QUANSER
INNOVATE · EDUCATE

2 DOF HELICOPTER & 3 DOF HELICOPTER

"The 3 DOF Helicopter is straightforward to use and the lessons learned are easily transferable into real-world situations."

Guido Herrmann,
Senior Lecturer, Bristol University,
United Kingdom

Quanser Helicopters allow you to fully engage students in learning flight dynamics and control.

The 2 DOF Helicopter system offers students a unique opportunity to gain hands-on experience and learn introductory concepts of flight dynamics and control.

TEACH AEROSPACE FUNDAMENTALS MORE EFFECTIVELY

The 2 DOF Helicopter experiment provides an economical test bed to understand and develop control laws for vehicles with dynamics representative of a tethered rigid body helicopter, spacecraft or underwater vehicle.

HOW IT WORKS

The 2 DOF Helicopter is comprised of a model helicopter body and a metal base. The helicopter has two propellers mounted perpendicularly to each other and are both actuated by DC motors. This emulates the common helicopter configuration with a main rotor and anti-torque tail rotor. The front propeller controls the pitch axis - rotating the center of the body about the horizontal (i.e. front propeller goes up and down). The back propeller controls the yaw axis - the angle about the vertical base. Both axes are measured using high-resolution encoders. The slip ring mechanism on the vertical axis allows the body to freely rotate about the yaw angle, by eliminating the need for any wires to connect the motors and encoders to the base. The inherent torque effect from the front propeller causes the body to rotate and must be compensated by the tail rotor, just like in full-sized helicopters, which can make for interesting modeling and control challenges.

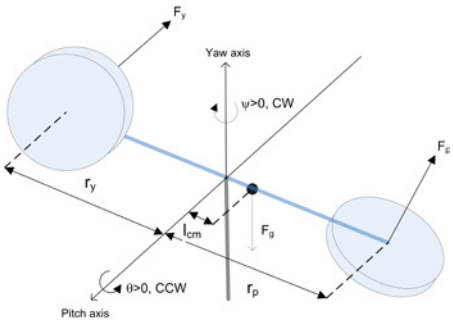
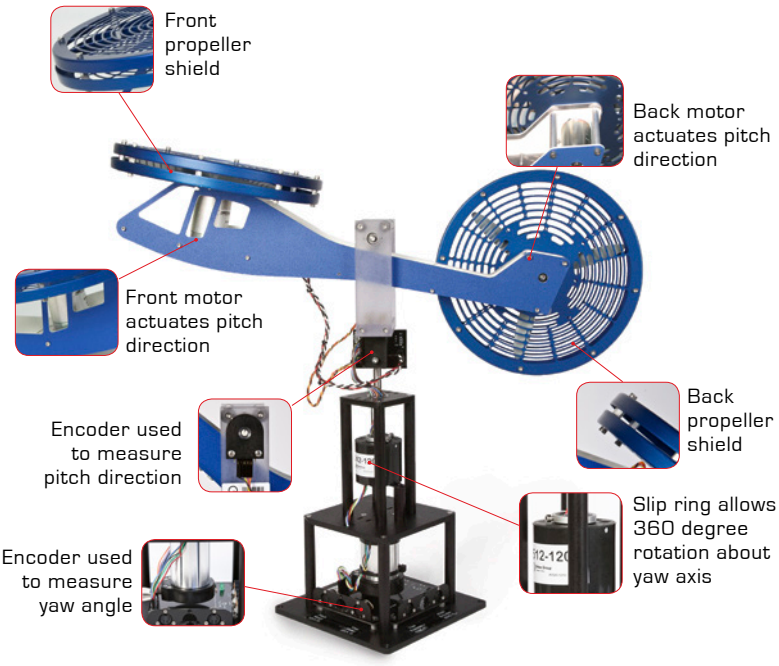


Figure 1.

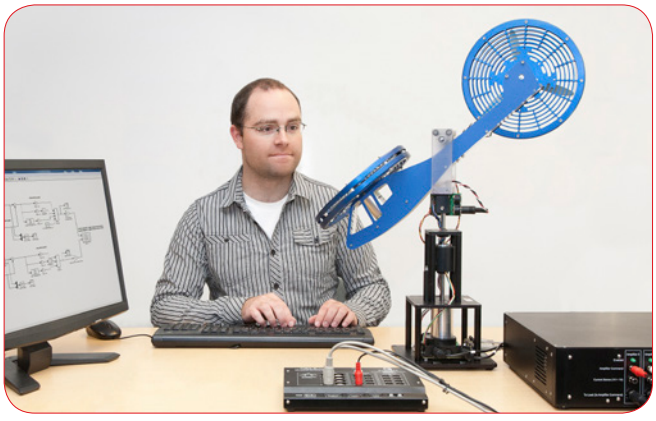
An example of a free body diagram for the 2 DOF Helicopter provided in the courseware. Students can use this model to study the forces interacting with the helicopter and the direction conventions.



System specifications on reverse page.

2 DOF HELICOPTER WORKSTATION COMPONENTS

- 2 DOF Helicopter plant
- Q2-USB data acquisition device
- VoltPAQ-X2 dual-channel linear voltage amplifier
- QUARC real-time control software for MATLAB®/Simulink®
- Instructor and Student Workbooks, User Manual, and Quick Start Guide (provided in digital format)
- Sample of pre-built controllers and complete dynamic model



2 DOF Helicopter workstation

The 3 DOF Helicopter system exposes students to more advanced flight dynamics concepts by extending control to three axes (travel, yaw and pitch).

EXPLORE INTERMEDIATE AEROSPACE CONCEPTS

The 3 DOF Helicopter experiment provides a bench top model of a Tandem rotor helicopter, used for transport and search and rescue missions. It can be used to understand and develop control laws for a vehicle that has dynamics representative of a dual rotor rigid body helicopter, or any device with similar dynamics.

HOW IT WORKS

The 3 DOF Helicopter is composed of a model helicopter body, a metal base, and an aluminum frame. The helicopter has two propellers mounted in parallel to each and are actuated by DC motors - similarly to Tandem dual rotor helicopters.

The helicopter body is suspended from an instrumented joint that is mounted at the end of a long arm and is free to pitch about its centre. The other end of the arm is fastened to the base using a two degree of freedom joint. This allows the arm, and thus the helicopter, to be rotated about the vertical axis - the travel axis - as well as up and down - the elevation axis. The other end of the arm has an adjustable counterweight that changes the effective mass of the helicopter system - making it light enough to be lifted by the thrust from the propellers. All axes are measured using high-resolution encoders to obtain precise position feedback. The slip ring mechanism on the vertical axis allows the body to rotate continuously by eliminating the need for any wires to connect the motors and encoders to the base. The front and back propellers control the movement of the helicopter.

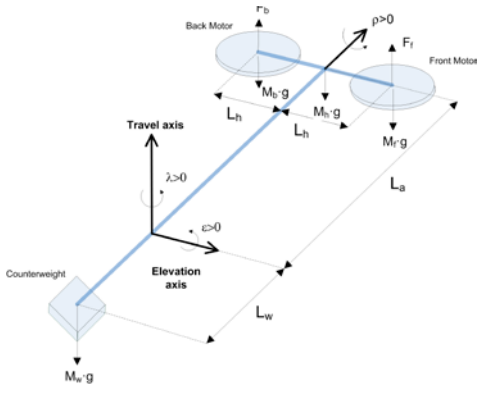
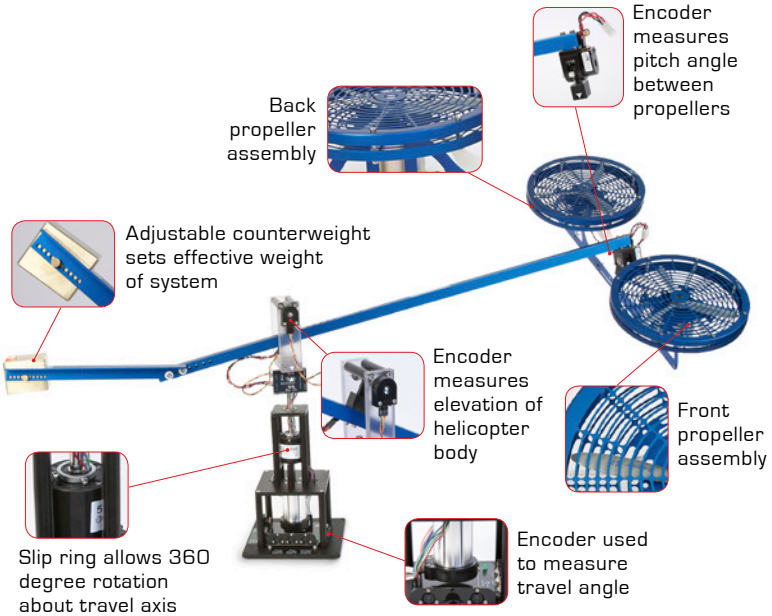


Figure 2.
A free body diagram for the 3 DOF Helicopter illustrates the added complexity of the third axis of motion.



System specifications on reverse page.

3 DOF HELICOPTER WORKSTATION COMPONENTS

3 DOF Helicopter plant
Q8-USB data acquisition device
VoltPAQ-X2 dual-channel linear voltage amplifier
QUARC real-time control software for MATLAB®/Simulink®
Instructor and Student Workbooks, User Manual, and Quick Start Guide (provided in digital format)
Sample of pre-built controllers and complete dynamic model

3 DOF Helicopter workstation

SYSTEM SPECIFICATIONS

CURRICULUM TOPICS PROVIDED	2 DOF HELICOPTER	3 DOF HELICOPTER
Derivation of simple dynamic model	✔	✔
State space representation	✔	✔
State feedback control (with)	feed-forward & integral anti-windup	✔
LQR control design	✔	✔
Control parameter tuning	✔	✔
FEATURES		
Flexible operation and control design from NI LabVIEW™ using the Quanser Rapid Control Prototyping (RCP) Toolkit	✔	✔
High-resolution optical encoders for precise position measurements	✔	✔
Sample model and control design documented and derived in Maple™ worksheet	✔	✔
Fully documented system parameters	✔	✔
Precise, stiff and heavy-duty machined components	✔	✔
Open architecture	✔	✔
Propellers driven by high-quality DC motors	MICROMO and Pittman	Pittman
Slip ring allows infinite motion about the vertical axis	vertical/yaw axis	vertical/travel axis
Two degrees of freedom (2 DOF) - body rotates about pitch and yaw axes	✔	--
Three degrees of freedom (3 DOF) - body rotates about pitch, travel, and elevation axes	--	✔
DEVICE SPECIFICATIONS		
Device mass	3.46 kg	6.2 kg
Device height (ground to top of base)	45 cm	45 cm
Device length (counterweight to front of propellers)	--	127 cm
Helicopter body mass	1.39 kg	1.15 kg
Helicopter body length	48 cm	49.8 cm
Base dimensions – W × L	17.5 cm x 17.5 cm	17.5 cm x 17.5 cm
Pitch encoder resolution (in quadrature)	4096 counts/rev	4096 counts/rev
Yaw/travel encoder resolution (in quadrature)	8192 counts/rev	8192 counts/rev
Pitch angle range	75 (± 37.5 deg)	64 (± 32.0 deg)
Yaw angle range	360 deg	--
Elevation angle range	--	63.5 deg
Travel angle range	--	360 deg
Pitch force thrust constant	0.22 N/V*	0.22 N/V*
Yaw pitch thrust constant	0.43 N/V*	--
Propeller diameter	20.3 cm	20.3 cm
Propeller pitch	15.2 cm	15.2 cm
Pitch/front motor: Resistance	0.83 Ω	0.83 Ω
Pitch/front motor: Current-torque constant	0.0182 N.m/A	0.0182 N.m/A
Yaw/back motor: Resistance	1.60 Ω	0.83 Ω
Yaw/back motor: Current-torque constant	0.0109 N.m/A	0.0182 N.m/A

*These parameters were identified experimentally and will be different on each system.

COMPLETE WORKSTATION COMPONENTS

Plant	2 or 3 DOF Helicopter
Control design environment	Quanser QUARC® add-on for MATLAB®/Simulink® Quanser Rapid Control Prototyping (RCP) Toolkit add-on for LabVIEW™
Documentation	Quick Start Guide, User Manual and Laboratory Guide
LabVIEW targets	Microsoft Windows® and NI CompactRIO
Data acquisition devices	Quanser Q2-USB (for 2 DOF Helicopter only) Q8-USB, QPID/QPIDe, or NI CompactRIO with two Quanser Q1-cRIO modules
Amplifier	Quanser VoltPAQ-X2 or two VoltPAQ-X1 linear voltage amplifiers

The linear state space model and a sample controller(s) are supplied

About Quanser:

Quanser is the world leader in education and research for real-time control design and implementation. We specialize in outfitting engineering control laboratories to help universities captivate the brightest minds, motivate them to success and produce graduates with industry-relevant skills. Universities worldwide implement Quanser's open architecture control solutions, industry-relevant curriculum and cutting-edge work stations to teach Introductory, Intermediate or Advanced controls to students in Electrical, Mechanical, Mechatronics, Robotics, Aerospace, Civil, and various other engineering disciplines.