MATLAB EXPO 2021

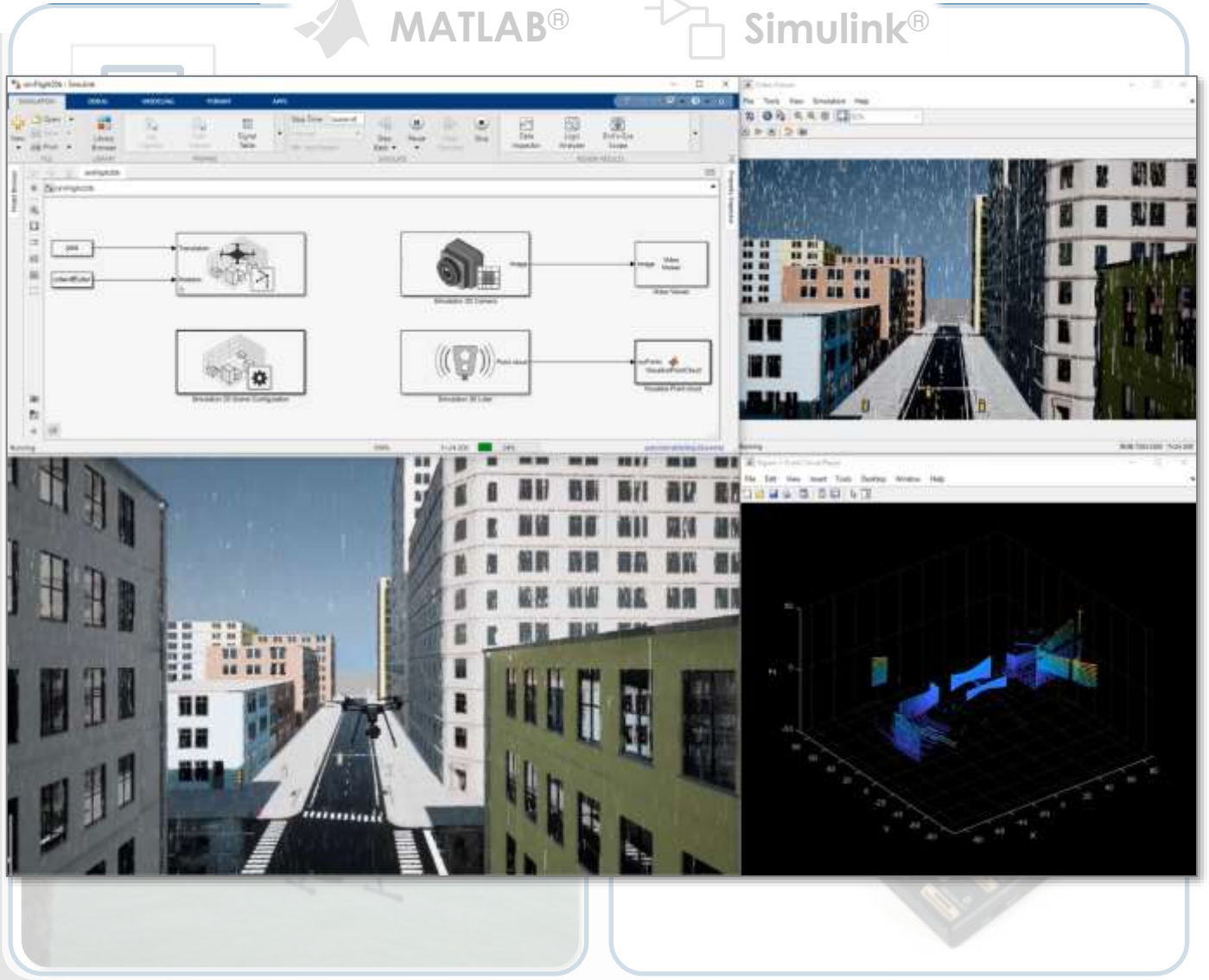
MATLAB과 Simulink를 이용한 자율 무인항공기(UAV) 개발 및 검증

김종헌

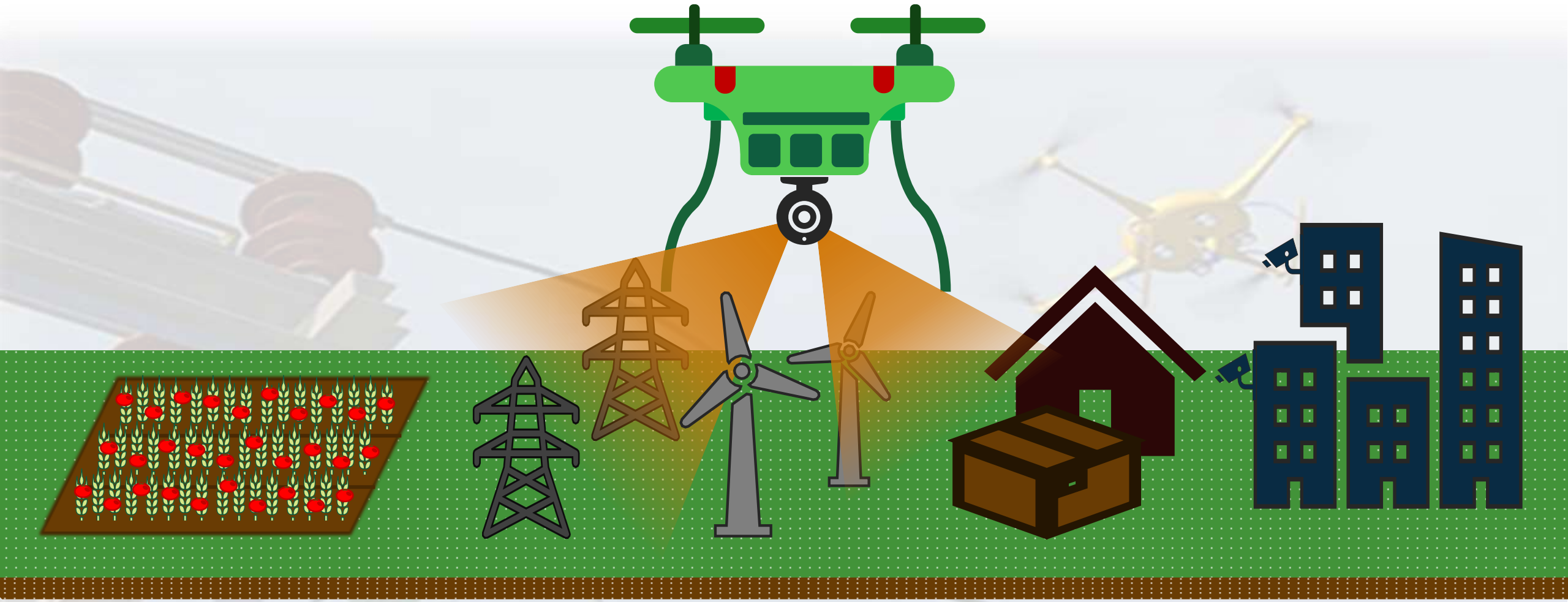
MathWorks

Autonomous UAV Development and Evaluation

- Integrated workflows enabled by MATLAB and Simulink
- Tools to design UAV systems and autonomous applications
- Select appropriate methods for your UAV development tasks
- Evaluating systems through closed-loop simulations with sensor models



Increase in Autonomous UAV Usage



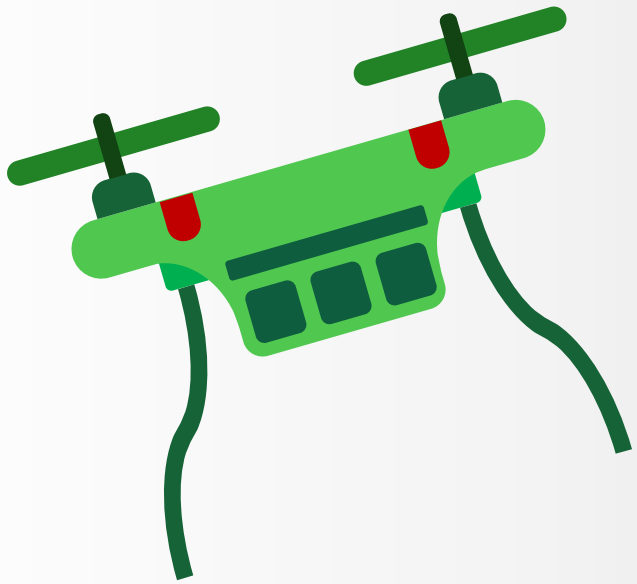
Mapping & Surveying

Inspections & Monitoring

Delivery & Transport

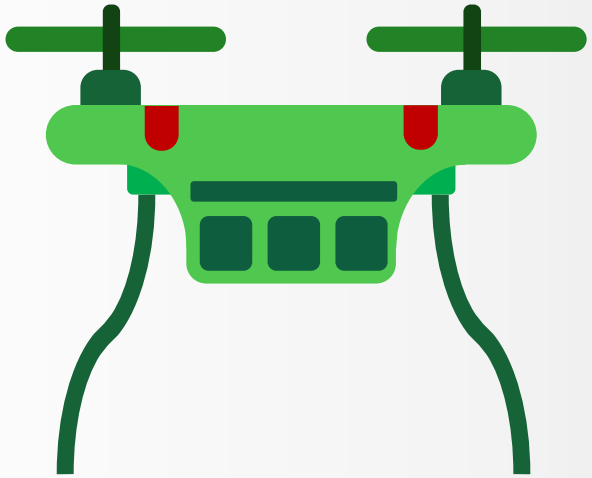
Security & Defense

Challenges in Developing Autonomous UAV Systems & Applications



- Complexity of advanced autonomous algorithms
- Need of end-to-end workflows
- Ensuring system quality and reducing flight risk

Solutions for Developing Autonomous UAV Systems & Applications

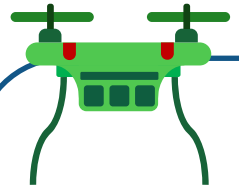


Robust tools and features for designing and testing UAV systems and algorithms

Integrated development environment that covers development from ideas to production

Extensive verification and validation tools to evaluate design quality through virtual testing

Integrated Workflows for Developing UAV Applications

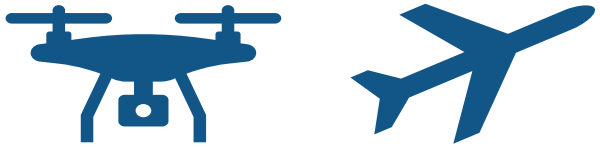


MATLAB®

Simulink®

System Architecture

Model UAV



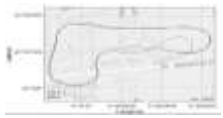
Design Algorithms

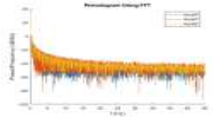
Perception

Planning & Decision

Control

Analyze Data





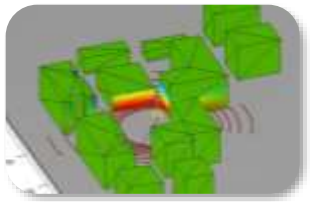
Verification & Validation

DO-178

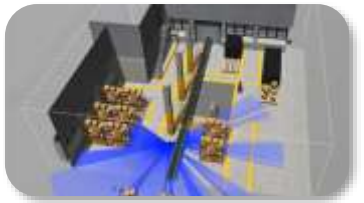
Implement

Connect

Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

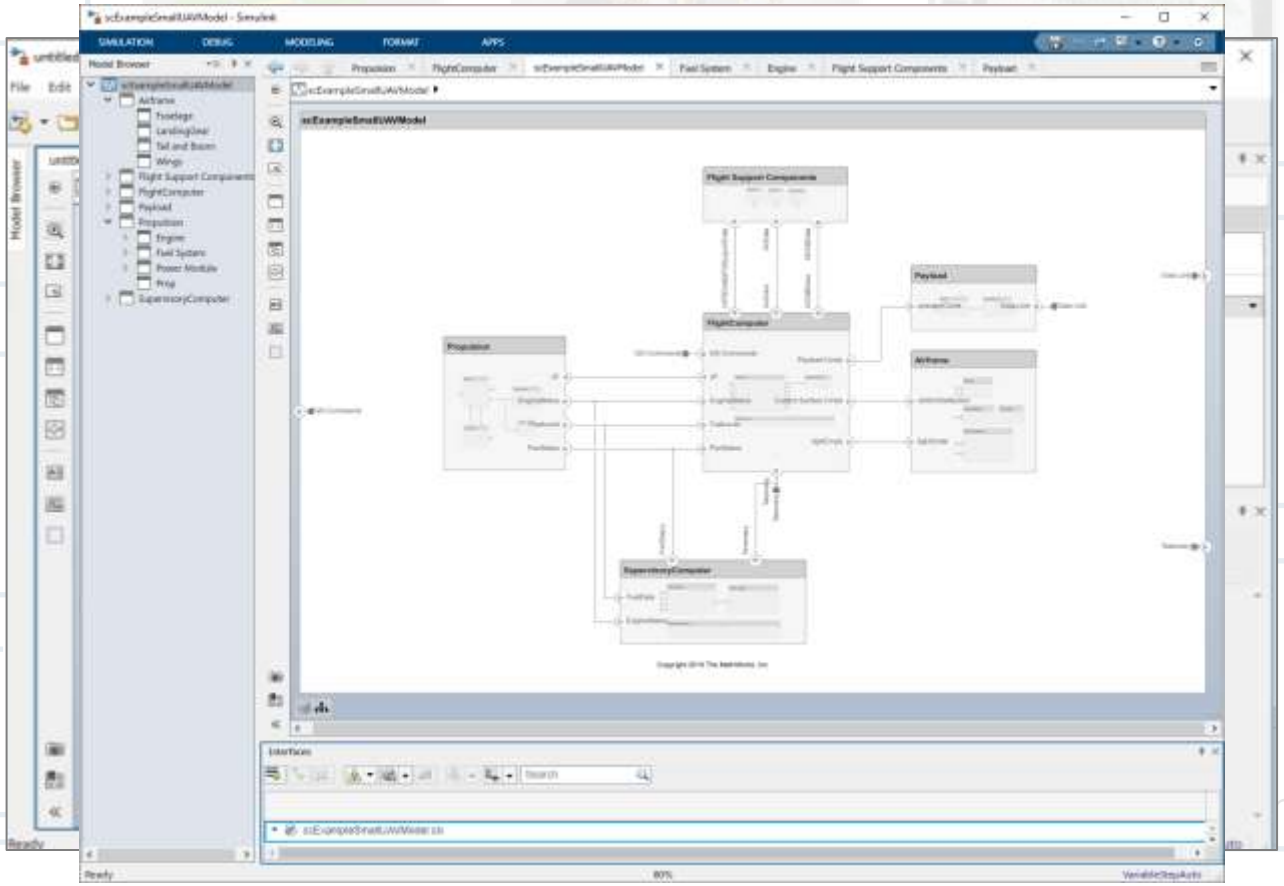
UAV

Ground Control Station

System Architecture

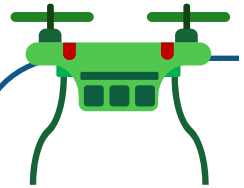
System Architecture

- System Composer™ for designing and analyzing system and software architecture
- Simulink integration and requirement allocation for traceability



Link

Integrated Workflows for Developing UAV Applications



MATLAB®

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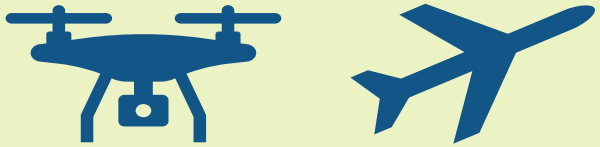
System Architecture

Model UAV



Verification & Validation

DO-178

Design Algorithms

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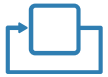
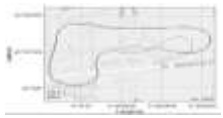
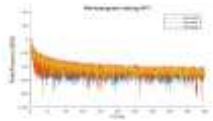


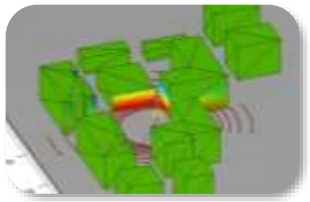
Control

Analyze Data





Simulate with Sensor Models



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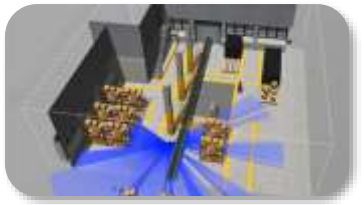

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Connect

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Ground Control Station

UAV Plant Modeling: Selecting the Appropriate Fidelity

High-Fidelity
Building UAV

Approximate
Programming UAV

- More Detailed

- Slow
- Modeling effort

Worst-case test

- Fast
- Easy to model

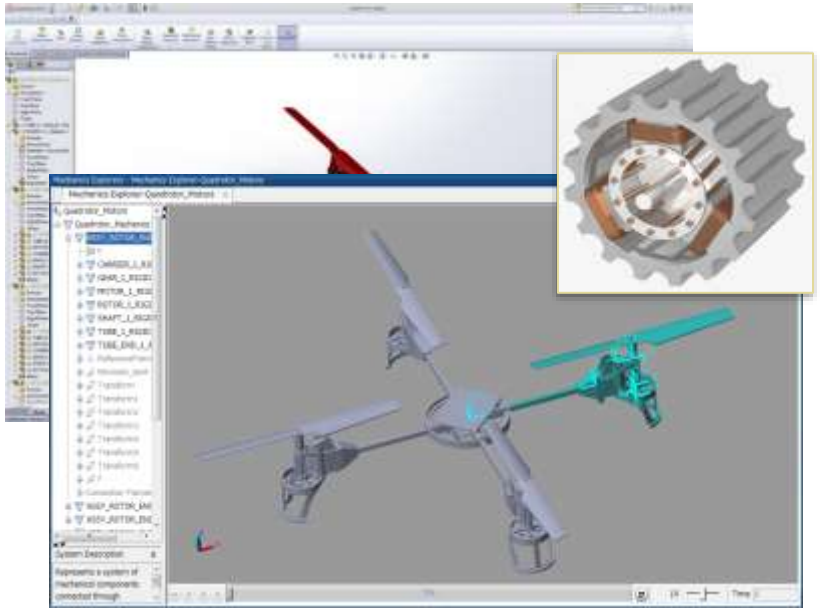
- Less detailed

Navigation algorithm test

UAV Plant Modeling: Selecting the Appropriate Fidelity

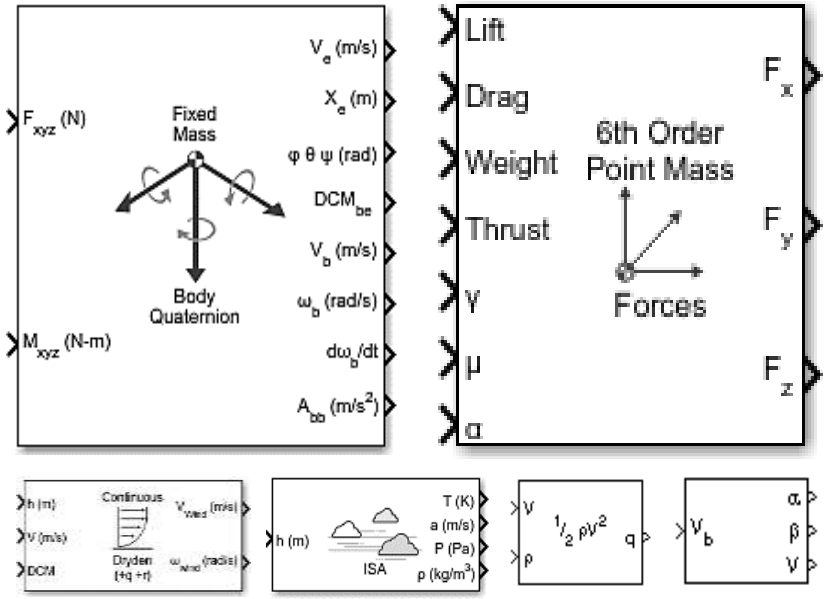
High-Fidelity
Building UAV

Approximate
Programming UAV



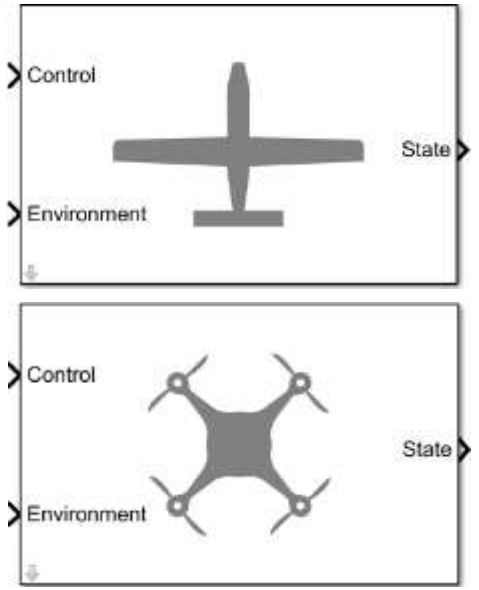
Physical Modeling

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



Vehicle Dynamics

Model aerodynamics, propulsion, and motion of aircraft and spacecraft

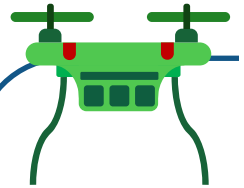


Guidance Model

Reduced-order model for UAV

Simscape Multibody, Aerospace Blockset, UAV Toolbox

Integrated Workflows for Developing UAV Applications



MATLAB®

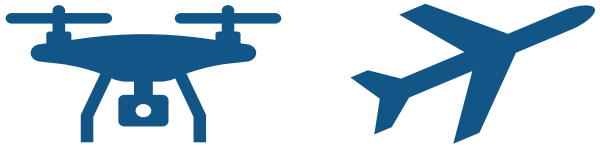
Simulink®

System Architecture

Verification & Validation

DO-178

Model UAV



Design Algorithms

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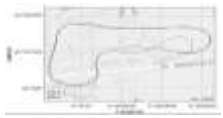
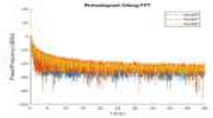
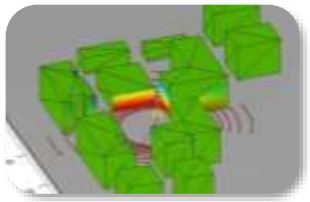




Simulate with Sensor Models



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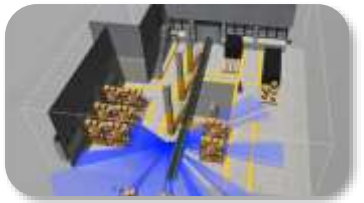

Gazebo

Unreal Engine

Implement

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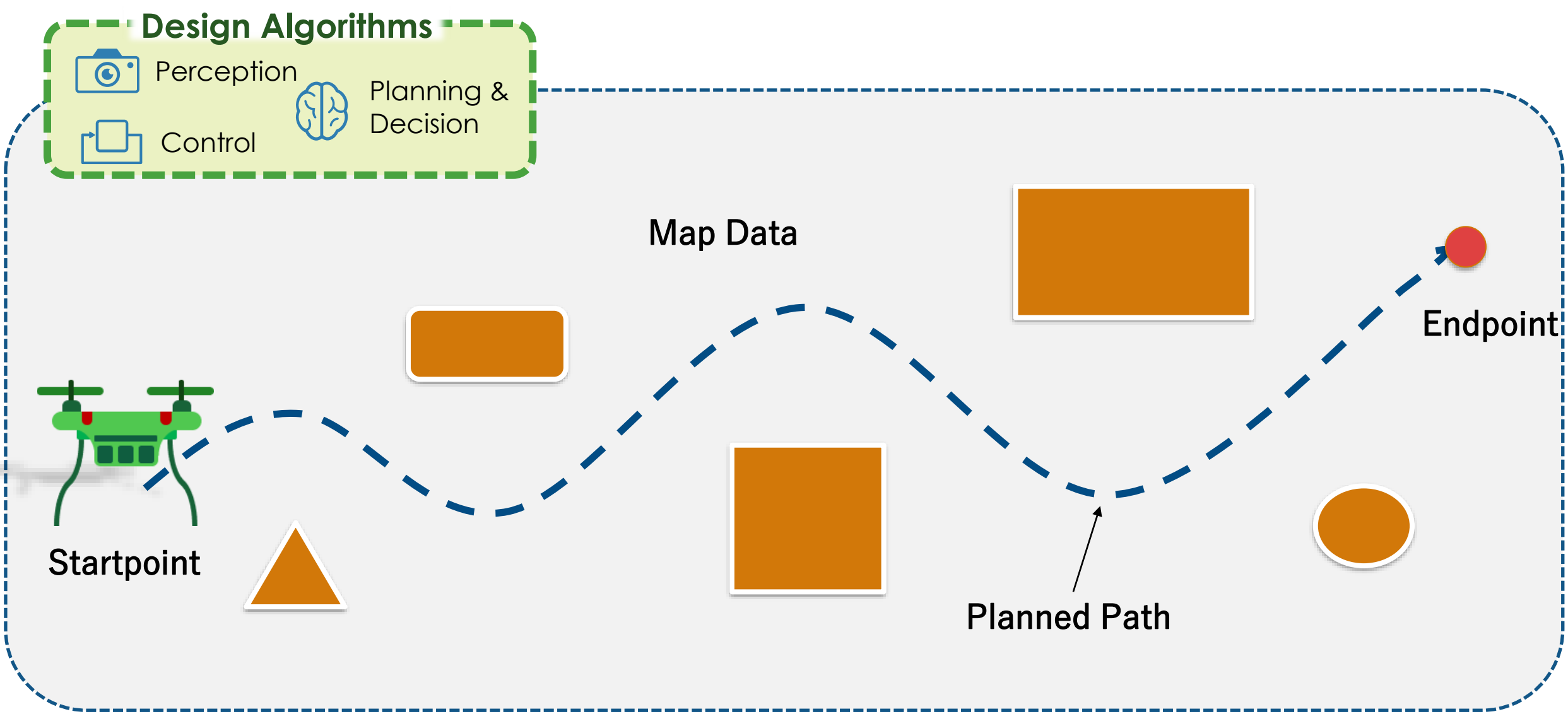
Autonomous UAV Algorithm Development

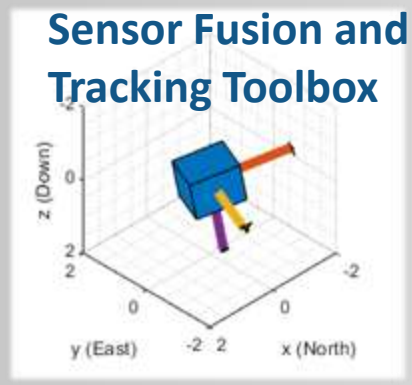


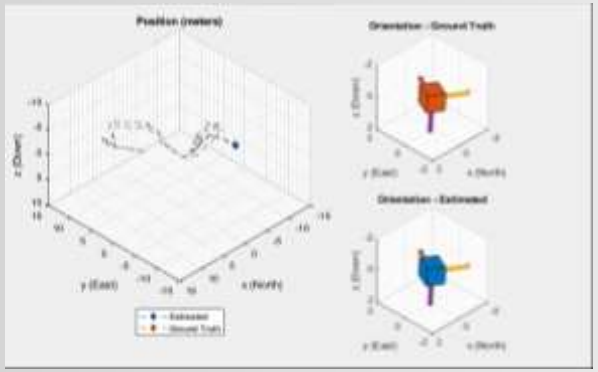
Autonomous UAV Algorithm Design with Robust Capabilities

Perception | Planning & Decision | Control

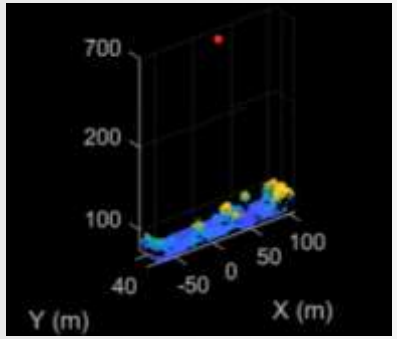
Self Awareness

Sensor Fusion and Tracking Toolbox

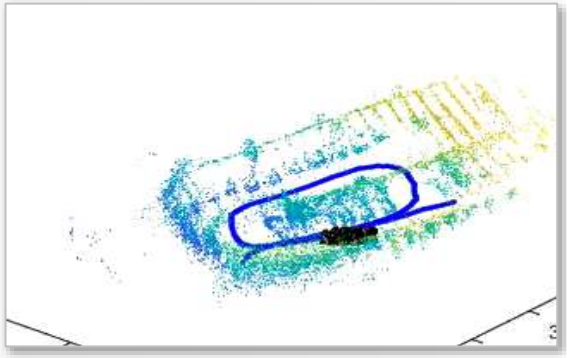




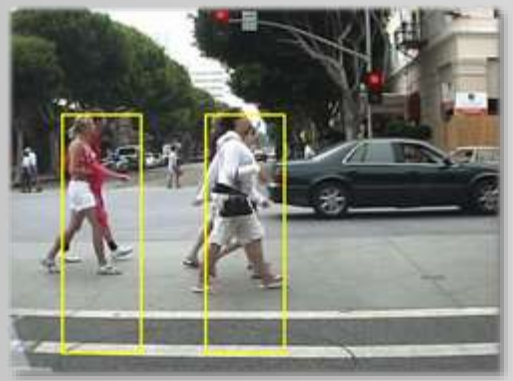
Computer Vision Toolbox
LIDAR Toolbox

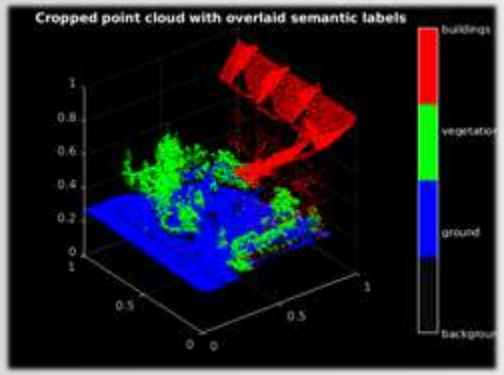


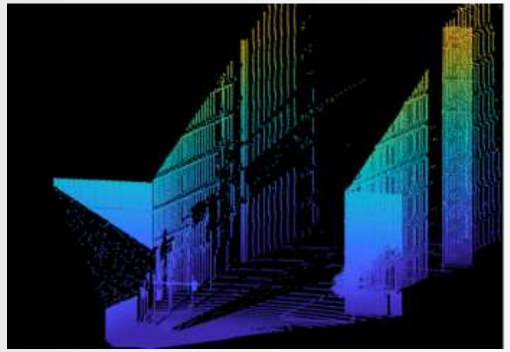
Navigation Toolbox

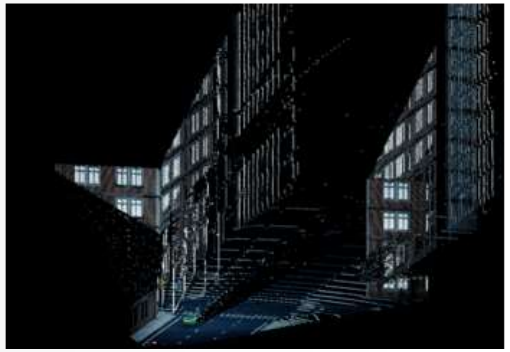


Situational Awareness









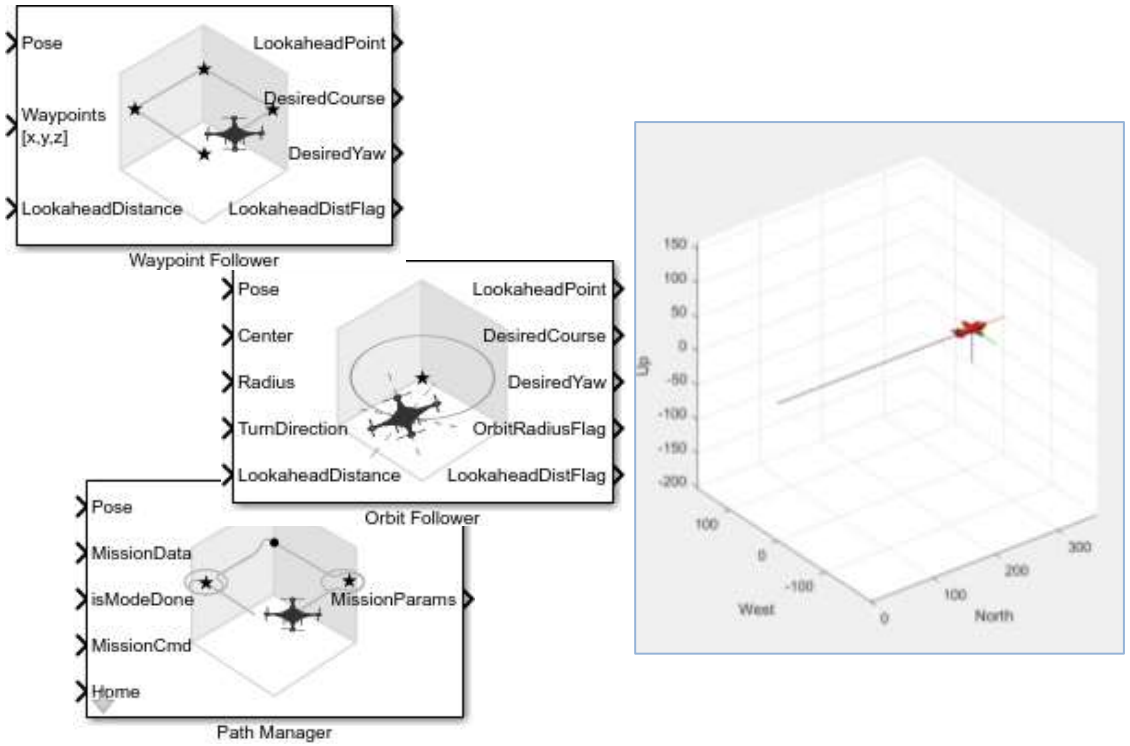
Sensor Fusion and Tracking Toolbox, Lidar Toolbox, Navigation Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

Autonomous UAV Algorithm Design with Robust Capabilities

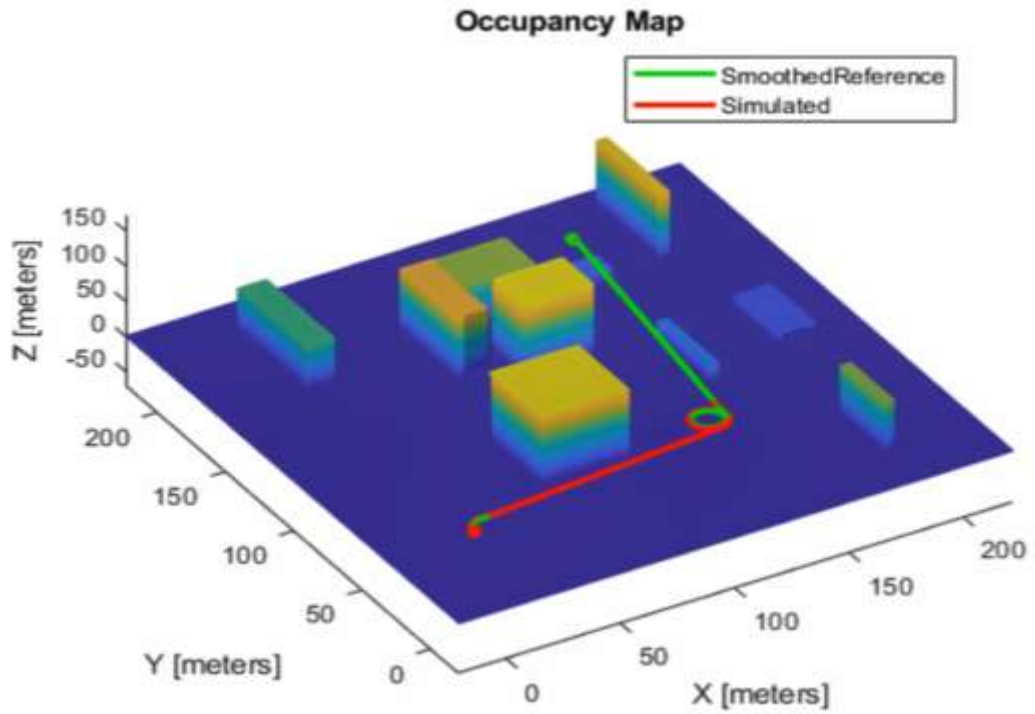
Perception

Planning & Decision

Control



Define UAV missions with waypoint and trajectory-following algorithms



UAV motion planning with advanced path planners

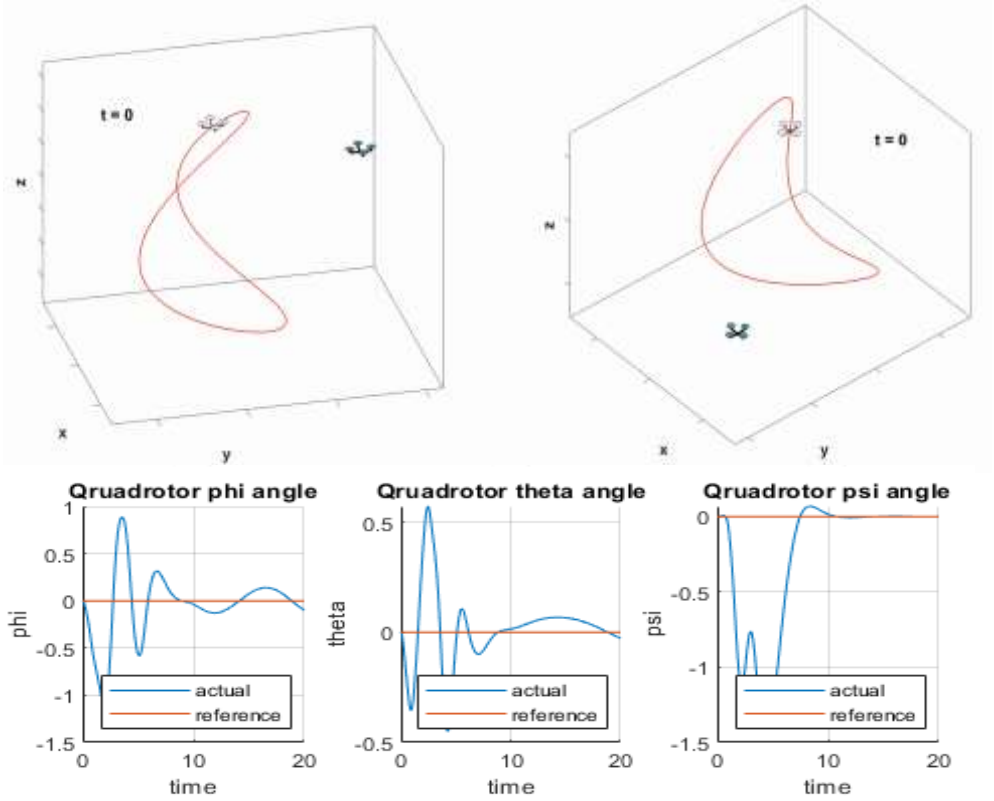
UAV Toolbox, Navigation Toolbox

Autonomous UAV Algorithm Design with Robust Capabilities

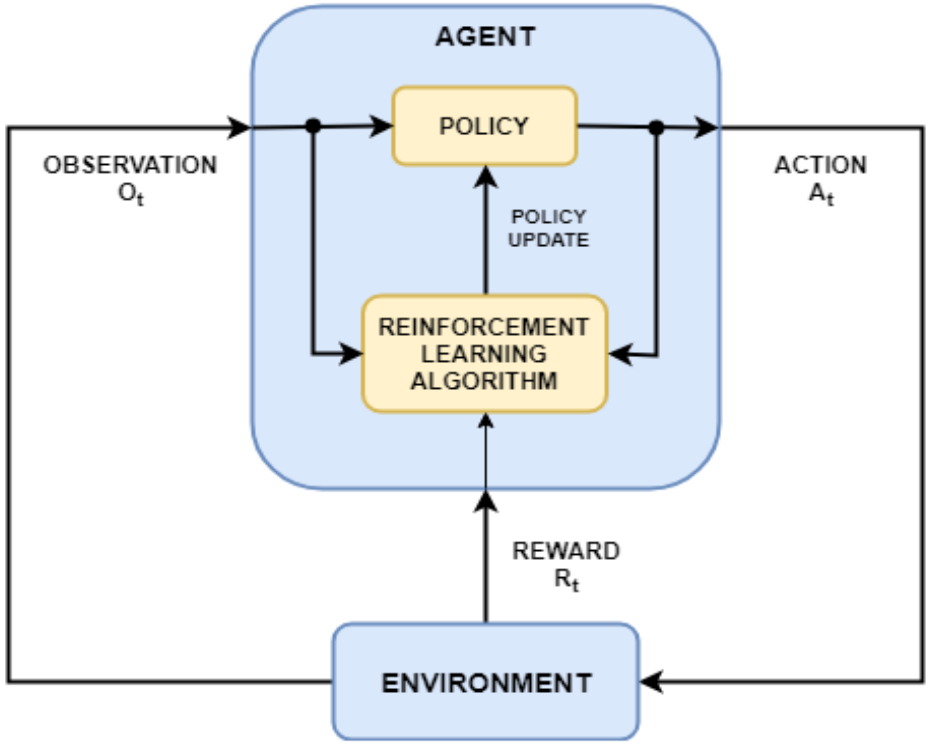
Perception

Planning & Decision

Control



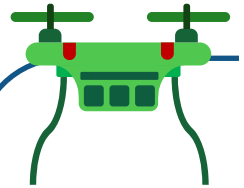
Trajectory tracking controller with nonlinear model predictive control (MPC)



Train policies for trajectory generation using reinforcement learning algorithms

Model Predictive Control Toolbox, Reinforcement Learning Toolbox

Integrated Workflows for Developing UAV Applications



MATLAB®

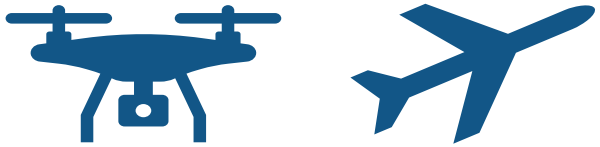
Simulink®

System Architecture

Verification & Validation

DO-178

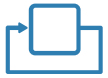
Model UAV



Design Algorithms

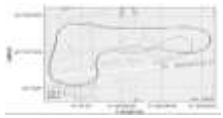
Perception

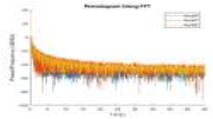
Planning & Decision



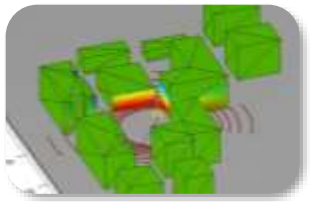
Control

Analyze Data





Simulate with Sensor Models



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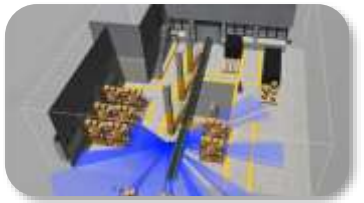

Gazebo

Unreal Engine

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Connect

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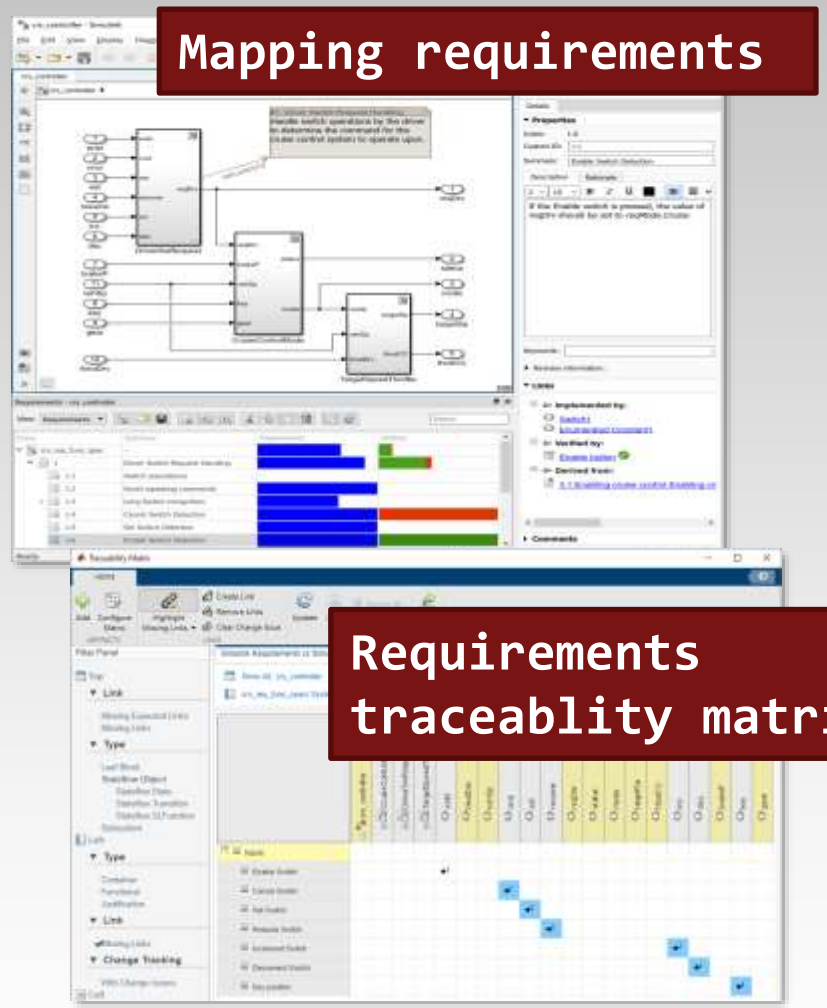
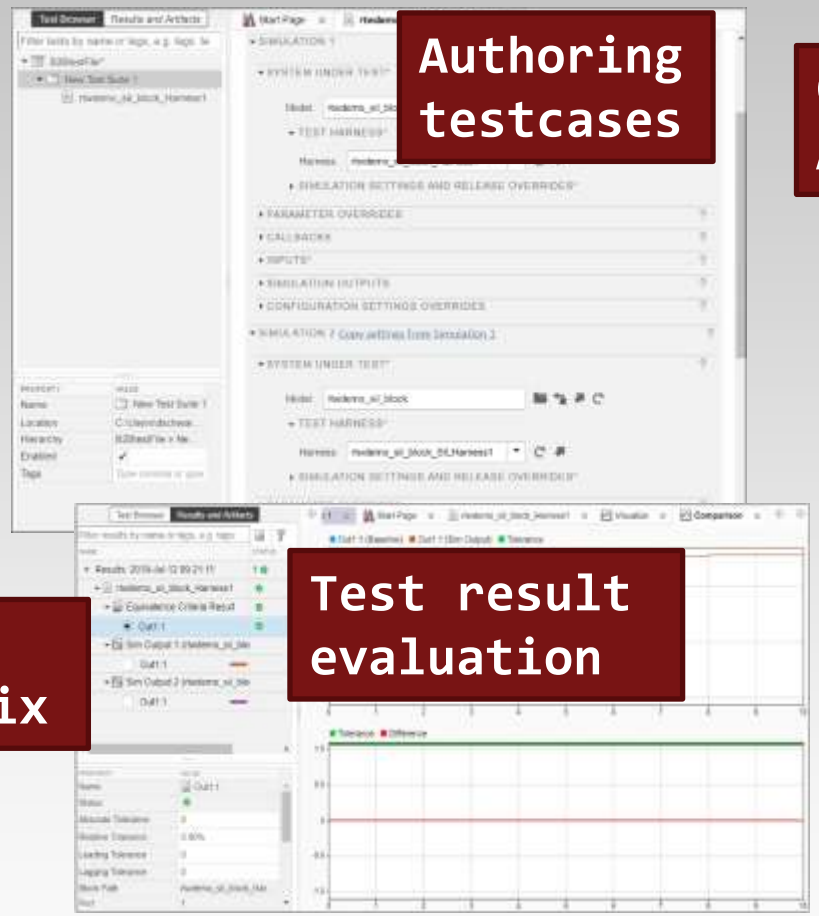
Tracking and Automating Verification and Validation Activities

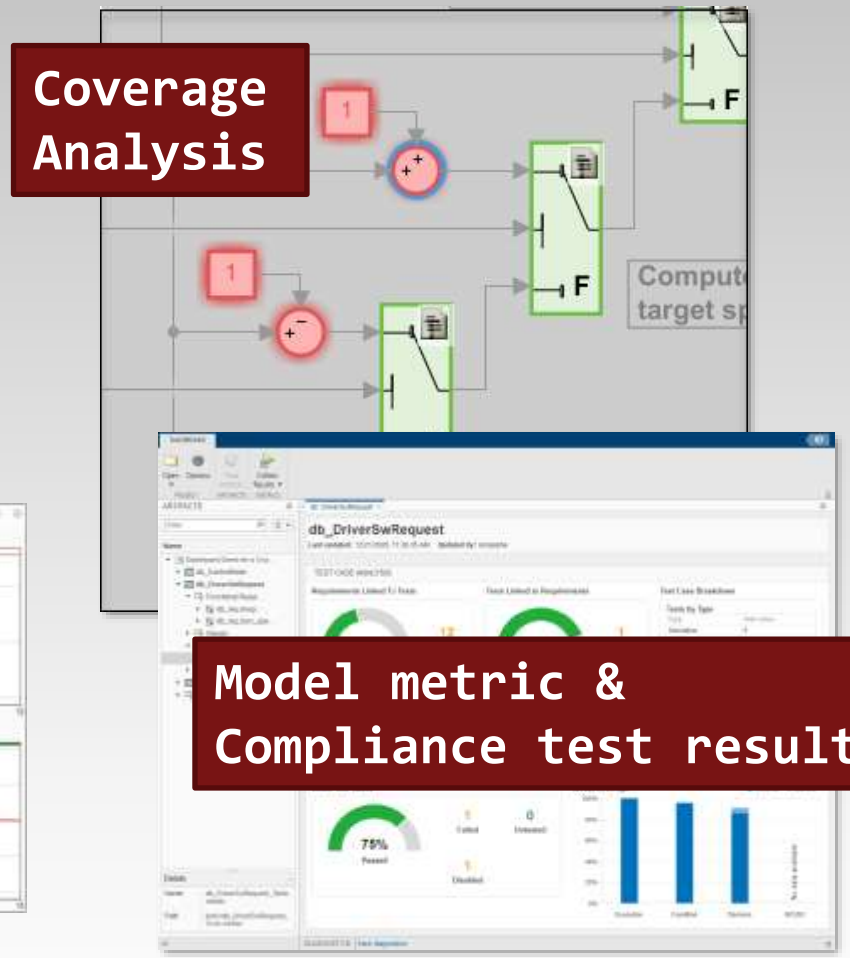
Requirements Traceability



Test Management & Automation

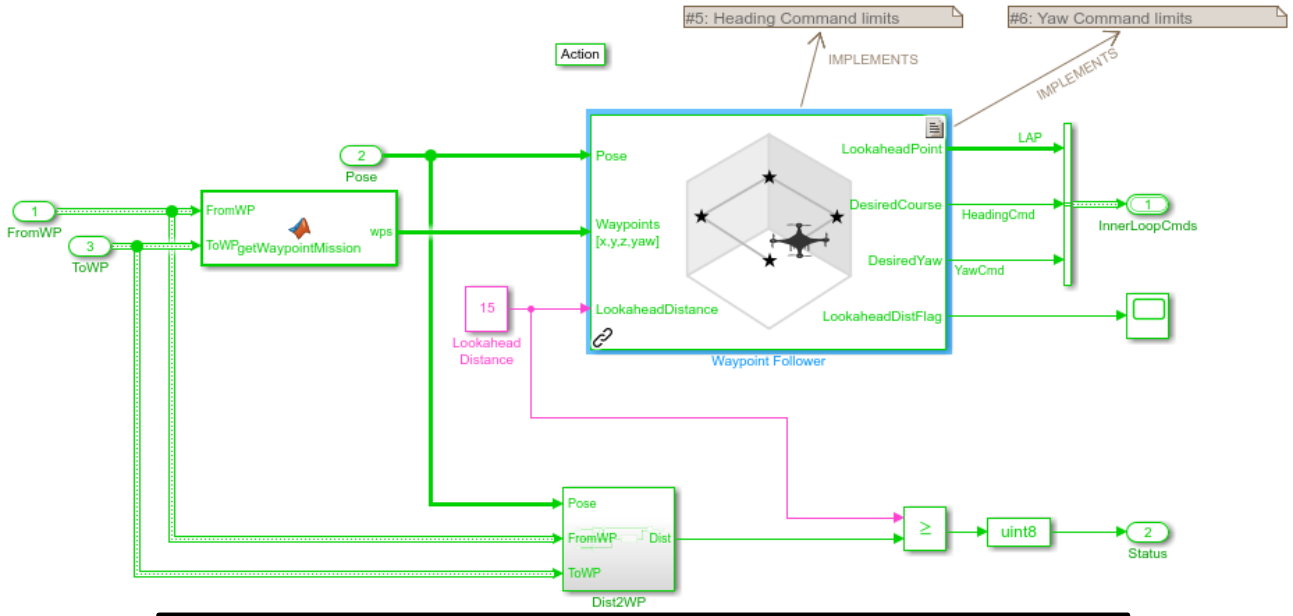


Evaluate Completeness

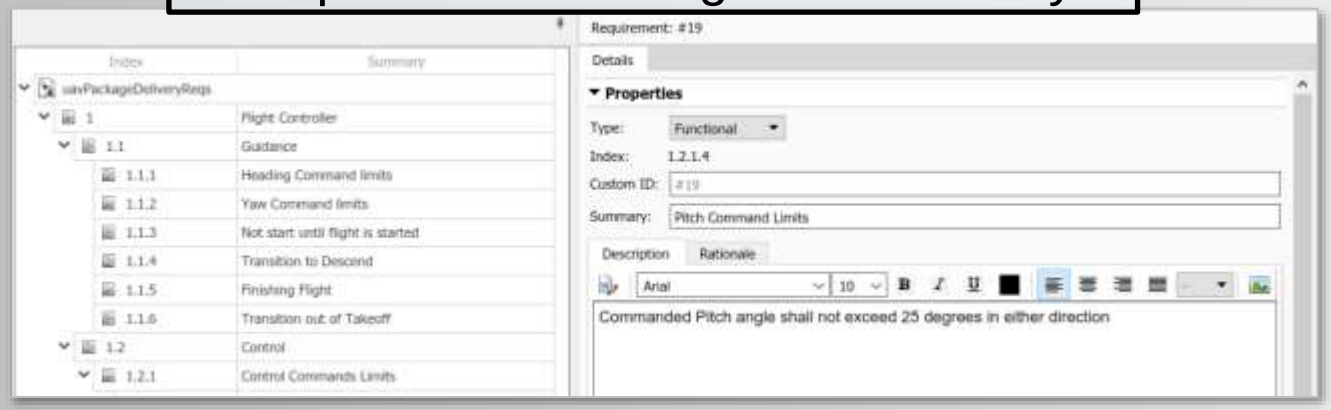


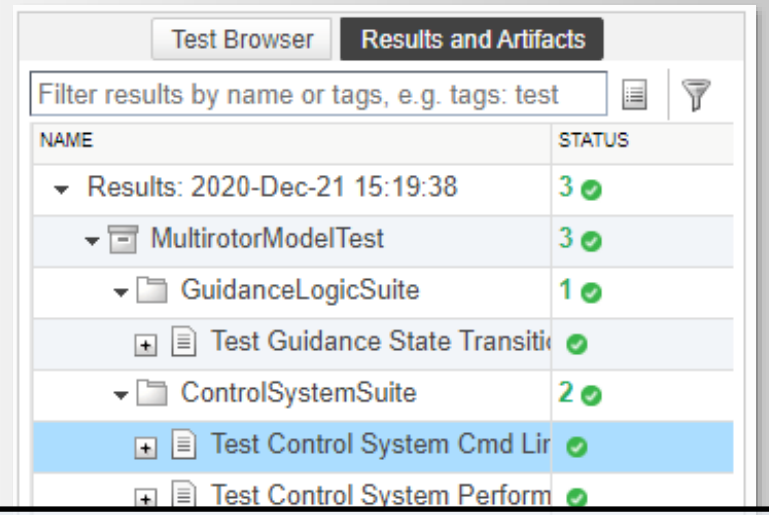
Simulink Requirements, Simulink Test, Simulink Coverage, Simulink Check

Example: Automating UAV Testing with Requirements Linking

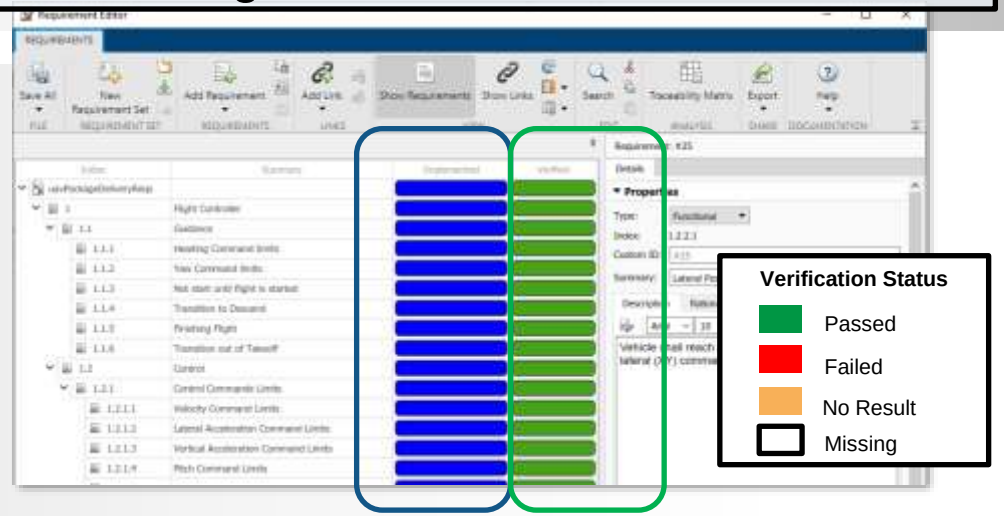


Requirements linking for traceability



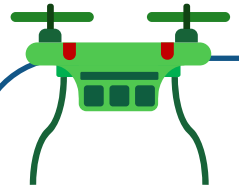


Automating test execution and evaluation



UAV Toolbox, Simulink Requirements, Simulink Test [Link]

Integrated Workflows for Developing UAV Applications



MATLAB®

Simulink®

System Architecture

Verification & Validation

87.5%

DO-178

Model UAV

Design Algorithms

Perception

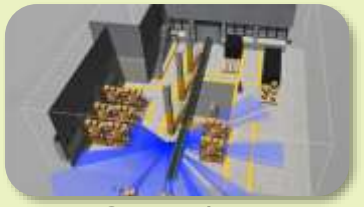
Planning & Decision

Control

Analyze Data

Simulate with Sensor Models

Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

Connect

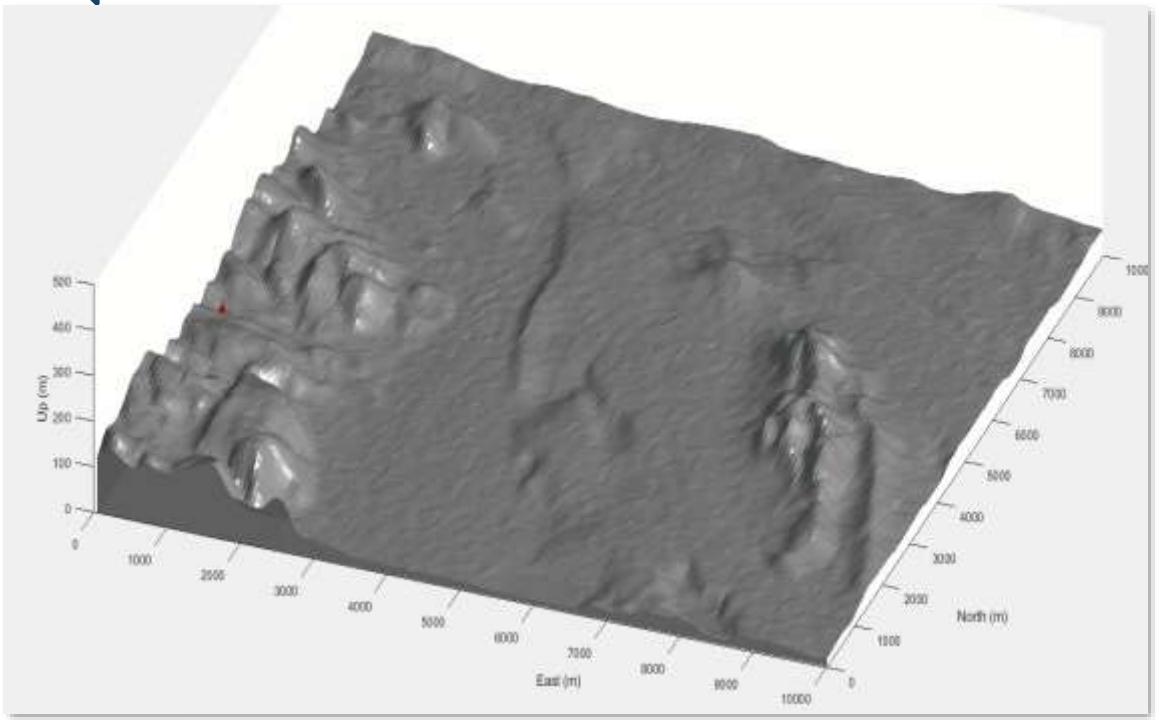
UAV

Ground Control Station

Integrated Simulations with Sensor Models

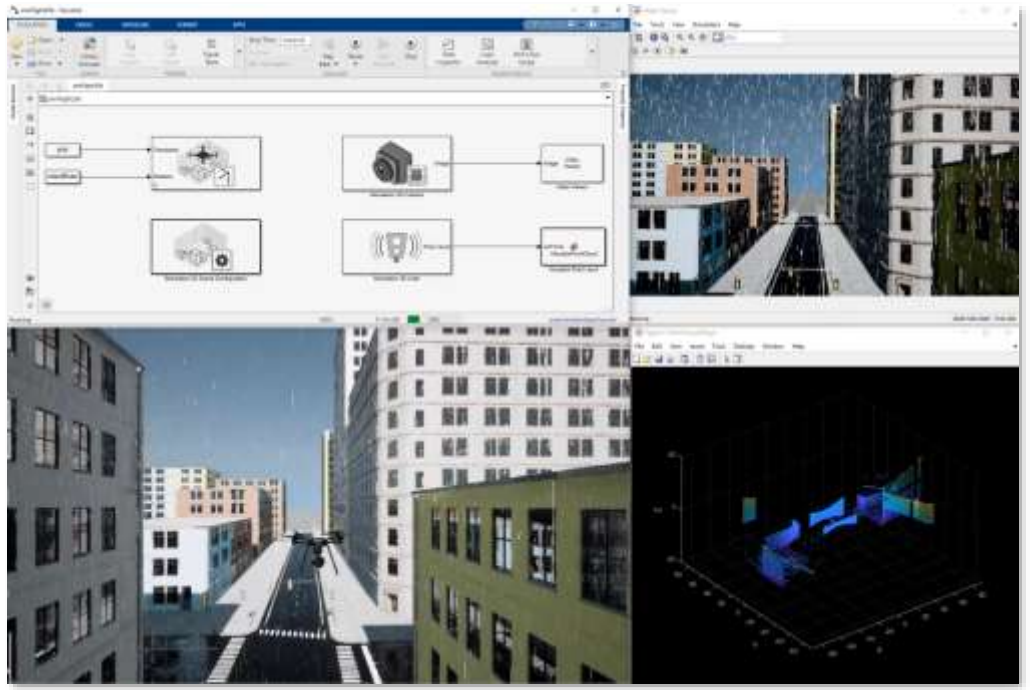
Cuboid
Performance

Unreal Engine®
Photorealistic



Rapidly author scenarios and generate sensor data

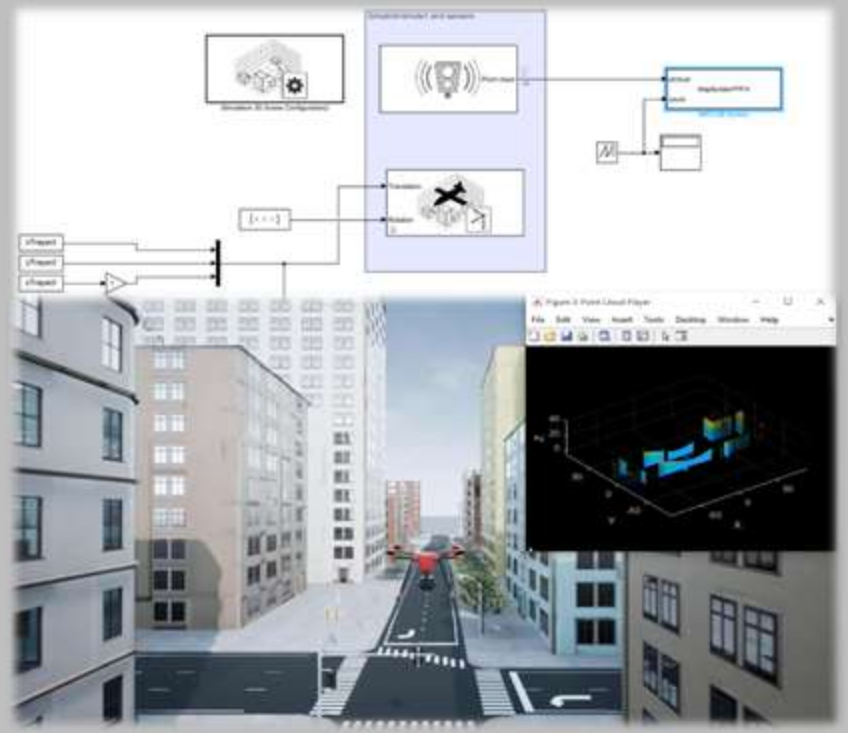
Link



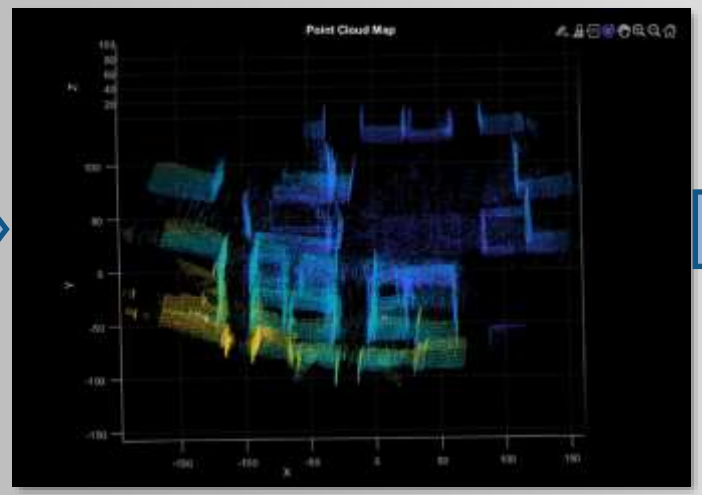
Realistic graphics to test autonomous algorithms in closed-loop simulations

Link

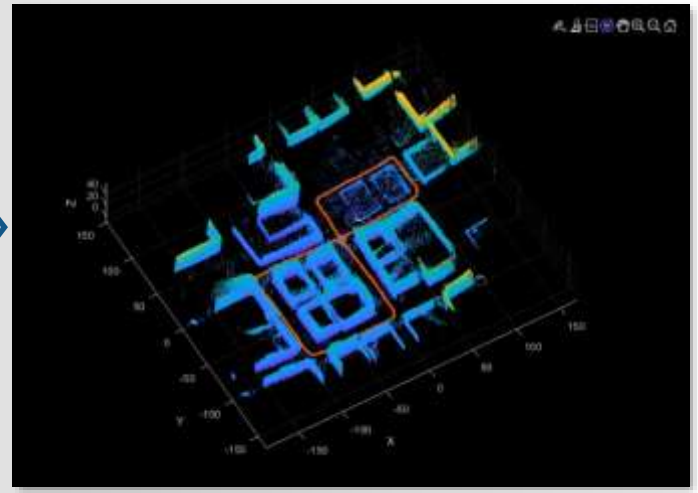
Example: Building 3D Map using Lidar Point Cloud Simulation



Execute simulation
Obtain sensor data



Extract and match features
Register and align point cloud



Detect loop-closures
Create pose graph
Optimize poses

3D Scene Creation for UAV Simulations

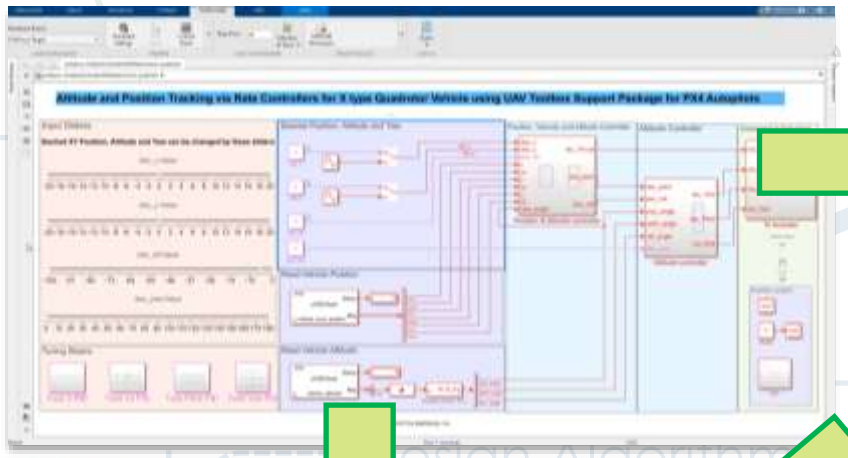
Link

Link

Design 3D scenes for simulating and testing autonomous algorithms

RoadRunner, RoadRunner Asset Library, UAV Toolbox Interface for Unreal Engine Projects

Automatic Code Generation for Hardware Implementation



Deploy flight controls to autopilot hardware

Link

Deploy to Hardware

PX4®

NVIDIA® Jetson®

CPU

FPGA

GPU

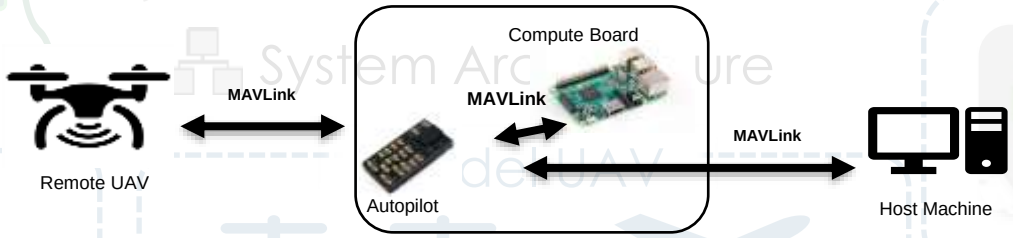
ROS

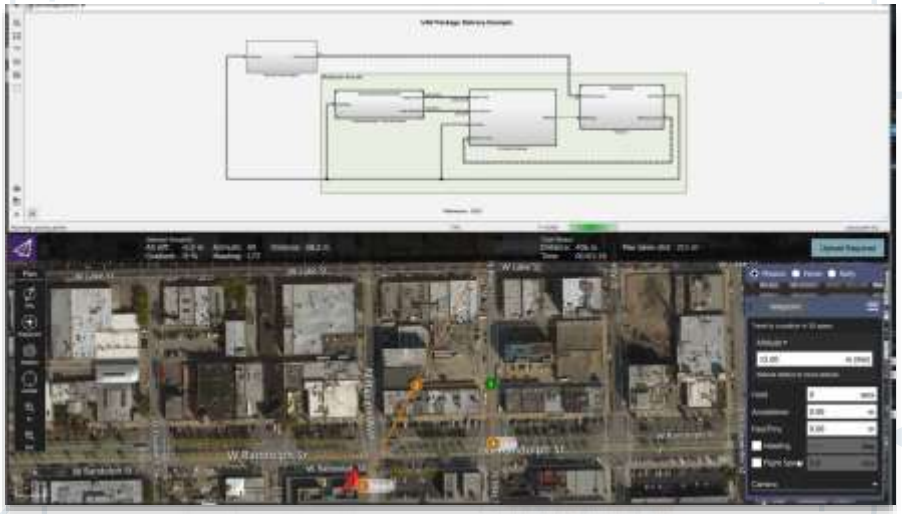
Deploy autonomous algorithms to onboard computers

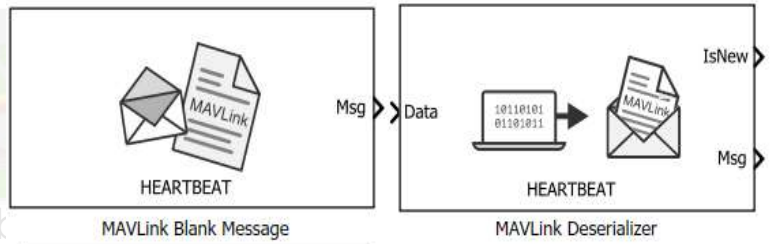
Link

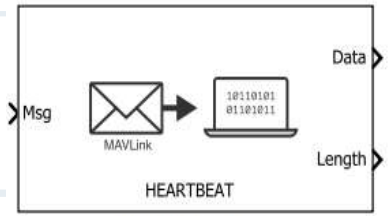
UAV Toolbox, Simulink Coder, Embedded Coder, GPU Coder

Connecting to UAV Hardware through MAVLink Protocol









Message Blocks

Connect

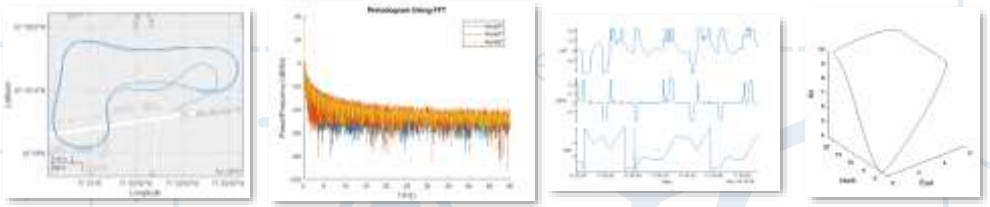
Link

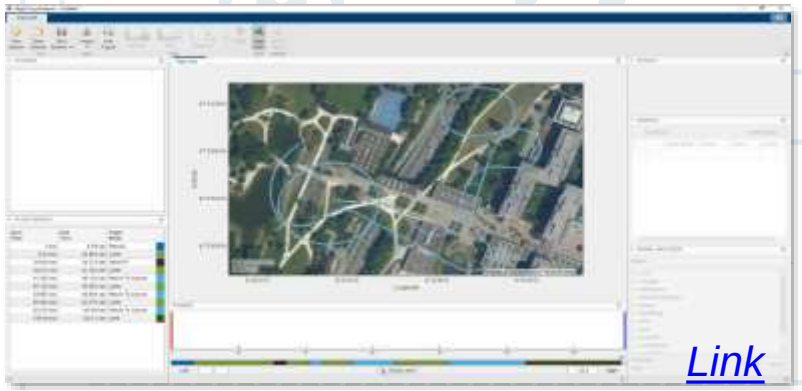
UAV Ground Control Station

Post-Flight Data Analysis

Flight Log Analysis

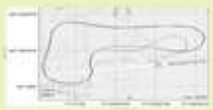
Payload Data Analysis

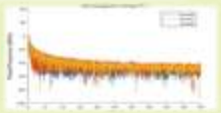


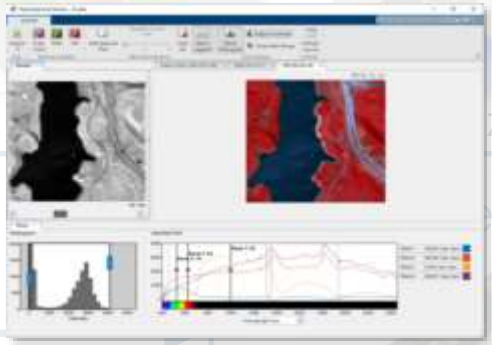


Link

Analyze Data





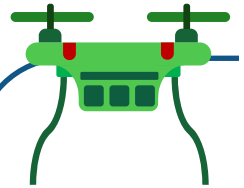


Link

Link

UAV Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

Integrated Workflows for Developing UAV Applications



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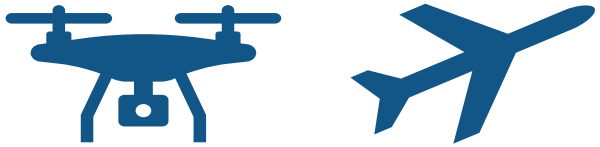
System Architecture

Verification & Validation

DO-178

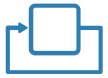
Model UAV



Design Algorithms

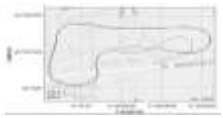
Perception

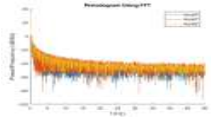
Planning & Decision



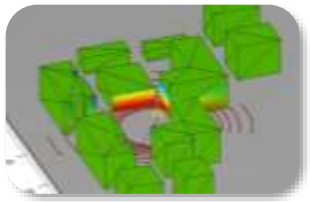
Control

Analyze Data

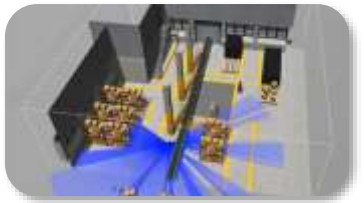




Simulate with Sensor Models



Cuboid



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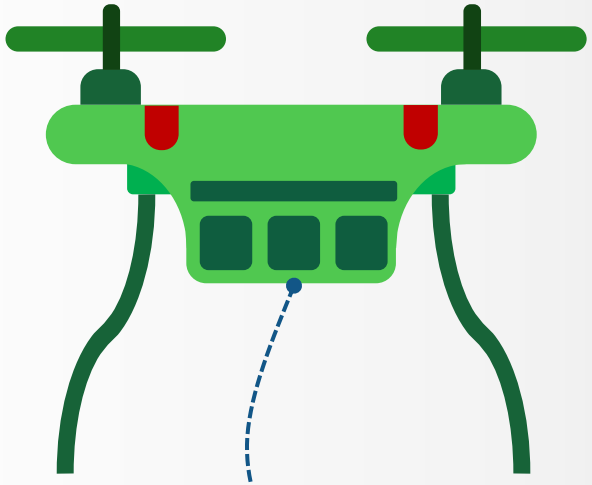
UAV

Ground Control Station

Key Takeaways



Call To Action:

- Download presentation file and investigate linked examples and pages
- Contact us for to learn more details or for trials

Integrated development workflows from prototyping to productization with MATLAB and Simulink

Robust tools/features for autonomous UAV design and simulations with sensor models

Quality through verification & validation tools for traceability, test completeness, and test management/automation

MATLAB EXPO 2021

Thank you