TECHNOLOGY OF ROBOTIC DESIGN

SENSE THE WORLD. MANAGE UNCERTAINTY. BUILD SYSTEMS THAT WORK.

Grace Hopper Center | VDOE Course 8421 | 36 Weeks | 2026–2027

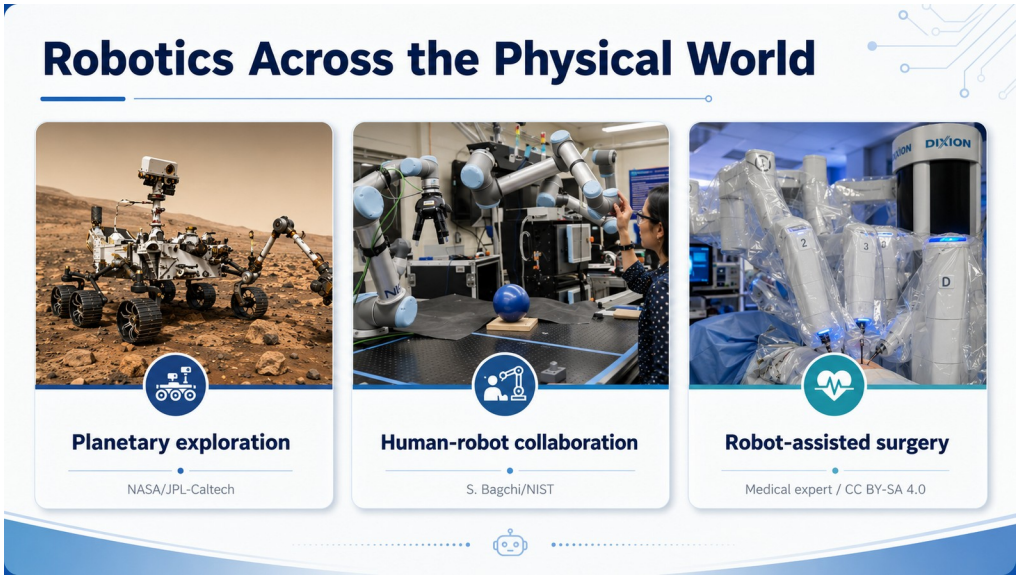
Course Overview

Why this course exists

Robotics is the science of using computer-controlled devices to sense and act on the physical world. Unlike technologies that operate only on screens, robots must function in a physical world that changes. Wheels slip. Batteries drain. Sensors return incomplete or noisy measurements. Parts are never manufactured or assembled with perfect precision. A robot must still make useful decisions and act safely.

This makes managing uncertainty the central problem of robotics. Robots operate across a spectrum from highly controlled environments to dynamic settings filled with changing surfaces, objects, and people. Their actuators are imperfect, their sensors require calibration, their mechanisms depend on precise construction, and their paths must be planned using only the information available. No digital model captures every nuance of the physical world. Models are abstractions; many rely on estimates, thresholds, or probabilities. In this course, students learn to compare what a system expects with what actually happens, then use evidence to calibrate, troubleshoot, revise, and improve.

The goal is not simply to build robots. It is to become more capable of understanding systems, working through uncertainty, documenting technical decisions, collaborating dependably, and using technology with judgment and purpose. These habits prepare students for advanced study in mechatronics and related technical fields.



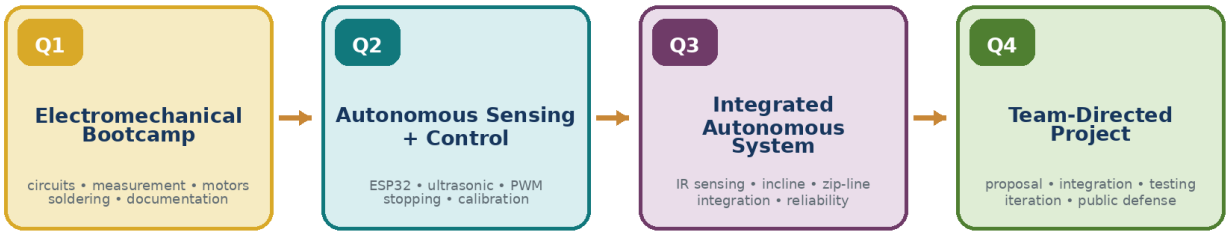
Robotics applications span planetary exploration, human-robot collaboration, and robot-assisted surgery.

How the Course Is Structured

Each quarter follows a repeated cycle: understand the task and setting, learn the needed theory and skills, build and test components, connect them into one system, compare expected and actual behavior, and improve the design using evidence. Early work is highly guided; responsibility increases as students gain competence.

- Understand the task, environment, criteria, and constraints.
- Learn the theory, vocabulary, tools, and safety procedures needed for the next build.
- Build and verify components or subsystems before integrating them.
- Use measurements, simulations, diagrams, and repeated trials to compare predictions with reality.
- Troubleshoot by isolating causes rather than changing many variables at once.
- Document what changed, why it changed, and what evidence supports the next decision.

Four-Quarter Course Arc



The four-quarter arc moves from an electromechanical bootcamp through autonomous sensing and integrated missions toward a student-directed team project.

Assessment and Individual Evidence

Assessment remains 40% formative and 60% summative. Formative evidence includes practice, check-ins, troubleshooting records, reflections, and quizzes. Summative evidence includes project milestones, portfolios, concept tests, demonstrations, and short technical defenses. Team projects create shared system evidence, while individual checkouts, explanations, drawings, measurements, code, and contribution records show each student's learning.

Responsible Use of AI

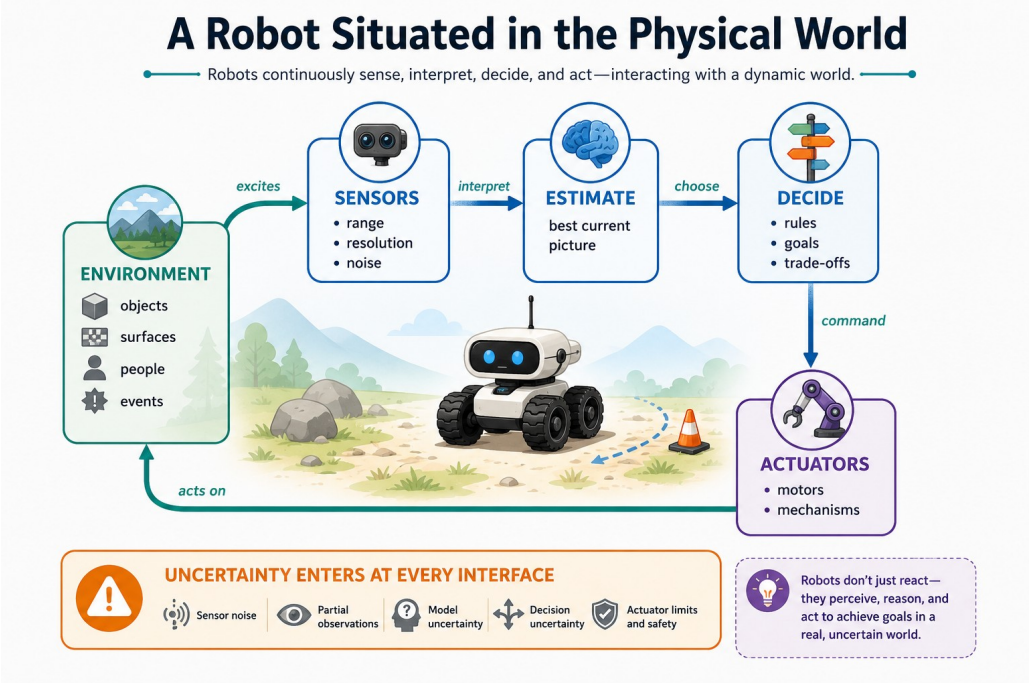
AI may support brainstorming, research, programming, feedback, documentation, and troubleshooting. Students remain responsible for testing suggestions, understanding the code and models they use, making final decisions, and explaining their work. AI can accelerate pattern recognition and iteration, but it does not remove the need to measure the physical system and verify what is actually happening.

Robotics in the Physical World

The central design problem: managing uncertainty

A useful robot must act despite incomplete information. Uncertainty can enter through the environment, sensors, software models, motors, mechanisms, construction tolerances, timing, power, communication, and human behavior.

- **The environment changes.** A robot on a protected assembly line faces fewer surprises than one on a ramp, outdoors, in a home, or near moving people.
- **Sensors have limits.** Readings can shift because of noise, range, resolution, lighting, surface properties, placement, damaged wires, or failure.
- **Movement is not perfectly repeatable.** Motors, wheels, gears, batteries, structures, and mechanisms respond differently as load, friction, alignment, temperature, wear, or damage changes.
- **Software uses simplified models.** A drawing, threshold, state diagram, simulation, or program represents only part of what is happening in the real world.
- Construction matters. Small differences in fit, center of mass, wheel alignment, sensor height, or zip-line geometry can change system behavior.
- **Reliable robots are designed for uncertainty.** Students calibrate, repeat trials, vary conditions, use safety margins, document limitations, and revise from evidence.



A robot gathers information, forms a best current estimate, chooses an action, and checks what happened.

Stage 1 — Desired Results

Transfer Goals

By the end of the course, students can independently:

- Work safely and responsibly in a shared engineering lab.
- Identify the mechanical, electrical, sensing, and computational subsystems inside a robot.
- Build circuits and electromechanical systems from schematics, data sheets, and technical directions.
- Use a multimeter, calculations, simulations, and trial data to explain what is happening in a system.
- Design, fabricate, assemble, program, test, and improve robotic systems in response to clear criteria and constraints.
- Recognize that digital models are incomplete and use calibration, repeated testing, and feedback to manage uncertainty.
- Create technical/system drawings and documentation that allow another person to understand, reproduce, troubleshoot, or improve the work.
- Contribute dependable individual work to a team and defend technical decisions with evidence.

Enduring Understandings

Students will understand that:

- Robotics is the science of using computer-controlled devices to sense and act on the physical world. A robot gathers inputs, processes information, uses energy, acts through motors and mechanisms, and uses feedback.
- The physical world contains uncertainty. Sensors are noisy and limited; actuators and mechanisms respond differently as load, friction, voltage, alignment, wear, and construction change.
- Current must travel through a complete path. Voltage, resistance, current, and power can be predicted, measured, and compared to diagnose circuit behavior.

- Mechanical advantage changes force and motion. Gear reduction, link length, center of mass, friction, and torque influence whether a robot can move a load reliably.
- Reliable systems are built by verifying subsystems, measuring before guessing, changing one variable at a time, and retesting after revisions.
- Good technical documentation includes clear diagrams, labeled photos, measured data, concise captions, and honest explanations of limitations.
- AI can accelerate research and coding, but students must test outputs, understand results, and remain responsible for decisions.

Overall Course Structure

Year at a glance: four quarters, four systems, one design cycle

Quarter	Focus	Culminating Evidence
Q1	**Electromechanical Bootcamp** — syllabus, robotics definition, uncertainty, lab safety, regulated power, breadboards, LED/resistor/switch circuits, series and parallel paths, multimeter use, Ohm's law, KVL/KCL, DC motors, soldering, technical drawings, and documentation	Hello World electromechanical system; quantitative circuit evidence; soldering practical; technical/system drawings; concept test
Q2	**Autonomous Sensing + Control** — FDM 3D printing with an embedded CNC/manufacturing comparison; chassis and power; ESP32 + L298N motor control; computing and communication architecture; ultrasonic distance sensing; direct/indirect measurement; PWM; stopping distance; thresholds; calibration; safety margins; repeated trials; and reliability	Autonomous Braking Challenge: approach a wall at speed and stop inside a target zone without contact; calibration and stopping-distance evidence; system documentation; concept test
Q3	**Integrated Autonomous System** — IR reflectance sensing, line following, differential correction, incline traction, capture geometry, zip-line attachment design, subsystem integration, failure analysis, and reliability	Autonomous Zip-Line Mission: follow a marked path up an incline, align with and capture an elevated line, then ride the zip-line; repeated-trial evidence; technical/system documentation; concept test

Quarter	Focus	Culminating Evidence
Q4	**Team-Directed Project** — problem identification; team agreements and professional practice; proposal; system requirements; sketches and diagrams; budget; responsibilities; schedule; risk review; prototyping; integration; testing; troubleshooting; iteration; user feedback; industry/WBL feedback, career connections, and professional communication; and public communication	Team-directed robotic system; technical portfolio; public demonstration; individual technical defense, reflection, and final concept assessment

Essential Questions

How can we make a robot do something useful in the physical world?	**Where does uncertainty enter a robotic system, and what can we do about it?**
How can measurements tell us whether a circuit or mechanism is behaving as expected?	**How do electrical energy, motors, mechanisms, sensors, and software become one working system?**
How do we design a system that is not only functional once, but accurate and repeatable?	**How should we respond when the solution to a technical problem is not immediately apparent?**
What does it mean to produce technical work that another person can understand and trust?	**What does it mean to be a teammate others can depend on?**

Stage 2 — Evidence of Learning

Major Performance Tasks

Quarter 1 — Electromechanical Bootcamp Students progress from simulated circuits to physical construction. They create a documented “Hello World!” circuit with an LED, 330-ohm resistor, and switch; compare series and parallel circuits; use a multimeter and Ohm’s law to collect quantitative evidence; add a DC motor as a parallel load; solder motor leads and a practice board; and communicate the system through technical drawings, photos, captions, and a concept test.	**Quarter 2 — Autonomous Sensing + Control** Teams build a two-motor ESP32 robot on a teacher-designed laser-cut frame, print a provided caster, and wire an L298N motor driver and ultrasonic sensor. The baseline challenge is to approach a wall as quickly as possible and stop autonomously inside a defined target zone without contact. Students use repeated measurements to connect sensor variation, PWM, stopping distance, thresholds, safety margins, and reliability. Bluetooth manual/service control, custom electronics packaging, and more aggressive speed profiles are optional extensions after the baseline works reliably.
Quarter 3 — Integrated Autonomous System Students extend the same mobile robot rather than starting a new platform. They add paired IR reflectance sensors or a dual-sensor module, calibrate line detection, and tune differential correction so the robot can follow a marked path up an incline. Teams then design and fabricate the mechanical interface that aligns with and captures an elevated line before the robot transitions to a gravity-powered zip-line ride. Success is judged through baseline mission reliability, failure analysis, technical/system drawings, documentation, and an individual concept test.	**Quarter 4 — Team-Directed Project** Teams identify a problem or challenge, define measurable success criteria, establish a team operating agreement, propose a robotic system, divide meaningful technical responsibilities, and build from early risk-reduction prototypes toward a complete system. Teams integrate mechanical, electrical, sensing, programming, and fabrication skills from the year; test repeatedly; troubleshoot failures; revise from evidence; present proposals and beta systems to industry professionals; respond to technical and user feedback; document limitations; and publicly demonstrate the final system. Each student completes an individual technical defense and reflection.

VDOE Competency Alignment

This framework explicitly schedules 78 of the 81 required VDOE Course 8421 competencies and all three optional competencies. The three required Student Life competencies (31–33) specifically require participation in a student organization; because a CTSO/student organization is not integrated into this course, they are identified as not addressed rather than replaced with unrelated evidence. Work-based learning is instead built through structured interaction with industry professionals, including preparation, technical conversation, project critique, response to feedback, career exploration, and reflection. Core robotics, electronics, measurement, fabrication, programming, troubleshooting, documentation, teamwork, testing, and redesign competencies remain embedded repeatedly across the four projects rather than appearing as isolated checklist items.

Embedded Competency Connections

Not every competency warrants a separate unit. When a competency asks students to describe, compare, identify, or connect an adjacent technology, it is attached to the project where the idea is technically meaningful and produces a small piece of visible evidence. For example, CNC fundamentals are taught beside FDM printing through additive-versus-subtractive process comparison, coordinate systems, workholding, toolpaths, and machine instructions rather than by interrupting the course for a separate CNC machining project.

Course Milestones:

Week 1 — Course launch: robotics, automation, and control-system definitions; AC/DC and electrical safety; Internet/acceptable-use expectations; robotics careers, history/future, industrial hardware; and an introduction to the year's work-based-learning sequence and types of WBL opportunities.

Weeks 4–6 — Logic and simulation: analog versus digital control, plus electronic/control-system simulation before physical construction.

Week 7 — Actuation: electric motor control compared with pneumatic/hydraulic fluid-power systems and their major components.

Week 10 — Digital fabrication and first industry interaction: FDM additive manufacturing compared with CNC subtractive manufacturing, including coordinates, workholding, toolpaths, precision measurement, and production/quality roles. Students prepare questions for an industry professional, connect the conversation to manufacturing and robotics careers, and record one technical or career insight they can apply to the course.

Week 12 — ESP32 control architecture: microcontroller purpose, processor/memory/I/O, operating-system versus firmware roles, analog versus digital control, open versus proprietary hardware, data-transmission hardware, programming-platform selection, and program-security habits.

Weeks 13 and 19 — Sensing and measurement: direct measurement compared with sensor-based indirect measurement; analog physical quantities converted into digital decisions; and the interfaces that carry sensor information into the controller.

Weeks 22–23 — Fabrication decisions: students use additive manufacturing for the zip-line interface, then compare when the same geometry might be better produced through CNC or another subtractive process based on tolerance, material, setup, and repeatability.

Weeks 28–36 — Industry/WBL and project transition: students connect project choices to careers and WBL opportunities, prepare for an industry-professional proposal critique, respond to professional feedback during development, receive a second industry/user review of the beta system, and finish with a career- and life-management reflection that explains what they learned from the WBL experience and what they would pursue next.

Stage 3 — Learning Plan

A 36-Week Progression from Guided Foundations to a Student-Directed System

Each quarter uses the same progression: establish the system and safety expectations; build foundational skill; verify components; integrate subsystems; test under changed conditions; troubleshoot with evidence; revise; and explain what the system can and cannot do. The weekly plan is specific enough to maintain alignment while leaving room for schedule changes, student needs, and extension opportunities. 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.

Q1 Electromechanical Bootcamp

Trace energy, measure evidence, and document systems

Quarter 1 creates a common technical baseline for ninth-grade students. The sequence deliberately begins with safety, regulated power, breadboard organization, and simulation before students move into measurement, motors, and soldering. The goal is not to race toward a microcontroller. Students first learn to trace energy through a circuit, measure what is actually happening, and document a system clearly enough that another person can inspect or reproduce it.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **Course Launch, Robotics, Safety, and Power** **Purpose:** Establish what robotics is, why uncertainty matters, and how to work safely with regulated lab power.	Robotics; automation; control system; input; output; feedback; uncertainty; AC; DC; source; load; PPE; acceptable use; WBL; career	**Teacher:** Frame robotics, uncertainty, lab and digital safety, AC/DC power, and the year's industry/WBL sequence. **Students:** Complete safety checks, classify example systems, research one career/future direction, prepare an industry question, and demonstrate safe bench-power setup.	Safety/AUP check; robotics/career mini-brief; WBL question; power-supply checkout.	Input → decision → output → feedback diagram; safe power-up sequence; AC/DC comparison.
Week 2 **Breadboards, LEDs, Resistors, and Switches** **Purpose:** Build complete circuits cleanly and understand how breadboard connections create a current path.	Breadboard; node; power rail; LED; resistor; switch; polarity; anode; cathode; series; parallel; continuity	**Teacher:** Model breadboard connections, LED/resistor/switch circuits, continuity, and schematic-to-breadboard translation. **Students:** Simulate and build LED/switch circuits, verify continuity and polarity, compare series/parallel paths, and document current flow.	Working circuit; continuity checkout; schematic and annotated current path.	Breadboard anatomy; schematic-to-breadboard example; LED polarity close-up.
Week 3 **Measurement, Ohm's Law, and Circuit Evidence** **Purpose:** Use a multimeter and simple calculations to determine what is actually happening in a circuit.	Multimeter (DMM); continuity; voltage; current; resistance; Ohm's law; voltage drop; tolerance; troubleshooting	**Teacher:** Demonstrate safe DMM use and Ohm's law, then model evidence-based fault isolation. **Students:** Predict and measure circuit values, compare results, and diagnose seeded faults using measurements rather than guesswork.	DMM checkout; predicted-versus-measured data; troubleshooting record.	DMM connection diagrams; measurement points; predicted-versus-measured example.
Week 4 **From Switches to Digital Logic** **Purpose:** Discover AND, OR, NOT as physical relationships before introducing logic-gate ICs.	Analog; digital; threshold; binary; HIGH/LOW; 1/0; input; output; truth table; AND; OR	**Teacher:** Use switch circuits to introduce binary states, truth tables, AND/OR logic, and analog-to-digital threshold thinking. **Students:** Build and test switch logic, create truth tables, and explain how a continuous voltage can become a HIGH/LOW decision.	Switch-logic circuits; truth tables; analog/digital explanation.	Series/parallel switch circuits beside truth tables and logic symbols.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 5 **Logic Gates on the Breadboard** **Purpose:** Use logic ICs to reproduce known decision rules and understand why digital inputs must be defined.	DC motor, gear reduction, torque, speed, load, PWM	**Teacher:** Introduce 74HC08, 74HC32, and 74HC04 gates, including pinouts, pull-down resistors, and floating inputs. **Students:** Build AND/OR/NOT circuits, verify truth-table cases, and diagnose one logic-gate fault.	AND/OR/NOT checkouts; truth-table verification; diagnosed logic fault.	Annotated 74HC pinout; breadboard layout; floating-input versus pull-down example.
Week 6 **Combinational Logic Design Challenge** **Purpose:** Translate a simple robotic decision problem from words into a working logic circuit.	Soldering, tinning, joint, continuity, strain relief	**Teacher:** Model the path from a control problem to I/O definitions, truth table, logic diagram, simulation, and physical circuit. **Students:** Design, simulate, build, and test a simple robot-control logic circuit, then compare simulation with physical behavior.	Logic design package; simulation/physical comparison; individual explanation.	Problem → truth table → logic diagram → circuit workflow.
Week 7 **TIP122 Transistor and DC Motor Control** **Purpose:** Use a small control current to switch the larger current required by a DC gearmotor.	DC motor; gear reduction; torque; speed; load; transistor; control current; flyback diode; fluid power; pressure; flow; valve; cylinder	**Teacher:** Explain DC gearmotor behavior, TIP122 low-side switching, flyback protection, and the systems-level contrast with fluid-power actuation. **Students:** Build and measure a TIP122 motor controller, reverse motor direction, explain gearing, and annotate a fluid-power system comparison.	TIP122 controller; annotated schematic; fluid-power comparison; targeted measurements.	TIP122 current-path schematic; flyback-diode orientation; motor-control photo.
Week 8 **Soldering, Troubleshooting, and Technical Communication** **Purpose:** Create durable connections and use evidence to diagnose faults across circuits, logic, and motor control.	Fault, troubleshooting, isolate, root cause, repair, retest	**Teacher:** Teach soldering, rework, strain relief, continuity testing, and structured troubleshooting/documentation. **Students:** Solder and inspect connections, diagnose and repair circuit faults, and assemble concise Q1 technical evidence.	Soldering checkout; fault-and-repair log; selected Q1 technical evidence.	Good/bad solder-joint photos; troubleshooting flowchart; annotated fault example.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 9 **Q1 Practical, Concept Test, and Technical Defense** **Purpose:** Demonstrate individual understanding of circuits, logic, transistor switching, and evidence-based troubleshooting.	Evidence; logic; control signal; load; transistor; troubleshooting; reliability; limitation; technical defense	**Teacher:** Administer an individual practical and concept test focused on circuits, logic, transistor switching, and troubleshooting. **Students:** Complete the assessment, diagnose an unfamiliar fault, explain the motor controller, and defend selected evidence.	Concept test; individual practical; troubleshooting checkout; technical defense and reflection.	Q1 system map; practical-checkout sequence; concise evidence exemplar.

Q2 Autonomous Sensing + Control

Sense distance, make a decision, and stop reliably

Quarter 2 turns the Q1 bootcamp skills into a complete mobile robot and introduces autonomous decision-making. Students build a two-motor robot on a teacher-designed laser-cut chassis, print a provided caster, wire an ESP32 and L298N, and use an ultrasonic sensor to estimate distance. The baseline challenge is intentionally narrow: approach a wall as quickly as possible and stop inside a defined target zone without contact. This gives students time to study sensor variation, PWM, stopping distance, calibration, and reliability rather than layering on multiple new features.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **FDM Printing for Fit and Function** **Purpose:** Use the FDM concepts needed to fabricate a caster that fits, rolls, and can be checked against critical dimensions.	FDM; additive manufacturing; subtractive manufacturing; CNC; layer height; orientation; support; tolerance; fit; coordinate system; workholding; toolpath; G-code; caliper	**Teacher:** Teach FDM for functional fit, compare it with CNC/subtractive workflow and precision measurement, and facilitate the first industry/WBL conversation. **Students:** Slice, print, and measure the caster; compare FDM and CNC workflows; ask a prepared industry question; and record one technical or career insight.	Printed caster and fit measurements; FDM/CNC comparison; industry/WBL question and reflection.	FDM layer/orientation examples; CNC subtraction comparison; critical-dimension callout.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 2 **Vehicle Architecture, Chassis, and Power** **Purpose:** Assemble a straight, serviceable drivetrain and understand where mechanical and electrical energy move through the robot.	Chassis, drivetrain, caster, center of mass, alignment, power path	**Teacher:** Model chassis and drivetrain assembly, alignment, center of mass, serviceability, and power flow. **Students:** Assemble the chassis, mount the drivetrain and caster, verify alignment, plan component placement, and create architecture/power sketches.	Rolling chassis; mechanical checkout; architecture and power-flow diagrams.	Exploded chassis view; center-of-mass example; mechanical and electrical power paths.
Week 3 **ESP32, L298N, and H-Bridge Motor Control** **Purpose:** Extend Q1 transistor switching so small ESP32 logic signals can control the direction and speed of two DC motors.	Microcontroller; processor; memory; GPIO; I/O; firmware; operating system; analog; digital; H-bridge; L298N; PWM; USB/UART; Bluetooth; Wi-Fi; open hardware; proprietary hardware; platform; program security	**Teacher:** Connect Q1 transistor switching to ESP32/L298N control, introducing GPIO/PWM, computing and communication architecture, platform choice, and basic code security. **Students:** Wire and test the ESP32/L298N, trace logic and power paths, test direction/PWM, map interfaces, justify the platform, and complete a security check.	Wiring checkout; H-bridge map; computing/communication map; platform/security rationale.	TIP122-to-H-bridge comparison; L298N/ESP32 pin map; motor-current paths.
Week 4 **Ultrasonic Sensing and Distance Evidence** **Purpose:** Turn repeated distance measurements into evidence the robot can use for autonomous decisions.	Ultrasonic; echo; time-of-flight; direct measurement; indirect measurement; analog; digital; signal; interface; coordinate system; reference; range; sampling; calibration	**Teacher:** Teach ultrasonic time-of-flight, calibration and noise, direct versus indirect measurement, reference coordinates, and the sensor-to-controller data path. **Students:** Calibrate the sensor against measured distance, document range and limitations, trace the data path, and define the test reference point.	Calibration data; direct/indirect measurement comparison; reference/data-path sketch; limitations.	Ultrasonic pulse/echo diagram; sensor-placement sketch; calibration plot.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 5 **PWM, Speed, and Stopping Distance** **Purpose:** Measure how commanded speed changes the distance required to stop.	PWM, duty cycle, stopping distance, braking, coasting, momentum	**Teacher:** Connect PWM to motor speed, braking/coasting, latency, battery condition, and stopping distance; establish a consistent test method. **Students:** Measure stopping distance across several PWM settings and recommend a speed from repeated trial data.	PWM/stopping-distance data; braking comparison; evidence-based speed recommendation.	PWM duty-cycle waveforms; speed/stopping-distance graph; braking versus coasting.
Week 6 **Thresholds, Safety Margins, and Autonomous Stop** **Purpose:** Use sensor evidence and a safety margin to make one consequential autonomous decision.	threshold, safety margin, latency, decision rule, tolerance, repeatability	**Teacher:** Model threshold logic, latency, sensor variation, safety margins, and repeatability for the autonomous stop. **Students:** Program the stop, choose a threshold from data, test repeatedly, tune one variable at a time, and explain the safety margin.	Autonomous stop; threshold and safety margin; repeated-trial evidence.	Threshold and safety-margin diagram; target-zone graphic; decision-rule example.
Week 7 **Autonomous Braking Challenge Development** **Purpose:** Optimize speed while maintaining control of stopping accuracy and collision risk.	Optimization, parameter, controlled variable, trial, error, target zone	**Teacher:** Formalize the braking challenge and model fair testing, parameter logs, and evidence-based optimization. **Students:** Run development trials, tune PWM and threshold values, track performance, isolate the main error source, and revise the system.	Development trial/parameter log; identified error source; documented revision.	Challenge-course diagram; parameter-log example; fair-test setup.
Week 8 **Reliability and Changed Conditions** **Purpose:** Determine whether the robot can reproduce its stopping behavior when conditions are not perfectly identical.	Reliability, success rate, failure mode, root cause, validation, revision	**Teacher:** Introduce reliability, success rate, failure modes, and root-cause analysis, then vary one relevant test condition. **Students:** Compare standard and changed-condition trials, calculate success rate, revise the main failure cause, and retest.	Reliability data and success rate; failure analysis; before/after revision evidence.	Failure-mode categories; baseline-versus-changed-condition data; success-rate example.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 9 **Final Braking Challenge, Documentation, and Concept Test** **Purpose:** Demonstrate autonomous stopping and explain how sensing, control, mechanics, and uncertainty interact.	Evidence, limitation, validation, system diagram, technical defense	**Teacher:** Facilitate official runs, documentation review, and a concept test integrating manufacturing, computing, sensing, control, measurement, and reliability. **Students:** Complete the official challenge, present system evidence, explain the threshold/safety margin and one limitation, and complete the assessment.	Official challenge; system documentation; individual explanation; concept test and reflection.	Complete robot system diagram; final evidence board; threshold rationale example.

Q3 Integrated Autonomous System

Sense, steer, climb, capture, and transition

Quarter 3 extends the same mobile robot rather than introducing a new platform. Students add IR reflectance sensing and a mechanical interface so the robot can follow a marked path up an incline, align with an elevated line, capture it, and transition from wheel-driven motion to a gravity-powered zip-line ride. The emphasis shifts from one autonomous decision to coordinating sensing, traction, geometry, timing, and construction across a multi-stage mission.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **IR Reflectance Sensing and Calibration** **Purpose:** Measure surface reflectance before asking the robot to steer from it.	Infrared; reflectance; contrast; raw value; analog; digital; threshold; signal; interface; calibration	**Teacher:** Teach IR reflectance calibration, sensor placement, thresholds, analog/digital conversion, and the sensor-to-controller data path. **Students:** Calibrate sensors across surfaces and heights, trace the data path, select decision thresholds, and document unreliable conditions.	IR calibration data; threshold/data-path explanation; placement and limitation notes.	Reflectance-by-surface graph; sensor-height diagram; threshold from raw readings.
Week 2 **Line Following and Differential Correction** **Purpose:** Use sensor feedback to keep a two-motor robot aligned with a marked path.	Differential drive, feedback, correction, sensor placement, sampling, alignment	**Teacher:** Model differential drive, feedback correction, sampling, and the oscillation caused by overly aggressive steering. **Students:** Implement and tune line following on a level path, record adjustments, and explain how placement and correction strength affect alignment.	Line-following demonstration; sensor-to-motor decision table; tuning log.	Sensor states → left/right motor corrections; feedback loop; oscillation example.
Week 3 **Incline Traction and Load** **Purpose:** Maintain sensing and alignment while the drivetrain works against gravity and changing traction.	Traction, friction, incline, load, wheel slip, center of mass	**Teacher:** Teach incline traction, wheel slip, load, center of mass, battery condition, and changing sensor geometry; model controlled testing. **Students:** Test incline performance, document failures, adjust speed/sensing/traction, and identify the largest mechanical source of variation.	Incline trial data; failure analysis; mechanical or control revision.	Incline free-body sketch; traction/wheel-slip examples; center-of-mass placement.

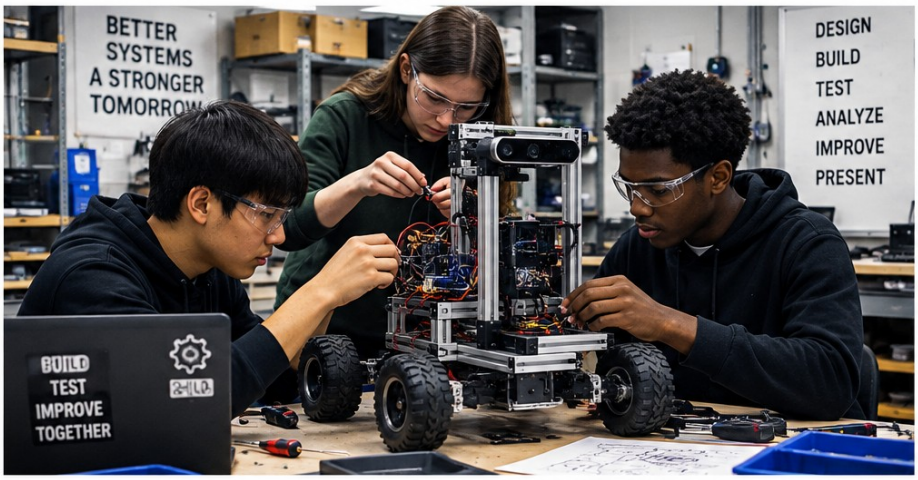
Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 4 **Zip-Line Interface Design** **Purpose:** Design the mechanical interface that allows the robot to transition from driving to suspended travel.	Interface; clearance; capture geometry; constraint; prototype; tolerance; additive manufacturing; CNC; subtractive manufacturing; fabrication choice	**Teacher:** Define zip-line capture geometry, constraints, and safety while comparing FDM, CNC/subtractive, and sheet-fabrication choices. **Students:** Sketch concepts, identify critical dimensions, compare manufacturing routes, prototype and test capture, and select a design from evidence.	Concept sketches; manufacturing decision; capture prototype and test evidence.	Annotated zip-line geometry; clearance dimensions; two interface concept sketches.
Week 5 **Prototype, Fabricate, and Verify Capture** **Purpose:** Turn the selected interface concept into a robust part and prove that it captures the line repeatedly.	Retention; friction; alignment; iteration; additive manufacturing; CNC; fabrication; fit; tolerance	**Teacher:** Model fit, retention, stiffness, and serviceability; require an additive iteration and compare its workflow with CNC/subtractive production. **Students:** Print, measure, mount, and repeatedly test the attachment; revise geometry or print settings; and explain when CNC would be preferable.	Printed attachment; fit measurements; capture data; CNC/subtractive comparison.	Prototype/CAD iteration sequence; critical dimensions; fit and retention examples.
Week 6 **Integrate the Mission Sequence** **Purpose:** Connect sensing, steering, incline motion, capture, and transition into one complete sequence.	Subsystem, integration, state, transition, sequence, interface	**Teacher:** Model subsystem interfaces and simple mission states for line following, climb/capture, and ride/stop. **Students:** Integrate verified subsystems, run slow full-sequence trials, tune the transition, log failures, and update the system diagram.	Integrated alpha mission; mission-state/system diagram; integration-failure log.	Mission-state flowchart; subsystem-interface diagram; transition-zone sketch.

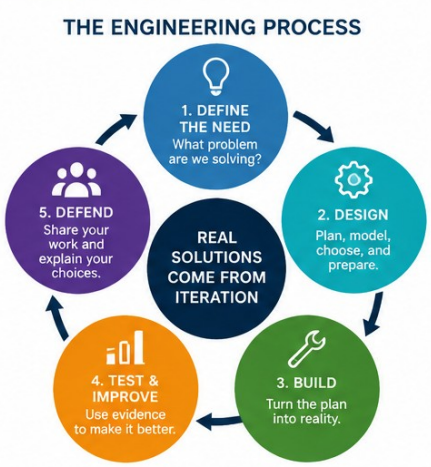
Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 7 **Full-Mission Testing and Failure Analysis** **Purpose:** Use repeated trials to identify where a multi-stage autonomous mission is least reliable.	Failure mode, root cause, reliability, success rate, controlled variable, evidence	**Teacher:** Establish a standard mission course and failure categories; model root-cause testing with one variable changed at a time. **Students:** Run repeated missions, calculate success rate, classify failures, revise the highest-priority subsystem, and retest.	Mission trial data and success rate; failure analysis; revision evidence.	Failure-source map; repeated-trial table; success-rate chart.
Week 8 **Reliability, Revision, and Extensions** **Purpose:** Meet a reliable baseline before increasing difficulty or adding features.	Iteration, optimization, extension, validation, reliability, limitation	**Teacher:** Set a baseline reliability target and approve extensions only after repeatable mission success. **Students:** Demonstrate the baseline repeatedly, make one final reliability revision, and pursue an extension only if the baseline remains reliable.	Baseline reliability; final revision; extension evidence if attempted.	Baseline-versus-extension decision graphic; reliability evidence comparison.
Week 9 **Timed Zip-Line Mission, Documentation, and Concept Test** **Purpose:** Demonstrate the integrated mission and explain how multiple imperfect subsystems became one reliable robot.	Technical defense, system evidence, reliability, limitation, reflection	**Teacher:** Facilitate the timed mission, individual technical questions, documentation review, and the Q3 concept test. **Students:** Complete official runs, present drawings and data, explain the largest uncertainty and its mitigation, state a limitation, and complete the assessment.	Official mission; technical documentation/defense; concept test and reflection.	Full mission sequence; final system diagram; concise evidence/limitation exemplar.

Q4 Team-Directed Project

Define success, reduce risk, and defend the evidence

Quarter 4 is a guided but student-directed culminating project. Teams apply the year's foundational skills to a problem or challenge they can meaningfully investigate within the available time, tools, and budget. The project is intentionally not a free-build: teams must define success, reduce technical risk early, document system interfaces, test repeatedly, and defend what their evidence does and does not show. Industry professionals serve as technical reviewers at the proposal and beta stages so students must communicate unfinished work, respond to external feedback, and connect project decisions to real careers and workplace practice.





WHAT YOU'LL DO

SET A CLEAR GOAL
Turn a real need into a focused, achievable project with measurable success.

MANAGE RISK
Identify what could go wrong, plan for it, and build safer, more reliable systems.

USE EVIDENCE
Test, analyze, and let data guide your decisions — not assumptions.

MAKE AN IMPACT
Defend your work, explain your reasoning, and show how your solution matters.

Same tools. Bigger questions. Real-world impact. DESIGN / BUILD / TEST / IMPROVE / TOGETHER

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 1 **Identify a Problem and Build Evidence** **Purpose:** Choose a project that is meaningful, safe, and achievable, then begin experimenting immediately.	Need; criteria; constraint; stakeholder; assumption; conflict resolution; diversity; leadership; WBL; career; labor; community; platform; open/proprietary; manufacturing process	**Teacher:** Set project boundaries, team agreements and conflict-resolution expectations, WBL/career context, and requirements for early risk and technology choices. **Students:** Define the problem, criteria, roles, system map, and first experiment; prepare industry questions and preliminary platform/hardware/fabrication decisions.	Problem and criteria; team agreement/roles; first system map/test; preliminary decisions and industry questions.	Example system map; criteria/constraints model; strong industry-question prompts.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 2 **Proposal and Risk-Reduction Prototype** **Purpose:** Use evidence to prove that the project should proceed at its proposed scope.	Scope; feasibility; risk; prototype; BOM; budget; professional feedback; WBL; career; industry	**Teacher:** Run proposal defenses and an industry-professional critique focused on scope, risk, budget, technical choices, and career connections. **Students:** Present the proposal, ask follow-up questions, document feedback, build a risk-reduction prototype, revise the plan, and record a WBL reflection.	Proposal/BOM/ schedule/risk; industry critique and WBL reflection; risk prototype and revised plan.	One-page proposal exemplar; simple risk matrix; BOM and schedule snapshot.
Week 3 **Develop Core Subsystems** **Purpose:** Build and verify the major parts separately before connecting everything.	Subsystem; interface; specification; operating range; data transmission; platform; open/proprietary; fabrication process	**Teacher:** Hold subsystem reviews requiring clear mechanical, electrical, and data interfaces plus justified platform, hardware, and fabrication choices. **Students:** Develop and test subsystems, document interfaces and operating ranges, and defend key technology and fabrication choices against alternatives.	Subsystem demonstrations/interfaces; technology/fabrication rationale; operating-range evidence.	Subsystem-interface diagram; specification table; expected operating-range example.
Week 4 **Integrate the Alpha System** **Purpose:** Connect verified subsystems and find problems caused by their interaction.	Integration, alpha prototype, interference, fault	**Teacher:** Lead an alpha review focused on integration failures across power, geometry, wiring, timing, code, safety, and serviceability. **Students:** Integrate the main function, log failures, update documentation/code, and revise the schedule around the highest-priority problems.	Alpha prototype; integration-failure log; updated documentation and schedule.	Alpha integration map; annotated interference/failure example; updated system diagram.
Week 5 **Minimum Viable Robot** **Purpose:** Produce a complete but unfinished system that meets the essential success criteria.	Minimum viable robot, acceptance criteria, test plan, fault response	**Teacher:** Help teams define the minimum viable robot, acceptance test plan, and safe behavior when a fault occurs. **Students:** Demonstrate the full sequence, compare it with criteria, test one fault condition, identify the weakest subsystem, and prioritize revision.	Minimum viable robot; test plan/fault response; midpoint defense and revision plan.	Acceptance-test plan; minimum-viable-system diagram; fault-response flowchart.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 6 **Test, Break, and Reengineer** **Purpose:** Expose failure modes through repeated testing and redesign an important weak point.	Failure mode, root cause, redesign, controlled variable	**Teacher:** Require stress tests and root-cause analysis across mechanical, electrical, sensing, software, fabrication, and operator causes. **Students:** Test under at least two conditions, classify failures, redesign one critical weakness, and compare performance before and after the change.	Repeated-trial data; failure analysis; redesign before/after evidence; safety recheck.	Root-cause diagram; before/after redesign evidence; controlled-variable example.
Week 7 **Reliability, Usability, and Peer Review** **Purpose:** Improve not only whether the robot works, but whether another person can understand and operate it.	Reliability; usability; beta prototype; professional feedback; customer service; WBL; career; maintenance	**Teacher:** Organize peer/user testing and an industry beta review focused on reliability, usability, maintenance, customer-service communication, and professional feedback. **Students:** Support external evaluators, capture and prioritize feedback, revise reliability/usability, update instructions, and connect one comment to a technical or career insight.	Beta prototype; professional/user feedback; response and reliability evidence; updated instructions/WBL reflection.	User-test checklist; serviceability callouts; feedback-to-revision example.
Week 8 **Final Build and Technical Story** **Purpose:** Complete the system and organize evidence so another person can understand what was built and how well it works.	Prototype freeze; claim; limitation; citation; technical portfolio; handoff; career management	**Teacher:** Conduct final readiness review of evidence, documentation, code security/handoff, and remaining time and resources. **Students:** Freeze the build, finish the portfolio, complete the code/handoff check, prioritize final work, and rehearse an evidence-based explanation.	Final prototype/portfolio; security/handoff check; readiness/time plan; individual technical story.	Technical-portfolio exemplar; claim → evidence → limitation layout; final diagram set.

Week and Focus	Vocabulary	Learning Plan	Evidence Due	Student Visuals / Reference
Week 9 **Public Demonstration and Final Defense** **Purpose:** Demonstrate the robot publicly and explain what it can do reliably, what remains uncertain, and what the team learned from iteration.	Validation, demonstration, defense, evidence, reflection	**Teacher:** Facilitate the public demonstration, individual defense, final assessment, and career/WBL synthesis. **Students:** Demonstrate the system, defend decisions with evidence, state limitations, reflect on growth, and identify a next technical, WBL, or career step.	Final demonstration/portfolio; individual defense; career/WBL reflection; final assessment.	Demo flow and defense prompts; final evidence board; reflection structure.

Course Throughline

The year begins by slowing down: students learn where energy flows, how circuits are connected, how measurements reveal what a system is doing, and why documentation matters. Quarter 2 adds programmable control and ultrasonic sensing inside a deliberately narrow autonomous braking problem, giving students time to connect sensor evidence with speed, stopping distance, and safety margins. Quarter 3 keeps the same mobile platform but adds IR sensing, line following, incline traction, and a student-designed zip-line interface so students must coordinate multiple imperfect subsystems. By Quarter 4, students have enough shared language and skill to make more independent engineering decisions.

Across all four quarters, uncertainty is not treated as a problem that disappears once the robot is "finished." It is the condition that makes robotics worth studying. Students learn that digital models and simulations are useful but incomplete, that hardware varies, and that one successful trial is weak evidence. Reliable performance comes from careful construction, calibration, measurement, repeated testing, honest documentation, and focused revision.

The course therefore measures more than whether a robot works on demonstration day. Students are expected to understand the systems they build, communicate technical evidence clearly, troubleshoot when reality differs from the plan, contribute dependable work to a team, interact professionally with people working in technical fields, use external feedback without surrendering their own judgment, and leave the course better prepared to learn unfamiliar tools and technologies in the future.