Satellite GNC Design Workshop

MathWorks

Satellite GNC Design Workshop

- Simulate an orbit with 2 slews
  - Orbit propagation
  - Pointing logic
  - Different visualization methods
- Design an attitude controller
- Improve controller with automated tuning tools
- Test a tuned controller back in the scenario

Today's Agenda

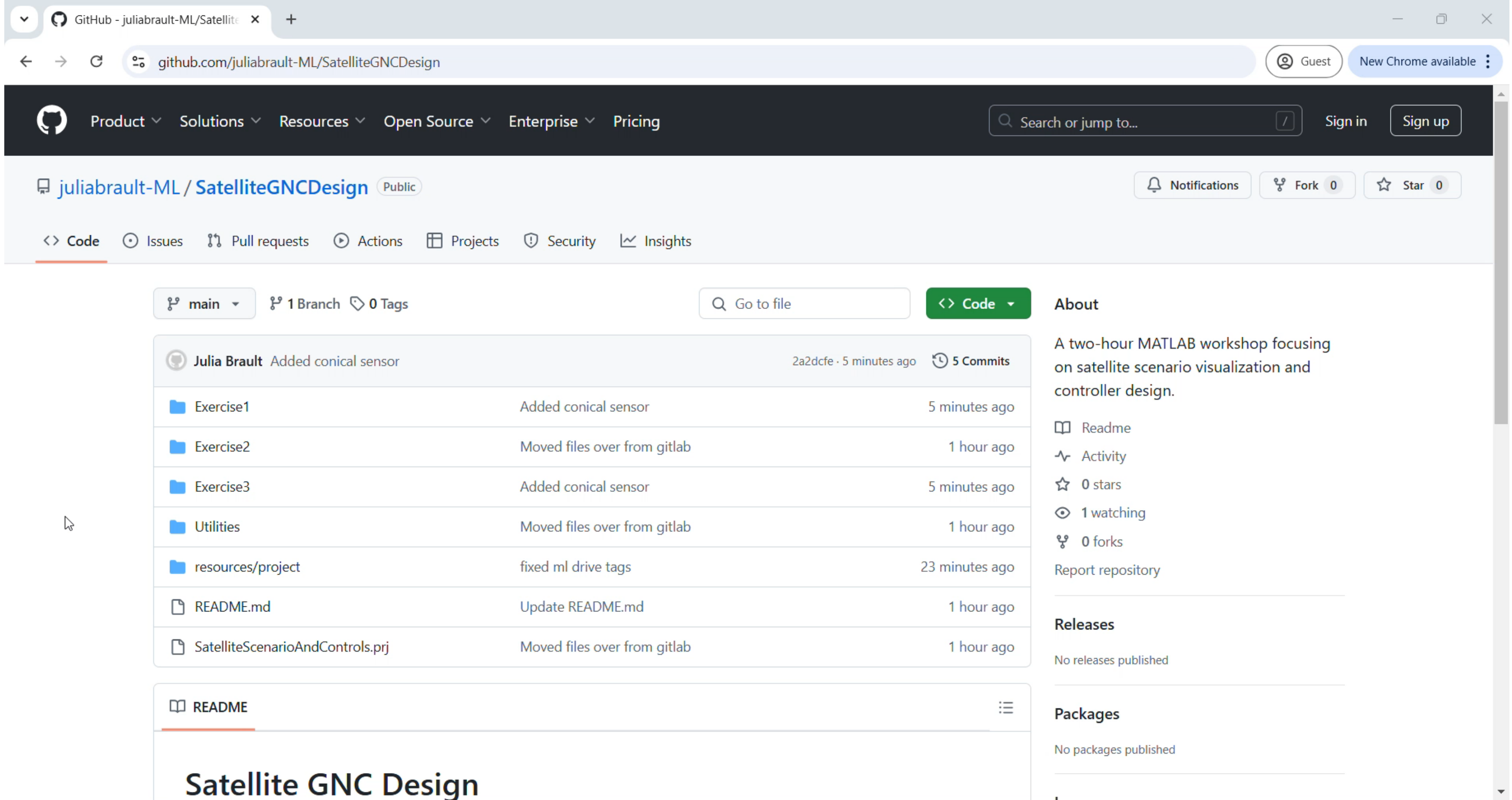
Time	Item
11AM – 12PM	Workshop Introduction and MATLAB Online Set-Up (15 mins) Exercise 1: Simulate an Ideal Scenario (15 mins) Begin Exercise 2: Controller Design and Tuning (30 mins)
12PM – 12:30PM	Lunch
12:30PM – 1:30PM	Continue Exercise 2: Controller Design and Tuning (45 mins) Exercise 3: Simulate a Scenario Including a Tuned Controller (15 mins)

Setting Up MATLAB Online

Conference Wifi
Beaver Run Meeting 1
conferencewifi

Launch your browser (Google Chrome recommended) and follow the instructions in the readme of this GitHub repository:

https://github.com/juliabrault-ML/SatelliteGNCDesign



Exercise 1: Simulate an Ideal Scenario

Purpose of this exercise:

- Familiarize yourself with the MATLAB and Simulink Online environment
- Get to know Aerospace Toolbox and Blockset features for mission simulation
  - Orbit Propagation
  - Pointing Logic
  - Visualization

Exercise 2: Controller Design and Tuning

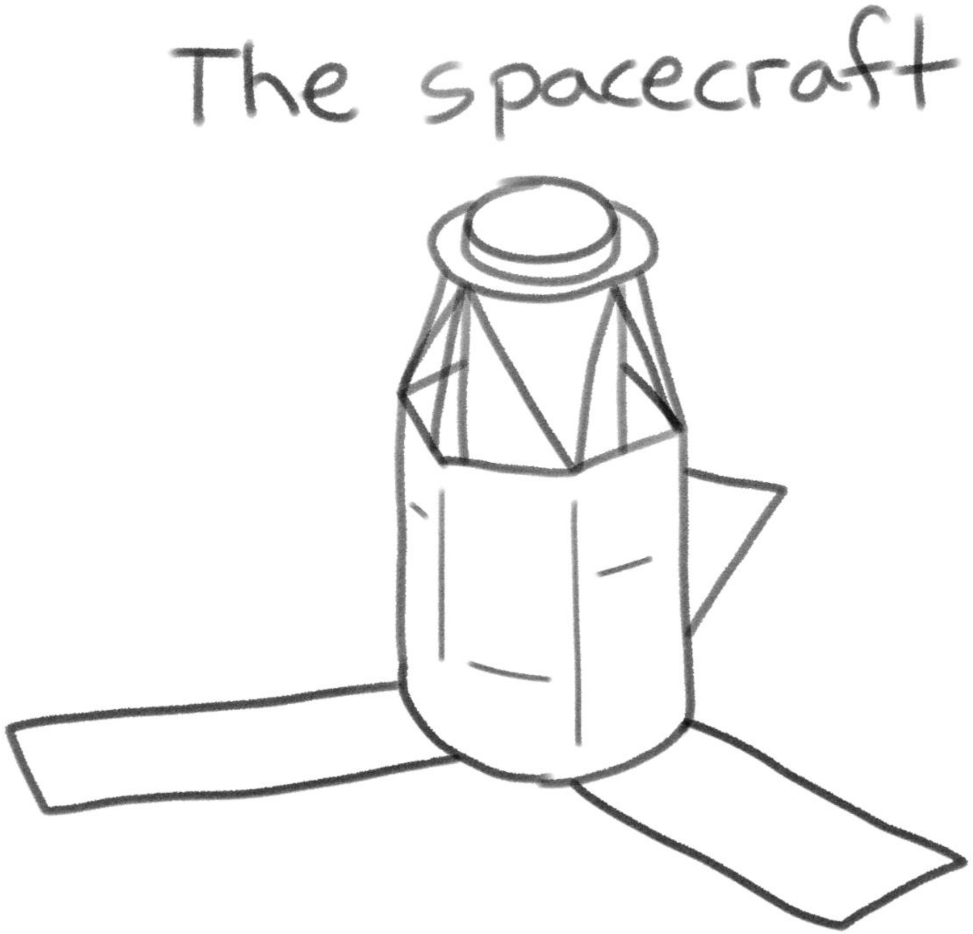
Exercise 2: Controller Design and Tuning

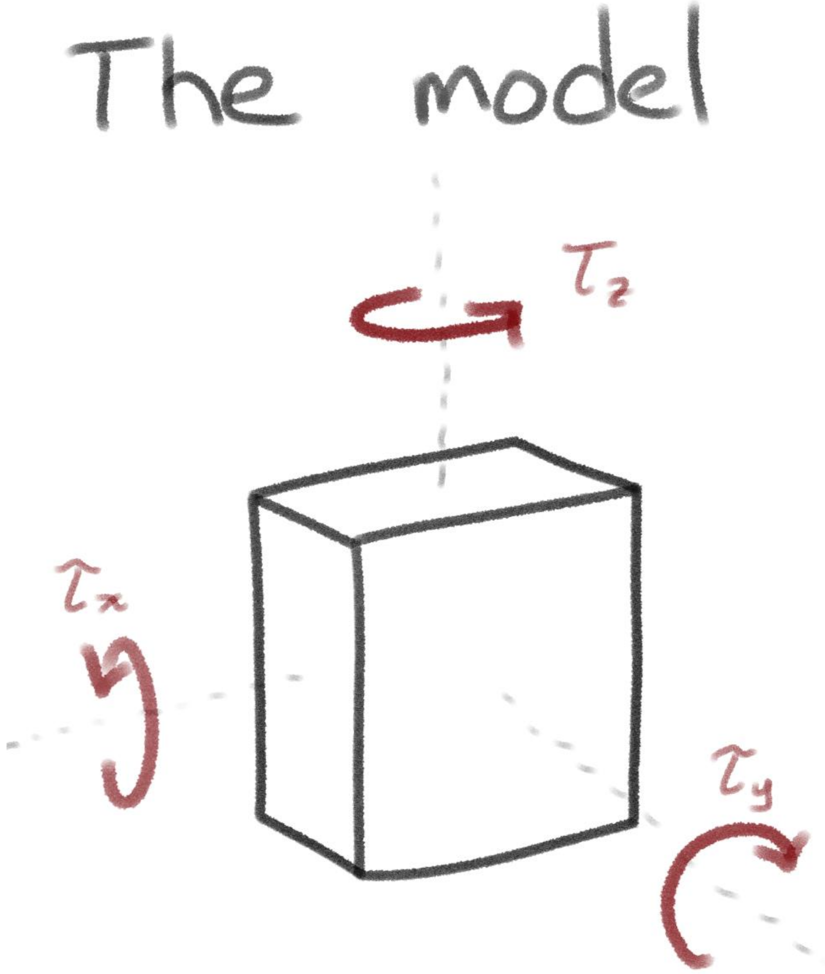
- We're going to **develop a controller** that will follow an attitude profile
- We're going to use Simulink and the **Control System Tuner app**
- The controller we design is not as important as **the process** we follow
- Be thinking of how you can apply this workflow to your problems

Take away

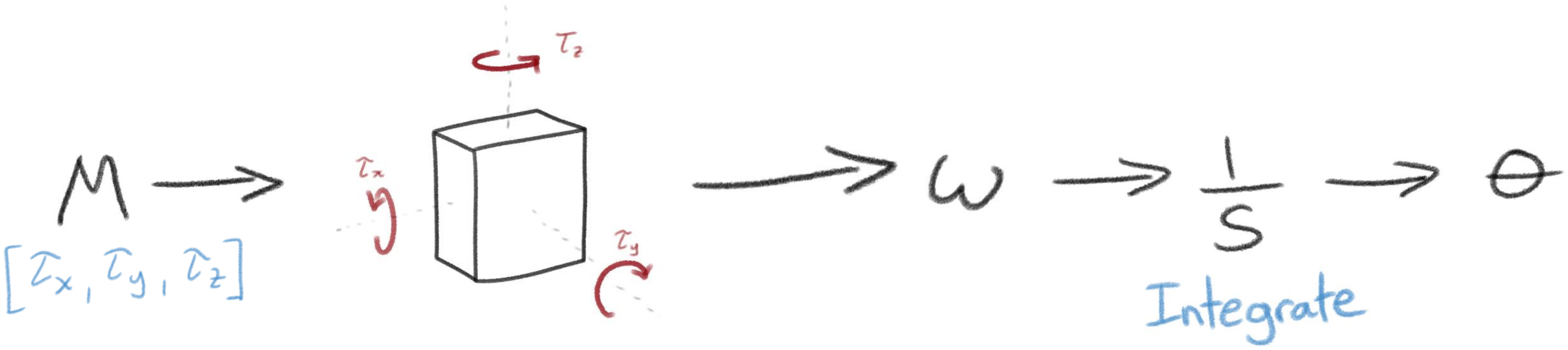
"Wow! There are some powerful tuning tools that I haven't been using!"

We’re using a simplified model of the spacecraft





The governing dynamics are Euler's rigid body equations



$$M = I\dot{\omega} + \omega \times (I\omega)$$

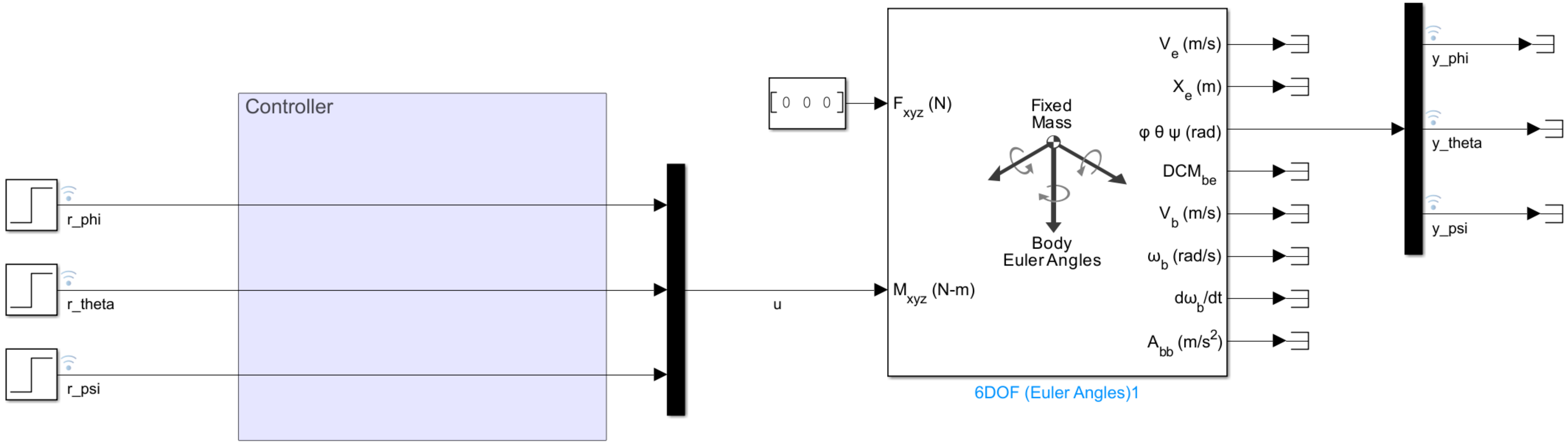
Applied torque

Directly affects angular acceleration

Plus this cross-coupling term

Discussion

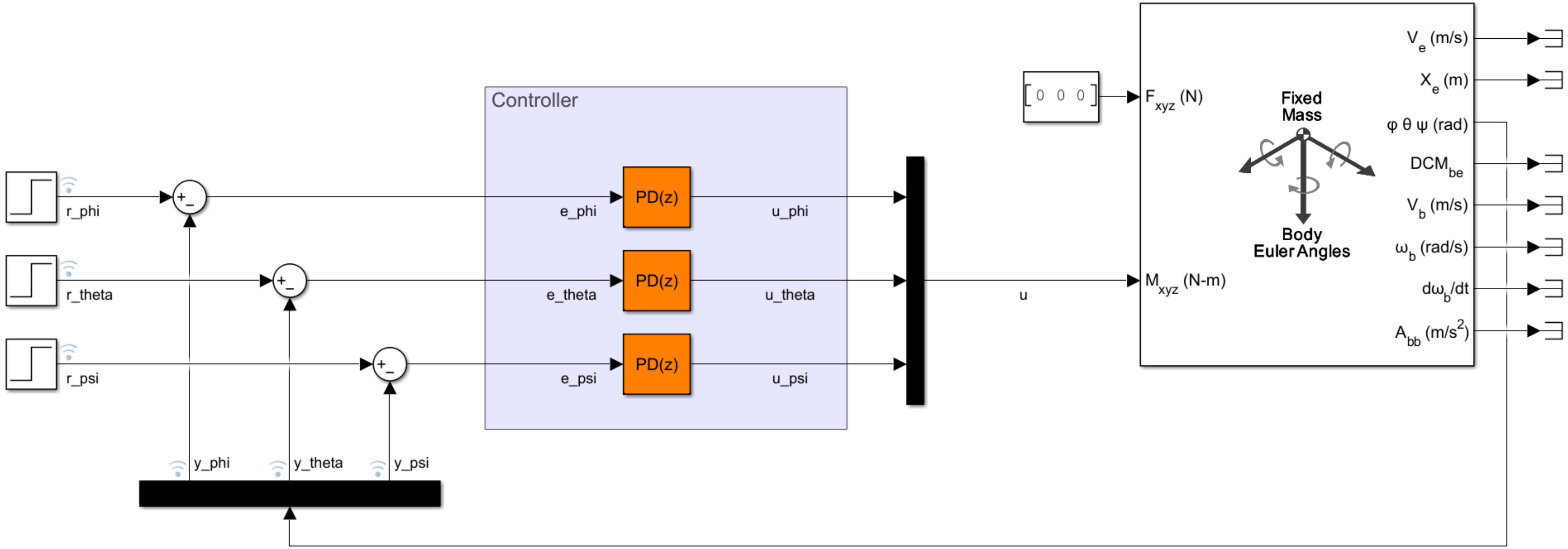
How would you approach this problem?



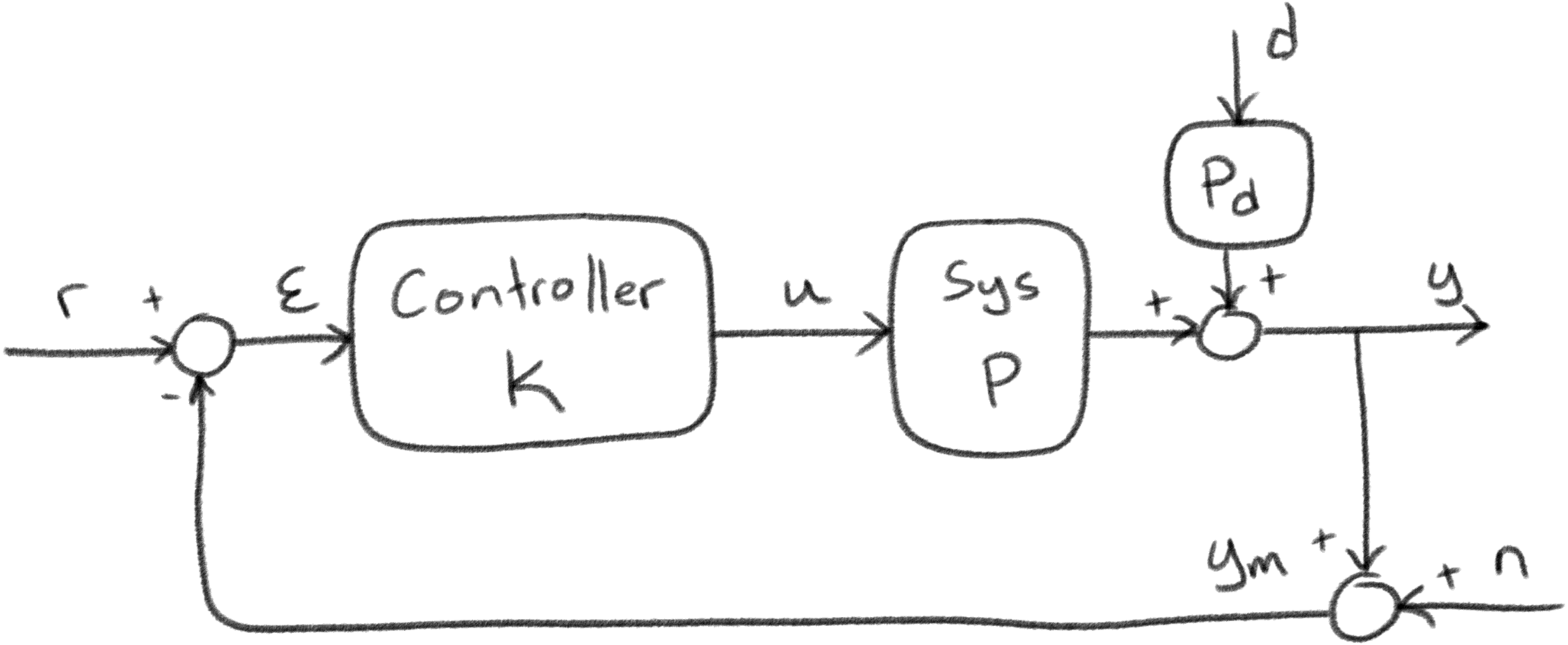
We’re going start with three PD controllers

Run Part 1

Tune controller with Control System Tuner App



A fuller picture of the problem



Loop shaping overview

$$y = \underbrace{(I + PK)^{-1} PK}_{T} r + \underbrace{(I + PK)^{-1}}_{S} P_d d - \underbrace{(I + PK)^{-1} PK}_{T} n$$

follow all frequencies

reject low frequencies

attenuate high frequencies

We want K to be more than PD control

PD + Nonlinear feedback + decoupler

$$M = I\dot{\omega} + \omega \times (I\omega)$$

$$\overbrace{K_{mix}[\omega, \theta] + PD_{control} + \omega \times (I\omega)}^{M} = I\dot{\omega} + \omega \times (I\omega)$$

Decoupler to remove disturbances

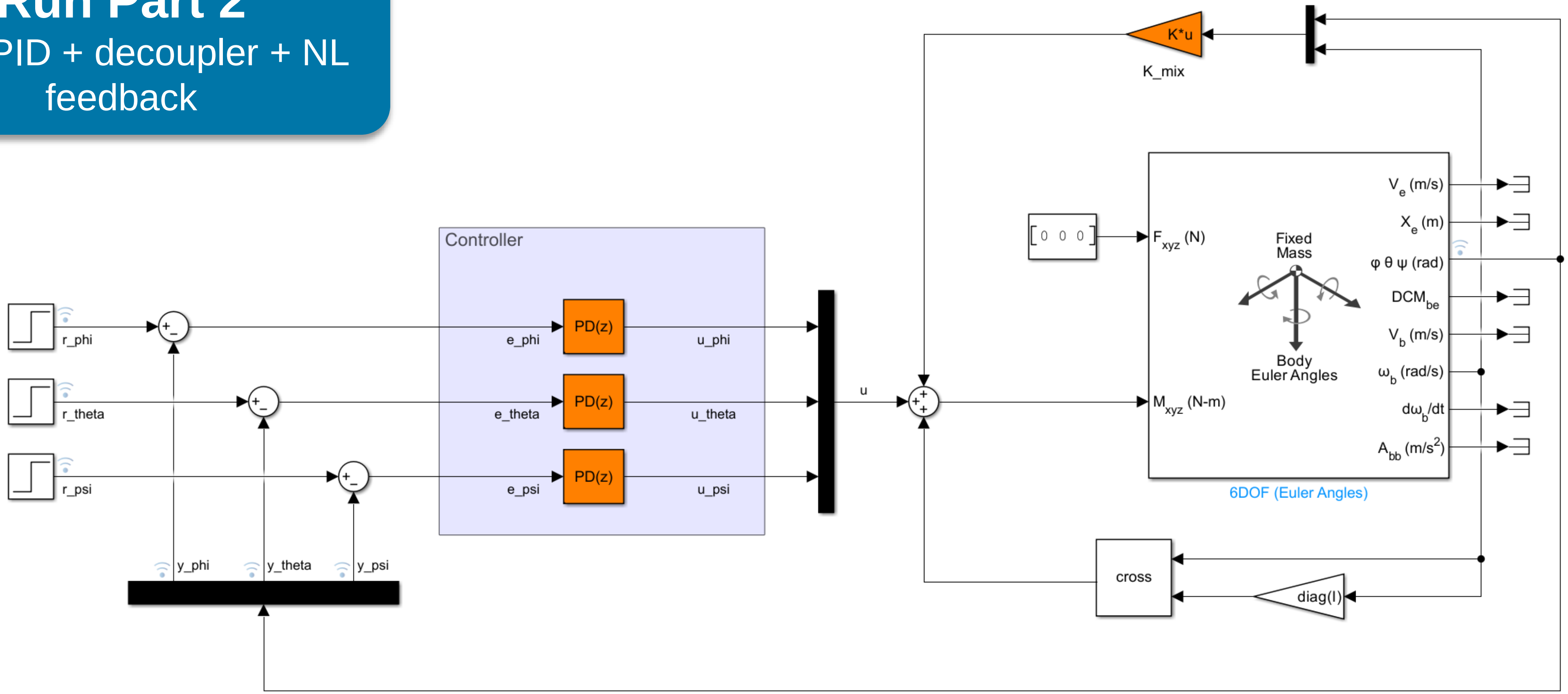
Track reference

Known nonlinearities

Controller Design and Tuning

Run Part 2

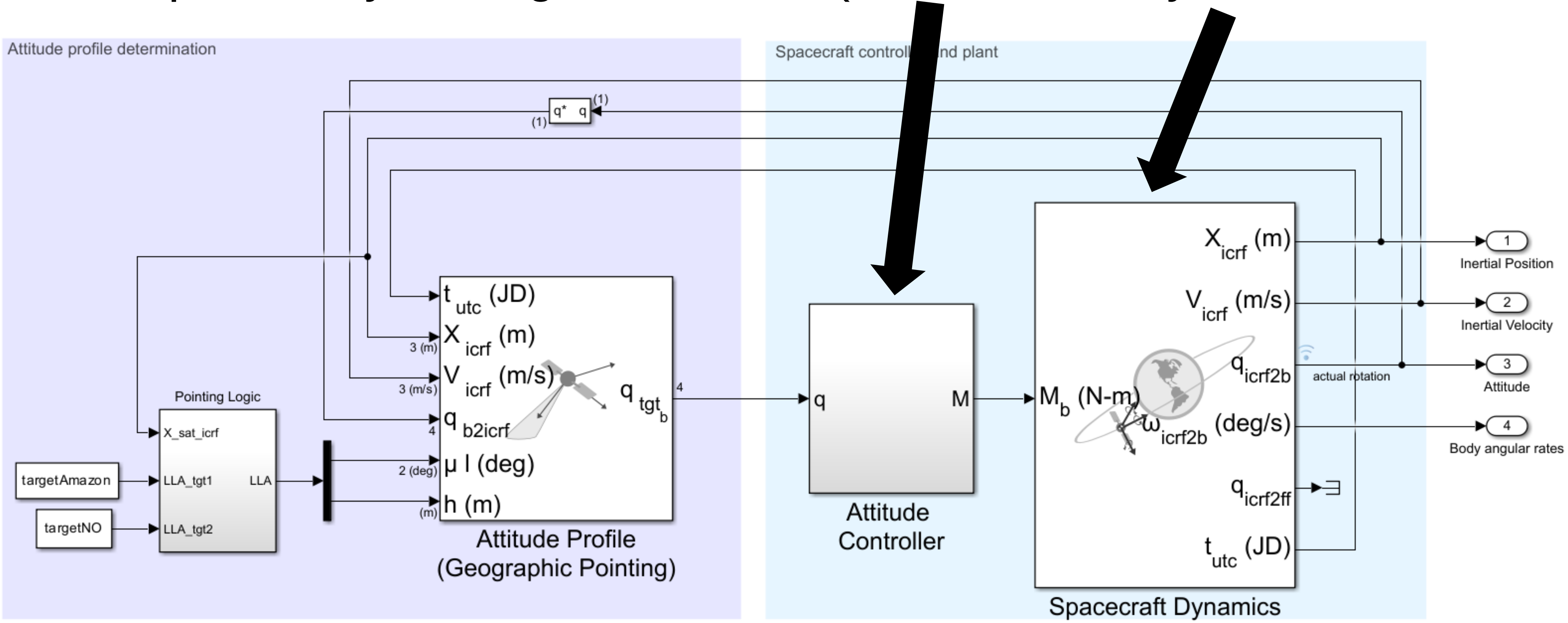
Tune PID + decoupler + NL feedback



Exercise 3: Simulate a Scenario Including a Tuned Controller

Purpose of this exercise:

- Show how the fidelity of Exercise 1 (ideal pointing, no simulation of dynamics) can be improved by adding a controller (controls and dynamics both simulated)



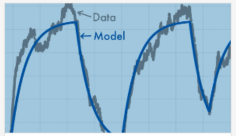
Resources for Aerospace Toolbox & Blockset

- Product Pages
  - https://www.mathworks.com/products/aerospace-toolbox.html
  - https://www.mathworks.com/products/aerospace-blockset.html
- Product Overview Videos
  - https://www.mathworks.com/videos/what-is-aerospace-toolbox--1539774600779.html
  - https://www.mathworks.com/videos/what-is-aerospace-blockset--1539869697000.html
- Documentation
  - https://www.mathworks.com/help/aerotbx/index.html
  - https://www.mathworks.com/help/aeroblks/index.html
- Examples
  - https://www.mathworks.com/help/aerotbx/examples.html
  - https://www.mathworks.com/help/aeroblks/examples.html

Resources for Controls

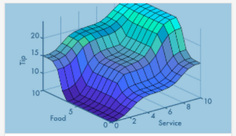
[Tech Talk Videos]

Explore the Control Systems Video Series



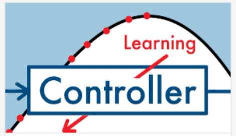
System Identification

Watch videos (4 videos)



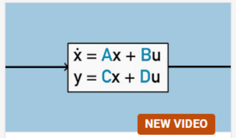
Fuzzy Logic

Watch videos (4 videos)



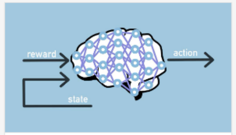
Learning-Based Control

Watch videos (3 videos)



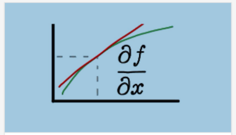
State Space

Watch videos (5 videos)



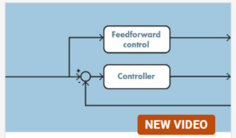
Reinforcement Learning

Watch videos (7 videos)



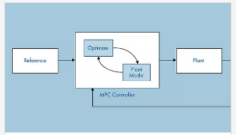
Trimming and Linearization

Watch videos (2 videos)



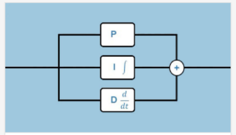
Control Systems in Practice

Watch videos (16 videos)



Understanding Model Predictive Control

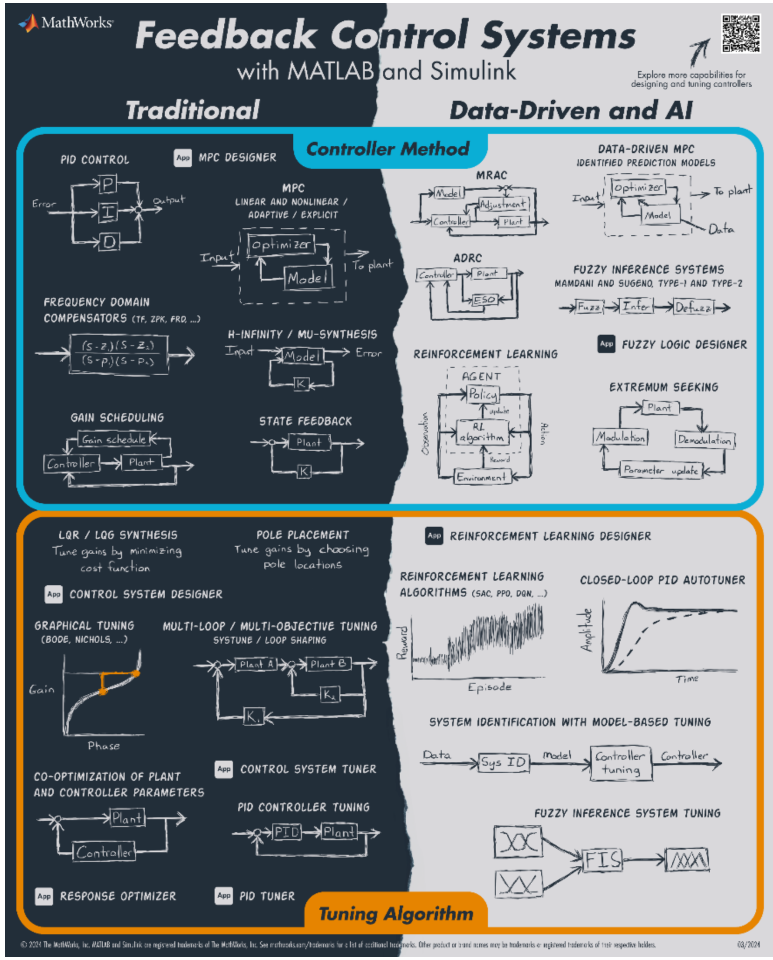
Watch videos (9 videos)



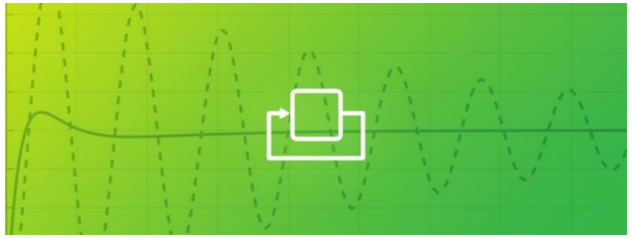
Understanding PID Control

Watch videos (7 videos)

[Reference Posters]



[Onramps]



Control Design Onramp with Simulink

7 modules | 1 hour | Languages

Get started quickly with the basics of feedback control design in Simulink.

Reinforcement Learning Onramp

5 modules | 2.5 hours | Languages

Master the basics of creating intelligent controllers that learn from experience.