QUANSER
INNOVATE · EDUCATE

Rethinking Mechatronics Design Education for the Modern Era

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THE BACKGROUND

This project comes as a solution to the need of developing the higher education capacity & offerings in Uzbekistan in the field of Mechatronics. The main objective of the program is to develop a continuous education program to train a new generation of engineers well capable of performing constructive engineering works and meeting today's technological challenges by development of a new curriculum.

The main aim of the project is to develop bachelor's degree program in the field of Mechatronics; to improve the mechatronics' specialist's knowledge in Automation sphere, to support the capacity building of higher education institutions and to make contribution for the sustainability

This initiative is based on the theme of "**Modernization of Mechatronics and Robotics for bachelor's degree in Uzbekistan through innovative ideas and Digital Technology"**

The project will focus on:

- Developing and implementing a new scheme of cooperation for university-industry links based on EU skills in Mechatronics sphere.

- Developing standards and curricula, courses, teaching methods, materials, and tools (soft skills) in the field of Mechatronics.

- Developing and implementing new courses for teachers, staff, and engineers of the enterprises.

- Training teachers from HEIs in Uzbekistan with teaching methodologies based on Mechatronics at EU partner universities.

- Developing and publishing a new generation of handbooks/manuals for direction of Mechatronics.

- Establishing the Innovation laboratories (I-LAB), Training Centre and Mechatronics Society of Uzbekistan for disseminate the results of project.

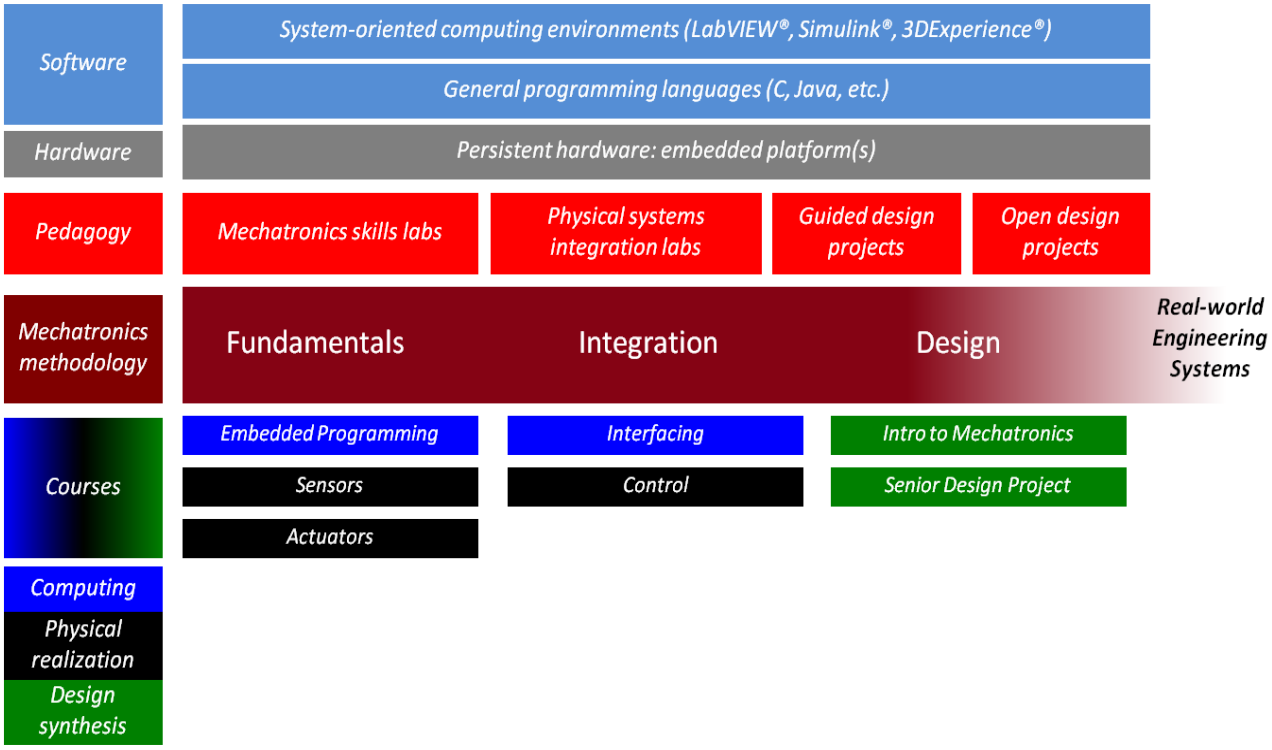
- Testing, adapting and accrediting curriculum, materials, and methods.

- Transferring the recommendations of the new model of education system to other sectors of the Uzbek economy.

THE MOTIVATION

The global engineering academic community is witnessing an explosive growth in the number of programs and courses in mechatronics. They take the form of options or electives within conventional departments, or as fully realized programs and departments. This is not surprising as society is inundated with chatter about the "Internet of Things", robotics, drones, etc. Additionally, within the engineering profession, the computer control of complex engineering systems is now firmly entrenched in a principal framework for increasing the precision, performance, efficiency, and decreasing the cost of modern systems. Understandably, the mechatronics programs are part of the academic response to these trends.

Quanser has looked through many university programs and recommended solutions that may benefit their education and research goals. Over the last few years, there has been a large increase in mechatronic programs that include control systems, robotics, instrumentation, software programing, mechanical design, and so on. Pedagogical courseware is also included with most of our products. These include full **student/instructor workbooks** and **laboratory guides** that cover many of the course topics taught in mechatronic programs.



THE CHALLENGES

By its nature, a mechatronics program relies heavily on hands-on experiences and labs. Microprocessor programming, sensor integration, or hobby robotics are all very typical kinds of labs that many institutions have introduced. A common lab sequence sees students programming hobby microprocessor boards and then connecting them to simple sensors to operate small motors, lights, or other components. Because of the use of hobby-grade components, often the essential learning challenge becomes the programming as opposed to the system, in addition to the programming.

In many cases, the lab sequence culminates in projects where students might build small hobby robots to perform a relatively complex task. The challenge is again, typically in the programming to refine the smarts of the control software. The physical system itself remains relatively simple in configuration.

While the core curriculum sequence of most undergraduate engineering programs is based on modeling and analysis of complex physical systems using mathematical and scientific methods, the mechatronics lab sequences remain problematically disconnected from this core. Quanser's contribution in this context is to offer a learning platform that reconciles the traditional applied sciences with modern mechatronic technique.

THE SOLUTION, A MODERN MECHATRONICS PROGRAM

Based on the mechatronic programs from different universities around the world that we have reviewed and our collaborations with various institutions, we have listed the following courses that would make up a well-rounded, modern Mechatronics program:

- Fundamentals
    - Sensors
    - Actuators
    - Microprocessor Architecture
    - Embedded Programming

- Integration
    - Control Systems I – Classical Control
    - Control Systems II – Modern Control
    - Digital Control Systems
    - Robotic Manipulators and Mobile Robotics
    - Flight Dynamics and Control
    - Mechanical Design (CAD)

- Design
    - Senior Design Project

THE QUANSER METHOD FOR MECHATRONICS

The term Quanser Method refers to a core philosophy of harmonization of key concepts and techniques that are quite often treated independently in a curriculum sequence. For mechatronics programs, the Quanser Method focuses on the development of fundamental skills in a guided way that effectively prepares students to apply those skills in a more open-ended project and design context.

Additionally, the Quanser Method places significant emphasis on the inherent dynamics of engineering physical systems. In this way, the method differentiates itself from a programming-centric approach, and arguably is better at conceptually connecting to most of the courses in typical undergraduate programs that are founded on engineering science, modeling, and mathematics.

THE QUANSER'S PLATFORM FOR UNDERGRADUATE MECHATRONICS

This section provides a summary of the rational framework that drove the design of Quanser's Mechatronics lab series of products:

1. INTRODUCTORY SYSTEMS

Applicable Courses

Mechatronics I and II
Introduction to Mechatronics Engineering
Measurement and Instrumentation

a. QUBE-SERVO 2 with DC Motor/ Inverted Pendulum modules (USB/Embedded/myRIO Interface Panels)

The QUBE™ Servo 2 is a fully integrated, modular servomotor lab experiment designed for teaching mechatronics and control concepts at the undergraduate level. Integrating Quanser-developed QFLEX 2 computing interface technology, QUBE-Servo 2 provides more flexibility in lab configurations, using a PC, or microcontrollers, such as NI myRIO, Arduino and Raspberry Pi.

Topics Covered

Inertia Disk Module

- Hardware integration
- Step response modeling
- Electromechanical modeling
- Second-order systems
- PD control
- Stability analysis
- Lead Compensation

Pendulum Module

- Pendulum modeling
- Moment of inertia
- Balance control
- State-feedback LQR-based control
- State-space modeling
- Swing-up control

b. QBOT2e (MOBILE GROUND ROBOT)

The Quanser QBot 2e is an innovative open-architecture autonomous ground robot, equipped with built-in sensors, and a vision system. Accompanied by extensive courseware, the QBot 2e is ideally suited for teaching undergraduate and advanced robotics and mechatronics courses, surpassing capabilities of hobby-level robotic platforms.

The open-architecture control structure allows users to add other off-the-shelf sensors and customize the QBot 2e for their research needs.

Topics Covered

- Differential drive kinematics
- Forward and inverse kinematics
- Dead reckoning and odometrical localization
- Path planning and obstacle avoidance
- 2D mapping and occupancy grid map
- Image acquisition, processing, and reasoning
- Localization and mapping
- High-level control architecture of mobile robots
- Vision-guided vehicle control

2. ADVANCED APPLICATION AND CONTROLS

Applicable Courses

Introductory system courses plus,
Embedded control
Micro-controllers
Advanced mechatronic systems

a. QUANSER AERO (USB/Embedded/myRIO Interface Panels)

The experiment is reconfigurable for various aerospace systems, from 1 DOF and 2 DOF helicopter to half-quadrotor. Integrating Quanser-developed QFLEX 2 computing interface technology, the Quanser AERO also offers flexibility in lab configurations, using a PC, or microcontrollers, such as NI myRIO, Arduino and Raspberry Pi. With the comprehensive course materials included, you can build a state-of-the-art teaching lab for your mechatronics or control courses, engage students in various design and capstone projects, and validate your research concepts on a high-quality, robust, and precise platform.

Topics Covered

ABET-aligned Instructor and Student Workbooks with complete lab exercises, covering topics

- Hardware integration
- Single propeller speed control
- 1 DOF attitude control configuration
    - PID control
    - Introduction to IMU
    - Modeling and model validation using transfer function
    - System identification
    - Gain scheduling

Laboratory Guides with modeling and control design examples

- 2 DOF helicopter configurations
    - Modeling
    - Linear state-space representation
    - State-feedback control
    - Coupled dynamics

- Half-quadrotor configuration
    - Modeling
    - Simple yaw control
    - Kalman filter

b. QARM (4 DOF ROBOTIC MANIPULATOR)

The fastest and easiest way to introduce modern hardware into undergraduate robotics.

- The only robotic manipulator designed for modern engineering education
- Complete curriculum mapped to both Spong and Craig
- Tendon based two-stage gripper
- Intel RealSense D415 RGBD Camera
- Quanser-developed studio-course resources provided save time on course development
- Integrating Quanser-developed QFLEX 2 computing interface technology, the Quanser Arm will offer flexibility in lab configurations, using a PC, or microcontrollers, such as NI myRIO, Arduino and Raspberry Pi. Camera system, and digital twin enable modern teaching methods
- Rich application environments in Unreal Engine offer students an exciting motivation for learning, and basis for interactive challenges
- QUARC – Robotics License
    - Leverages the intuitive graphical interface of Simulink to give students a systematic understanding of the design of robotic systems
    - Optimized application library for robotics including reference frame operations, kinematics, image processing, and video compression and transmission

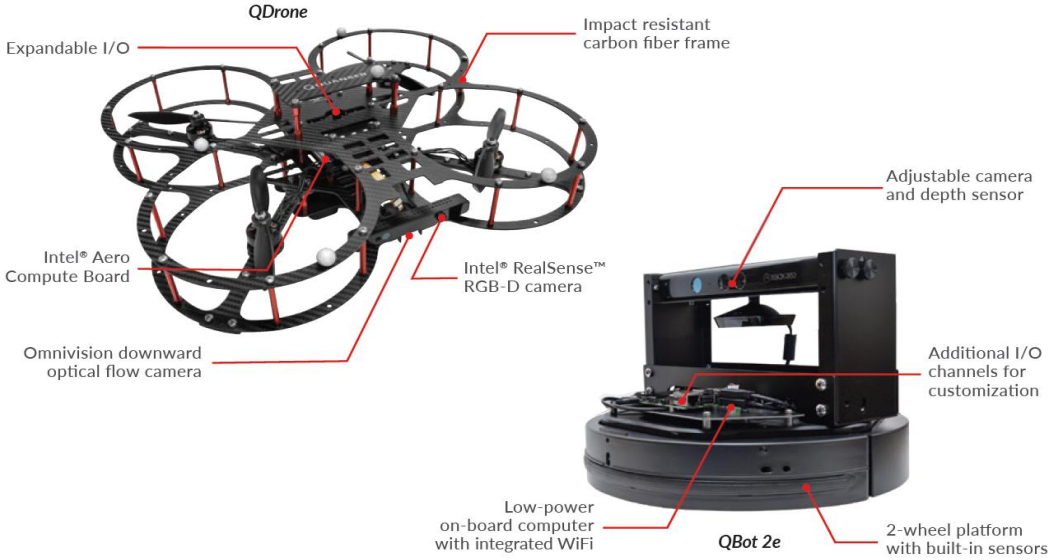
Product Specifications

- 4 DOF serial manipulator with a reach of 750mm
- 1 kg payload at 90°/s
- Joint based internal and external control at 1KHz
- Position, current, temperature, and velocity measurement
- Versatile custom interfacing board enabling students to interface custom electrical components
    - Analog In, Encoders, I2C, SPI, UART, PWM, and regulated power

3. PROJECT DESIGN

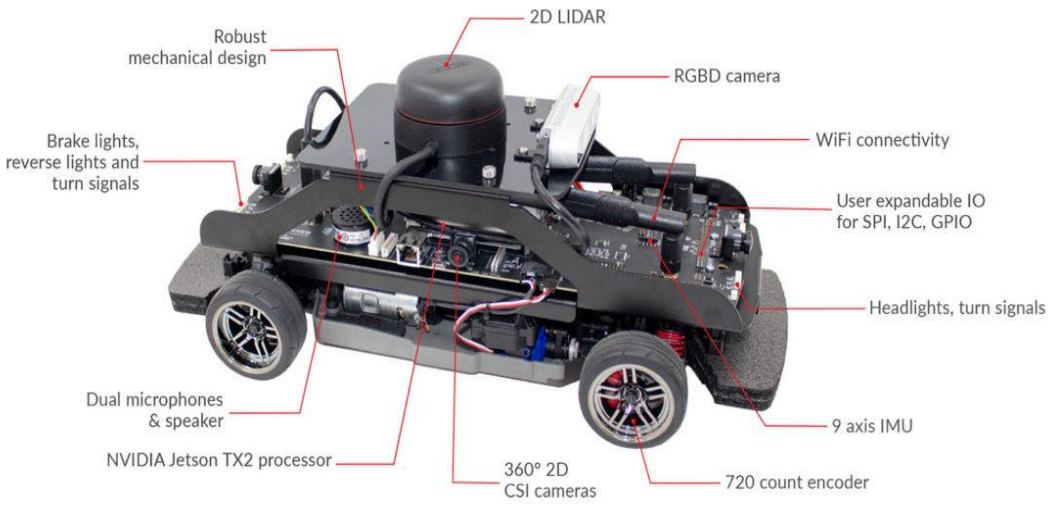
a. AUTONOMOUS VEHICLE RESEARCH STUDIO

Quanser's new Autonomous Vehicles Research Studio is the ideal solution for academics looking to build an indoor multi-vehicle research lab in a short amount of time. Consisting of QDrone quadrotors and QBot 2e ground vehicles, ground control station, vision, and safety equipment, the Autonomous Vehicles Research Studio is the only option for research groups looking to jumpstart autonomous robotics research programs and be productive in a very short amount of time.



	RECOMMENDED CONFIGURATIONS	Small Labs	Medium Labs	Large Labs
Vehicles	QDrone	4	8	12
	QBot 2e			
Studio Space & Components	Minimum recommended room size (m)	5x5x2.5	6x6x2.5	7x7x2.5
	Recommended workspace (m)	3.5x3.5x2	5x5x2	6x6x2
	Optitrack Flex 13 localization cameras	6	8	12
Ground Control Station	High performance computer with Intel® Core i7	✓	✓	✓
	Three monitors	✓	✓	✓
	QUARC™ Autonomous Software License	✓	✓	✓
Accessories	USB flight controller joystick High performance router Ground camera Protective floor tiles Protective netting	✓	✓	✓

b. SELF-DRIVING RESEARCH STUDIO



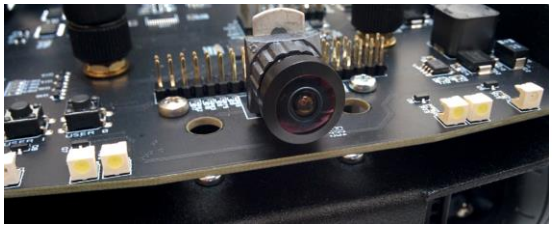
At the center of the Self-Driving Car Research Studio, the QCar, is an open-architecture scaled model vehicle, powered with NVIDIA® Jetson™ TX2 supercomputer, and equipped with a wide range of sensors, cameras, encoders, and user-expandable IO.

Relying on a set of software tools including Simulink®, Python™, TensorFlow, and ROS, the studio enables researchers to build high-level applications and reconfigure low-level processes that are supported by pre-built modules and libraries. Using these building blocks, you can explore topics such as machine learning and artificial intelligence training, augmented/mixed reality, smart

transportation, multi-vehicle scenarios and traffic management, cooperative autonomy, navigation, mapping, and control, and more.

QCar Hardware Features

- 1/10 scale model car
- RPLidar A2M8 2D Lidar
- Intel D435 RGBD Camera
- 360° 2D CSI Cameras using 4x 160° FOV wide angle lenses
- 512 count motor encoder pre-gearing with hardware digital tachometer
- 9 axis IMU sensors (Gyro, Accelerometer, Magnetometer)
- NVidia TX2 Processor
- Headlights, brake lights, turn signals, reverse lights
- Dual microphones
- Speaker



- LCD screen with address, battery voltage, and custom text support
- Hardware “safe” shutdown button
- Auto-power off to protect batteries
- User expandable IO for SPI, I2C, GPIO, additional encoders with digital tachometers
- 4x USB 3.0 ports
- 1x USB 2.0 OTG port
- 2x CAN Bus
- 2x HDMI ports for dual monitor support
- Robust mechanical design
- User customizable mechanical breadboard for mounting custom hardware
- Custom designed bumpers for collisions at scaled speeds of 120km/hr

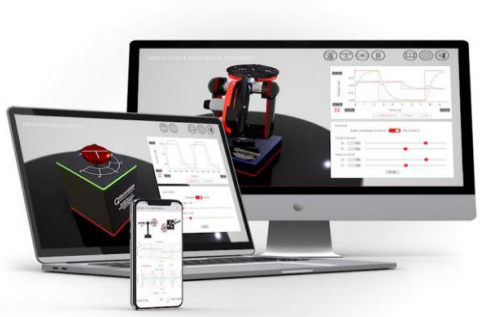
QCar Software Features- Installed Software & API’s

- QUARC Autonomous for MATLAB/Simulink
- Quanser APIs
- TensorFlow
- TensorRT
- Python 3
- ROS 1 & 2
- CUDA
- cuDNN
- OpenCV
- Deep Stream SDK

SUPPLEMENTARY SOFWTARE TOOLS

QLABS CONTROLS APPLICATION

*** Available on Desktop and Mobile**



QLabs Controls is a collection of virtual laboratory activities that supplement traditional or online control systems courses. The virtual hardware labs are based on **QUBE-Servo 2** and **Quanser AERO** systems which allows you to combine physical and virtual plants to enrich lectures and in-lab activities and increases engagement and students' learning outcomes in class-based or online courses.

QLabs Controls is a scalable platform capable of delivering credible, academically appropriate, and high-fidelity lab experiences through interactions with virtual hardware. QLabs Controls is based on Quanser physical plants and is accompanied by comprehensive curriculum covering topics such as modelling, speed and position control, and aerospace control, instructor resources, and tools to manage student access and monitor their progress.

QLabs Controls is available as a 12-month subscription and runs on Windows, macOS, iOS, and Android with no need for any institutional IT infrastructure or resources to integrate the platform.

QLABS VIRTUAL ROBOTICS APPLICATION

*** Available on Desktop and Mobile**

QLabs Virtual Robotics is a scalable platform capable of delivering credible, academically appropriate, and high-fidelity lab experiences through interactions with virtual hardware. QLabs Virtual Robotics offers fully instrumented and dynamically accurate digital twins of Quanser physical systems such as **Qbot 2e ground robot** and **QArm robotic manipulator**. These digital twins look, behave, and can be measured and controlled using MATLAB/Simulink and other platforms exactly as the real systems would be.

QLabs Virtual Robotics is available as a 12-month subscription and runs on Windows, with no need for any institutional IT infrastructure or resources to integrate the platform.

EXPERIENCE CONTROLS TEXTBOOK APPLICATION

*** Available on Mobile Only**

A Free Mobile Control Systems Textbook

The Experience Controls app is a unique interactive mobile textbook introducing students to control systems fundamentals in an engaging way, through accessible language, real-time dynamic simulations, and self-directed learning. The accompanying instructor resources allow educators to easily implement Experience Controls into any new or existing control systems course. Experience Controls can be downloaded for free on the App Store and Google Play.

ABOUT QUANSER

Quanser is the world leader in innovative technology for engineering education and research. With roots in control, mechatronics, and robotics, Quanser has advanced to the forefront of the global movement in engineering education transformation in the face of unprecedented opportunities and challenges triggered by autonomous robotics, IoT, Industry 4.0, and cyber physical systems. Quanser is unique in its approach. Deploying an extensive portfolio of advanced technology and IP, Quanser has distinguished itself as the only commercial organization that offers a comprehensive, academically sound platform for delivering programs in these progressive fields in a timely and rational way. Increasingly Quanser is playing a leadership role within the global community of engineering Deans and the progressive education leadership as our academic achievements have positioned the company as true colleagues as opposed to conventional vendors.

QUANSER's CUSTOMERS

Selecting the right solution to educate and develop tomorrow's leading engineers, as well as solve complex control problems involves much more than just deciding who can offer you a system with required features and functions for the best price. It also means making the right long-term partnership decision. Because your system selection affects virtually every aspect of your curriculum, research, and development efforts; and has a direct impact on your future success, you must think about what you want for the long-term.

When you collaborate with Quanser you benefit from the years of knowledge and learning that comes with every customer interaction. For over 25 years, Quanser has put as much emphasis on fostering and building our relationships with customers as on developing the best functional solutions. And our customers feel that Quanser is a true partner in their success.

Quanser customers can continually rely on ongoing support of the whole Quanser team, including the engineers who developed the systems - from the installation through to full laboratory setups and curriculum development and well beyond. Maybe that is why over 3,000 universities, colleges, research institutions and companies around the world, including **MIT, University of California at Berkeley, University of Tokyo, McGill University, Imperial College London, Swiss Federal Institute of Technology**, use Quanser's solutions today.

THE BOTTOM LINE

Quanser is excited to propose these solutions for **Andijan Machine Building Institute, Uzbekistan**. The progressive ideas and technology embodied in this initiative break new ground on how regions and institutions can quickly transform conventional practice to highly efficient and effective programs that seize the opportunities of contemporary technology movements.

Virtually overnight, **Andijan Machine Building Institute, Uzbekistan** will establish an exemplary global showcase for research covering the most strategic application themes. We believe that the fundamental enrichment of the region's innovation reputation will be significant if not profound and we believe that collaboration with Quanser and our unique collaborative approach to academic innovation will be essential to timely progression.