MATLAB EXPO

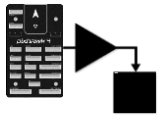
Simulate and Deploy UAV Applications with SIL and HIL Workflows

Mihir Acharya, MathWorks *Ronal George, MathWorks* *Julia Antoniou, MathWorks*

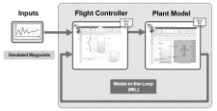
MathWorks

Agenda

Introduction



PX4 with Simulink



MIL, SIL and HIL Workflows

Scenario Simulation

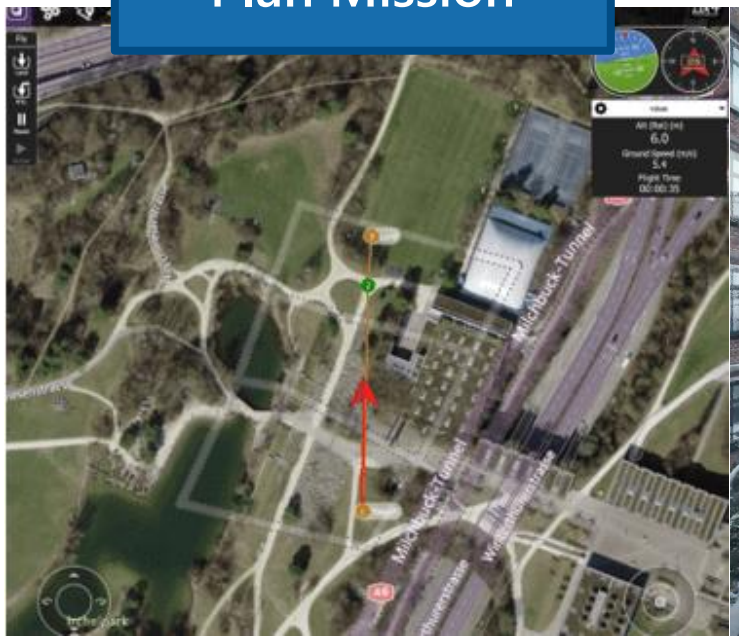
HIL with Scenario Simulation

Summary and Resources

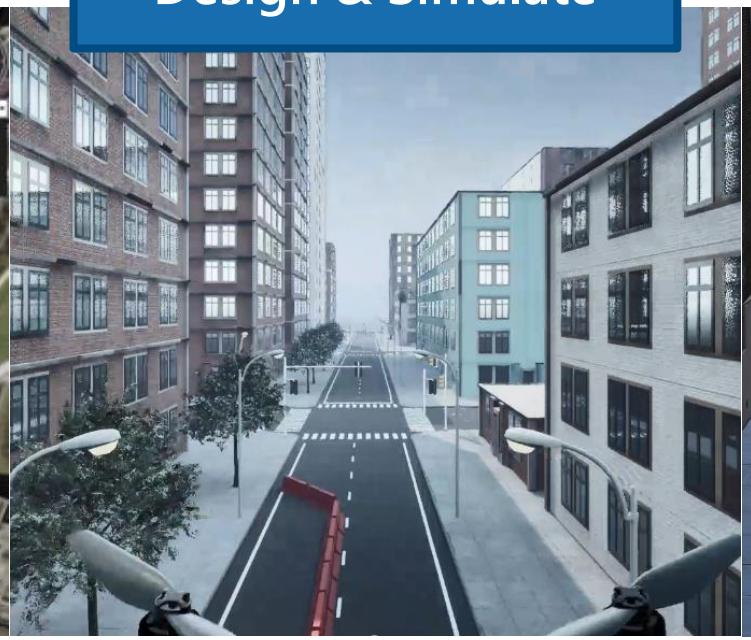
Fly a Drone Through a City Block

Simulation in a Virtual Scenario

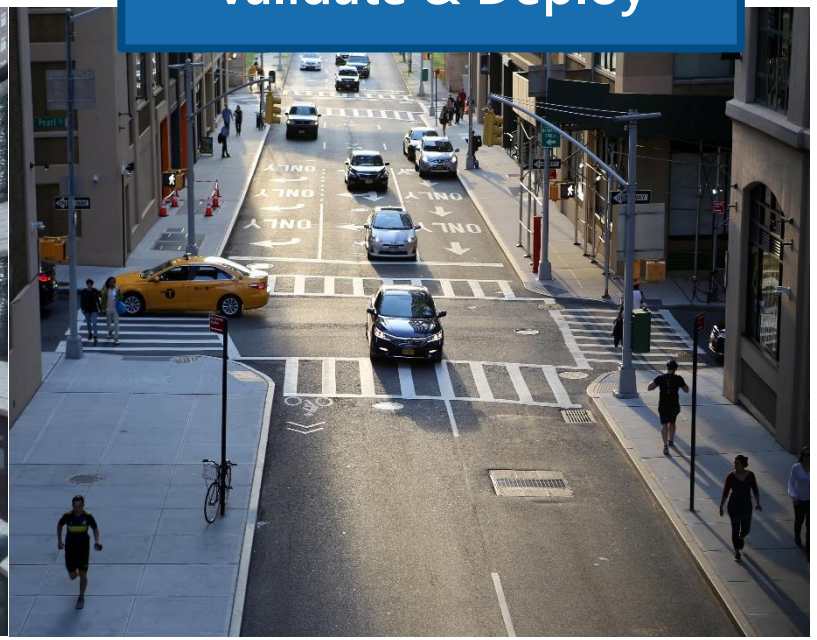
Plan Mission



Design & Simulate



Validate & Deploy

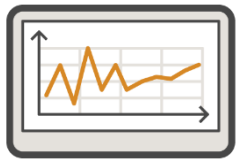


Building Blocks for UAV Simulation

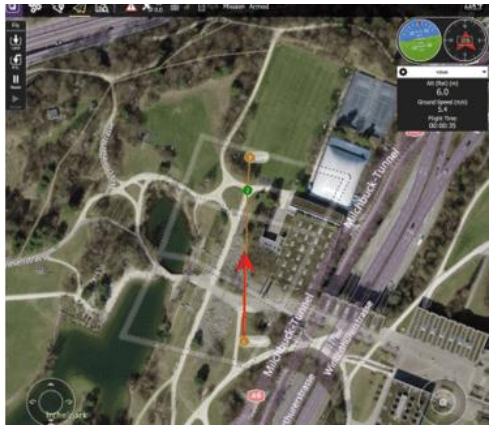
Plan Mission

Generate flight path for the mission

Simulated Waypoints



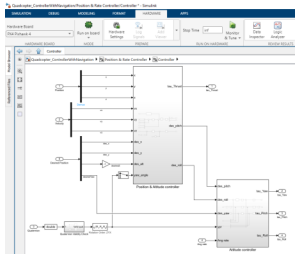
Ground Control Station



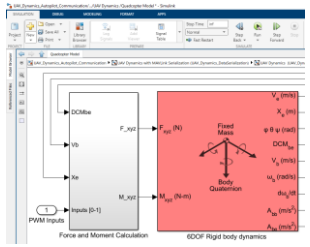
Design & Simulate

Design flight controller and simulate plant behavior in virtual scenarios

Flight Controller



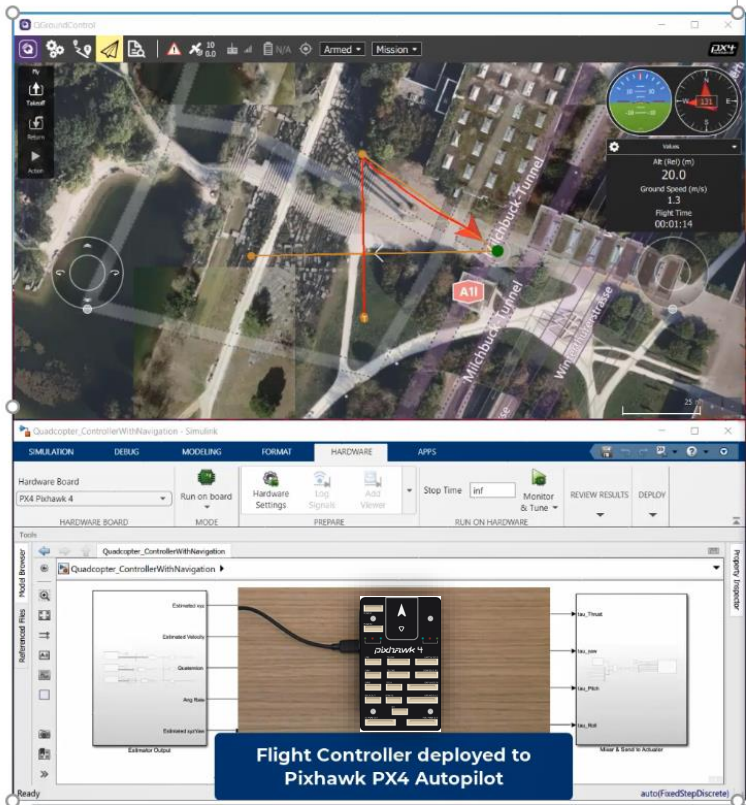
Plant Model



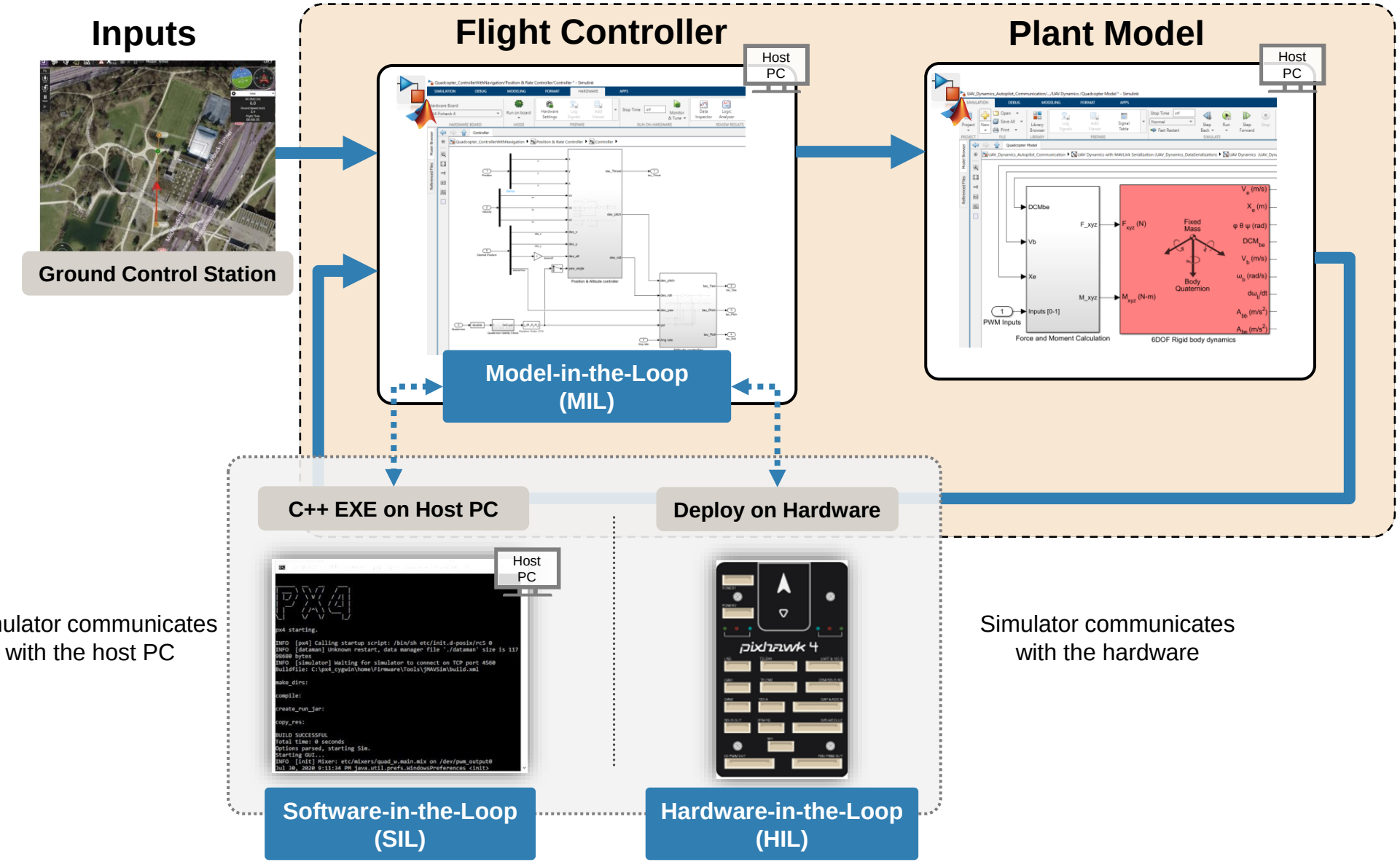
Scenario Simulation

Validate & Deploy

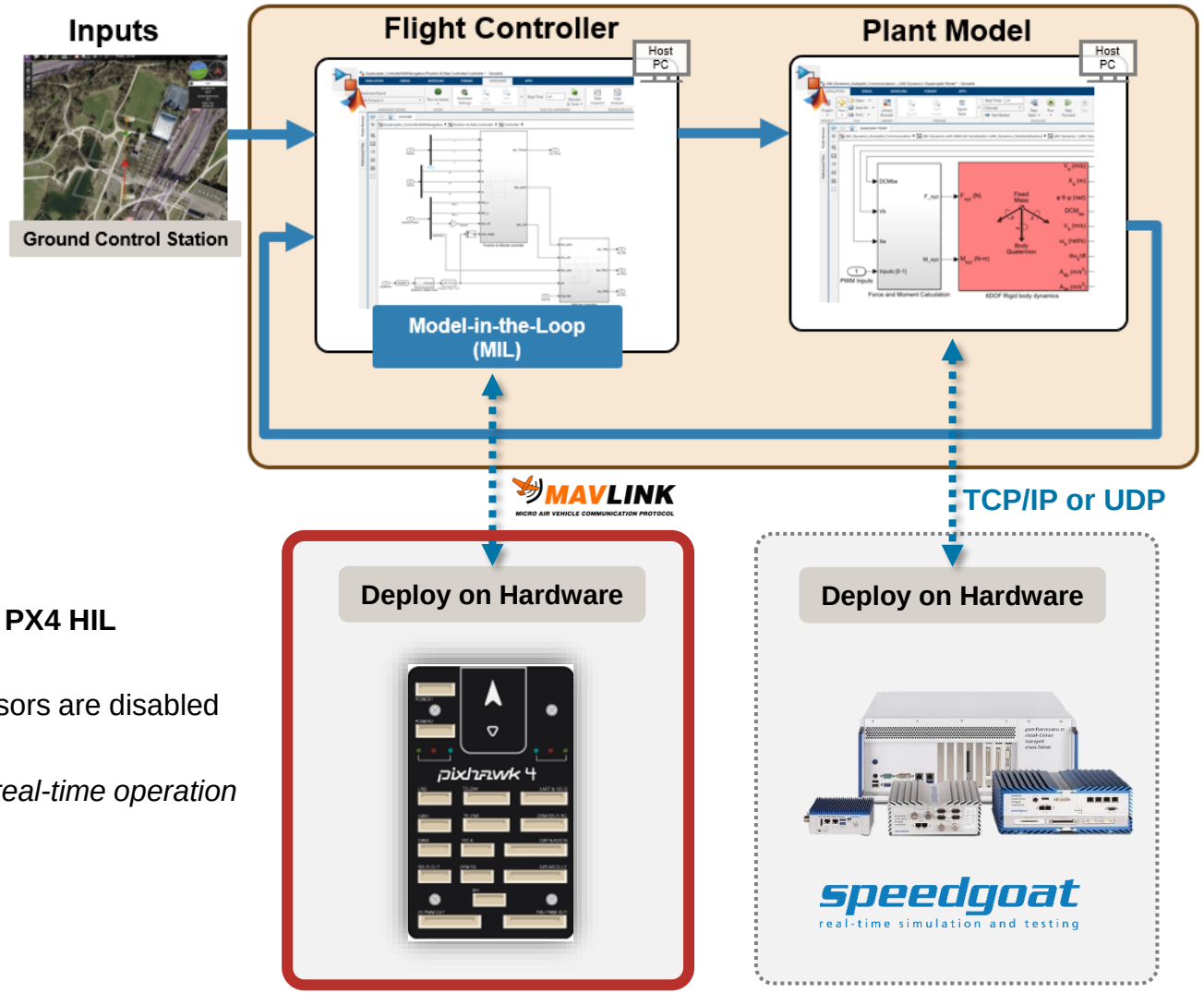
Deploy flight controller and autonomy algorithms to the platform



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*

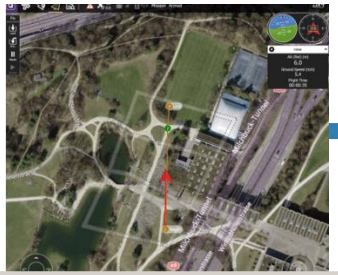
Focus of this talk

Full HIL Workflow

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

Visualize Flight Behavior in a Virtual Scenario

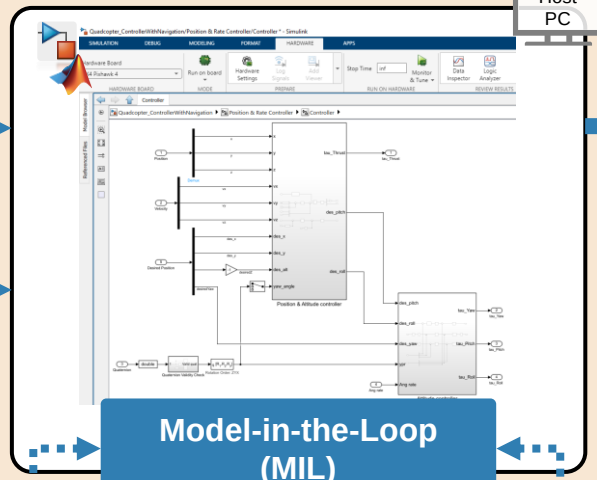
Inputs



Ground Control Station

Flight Controller

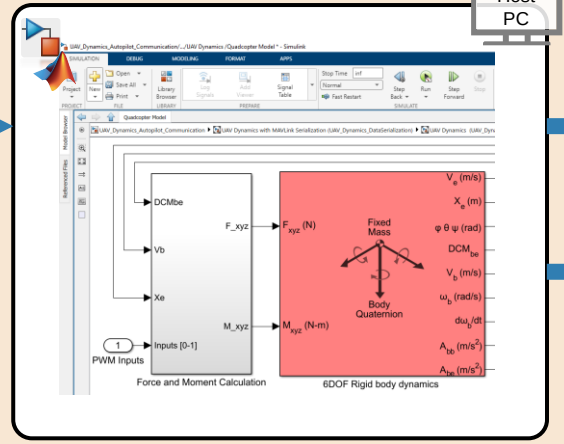
Host PC



Model-in-the-Loop (MIL)

Plant Model

Host PC



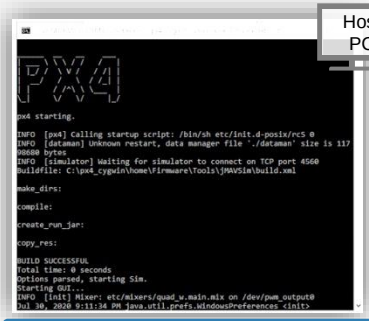
Scenario Simulation

Host PC

C++ EXE on Host PC

Deploy on Hardware

Host PC

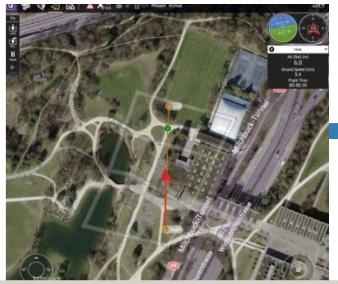


Software-in-the-Loop (SIL)

Hardware-in-the-Loop (HIL)

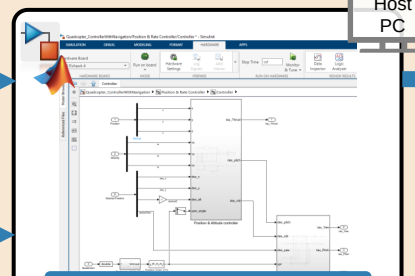
Design Autonomy Algorithms with UAV Simulation Workflow

Inputs



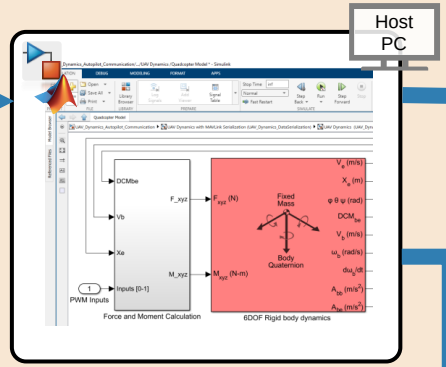
Ground Control Station

Flight Controller

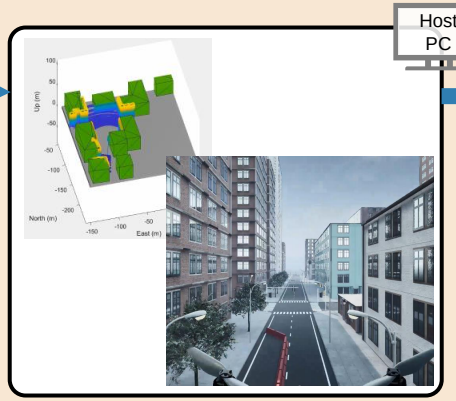


Model-in-the-Loop (MIL)

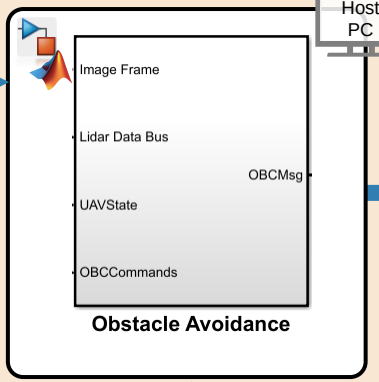
Plant Model



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™

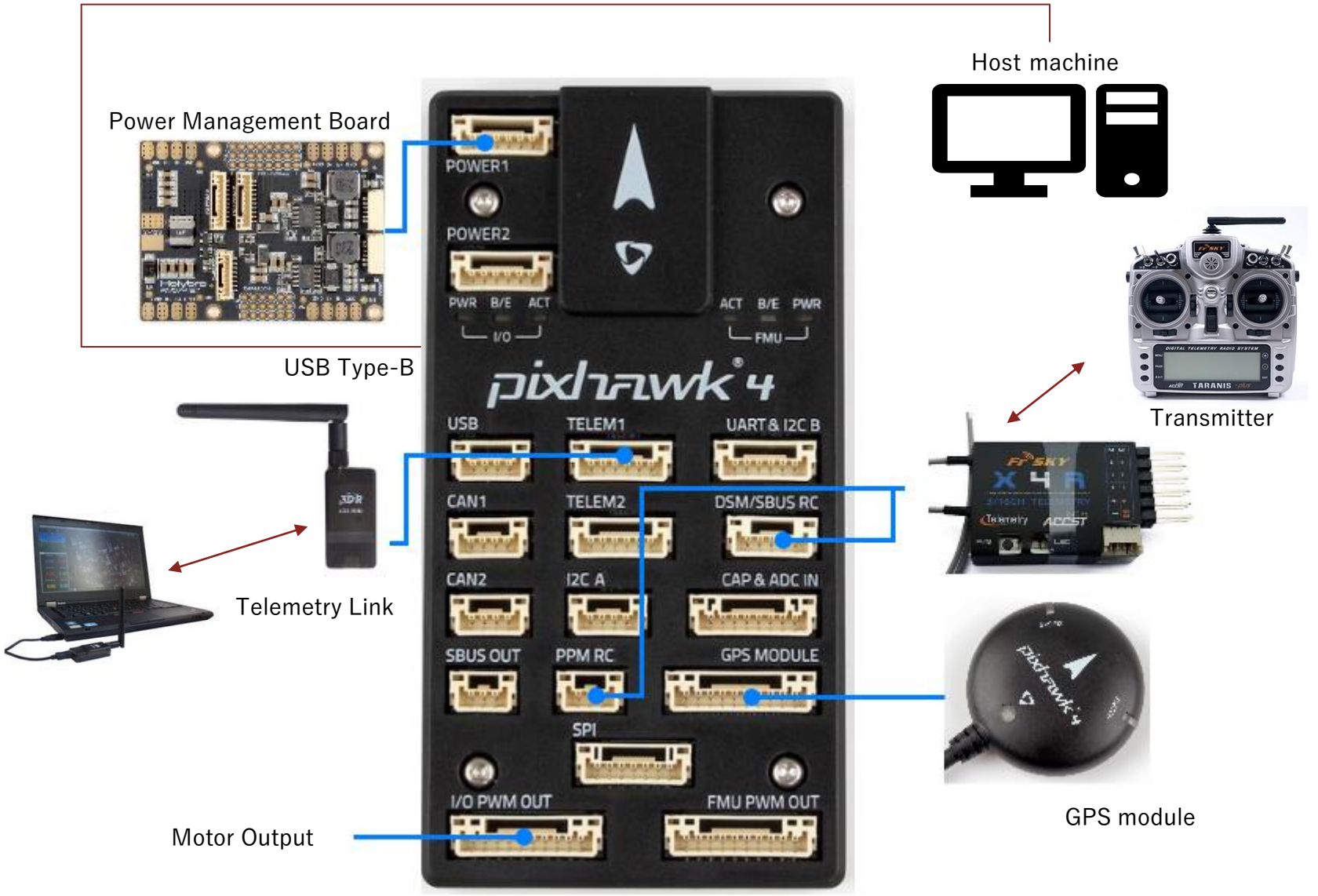
What is Pixhawk®

On-board sensors:

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

Interfaces:

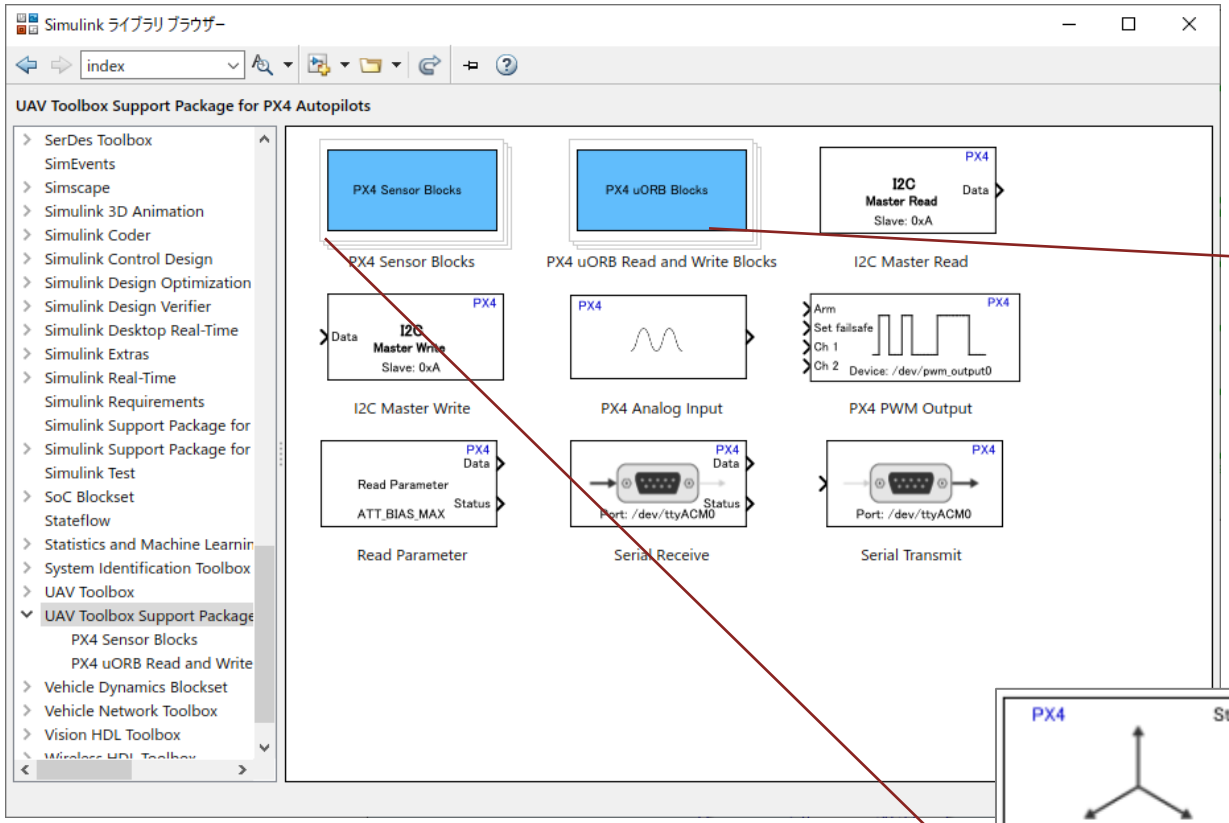
- 8-16 PWM outputs
- 3 dedicated PWM
- Dedicated R/C
- 5 serial ports
- 3 I2C ports
- 4 SPI buses
- 2 CANBuses

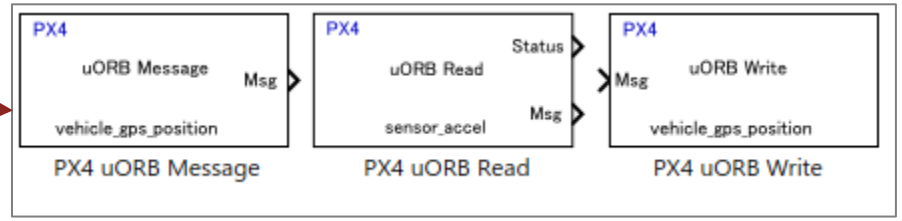


https://docs.px4.io/en/assembly/quick_start_pixhawk4.html

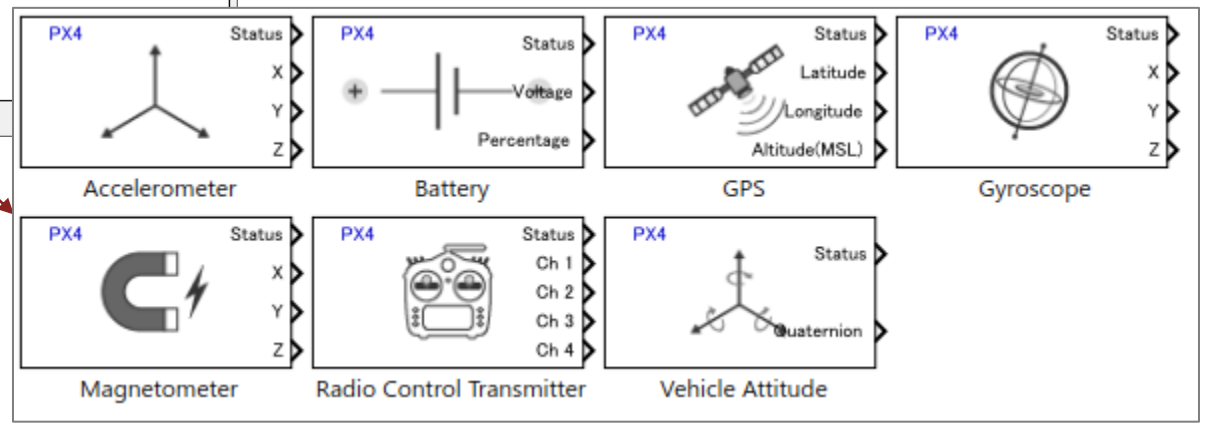
UAV Toolbox Support Package for PX4 Autopilots

Simulink Block Library

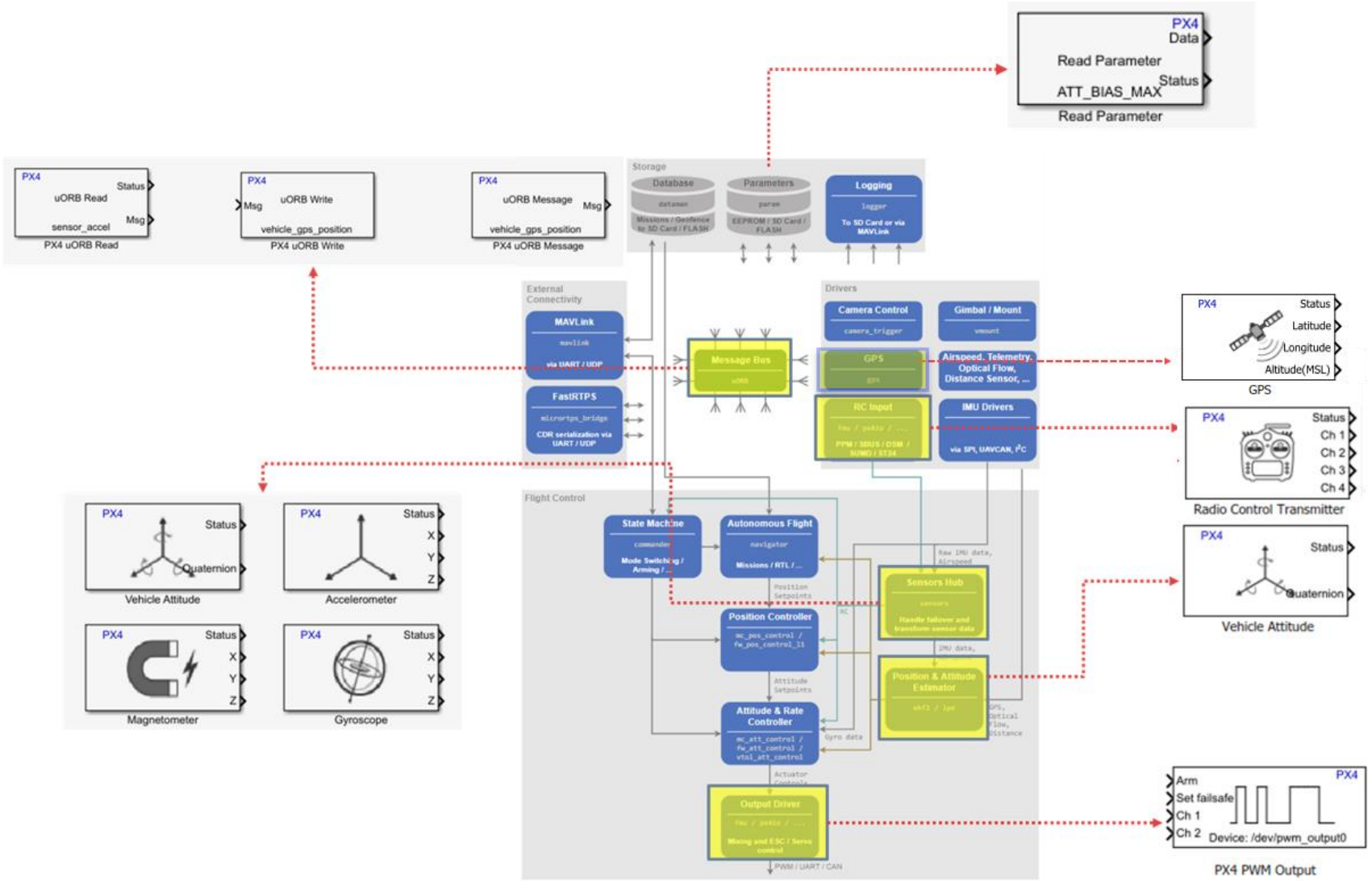




uORB: Asynchronous pub/sub messaging API (middleware)



PX4 Autopilots Support Package Relationship to PX4 Architecture



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

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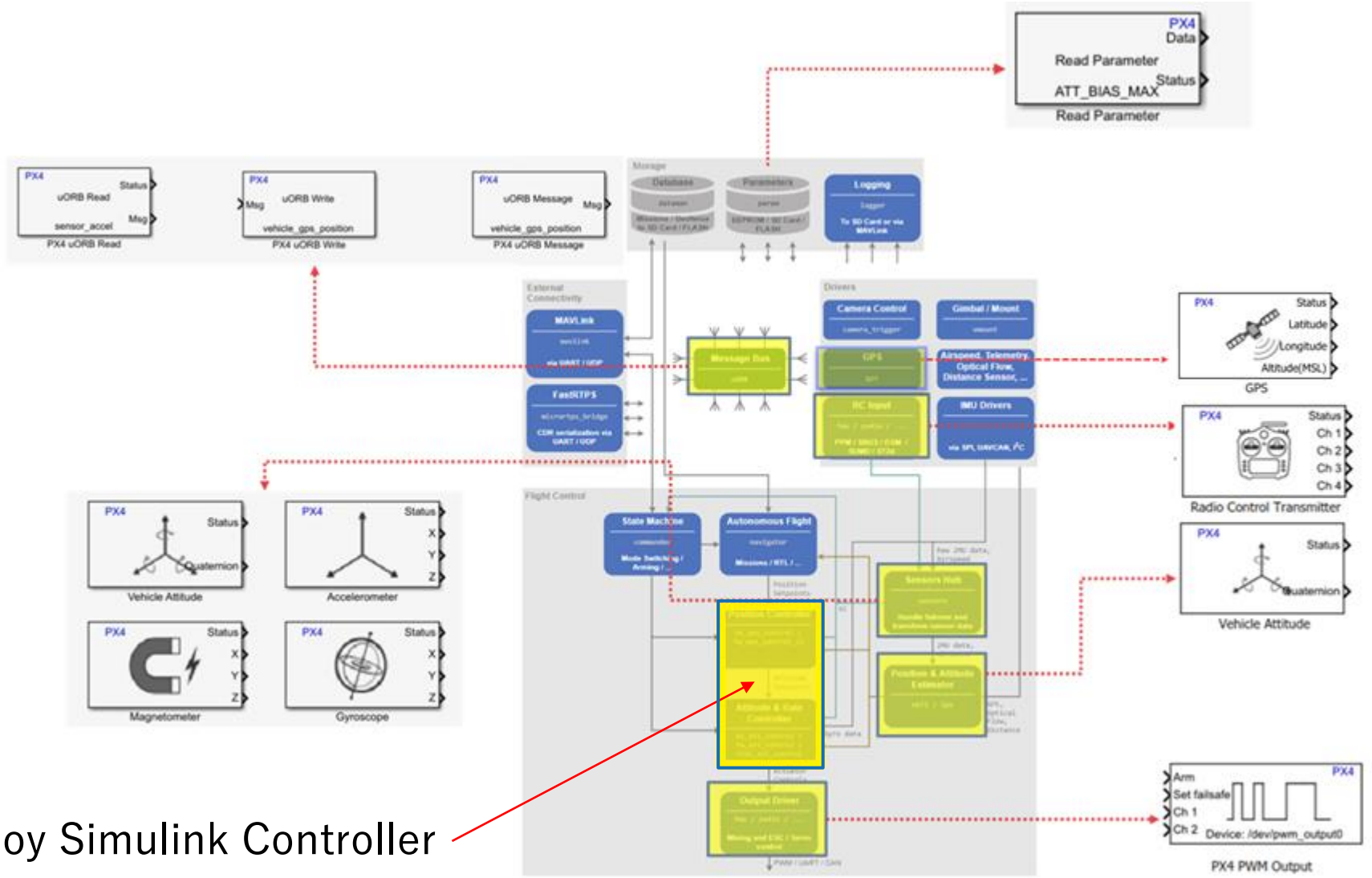

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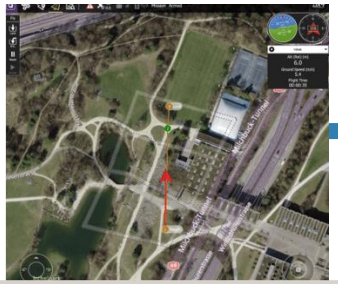
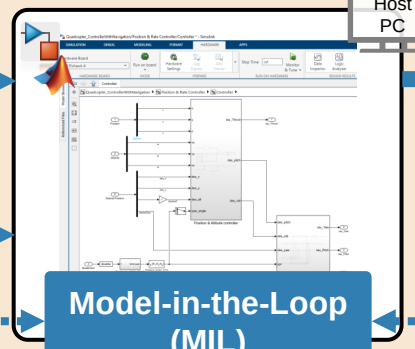
UAV Simulation Workflow with PX4 and Simulink

Inputs



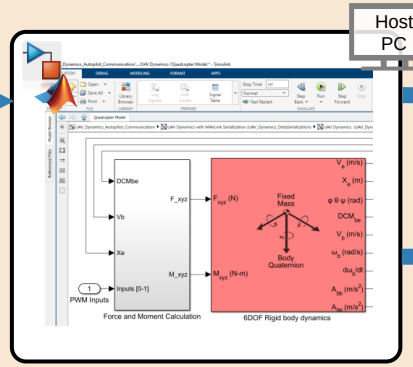
Ground Control Station

Flight Controller

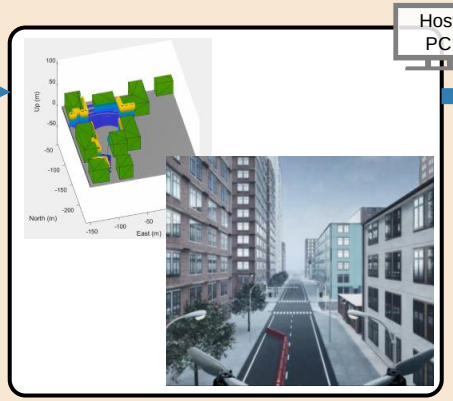


Model-in-the-Loop (MIL)

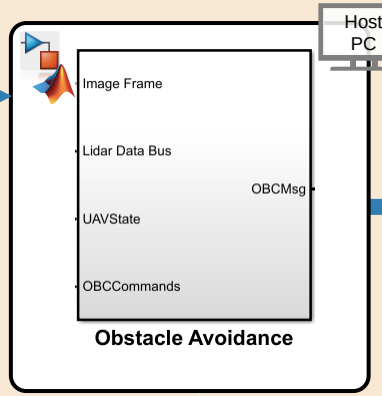
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

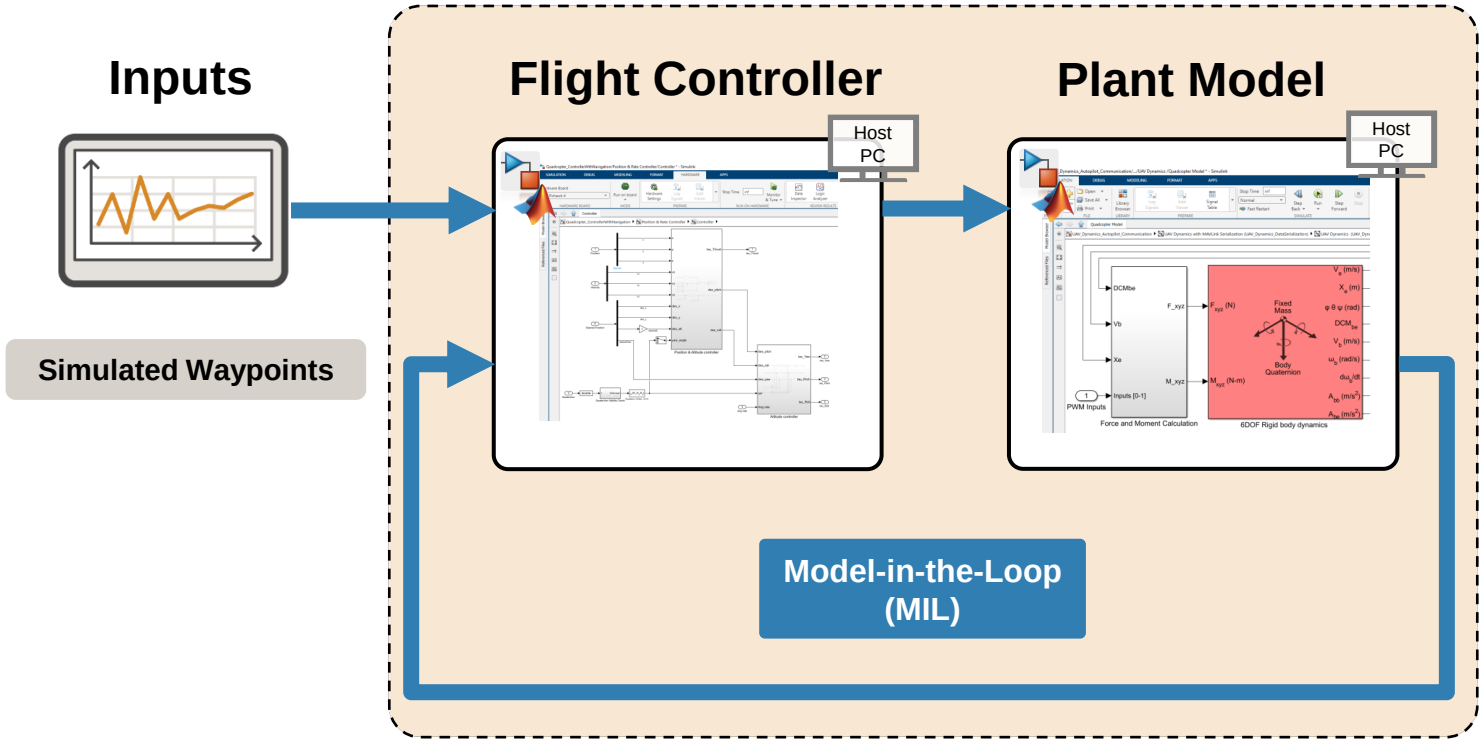
Deploy on Hardware

Software-in-the-Loop

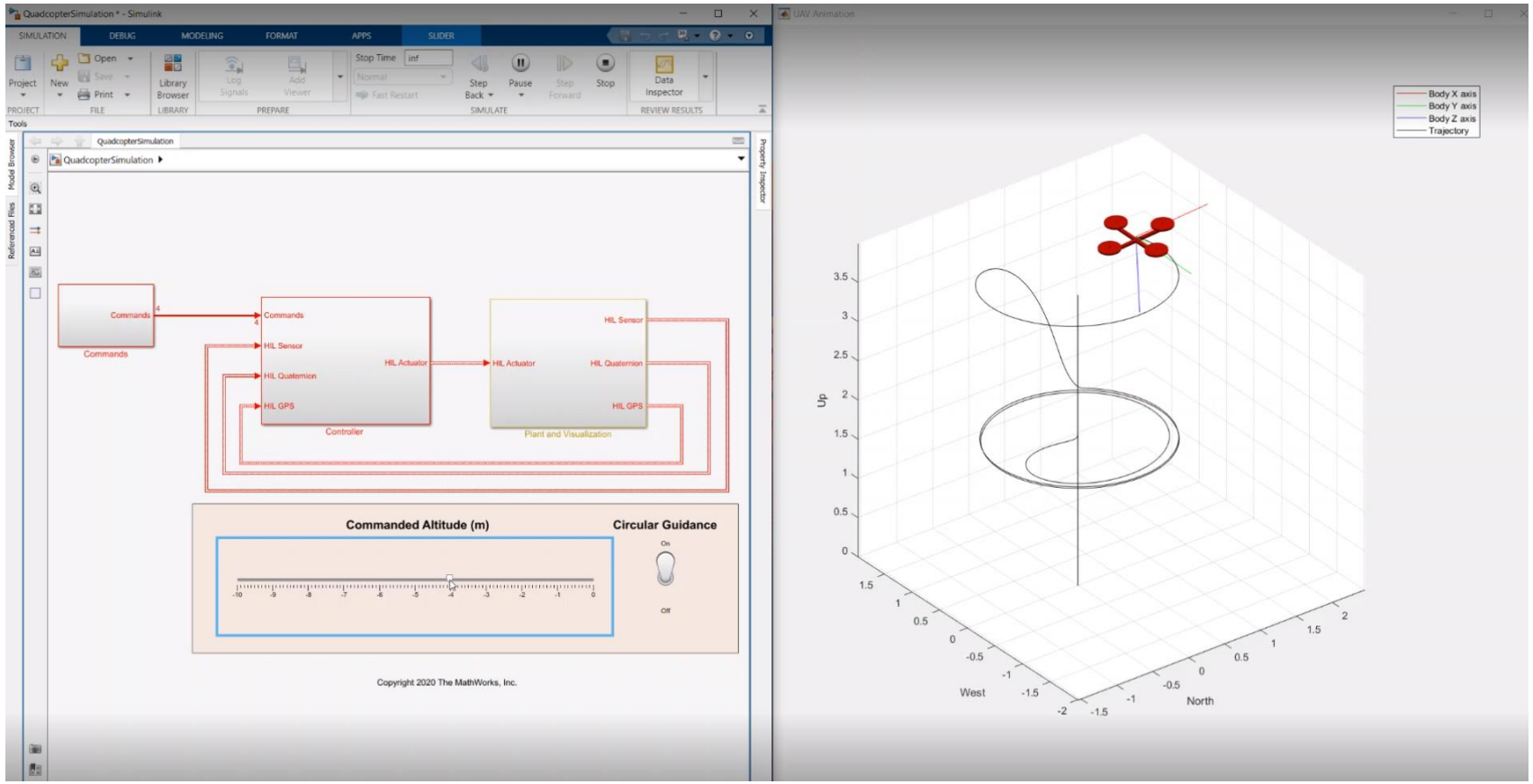
Hardware-in-the-Loop

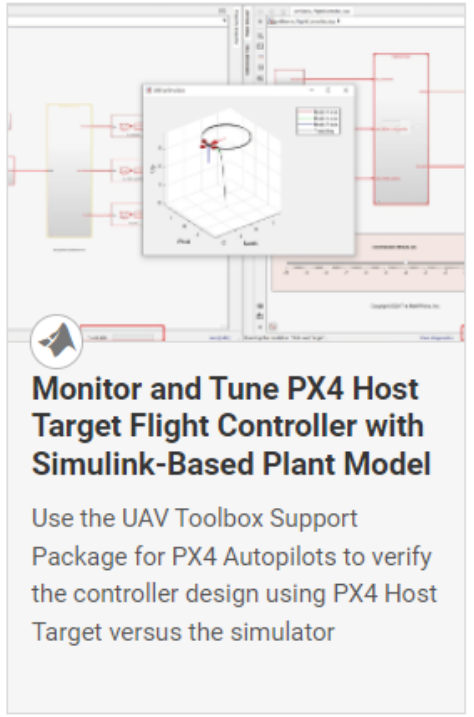
NVIDIA Jetson

Model In the Loop



Quadcopter Simulation in Simulink



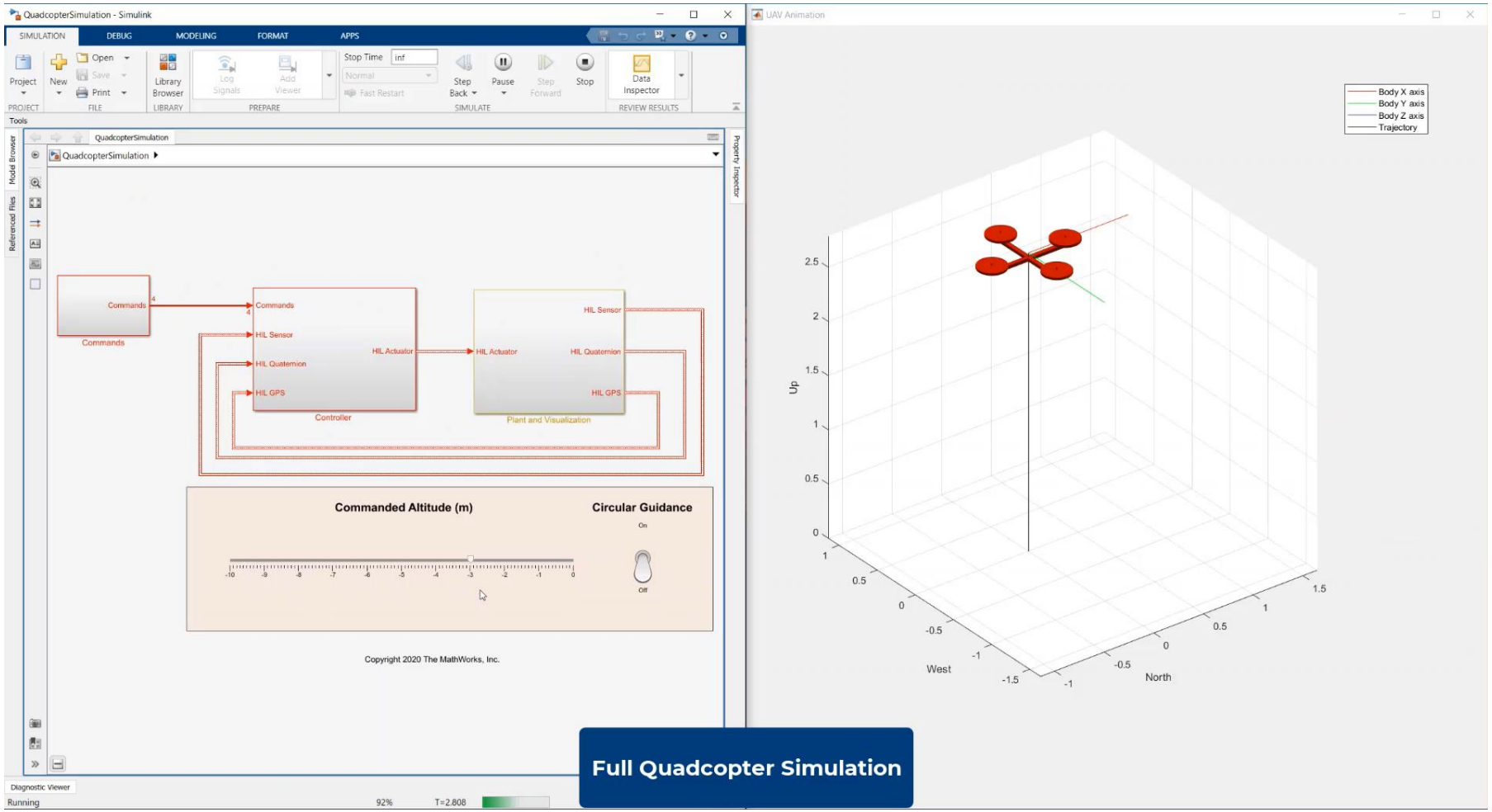


Monitor and Tune PX4 Host Target Flight Controller with Simulink-Based Plant Model

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

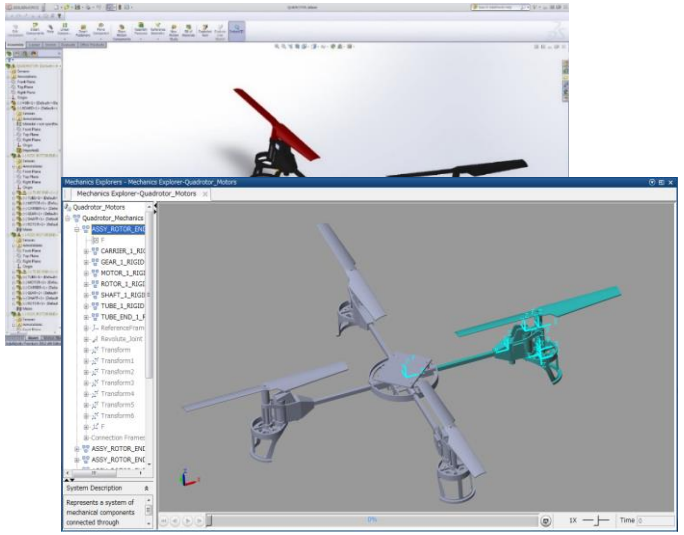


Video included with session content package

Simulink Plant Modelling

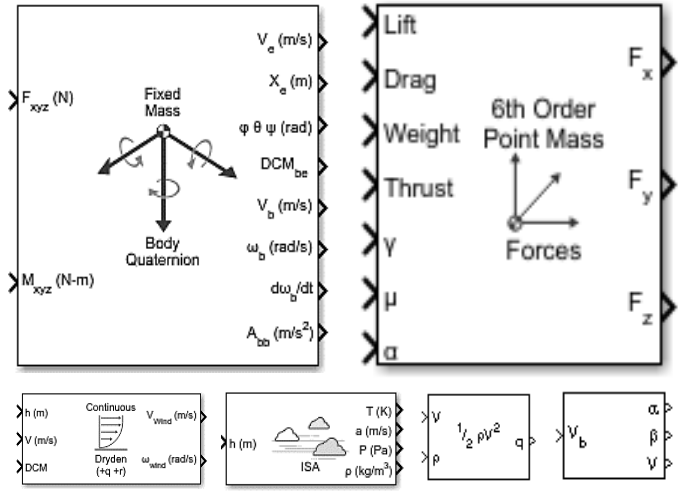
High-Fidelity
Building UAV

Low-Fidelity
Programming UAV



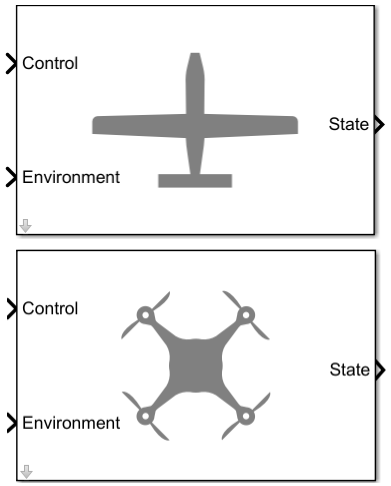
Physical Modeling

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



Vehicle Dynamics

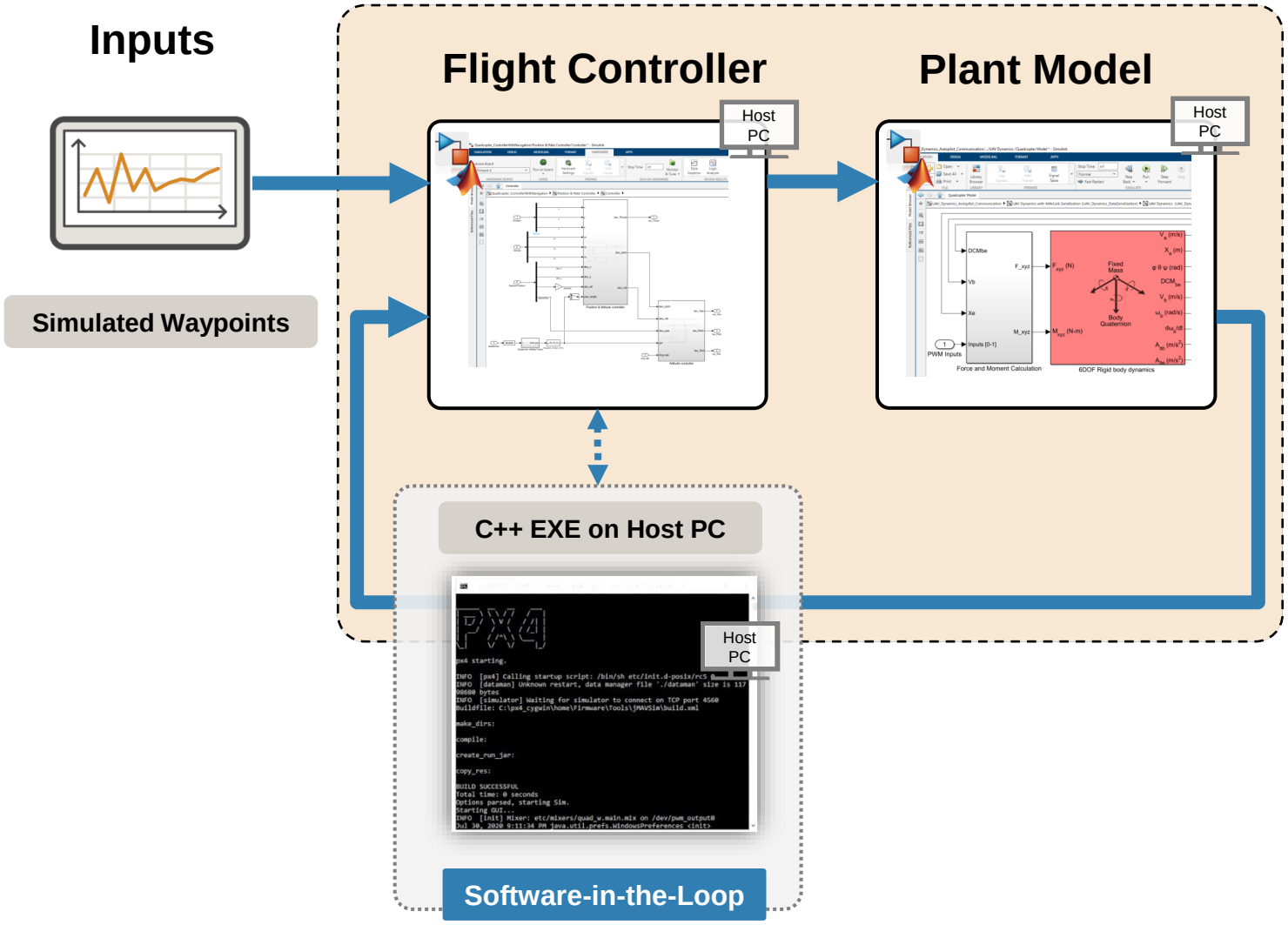
Model aerodynamics, propulsion, and motion of aircraft and spacecraft



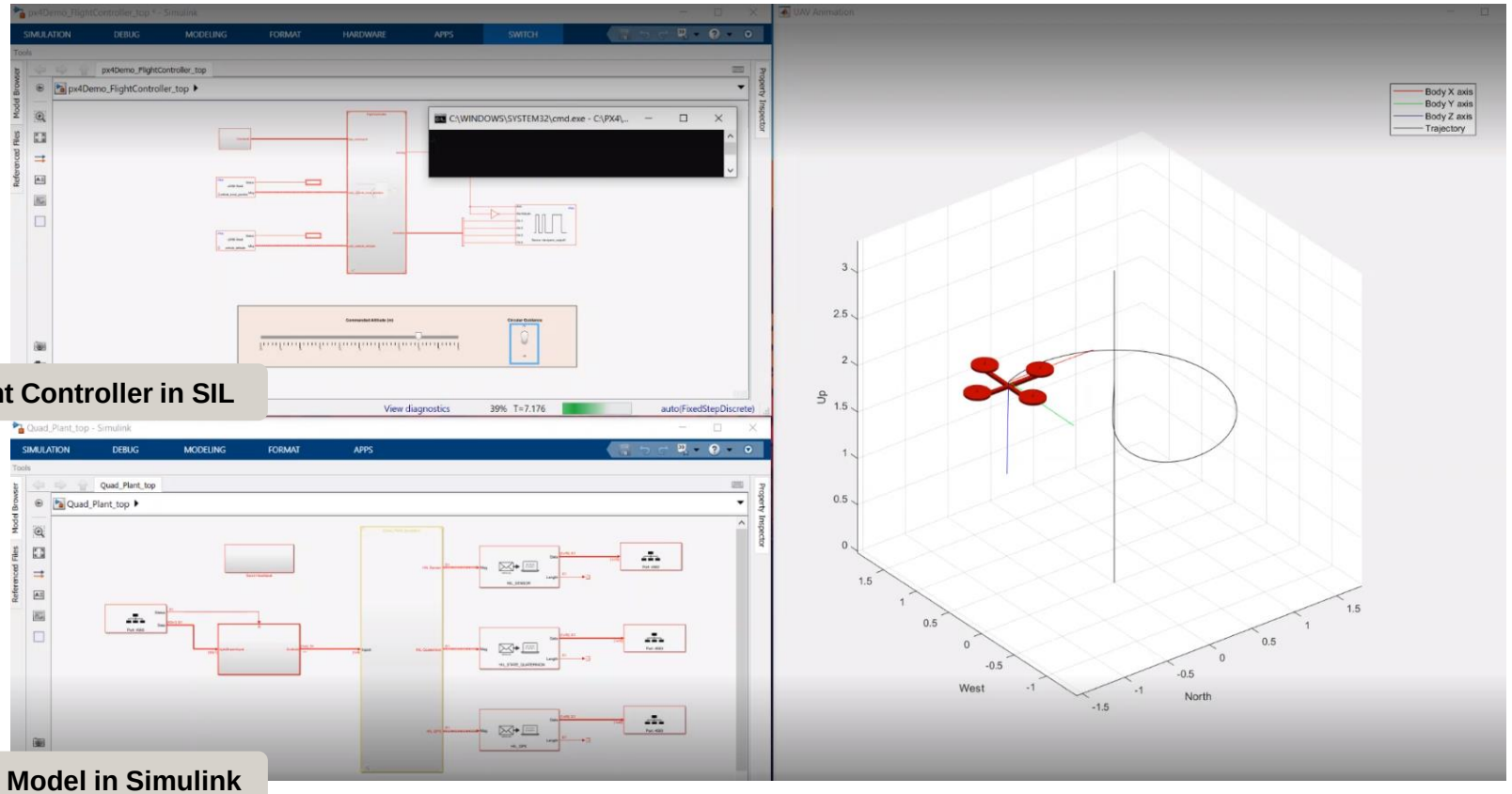
Guidance Model

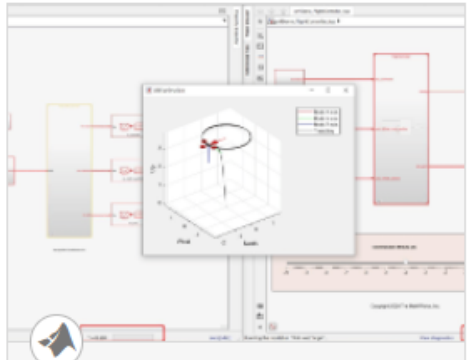
Reduced-order model for UAV

Software-in-the-Loop (SIL)



SIL with PX4 HSP and Simulink Plant



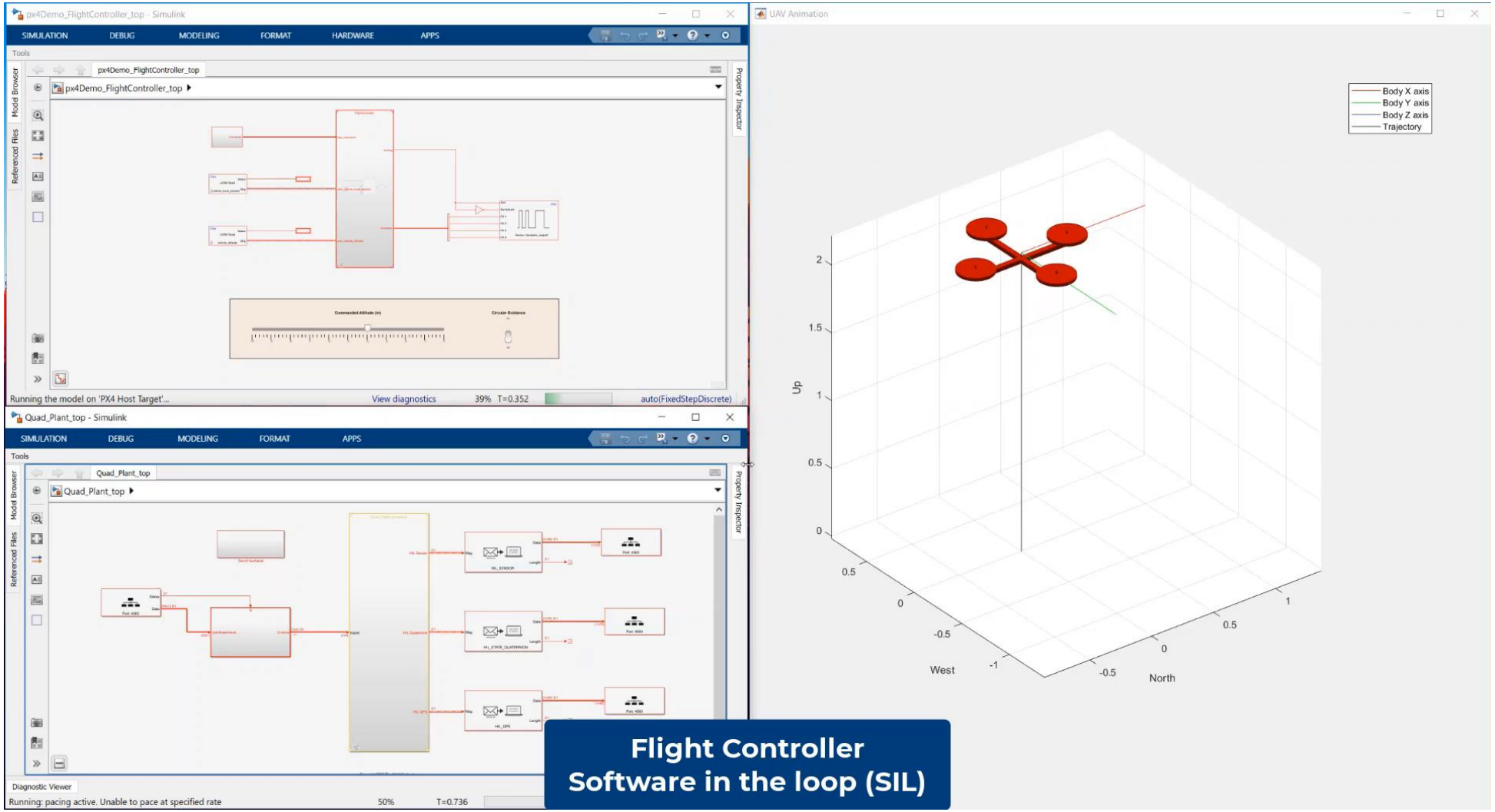


Monitor and Tune PX4 Host Target Flight Controller with Simulink-Based Plant Model

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

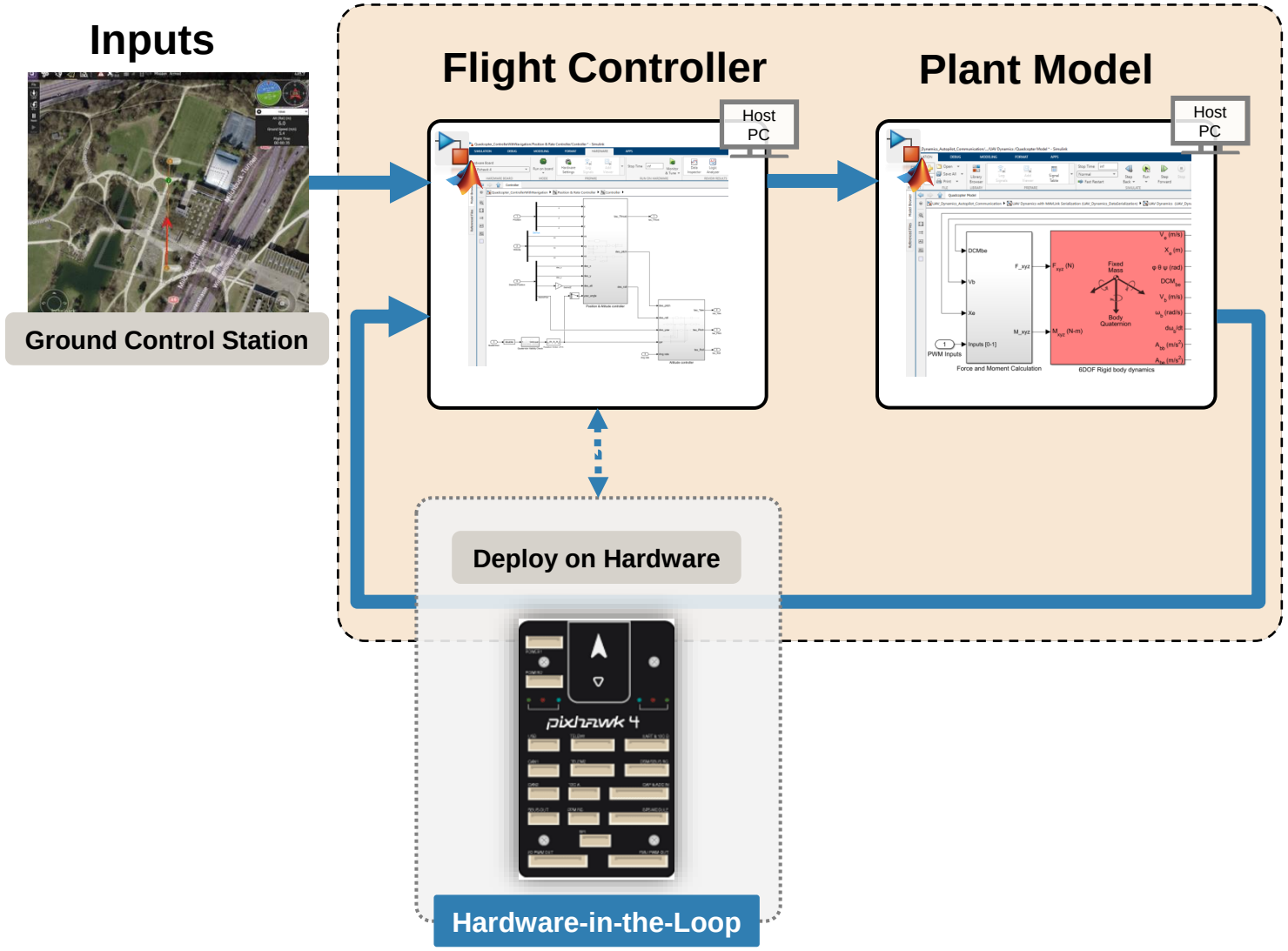
[Shipping example in UAV Toolbox]
(See Task 2 in the example)

SIL with PX4 HSP and Simulink Plant

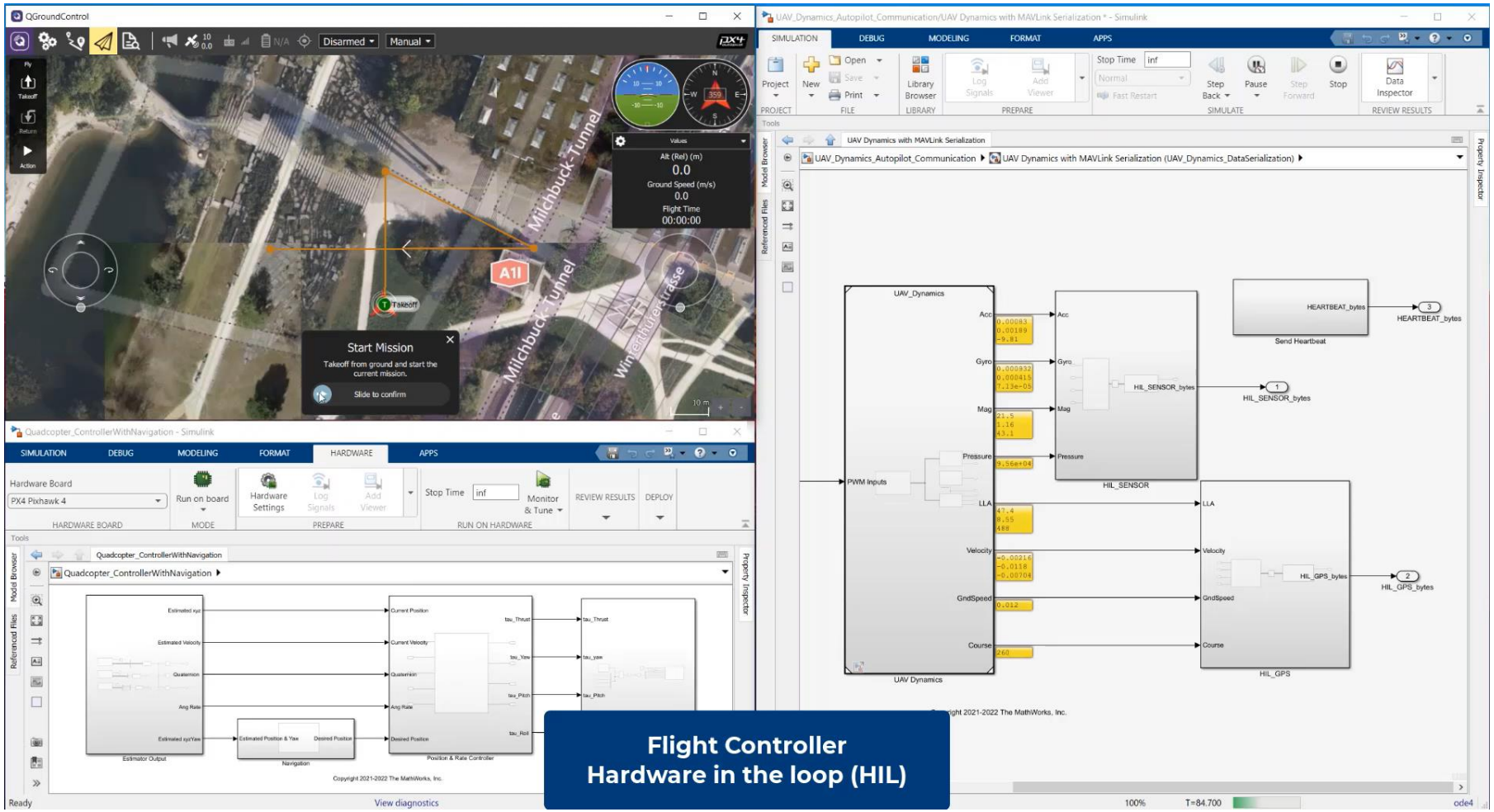


Video included with session content package

Hardware-in-the-Loop (HIL)



HIL with PX4 HSP and Simulink Plant



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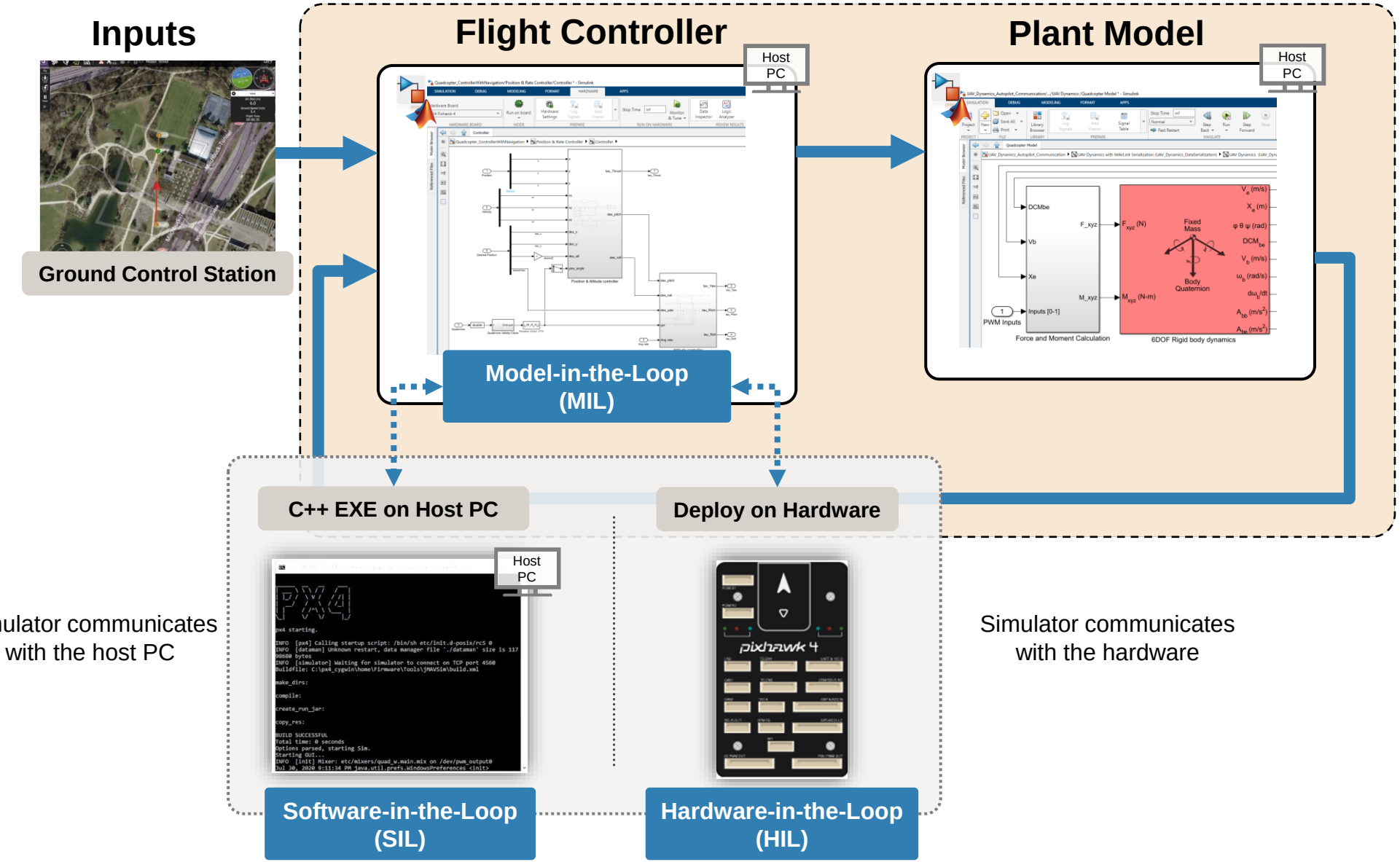
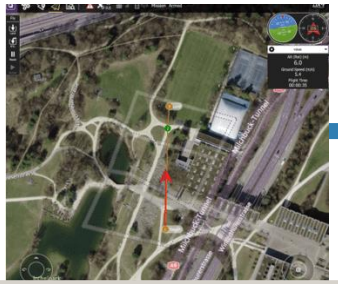
UAV Simulation Workflow with PX4 and Simulink



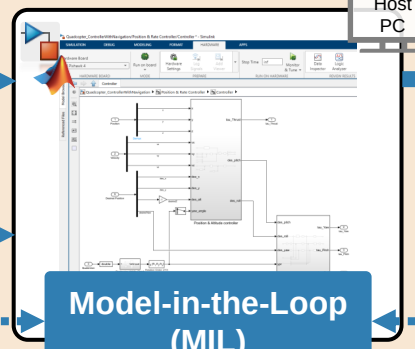
UAV Simulation Workflow with PX4 and Simulink

Inputs



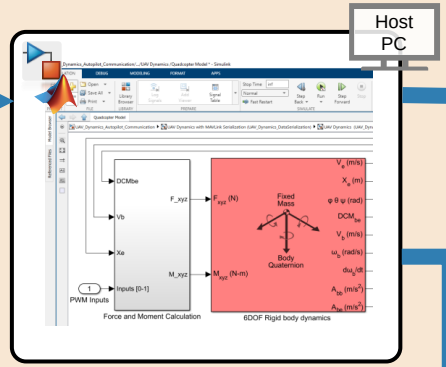
Ground Control Station

Flight Controller

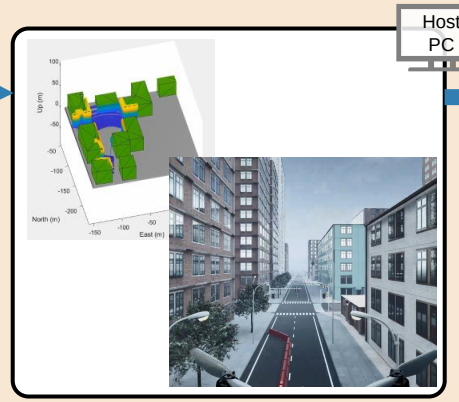


Model-in-the-Loop (MIL)

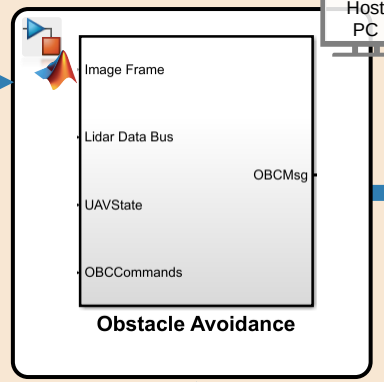
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

C++ EXE on Host PC

Deploy on Hardware

Deploy on Hardware

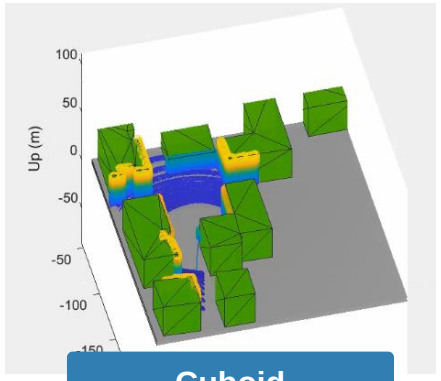
NVIDIA Jetson

Software-in-the-Loop

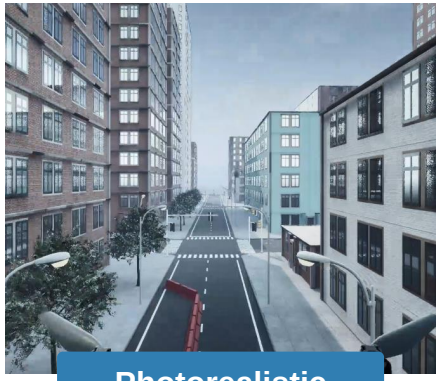
Hardware-in-the-Loop

Closed-loop autonomy simulation

Scenario Simulation



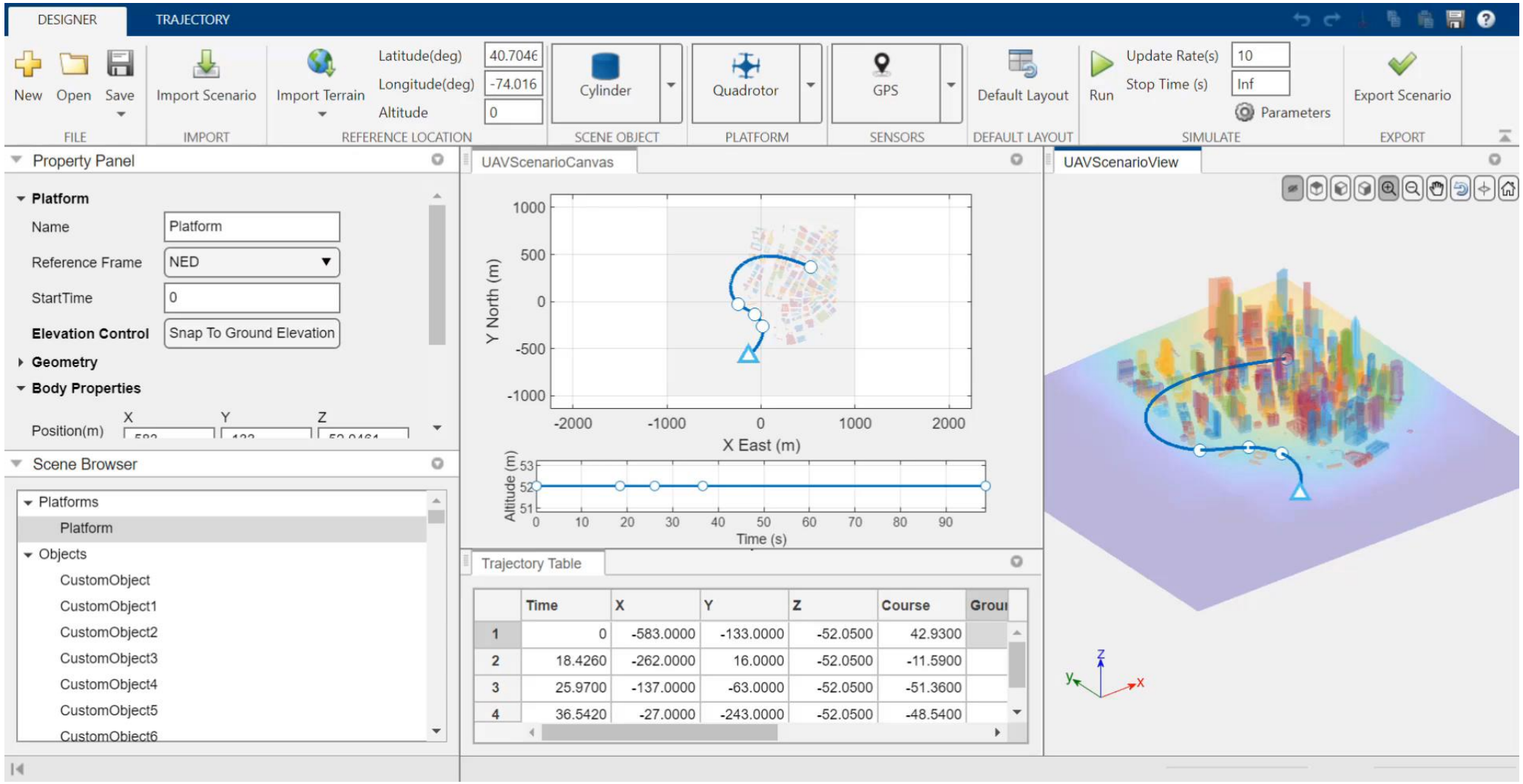
Cuboid Environments



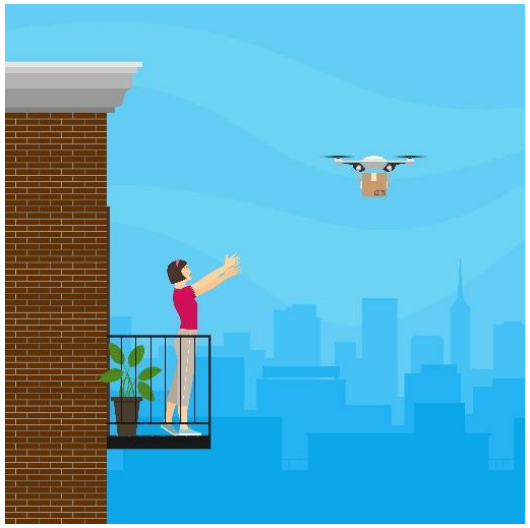
Photorealistic Environments

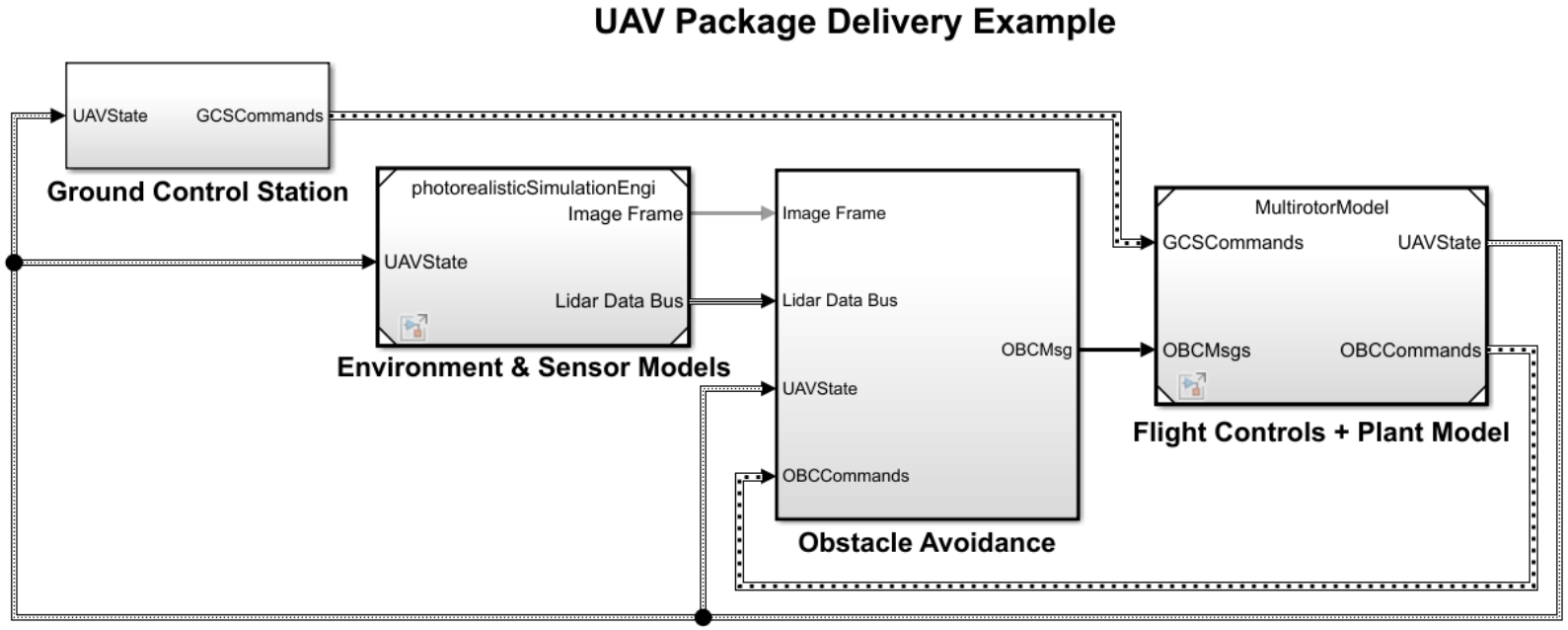
Create environments and simulate sensor readings

UAV Scenario Designer

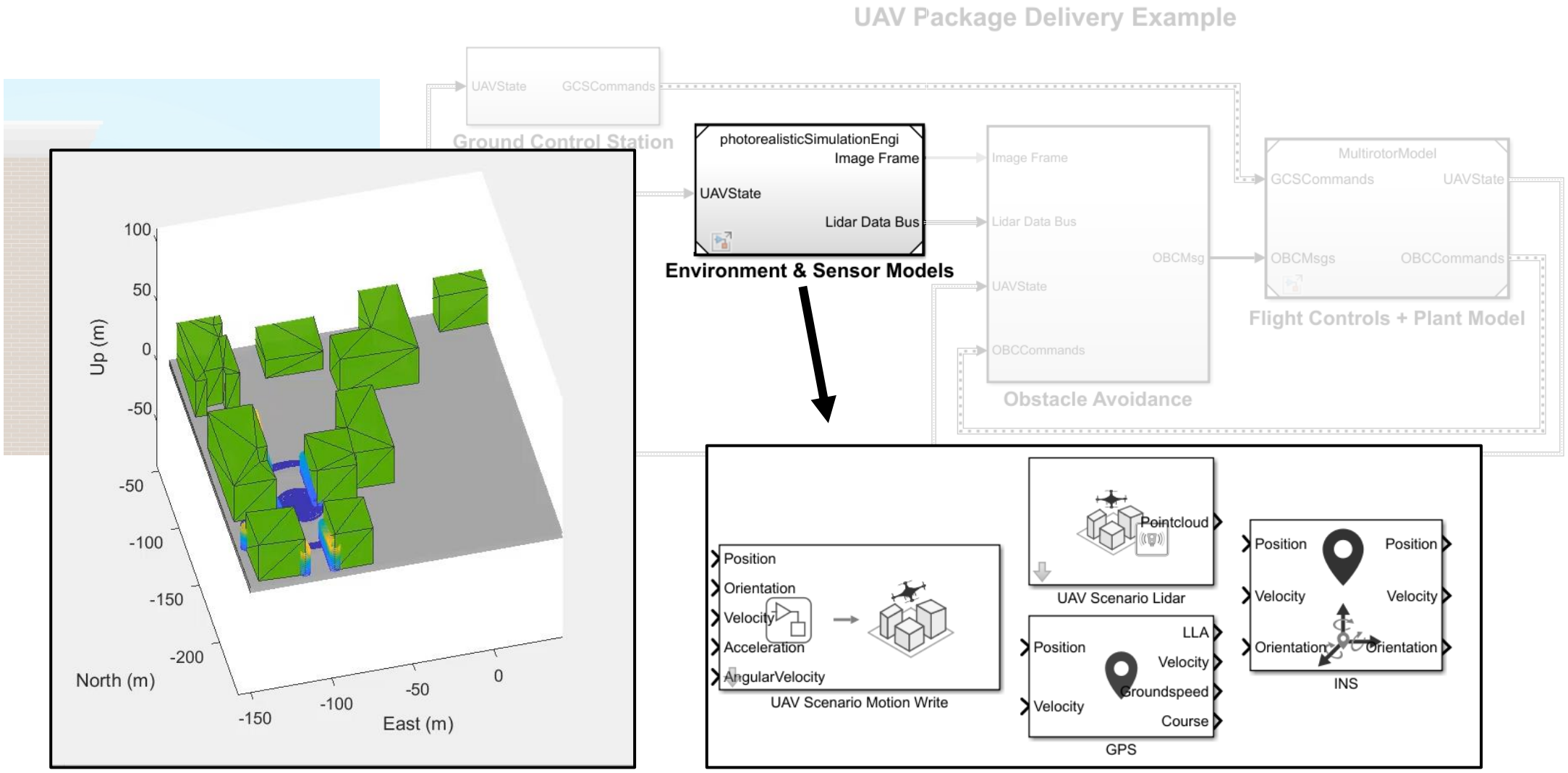


Integrate environments into full-system simulation

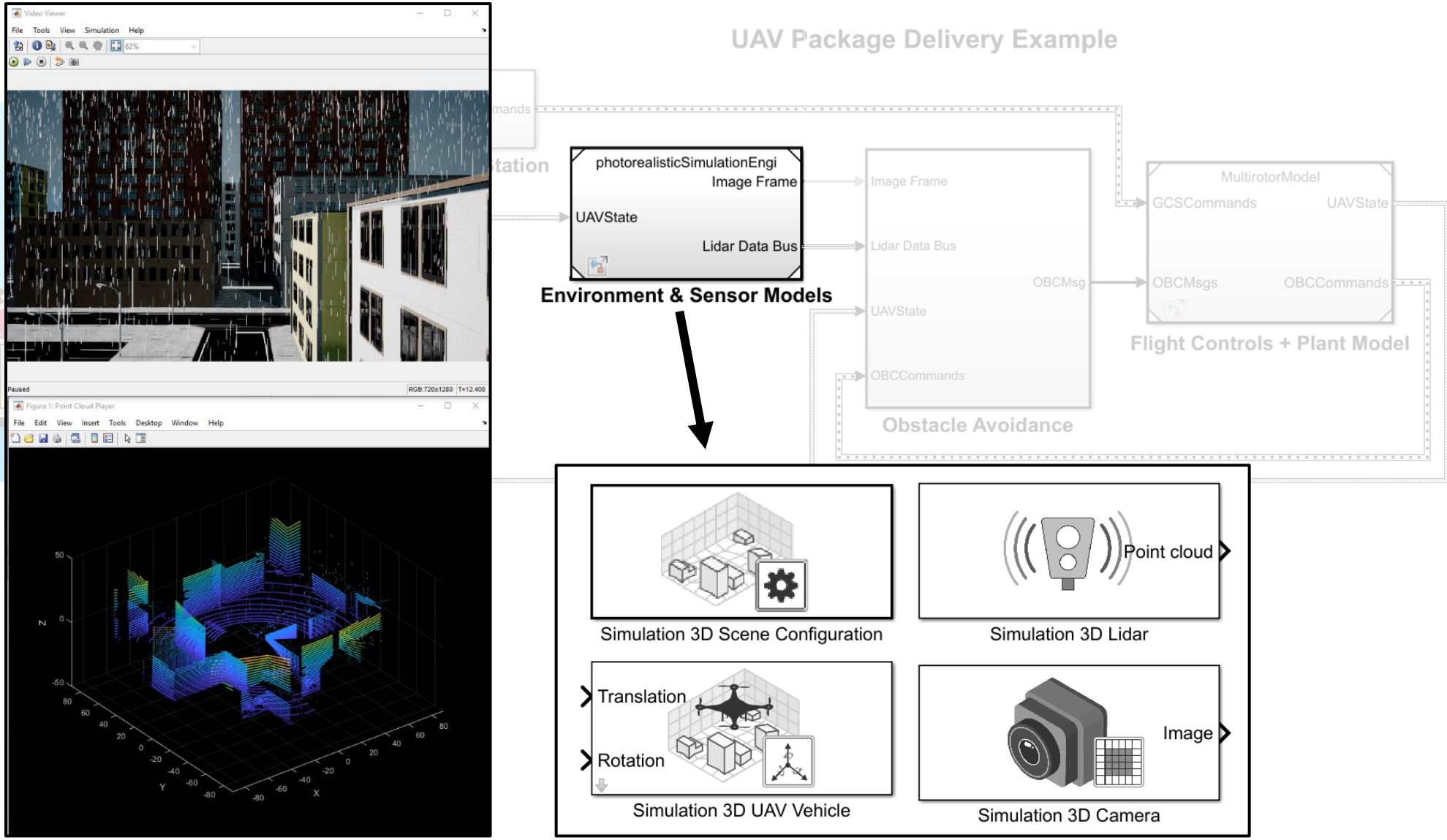




Integrate environments into full-system simulation

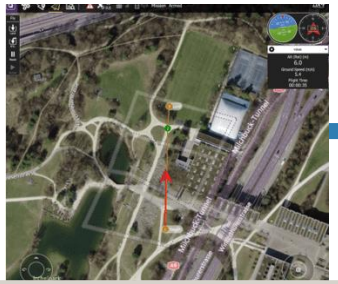


Integrate environments into full-system simulation



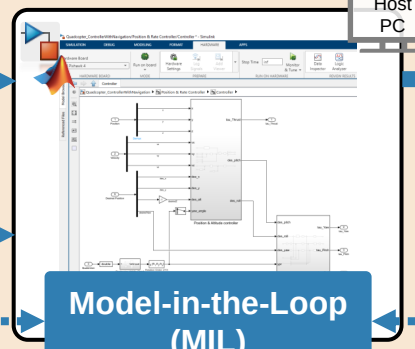
UAV Simulation Workflow with PX4 and Simulink

Inputs



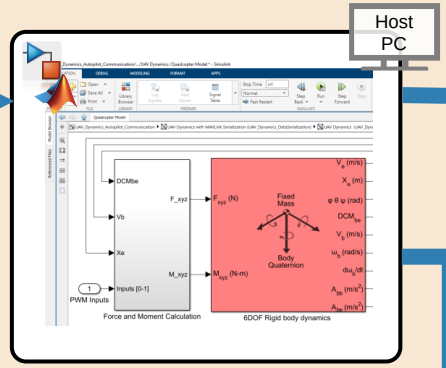
Ground Control Station

Flight Controller

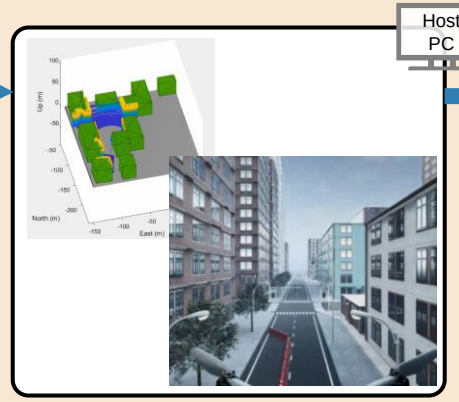


Model-in-the-Loop (MIL)

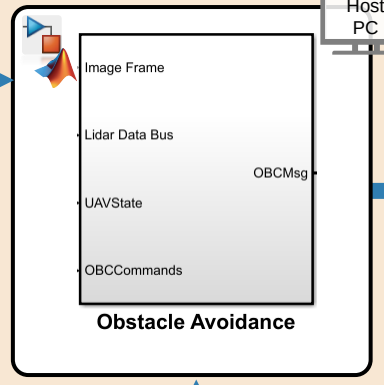
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

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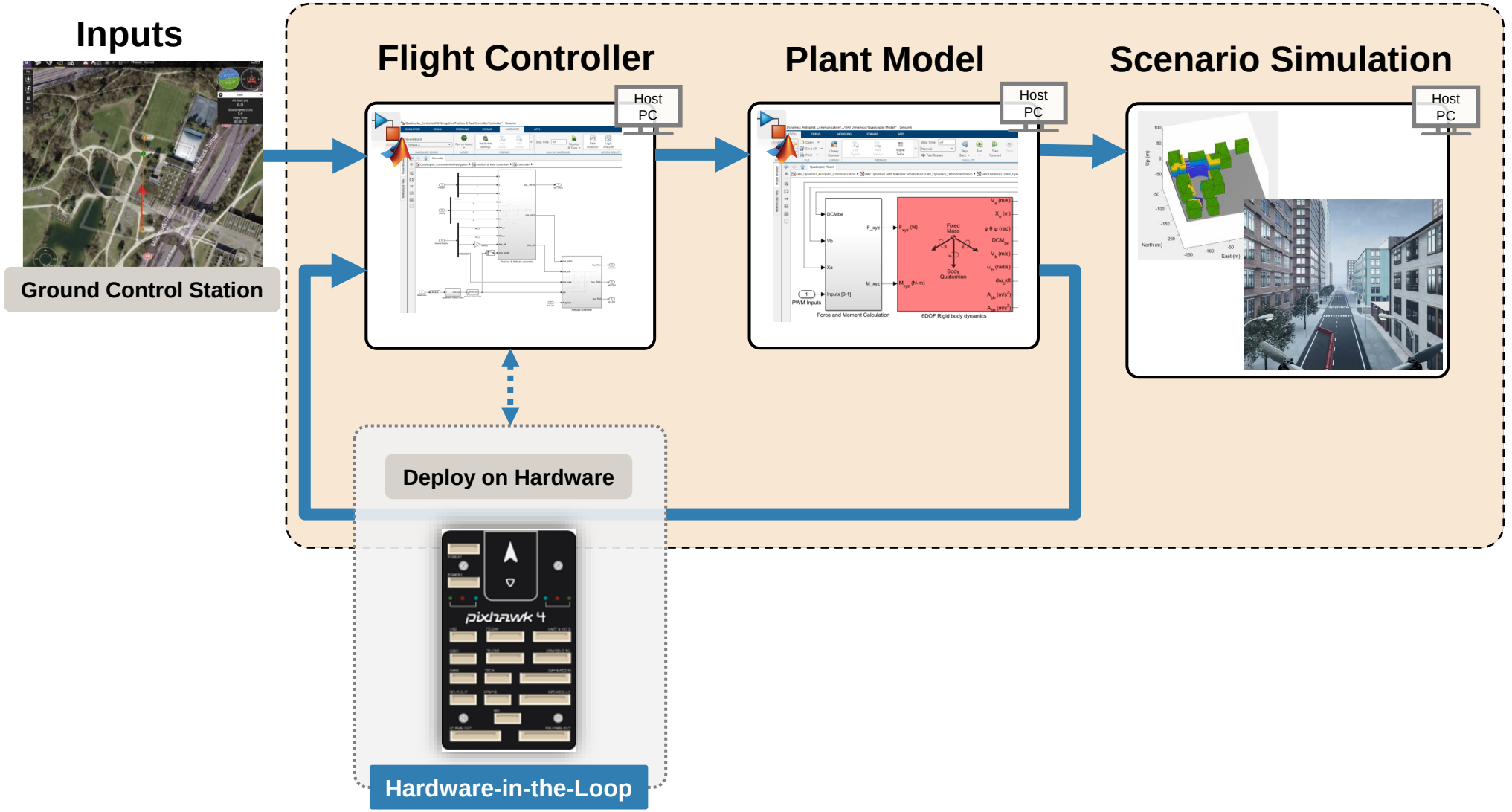
Deploy on Hardware

Software-in-the-Loop

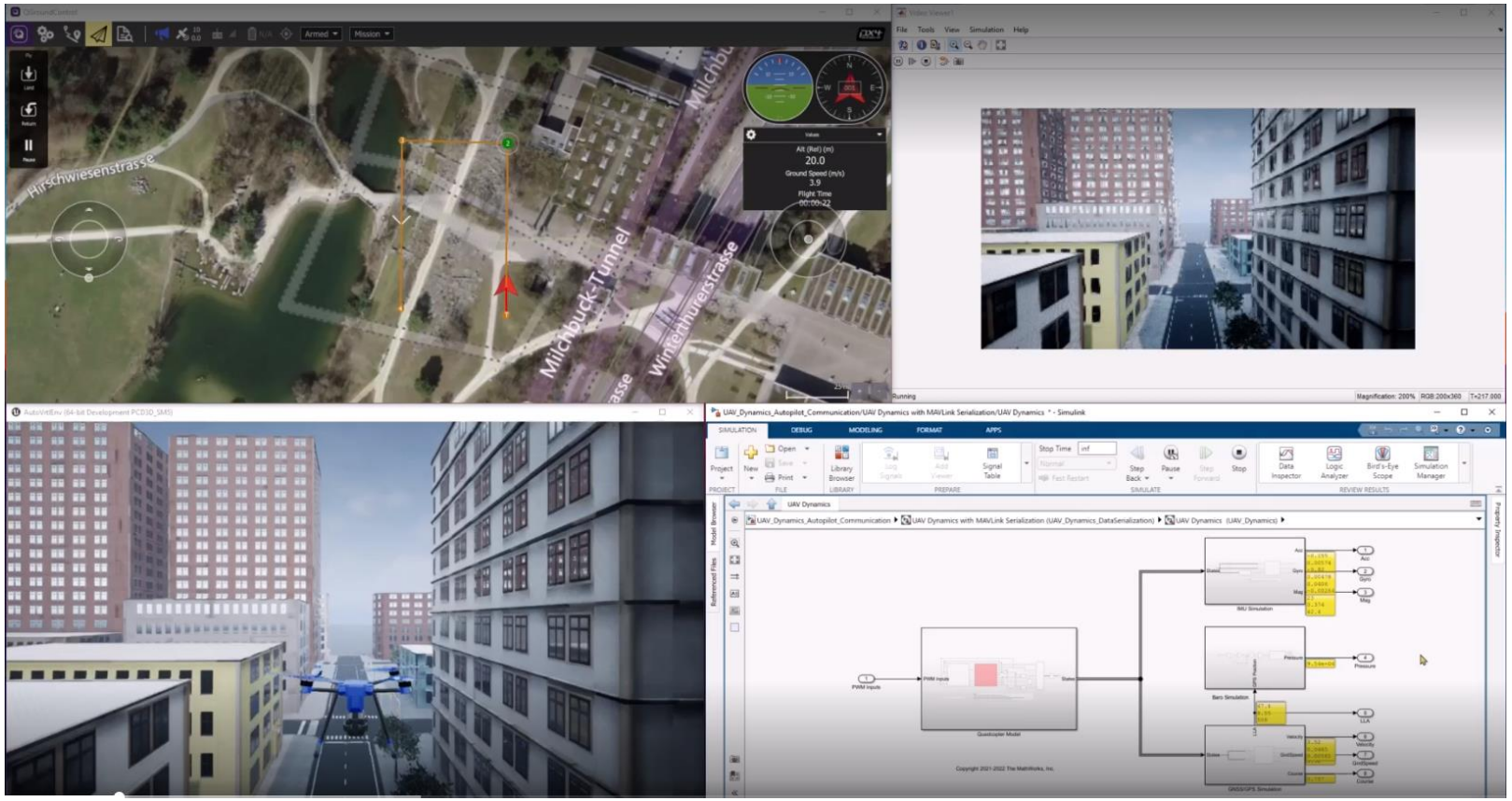
Hardware-in-the-Loop

NVIDIA Jetson

HIL with Scenario Visualization



HIL with Scenario Visualization

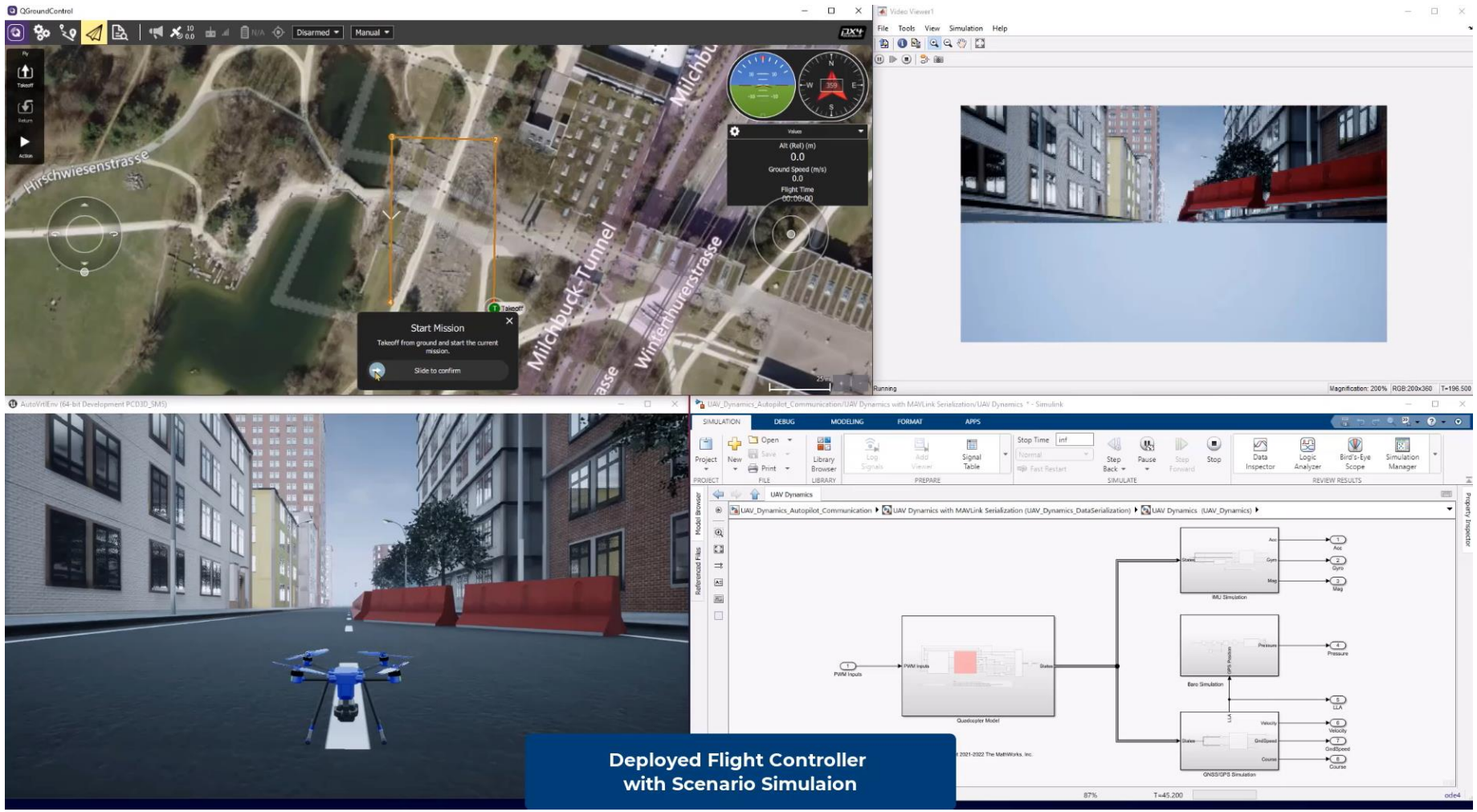


Scenario Simulation and Flight Visualization with PX4 Hardware-in-the-Loop...

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

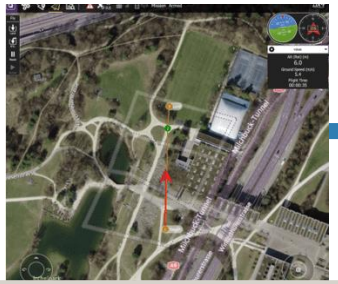
Shipping example in UAV Toolbox

HIL with Scenario Visualization



UAV Simulation Workflow with PX4 and Simulink

Inputs



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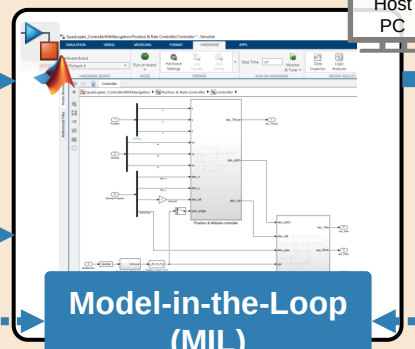
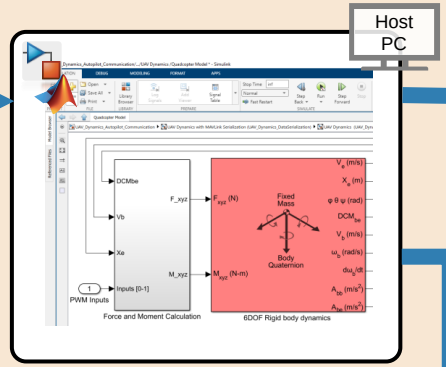
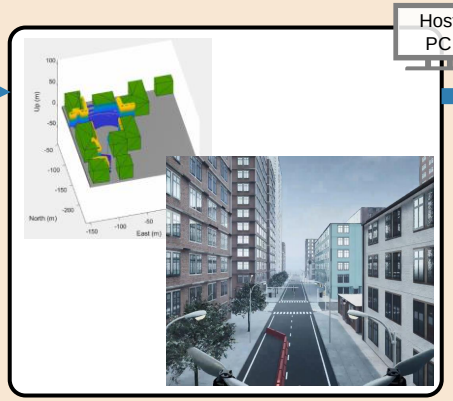


Model-in-the-Loop (MIL)

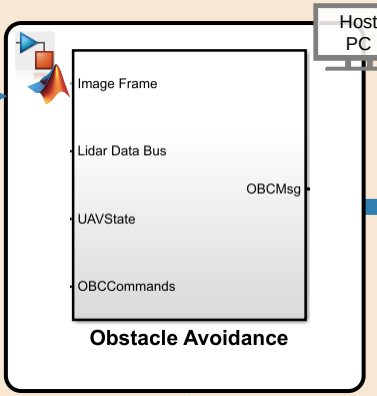
Plant Model



Scenario Simulation



Onboard Autonomy



Obstacle Avoidance

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Deploy on Hardware

Software-in-the-Loop

Hardware-in-the-Loop

NVIDIA Jetson

Shipping example in UAV Toolbox

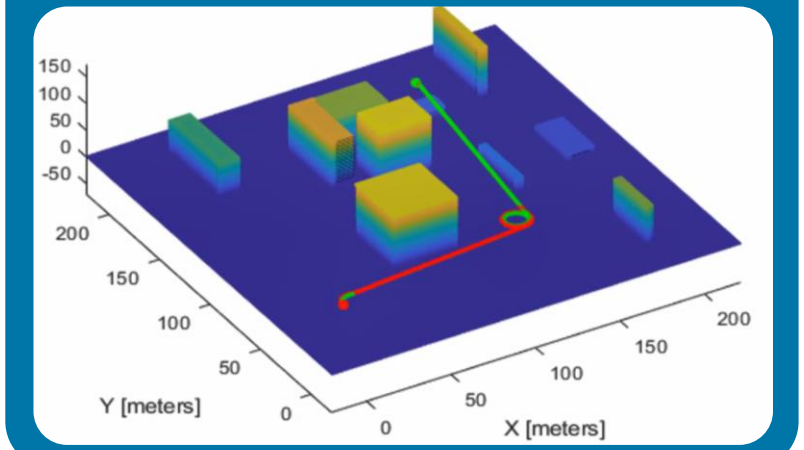
Simulate and Deploy UAV Applications with SIL and HIL Workflows

- 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

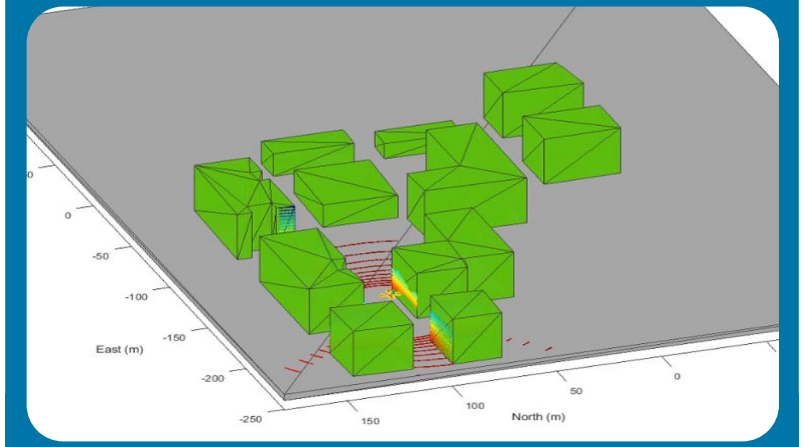
Relevant MATLAB EXPO Workshop

UAV Toolbox

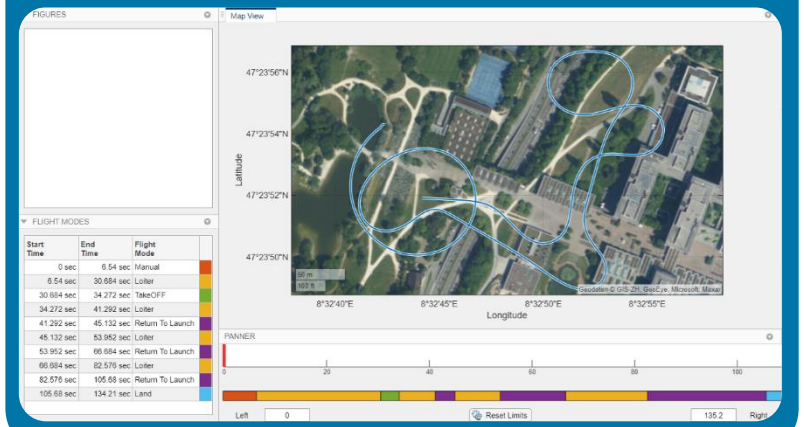
UAV Algorithms for Planning and Control



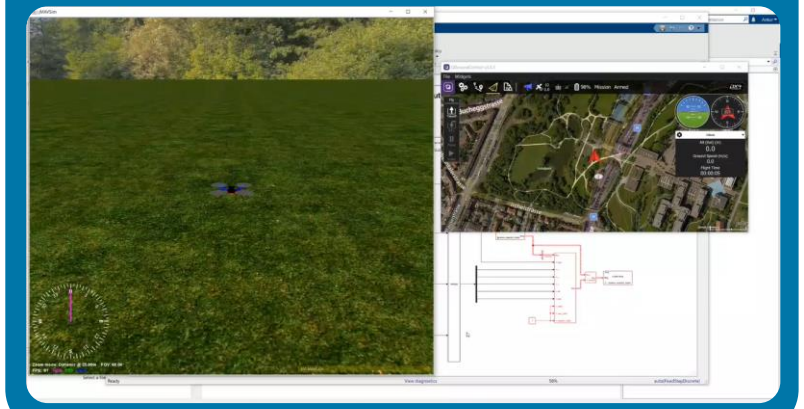
Scenario Design & Low-Fidelity Sensor Simulation



Flight Telemetry Data Analysis Flight Log Analyzer App

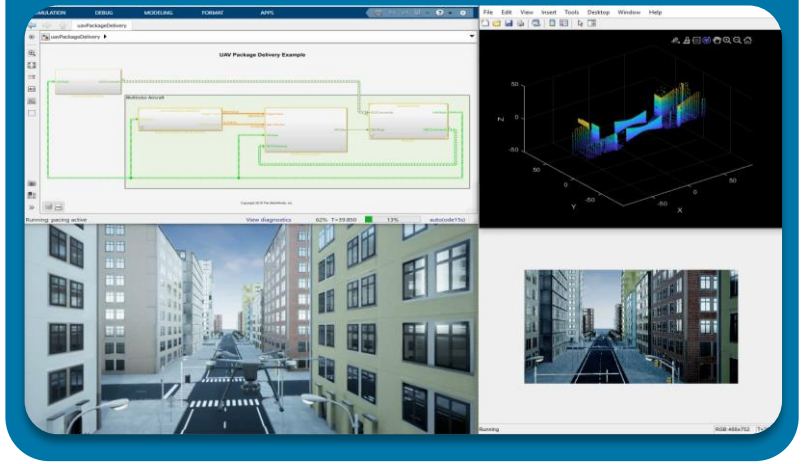


Connectivity and Deployment with MAVLink and PX4



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

Mihir Acharya, MathWorks

https://www.linkedin.com/in/amihir/

Ronal George, MathWorks

https://www.linkedin.com/in/ronalgeorge/

Julia Antoniou, MathWorks

https://www.linkedin.com/in/julia-antoniou/

MATLAB EXPO

Thank you

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