MATLAB EXPO

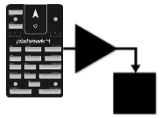
UAV 시스템 검증을 위한 SIL HIL 테스트 환경 개발

김종헌 부장, 매스웍스코리아

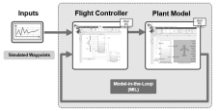
MathWorks®

Agenda

Introduction



PX4 with Simulink



MIL, SIL and HIL Workflows

Scenario Simulation

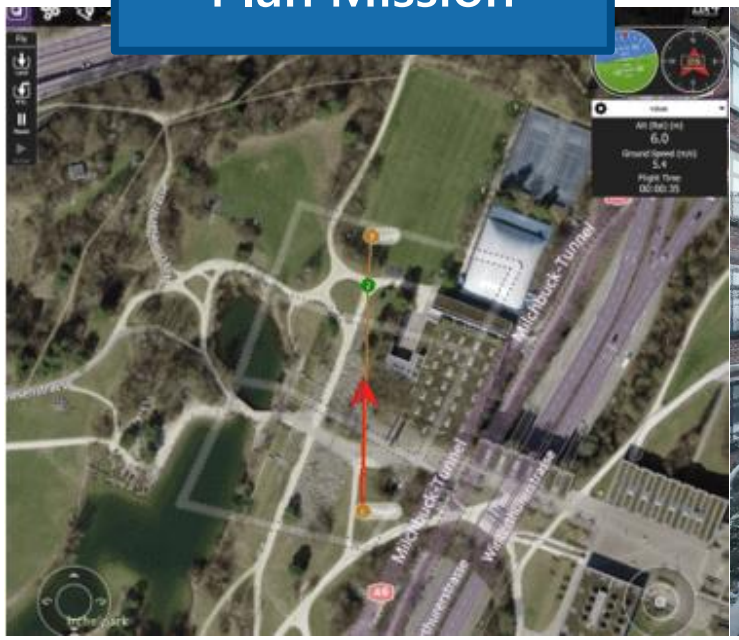
HIL with Scenario Simulation

Summary and Resources

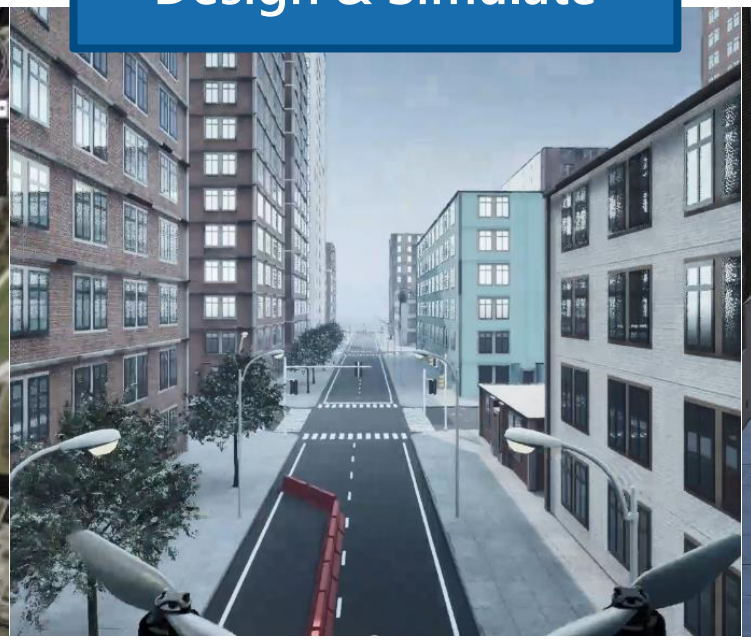
Fly a Drone Through a City Block

Simulation in a Virtual Scenario

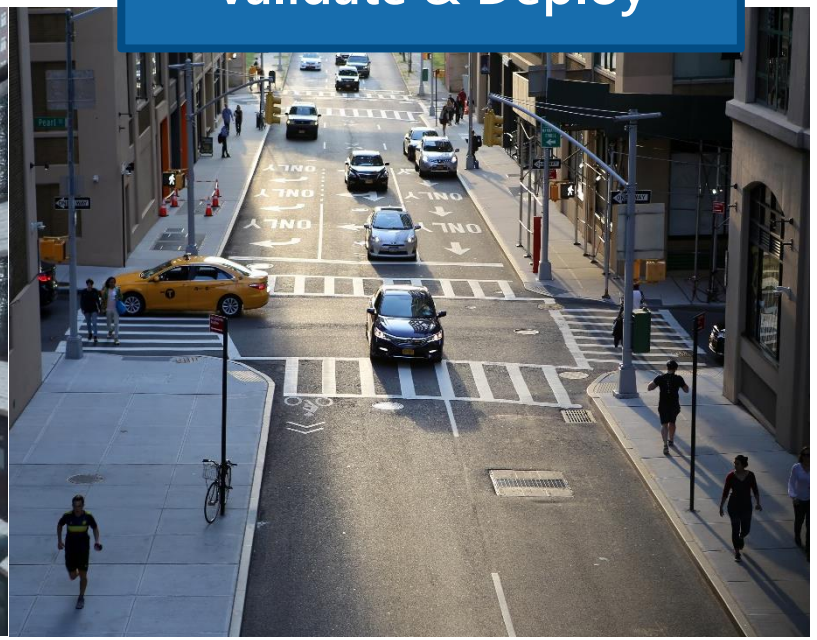
Plan Mission



Design & Simulate



Validate & Deploy

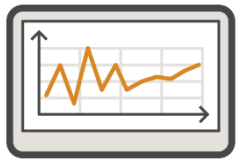


Building Blocks for UAV Simulation

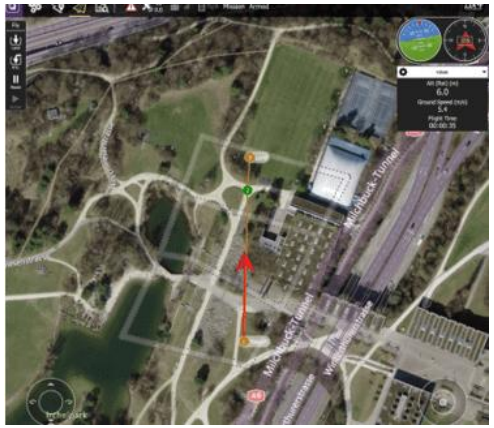
Plan Mission

Generate flight path for the mission

Simulated Waypoints



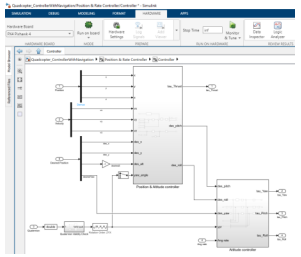
Ground Control Station



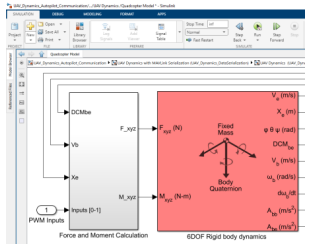
Design & Simulate

Design flight controller and simulate plant behavior in virtual scenarios

Flight Controller



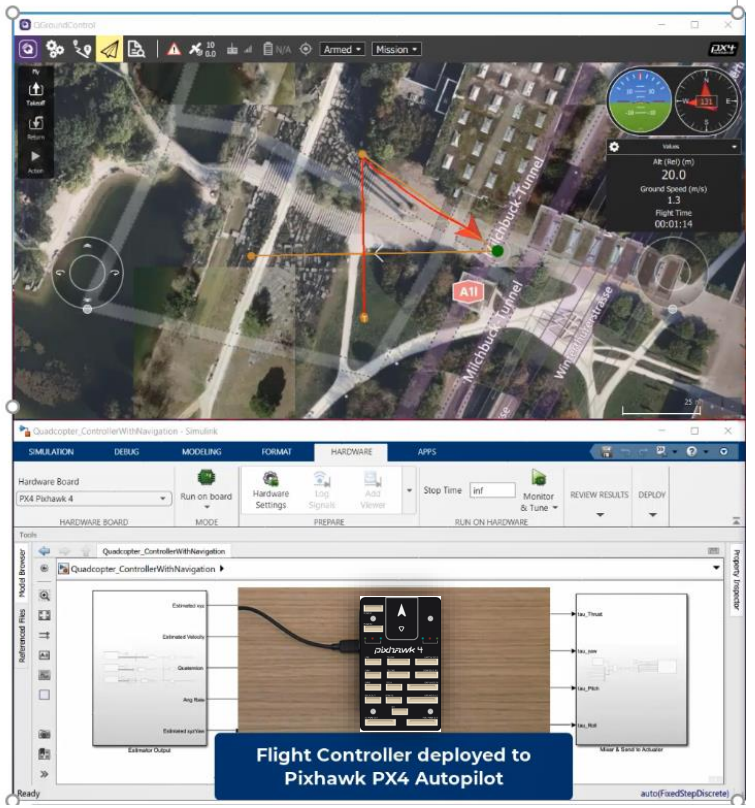
Plant Model



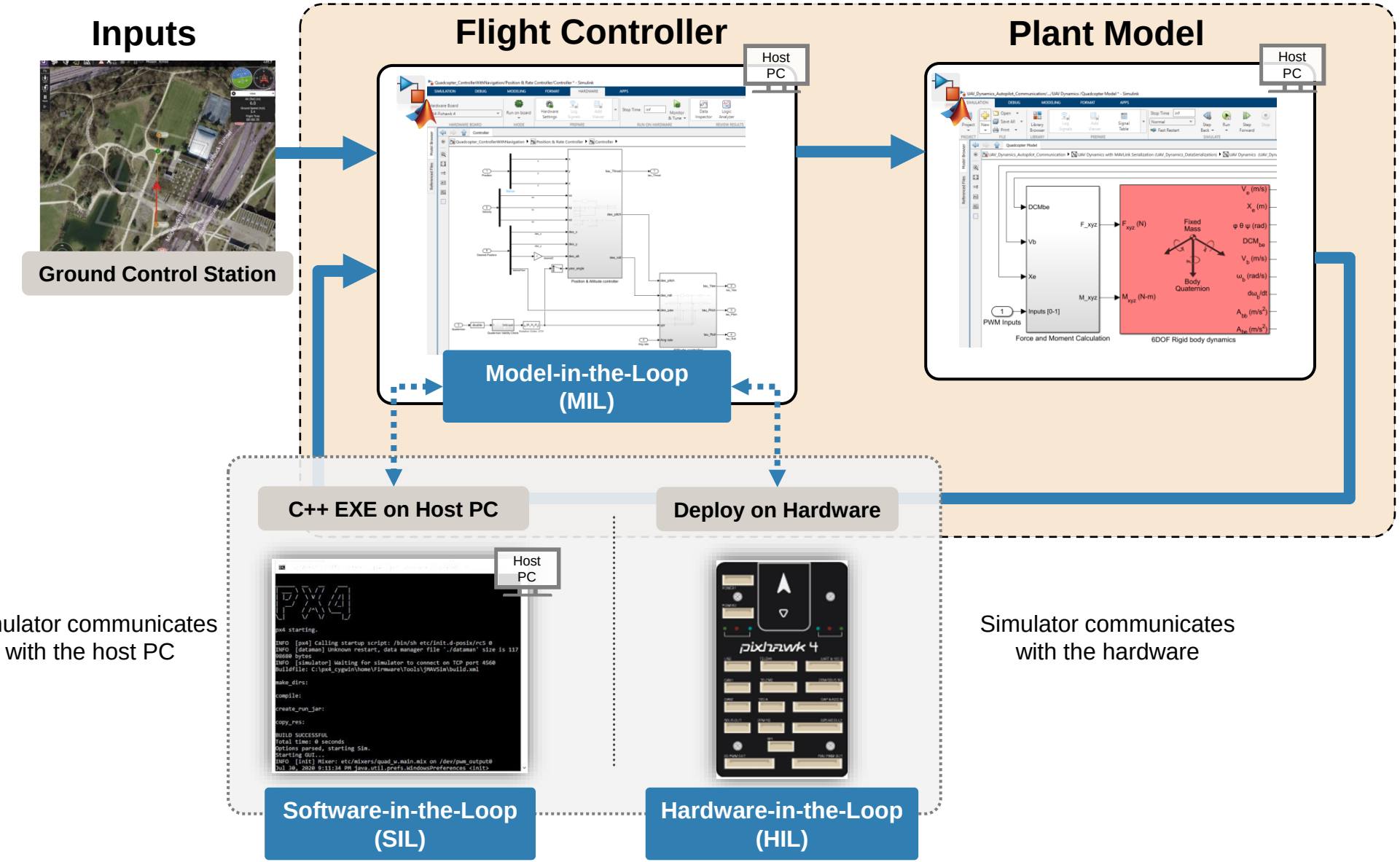
Scenario Simulation

Validate & Deploy

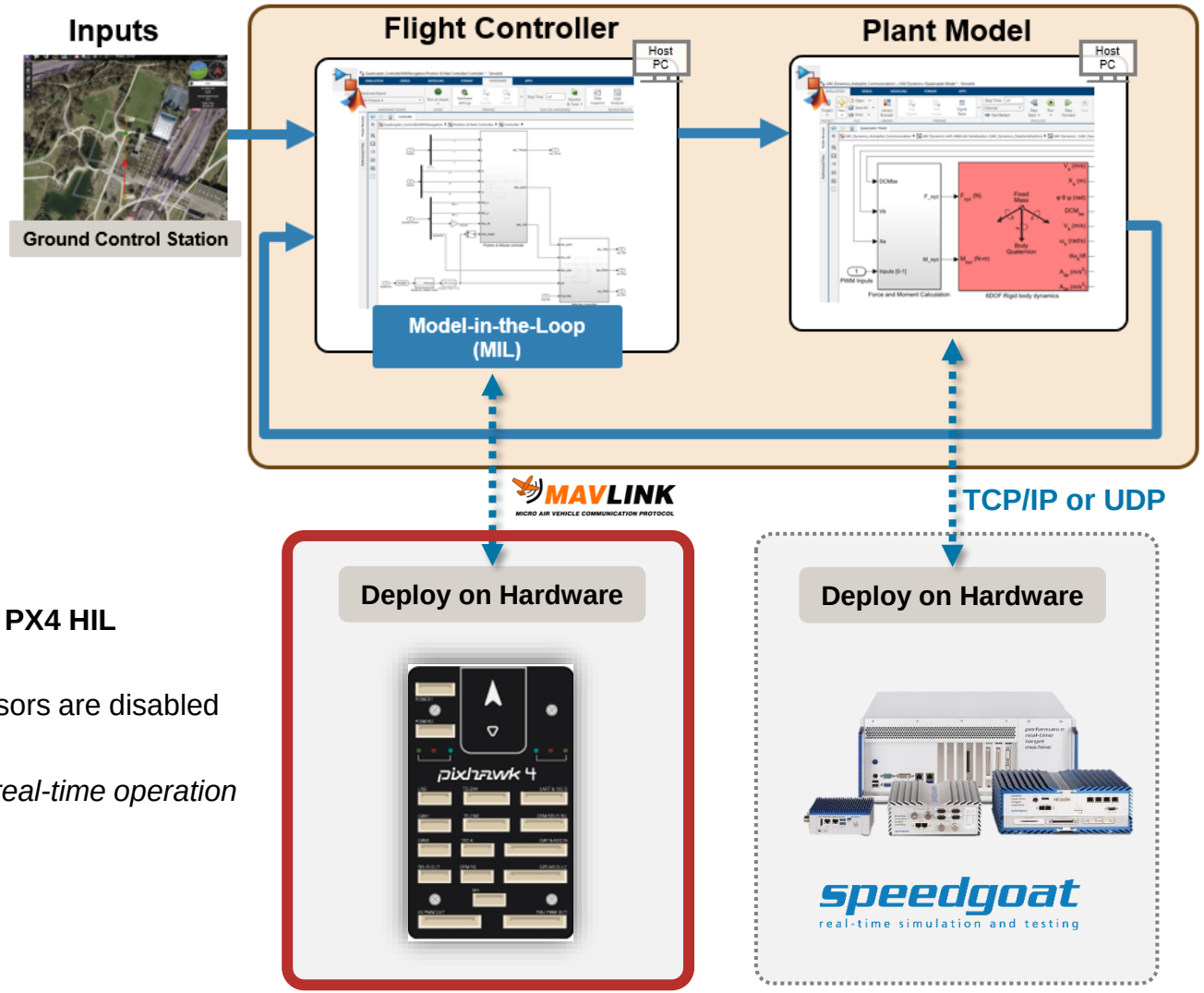
Deploy flight controller and autonomy algorithms to the platform



MIL, SIL and HIL Workflows for UAV Simulation



HIL with Flight Controller Deployed on PX4



PX4 HIL

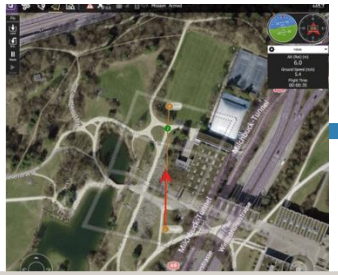
- PX4 sensors are disabled
- *Psuedo real-time operation*

Full HIL Workflow

- Communicates with actuators, sensors and the drone peripherals
- *Real-time operation*

Visualize Flight Behavior in a Virtual Scenario

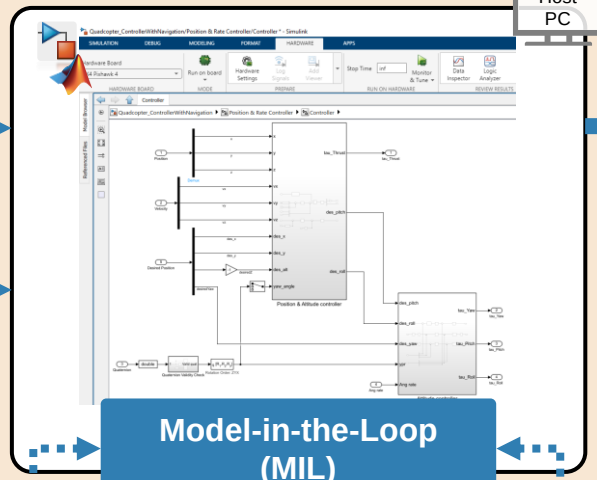
Inputs



Ground Control Station

Flight Controller

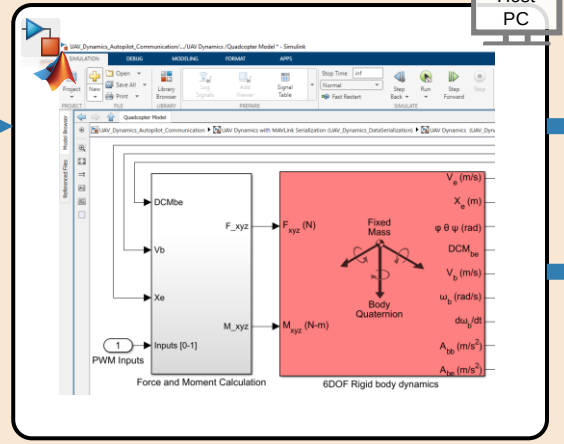
Host PC



Model-in-the-Loop (MIL)

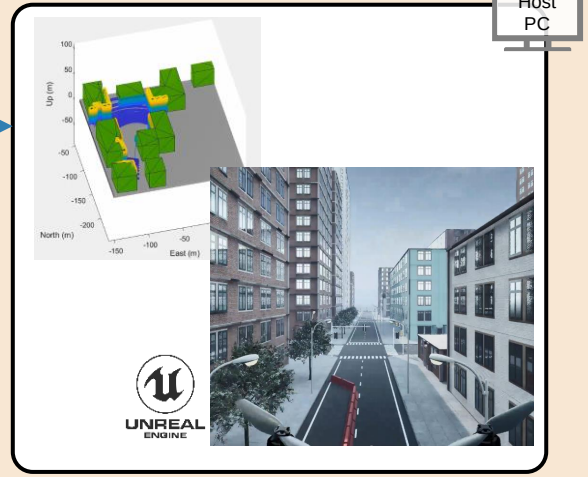
Plant Model

Host PC



Scenario Simulation

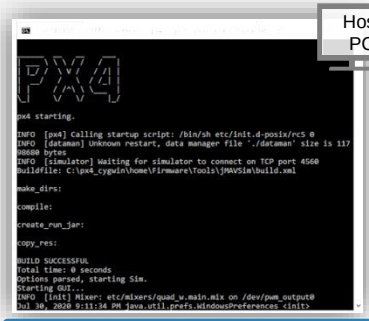
Host PC



C++ EXE on Host PC

Deploy on Hardware

Host PC

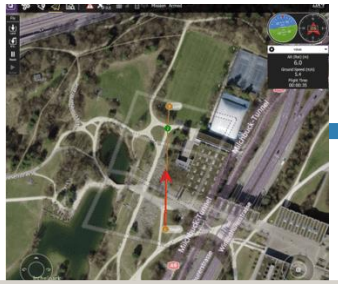


Software-in-the-Loop (SIL)

Hardware-in-the-Loop (HIL)

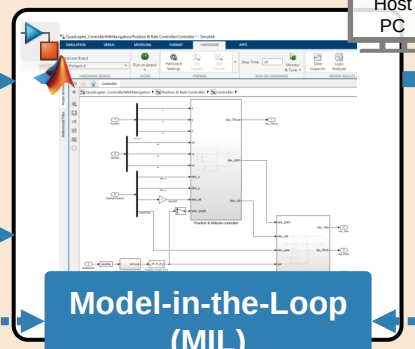
Design Autonomy Algorithms with UAV Simulation Workflow

Inputs



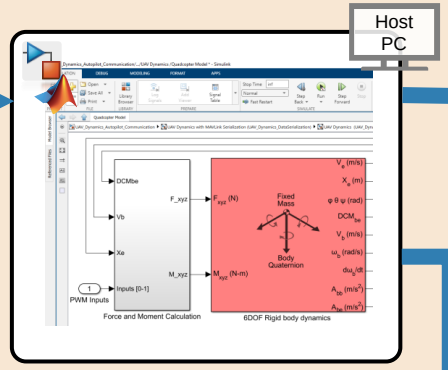
Ground Control Station

Flight Controller

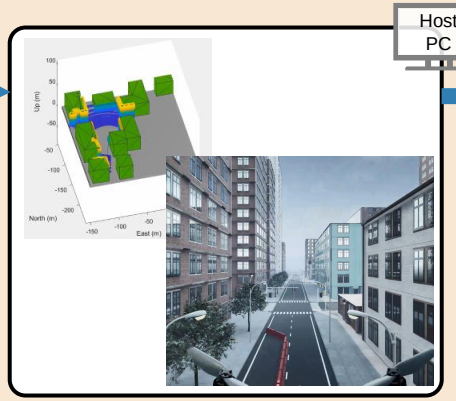


Model-in-the-Loop (MIL)

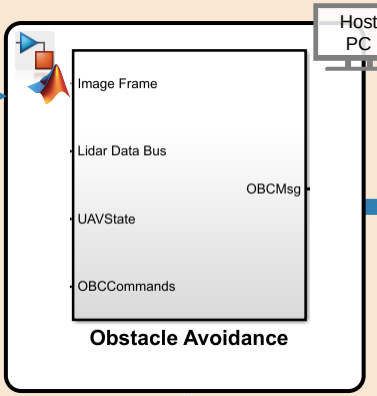
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

Deploy on Hardware

Software-in-the-Loop

Hardware-in-the-Loop

NVIDIA® Jetson™

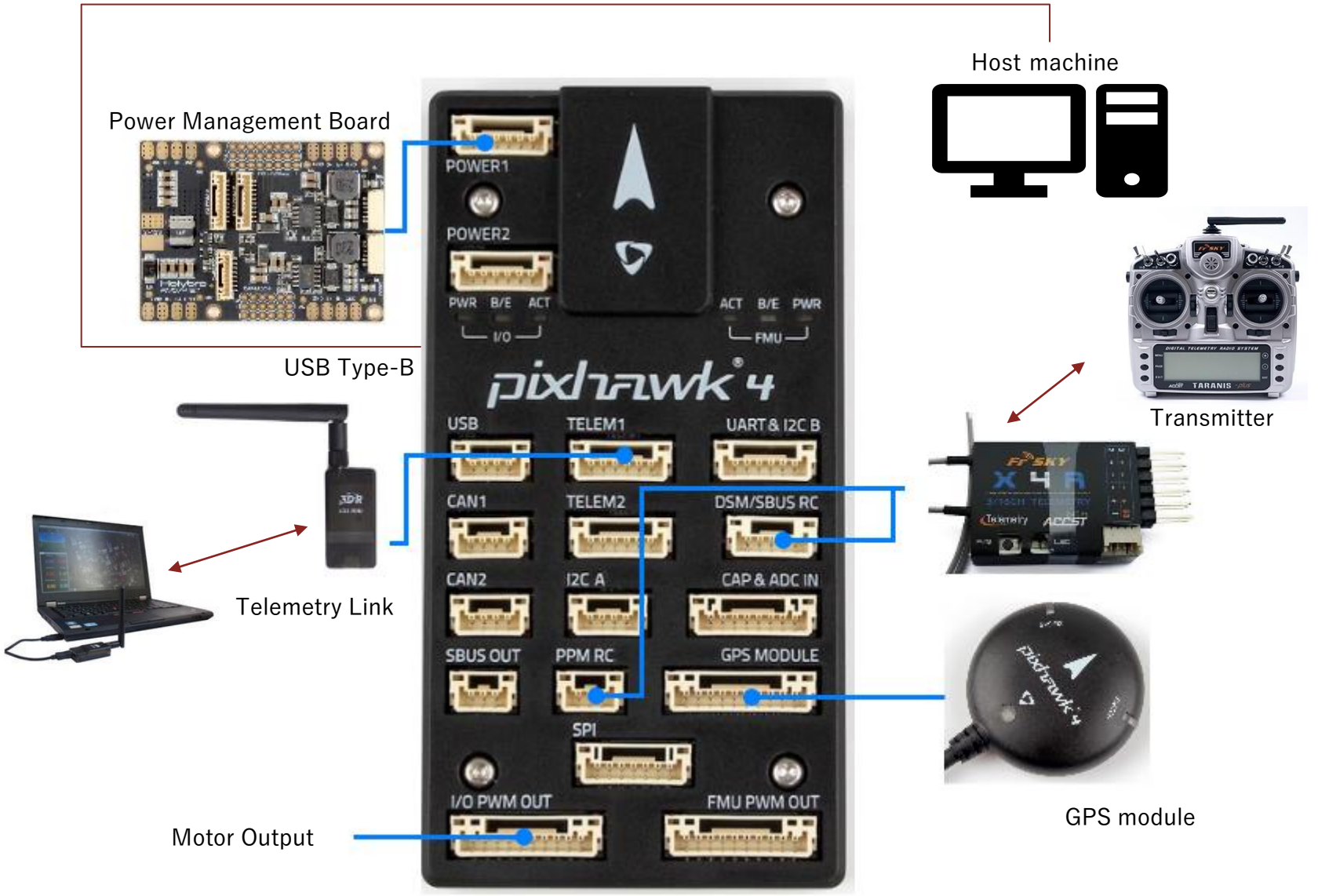
What is Pixhawk®

On-board sensors:

- Accel/Gyro: ICM-20689
- Accel/Gyro: BMI055 or ICM20602
- Magnetometer: IST8310
- Barometer: MS5611

Interfaces:

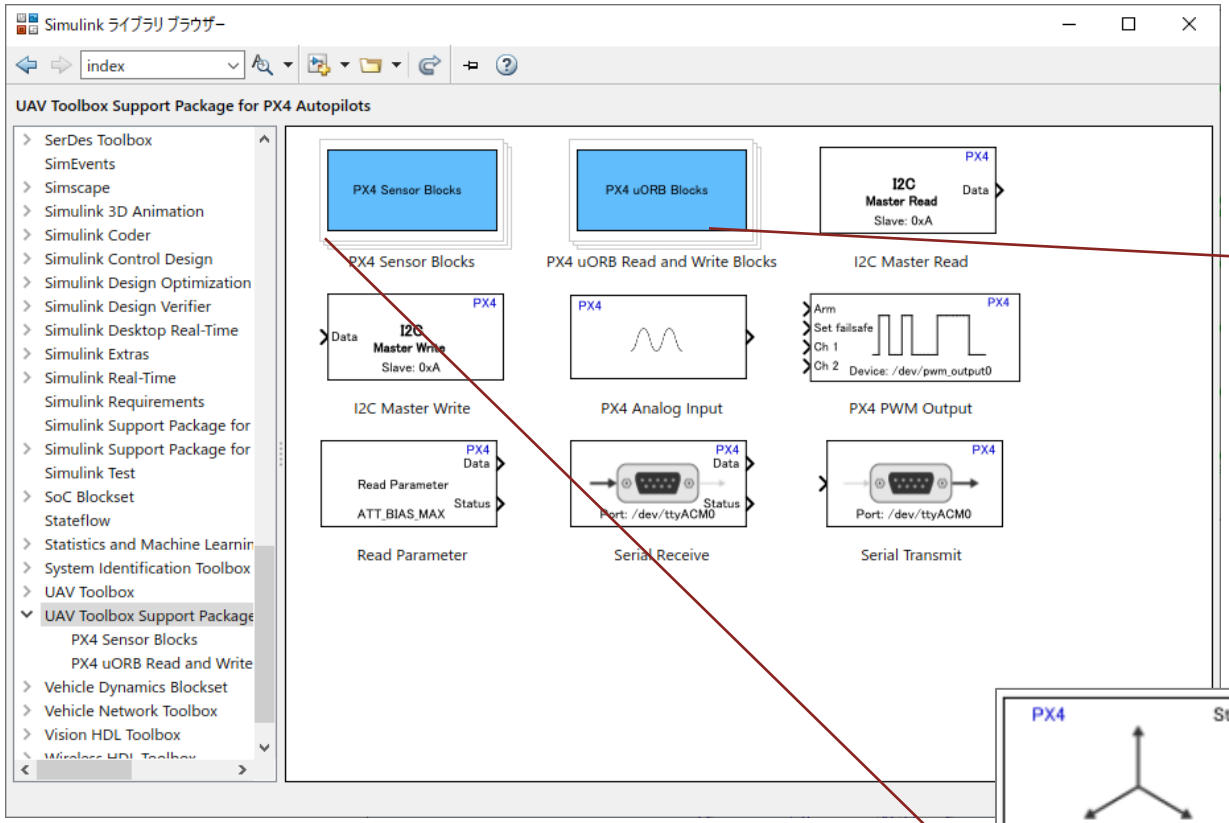
- 8-16 PWM outputs
- 3 dedicated PWM
- Dedicated R/C
- 5 serial ports
- 3 I2C ports
- 4 SPI buses
- 2 CANBuses

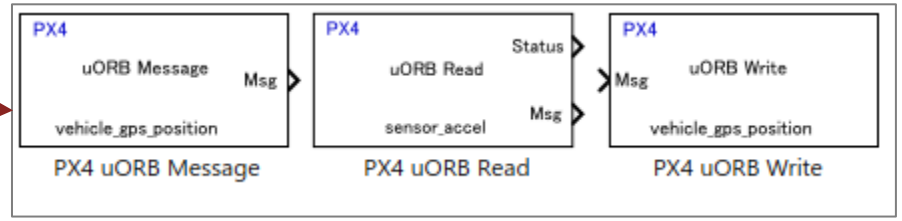


https://docs.px4.io/en/assembly/quick_start_pixhawk4.html

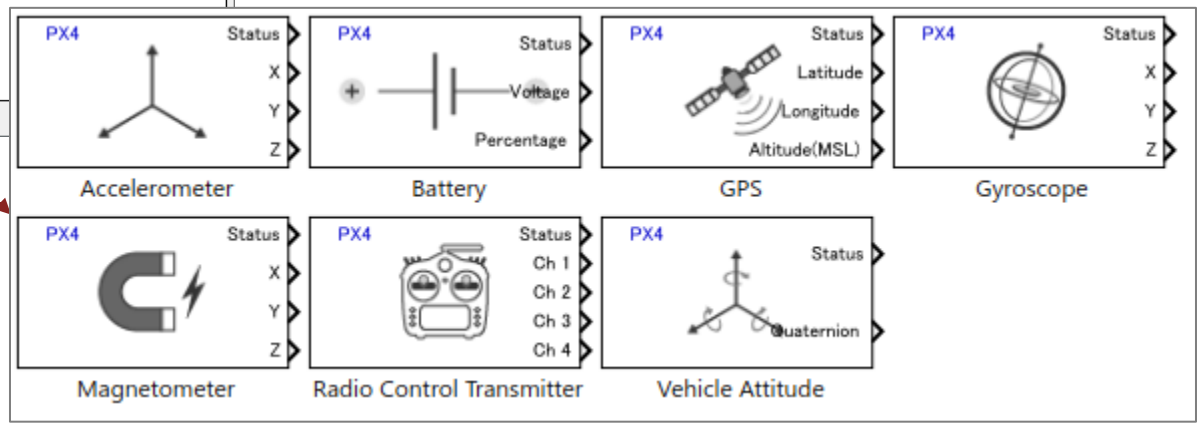
UAV Toolbox Support Package for PX4 Autopilots

Simulink Block Library

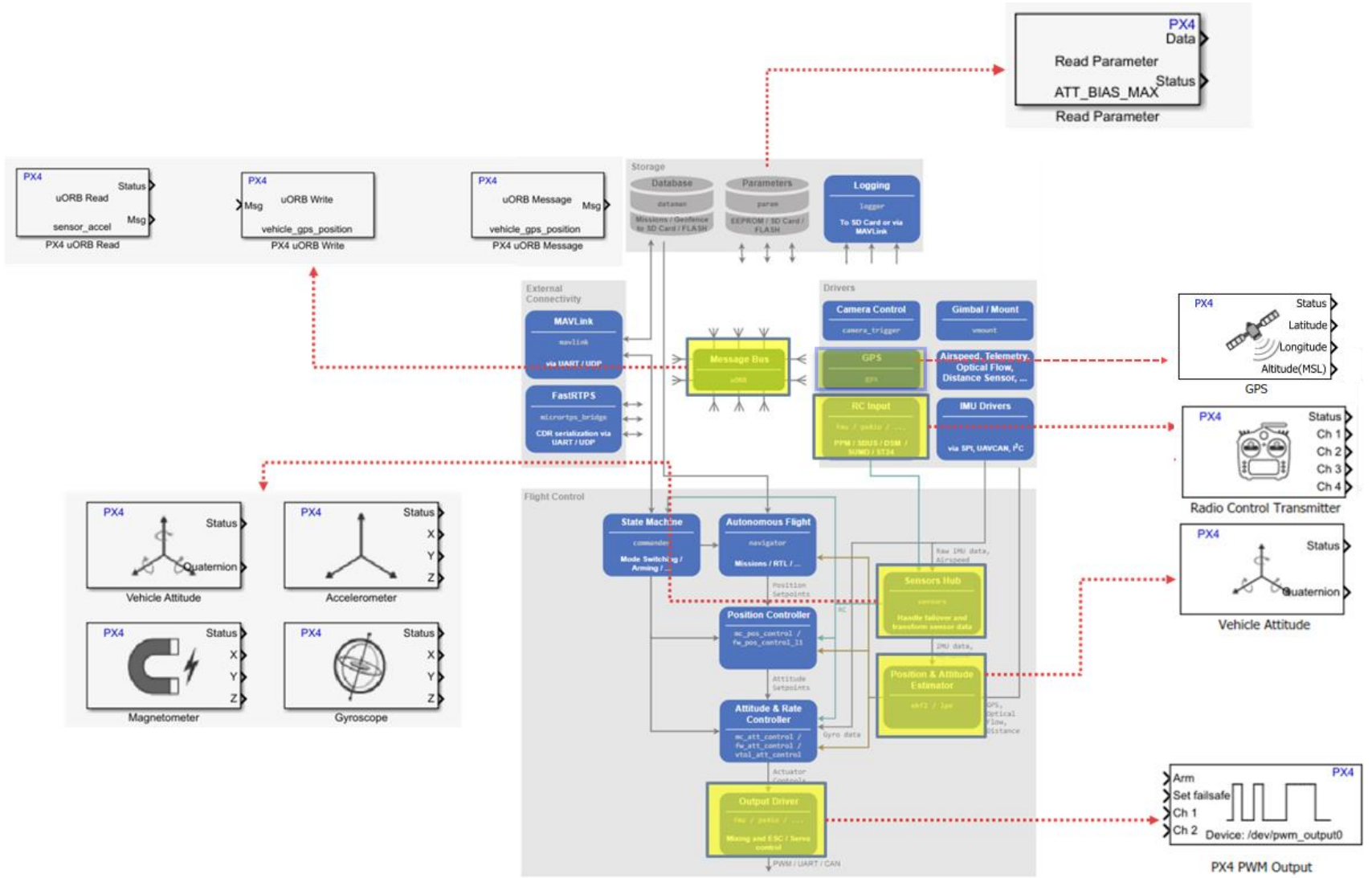




uORB: Asynchronous pub/sub messaging API (middleware)

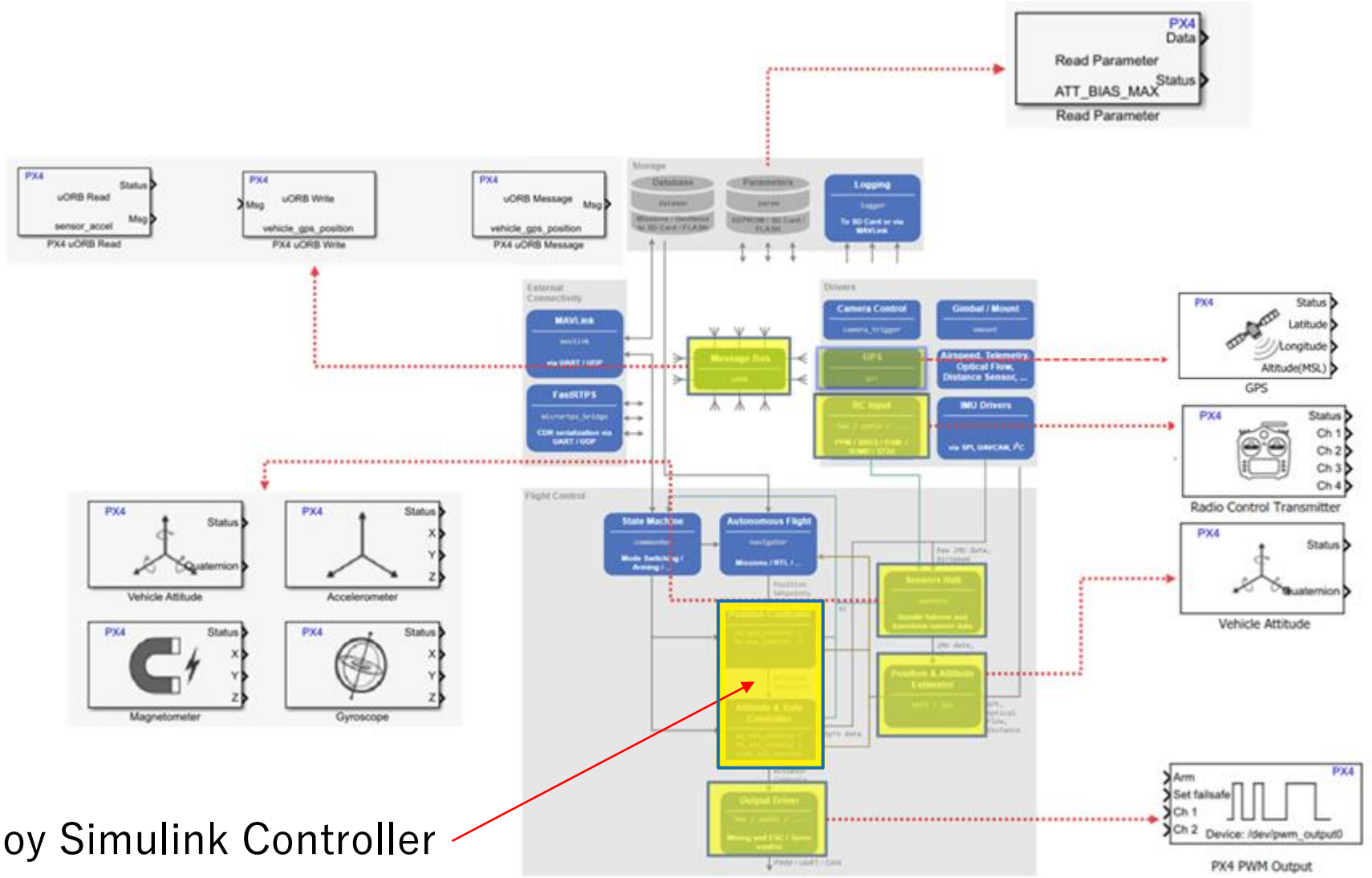


PX4 Autopilots Support Package Relationship to PX4 Architecture



https://www.mathworks.com/help/supportpkg/px4/ug/px4-capabilities-integration.html

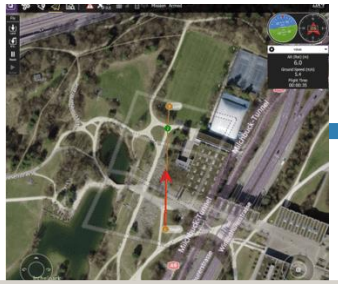
PX4 Autopilots Support Package Relationship to PX4 Architecture



https://www.mathworks.com/help/supportpkg/px4/ug/px4-capabilities-integration.html

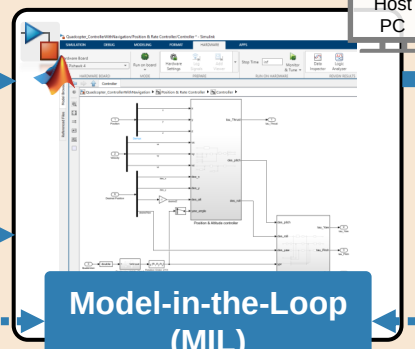
UAV Simulation Workflow with PX4 and Simulink

Inputs



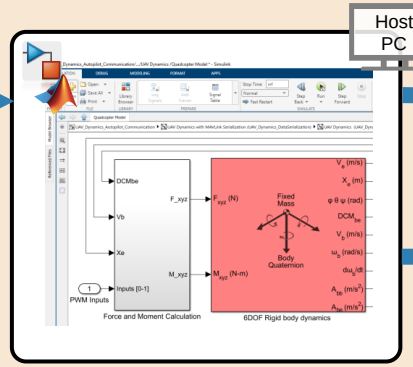
Ground Control Station

Flight Controller

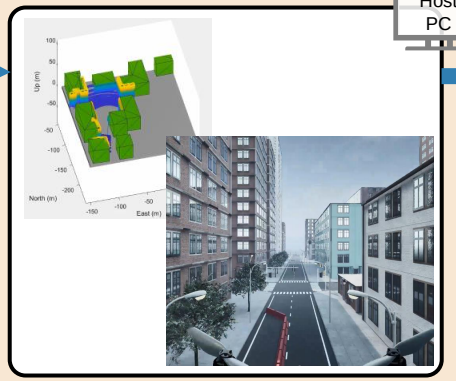


Model-in-the-Loop (MIL)

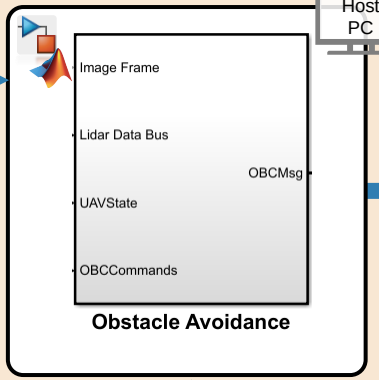
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

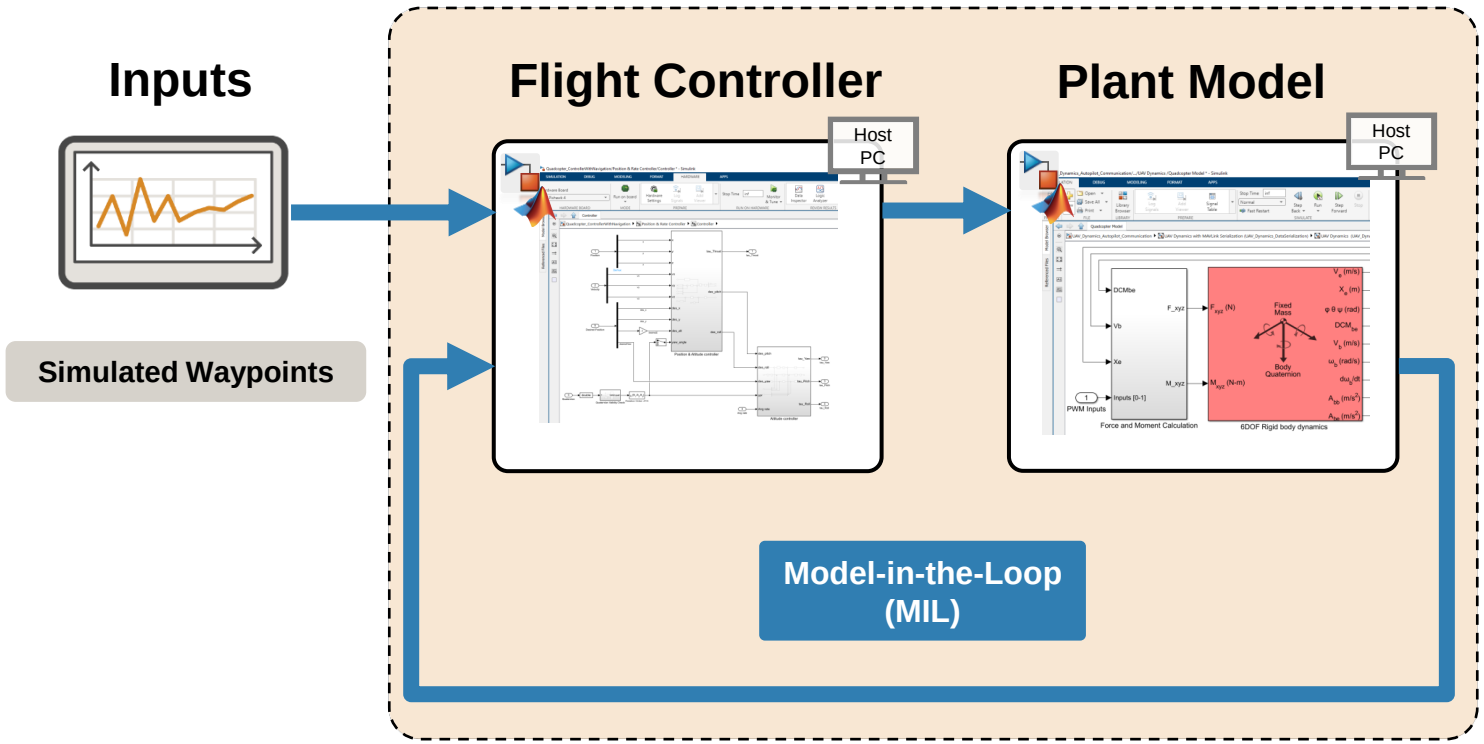
Deploy on Hardware

NVIDIA Jetson

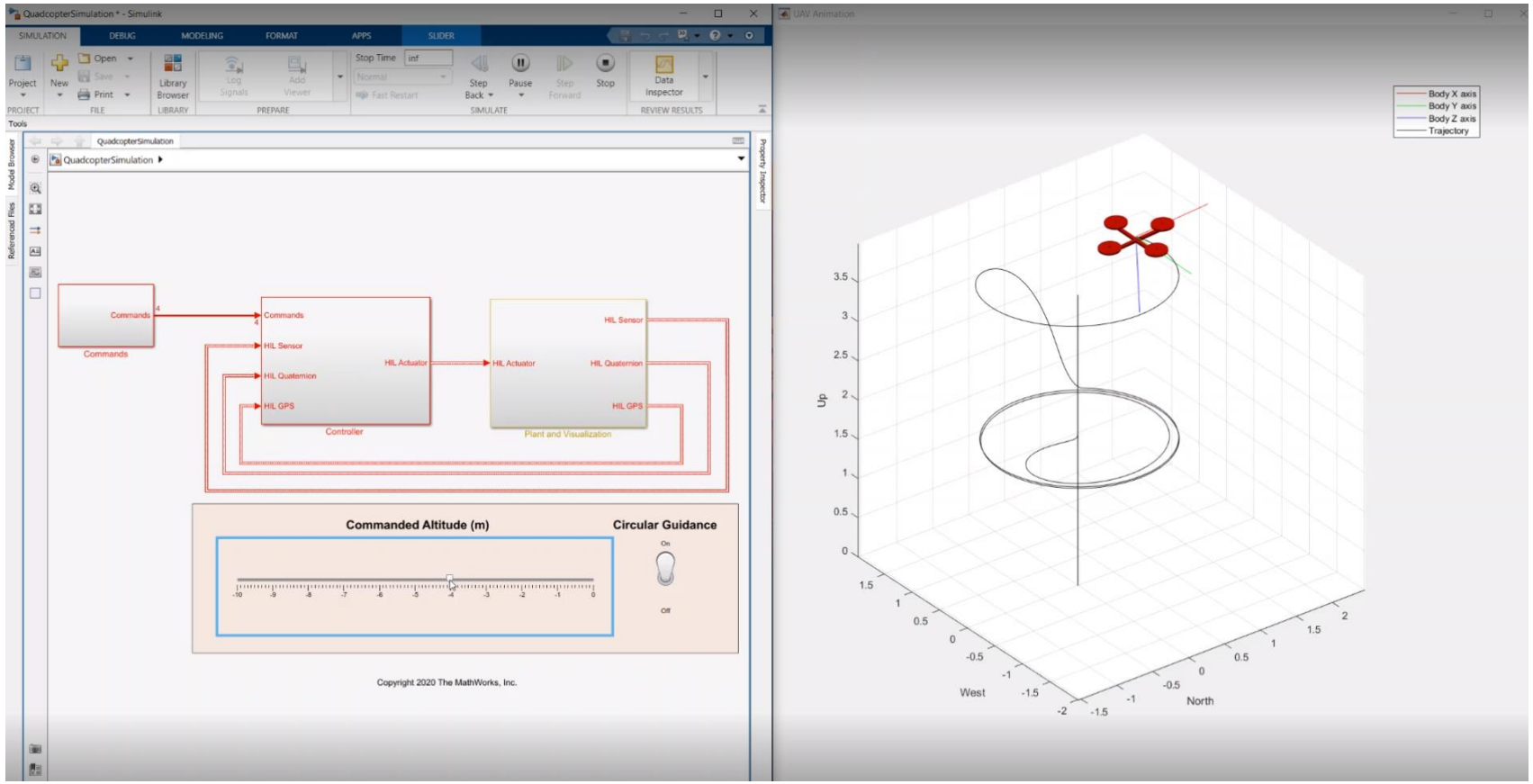
Software-in-the-Loop

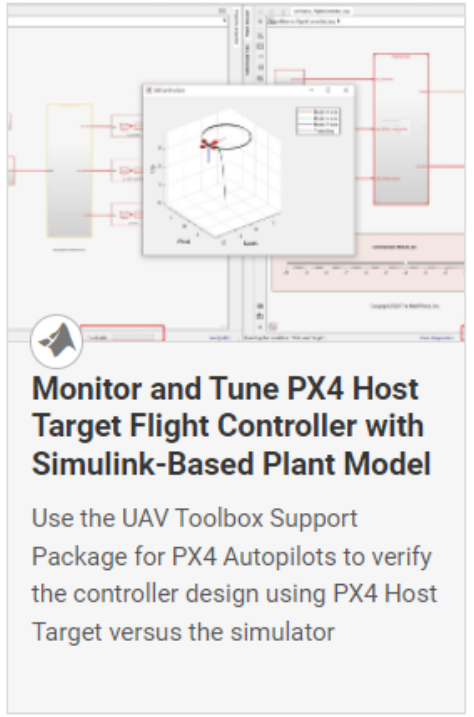
Hardware-in-the-Loop

Model In the Loop



Quadcopter Simulation in Simulink



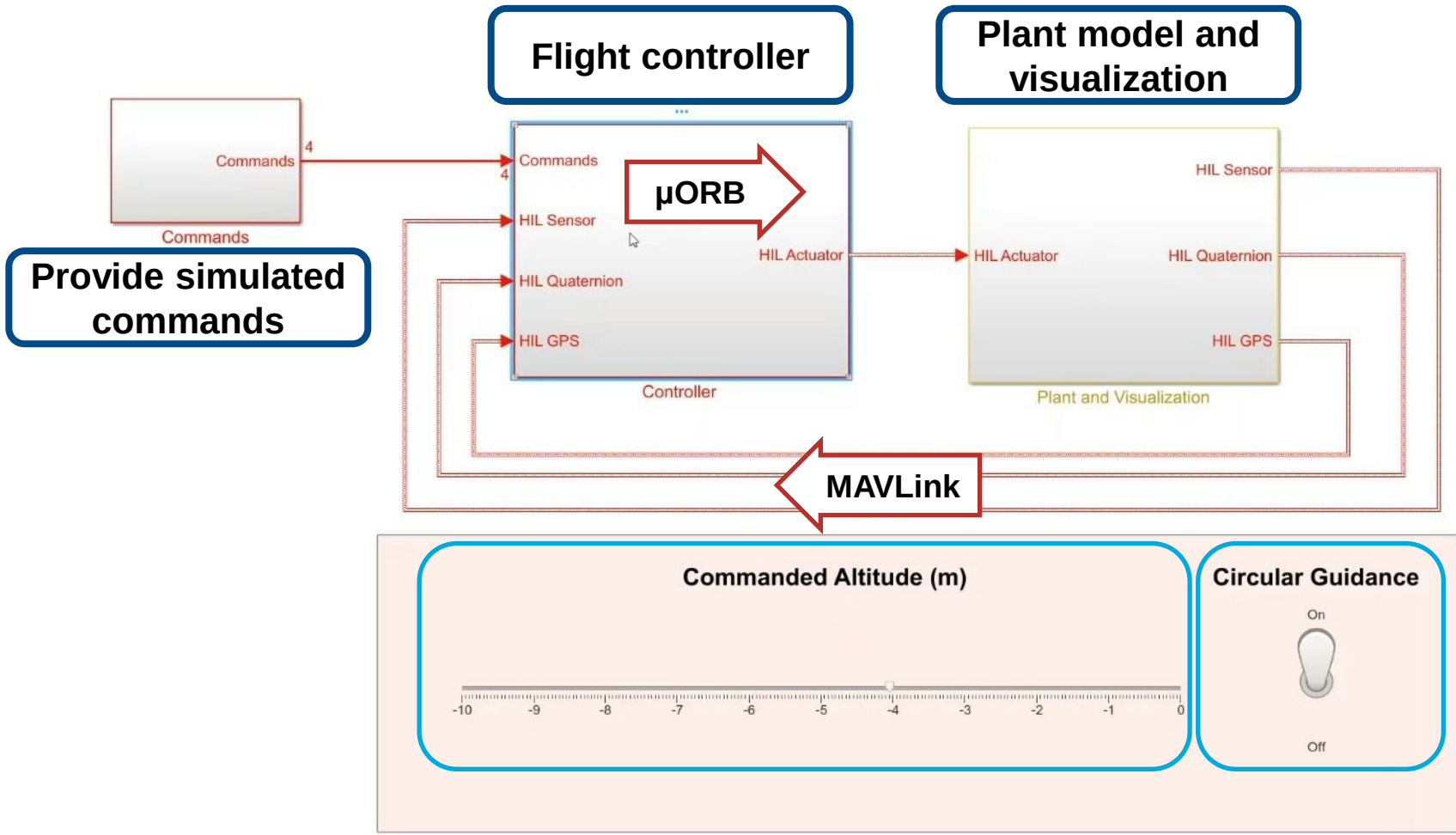


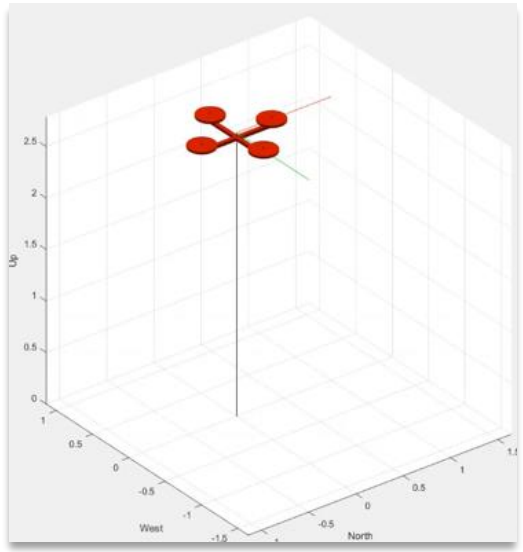
Monitor and Tune PX4 Host Target Flight Controller with Simulink-Based Plant Model

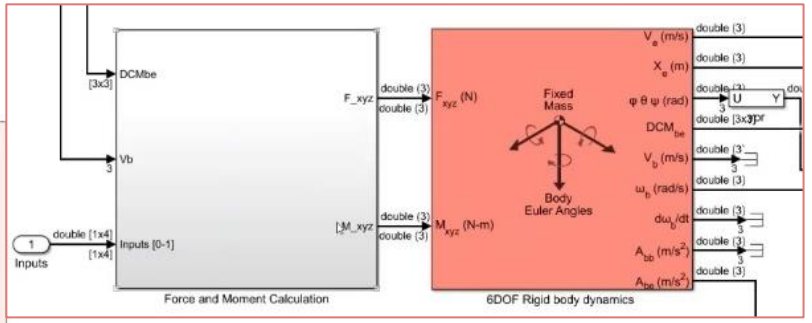
Use the UAV Toolbox Support Package for PX4 Autopilots to verify the controller design using PX4 Host Target versus the simulator

[Shipping example in UAV Toolbox]

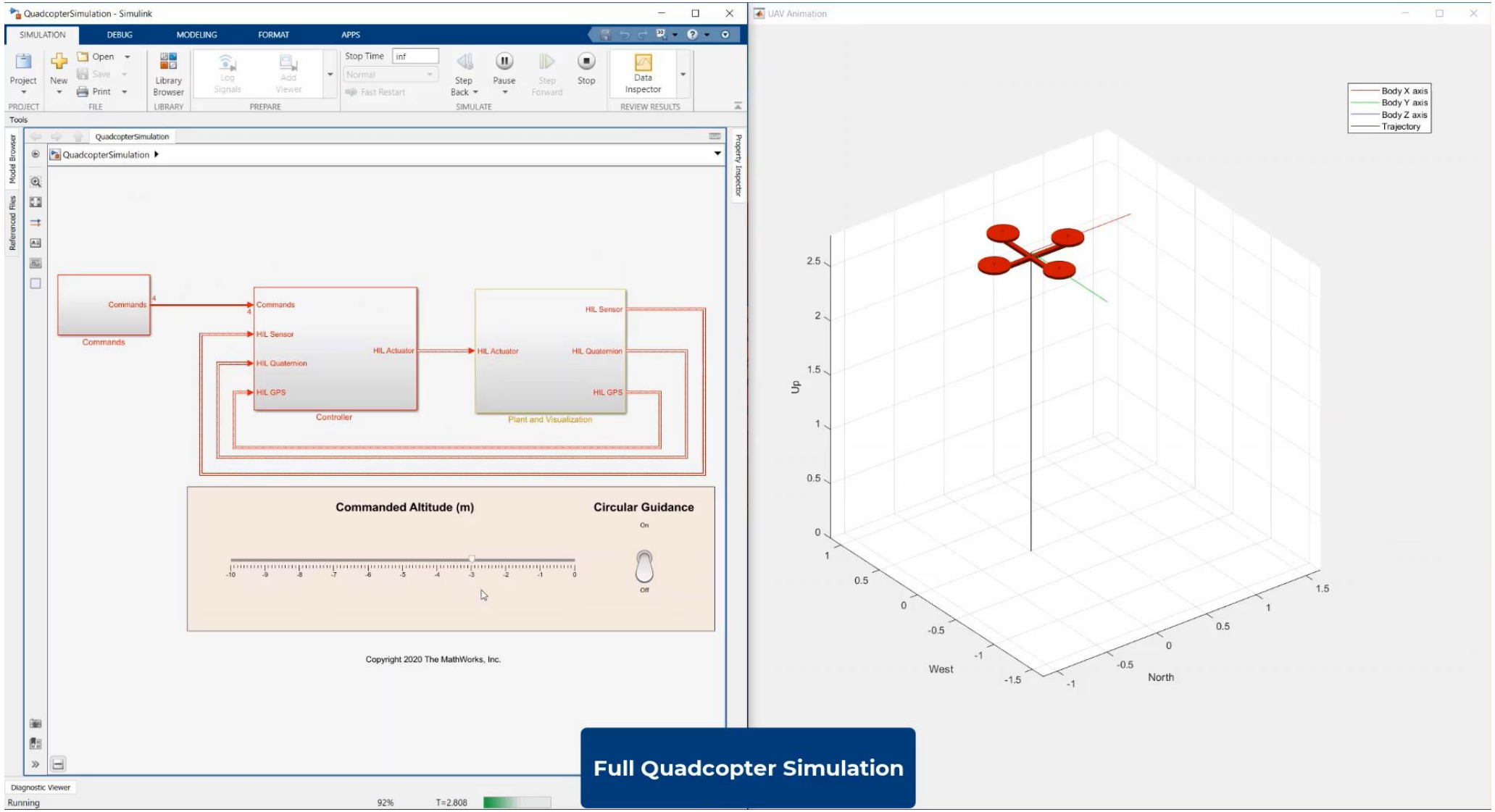
Quadcopter Simulation in Simulink







Quadcopter Simulation in Simulink

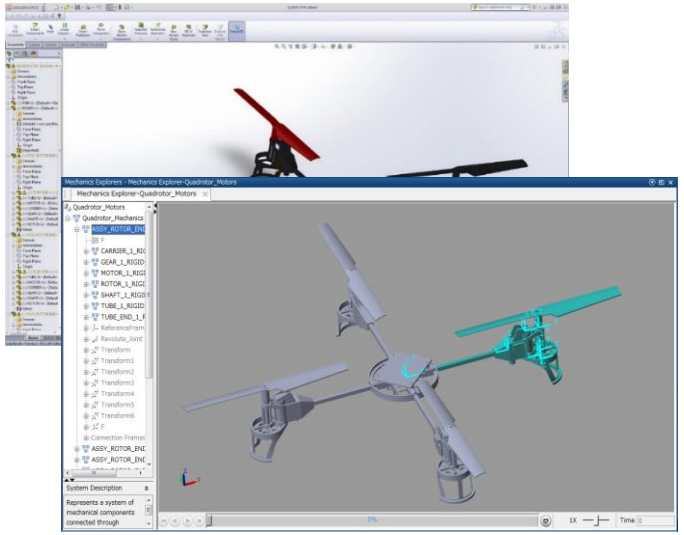


Full Quadcopter Simulation

Simulink Plant Modelling

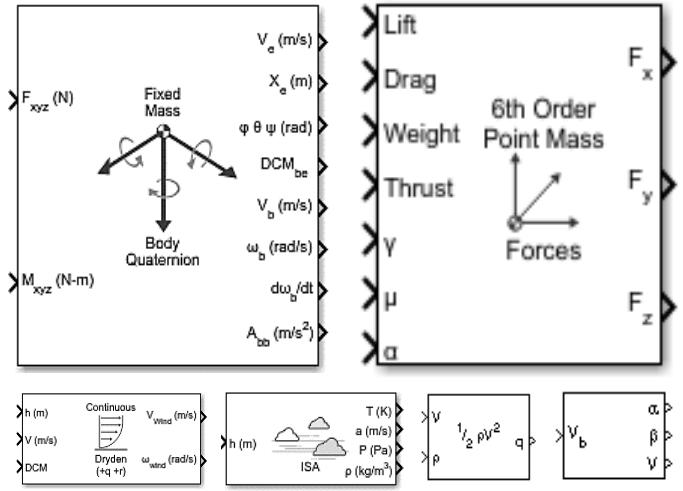
High-Fidelity
Building UAV

Low-Fidelity
Programming UAV



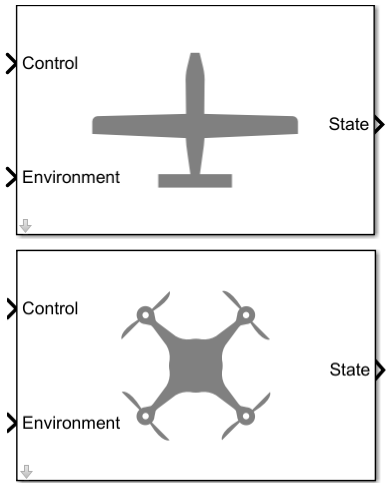
Physical Modeling

Model construction techniques and best practices, domain-specific modeling, physical units



Vehicle Dynamics

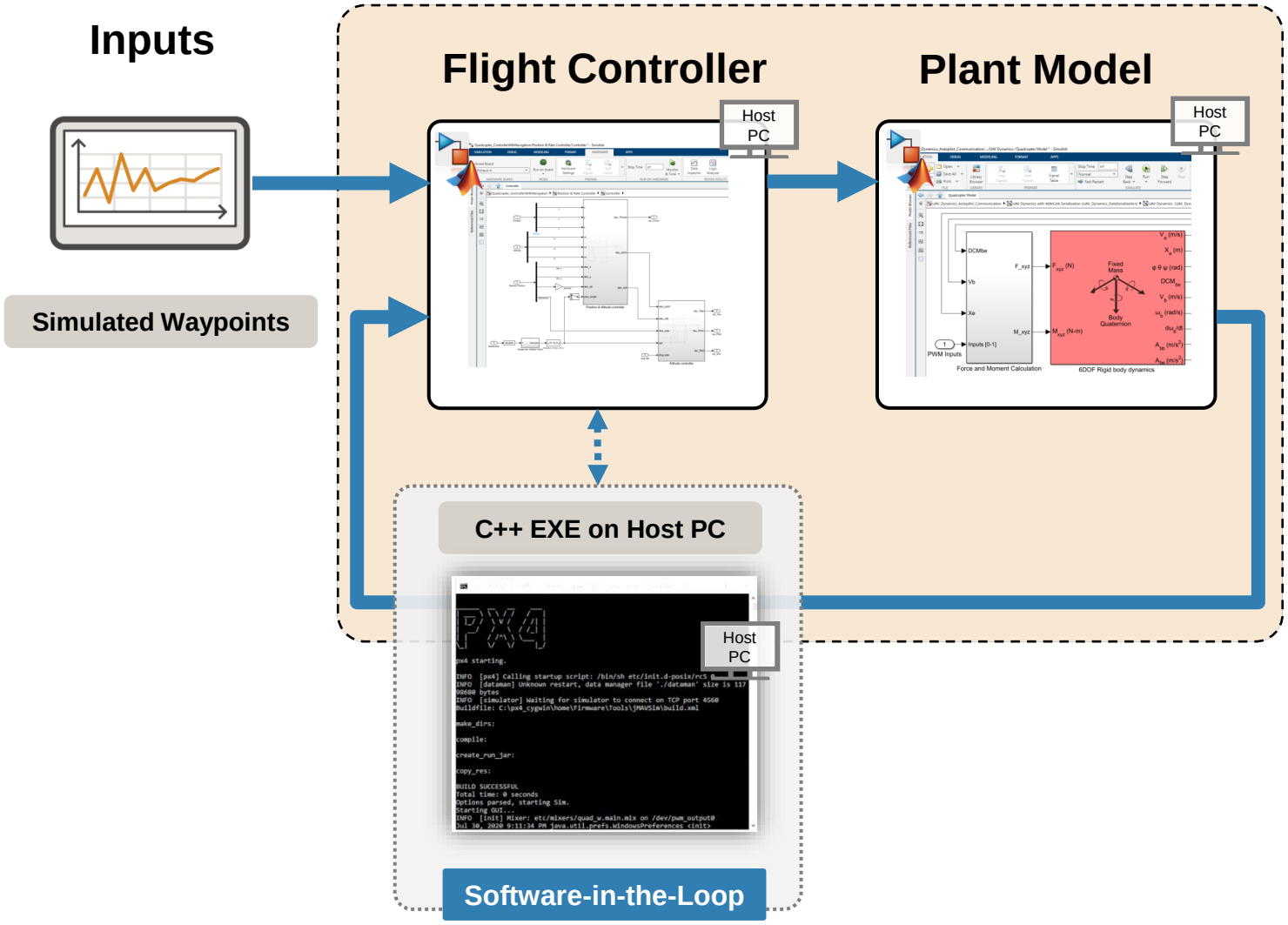
Model aerodynamics, propulsion, and motion of aircraft and spacecraft



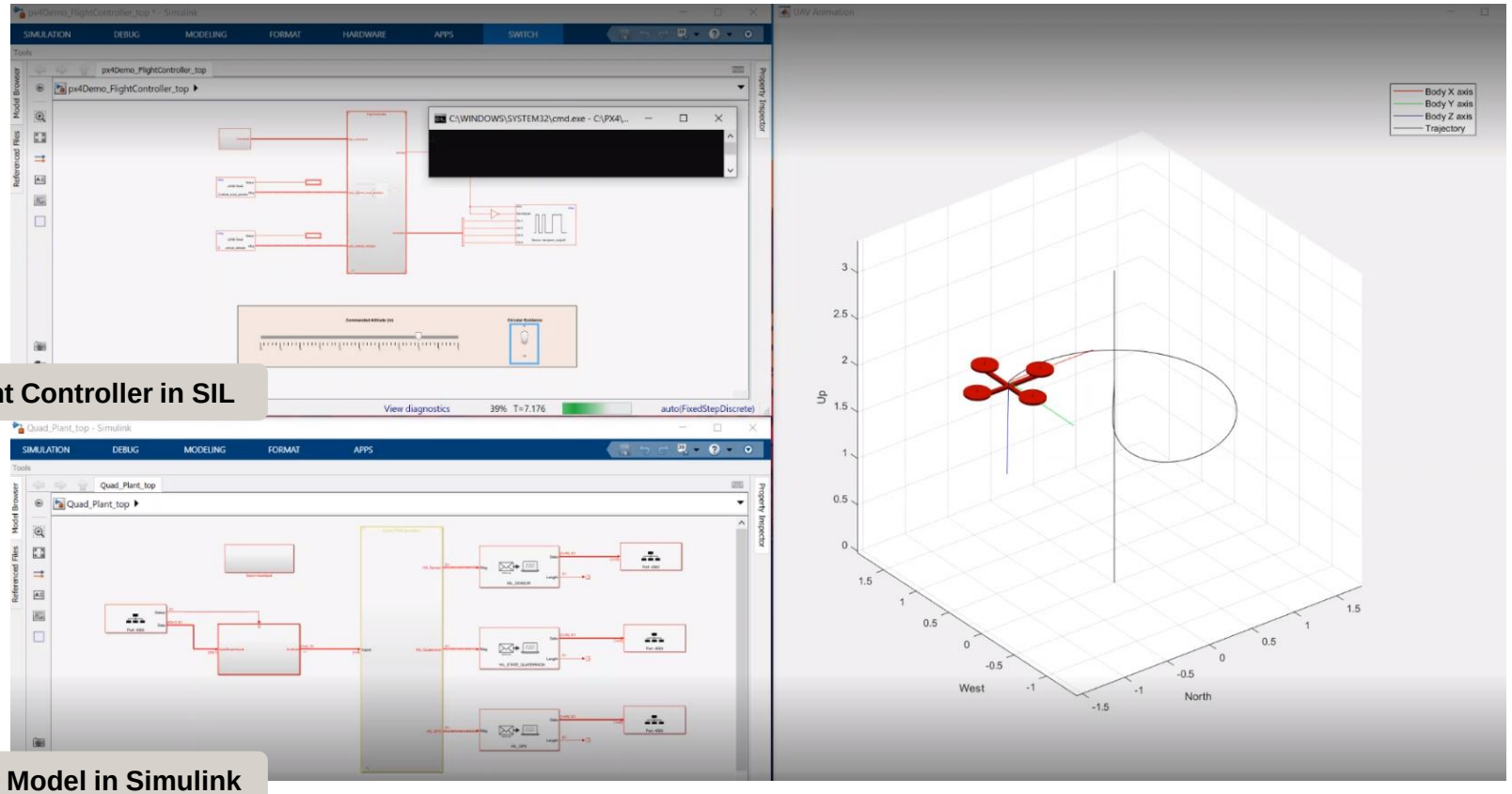
Guidance Model

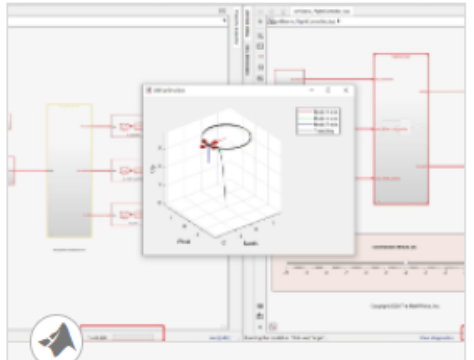
Reduced-order model for UAV

Software-in-the-Loop (SIL)



SIL with PX4 HSP and Simulink Plant



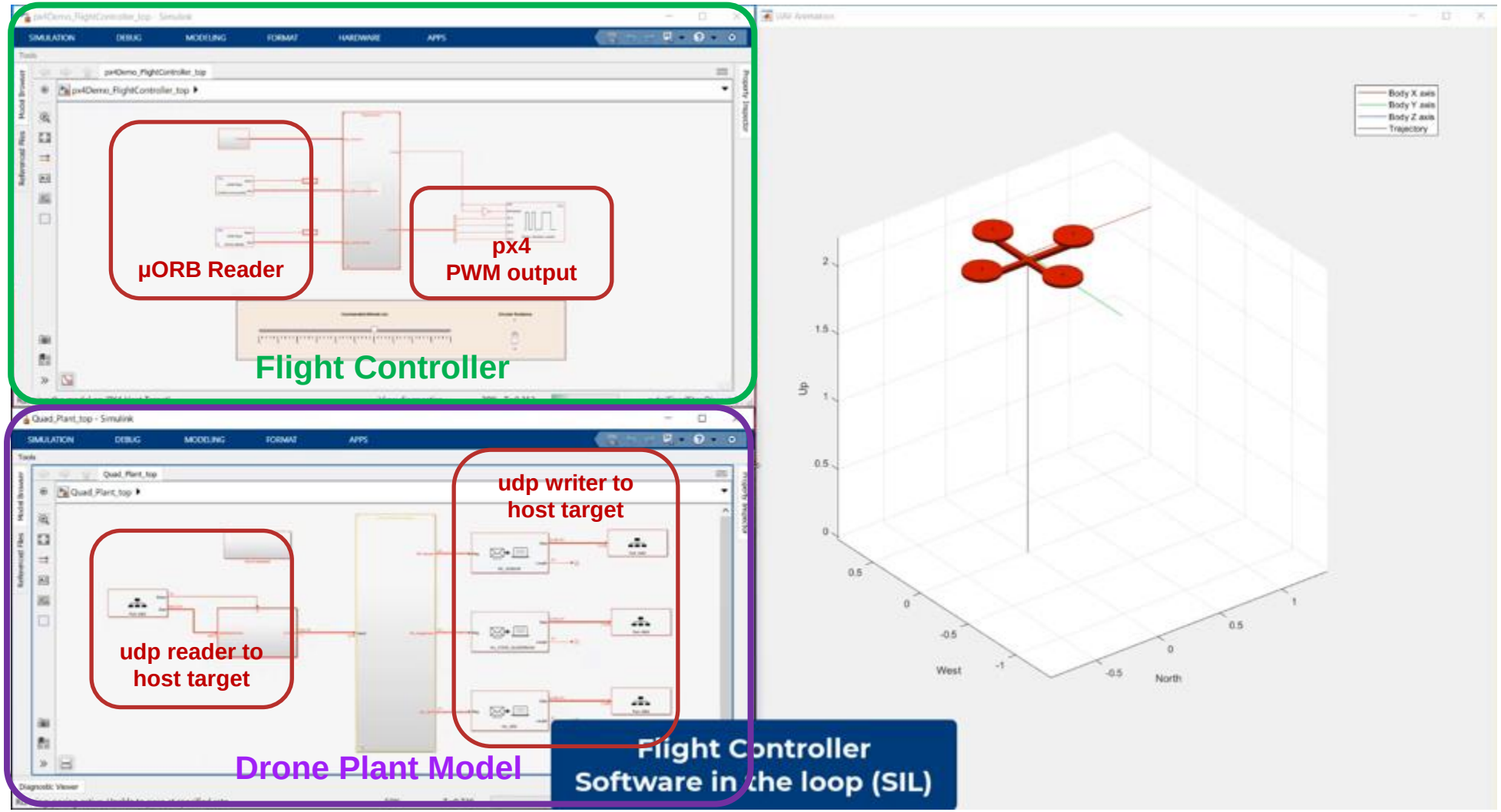


Monitor and Tune PX4 Host Target Flight Controller with Simulink-Based Plant Model

Use the UAV Toolbox Support Package for PX4 Autopilots to verify the controller design using PX4 Host Target versus the simulator

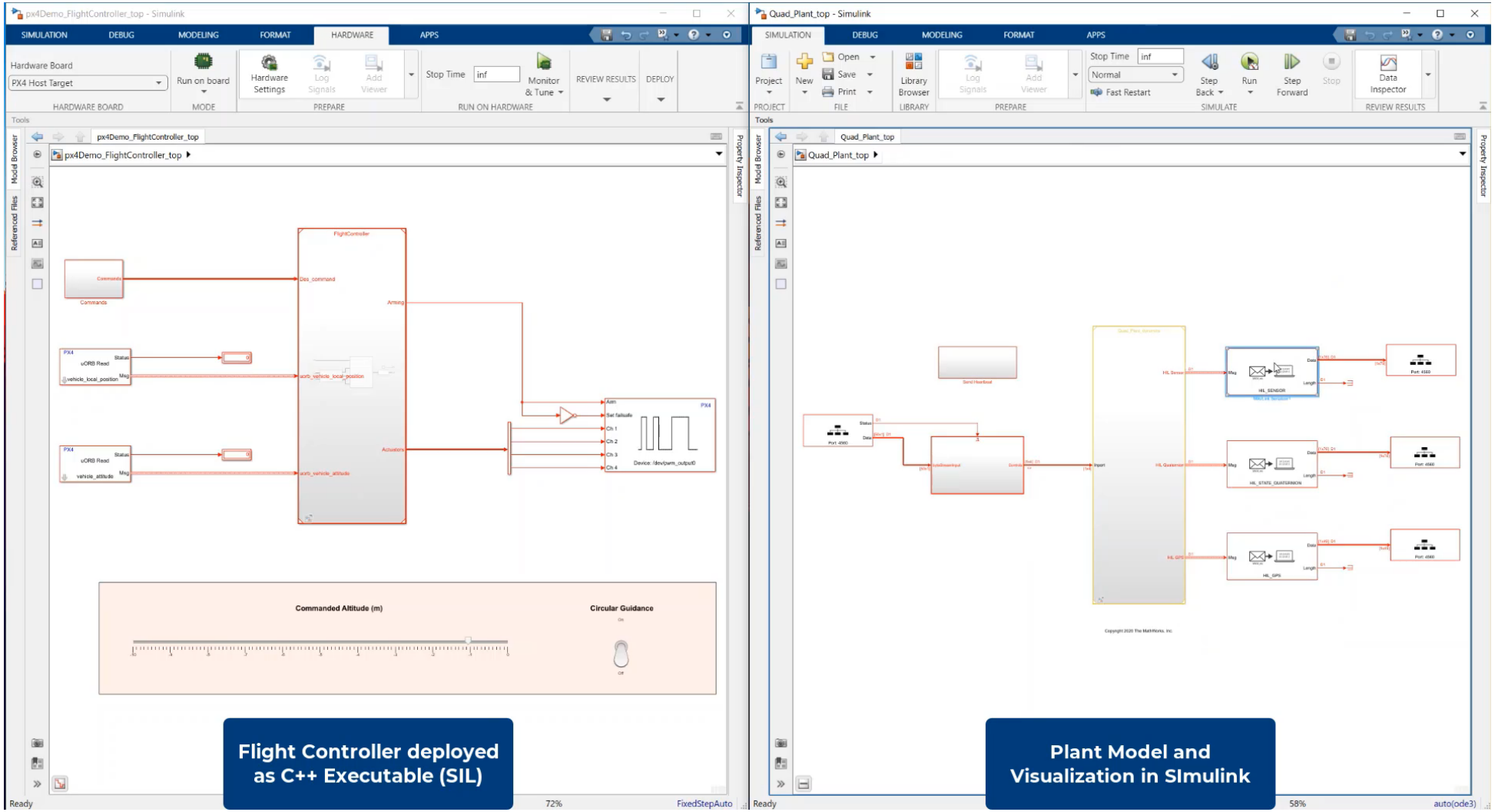
Shipping example in UAV Toolbox
(See Task 2 in the example)

SIL with PX4 HSP and Simulink Plant



Video included with expo session content package

SIL with PX4 HSP and Simulink Plant



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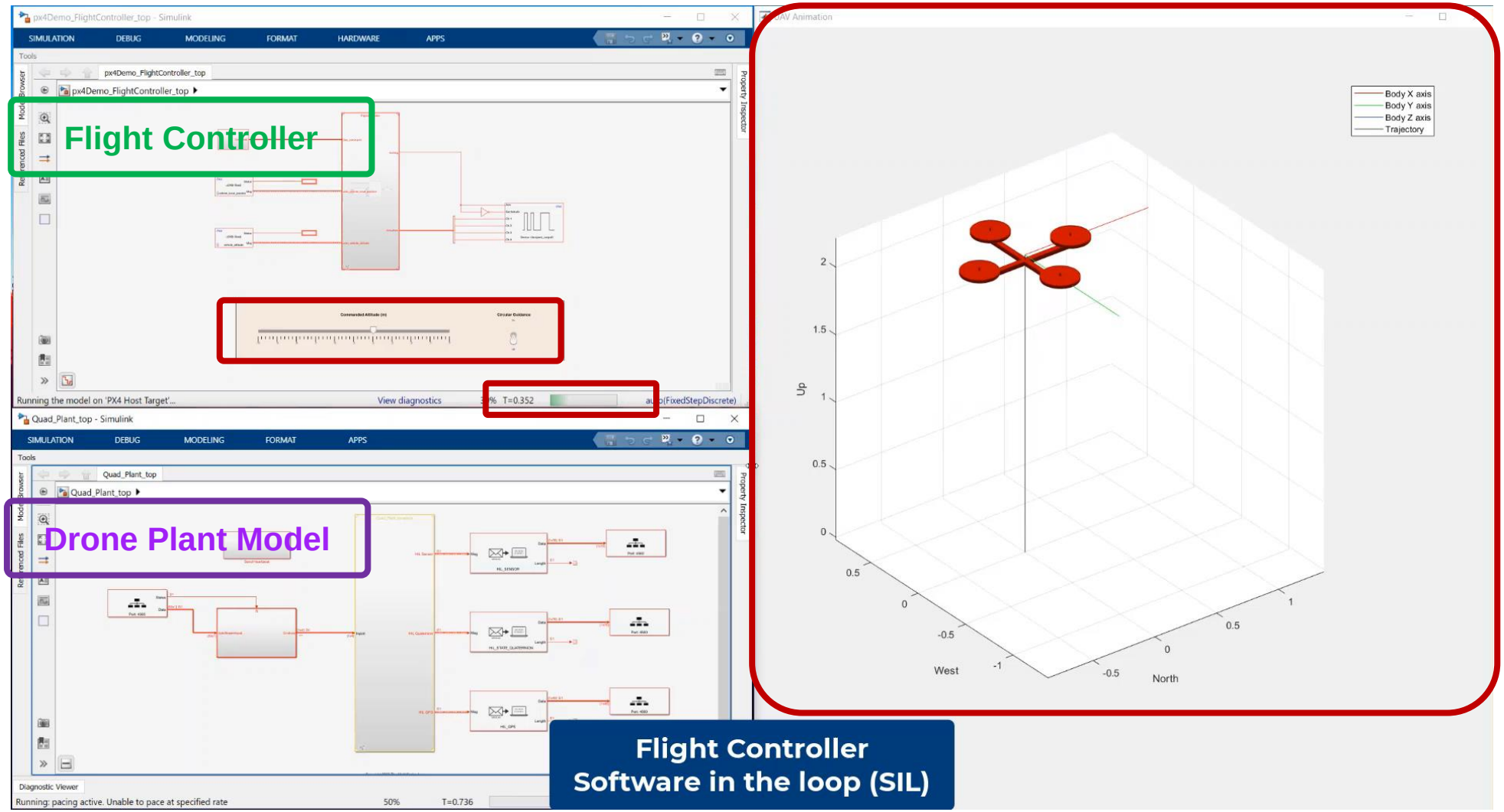
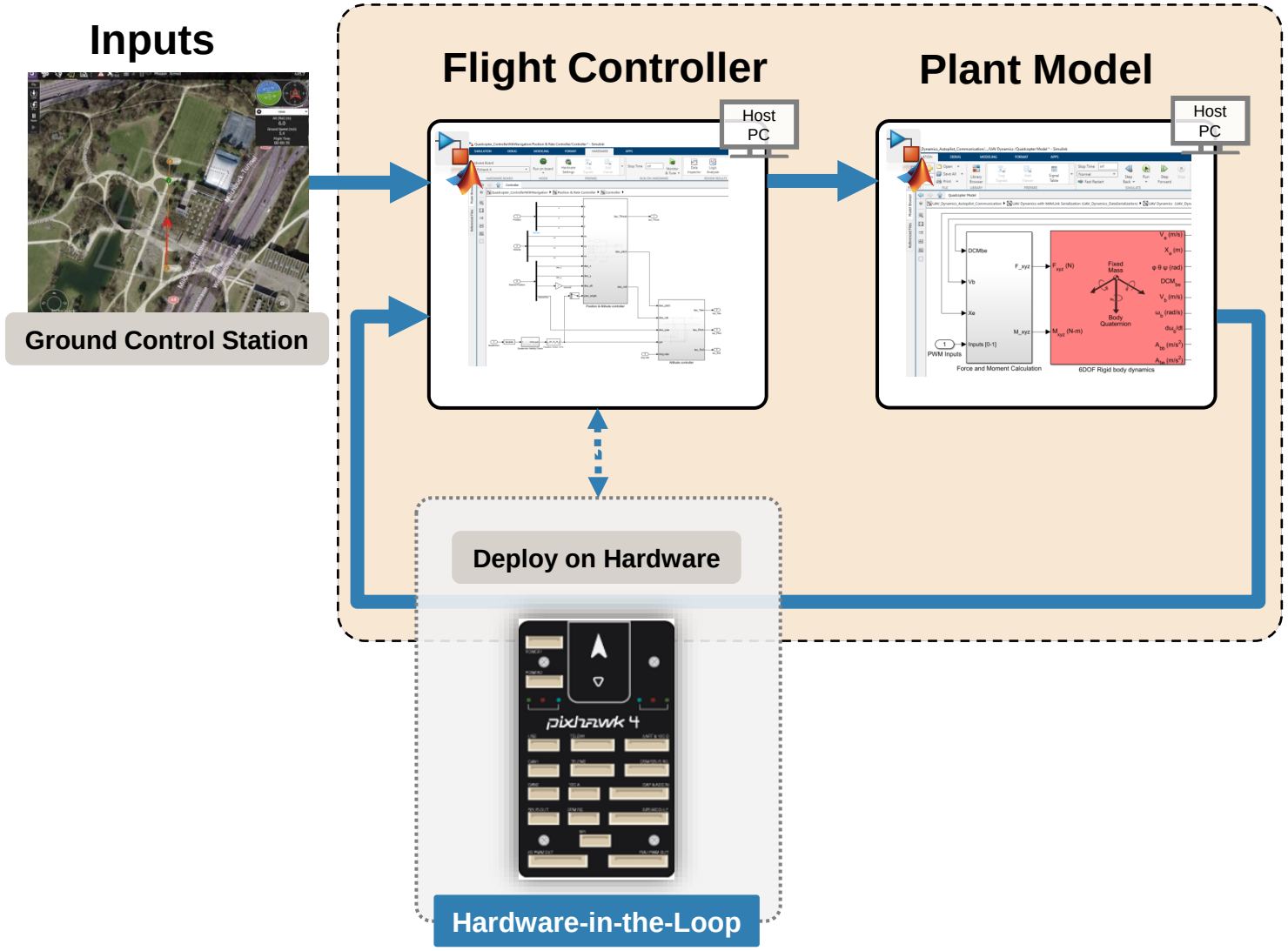
SIL with PX4 HSP and Simulink Plant

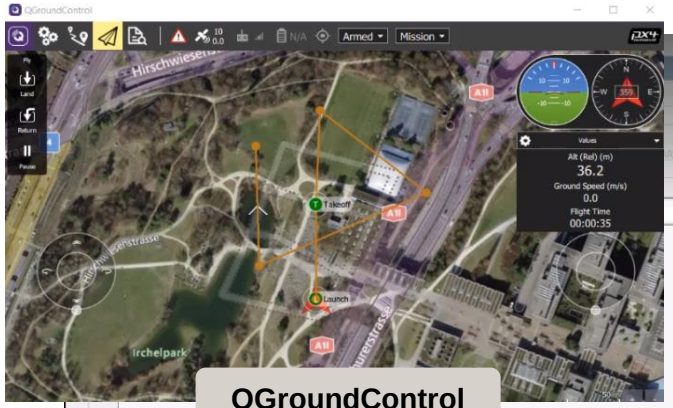


Video included with expo session content package

Hardware-in-the-Loop (HIL)

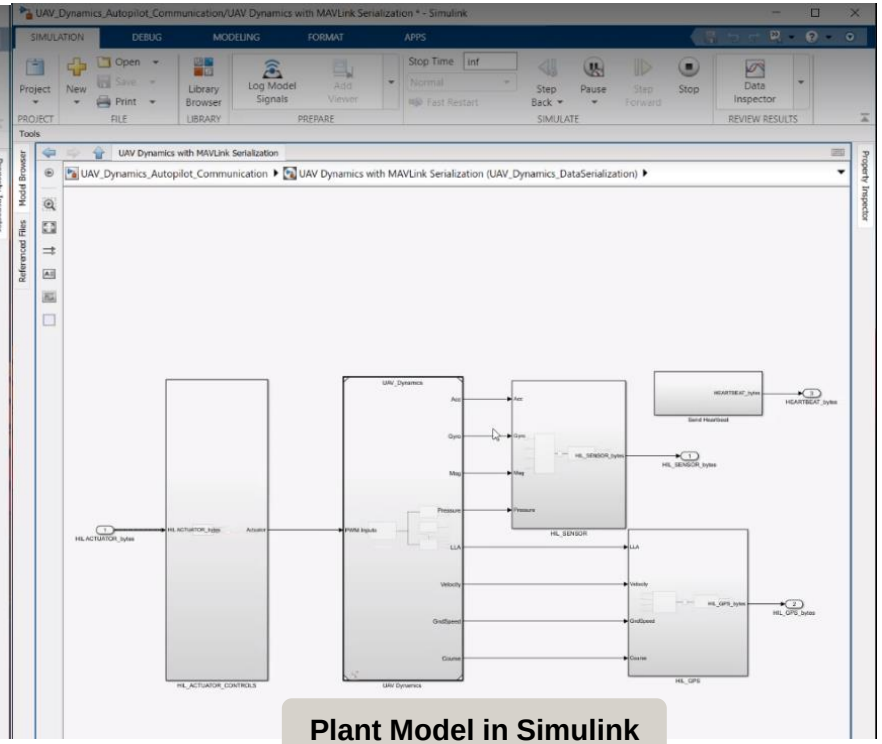


HIL with PX4 HSP and Simulink Plant

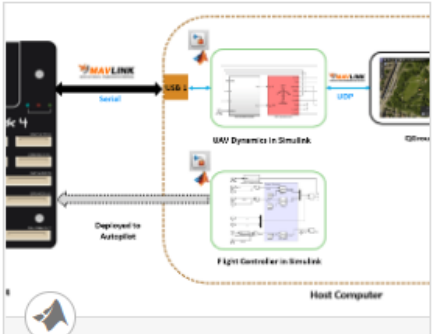


QGroundControl

Deploy on Hardware



Plant Model in Simulink



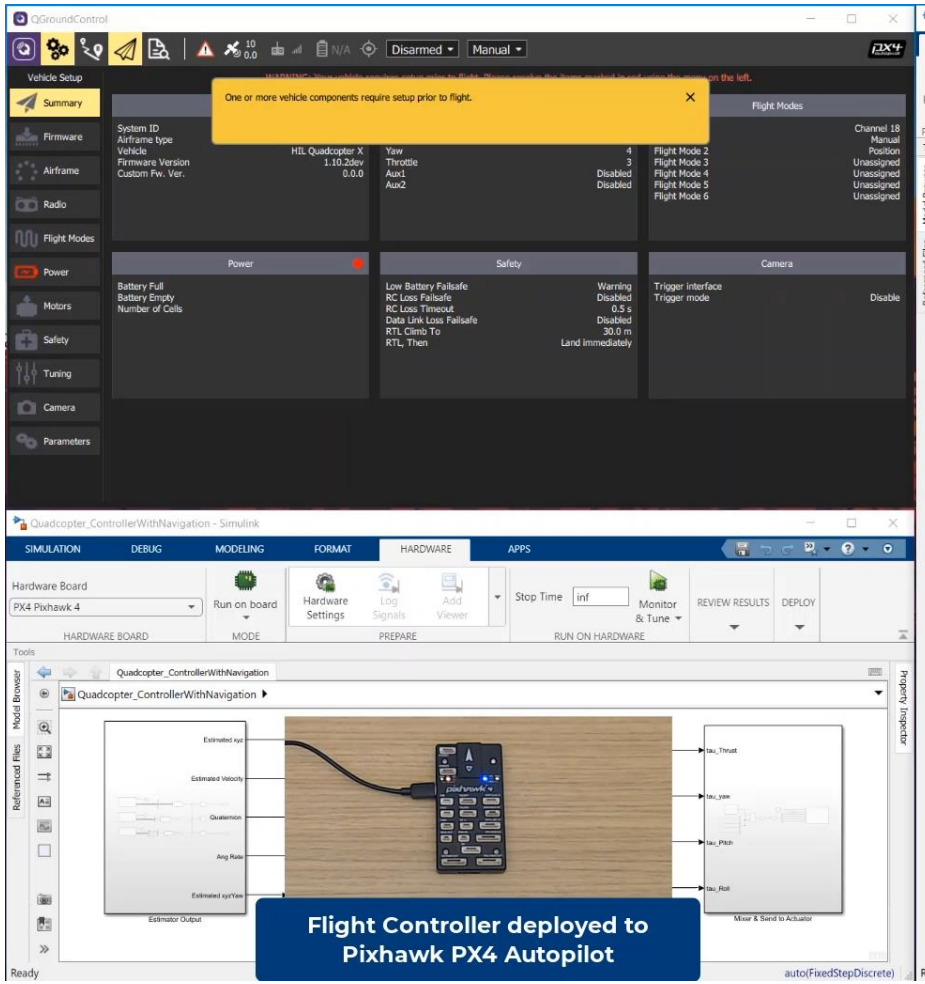
PX4 Autopilot in Hardware-in-the-Loop (HITL) Simulation with UAV...

Use the UAV Toolbox Support Package for PX4 Autopilots to verify the controller design by deploying on the Pixhawk hardware board, in HITL

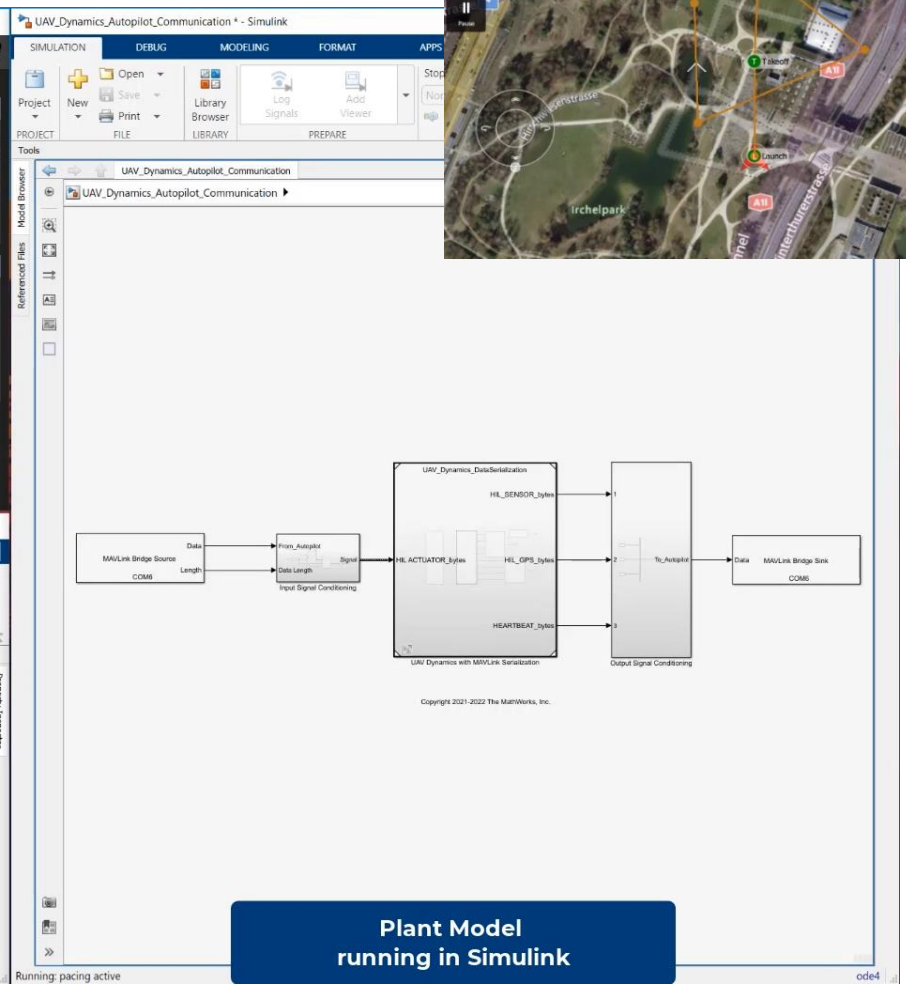
Shipping example in UAV Toolbox

HIL with PX4 HSP and Simulink Plant

QGroundControl for Planning Mission



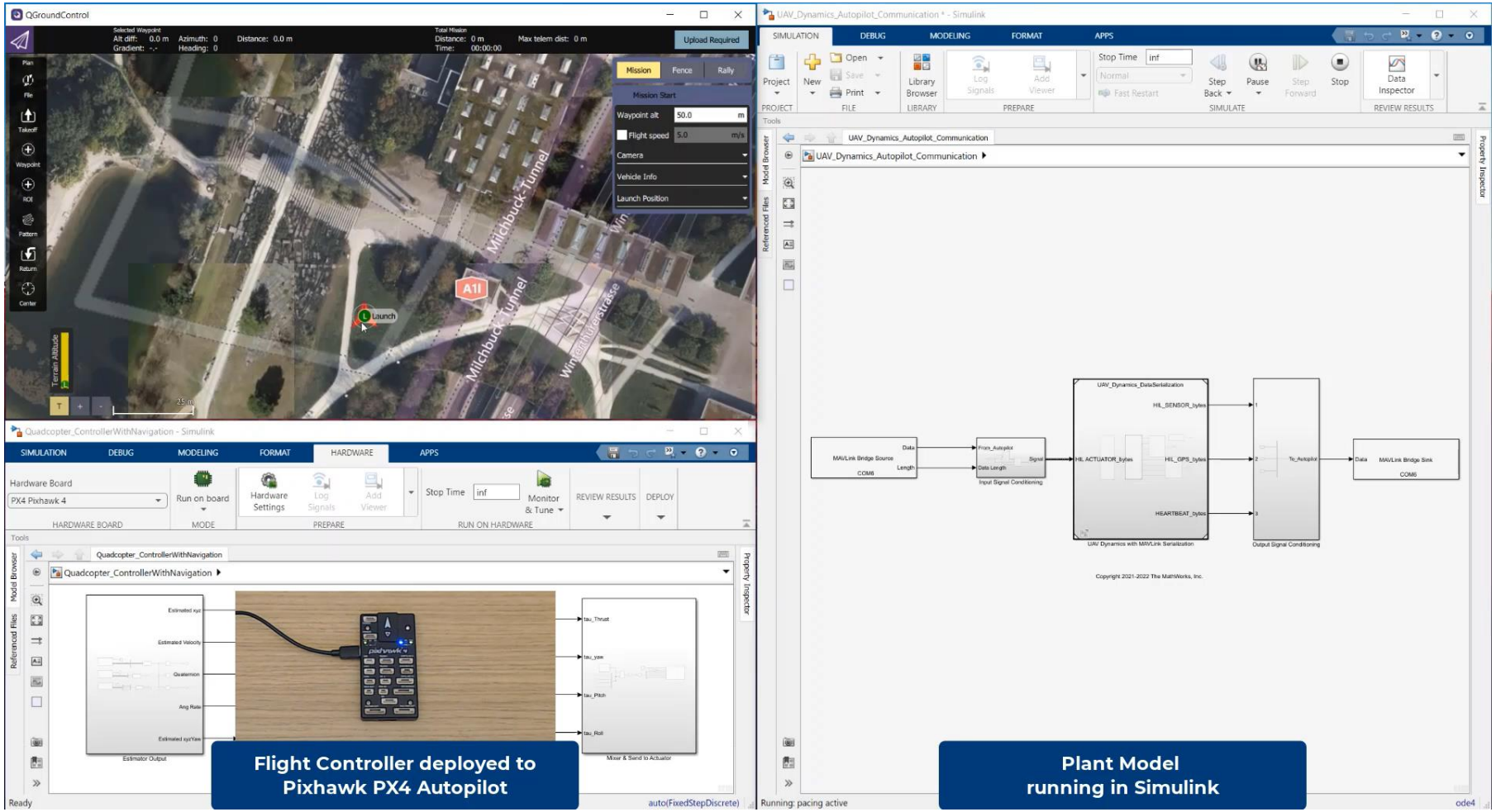
Flight Controller deployed to Pixhawk PX4 Autopilot



Plant Model running in Simulink

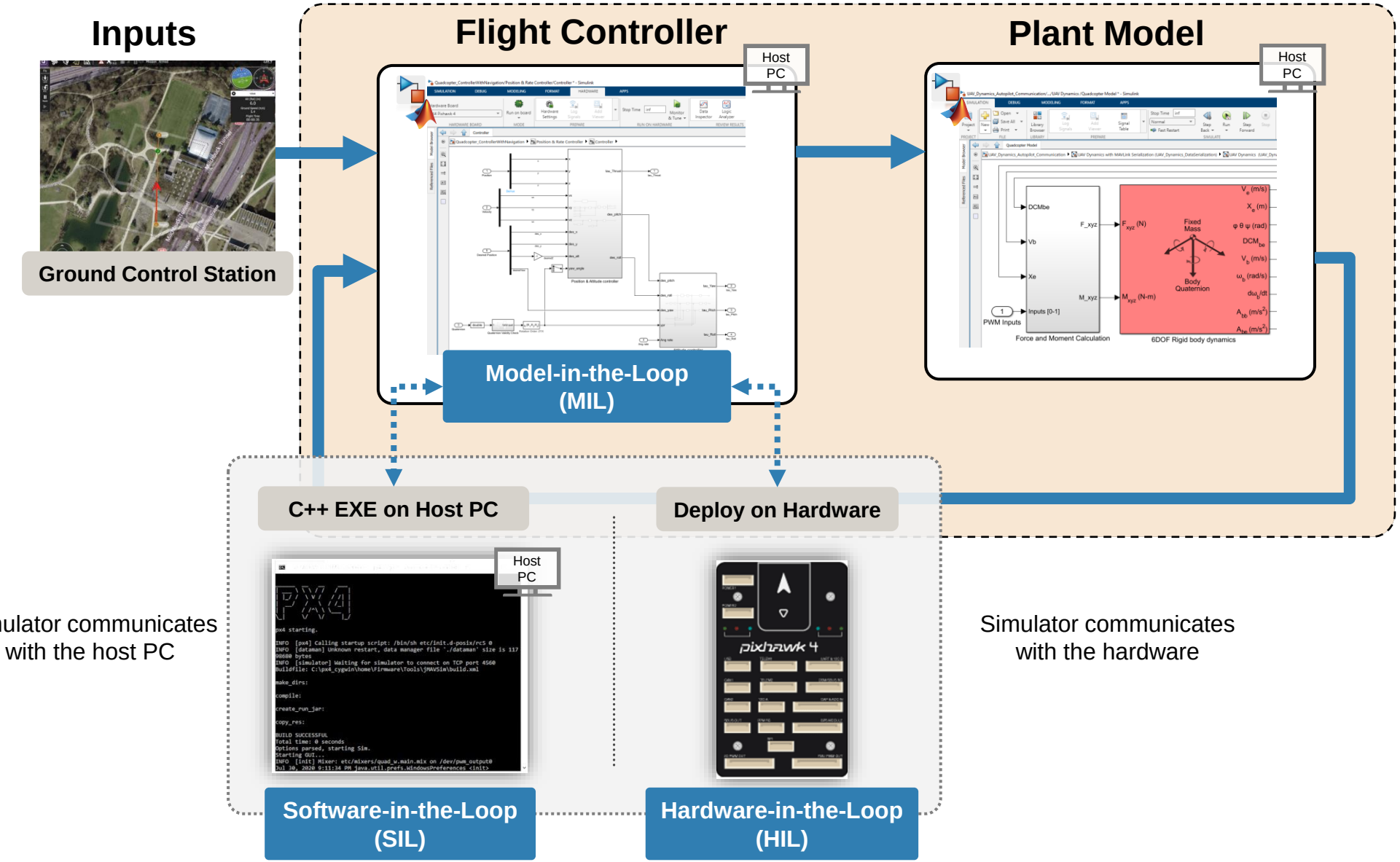
Video included with expo session content package

HIL with PX4 HSP and Simulink Plant



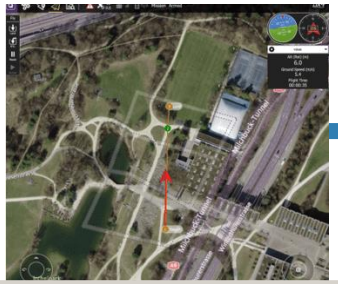
Video included with expo session content package

UAV Simulation Workflow with PX4 and Simulink



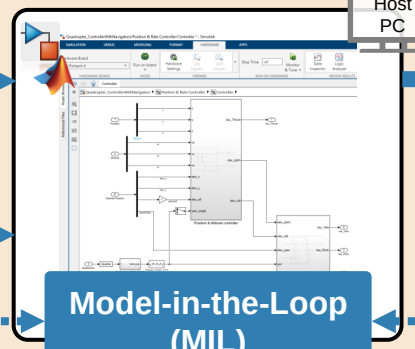
UAV Simulation Workflow with PX4 and Simulink

Inputs



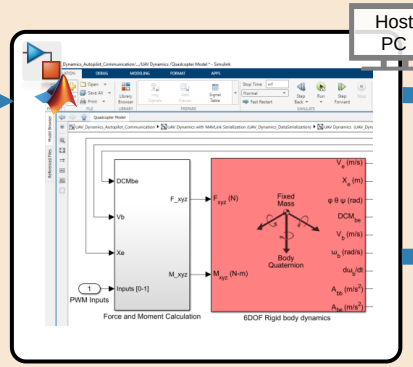
Ground Control Station

Flight Controller

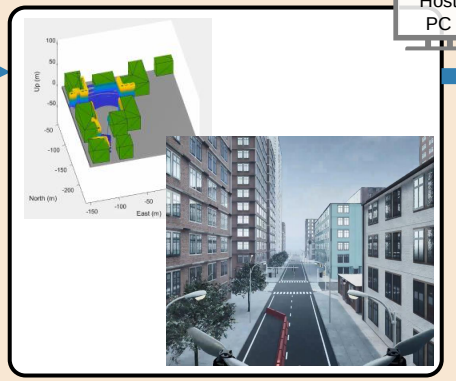


Model-in-the-Loop (MIL)

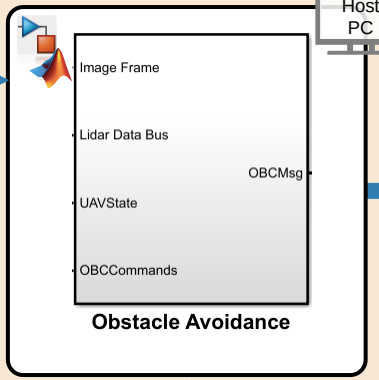
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

Deploy on Hardware

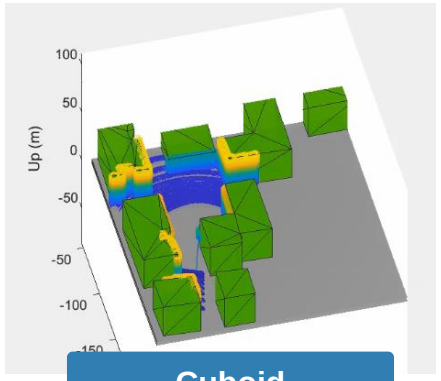
Software-in-the-Loop

Hardware-in-the-Loop

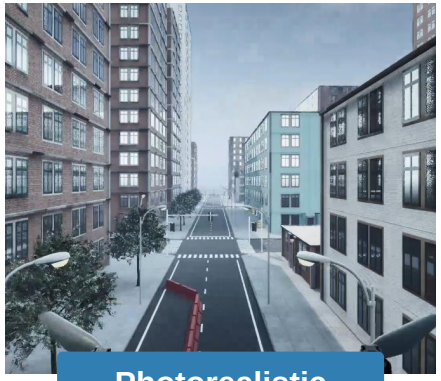
NVIDIA Jetson

Closed-loop autonomy simulation

Scenario Simulation



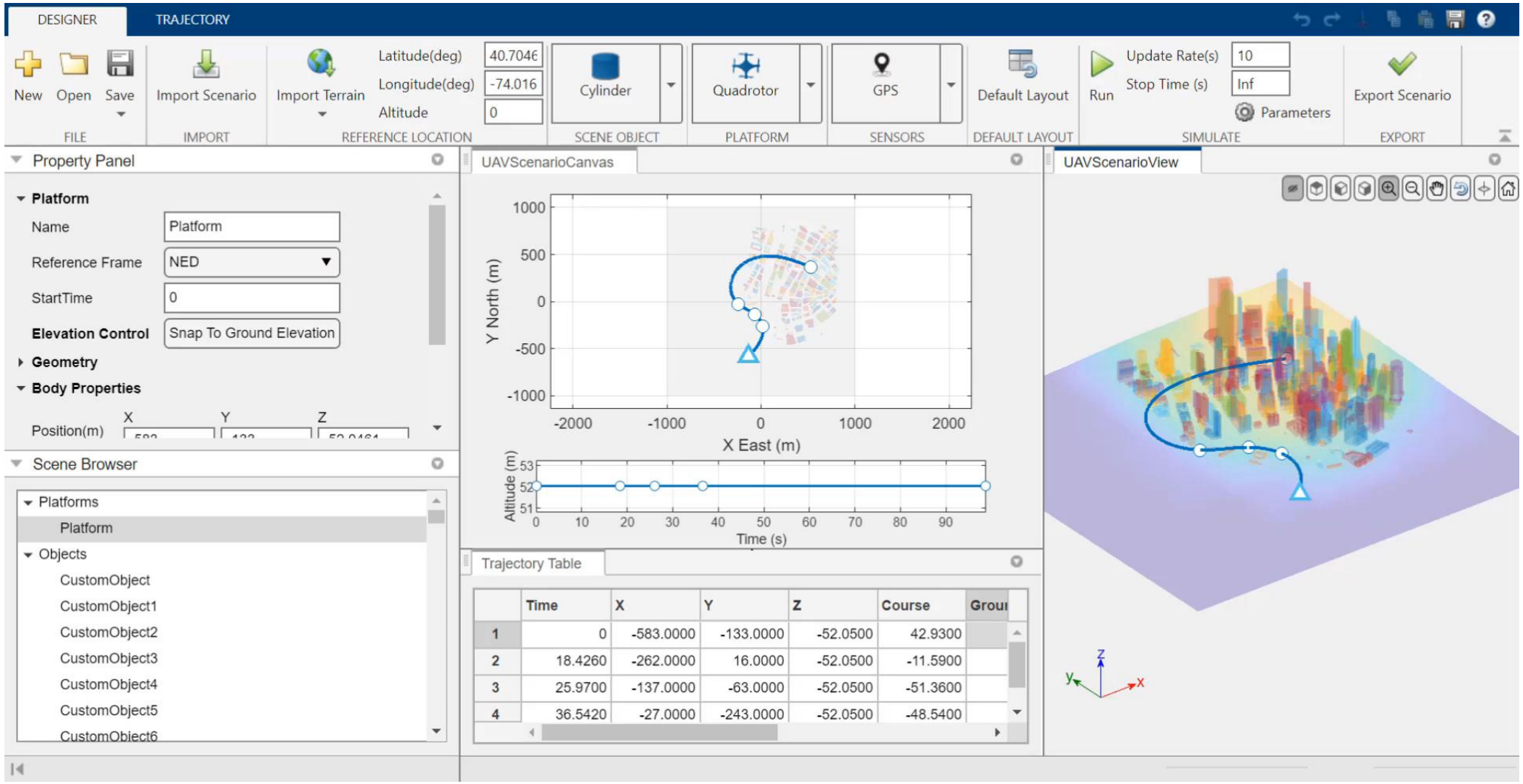
Cuboid Environments



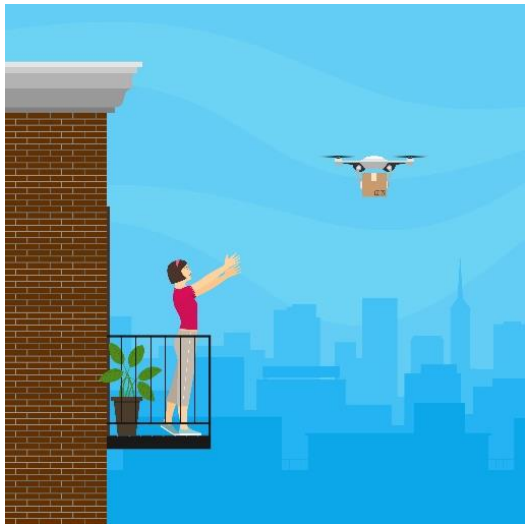
Photorealistic Environments

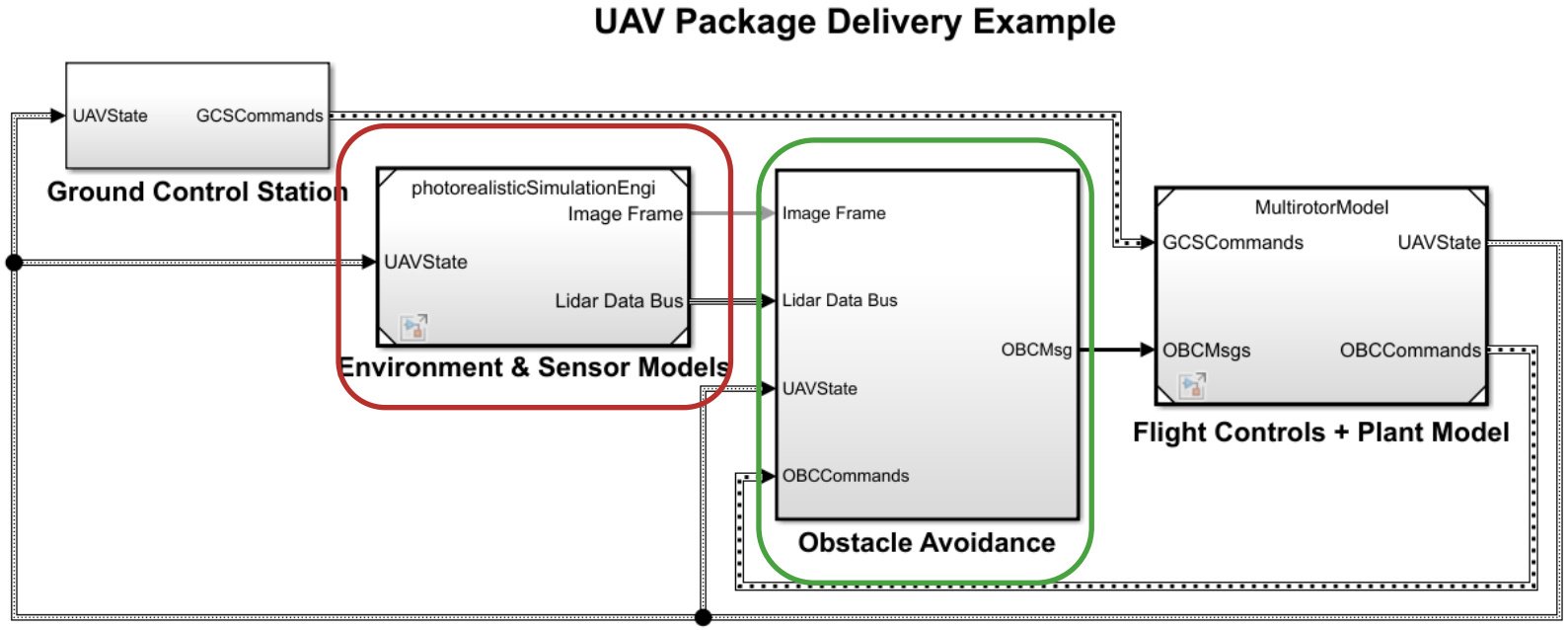
Create environments and simulate sensor readings

UAV Scenario Designer

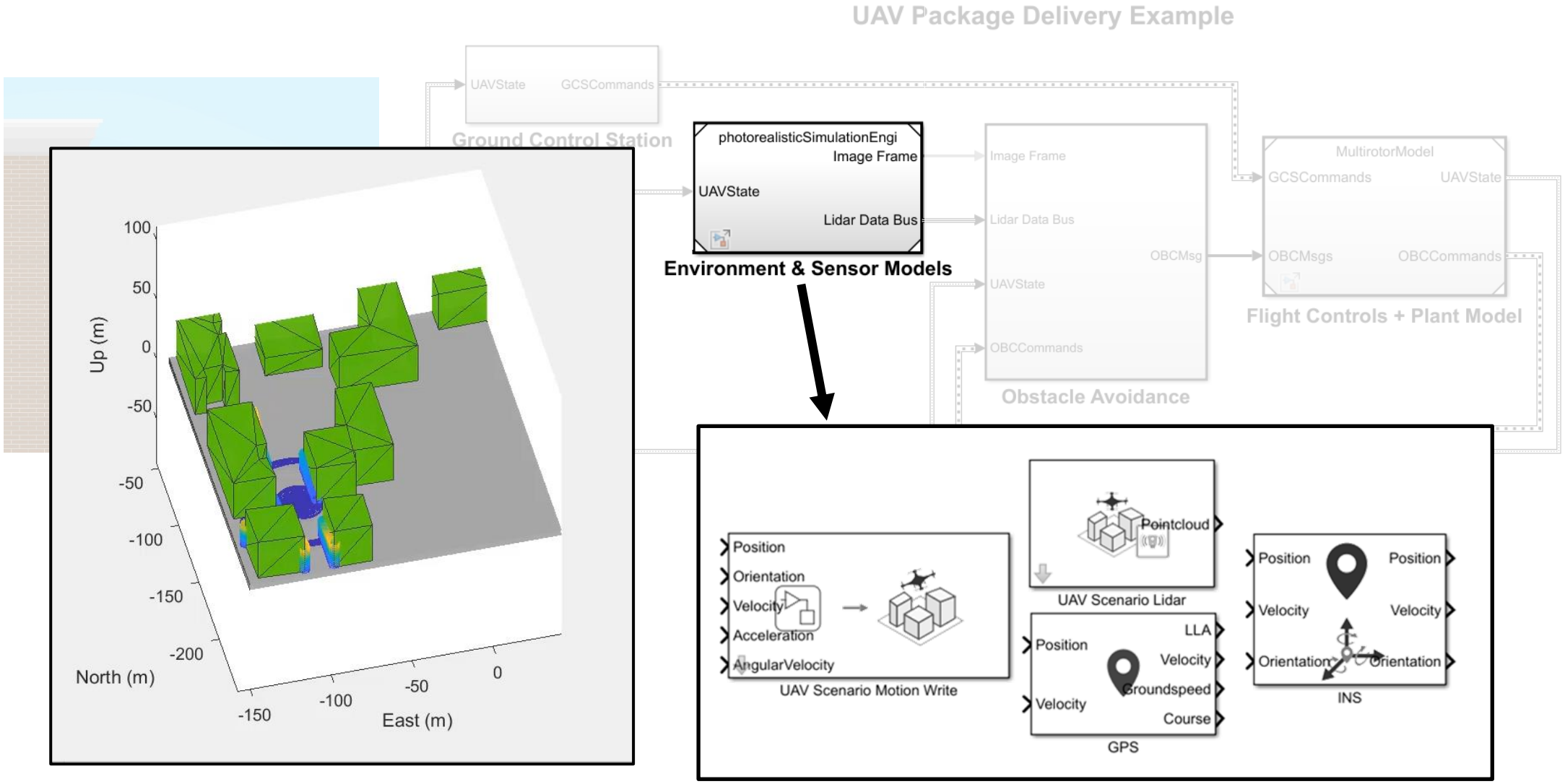


Integrate environments into full-system simulation

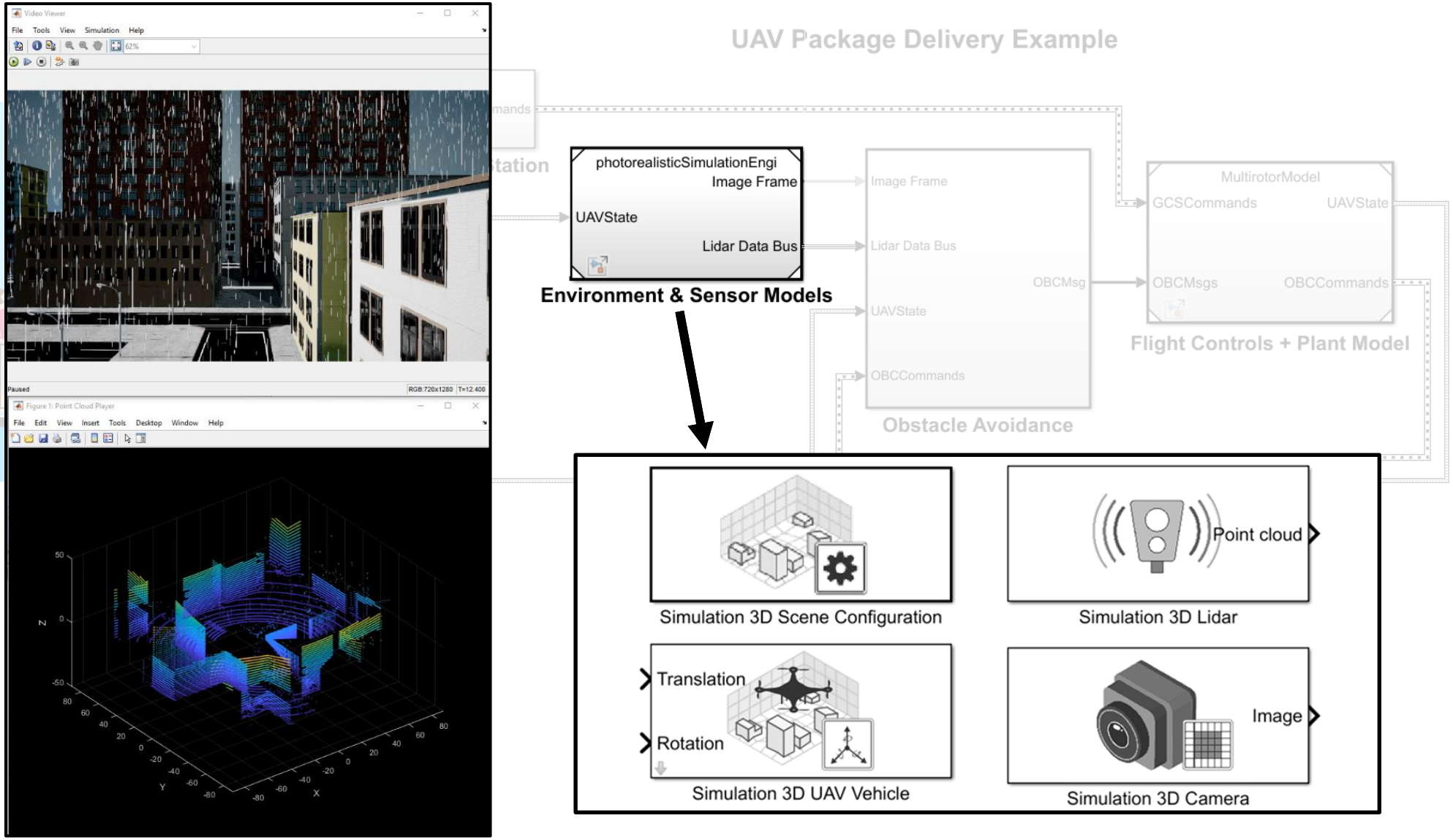




Integrate environments into full-system simulation

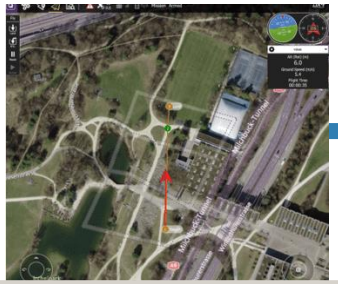


Integrate environments into full-system simulation



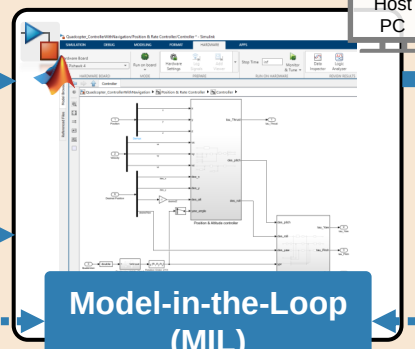
UAV Simulation Workflow with PX4 and Simulink

Inputs



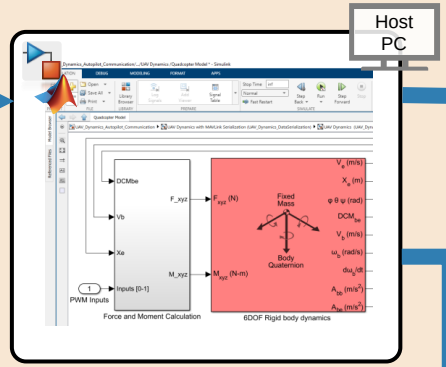
Ground Control Station

Flight Controller

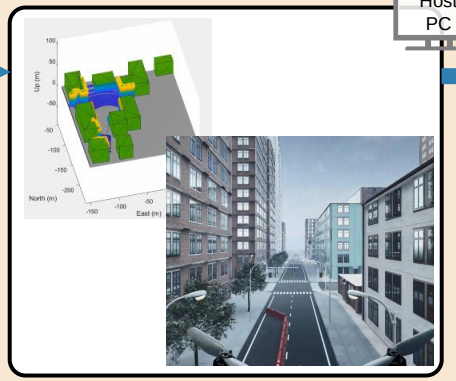


Model-in-the-Loop (MIL)

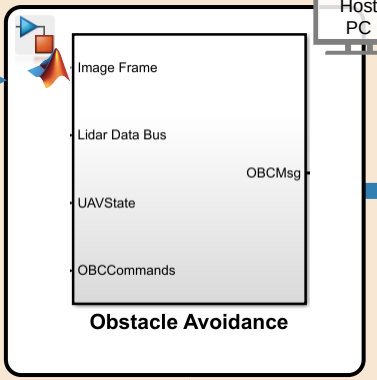
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

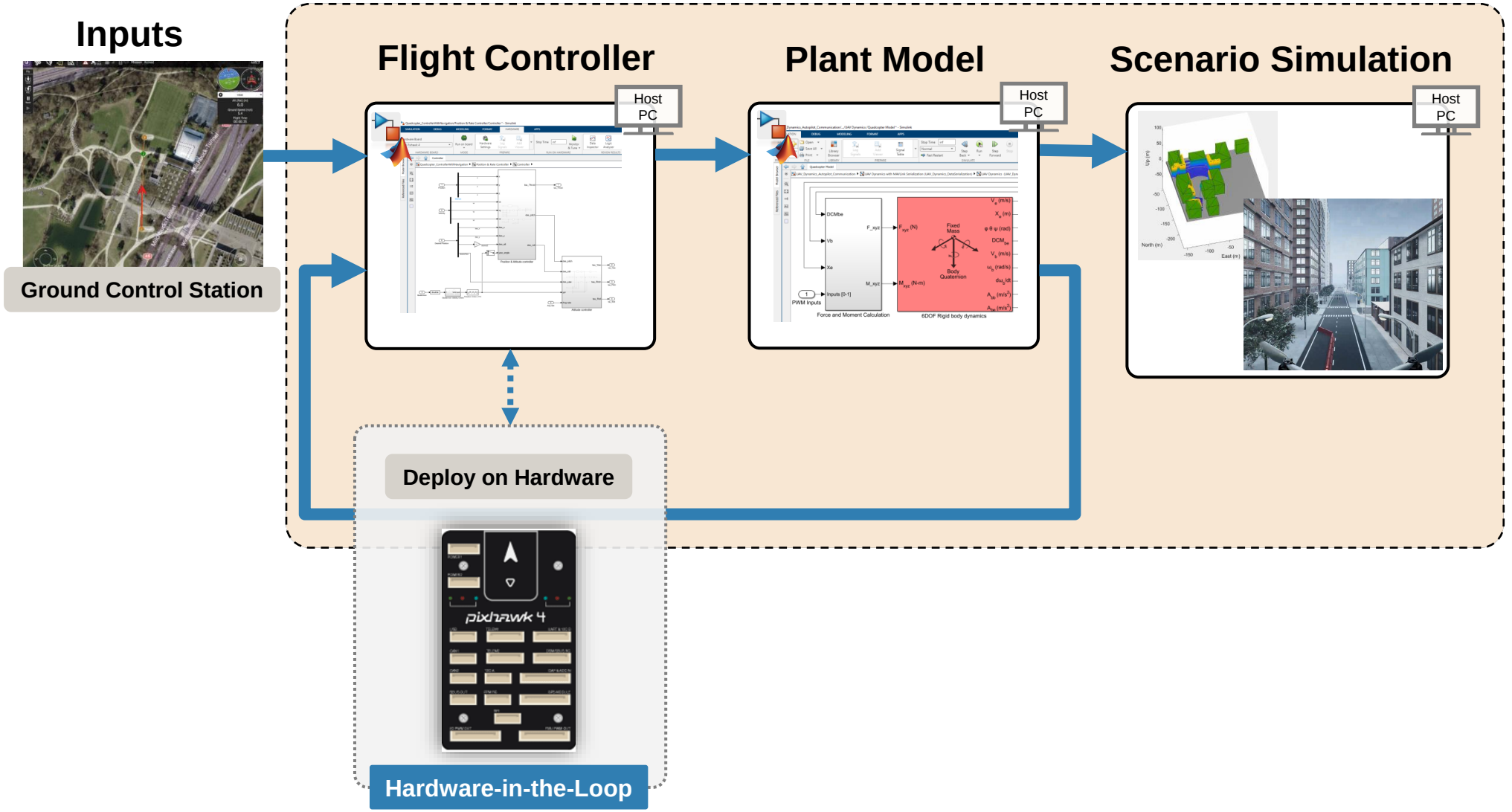
Deploy on Hardware

Software-in-the-Loop

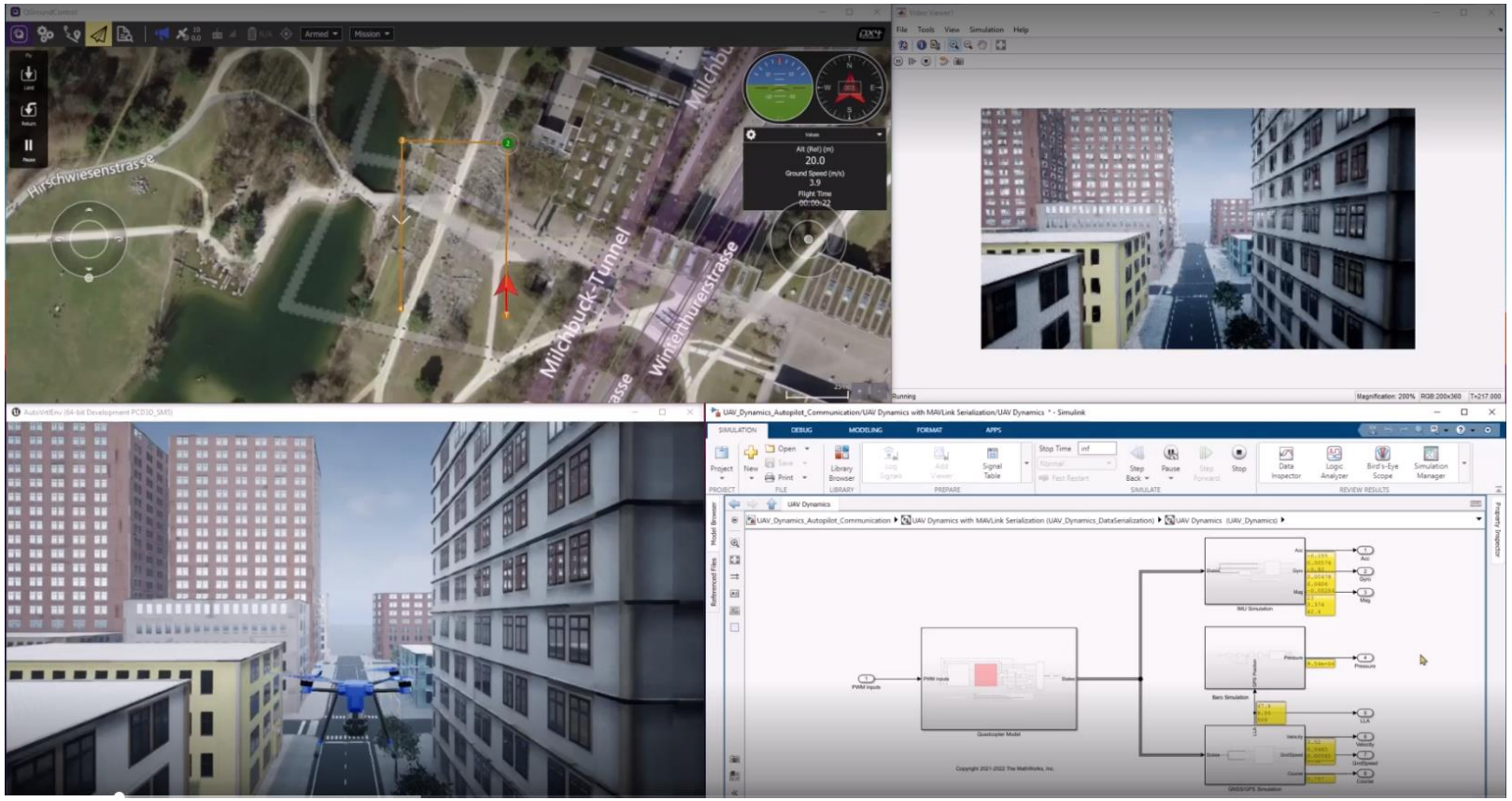
Hardware-in-the-Loop

NVIDIA Jetson

HIL with Scenario Visualization



HIL with Scenario Visualization

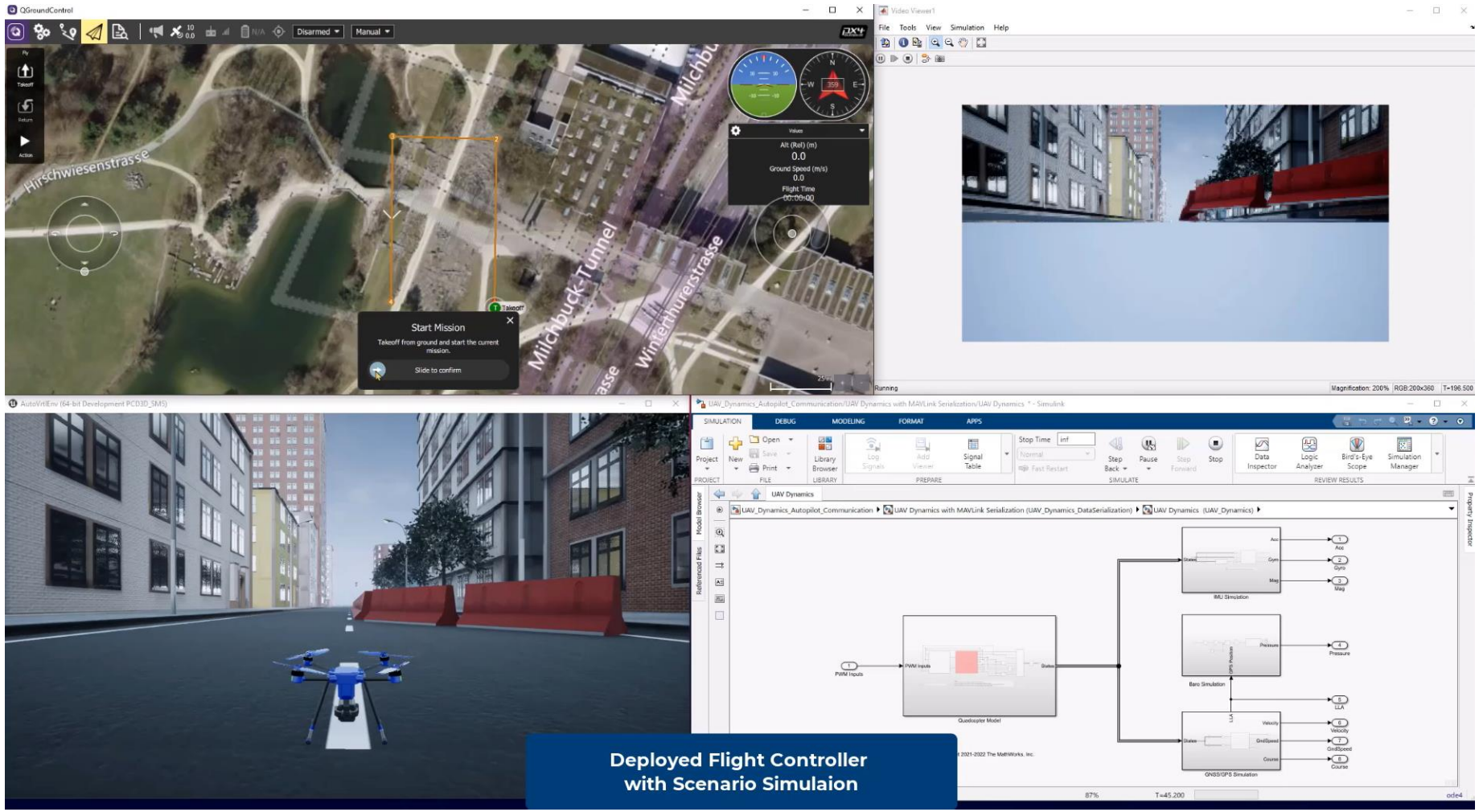


Scenario Simulation and Flight Visualization with PX4 Hardware-in-the-Loop...

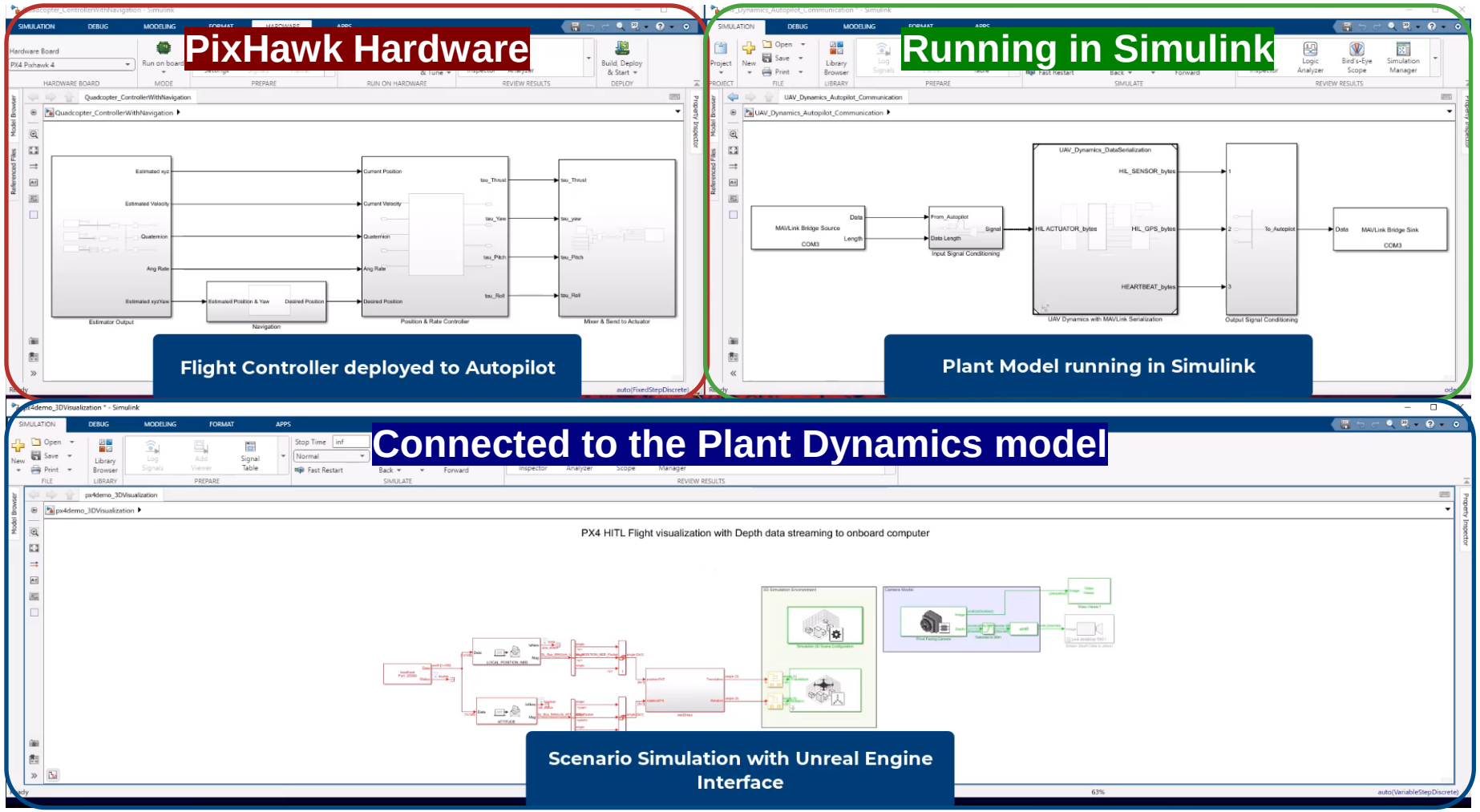
Demonstrates 3D scenario Simulation and Flight visualization with PX4 Hardware-in-the-Loop (HITL) and UAV Dynamics contained

Shipping example in UAV Toolbox

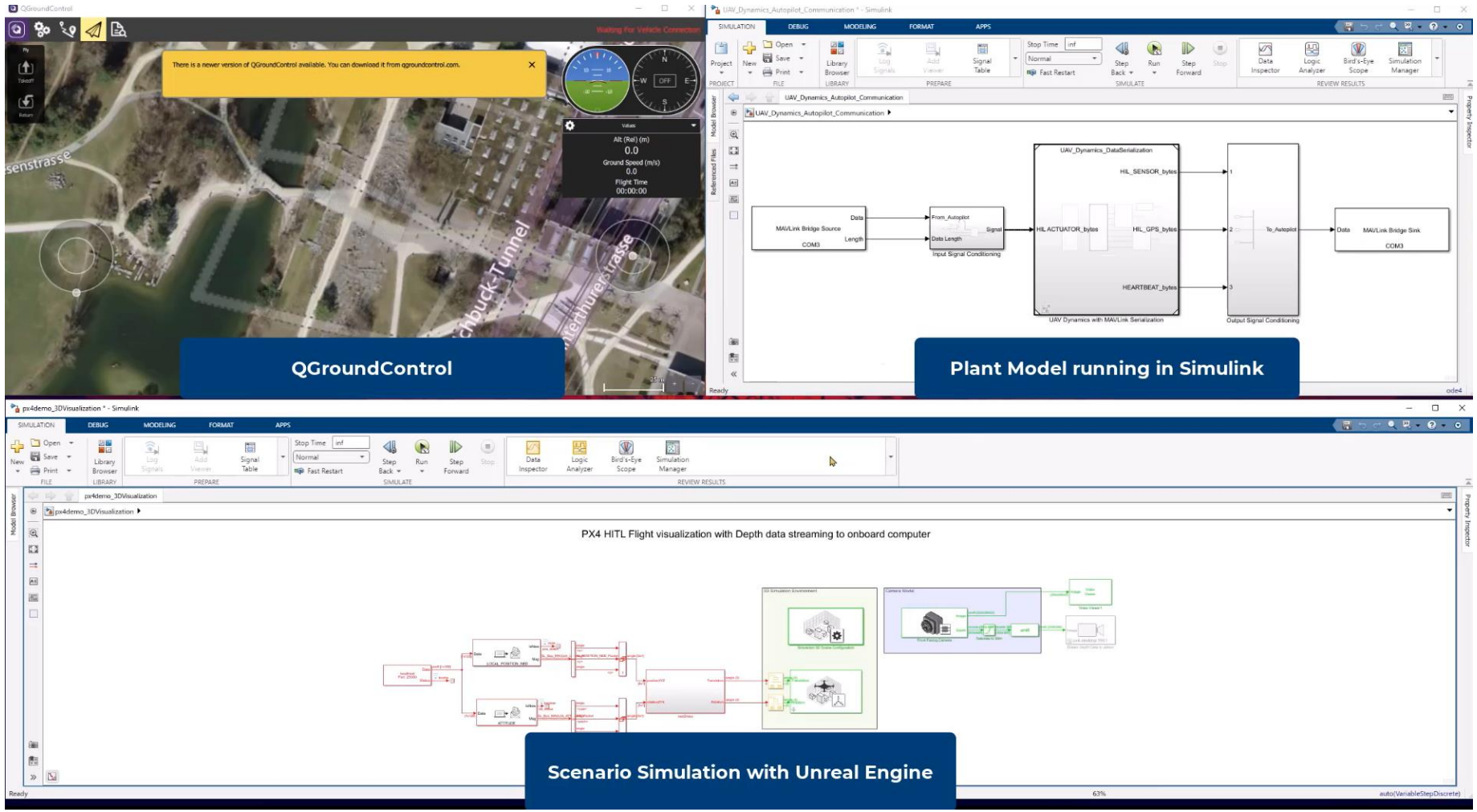
HIL with Scenario Visualization



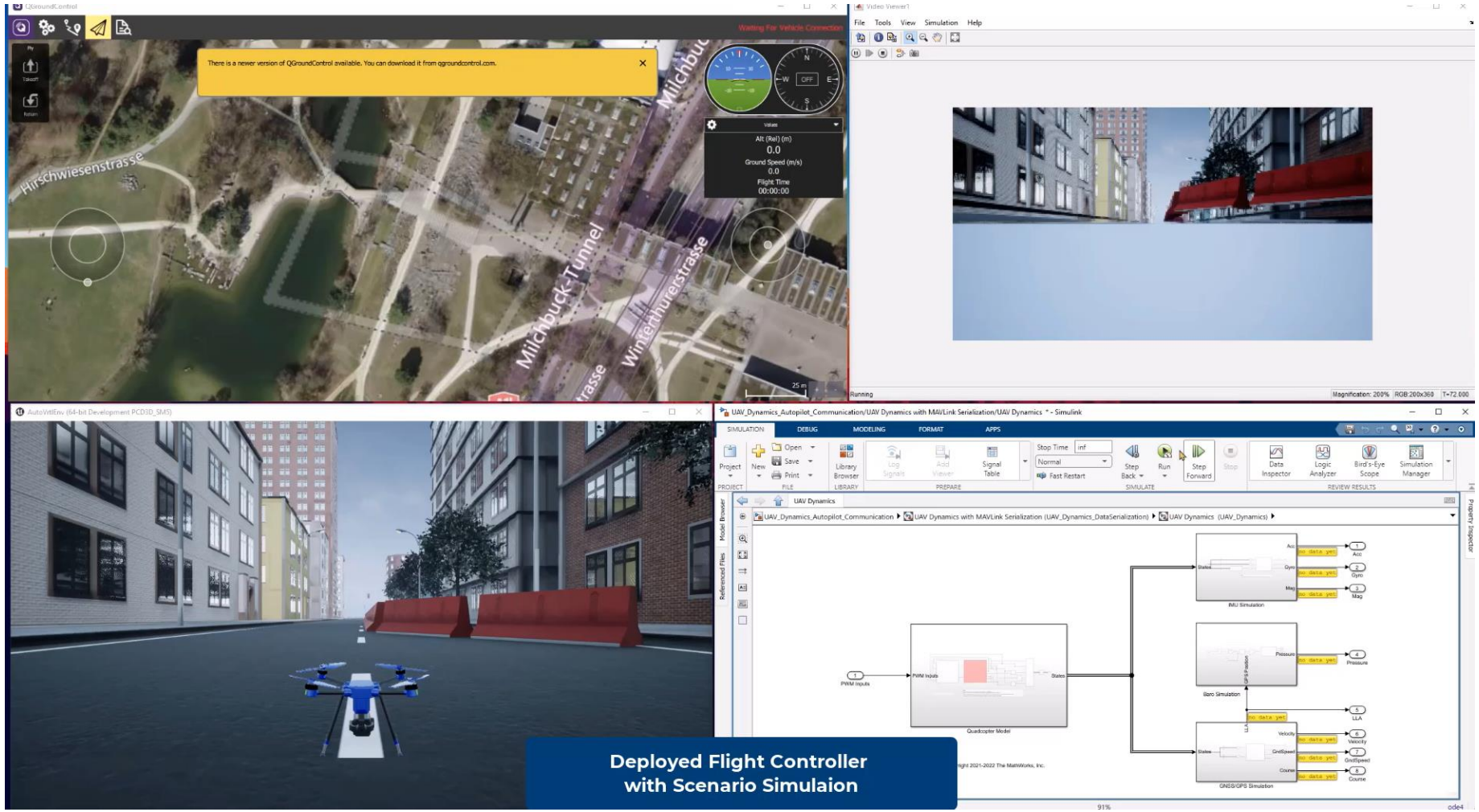
HIL with Scenario Visualization



HIL with Scenario Visualization

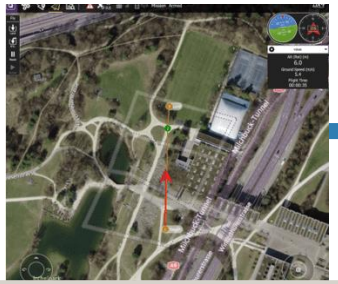


HIL with Scenario Visualization



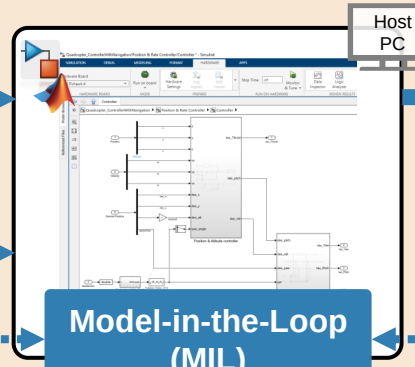
UAV Simulation Workflow with PX4 and Simulink

Inputs



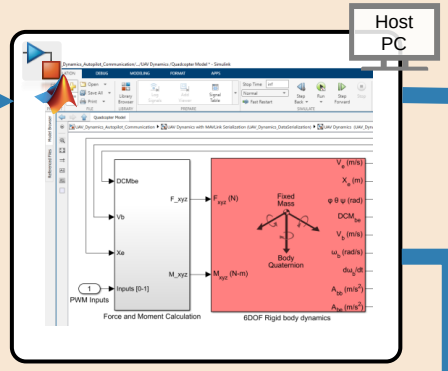
Ground Control Station

Flight Controller

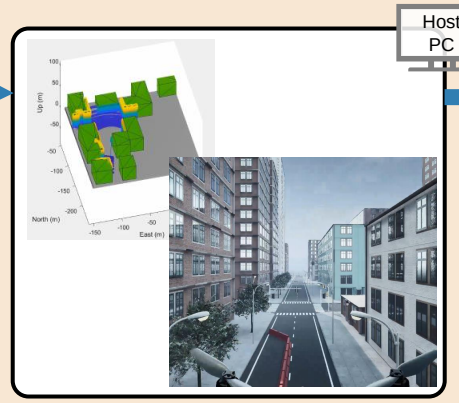


Model-in-the-Loop (MIL)

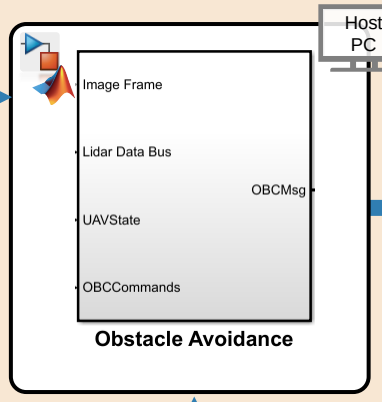
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

Deploy on Hardware

NVIDIA Jetson

Software-in-the-Loop

Hardware-in-the-Loop

Shipping example in UAV Toolbox

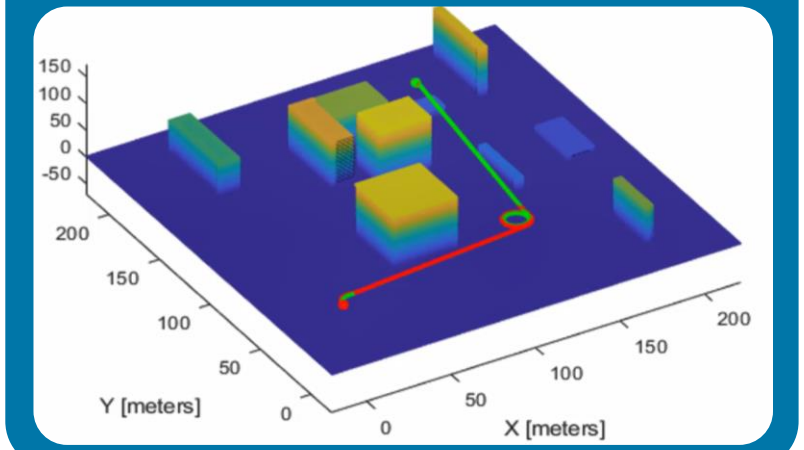
Simulate and Deploy UAV Applications with SIL and HIL Workflows

- Why SIL and HIL?
  - Ensure safety in real flights
  - Test flight behavior in simulation

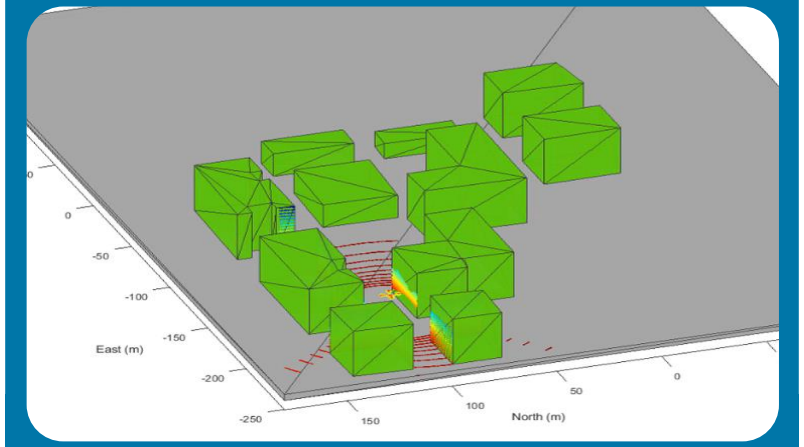
- Why MATLAB & Simulink?
  - Integrate with external autopilots
  - Generate C/C++ code for onboard computers
  - Scenario simulation with MATLAB and Unreal Engine

UAV Toolbox

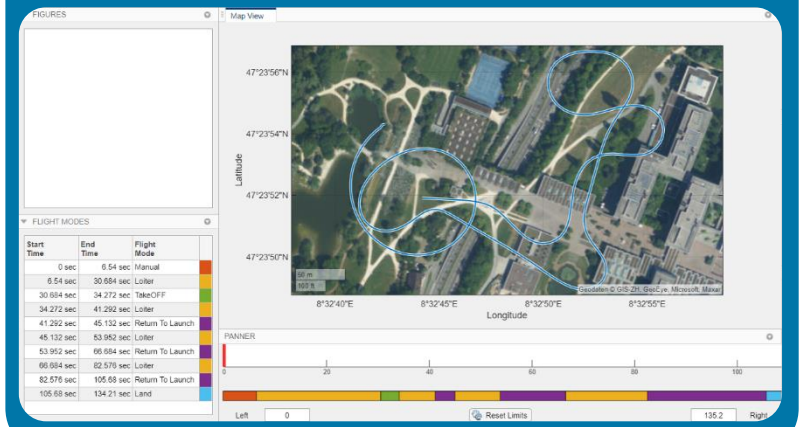
UAV Algorithms for Planning and Control



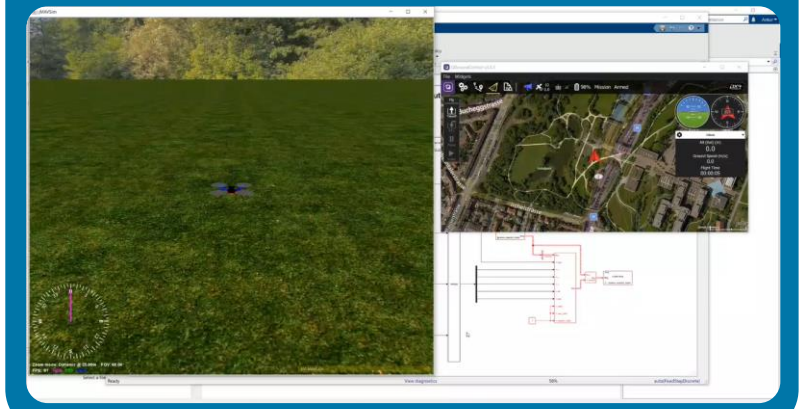
Scenario Design & Low-Fidelity Sensor Simulation



Flight Telemetry Data Analysis Flight Log Analyzer App

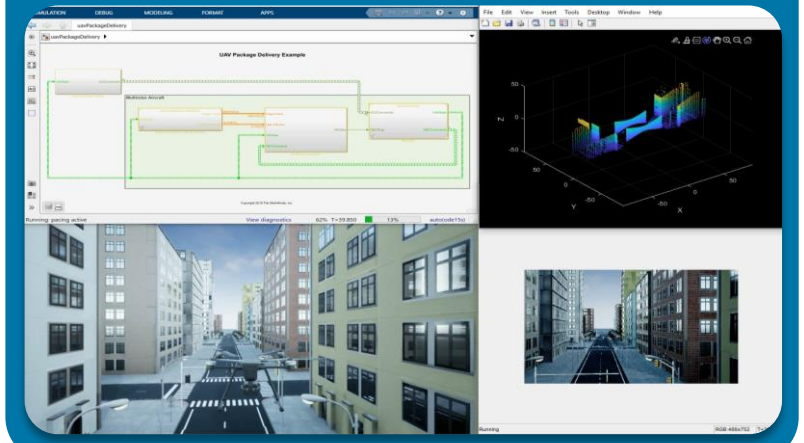


Connectivity and Deployment with MAVLink and PX4



Unreal Engine Co-Simulation with Sensor Models

Reference Applications



Resources

- Product Page
  - www.mathworks.com/products/uav.html
- Product Overview Video
  - https://www.mathworks.com/videos/what-is-uav-toolbox-1600154005892.html
- UAV Toolbox Support Package for PX4 Autopilots
  - https://www.mathworks.com/help/supportpkg/px4/index.html?s_tid=CRUX_topnav
- Documentation
  - www.mathworks.com/help/uav/
- Examples
  - www.mathworks.com/help/uav/examples.html

MATLAB EXPO

Thank you