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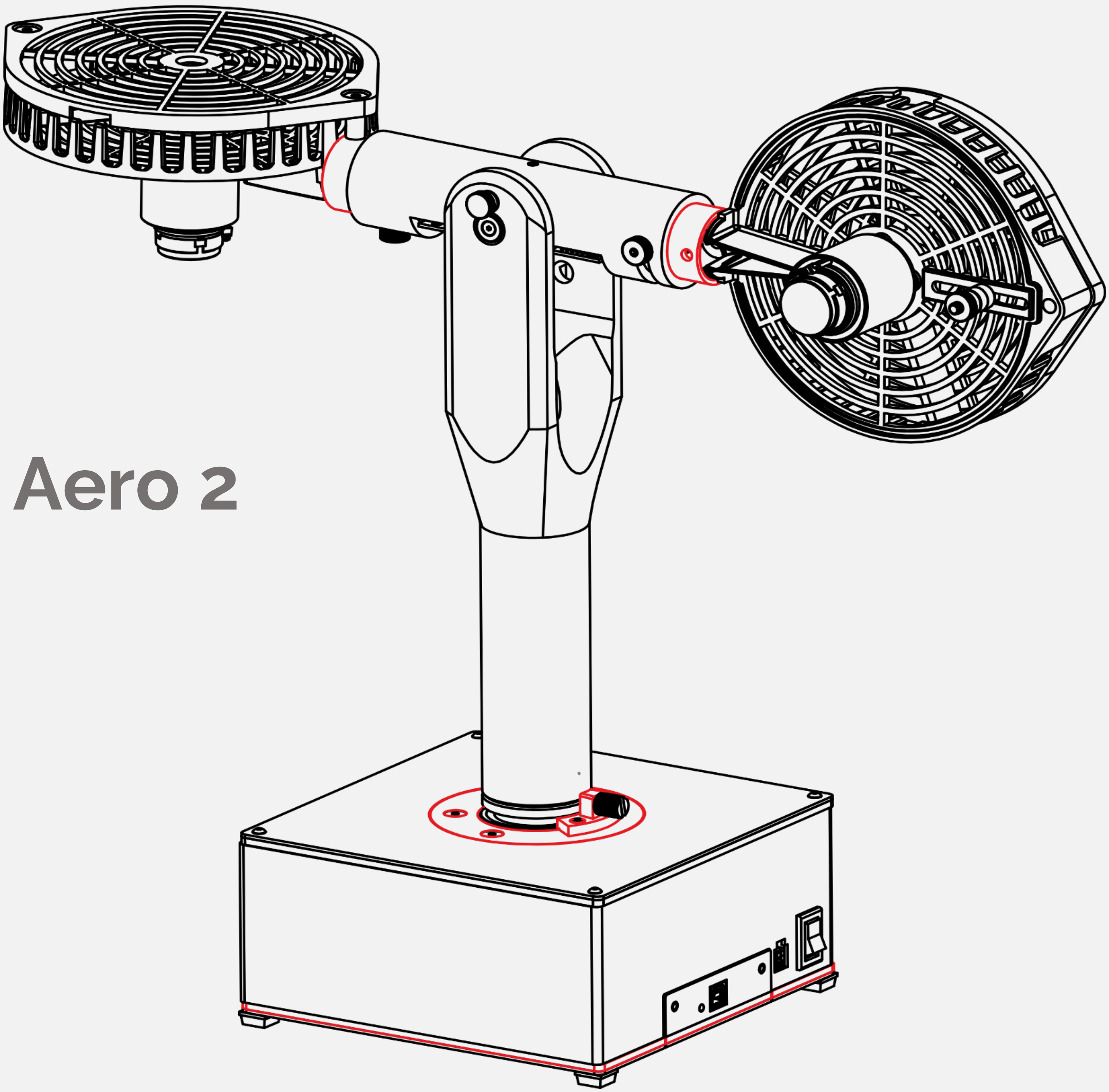

Aero 2

2 DOF Helicopter Application Guide
for MATLAB/Simulink

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2 DOF Helicopter System

Why Explore the 2 DOF Helicopter System?

The 2 DOF Helicopter configuration emulates the most common type of helicopter with a main rotor providing the lift or vertical thrust and a rear tail rotor. The tail rotor, also known as an anti-torque rotor, is used to compensate for the aerodynamic drag that is produced by the main rotor. This cross-coupling effect along with other aerodynamics makes it a unique system for modelling and control system design.

Topics

- Derive linear equations of motion for the 2 DOF Helicopter configuration
- Find the transfer function and state-space representation models
- Find the viscous damping coefficients about the pitch and yaw axes experimentally
- Find the thrust force constants experimentally
- Design a de-coupled PD control to control the pitch and yaw axes
- Simulate the closed-loop system and implement on the Aero 2 Experiment
- Design state-feedback control using LQR optimization
- Simulate the closed-loop system and implement on the Aero 2 Experiment

System Overview

The Aero 2 can be configured as a conventional dual-rotor helicopter, as shown in Figure 1. The front rotor is horizontal to the ground while the rear or tail rotor is vertical. See the Aero 2 User Manual for a full description of the various sensors and actuators on the system.

Figure 1 – Aero 2 - 2 DOF Helicopter configuration.

The tail rotor in helicopters is also known as the anti-torque rotor because it is used to compensate for the torque that the main rotor generates about the yaw – due to aerodynamic drag – as shown in Figure 2. Without this, the helicopter would be difficult to stabilize about the yaw axis. Because the rotors on the Aero Experiment are the same size and equidistant from each other, the tail rotor also generates a torque about the pitch axis. As a result, both the front and back/tail rotors generate a torque on each other.

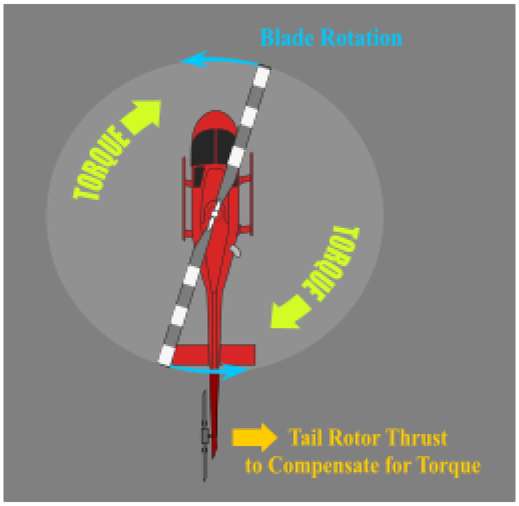


Figure 2 - Tail rotor used to compensate for torque from main rotor
[https://commons.wikimedia.org/wiki/File:Rotor_Antitorque_System.svg]

Lab Modules Overview

Each of the lab modules has a MATLAB Live Script that gives a general background on the modelling or controller technique used in the application as well as the code needed to setup the MATLAB workspace to run the Simulink models in QUARC.

A summary of the 2 DOF Helicopter labs supplied is given in .

Lab Module/Application	MATLAB Live Script	Description
Parameter Estimation	aero2_2dof_modeling.mlx virtual_aero2_2dof_modeling.mlx	Overview of the linear model used in the Aero 2 2 DOF Helicopter. Includes the transfer function and state-space model derivation.
	aero2_2dof_pitch_id.mlx virtual_ aero2_2dof_pitch_id.mlx	Measure the thrust force gain, damping, and stiffness of the pitch axis.
	aero2_2dof_yaw_id.mlx virtual_ aero2_2dof_yaw_id.mlx	Measure the thrust force gain and damping of the yaw axis
	aero2_2dof_pitch_from_yaw_id.mlx virtual_aero2_2dof_pitch_from_yaw_id.mlx	Find the thrust force gain representing the force acting on the pitch axis from the yaw/rear rotor.
	aero2_2dof_yaw_from_pitch_id.mlx virtual_aero2_2dof_yaw_from_pitch_id.mlx	Find the thrust force representing the force acting on the yaw axis from the pitch or front rotor.
PD Control	aero2_2dof_pd_control.mlx virtual_aero2_2dof_pd_control.mlx	Design two PD control loops to control the position of the pitch and yaw axes.
LQR Control	aero2_2dof_lqr_control.mlx virtual_aero2_2dof_lqr_control.mlx	Design a state-feedback control using LQR to control the position of the pitch and yaw axes.

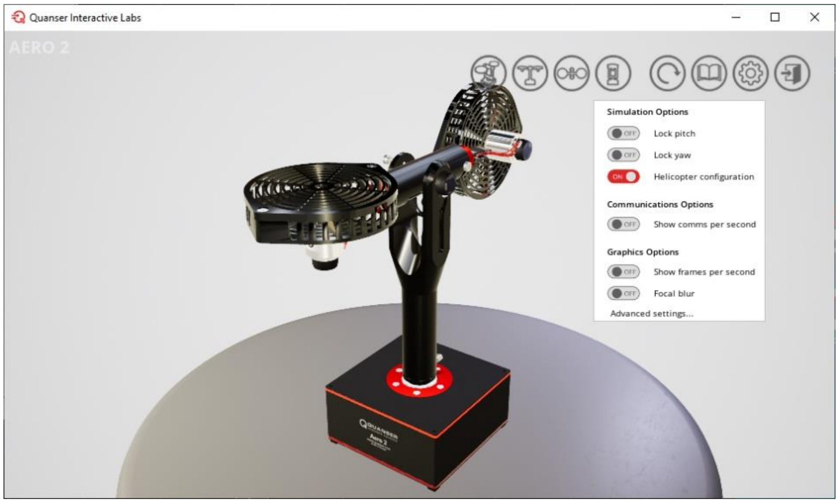
Aero 2 Setup

1. Make sure the Aero 2 has been tested as instructed in the Quick Start Guide.
2. Setup the Aero 2 in the 2 DOF Helicopter configuration, as shown in Figure 1:
    a. Lock the pitch axis and unlock the yaw axis.
    b. Both rotors are horizontal (i.e., rotor shields are parallel with the ground).
    c. Mount weight on each rotor.
3. Connect the USB cable to your PC/laptop.
4. Connect the power and turn the power switch ON. The Aero base LED should be red

Virtual Aero 2 Setup

1. Launch MATLAB and browse to the working directory that includes the Simulink models for this lab.
2. Run the Quanser Interactive Labs (QLabs) software and login using your account.
3. From the product list select *Aero 2*, then select *Aero 2 Workspace*.
4. Configure the Virtual Aero 2 in the 2 DOF Helicopter configuration. To do this, click the *Options* icon and ensure the following settings are selected
    a. Lock pitch ON
    b. Lock yaw OFF
    c. Helicopter configuration ON

    The Virtual Aero 2 should look as shown below.



How to Run the Labs

1. Launch MATLAB.
2. Browse to the working directory that includes the Simulink models for the lab.
3. Open the Live Script for the lab, e.g., aero2_2dof_pd_control.mlx.
4. Go through each section by clicking on the *Run Section* button.
5. Run the Simulink model for simulations and the Virtual Aero 2. Use QUARC to run the model on the Aero 2 hardware.