **Students:** Revise one consequential failure source, repeat the same test, and compare before-and-after performance.	Before/after performance data; documented revision; updated system/code evidence.	Backlash/flex/alignment examples; root-cause diagram; before/after error plot.
Week 9 **Automation Demonstration, Manufacturing, and Industry Connection** **Purpose:** Demonstrate repeatable motion and connect the workcell to manufacturing and mechatronics as evolving technological systems.	automation; workcell; manufacturing; production process; primary process; secondary process; advanced manufacturing; validation; limitation; technical defense; worker skill; emerging trend; transfer	**Teacher:** Run standardized trials and the concept test/technical defense; teach a concise manufacturing arc—definition, manufacturing as a technological system that transforms raw materials into products in a coordinated production setting such as a factory, five general steps, primary vs. secondary processing, and history from mechanization to advanced manufacturing—and connect precision positioning to authentic mechatronic systems, production work, and emerging trends. **Students:** Complete official cycles, present calibration/repeatability evidence, defend key decisions, and research the field of mechatronics through one application or emerging trend; map the workcell into one manufacturing system by identifying production steps, required worker skills, underlying technology, and the role of advanced manufacturing.	Final workcell demonstration; repeatability evidence; concept test/technical defense; concise manufacturing/mechatronics industry connection.	Manufacturing system flow and five-step overview; primary vs. secondary process; manufacturing timeline → advanced manufacturing; authentic automation examples.

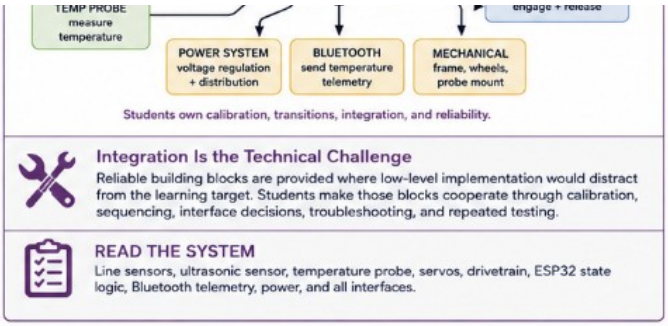


Quarter 3 shifts from controlling individual motions to integrating a complete mechatronic autonomous system. For students who completed Technology of Robotic Design, the mission extends familiar line-following and zipline behaviors into a more demanding sequence with sensing, environmental measurement, and wireless reporting. Students entering from another engineering pathway receive the same verified baseline hardware and starter code so prior robotics experience does not determine access to the challenge.

The common mission is intentionally fixed. After START, the robot follows a black line, enters a standardized zipline interface, travels down the zipline, exits into a known landing/alignment area, reacquires the black line, approaches a wall, and stops at a specified distance using an ultrasonic sensor. It then lowers a temperature probe into a standardized medium, waits for a trustworthy reading, retracts the probe, transmits the temperature to a student computer through a provided Bluetooth framework, and ends the mission. No human steering or communication control is used after the mission begins.

The goal is depth through systems integration, not a collection of sensor tutorials. Students are not expected to design the zipline docking hardware, write low-level sensor drivers, or build the Bluetooth protocol from scratch. Instead, they calibrate line sensing and stopping thresholds, apply Q2 servo-position skills to the probe mechanism, organize behavior into clear states and transitions, diagnose failures at subsystem interfaces, and use repeated trials to improve reliability. The standard is a system that can explainably and repeatedly complete the mission—not one that succeeds once by chance.





Quarter 3 — Weekly Learning Plan

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **Mission Architecture and Line Following** **Purpose:** Understand the complete mission as a sequence of states and verify a reliable floor-navigation baseline.	autonomous; system; state; transition; line sensor; calibration; threshold; input; output; interface	**Teacher:** Launch the full field mission as a state sequence; identify the sensor types used across the mission and their roles; provide baseline hardware/code and review line-sensor calibration, thresholds, and stage transitions. **Students:** Map the mission, identify line, distance, and temperature sensing functions, verify drivetrain and line-sensor behavior, tune the baseline, and document the evidence for successful line following.	Mission-state map; line-following checkout; calibration/threshold record; troubleshooting notes.	Full mission map; state/action/exit-condition diagram; line-sensor readings and threshold visual.
Week 2 **Zipline Transition and Mechanical Integration** **Purpose:** Make the floor-to-zipline-to-floor transition repeatable without turning the quarter into a mechanical-design project.	mechanical interface; alignment; clearance; transition; attachment; release; repeatability; failure mode; calibration	**Teacher:** Provide the standardized zipline interface and model safe testing, alignment, clearance, attachment, release, and interface failure analysis. **Students:** Assemble and calibrate the transition hardware, test entry and exit separately, record failures, and make evidence-based adjustments.	Zipline-transition checkout; repeated trials; alignment/adjustment record; failure notes.	Zipline interface geometry; align → attach → ride → release sequence; common interface failures.
Week 3 **Reacquire the Line and Stop at the Destination** **Purpose:** Use sensor evidence and thresholds to move from one autonomous behavior to another and stop at a defined physical location.	ultrasonic sensor; distance; threshold; valid reading; reacquire; stopping distance; tolerance; sensor evidence	**Teacher:** Model line reacquisition and ultrasonic stopping, including range, threshold selection, and simple reading validation. **Students:** Tune line reacquisition, select a stopping threshold, run repeated approaches, and compare stopping behavior with measured distance.	Line-reacquisition checkout; stopping-distance data; selected threshold and justification.	Line-reacquisition path; ultrasonic pulse/echo diagram; stopping threshold and tolerance zone.
Week 4 **Deploy the Probe and Measure Temperature** **Purpose:** Apply positional control to a useful measurement task and distinguish a sensor reading from a trustworthy measurement.	temperature sensor; probe; servo; deploy; retract; calibration; stabilization; measurement; valid data; repeatability	**Teacher:** Connect Q2 servo calibration to probe deployment; model stabilization time, repeated readings, immersion depth, and measurement validity. **Students:** Calibrate deploy/retract positions, measure a standard medium, decide when readings are trustworthy, and verify repeatability.	Probe-deployment checkout; servo-position record; repeated temperature data; validity explanation.	Probe deploy/retract positions; temperature stabilization graph; valid-reading criterion.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 5 **State-Based Mission Logic, Telemetry, and Information Security** **Purpose:** Organize robot behaviors so sensor evidence triggers the next state while data is transmitted through safe, responsible practices.	state; transition; condition; sequence; state logic; telemetry; Bluetooth; data transmission; information security; acceptable use; pairing; mission complete	**Teacher:** Provide the mission-state framework and Bluetooth function; show how sensor evidence triggers transitions and telemetry reports the final value; review Internet safety issues, acceptable-use standards, safe device pairing, information security, and responsible handling of transmitted data. **Students:** Define transition conditions, integrate verified subsystem code, confirm automatic temperature transmission without manual control, and document Internet-safety, acceptable-use, safe-pairing, and data-handling practices.	State/transition diagram; annotated mission-code checkpoint; automatic telemetry checkout; information-security/acceptable-use checkpoint.	Mission state-transition flowchart; sensor → decision → action chain; Bluetooth/telemetry data flow; safe-pairing/data-handling reference.
Week 6 **Integrate the Full Autonomous Mission** **Purpose:** Connect individually verified subsystems and identify failures that appear only when the complete system runs.	integration; interface; subsystem; data flow; control flow; alpha; fault; troubleshooting; baseline	**Teacher:** Model integration through interfaces: mechanics, sensing, timing, power, state changes, and data flow; preserve known-working subsystems while troubleshooting. **Students:** Run the complete mission, log where failures occur, and revise only what is needed to establish an integrated baseline.	Integrated alpha mission; complete run log; updated system/state diagram; prioritized interface failures.	Full system interface map; power/control/data paths; integration-failure log example.
Week 7 **Reliability and the Dominant Failure** **Purpose:** Use repeated evidence to identify the one failure source that most limits mission success.	reliability; success rate; trial; failure classification; root cause; symptom; evidence; consequential failure	**Teacher:** Establish standardized trials and review success rate, failure classification, root cause, and symptom-versus-cause reasoning. **Students:** Run repeated missions, classify failures by state, calculate success rate, identify the dominant failure, and propose one revision.	Baseline reliability data; failure-by-state record; root-cause claim; approved revision plan.	Failure-by-state chart; success-rate calculation; symptom vs. root-cause example.
Week 8 **Improve and Verify** **Purpose:** Make one meaningful change, then repeat the same test to determine whether reliability actually improved.	revision; validation; before/after; performance metric; controlled test; serviceability; evidence; improvement	**Teacher:** Coach one controlled reliability revision and prevent feature creep; require before-and-after validation under the same conditions. **Students:** Implement the revision, rerun the standardized trials, compare performance, and finalize selected technical evidence.	Before/after reliability evidence; documented revision; final system/state diagram; selected portfolio evidence.	Before/after reliability chart; controlled-change diagram; serviceability check example.

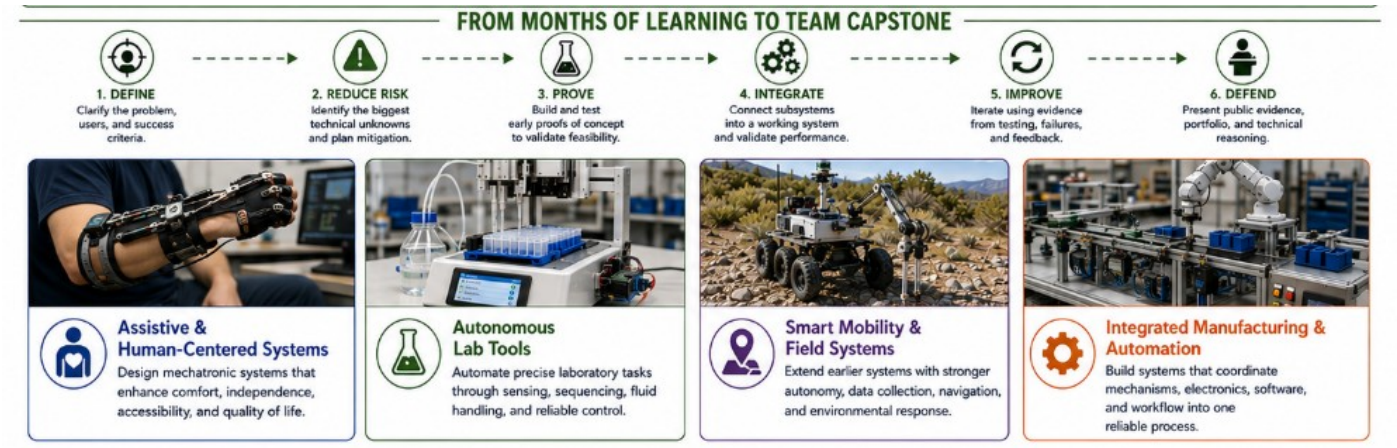
Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 9 **Autonomous Mission Demonstration and Concept Test** **Purpose:** Demonstrate repeatable autonomous performance and show individual understanding of how the complete system senses, decides, acts, and communicates.	autonomous mission; reliability; validation; state transition; sensor evidence; telemetry; technical defense; limitation; transfer	**Teacher:** Run official mission trials and an individual defense focused on sensors, states, interfaces, troubleshooting, and reliability. **Students:** Complete repeated official runs, report temperature automatically, explain a limitation and improvement, and reason through an unfamiliar mission fault.	Final autonomous mission; official reliability evidence; concept test/technical defense; reflection.	Complete mission sequence; final system/state diagram; evidence-and-limitation exemplar.



Quarter 4 is a student-directed design studio in which teams of three to four design, build, test, and publicly defend a mechatronic system tied to their interests and future pathways. The quarter begins by defining a meaningful problem, narrowing scope, establishing architecture and success criteria, identifying the biggest technical risks, and building immediate proofs of concept before committing to a final design.

Responsibility shifts from the teacher to the team. No new whole-class technology sequence is added; students independently learn the specialized tools and processes their projects require while remaining accountable for individual technical contributions and understanding the larger system.

Teams may extend a project from an earlier quarter, but the capstone must move the needle. Refinement alone is not enough; the work must demonstrate meaningful technical advancement through new capability, deeper integration, stronger reliability, or substantially improved performance. The year culminates in a public demonstration, technical portfolio, concept exam, and individual defense.



Quarter 4 — Weekly Learning Plan

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **Define, Validate, and Build** **Purpose:** Define and validate a project that is meaningful, safe, achievable, and responsive to material, organizational, financial, workforce, community, and environmental constraints.	project charter; scope; stakeholder; system architecture; success criteria; milestone; bill of materials; material property; planning; management; budget; workforce; labor; community impact; environmental impact; hazard review; proof of concept	**Teacher:** Run rapid proposal conferences; narrow scope, verify safety and purchasing needs, establish milestones and individual responsibility; distinguish among common manufacturing material families and require research and selection based on relevant physical, mechanical, chemical, thermal, electrical/magnetic, acoustical, or optical properties; and apply an industry/organization lens to planning, management, finance, technical/production skills, technology, labor, community, health/safety, and environmental issues. **Students:** Finalize the project charter, architecture, responsibilities, budget, researched material-family/property justification, industry/context scan, and first proof of concept; define measurable advancement for any extension project.	Approved project charter; system architecture; BOM/budget; material-property justification; industry/context scan; hazard review; first experiment.	Problem → criteria/constraints → system map; material-properties matrix; industry/organization lens; scope boundary; project-charter exemplar.
Week 2 **Prototype the Biggest Unknowns** **Purpose:** Test the assumptions most likely to prevent the project from succeeding.	technical uncertainty; risk; risk reduction; assumption; feasibility; experiment; test condition; constraint; scope revision; evidence	**Teacher:** Help teams identify the assumptions most likely to force redesign and require focused risk-reduction experiments before final construction. **Students:** Prototype the biggest technical unknowns, collect evidence, and revise scope, architecture, or budget when needed.	Risk-reduction prototypes; test evidence; revised architecture, budget, and plan.	Simple risk matrix; proof-of-concept examples; experiment plan; architecture revision example.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 3 **Develop the Core Subsystems** **Purpose:** Build major parts separately so each can be understood, measured, and improved before integration.	subsystem; interface; interface specification; dependency; input; output; technical ownership; integration requirement; specification; modularity	**Teacher:** Conduct subsystem conferences, review technical resources and AI use, require explicit interface agreements and individual ownership, and require common machine- and hand-tool checkouts covering safe selection, operation, inspection, and care before independent project use. **Students:** Develop and test the project's major subsystems separately; complete required machine- and hand-tool checkouts; safely use and care for appropriate tools; and document what each subsystem requires from the others.	Subsystem demonstrations; safe tool-use/care evidence; interface specification; individual technical-contribution evidence.	Subsystem/interface diagram; interface-specification table; technical ownership map.
Week 4 **Integrate the First Complete System** **Purpose:** Connect verified subsystems and identify new problems created by their interaction.	system integration; alpha prototype; interface failure; interoperability; power budget; communication; timing; failure mode; failure log; debugging	**Teacher:** Facilitate an alpha review focused on power, dimensions, timing, communication, safety, usability, and integration failures. **Students:** Connect enough verified subsystems to demonstrate the central function, log new failures, and update technical documentation.	Integrated alpha prototype; updated technical documentation; failure log; revised schedule.	Alpha integration map; power/timing/communication interfaces; annotated integration failure.
Week 5 **Minimum Viable Prototype** **Purpose:** Produce a complete but unfinished system capable of performing its essential sequence.	minimum viable system; essential function; feature; acceptance criteria; test plan; performance requirement; verification; validation; prioritization; technical defense	**Teacher:** Require teams to separate essential functions from optional features and finalize measurable acceptance criteria and a formal test plan. **Students:** Demonstrate the complete minimum viable system, compare performance with criteria, and prioritize the revisions that matter most.	Minimum viable system; formal test plan; midpoint technical defense.	Minimum-viable-system diagram; essential vs. optional features; acceptance-test plan.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 6 **Test, Break, and Rebuild** **Purpose:** Deliberately test the system under repeated and increasingly demanding conditions.	reliability; repeatability; stress test; trial; failure analysis; root cause; failure classification; redesign; performance data; safety recheck	**Teacher:** Challenge weak testing and require root-cause evidence before major redesign. **Students:** Run repeated and demanding trials, classify failures, redesign the most consequential weak point, and retest.	Repeated-trial data; failure analysis; documented redesign; safety recheck.	Root-cause/failure tree; repeated-trial plot; before/after redesign evidence.
Week 7 **Refine the User and System Experience** **Purpose:** Improve reliability, usability, repairability, and professional interaction with users, teammates, and stakeholders.	beta prototype; usability; ergonomics; stakeholder feedback; customer service; conflict resolution; respect for diversity; serviceability; repairability; enclosure; user interface; maintenance; environmental consideration	**Teacher:** Organize structured feedback from peers, users, mentors, or industry partners; model professional customer-service communication, respectful listening across different perspectives, and constructive conflict resolution; critique reliability, usability, repairability, and system clarity. **Students:** Respond to external feedback and team disagreements professionally; improve controls, ergonomics, fabrication, wiring, service access, procedures, or environmental performance; and document how feedback changed the system.	Beta prototype; stakeholder/customer-service feedback record; team-resolution evidence when applicable; updated user/maintenance documentation.	User/system interaction diagram; serviceability callouts; professional feedback cycle; feedback → revision example.
Week 8 **Final Build and Technical Story** **Purpose:** Complete the system and assemble the evidence needed for another person to understand, operate, and evaluate it.	design freeze; technical documentation; schematic; CAD; citation; traceability; operating procedure; test evidence; technical claim; portfolio	**Teacher:** Conduct final readiness reviews of the system, documentation, technical claims, citations, AI-use records, safety information, and evidence quality. **Students:** Freeze the design, complete the technical portfolio, prepare the demonstration, and rehearse explanations grounded in evidence.	Final design freeze; complete draft portfolio; exhibition-readiness approval.	Technical-portfolio exemplar; claim → evidence → limitation layout; final drawing set.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 9 **Public Demonstration and Capstone Defense** **Purpose:** Publicly demonstrate the system and defend the decisions, evidence, collaboration, and learning behind it.	technical defense; stakeholder evaluation; performance evidence; design justification; limitation; tradeoff; contribution; reflection; demonstration; professional communication	**Teacher:** Facilitate the public demonstration, technical questioning, stakeholder feedback, and individual contribution defense. **Students:** Demonstrate the system, defend major decisions and failures, present performance evidence, answer questions, and reflect on growth.	Final capstone system; technical portfolio; public defense; individual reflection/contribution record.	Demonstration flow; technical-defense prompts; final evidence board; reflection structure.

Completing the Mechatronics I Progression

Mechatronics I prepares students to understand and contribute to a world increasingly shaped by integrated technical systems. Across the year, students move from electronics, measurement, semiconductor switching, and motor control into programmable precision motion, homing, calibration, autonomous sensing, state-based sequencing, environmental measurement, telemetry, reliability, and self-directed engineering. The technologies become more complex, but the central habit remains the same: understand the system, identify the interfaces, and use evidence to determine what is actually happening.

As students gain technical capacity, they also take on greater responsibility. They learn to work safely, communicate with appropriate technical language, collaborate across areas of expertise, test rather than assume, and revise when evidence challenges their first idea. By the end of the course, students are expected not simply to make something work, but to explain why it works, recognize how it could fail, consider who is affected by their decisions, and defend the choices they made.

The specific tools, platforms, and technologies students encounter will continue to change. More durable is the ability to approach an unfamiliar problem, break it into understandable parts, learn what is needed, persist through uncertainty, and build something purposeful with others. Mechatronics I ultimately aims to develop the technical confidence, judgment, curiosity, and agency students need not only to adapt to what comes next, but to participate in shaping it.