

Robotics and Automation Outreach Program (RAOP)

RAOP 2026 Educator Guide to Robotics and Automation

Laboratory Activities and Classroom Integration

Howard University
NSF Robert Noyce Teacher Scholarship Program
Research Experiences in STEM Settings
Award Number 2503860
Prepared by the RAOP Project Team
2026 Edition

Principal Investigator: Dr. Fadel Lashhab

Co-Principal Investigators: Dr. Imtiaz Ahmed and Dr. Katherine Picho

A practical guide for participating STEM educators and the RAOP team, connecting research experience, guided inquiry-based learning, and school teaching.

The guide presents the program sequence, illustrated platform activities, classroom planning, and the T1–T6 assessment framework. It provides the foundation for an adaptable curriculum informed by educator experience and continued evaluation.

Contents

1 Program Purpose and Scope	2
2 Program Objectives and Curriculum Development	2
3 Recruitment, Support, and Educator Groups	4
4 Program Schedule and Delivery	6
5 Resources and Software Preparation	7
6 Sensors, Communication, and Guided Inquiry-Based Learning	10
7 Activity Workflow and Evidence	12
8 Group 1: Qube-Servo 3	13
9 Group 2: Aero 2	16
10 Group 3: QArm	18
11 Group 4: QBot Platform	21
12 Laboratory Practice and Advanced Demonstrations	24
13 Classroom Integration and October Follow-Up	27
14 Assessment and Evaluation Framework	28
15 Reviewing Learning and Organizing Evidence	32
16 Lessons Learned from the 2026 Cycle	32
17 Activity Planning and Facilitation Records	34
18 Program and Technical Resource Links	35



Empowering STEM Educators Through Robotics and Automation

Robotics and Automation Outreach Program (RAOP)

NSF Robert Noyce Teacher Scholarship Program

Research Experiences in STEM Settings (RESS) | Howard University | AVRC Lab
NSF Award #2503860

2026 Noyce Summit | Washington, DC | June 30–July 2, 2026

PI: Dr. Fadel M. Lashhab | Co-PIs: Dr. Imtiaz Ahmed, Dr. Katherine Picho



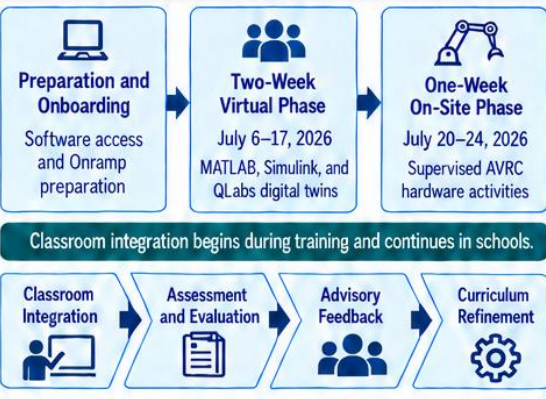
1867
HOWARD
UNIVERSITY

PROJECT OBJECTIVES



- Research experience in robotics and automation
- Guided inquiry-based learning
- Digital-twin practice and hardware investigation
- Classroom, course, and club integration
- User-friendly, adaptable grades 6–12 curriculum

RAOP PROGRAM STRUCTURE



INTENDED PROGRAM OUTCOMES



- Educators connect robotics and automation research with teaching.
- Learning is adapted for courses, curriculum units, after-school activities, and clubs.
- Educator feedback informs an adaptable curriculum across five annual cycles.
- Assessment and follow-up document classroom use and guide improvement.

IMPLEMENTATION FOLLOW-UP



October 2026: examine how educators use and adapt the learning in their schools.

PROJECT INPUTS



- NSF award support
- Howard University faculty and AVRC Laboratory
- PI, co-PIs, advisory board, and training assistants
- Eight educators in the 2026 cohort
- Four core robotics platforms
- Quanser industrial partner: platforms, QLABs access, and technical resources
- MathWorks STEM Outreach License: MATLAB and Simulink

MathWorks license access was approved and shared one month before training for MATLAB Onramp and Simulink Onramp preparation.

PLATFORM ACTIVITY MAP

1		Qube-Servo 3	DC motor, encoders, and feedback
2		Aero 2	Rotor sensing, pitch, and yaw
3		QArm	Joint motion, manipulation, and sensing
4		QBot Platform	Mobile ground robotics and sensing

Introductory and advanced activities in virtual and physical settings.
Assigned pairs during virtual work; all four platforms during on-site rotations.

ASSESSMENT AND EVALUATION: T1 – T6

T1	Setup Readiness Form	Before virtual instruction
T2	Virtual Lab Checkpoint Form	End of virtual phase
T3	Hardware On-Site Checkpoint Form	End of on-site phase
T4	Participant Feedback Survey	End of on-site phase
T5	Group Discussion and Classroom Translation Form	July 24, 2026
T6	Advisory Board Feedback Form	Initial and follow-up reviews

CONTINUOUS CURRICULUM IMPROVEMENT



1 Program Purpose and Scope

The Robotics and Automation Outreach Program (RAOP) provides pre-service and in-service STEM educators with a research experience that connects robotics and automation with teaching. Its central objective is classroom integration: educators bring the knowledge, practical experience, and instructional ideas developed through the program back to their schools. They can incorporate these ideas into courses, curriculum units, after-school activities, and clubs while continuing their own inquiry and professional learning.

RAOP is supported by the National Science Foundation through Award Number 2503860, titled Robert Noyce Teacher Scholarship Program RESS Project: Empowering STEM Educators through Robotics and Automation. The award period is October 1, 2025, through September 30, 2030. Howard University hosts the program through the Autonomous Vehicle, Robotics and Control (AVRC) Laboratory.

The 2026 pilot involved eight educators: two pre-service and six in-service educators. The learning sequence comprised two weeks of virtual instruction using MATLAB, Simulink, and Quanser Interactive Labs (QLabs), followed by one week of on-site laboratory experience. Educators worked in pairs on Qube-Servo 3, Aero 2, QArm, or QBot Platform during the virtual phase and rotated through all four platforms on site.

This guide serves two related audiences. Participating educators use it to understand the equipment, conduct supported investigations, interpret evidence, and develop school activities. RAOP facilitators—the project team members, mentors, and training assistants assigned to lead sessions—use it to prepare resources, supervise equipment, guide inquiry, and review learning. In school settings, the participating educator takes the teaching role and adapts the activity to the students and available resources.

The guide emphasizes sensors, actuators, software and hardware interfaces, data collection, and interpretation. The school activities are proposed adaptations for high school teaching, with scope for adjustment within grades 6–12. Educators will examine classroom use and suitability through follow-up, beginning in October 2026, and in subsequent program cycles.

Use platform activities with the assigned models, manufacturer documentation, and AVRC operating procedures. The functional diagrams explain how components interact; the platform guides specify physical connections, operating limits, and startup and shutdown procedures.

2 Program Objectives and Curriculum Development

Guided inquiry-based learning is an explicit RAOP objective. Educators investigate a practical question, make a prediction, collect measurements, interpret the evidence, and explain a result. Facilitators provide a manageable question, tested resources, and sufficient support while leaving space for educators to reason, compare observations, and decide what the evidence means.

Educational objectives

1. Develop practical understanding of robotics and automation by identifying sensors, actuators, commands, measurements, and the interfaces that connect them.

2. Use MATLAB and Simulink with QLABs digital twins to investigate a system before working with physical equipment.
3. Collect and interpret data from supervised hardware activities, including encoder measurements, plots, images, and other available sensor outputs.
4. Apply guided inquiry-based learning to connect a question, a controlled investigation, and an explanation supported by evidence.
5. Adapt selected concepts into realistic learning experiences for school courses, curriculum units, after-school programs, and clubs.
6. Contribute lessons learned to a user-friendly curriculum that is expanded, evaluated, and refined across annual cycles.

Five instructional modules

Module 1 establishes foundations in sensors, actuators, signals, software interfaces, graph interpretation, and guided inquiry-based learning. Educators begin with the physical meaning of a measurement and the purpose of an activity.

Module 2 develops virtual laboratory experience. Educators use QLABs with MATLAB and Simulink to investigate their assigned platform and prepare evidence for T2. The 2026 assignment included one introductory activity and one advanced activity using the designated resources.

Module 3 provides supervised hardware experience. Educators work across the four core platforms, observe actual components and connections, collect measurements, and compare physical behavior with relevant virtual observations. T3 records evidence of completion and demonstrated competency.

Module 4 develops classroom translation. Educators select a concept that fits their teaching, define a student learning objective, and prepare a feasible activity. Planning begins during technical instruction and continues through the T4 feedback survey, T5 discussion, and academic-year follow-up.

Module 5 supports annual curriculum development. The team uses assessment evidence, educator implementation experiences, and T6 advisory feedback to revise subsequent activities. Later cycles will expand examples, examine their suitability for different teaching contexts, and refine the instructions and assessment approach.

Program inputs and partnerships

Program inputs include NSF support, Howard University faculty and laboratory resources, educator participation, training assistance, and advisory feedback. MathWorks supported the program through an approved STEM Outreach License for MATLAB and Simulink. MathWorks shared license access with participants one month before the program began, enabling advance preparation through MATLAB Onramp and Simulink Onramp. Quanser serves as the industrial partner, providing robotics platforms, digital twins, technical resources, and instructional support. Together, these contributions support educators' preparation, research experience, and classroom integration.

Laboratory areas and progression

The control laboratory area in the AVRC Laboratory includes Qube-Servo 3, Aero 2, and 3 DOF Hover. Qube-Servo 3 provides a starting point for DC motor operation, encoder measurements, and the inertia disk or pendulum. A disk exercise can focus on one motor input and one measured output, such as angular position. Adding the pendulum introduces another measured angle while retaining one motor input.

Aero 2 extends the discussion to a two-rotor aerospace model. In its helicopter configuration, educators can observe pitch and yaw and discuss how two motor inputs affect two angular outputs. The 3 DOF Hover provides a further laboratory example with four motor inputs and measured roll, pitch, and yaw. These systems illustrate the progression from single-input, single-output (SISO) examples to multi-input, multi-output (MIMO) systems. The number of inputs and outputs refers to the signals selected for the activity, not simply the number of parts visible on the equipment.

The manipulation area uses QArm to introduce joint motion, a gripper, sensing, and a sequence of actions for handling an object. The mobile robotics area uses the QBot Platform as a ground vehicle for motion, wheel measurements, and observing the surrounding environment. QDrone 2 provides an additional example of aerial robotics through a facilitator-led demonstration in the Autonomous Vehicle Research Studio (AVRS).

The common starting point is understanding components and evidence. Advanced controller design, forward kinematics, and inverse kinematics remain extension topics. Educators can develop meaningful school activities without deriving these methods.

3 Recruitment, Support, and Educator Groups

Project leadership and teaching roles

The principal investigator, Dr. Fadel Lashhab, and co-principal investigators, Dr. Imtiaz Ahmed and Dr. Katherine Picho, lead the project, coordinate instruction and evaluation, and review program evidence. RAOP facilitators demonstrate procedures, support investigations, and connect laboratory work to teaching. The session lead assigns responsibility for technical assistance, hardware supervision, and assessment so educators know where to obtain help.

Recruitment and application process

RAOP recruits in-service teachers from high-need local education agencies and pre-service teachers pursuing certification, focusing on Washington, DC, Maryland, and Virginia. The published recruitment process includes district outreach, information sessions, and online announcements. Selection considers program alignment, readiness to participate, and a feasible plan for using robotics and automation in teaching.

Applications are submitted through the RAOP portal and include a résumé, eligibility documentation, a statement of purpose, a classroom integration plan, and a recommendation. In-service applicants provide a teaching certificate and employment verification; pre-service applicants provide a transcript and an advisor's confirmation of progress toward certification. The review process includes eligibility screening, rubric-based assessment, interviews for shortlisted applicants, offers, and onboarding. The application portal provides cycle-specific dates and requirements.

RAOP recruitment and selection

RAOP application portal

Participant support

The published support package provides up to \$5,900 per eligible educator: \$1,000 for virtual participation, \$2,000 for on-site participation, up to \$2,400 for housing, and up to \$500 for travel. Housing and travel support depend on eligibility and program arrangements. These amounts describe available support; actual payments depend on the applicable participation and administrative requirements.

Academic and technical support include software and account preparation, troubleshooting, curated resources, guided laboratory work, and assistance with classroom planning. During the 2026 cycle, onboarding and a technical follow-up session preceded virtual instruction, and virtual support was provided three times weekly. Individual assistance and on-site station support helped educators with different levels of prior experience engage with the activities.

RAOP participant support

2026 cohort and platform groups

Educators collaborate in pairs while maintaining individual explanations and assessment records. Partners may share a model, discuss results, and collect evidence together. Each educator should be able to explain the task, identify the main input and output, interpret the evidence, and describe a possible school activity. Facilitators should invite both partners to operate the system and discuss the results.

The 2026 group numbers corresponded to the four core experiments. The following overview connects each group with its platform, accessible learning objective, and intended educator outcome. Detailed activities appear in Sections 8–11.

Group	Platform	Learning objective	Intended educator outcome
1	Qube-Servo 3	Connect motor actuation with encoder measurements and observed rotation.	A labeled signal path, plot, and school activity about rotation or measurement.
2	Aero 2	Distinguish rotor motion, pitch, and yaw using identified sensor signals.	An explanation of the measurements and a school activity using motion data.
3	QArm	Relate joint commands, measured positions, and a gripper action sequence.	An annotated automation sequence and a feasible manipulation activity.
4	QBot Platform	Connect ground movement with wheel measurements and environmental sensing.	A motion record, sensor comparison, and school activity about routes or sensing.

The 2026 pair assignments were P05 and P07 in Group 1; P04 and P06 in Group 2; P01 and P08 in Group 3; and P02 and P03 in Group 4. During the on-site week, the groups rotated through all four core platforms.

The table identifies each platform's learning focus and intended outputs. The activity explanations and the T2 and T3 criteria assess individual understanding.

The required virtual workload consisted of one introductory activity and one advanced activity on the assigned platform. Additional introductory or advanced activities were optional enrichment. Facilitators should make this distinction explicit when distributing materials, estimating workload, and reviewing T2 submissions.

Assessment summaries use educator identifiers. The name-to-identifier record is maintained separately, and training assistant participation is distinguished from educator participation.

4 Program Schedule and Delivery

The first-cycle sequence began with onboarding on June 15 and a technical follow-up session on June 29. The T1 readiness deadline was July 3. Virtual instruction ran from July 6 through July 17, followed by on-site instruction from July 20 through July 24. This progression allowed educators to encounter the digital twin before investigating the corresponding physical system.

Preparation and onboarding

Before the virtual phase, the team provides the program schedule, software and account instructions, platform assignments, technical resources, and assessment expectations. T1 identifies completed setup tasks and areas requiring assistance. The team should review each educator's readiness status and arrange support before the assigned virtual activity begins.

Virtual instruction

The first virtual week introduces the program's inquiry approach and the assigned platform's introductory activity. The second week develops the advanced activity, evidence interpretation, and an initial classroom translation plan. Virtual support was provided three times weekly during the 2026 cycle. Facilitators should reserve support time for both access problems and questions about the meaning of the results.

The T2 submission deadline was July 16 at 11:59 p.m., with final virtual review on July 17. Educators prepared individual explanations and evidence for the required introductory and advanced activities. Review and technical assistance supported the transition to hardware work.

On-site instruction

The on-site week combines supervised introductory and advanced hardware activities with interpretation, comparison, and classroom planning. Advanced assignments use prepared models and guided observation; they do not require all educators to derive advanced control or kinematic methods. Facilitators organize station rotations, explain the expected evidence at each platform, and allocate time for individual documentation. Educators should save their work throughout the week rather than reconstruct it at the final checkpoint.

T3 and T4 were scheduled for July 24. The T5 guide was distributed on July 23 in preparation for the July 24 group discussion, which addressed learning, the program experience, and classroom integration.

Advisory review and follow-up

The initial advisory meeting, T6-1, occurred on July 7. A subsequent advisory review, T6-2, is planned to examine first-cycle outcomes and recommendations. The October 2026 educator follow-up will focus on implementation in courses, curriculum units, after-school programs, and clubs.

5 Resources and Software Preparation

Program information and resources are available through the [RAOP program website](https://avrc-lab.org/raop), <https://avrc-lab.org/raop>, and the AVRC Laboratory website, <https://avrc-lab.org/>. Educators can access activities, participant support, curriculum information, and technical links. Section 18 provides direct links to the resources used throughout this guide.

Each educator should receive setup instructions, the relevant quick-start and user guides, concept reviews, introductory and advanced activity instructions, evidence requirements, and the applicable assessment forms. Facilitators should identify required preparation clearly and provide optional resources separately.

Software pathway

The 2026 instructional pathway used MATLAB and Simulink with Quanser Interactive Labs (QLabs) for virtual activities. Hardware activities used the configured software and QUARC environment on AVRC Laboratory computers. Educators should follow the virtual setup instructions for their own computers; the hardware installation pathway is addressed through laboratory preparation.

Software versions and components must match the assigned activity. Facilitators should select the supported release, confirm the required toolboxes and account permissions, and test the starter models before distributing them. [Quanser's PC Setup Guide](#) distinguishes the MATLAB and Simulink installation pathways for virtual and hardware use and should be consulted when preparing the environment.

Finding and organizing the assigned resources

Start with the RAOP Activities page and Resource Navigator, then open the assigned platform guide. The facilitator provides the required resources in teaching order: setup instructions, platform documentation, a quick-start model, the introductory investigation, and the designated extension. Clearly label required work and optional resources.

The [Quanser Academic Resources repository](#) supplies libraries, setup materials, quick-start guides, user manuals, concept reviews, research examples, and teaching activities. Use the branch and files specified for the session. Download the ZIP archive from the repository's Code menu and extract it to a stable folder (e.g., Documents/Quanser) or use a facilitator-approved Git clone. Open models from the extracted folder and save activity work separately from the supplied examples.

The main folders are 0_libraries, 1_setup, 2_quick_start_guides, 3_user_manuals, 4_concept_reviews, 5_research, 6_teaching, and docs. The facilitator identifies the subset needed for each activity and records the resource version used. Educators preparing a school lesson can then select a manageable set of instructions, images, or data for their students.

Virtual setup sequence

1. Confirm the educator's computer access, institutional installation permissions, MathWorks account, and access to the approved MATLAB and Simulink license.
2. Install or verify the selected MATLAB and Simulink release and the required toolboxes. Resolve compatibility issues before adding the virtual environment.
3. In MATLAB, open Add-Ons, locate Quanser Interactive Labs for MATLAB, and follow the installation instructions for the selected release.
4. Complete the QLABs setup process. Where specified by the installed toolbox, run QLABs.setup and then QLABs.launch in the MATLAB Command Window.
5. Sign in with the Quanser Academic Portal account assigned to the educator and confirm access to the required virtual platform.

6. Open the assigned starter model, run a basic example, and verify that the virtual platform responds and the relevant output can be viewed.
7. Record readiness and support needs in T1. Retain the model name, software release, error message, or diagnostic information needed to resolve any remaining issue.

When a setup problem occurs, the facilitator should first identify whether it concerns account access, permissions, version compatibility, file paths, or model configuration. Reinstallation should follow a diagnosed need and the relevant technical guidance. A successful login alone does not establish readiness to run the assigned activity.

Facilitator quick-start verification before an activity

Treat the manufacturer's quick-start guide for the assigned platform as the operating reference for connections, startup, the baseline model, shutdown, and troubleshooting. Before an educator begins an activity, the facilitator should complete the applicable verification below with the exact software release and resource files selected for the cycle. A verified baseline separates installation or communication problems from questions raised during the investigation.

1. **Qube-Servo 3:** confirm the required module, 24 V power supply, USB connection, device recognition, and green power status. Attach the inertia disk for the introductory activity, open the supplied Simulink quick-start model, run it with Monitor and Tune, confirm that the position and motor-voltage displays respond, and stop the model through Simulink.
2. **Aero 2:** confirm the intended thruster orientation, disengage the pitch and yaw locks for the two-axis activity, provide the required clear space, inspect the guarded propellers, and verify power and USB status. Run the supplied quick-start model and confirm the expected startup indication and measured yaw and motor-current signals before educator use.
3. **QArm:** secure the base to the work surface, maintain the clear workspace specified in the quick-start guide, connect the arm interface and optional camera through their separate cables, and place the arm in the documented home configuration before power-up. Run the supplied quick-start model, confirm measured joint responses, return the arm to the prescribed position, support it during power-down, and place it in the documented rest configuration.
4. **QBot Platform virtual:** confirm Academic Portal and QLab access, launch the designated QBot workspace, open the virtual quick-start model, and verify that the robot can be armed and moved with the documented keyboard controls while the available camera and LiDAR display update.
5. **QBot Platform hardware:** confirm a charged battery, attached Wi-Fi antennas, network connection, displayed IP address, and a successful connection test from the development computer. Start the supplied physical driver on the robot, configure the quick-start model with the displayed address, verify the documented driver and application status indications, and test motion only in the prepared operating area. Stop the application and complete the documented platform shutdown.

These checkpoints confirm baseline operation; they are not substitutes for the complete quick-start guides or laboratory safety procedures. Record the guide version, model name, software release, result, and any unresolved diagnostic message in the technical support record.

6 Sensors, Communication, and Guided Inquiry-Based Learning

Understanding the physical system

A robotics system connects software, electronics, and moving equipment. A running application writes a command through the platform interface. Motor electronics provide power to an actuator, and sensors measure the resulting motion or other physical quantities. Measurements return to the application for display, recording, or feedback control. Educators operate and investigate this system, then adapt the learning for their students.

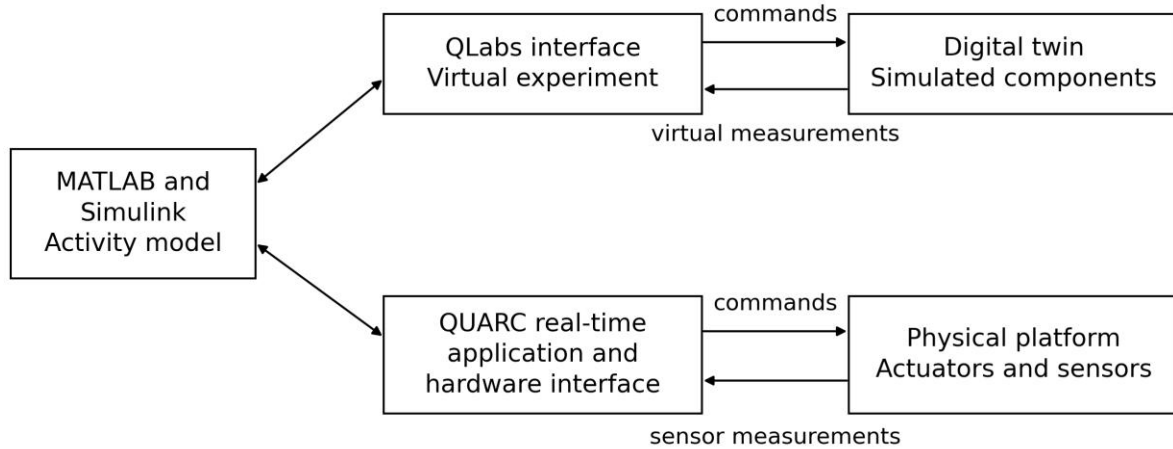


Figure 1. Virtual and physical pathways used in the program. QLABs provides the virtual environment; QUARC supports configured real-time hardware applications. The diagram summarizes the learning pathways and does not prescribe one connection method for every platform.

Component	Role in the system	Example for discussion
Sensor	Measures a physical quantity.	An encoder measures rotation; a camera records a view.
Actuator	Produces physical action.	A DC motor turns a shaft or wheel.
DAQ and interface	Acquires measurements and exchanges commands with the application.	Encoder input and motor command channels.
Amplifier or drive	Uses electrical power to operate the motor in response to a command.	Integrated amplifier on Qube-Servo 3.
Control application	Runs the selected logic and can use measurements to determine commands.	A prepared Simulink and QUARC model.
Communication link	Carries data between configured devices.	USB at a control station or a network link for a mobile platform.
Display and data record	Makes the signals available for inspection and comparison.	Scope, plot, logged values, image, or scan.

A signal is information carried between components. A command may represent motor voltage, desired joint angle, forward speed, or another quantity defined by the model. A measurement represents information obtained from a sensor or calculated from measured data. An amplifier supplies actuator power; a sensor measures behavior. QUARC is software and does not replace the power amplifier, data acquisition electronics, or sensor.

In feedback control, a controller uses a measurement to adjust a command toward a desired result, called the reference. For example, a joint controller compares a desired angle with the measured angle and adjusts motor actuation. The difference between the reference and measurement is the error. In an open-loop trial, the command is applied without using the measured response to correct it; measurements may still be displayed and recorded.

A digital twin is a software representation of a physical system used to explore its behavior. It allows educators to inspect signals and test prepared activities before entering the laboratory. A physical trial adds the actual equipment and operating conditions, providing an opportunity to compare the model with measured behavior.

Reading and writing with QUARC

QUARC supports real-time applications built from Simulink models. The selected target and platform driver determine where the application runs and how it communicates with the hardware. On a USB-connected control platform, the application exchanges data with the integrated interface. On a mobile platform, the configured application may run on the onboard computer. Follow the tested model for the station.

In a typical encoder activity, HIL Read Encoder obtains encoder counts from the configured channels. The model converts these values to useful units where required. HIL Write Analog writes an analog command on hardware that supports that interface. Other platforms use different command types and blocks: QArm may accept a joint position, and a QBot activity may accept motion references through its driver. Read and write refer to data direction relative to the application; they do not imply that every platform uses an analog voltage command.

1. Open the facilitator-tested model and identify the hardware initialization or platform interface. Confirm the selected device and target with the facilitator.
2. Locate one measurement block and trace its output to a display or Scope. Identify the quantity, units, and sampling information provided by the model.
3. Locate the command path. State whether the selected value represents voltage, angle, speed, or another defined quantity.
4. Run the approved baseline and record a short interval of command and measured data. Keep the time axis and units visible.
5. Compare a second facilitator-approved condition. In virtual work, educators may investigate an approved change; on hardware, operating limits and control settings remain under facilitator supervision.
6. Explain one observation using the saved data and identify a related question that students could investigate in school.

An encoder counts increments of rotation. When conversion is needed, the angle change in degrees equals 360 multiplied by the change in counts and divided by the configured counts per revolution. For a calculation using 2,048 counts per revolution, a change of 1,024 counts corresponds to half a revolution, or 180 degrees. This is a numerical example; the facilitator must use the correct encoder specification and starting reference for the actual channel. Some interfaces already report radians or degrees and must not be converted again.

Guided inquiry-based learning in practice

In guided inquiry-based learning, the facilitator frames the problem and provides the equipment, resources, and boundaries for the investigation. Educators make predictions, examine data, compare observations, and explain what they find. This approach structures a new technical task while preserving the educator's responsibility to reason from evidence.

For example, a group may investigate how measured disk rotation changes during two predefined motor trials. Before running the model, educators predict which plot will change and explain why. They then compare the traces, identify the relevant measurements, and decide whether the observations support their prediction. The discussion should connect the graph to the physical motor and encoder.

Begin with a small question that the available evidence can answer. Keep other conditions comparable, label the data, and repeat runs as needed. If virtual and physical results differ, first compare the setup and test conditions. Explanations involving friction, noise, or delay should be treated as possible causes until supported by evidence.

A school adaptation may use a digital twin, a teacher demonstration, or recorded data. Students can make predictions, interpret plots or images, and explain a result even when the school does not own the research platform. The educator selects the version that fits the course and available resources.

7 Activity Workflow and Evidence

The following workflow applies to each platform. It provides a consistent instructional structure while allowing the technical procedures to vary with the assigned model and hardware.

1. State the guiding question and its practical or classroom relevance. Identify the main concept and the evidence needed to examine it.
2. Review the assigned quick-start guide and the relevant operating procedure. Confirm the platform configuration, model version, starting condition, and stop procedure.
3. Run the baseline case using the approved settings. Identify the command, measured response, and relevant signal or sensor output.
4. Compare two approved conditions. Record the difference and keep other relevant conditions as consistent as possible. Hardware settings and operating limits are controlled by the supervising facilitator.
5. Save the model view and the plots, screenshots, measurements, or observations required by the activity. Label the platform, phase, activity, conditions, and units.

6. Explain the result. Describe the observable difference and connect it to the activity question without making claims beyond the evidence.
7. During hardware work, compare the physical response with the relevant virtual result. Record differences in configuration or test conditions that limit the comparison.
8. Develop a school activity with a clear learning objective, student task, resource requirement, and method for checking understanding.
9. Save the individual report, confirm that it opens correctly, and complete the applicable assessment record. Follow the approved shutdown procedure before leaving the station.

File names should identify the educator, platform, phase, and activity. For example, P01_QArm_Virtual_Introductory_Report clearly identifies a document without including a participant's name. Keep the model or source file, evidence images, and written explanation together in the assigned folder.

Identify shared evidence as collaborative work. Individual reports should contain each educator's own interpretation and classroom translation. Facilitators should avoid accepting identical partner explanations as evidence that both educators can independently interpret the activity.

8 Group 1: Qube-Servo 3

The Qube-Servo 3 group introduces control fundamentals through a DC motor, an encoder, and a removable inertia disk or rotary pendulum. The accessible starting point is observing rotation and understanding how software commands and encoder measurements relate to the physical equipment.



Figure 2. Qube-Servo 3 with the rotary pendulum attachment. The inertia disk is used for the beginner motor and measurement activity described below.

Objective and intended outcome

The objective is to identify the motor, encoder, integrated data acquisition system, power amplifier, and software interface, then use a short measurement record to explain motor motion. The intended educator outcome is an annotated signal path, a labeled plot, and a school activity about rotation, measurement, or feedback.

Components and their interaction

The integrated data acquisition system communicates with the computer through USB. A command passes to the power amplifier, which drives the DC motor. The motor encoder measures shaft rotation. With the pendulum installed, a second encoder measures its angle. Current sensing provides an additional measurement of motor operation. The Qube-Servo 3 user manual explains the physical components and interface in detail.

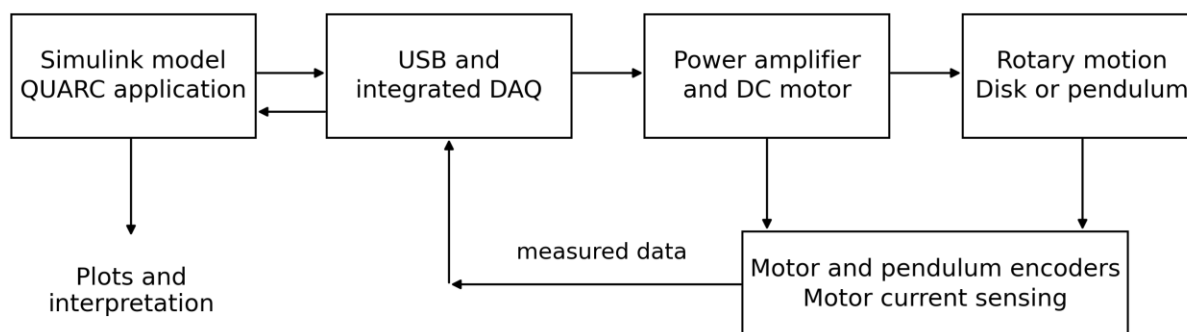


Figure 3. Simplified Qube-Servo 3 command and measurement paths, based on the Quanser user manual. The DAQ exchanges commands and measurements with the application; the amplifier drives the motor using the external power supply. The pendulum encoder is used when that attachment is fitted.

Proposed beginner activity on rotation and measurement

Guiding question: How does the encoder record the motion of the inertia disk? Begin with QLABs and the assigned instrumentation model. The physical activity uses a facilitator-tested model with the disk securely installed, a clear operating area, and an established stop procedure.

1. Identify the disk, motor, encoder, USB connection, power connection, command display, and measured output.
2. Predict how the measured angle will change during the facilitator's predefined short movement.
3. Run the virtual baseline and record the commanded quantity and measured angle on labeled time plots. Identify whether the displayed angle is already scaled.
4. Compare a second approved virtual trial, such as a different short command sequence. Explain the difference using the plots.
5. Repeat the corresponding approved trial on physical hardware under supervision. Observe without touching moving parts.

6. Compare the virtual and physical records and write a short explanation of one similarity or difference.

Evidence and school adaptation

Save an annotated model view, one labeled comparison plot, the test conditions, and a short explanation. Educators should distinguish the command from the measured angle and identify which component produced the measurement. An optional analysis compares how quickly the angle changes over equal time intervals.

A proposed high school activity asks students to use a prepared encoder data set to calculate fractions of a revolution, label an angle-versus-time graph, and explain when the disk was moving or stationary. A teacher can demonstrate the same idea with a digital twin. The activity connects to angular measurement, graph interpretation, and the relationship between a sensor and a physical quantity. Check understanding by asking students to justify one statement directly from the graph.

Learning checks for interfacing

Use the Qube-Servo 3 Hardware Interfacing application guide and its recommended assessment to connect the physical disk to the displayed measurement. Ask educators to document the encoder reference before and after restarting the approved model, compare the measured count change for a known rotation with the user-manual specification, and state the conversion used for degrees or radians. Record the viewing direction when describing clockwise or counterclockwise motion. Do not assume that a restart preserves the previous count reference.

The evidence should show the starting reference, the count change, the units, and the physical observation. A satisfactory explanation identifies the encoder as the measurement source and uses the correct scale for the selected channel. If the model already reports an angle, the educator should explain that scaling should be applied rather than applied again. A school version can use a facilitator-provided data record and a photograph showing the viewing direction.

Proposed investigation of speed measurement and filtering

After the interfacing activity, use the Qube-Servo 3 Filtering guide to ask: How does smoothing change a speed estimate calculated from encoder position? Begin with the inertia disk and a tested model or recorded data. Position readings have finite resolution, and estimating speed from changes over short time intervals can make quantization effects and measurement noise more prominent. A low-pass filter can reduce rapid fluctuations but may also delay or smooth real changes in motion.

1. Identify the position signal, the speed estimate derived from it, and the filtered estimate. Use the same recorded trial and time interval for the comparison.
2. Predict which changes will remain visible after filtering. Compare the traces on matching axes and label the units.
3. Describe both the reduction in fluctuations and any delay or loss of detail. A smoother trace alone does not establish greater measurement accuracy.

4. Where the model provides a separate speed channel labeled tachometer, compare it with the estimate derived from position. Identify each channel using the hardware documentation and avoid assuming that the label implies a separate physical sensor.

The learning check asks for one labeled comparison and an explanation of the benefit and trade-off of filtering. For high school use, students can compare prepared plots without constructing a filter or using calculus. The manufacturer's cutoff-frequency calculation is an optional facilitator extension once students understand the qualitative concept.

The advanced experiment included pendulum swing-up and balancing control with prepared models. This provides a guided observation or extension after the motor and encoder concepts are clear. Educators can compare disk and pendulum behavior without deriving an advanced control law. The pendulum adds a measured angle; it does not add a second motor input.

[Qube Servo 3 teaching resources](#)

[Qube Servo 3 user manual](#)

9 Group 2: Aero 2

The Aero 2 group connects sensing and actuation to the motion of a two-rotor aerospace model. The platform can represent different configurations, including a helicopter model with pitch and yaw motion. Educators first learn what the motors and sensors do, then examine a small set of measured signals.



Figure 4. Quanser Aero 2. The two guarded rotors and the pitch and yaw structure provide visible connections between actuator inputs and angular motion.

Objective and intended outcome

The objective is to distinguish rotor motion from body motion and identify the measurements used to observe each. The intended educator outcome is a labeled component explanation, a comparison of two signal traces, and an activity that connects sensing, motion, and evidence to a school course or club.

Components and their interaction

Aero 2 includes two DC motors with propellers, motor encoders, pitch and yaw encoders, an inertial measurement unit (IMU), and interface electronics. In the USB configuration, the computer communicates through the QFLEX 2 interface and DAQ. Amplifiers drive the motors, while the encoders and other sensors provide measurements. Rotor speed and body angle are different quantities and should be labeled separately.

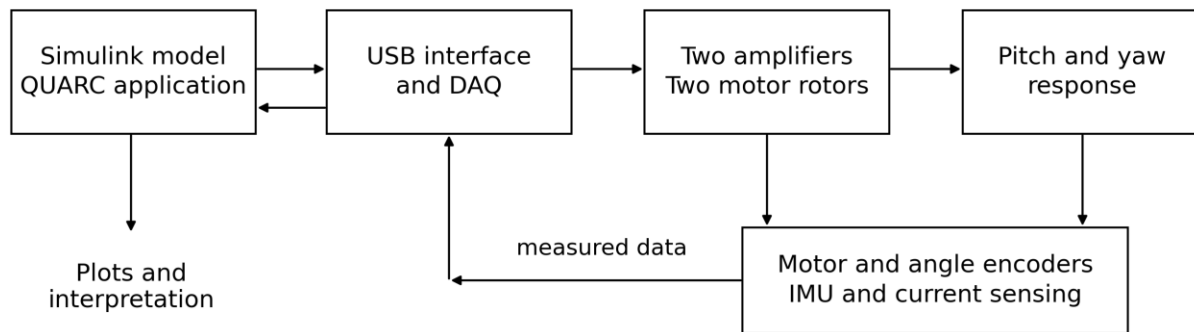


Figure 5. Simplified Aero 2 command and measurement paths, based on the Quanser user manual. Encoder and IMU measurements describe motion; current sensing measures electrical operation. The mechanical configuration determines which axes can move.

Proposed beginner activity on sensing motion

Guiding question: Which sensor tells us about rotor rotation, and which tells us about the angle of the body? Use the assigned QLab activity first. Before operating the hardware, the facilitator checks the propeller guards, axis configuration, connections, approved model, and stop procedure.

1. Identify the two rotors, pitch axis, yaw axis, and sensor displays in the model. Describe pitch and yaw using the physical platform.
2. Observe a predefined virtual trial and record one rotor-related signal and one body-angle signal where the selected model provides both.
3. Label the units and explain why the two signals describe different parts of the system.
4. Compare a second predefined virtual trial. Predict which signals should change and check the prediction against the record.
5. Observe or run the corresponding supervised physical trial. Keep clear of the rotor guards and moving structure.
6. Compare the evidence and explain which measurement supports each statement about the motion.

Evidence and school adaptation

The activity record should include the mechanical configuration, selected commands, labeled plots, and a brief explanation connecting each plot to a sensor. Educators should describe only the relationship examined; one observation does not establish a general control law.

A proposed high school lesson uses a short video and paired plots to distinguish motor rotation from pitch or yaw. Students label the axes, identify a period of change, and explain how a sensor records the motion. A mathematics or physics class can compare angles and rates of change. A robotics club can extend the lesson by interpreting two input channels and two measured angles in a prepared model.

Learning checks for hardware interfacing

The Aero 2 Hardware Interfacing guide and recommended assessment connect motor commands to observed rotor behavior and measured speed. Ask educators to identify the selected motor and viewing direction, describe the observed rotation under a facilitator-approved input, and relate the installed propeller orientation to the airflow direction. Use a demonstration or recording for this observation; the investigation does not require reaching toward an operating rotor.

For a data-based extension, provide a small set of approved voltage and speed measurements. Educators plot the values, describe the observed relationship, and state the tested range. Any fitted relation applies only to the recorded conditions and should not be extrapolated into an operating command. The learning check requires correct signal labels, a distinction between rotor speed and body angle, and a conclusion supported by the measurements. A high school version uses prepared plots and focuses on trend interpretation rather than deriving the motor model.

The 2026 advanced experiment includes rotor speed control. This remains an extension using a prepared model. A two-axis helicopter configuration also provides an introductory example of MIMO behavior: two motor inputs can affect pitch and yaw. The beginner curriculum focuses on identifying the signals and interpreting observations, with control design reserved for later study.

Aero 2 hardware interfacing activities

Aero 2 user manual

10 Group 3: QArm

The QArm group introduces robotic manipulation through a four-degree-of-freedom arm, joint sensing, and a gripper. The beginner pathway focuses on identifying joints, observing measured positions, and organizing a simple sequence of actions. Educators use prepared motion commands rather than deriving forward or inverse kinematics.



Figure 6. Quanser QArm. The arm, gripper, camera, and base provide a physical reference for the manipulation and sensing activities.

Objective and intended outcome

The objective is to connect a joint command with a measured position and explain the purpose of sensing during an object-handling sequence. The intended educator outcome is an annotated sequence, a labeled measurement record, and a feasible school activity about automation, order of operations, or robotic sensing.

Components and their interaction

QArm includes the base, shoulder, elbow, and wrist joints, joint servo motors, a gripper, and an RGBD camera. The servo units provide joint-position and other operating measurements. In position mode, a desired joint angle is sent through the configured interface, and the internal servo control moves the joint toward that angle. The interface can report joint position in radians, so educators should check the units rather than assume every reading is a raw encoder count.

The camera provides image and depth information through its camera connection. This is a separate information stream from the joint measurements. A sequence that uses known positions does not automatically perform camera-based object detection. The QArm user manual describes the joint interfaces, camera, and end-effector DAQ resources.

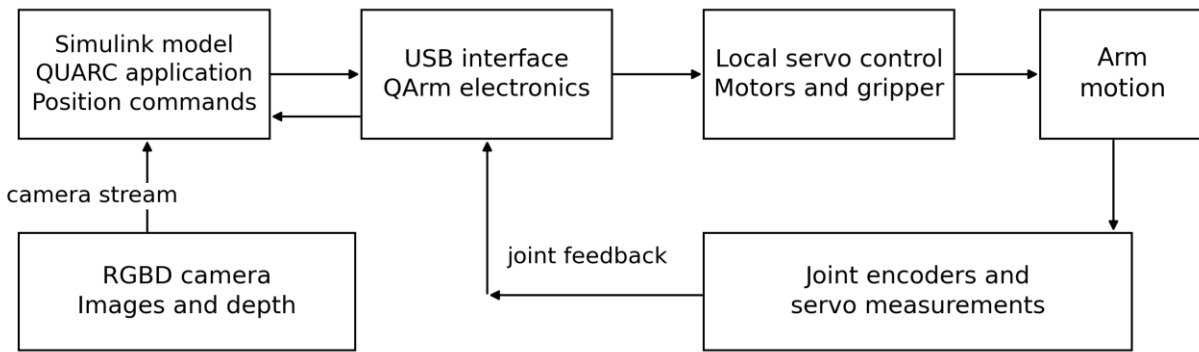


Figure 7. Simplified QArm command and sensing paths. Joint commands and measurements use the arm interface. In position mode, local servo controllers use encoder feedback to regulate joint motion. Camera data follows a separate path.

Proposed beginner activity on measured joint motion

Guiding question: How can we check whether a joint reached its commanded position? Begin in the QArm digital twin or assigned Play activity. The facilitator provides a short, tested sequence within the approved workspace and confirms the gripper, object, and stop procedure for physical work.

1. Identify the four joints and gripper. Locate a commanded joint position and the corresponding measured position.
2. Predict the motion produced by the first approved command. Identify which joint is expected to move.
3. Run the virtual sequence and compare the commanded and measured values at selected points.
4. Arrange a simple sequence of actions such as approach, grip, move, and release using facilitator-provided safe positions.
5. Observe the corresponding supervised hardware sequence. Record the motion and available measurements without entering the arm workspace.
6. Explain where a measurement helps verify the sequence and identify a limitation of the evidence.

Evidence and school adaptation

Save the command sequence, a labeled joint-position record, and a short explanation of the gripper's role. If you use images, describe what the camera shows separately from what the control model does. A completed movement alone does not establish that the system recognized an object or planned a new path.

A proposed high school lesson asks students to arrange action cards for moving an object between two marked locations, test the order using a digital twin or demonstration, and explain where sensing is needed to check progress. Students can revise an incomplete sequence and justify the change. This activity connects automation to logical order, geometry, and troubleshooting without requiring kinematic derivations. A later club activity may compare recorded camera views with the known object locations.

Learning checks for basic input and output

The QArm Basic IO guide distinguishes joint position mode from pulse-width-modulation (PWM) mode. In position mode, the model sends a desired joint angle and the built-in joint controller regulates the motion. PWM mode bypasses that position controller and requires an appropriate control application. Use position mode for the beginner pathway; custom PWM control remains a separate advanced activity led by the facilitator.

Ask educators to label the base, shoulder, elbow, and wrist, identify one joint command and its corresponding measured position, and draw the positive direction using the convention documented for the selected model. They should explain why a commanded angle and a PWM duty cycle are different quantities. Do not assume that positive values in different modes produce the same observed rotation; use the manufacturer's conventions and the tested configuration.

A satisfactory explanation connects a command, a joint, and a measurement while keeping the camera stream separate. As an optional low-complexity input-output example, a prepared model can change the base RGB LED so educators can associate a software value with a visible output before investigating joint motion. The manufacturer's questions about gravity compensation and custom position-controller design remain facilitator enrichment. The classroom adaptation can use a labeled arm image and recorded command-versus-position plots.

The advanced experiment includes trajectory generation and a pick-and-place workflow. Begin with a short, prepared sequence, then use the trajectory resources for further investigation. More advanced participants may inspect how a trajectory is represented after they can explain the joints, commands, and measurements.

[QArm Play activities](#)

[QArm user manual](#)

11 Group 4: QBot Platform

The QBot Platform group introduces ground vehicles and mobile robotics. Its two driven wheels provide a clear context for studying motion, and its sensors provide different kinds of information about the surroundings. The beginner pathway focuses on controlled movement, wheel measurements, and interpreting sensor data.



Figure 8. QBot Platform. This mobile ground robot supports investigations of movement, sensing, and navigation concepts.

Objective and intended outcome

The objective is to relate a short movement command to wheel measurements and compare information from the available sensors. The intended educator outcome is a documented movement sequence, a sensor comparison, and a school activity about measurement, routes, or the information a robot needs to move through a space.

Components and their interaction

QBot Platform includes two drive wheels, wheel encoders, motor electronics, an onboard computer, batteries, LiDAR, cameras, and an IMU. A configured Simulink and QUARC application exchanges commands and measurements with the QBot driver. Some applications run on the onboard computer and communicate with the development computer over the network. The assigned example determines the actual arrangement.

Wheel encoders measure wheel rotation. Travel estimates based on wheel rotation depend on rolling assumptions and can differ from actual movement when the wheels slip. LiDAR provides range information, cameras provide images or depth information, and the IMU provides inertial measurements. These signals answer different questions and should be interpreted using the labels and units in the selected model.

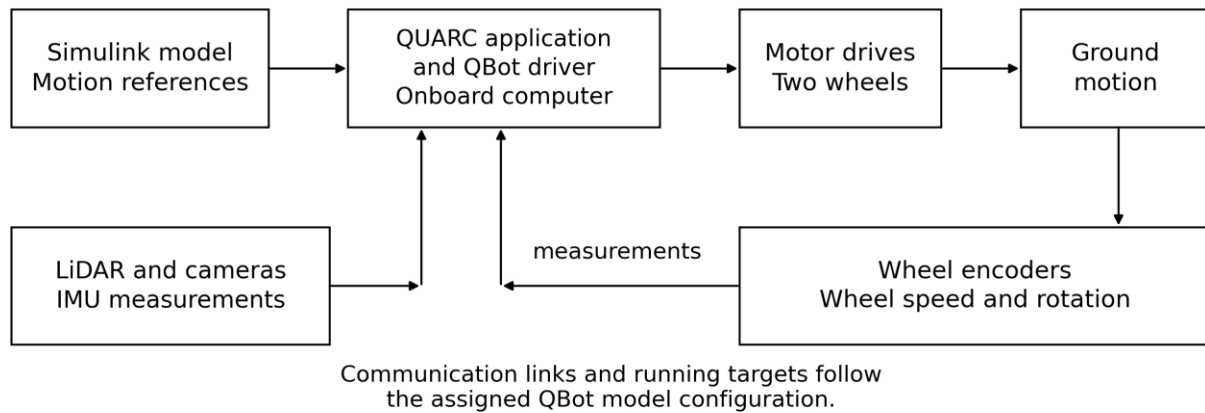


Figure 9. Simplified QBot Platform motion and sensing paths. The diagram distinguishes the drive measurements from the additional sensors used to observe the environment.

Proposed beginner activity on movement and sensing

Guiding question: What information helps us describe how a ground robot moved and what it could detect? Start with the assigned digital twin and QBot Play or quick-start model. The physical activity uses a clear operating area, a facilitator-approved movement sequence, verified communication, and the established stop procedure.

1. Identify the forward and turning controls, wheel measurements, and available sensor displays in the assigned model.
2. Predict the motion for a short predefined sequence that includes moving and stopping. Run the sequence virtually.
3. Record wheel rotation or speed and compare the values with the observed direction of movement. Use the model's documented sign convention.
4. Compare an object or scene feature in two available displays, such as a camera image and a LiDAR scan. State what each display reveals.
5. Complete the corresponding supervised hardware trial within the designated area and record the available evidence.
6. Explain one movement observation and one sensor comparison. Identify what additional information would be needed for a more reliable interpretation.

Evidence and school adaptation

Save the movement sequence, one labeled wheel or motion record, selected sensor views, and a short interpretation. Identify whether the activity used manual control, a prepared sequence, or an implemented autonomous behavior. Comparing sensor displays does not by itself demonstrate autonomous navigation.

A proposed school activity uses a floor plan, a short robot video, and recorded sensor views. Students trace the observed route, identify a possible obstacle, and explain which measurement supports their conclusion. A mathematics class can work with distance and wheel rotation, while a robotics club can compare alternative routes in a digital twin. Check understanding by asking students to distinguish an observation from a proposed movement decision.

Learning checks for movement and sensor comparison

The QBot Platform Play guide and recommended assessment support three short investigations: compare left and right wheel-speed records during straight travel and turning; compare the forward RGB image with the downward camera image; and compare the scene information available from the depth camera and LiDAR. Use the same identified motion interval or scene whenever possible so the comparison has a clear basis.

For motion, ask educators to explain how the wheel-speed relationship corresponds to the observed turn, using the model's sign conventions. For camera views, ask them to describe visible differences in color, field of view, or image detail and distinguish observations from possible explanations. For depth and LiDAR, ask what distance information each display provides and what it does not reveal about the scene.

The learning check requires a labeled record, a supported comparison, and one limitation. Do not treat a camera image, depth display, and LiDAR scan as interchangeable views. Differences can arise from sensing direction, coverage, scene conditions, and display settings; report a specific cause only when the evidence supports it. A school activity can use a short route video with paired sensor images, allowing students to explain which evidence helps answer a particular navigation question.

The advanced extension experiment examines sensing and perception in a mobile robotics context. These resources support deeper investigation after educators can explain the motion controls and basic measurements. Navigation algorithms and multi-robot coordination are later extensions, rather than prerequisites for the beginner activities.

[QBot Platform quick start resources](#)

[QBot Platform hardware manual](#)

12 Laboratory Practice and Advanced Demonstrations

Facilitators should begin each session with the activity's purpose, the expected evidence, and the connection to student learning. A brief demonstration should establish a shared starting point. Educators should then have time to operate the model, ask questions, compare results, and prepare their own explanations.

Support should reflect differences in prior experience. An educator who is new to MATLAB or Simulink may need help locating a block or opening a plot before discussing the response. A more experienced educator may be ready for an optional comparison. Both should complete the required core activity and explain the evidence at an appropriate level.

During pair work, facilitators should alternate questions and operating roles so that both educators participate. Ask one educator to identify the command and the other to interpret the response, then reverse the roles. Record the assistance needed when the assessment criterion requires a distinction between independent work and work completed with support.

Before physical operation, verify the correct hardware, attachment, connections, model, operating limits, workspace, and stop procedure. The station facilitator should authorize startup and supervise the activity. Educators should stop when motion or output is unexpected and request assistance before continuing.

Each station session should end with an approved shutdown, evidence verification, and a short interpretation discussion. Facilitators should allow time to confirm that saved files open and that the report contains the required plots and explanation. A visible robot response should not replace the documentation needed for T3.

Technical support notes should identify the problem, the conditions in which it occurred, the action taken, and the result. This record helps the team distinguish recurring setup barriers from isolated incidents and supports more precise revisions to the next cycle's instructions.

3 DOF Hover as a control laboratory extension

The 3 DOF Hover is an additional control laboratory resource for a facilitator-led comparison. Its frame is mounted on a pivot that permits roll, pitch, and yaw rotation. Four DC motors drive the propellers, and encoders measure the three angles. The mounted platform demonstrates attitude behavior; it is not a free-flying vehicle.



Figure 10. 3 DOF Hover. Source: Quanser product documentation. This resource extends the laboratory discussion beyond the four core 2026 group platforms.

The learning objective is to explain how several actuator inputs relate to several measured angular outputs. In a proposed demonstration, the facilitator identifies the four motors and three angular measurements, then shows a prepared response. Educators label the signals and discuss why changing one motor can influence more than one aspect of the motion. A school adaptation uses a photograph, a short recording, and labeled plots to introduce pitch, roll, and yaw without controller design.

The conceptual pathway is a configured control application, DAQ and amplifier channels, four motors and propellers, physical attitude, and encoder measurements returned to the application. The hardware configuration and operating procedure follow the laboratory's approved setup. Hover is presented here as an extension resource and is not an additional T3 core platform.

QDrone 2 demonstration in the research studio

During the 2026 on-site experience, educators observed an advanced QDrone 2 flight and mission control demonstration inside the Autonomous Vehicle Research Studio. The demonstration used the OptiTrack localization system and Motive software. It introduced a research application of sensing, communication, and control beyond the four core platform activities.



Figure 11. QDrone 2. Source: Quanser product documentation. The photograph identifies the platform used for the facilitator-led aerial robotics demonstration.

The objective is to identify the roles of mission reference, flight controller, vehicle actuators, and localization measurements. OptiTrack cameras observe vehicle markers, and Motive reconstructs the tracked rigid body's position and orientation. The configured control system uses this tracking information along with other required measurements. Motive provides tracking data; it does not directly supply motor power.

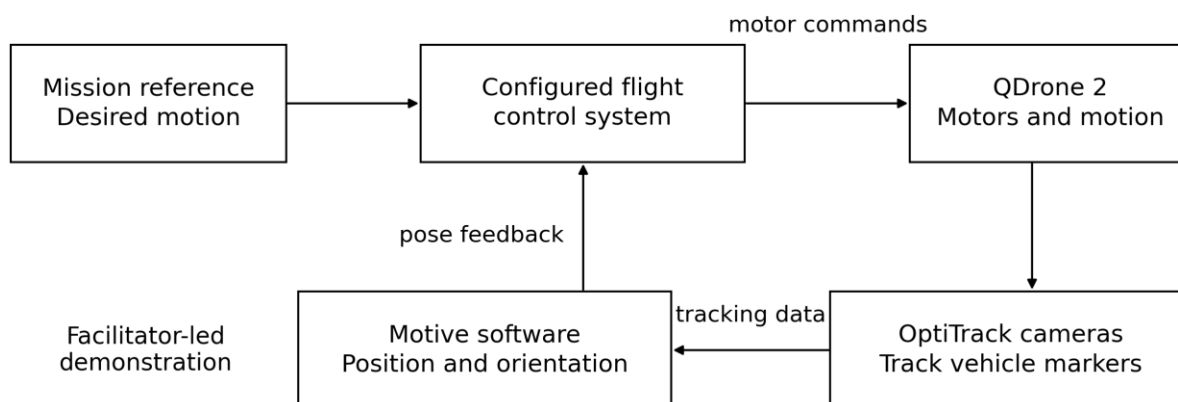


Figure 12. Simplified localization and control relationship for the QDrone 2 demonstration. The diagram highlights external tracking and omits lower-level implementation details and additional onboard sensor pathways.

Educators observe the demonstration and relate the displayed motion to the measured position and orientation. They can discuss how a desired route differs from the measured trajectory and how sensing supports the control task. The intended outcome is an accurate conceptual explanation, not independent flight operation. The facilitator manages the vehicle, tracking setup, operating area, and stop procedure; observers remain outside the designated flight enclosure.

A proposed school follow-up uses recorded trajectory data to plot a route and compare it with a reference. Students identify a difference and explain what the plot can show. This activity introduces measurement and coordinate reasoning without requiring a school flight system. QDrone 2 demonstration participation is not scored as an additional core T3 platform.

13 Classroom Integration and October Follow-Up

The project’s main educational objective is realized when educators apply what they learn in their own teaching. They may integrate a small robotics investigation into an existing course, develop a short curriculum unit, lead an after-school activity, or introduce a robotics or STEM club project. These manageable first activities can grow into continued inquiry and research engagement.

Classroom translation begins during the summer experience. After each platform activity, educators identify one idea that fits their subject and one task their students could complete. The aim is a feasible learning experience with a clear purpose. The facilitator helps educators connect the technical concept to their school context, including prior knowledge, available time, equipment, software access, and supervision.

Preparing a usable school activity

1. Identify the course, grade level, club, or after-school setting and the concept to be taught.
2. Write a learning objective that states what students will explain, measure, compare, or create.

3. Select a practical format: a digital-twin investigation, a teacher demonstration, an activity using recorded data, or supervised hardware work where resources permit.
4. Prepare the instructions, materials, sample or live data, expected evidence, and a short check of understanding.
5. Try the instructions, estimate the time required, and simplify any step that distracts from the main concept.
6. Record what happened when the activity was used and identify the next improvement.

For example, a physics educator may introduce an Aero 2 video and angular-motion plots in an existing lesson. A mathematics teacher may use Qube-Servo 3 encoder data for angle and graph interpretation. A robotics club may use a prepared QArm action sequence or QBot route activity. These are proposed adaptation examples. Each educator selects a context and level that fits the students.

Schools do not need to reproduce the AVRC research laboratory to use the curriculum. Recorded plots, images, a short demonstration, and accessible virtual resources can support an investigation. Check software availability and license permissions when planning a virtual activity. Advanced mathematical derivations are optional extensions after the core concept is understood.

October 2026 implementation follow-up

The RAOP team will contact the first-cycle educators in October 2026 to learn how they have used or adapted the program in their schools. The follow-up will distinguish activities already implemented, activities being prepared, and activities delayed by practical constraints. It will also identify support needed for continued implementation.

The discussion or follow-up record will address the teaching setting, concept or platform used, date of implementation, activity format, actual student participation, and the educator's observations. Where available, educators may share lesson materials, de-identified examples of student work, plots, or reflections. The team will ask what worked, what required adaptation, and what should be changed in the curriculum.

The review should examine actual classroom use, the quality of the activity, and the evidence available to assess student learning. The plan should include an estimated number of future students. A completed lesson and its records provide evidence of implementation; claims about learning require an appropriate assessment of student work.

T4 and T5 establish educators' initial plans and perceived needs. The October follow-up examines subsequent use. T6 provides advisory review of the broader program and curriculum development. Keeping these purposes clear allows the team to report progress toward classroom translation accurately.

14 Assessment and Evaluation Framework

The 2026 assessment framework uses six instruments, T1–T6. In these forms, classroom translation means adapting the program's learning for use in school teaching. Together, they address technical readiness, virtual activity evidence, hardware competency, participant experience, classroom translation, and advisory feedback. Each instrument has a defined purpose and should be interpreted using its own scale, evidence requirements, and respondent group.

Tool	Primary purpose	2026 timing
T1	Setup readiness	Before virtual instruction
T2	Virtual activity evidence	End of the virtual phase
T3	Hardware evidence and competency	End of the on-site phase
T4	Participant feedback and confidence	End of the on-site phase
T5	Group discussion and classroom translation	July 24 discussion
T6	Advisory board feedback	Initial and subsequent reviews

These instruments should not be combined into a single overall score. T1 is a readiness check; T2 and T3 evaluate activity evidence and performance; T4 records participant perceptions; T5 captures qualitative discussion; and T6 records advisory recommendations. Facilitators should use the official companion forms to collect data. The supplementary prompts in Section 17 support instruction and do not create additional numbered assessment instruments.

T1 Setup Readiness Form

T1 identifies whether educators can access and use the environment needed for virtual instruction. It covers computer and institutional permissions, MathWorks access, MATLAB and Simulink preparation, relevant toolboxes and introductory resources, QLABs access, local instructional resources, confidence, and support needs. It is a diagnostic readiness record, not a graded test.

The internal completion scale is 0 for not complete, 1 for partially complete, and 2 for complete. The overall readiness categories are Ready, Mostly ready with minor support, and Not yet ready with technical support required. Confidence items use a five-point scale from 1, not confident, to 5, very confident.

The team reviews readiness, arranges assistance, and checks that each educator can run the assigned virtual activity. T1 records the initial response and the outcome of subsequent support.

T2 Virtual Lab Checkpoint Form

T2 combines the virtual checkpoint with the educator's experiment evidence report. It documents the required introductory and advanced activities on the assigned platform, including access, model operation, inputs and outputs, inquiry, interpretation, lessons learned, and classroom translation. Pair collaboration is permitted, but each educator submits an individual explanation.

Score six criteria from 0 to 3: T2-V1, virtual access and operation; T2-V2, required activity completion; T2-V3, understanding of inputs, outputs, and signals; T2-V4, sensor, actuator, and block reasoning; T2-V5, inquiry and explanation using evidence; and T2-V6, classroom translation quality. The anchors are 0 (not observed), 1 (emerging), 2 (meets expectation), and 3 (exceeds expectation). Reviewers should apply the criterion-specific descriptions in the form.

The maximum total is 18. Individual T2 success requires a score of at least 13 out of 18 and completion of both required activities, Introductory 1 and Advanced 1. Optional activities may strengthen the evidence, but they are not required for minimum success.

T2 specifies minimum and preferred program attainment targets of 70% and 80% for its defined indicators, including activity completion, reasoning, inquiry, classroom integration, and overall individual success. Reviewers apply the indicator definitions and cohort denominator specified in the form.

T2 success is determined from criterion scores and evidence of both required activities. Technical support requests help the team identify where additional explanation or assistance is needed.

T3 Hardware On-Site Validation Checkpoint

T3 consolidates evidence from all four physical platforms. It has two complementary components: an evidence-completion checklist and a hardware competency rubric. Facilitators should review each platform's report and relevant observation before completing the corresponding record.

The evidence checklist contains seven items per platform: completion of the introductory activity; completion of the advanced activity; model screenshots for both activities; output scopes or plots for both activities; observations comparing expected and actual behavior; lessons learned and a classroom translation paragraph; and a saved report that opens correctly. Each checked item receives 1, and each unchecked item receives 0, for a maximum of 28 across four platforms.

Evidence completion is the number of checked items divided by 28, multiplied by 100. The minimum target is 80%, and strong evidence completion is 85%. Apply thresholds to the unrounded percentage, then round only the displayed result.

The competency rubric has five criteria per platform: B1, identification of components and interfaces; B2, safe connectivity and model execution; B3, understanding of inputs, outputs, sensors, and actuators; B4, response interpretation and inquiry; and B5, classroom translation. Each criterion is scored from 0 to 3, producing a maximum of 15 per platform and 60 overall.

A score of 0 indicates no demonstrated performance or no evidence. A score of 1 indicates substantial assistance and a limited or partly inaccurate explanation. A score of 2 indicates minor assistance with a generally accurate explanation supported by evidence. A score of 3 indicates independent performance with a clear, accurate explanation supported by evidence. Reviewers should use the full criterion descriptions in T3.

The minimum competency target is 70%, or 42 out of 60. Strong competency attainment is 85%, or 51 out of 60. An educator needs follow-up if competency is below 70% or evidence completion is below 80%. An educator meets the target when both minimum thresholds are reached. Strong attainment requires both competency and evidence completion to be at least 85%.

T3 describes attainment at the hardware checkpoint. It does not establish the amount of learning gained during the program or the program's effect compared with another instructional approach.

T4 Participant Feedback Survey

T4 records the educator's experience of the on-site program. It includes overall experience, feedback on each platform, retrospective confidence ratings, useful learning, challenges, suggestions for improvement, classroom plans, and support needs. The 2026 survey was scheduled for July 24.

The overall and platform feedback items use their specified five-point scales and allow a not-applicable response where indicated. The confidence section asks educators to rate eight competencies before and after the on-site week on a scale from 1 (very low) to 5 (very high). Collect both ratings retrospectively at the end of the week.

Overall satisfaction and likelihood of recommending the program use separate 0–10 scales. These responses should not be averaged with the five-point items. Exclude not-applicable or missing responses from the relevant item calculation and report the number of valid responses.

Changes in retrospective confidence describe participants' perceived development. They should not be labeled as independently measured pre–post knowledge gains. Classroom timelines and student estimates are plans until follow-up documents actual use and participation.

T5 Group Discussion and Classroom Translation Form

T5 guides a qualitative discussion of learning, program delivery, practical challenges, and classroom integration. The blank guide supports preparation and facilitation. It is not a required individual written submission and does not carry a numerical score.

The facilitator should invite specific examples, allow differing perspectives, and distinguish an educator's own experience from a suggestion about future delivery. The discussion record should preserve the meaning of participants' comments while removing repetition and unrelated conversation.

When summarizing a theme, count distinct educators who expressed it, not how many times it was mentioned. Identify the respondent group and keep training assistant comments separate when reporting educator counts. We do not present one participant's suggestion as a group consensus.

The 2026 discussion included eight educators and one training assistant. The companion T5 report includes the original blank form as an appendix. Its findings describe reported experiences and proposed classroom uses; implementation outcomes require follow-up evidence.

T6 Advisory Board Feedback Form

T6 records external and institutional advisory feedback on the program's design, assessment, classroom translation, recruitment, dissemination, and improvement priorities. T6-1 identifies the July 7, 2026 review. T6-2 identifies the subsequent review of first-cycle outcomes before further refinement. Advisory feedback is qualitative and is not an educator performance score.

The initial review emphasized a clear definition of project success, explicit outcome measures, early attention to classroom use, student-relevant motivation, recruitment that reaches educators who face participation barriers, and systematic dissemination. Advisors also requested an opportunity to review first-cycle outcomes before the next cycle.

The team records each advisory recommendation, its intended meaning, the corresponding response, and progress on the agreed action. This connects feedback to decisions about instruction, classroom integration, and evaluation.

15 Reviewing Learning and Organizing Evidence

Consistent assessment

Before reviewing T2 and T3, the assessment team discusses the criteria using sample responses. Reviewers apply the published scoring anchors, compare interpretations, and resolve differences by referring to the evidence and the criterion descriptions. The assessment lead clarifies as needed.

A useful explanation identifies the question, test condition, observation, and conclusion. For example, an educator may identify a slower response after an approved setting change and point to the relevant portion of a plot. The explanation should connect the data to the physical system and recognize the limits of the investigation.

Assessment serves both documentation and instruction. Facilitators use the results to identify concepts that need further explanation, practical skills that need additional support, and classroom ideas to develop. Technical performance, perceived confidence, and school implementation are interpreted separately because they address different aspects of the program.

Evidence records

Each activity record identifies the educator, platform, phase, activity, date, model, test conditions, evidence location, and explanation. Assessment records also identify the reviewer, criterion scores, assistance provided, and any follow-up action. Shared data may support pair investigations, while individual explanations document each educator's understanding.

Qualitative feedback is organized around setup and access, instructional clarity, pacing, technical support, classroom feasibility, and suggested improvements. Summaries preserve the meaning and range of educator experiences. Deidentified examples and accurate short quotations can illustrate a theme when useful.

The team links each improvement priority to a specific action, responsible person, and review point. Subsequent activity evidence and educator feedback help determine whether the change improved the learning experience.

16 Lessons Learned from the 2026 Cycle

The first cycle brought eight educators into a shared research experience spanning digital twins, physical robotics platforms, and classroom planning. The T1–T5 records and T6 advisory feedback provide complementary perspectives on technical preparation, learning activities, educator experience, and program development. This guide uses those perspectives to identify practical teaching priorities.

Establish a working foundation before virtual instruction

Educator feedback identified software installation, permissions, computer capability, and resource organization as important preparation needs. A short setup sequence, a clearly identified starter model, and an early test of the digital twin help make instructional time more productive. Technical support should address both access and the educator's understanding of the model.

Connect measurements to visible hardware

Educators valued physical equipment, station rotations, and direct support. Seeing a motor, encoder, arm, or mobile platform helped connect software signals with observable behavior. Activities therefore pair component identification with labeled data and a short explanation of what the measurements show.

Provide a clear entry point and room for deeper inquiry

The cohort brought different technical backgrounds and learning needs. Sensing, actuation, commands, and measurements provide a common starting point. Prepared advanced models allow educators to explore more complex behavior after understanding the main components. Pacing should leave time for questions, repeated observations, and discussion of the evidence.

Make resources easy to revisit

Educators emphasized the value of organized files, clear reading priorities, and materials they could revisit. A concise list of required resources, direct technical links, and well-labeled activity records supports continued learning. Available recordings and worked examples can reinforce explanations and help educators return to an investigation after training.

Keep documentation connected to the learning question

A labeled model or diagram, an informative plot or image, and a focused explanation provide useful evidence of an investigation. Time for this documentation belongs within the activity. Clear evidence requirements support assessment while preserving time for hands-on work and interpretation.

Plan classroom integration throughout the experience

Educators discussed using selected ideas in existing courses, interdisciplinary teaching, clubs, and after-school activities. Their plans also reflected constraints in time, equipment, and software access. Short lessons using digital twins, demonstrations, or recorded data offer practical starting points. The advisory review reinforced classroom use as a central measure of project success and recommended focusing on student relevance from the start of training.

The program seeks to sustain educators' interest in robotics and automation and support continued inquiry. October follow-up will examine how first-cycle educators have adapted the learning, what support they need, and which activities fit their students. Their implementation experiences will inform the next stage of curriculum development.

Curriculum development across annual cycles

The 2026 guide establishes the foundation for a user-friendly, adaptable curriculum. Across subsequent cycles, the RAOP team will expand examples, examine suitability for different courses and grade levels, evaluate classroom use, and refine activities and guidance. Educator experience, assessment evidence, and advisory feedback will inform this continuing process.

17 Activity Planning and Facilitation Records

The following prompts support preparation, facilitation, and documentation. They supplement the official T1–T6 forms and should not replace their questions, scoring criteria, or reporting definitions.

Session preparation record

Record the session date, facilitator, platform, activity, learning objective, required files, software release, expected evidence, and applicable assessment form. Note the starting configuration, operating limits, stop procedure, and support roles. Confirm that the model has been tested and that the educator instructions identify both required work and optional extensions.

Guided inquiry record

Ask educators to state the activity question and prediction, identify the baseline and approved change, list the evidence collected, and explain the result. Include a prompt asking what remains uncertain and what additional observation would help. End with one classroom connection that follows from the concept investigated.

Virtual and hardware comparison record

Record the virtual and physical model names, settings, commands, outputs, and relevant operating conditions. Describe the similarity or difference supported by the evidence. Identify any mismatch in conditions and separate a possible cause from a tested explanation. Link the written comparison to the saved plots or images.

Classroom activity planning record

Identify the grade level or course, student learning objective, prior knowledge, estimated lesson time, and materials. Describe what the teacher will introduce and what students will do. Specify the evidence students will produce and how the teacher will use it to check understanding. Include a simpler version for limited resources and an optional extension for students who are ready for more advanced work.

The plan should also address practical access, supervision, and classroom management. Record whether the activity is an initial idea, a developed plan, a demonstration, or an implemented lesson. A later implementation record should add the date, actual participation, adaptations, and available evidence of student work.

Technical support record

Record the educator identifier, platform, model, software release, problem description, error or diagnostic information, action taken, result, and remaining need. Use the record to identify recurring issues that require clearer instructions, a tested starter file, or earlier support.

Facilitator reflection and improvement record

After the session, record which objectives were addressed, where educators required assistance, which explanations showed understanding, and what evidence remains incomplete. Note the time needed for the core activity and the most useful classroom connections. Convert each proposed change into a specific action with an owner, status, and review point.

Advisory response record

For each T6 recommendation, record the issue raised, the team's response, the proposed action, the responsible person, and the evidence to be reviewed. Update the status after implementation or further discussion. This record supports a clear account of how advisory input informs program decisions.

18 Program and Technical Resource Links

The following resources support program participation, software preparation, platform activities, and further study. The facilitator selects compatible models and documentation for each session. The T1–T6 companion forms provide the program's assessment questions and criteria.

AVRC and RAOP websites

Recruitment and Selection. Eligibility, application review, and selection process.

RAOP Application Portal. Application requirements and cycle-specific submission information.

AVRC Laboratory website. Laboratory information, facilities, research, education, and news.

RAOP program website. Program overview and access to the RAOP pages.

Program Structure. Virtual and on-site program sequence.

Activities. Platform groups and activity information.

Professional Development. Educator learning and classroom adaptation resources.

Curriculum. Curriculum organization and development.

Evaluation. Program evaluation information. The T1–T6 companion forms govern the assessments described in this guide.

Participant Support. Program participation and support information.

Resource Navigator. Starting point for locating program and technical materials.

RAOP Links. Additional technical and educational links.

RAOP Contact. Program contact information.

Software and foundational resources

Quanser Academic Resources repository. Official setup, quick-start, user manual, concept review, research, and teaching resources.

Quanser PC Setup Guide. Virtual and hardware software preparation.

Quanser Academic Portal. Assigned account and platform access.

Quanser user manual collection. Platform hardware, connectivity, and software manuals.

Quanser concept reviews. Background topics for selected activities.

Quanser teaching content guide. Orientation to the instructional resource collection.

QUARC documentation. Real-time application and hardware interface documentation.

HIL Read Encoder. Reading configured encoder channels and interpreting count outputs.

HIL Write Analog. Writing configured analog command channels.

MathWorks MATLAB and Simulink learning resources. Introductory and further software learning resources.

Core platform manuals and activities

Qube Servo 3 user manual. Component interaction, motor, encoders, DAQ, amplifier, and setup; see printed pages 4–7.

Qube Servo 3 Simulink quick-start guide. Component check, hardware connection, baseline model, and troubleshooting.

Qube Servo 3 teaching resources. Instrumentation and control activities.

Qube Servo 3 pendulum extension. Prepared swing-up resources, including digital-twin and hardware pathways.

Aero 2 user manual. Configurations, components, and interface schematic; see printed pages 3–7.

Aero 2 quick-start resources. Digital-twin and hardware startup resources.

Aero 2 hardware interfacing. Introductory virtual and hardware activities.

Aero 2 rotor speed control extension. Prepared extension resources for the 2026 activity pathway.

QArm user manual. Joint sensing, position commands, gripper, camera, and DAQ; see printed pages 4–10.

QArm virtual quick-start guide. QLab access, workspace launch, model test, and curriculum access.

QArm hardware quick-start guide. Workspace, connections, home and rest configurations, baseline model, and shutdown.

QArm Play. Virtual and physical introductory manipulation activities.

QArm trajectory generation extension. Further resources for prepared motion sequences and trajectory study.

QBot Platform hardware manual. Physical components, wheel sensing, and platform hardware.

QBot Platform Simulink software manual. Target configuration, deployment, and driver use.

QBot Platform quick start. Initial operation and platform preparation.

QBot Play. Digital-twin and hardware activities for motion and sensing.

Demonstration and localization resources

3 DOF Hover. Mounted roll, pitch, and yaw platform; source of the Figure 10 photograph.

QDrone 2. Aerial robotics platform; source of the Figure 11 photograph.

QDrone 2 manuals. Hardware, power, and connectivity guidance for the configured system.

OptiTrack rigid body tracking. How Motive represents and tracks a rigid body from markers.

OptiTrack data streaming. Streaming tracking data to compatible applications.