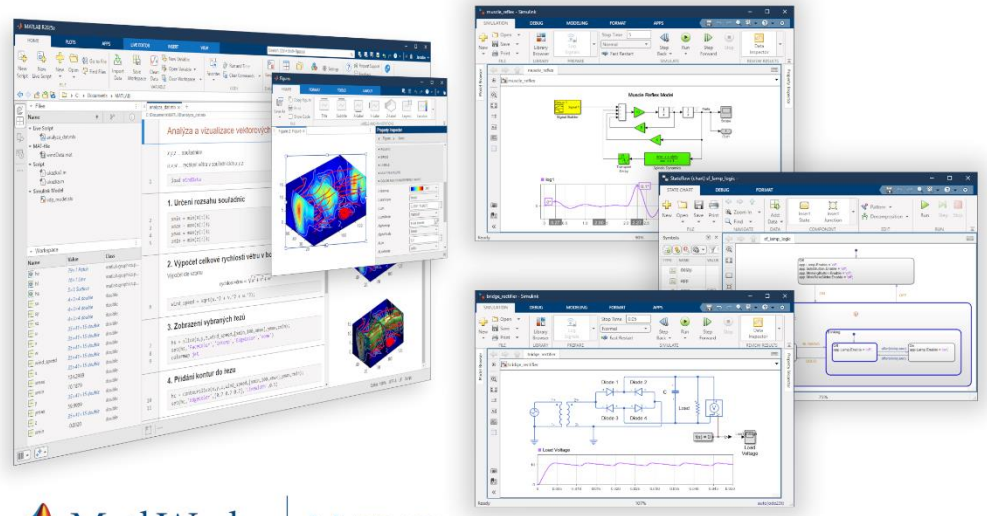
Model-Based Design pro autonomní systémy



MathWorks Authorized Reseller | MATLAB & SIMULINK

Michal Blaho

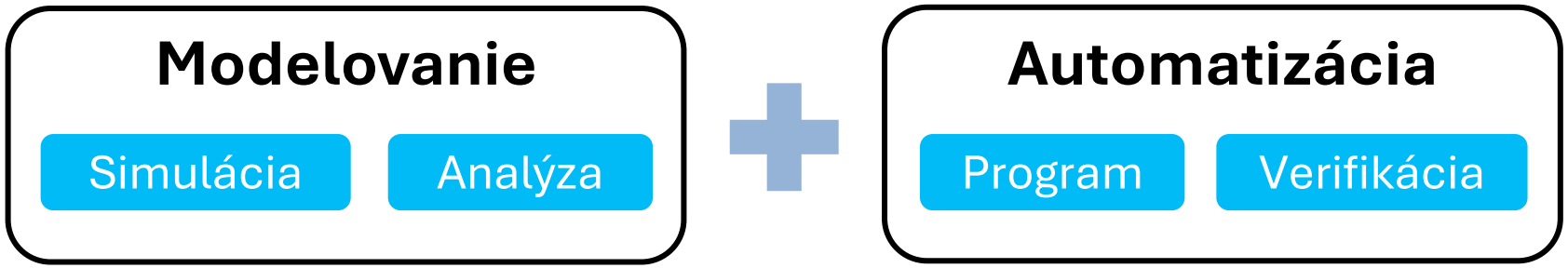
blaho@humusoft.sk

www.humusoft.cz
info@humusoft.cz

www.mathworks.com

Model-Based Design

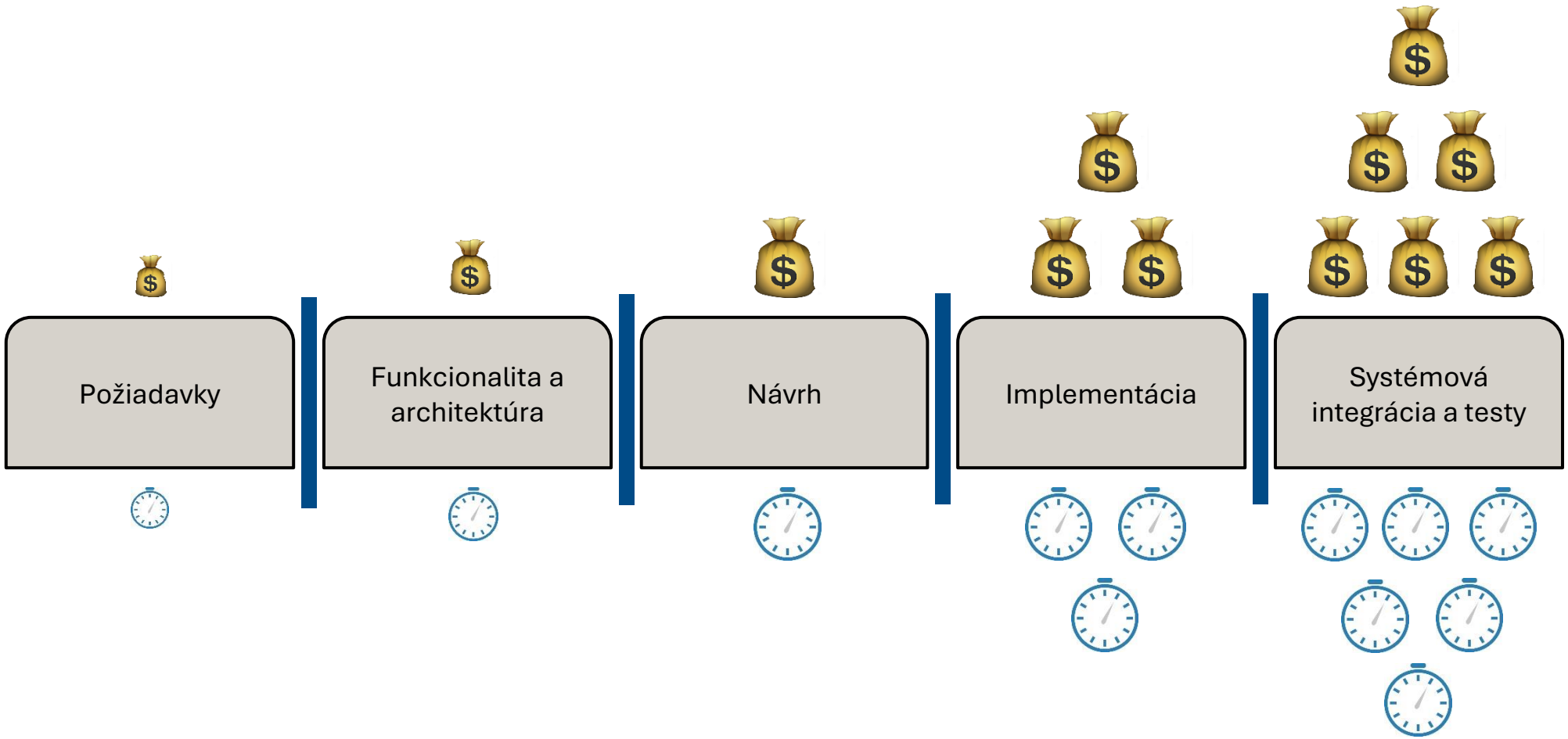
Systematické využívanie **modelov** počas vývoja



Skúšanie nových nápadov
Rýchle opakovateľné testy

Odstránenie manuálnych krokov a **ľudských chýb**

Náklady na opravenie chyby



Čas na opravenie chyby

Model-Based Design

Systematické využívanie **modelov** počas vývoja

Modelovanie

Simulácia | Analýza

+

Automatizácia

Program | Verifikácia

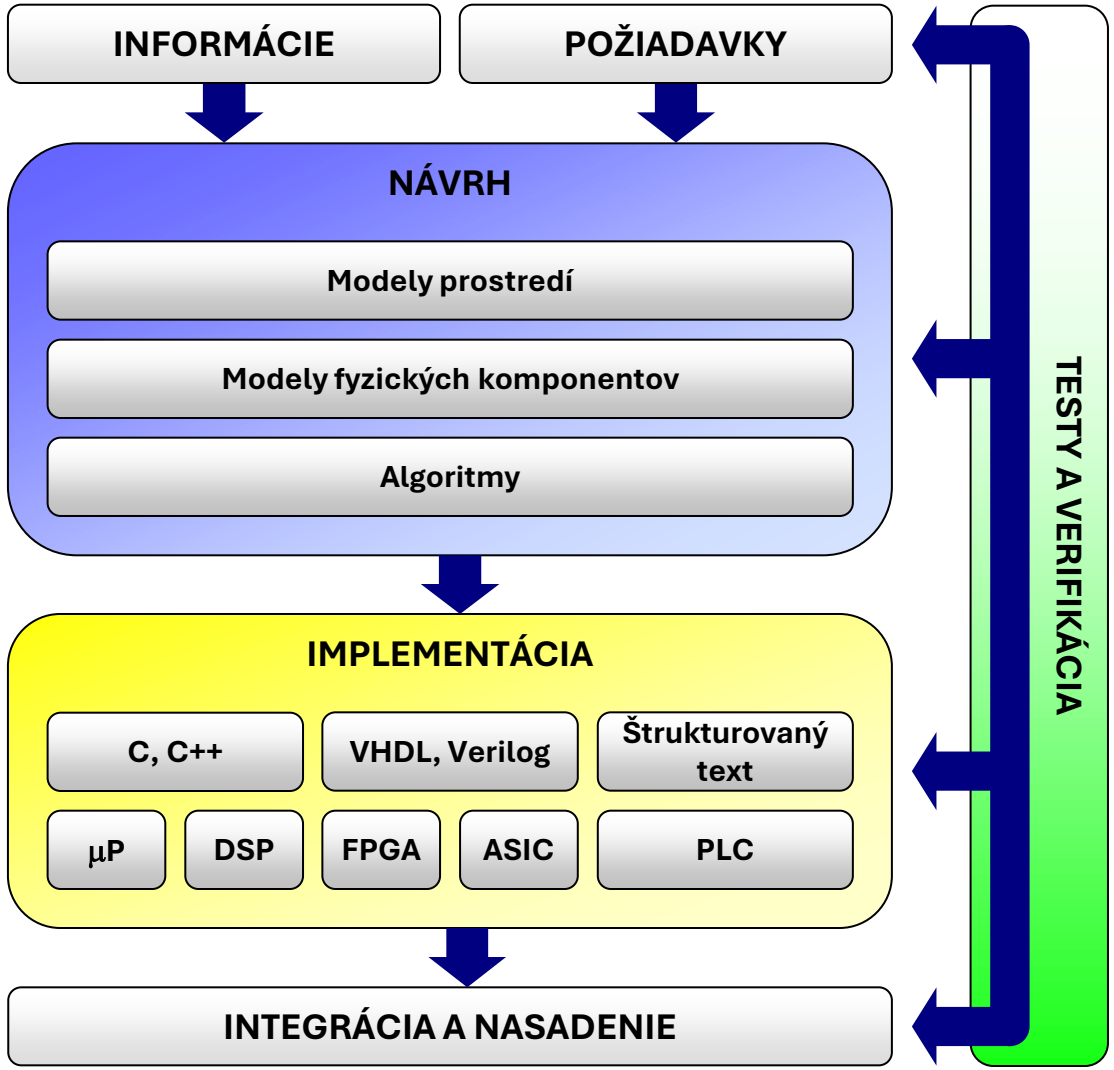
=

Krátke **agilné** iteračné cykly

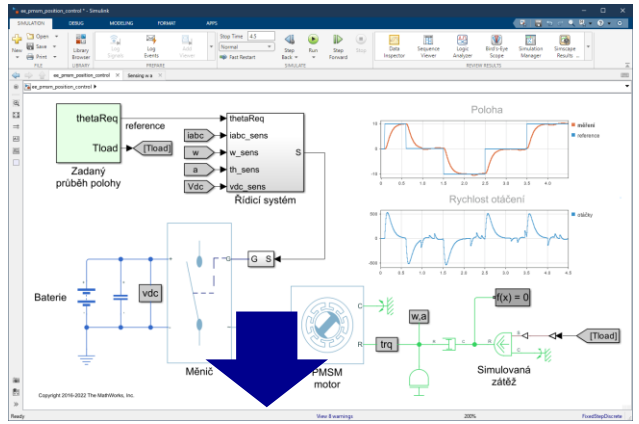
Šetrenie času a nákladov

Minumum defektov a **vysoká kvalita**

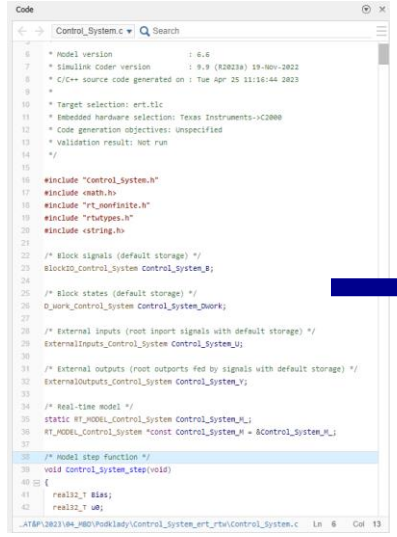
Model-Based Design



Modelovanie, simulácie a testovanie

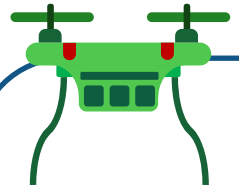


Automatické generovanie kódu



Nasadenie

Model-Based Design pre UAV aplikácie

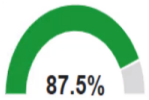


MATLAB®

Simulink®

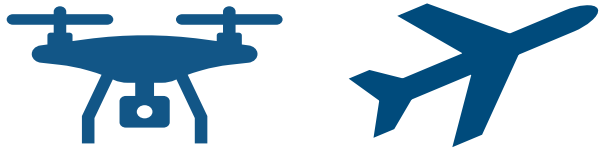
System Architecture

Verification & Validation



DO-178

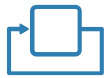
Model UAV



Design Algorithms

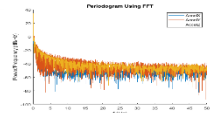
Perception

Planning & Decision

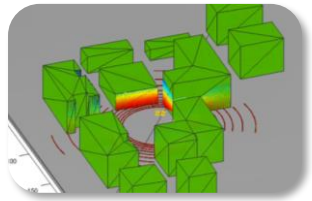


Control

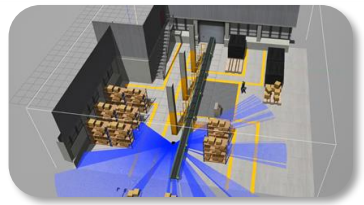
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

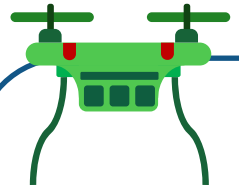
Connect

Connect

UAV

Ground Control Station

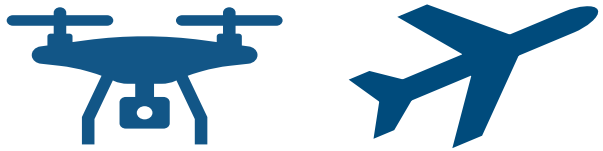
Model-Based Design pre UAV aplikácie



MATLAB® Simulink®

System Architecture

Model UAV



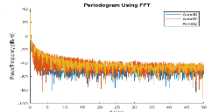
Design Algorithms

Perception

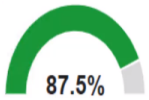
Planning & Decision

Control

Analyze Data



Verification & Validation

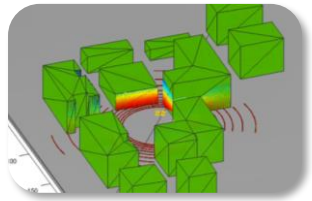


DO-178

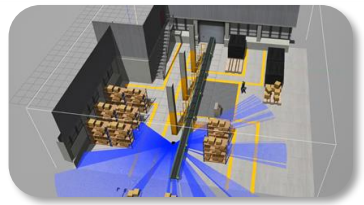
Implement

Connect

Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Deploy to Hardware

PX4®

NVIDIA® Jetson®

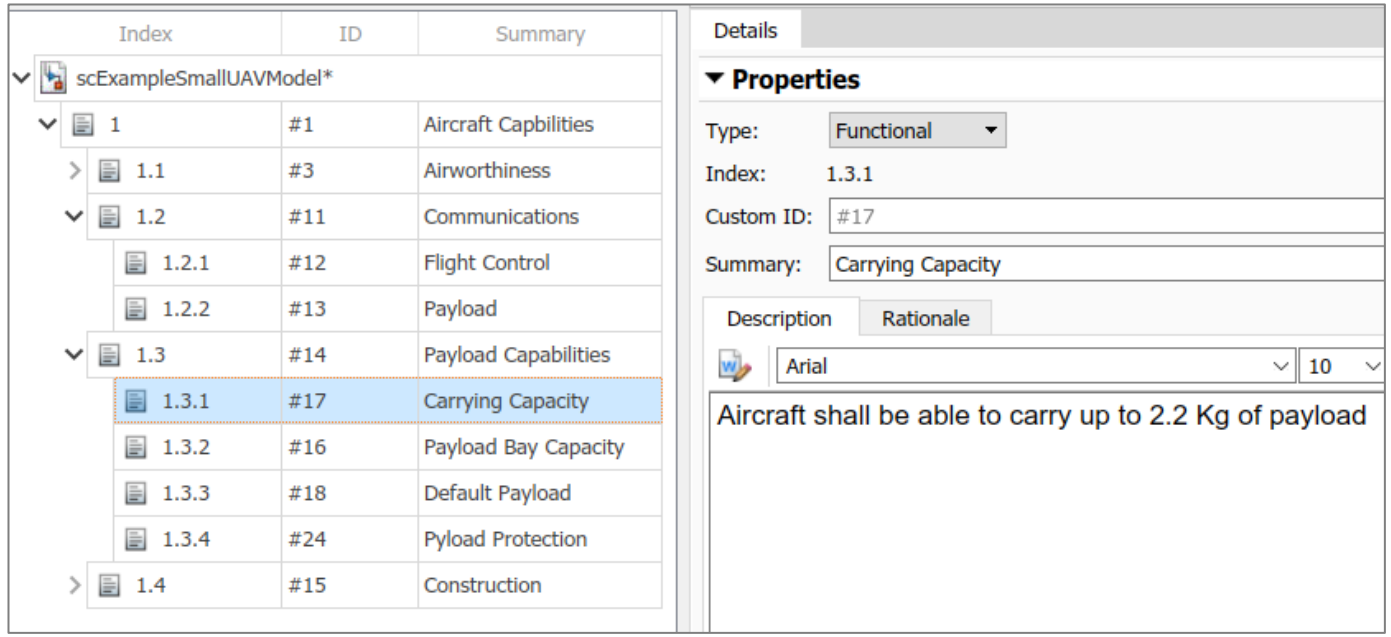
Connect

UAV

Ground Control Station

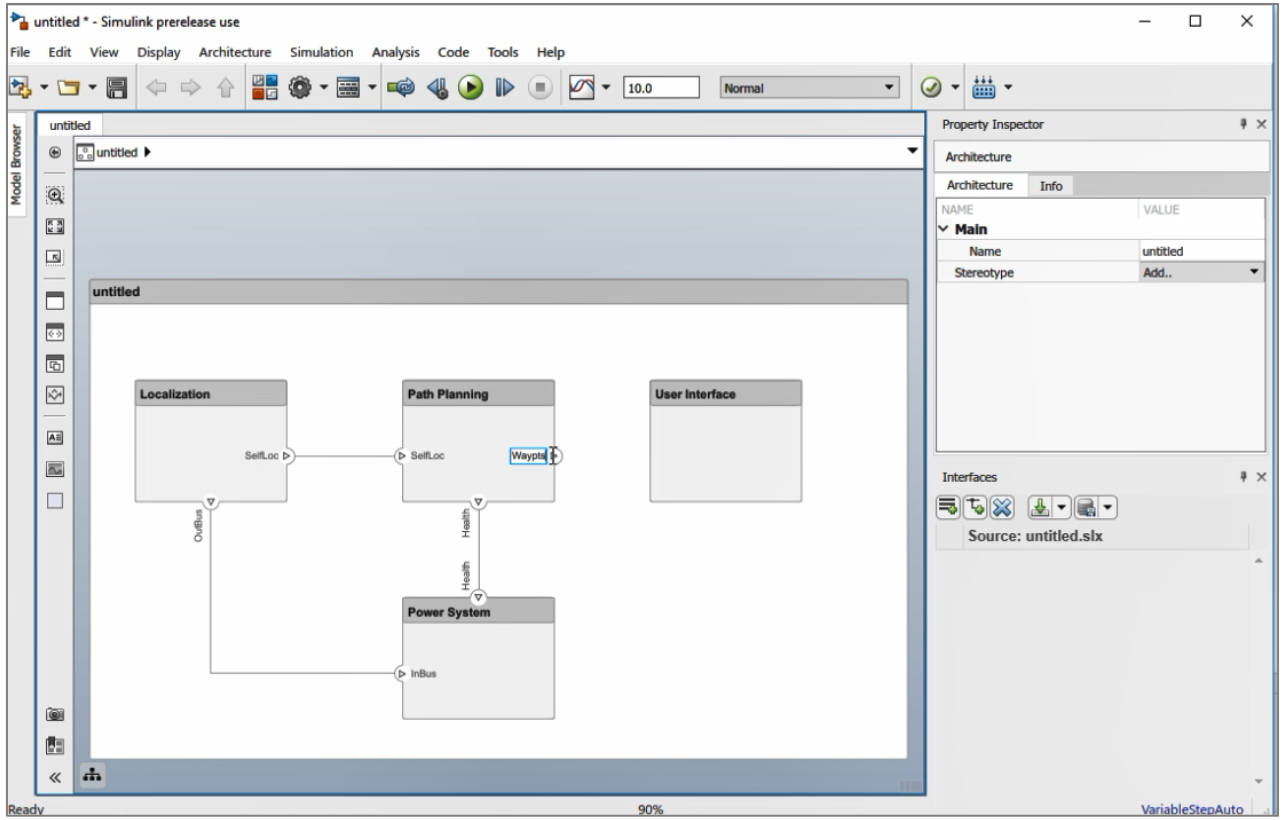
Požiadavky na systém

- Tvorba a organizácia
  - tvorba nových priamo v prostredí
  - formátovaný text, atribúty
- Integrácia z iných nástrojov
  - Word, Excel, ReqIF
- Prepojenie
  - MATLAB kód, model Simulinku
- Sledovateľnosť
  - návrh, implementácia, test
  - pokrytie požiadaviek
- Analýzy a reporty



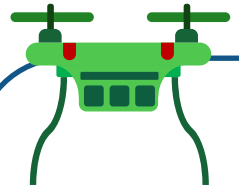
Architektúra systému

- Tvorba architektúry
  - komponenty, subsystémy
  - rozhrania, prepojenia komponentov
- Analýza architektúry
  - priraďovanie vlastností
  - štúdie v prostredí MATLAB
- Modelovanie správania
  - blokové schémy v Simulinku
- Viaceré pohľady na architekrútu
- Priraďovanie požiadaviek k architektúre



System Composer

Model-Based Design pre UAV aplikácie

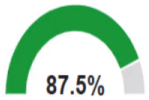


MATLAB®

Simulink®

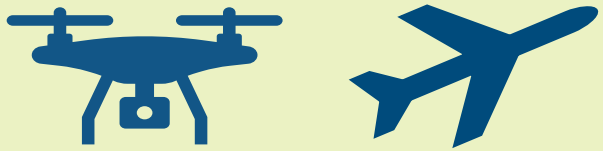
System Architecture

Verification & Validation



DO-178

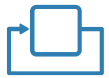
Model UAV



Design Algorithms

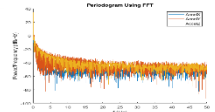
Perception

Planning & Decision

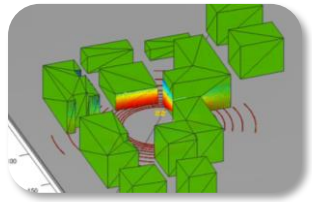


Control

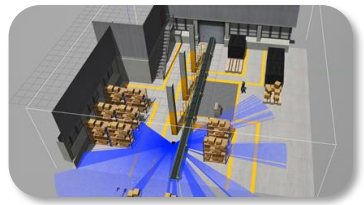
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

Connect

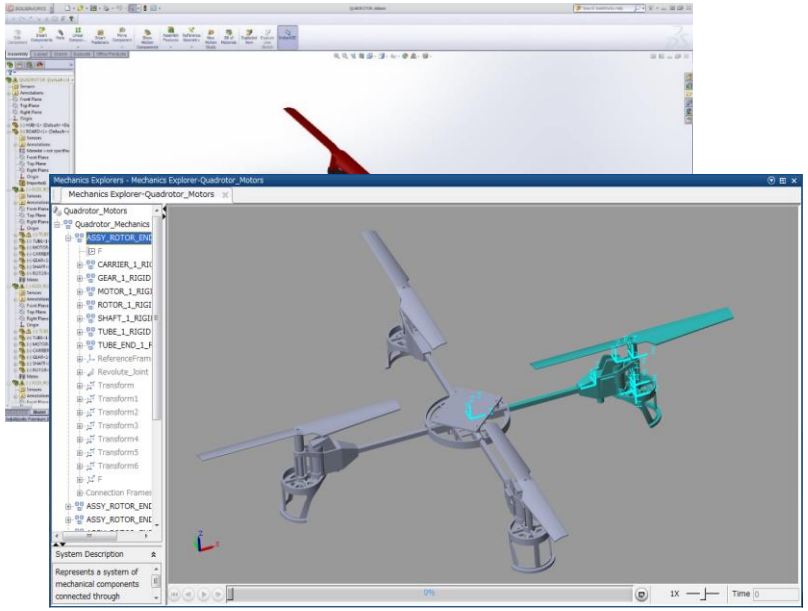
UAV

Ground Control Station

Modelovanie dynamiky UAV

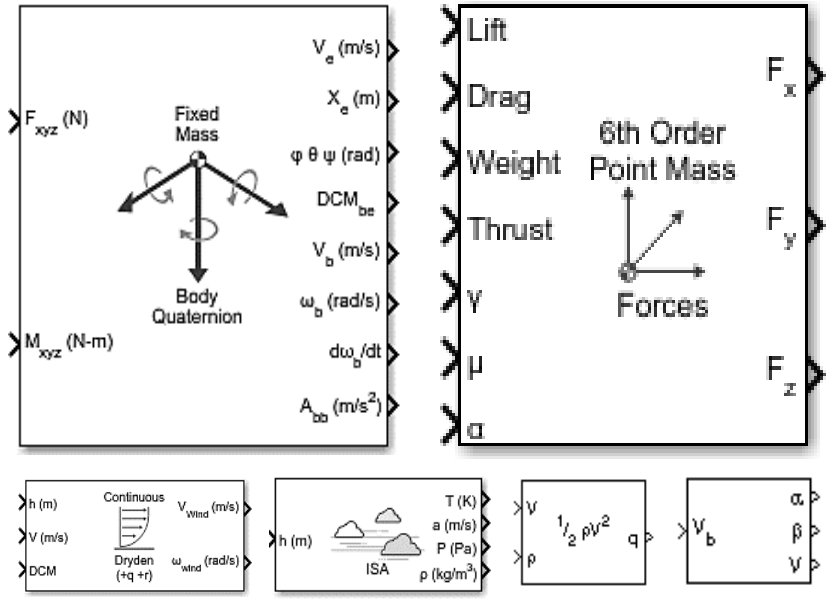
Vysoká presnosť
Konštrukcia UAV

Aproximácia
Programovanie UAV



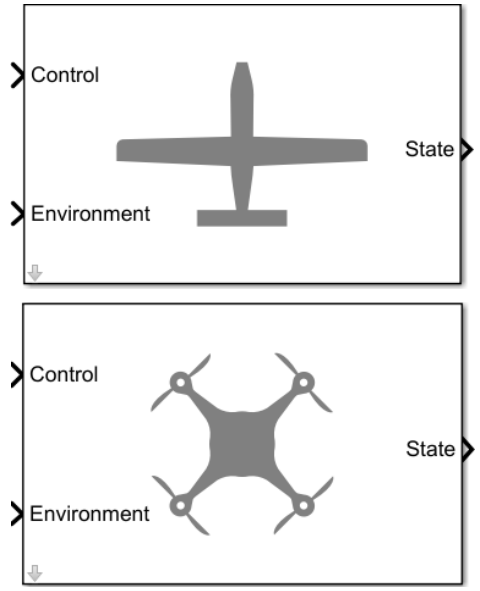
Physical Modeling

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



Vehicle Dynamics

Model aerodynamics, propulsion, and motion of aircraft and spacecraft

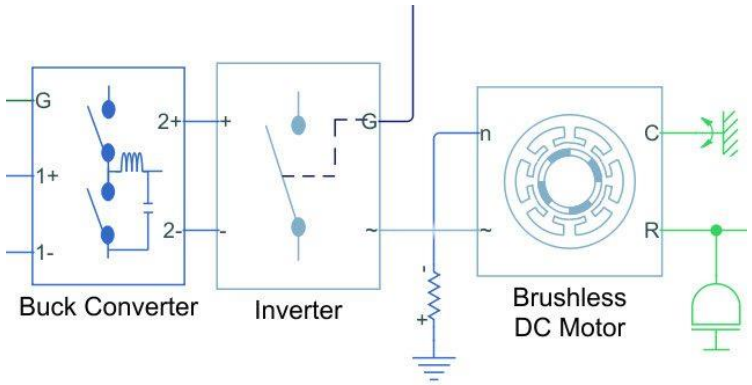


Guidance Model

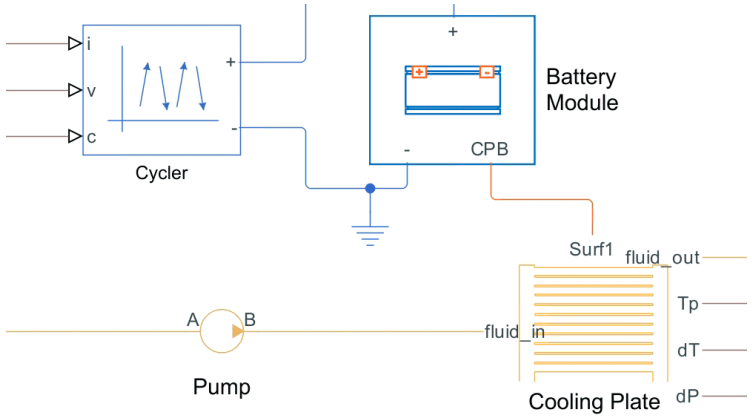
Reduced-order model for UAV

Simscape Multibody, Aerospace Blockset, UAV Toolbox

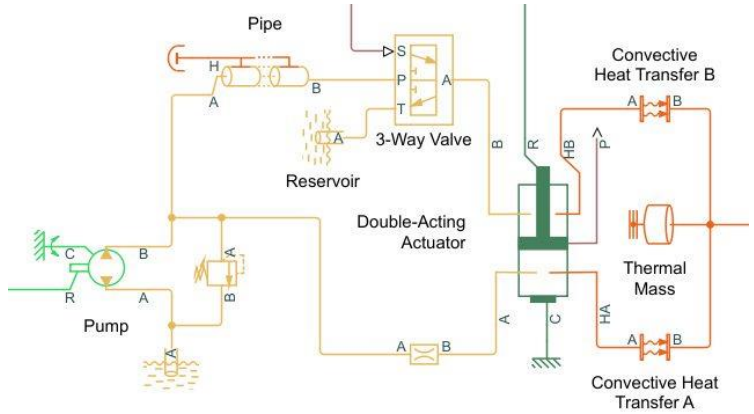
Modelovanie fyzikálnych systémov



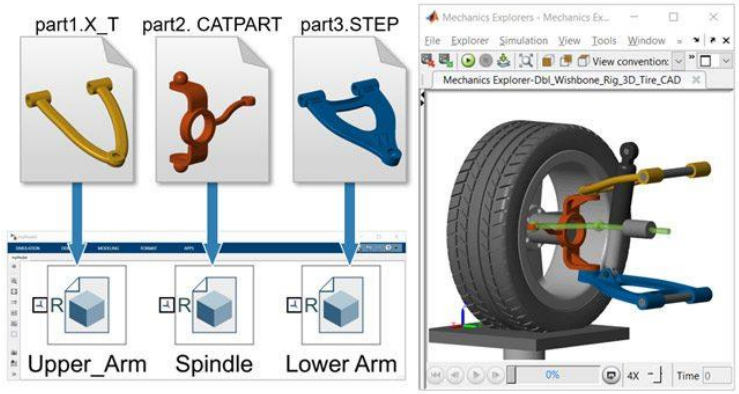
Simscape Electrical



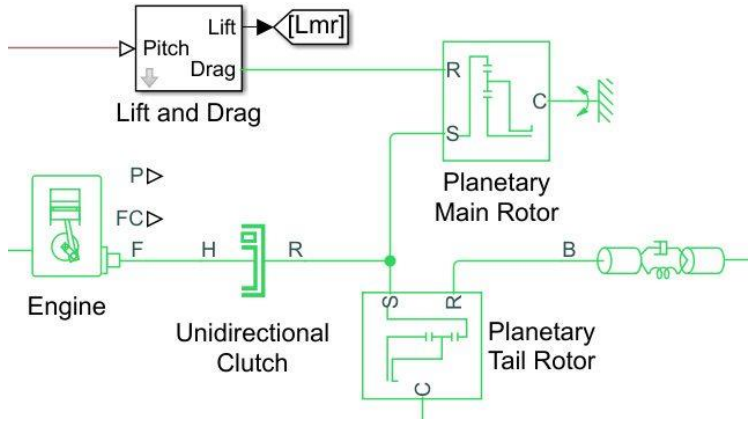
Simscape Battery



Simscape Fluids



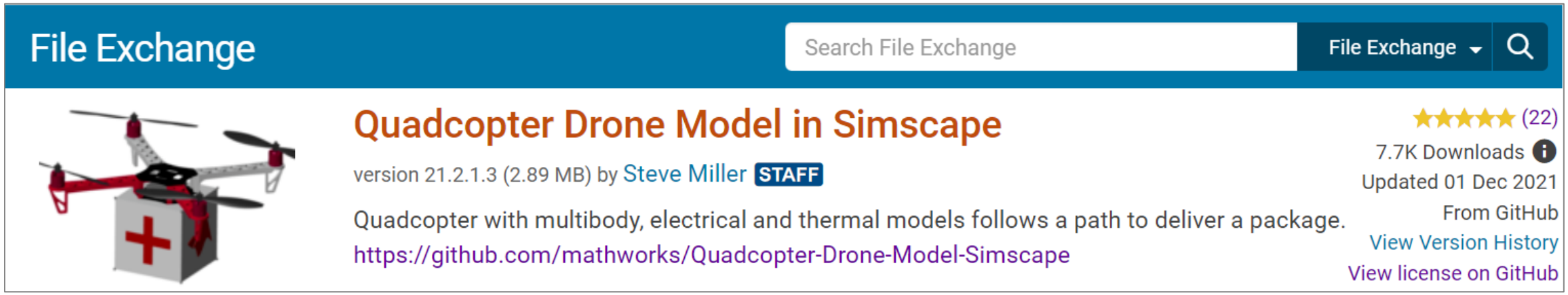
Simscape Multibody



Simscape Driveline

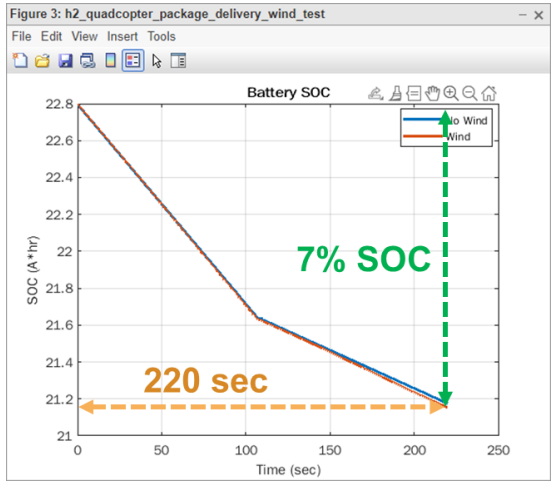
Model dronu v Simscape

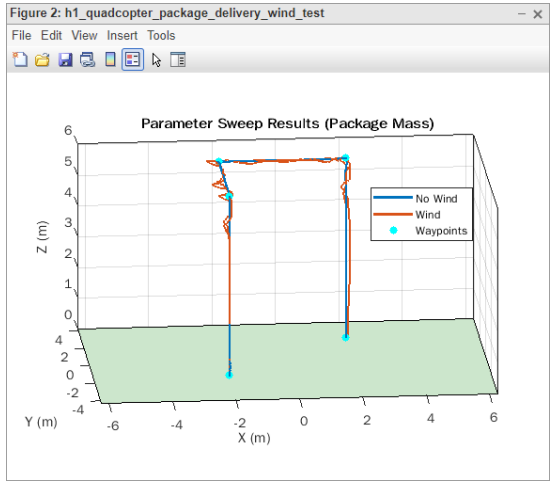
- Model kvadrokoptéry, ktorá sa pohybuje po trase a doručenie balíka
  - CAD súbory podvozku a vrtúľ, modelovanie mechanického systému
  - elektrické motory a batéria umožňujú odhad odberu prúdu a doletu dronu
  - kaskádové PID regulátory upravujú otáčky motora na riadenie výšky a polohy
  - sledovanie trasy a rýchlosti poskytujú príkazy pre nadradenú úroveň
  - profily nárazov vetra testujú stabilitu regulátorov dronu
  - analýza ziskovosti v prostredí MATLAB umožňuje skúmať technické a obchodné kompromisy

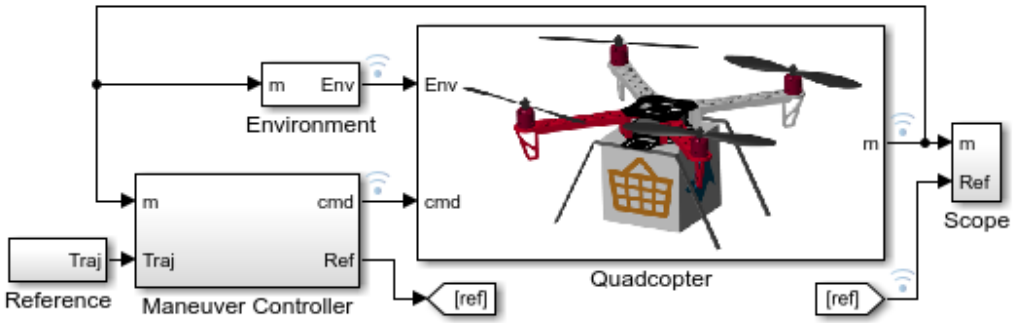


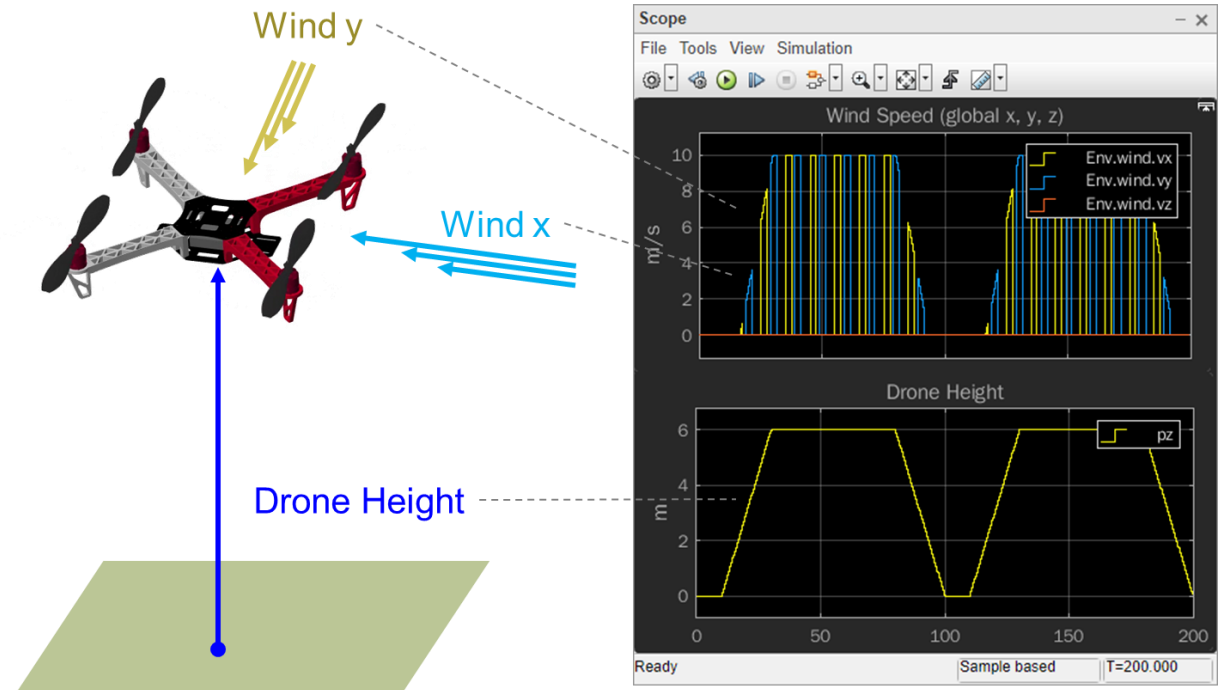
Stabilita a dosah dronu

- Testovanie lokálnych poveternostných podmienok
  - Regulátor udržiava stabilitu zmenou krútiaceho momentu, nabitie batérie je ovplyvnené prenášanou hmotnosťou a časom stráveným vo vzduchu



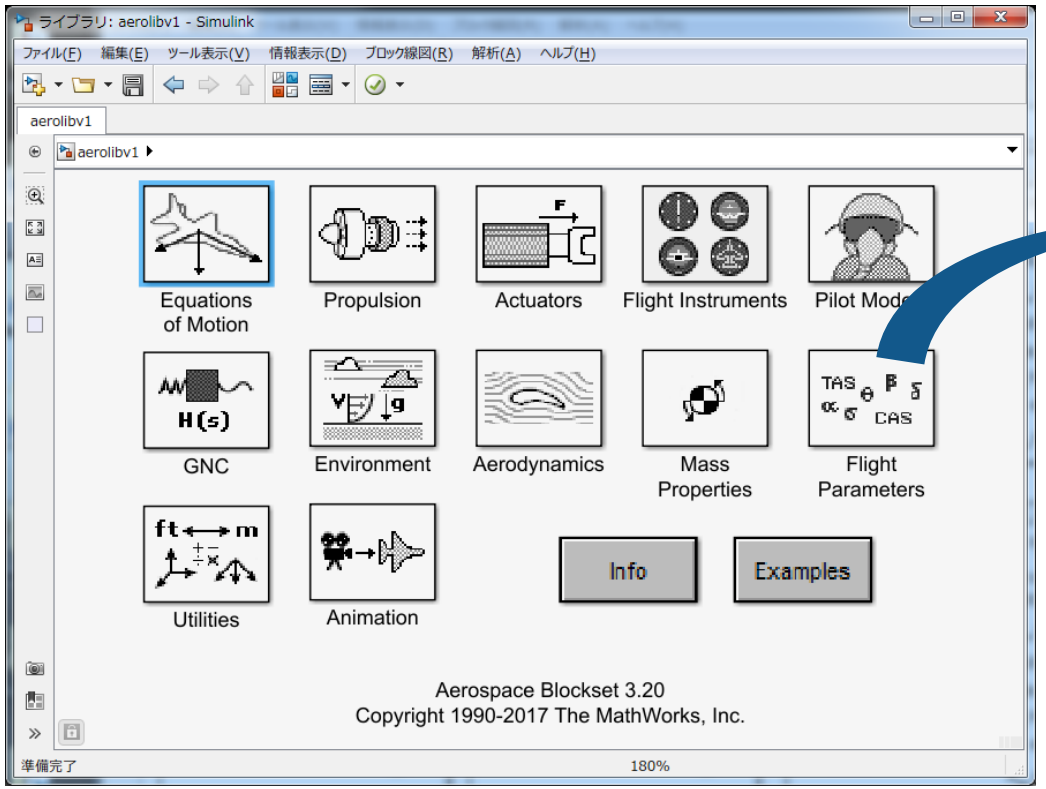




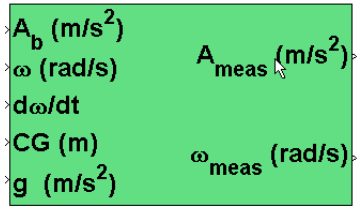


Modelovanie dynamiky s Aerospace Blockset

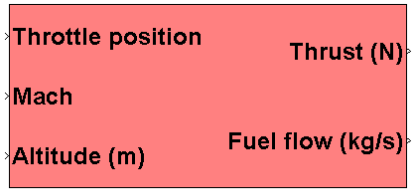
- modelovanie platformy so šiestimi stupňami voľnosti
- senzory, pohon, akčné členy, bloky prostredia



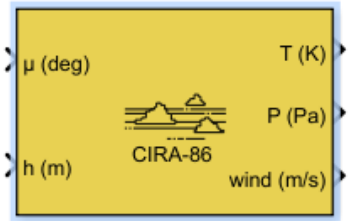
Three-axis Accelerometer



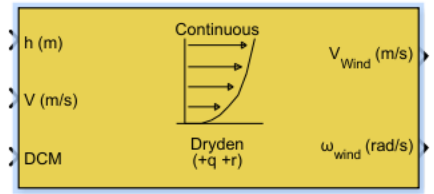
Three-axis Inertial Measurement Unit



Turbofan Engine System

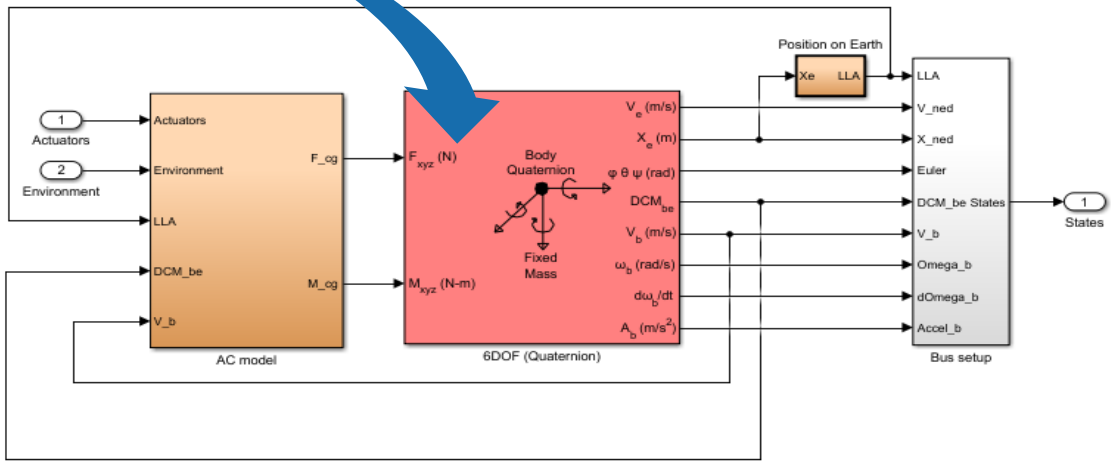


CIRA-86 Atmosphere Model



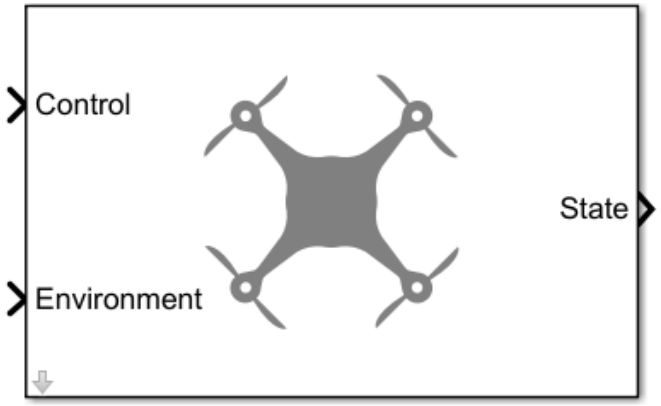
Dryden Wind Turbulence Model (Continuous (+q +r))

Second Order Nonlinear Actuator

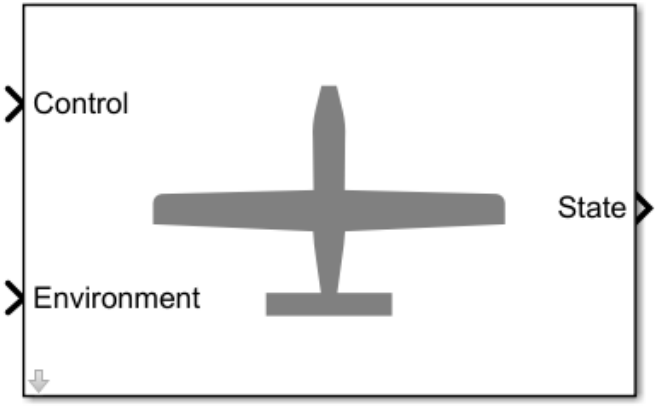


Aproximácia správania UAV pomocou UAV Toolboxu

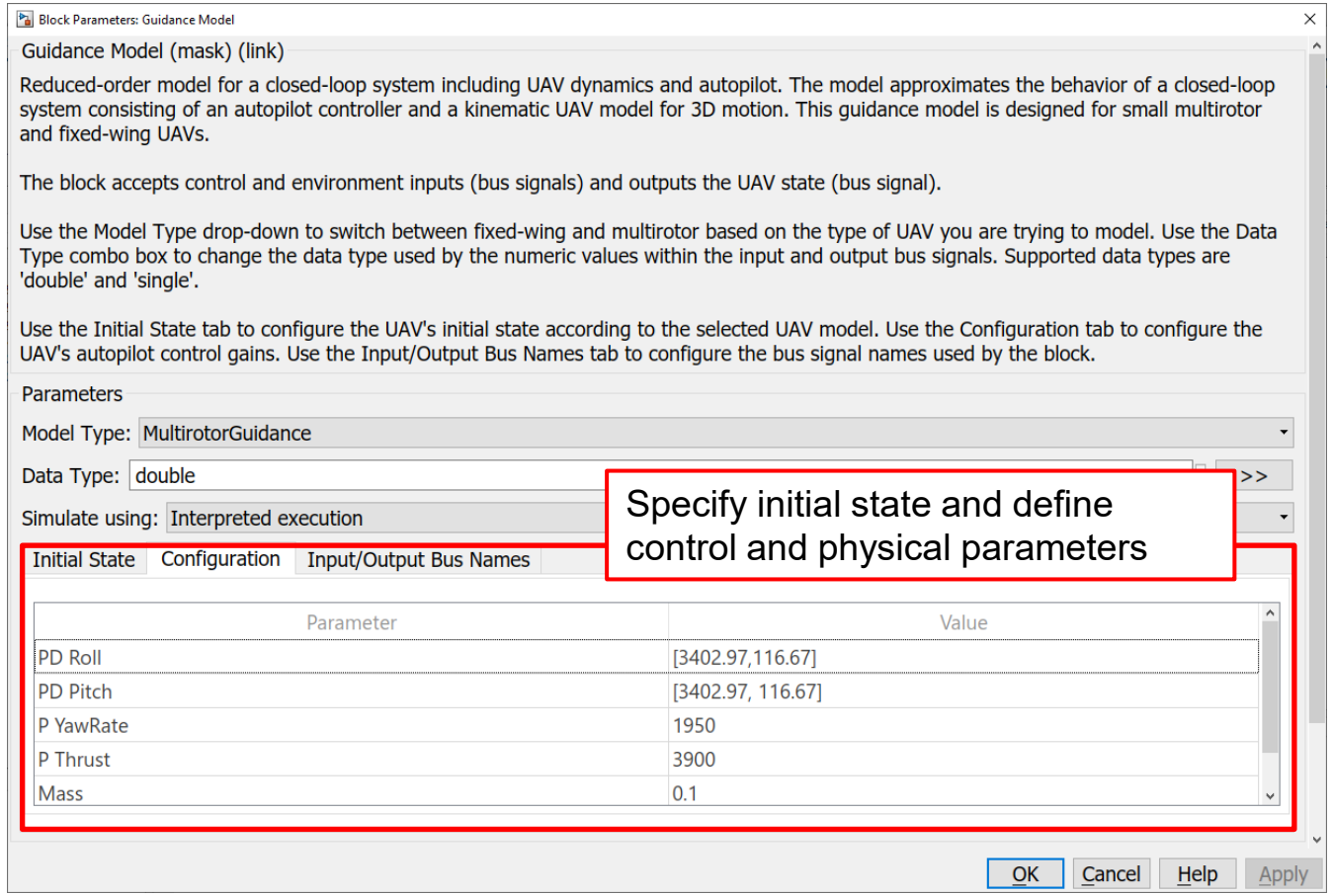
- Rýchla simulácia UAV (fixed-wing, multirotor) – UAV Guidance Model



Multirotor Guidance Model

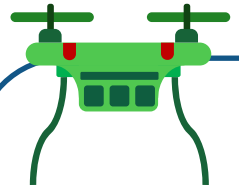


Fixed-Wing Guidance Model



Specify initial state and define control and physical parameters

Model-Based Design pre UAV aplikácie

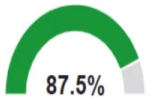


MATLAB®

Simulink®

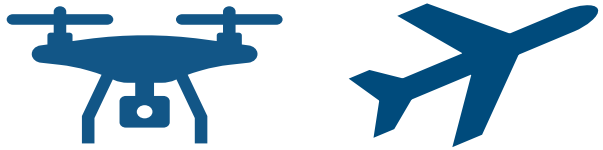
System Architecture

Verification & Validation



DO-178

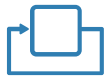
Model UAV



Design Algorithms

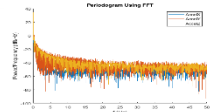
Perception

Planning & Decision

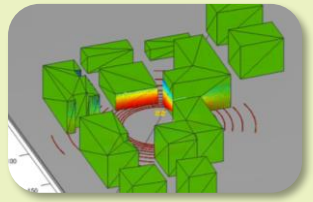


Control

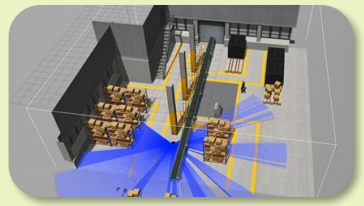
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

Connect

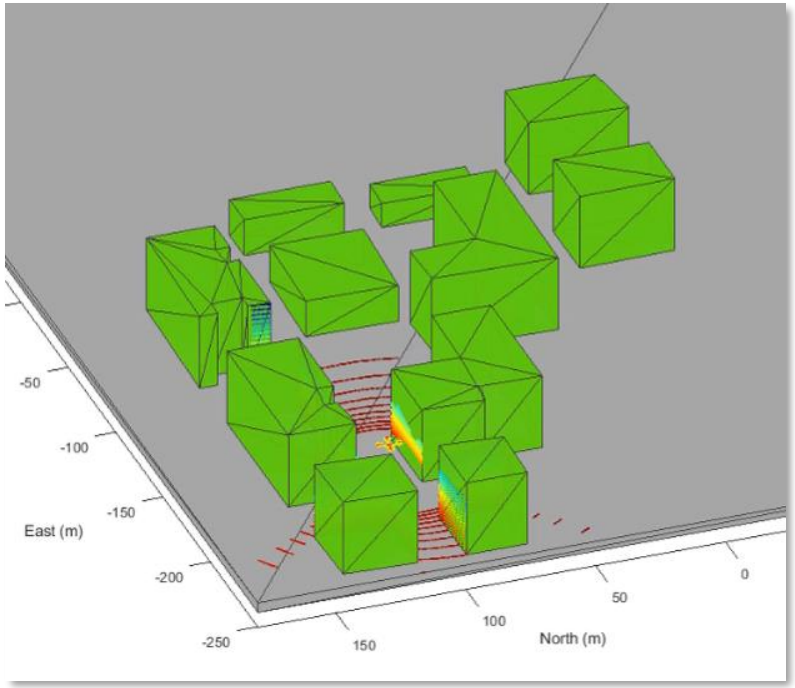
UAV

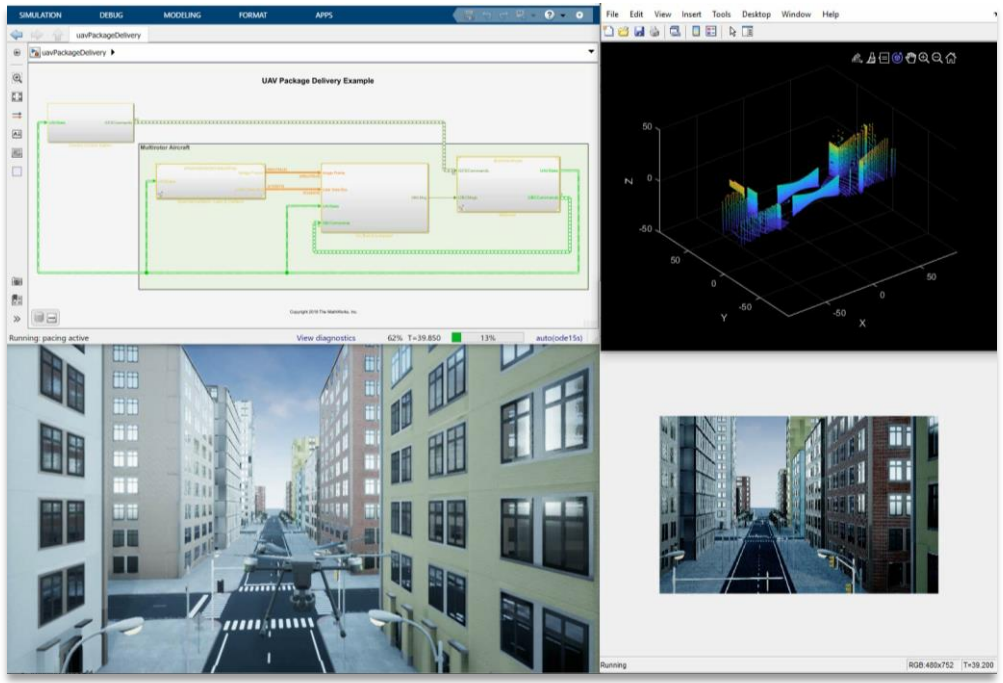
Ground Control Station

Integrované simulácie s modelmi senzorov

Cuboid
Rychlosť

Unreal Engine®
Blízke reálnemu svetu





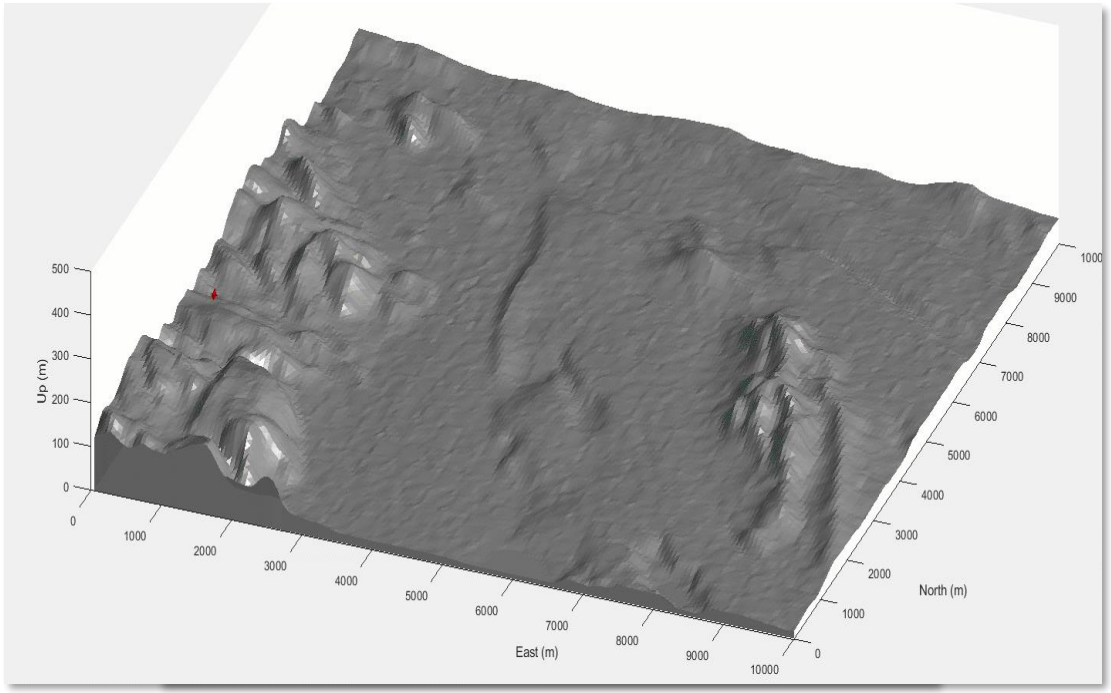
Rýchlo vytvárajte scenáre a generujte dáta zo senzorov

Realistická grafika na testovanie autonómnych algoritmov

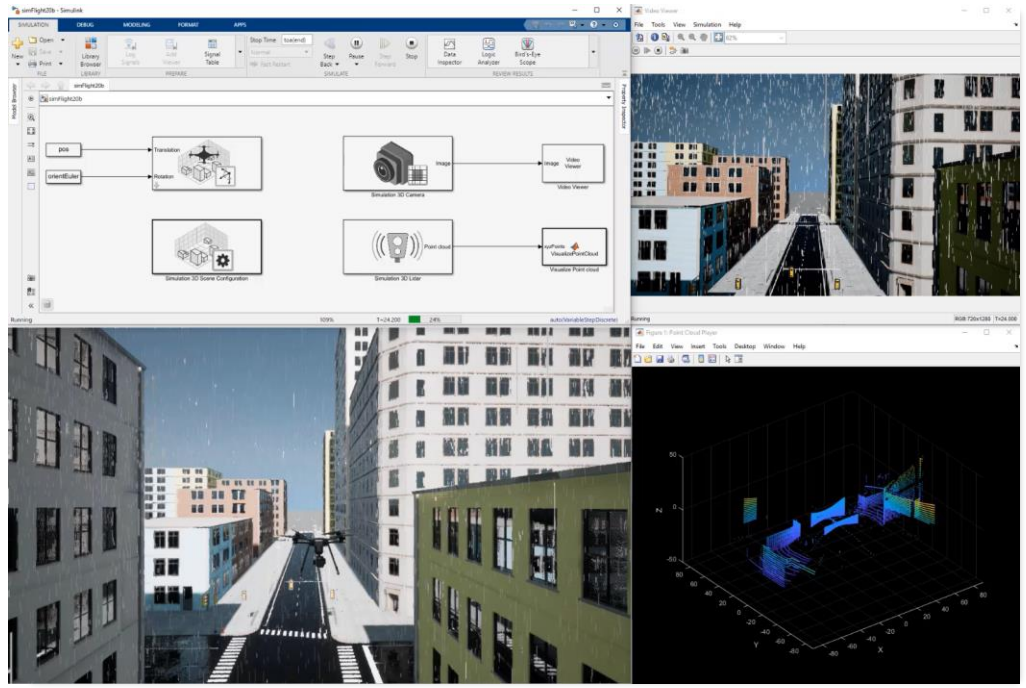
Integrované simulácie s modelmi senzorov

Cuboid
Rychlosť

Unreal Engine®
Blízke reálnemu svetu

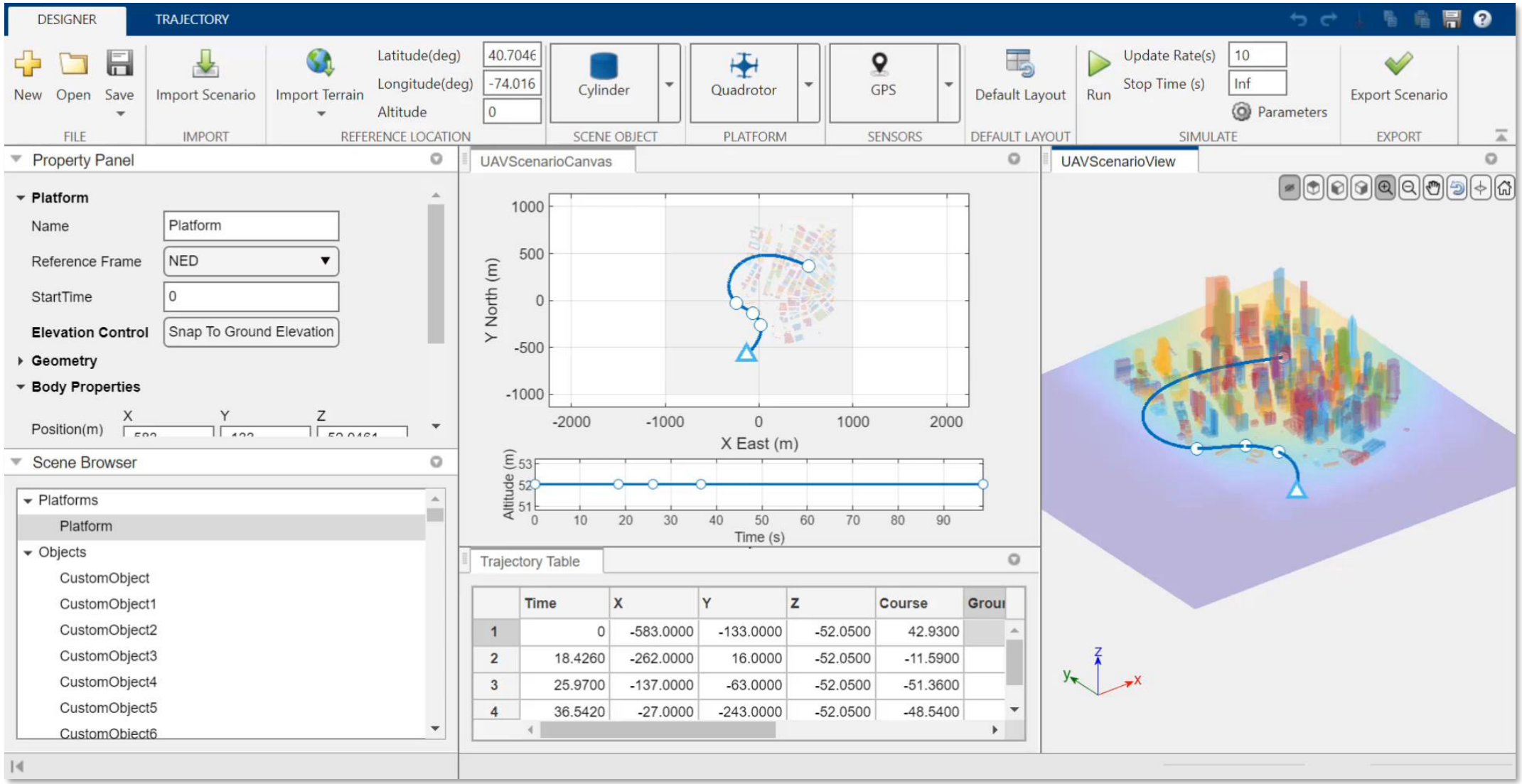


Rýchlo vytvárajte scenáre a generujte dáta zo senzorov

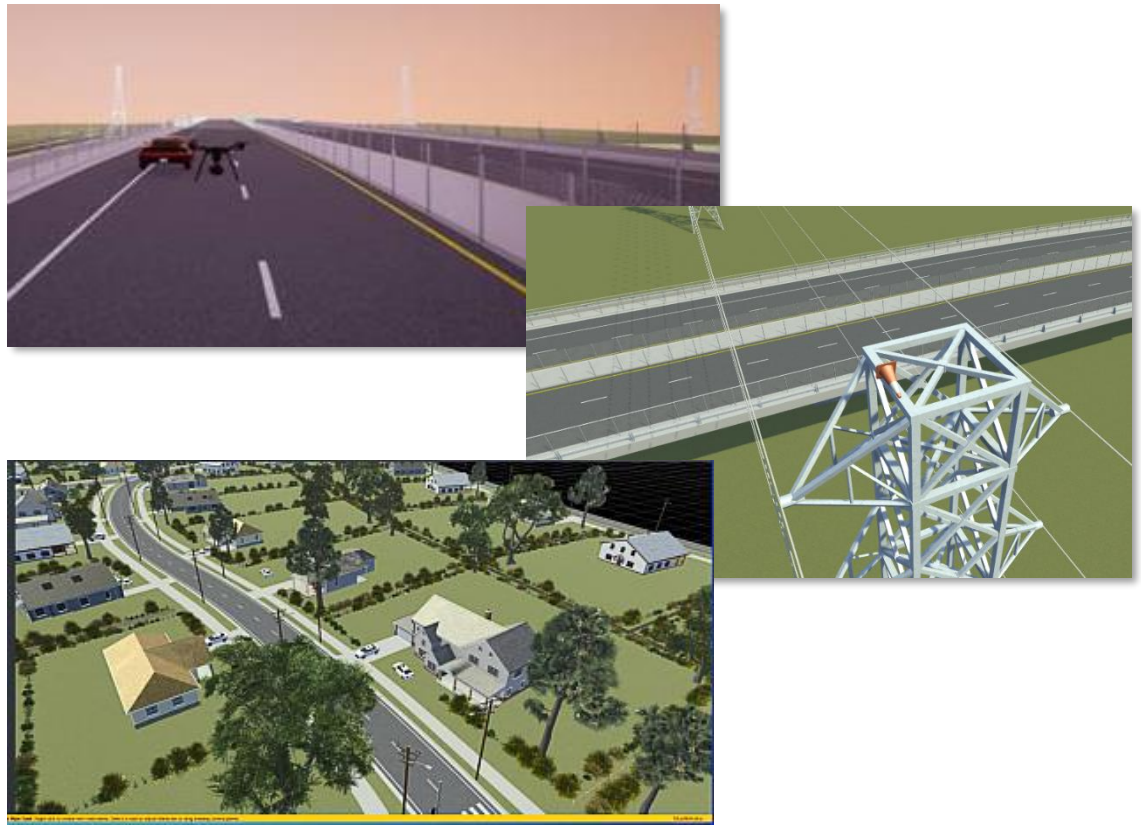


Realistická grafika na testovanie autonómnych algoritmov

UAV Scenario Designer



Tvorba 3D scén pre simulácie UAV



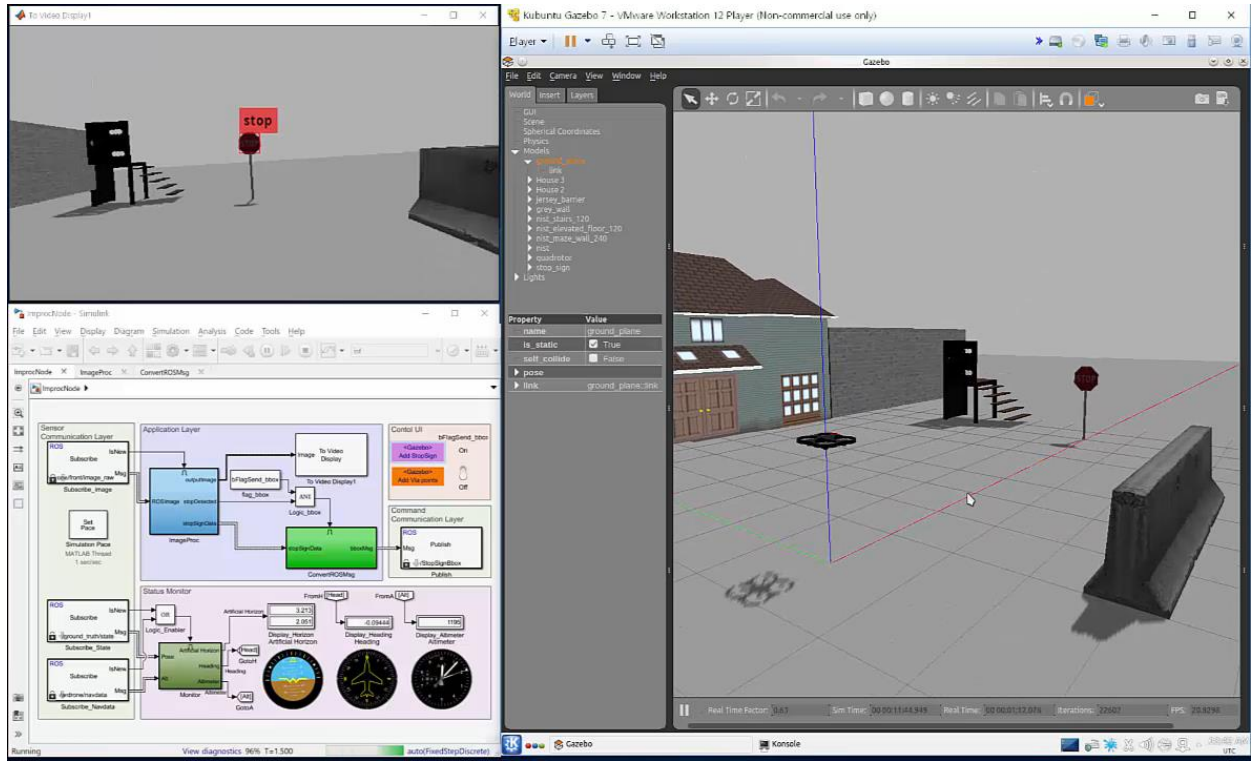
Návrh 3D scén na simuláciu a testovanie autonómnych algoritmov

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

Vizualizácia s Cesium

Streamovanie 3D máp, terénov a budovov v reálnom čase

Kosimulácia s Gazebom



Subscribe to custom messages from Gazebo Server

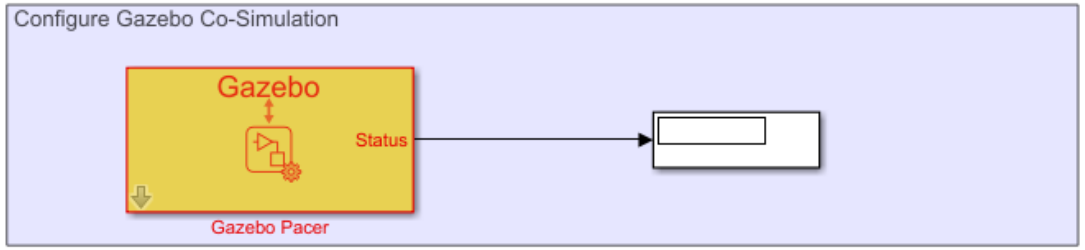
Create blank Gazebo command

Publish custom messages to Gazebo Server

Receive messages from Gazebo server

Select a Gazebo entity

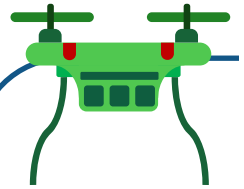
Send command **to Gazebo**



Set synchronized stepping between Gazebo and Simulink

Testovanie algoritmov v prostredí s podporou ROS

Model-Based Design pre UAV aplikácie

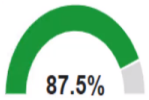


MATLAB®

Simulink®

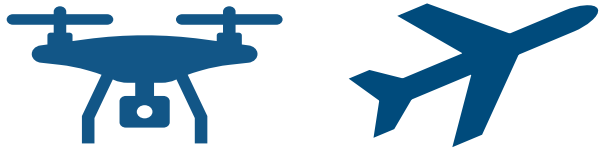
System Architecture

Verification & Validation



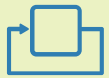
DO-178

Model UAV



Design Algorithms

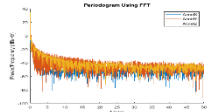
Perception



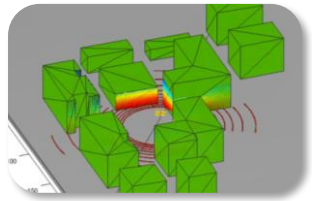
Control

Planning & Decision

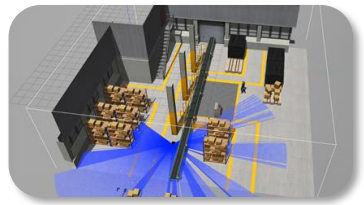
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

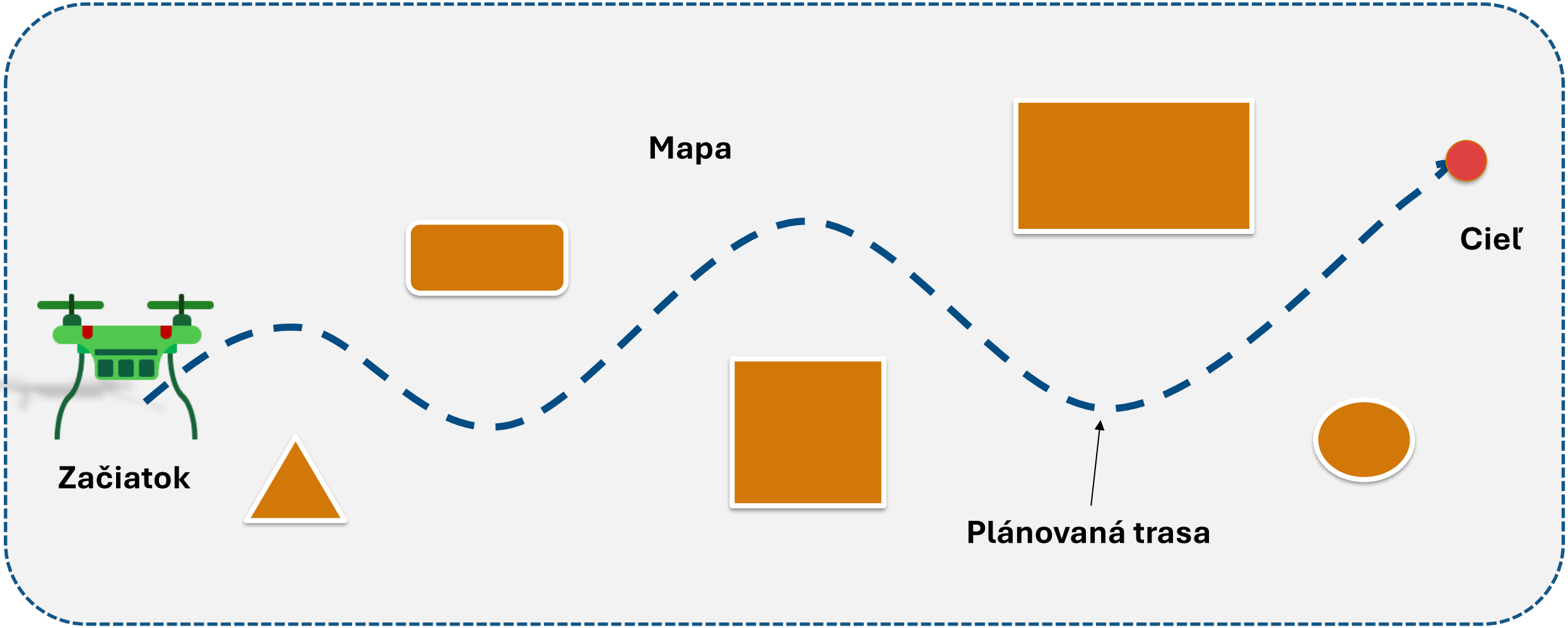
Connect

Connect

UAV

Ground Control Station

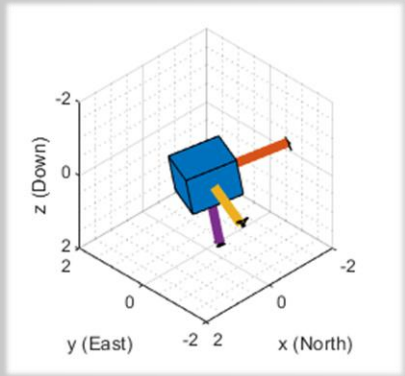
Tvorba algoritmov autonómnych systémov

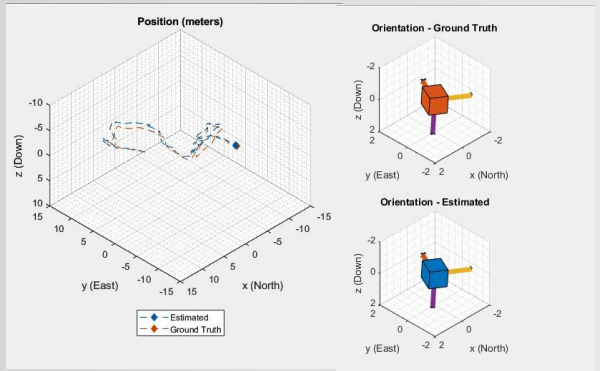


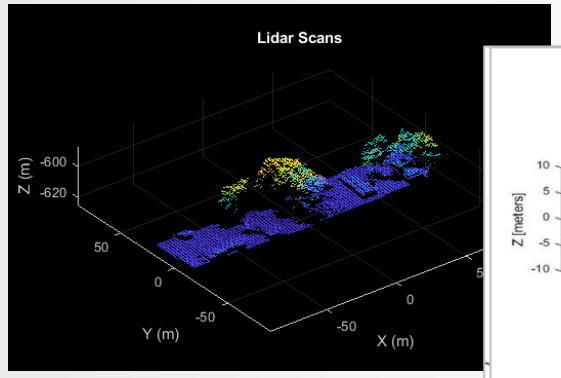
Tvorba algoritmov autonómnych systémov

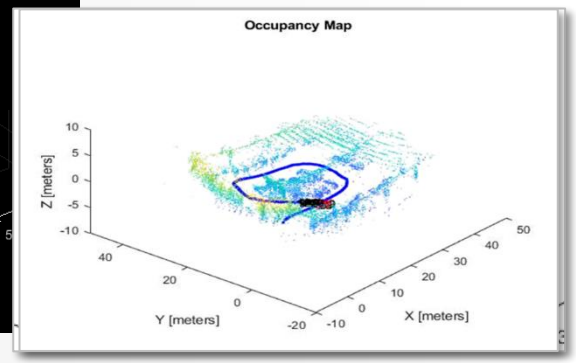
Perception | Planning & Decision | Control

Vlastné vnímanie

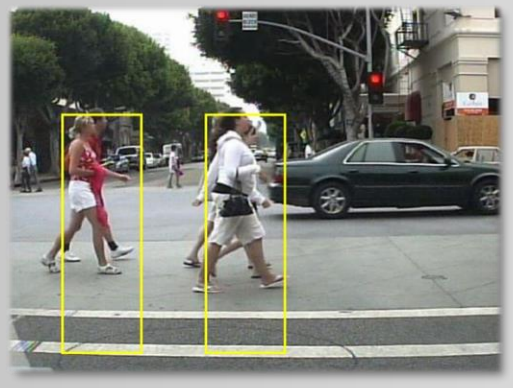


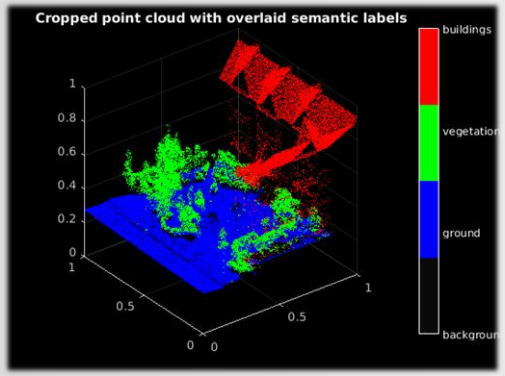




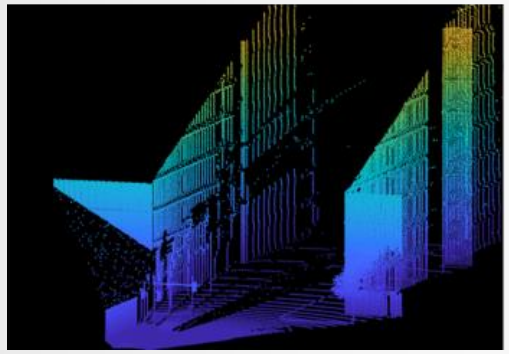


Situačné vnímanie

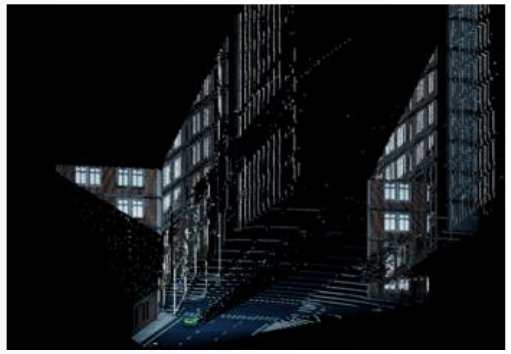




Lidar point cloud data



Fused lidar and camera data

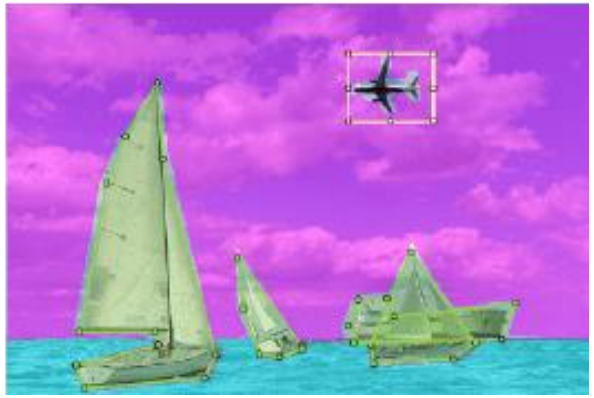


Lidar Toolbox, Navigation Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

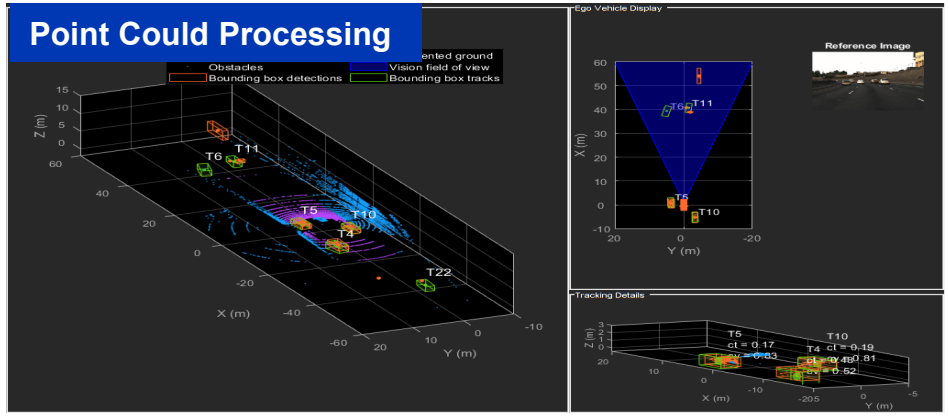
Tvorba algoritmov autonómnych systémov

Perception | Planning & Decision | Control

Image & Video Labeling

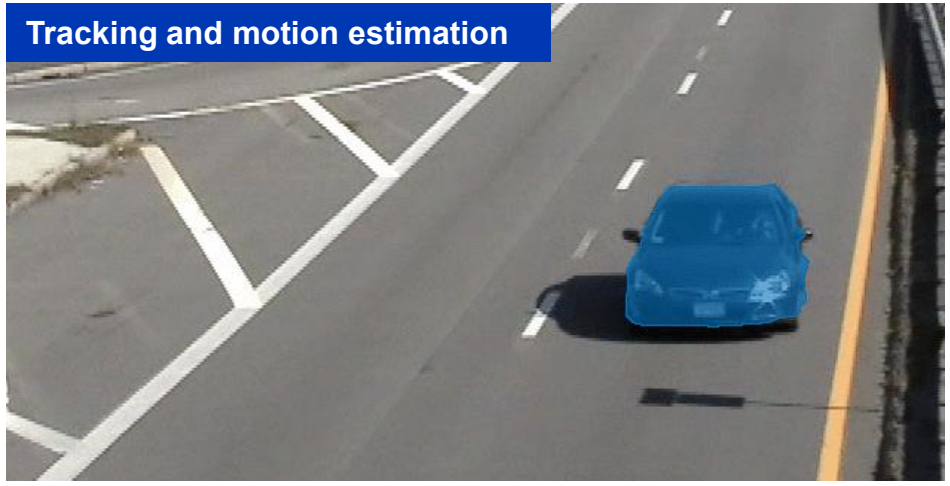


Point Could Processing



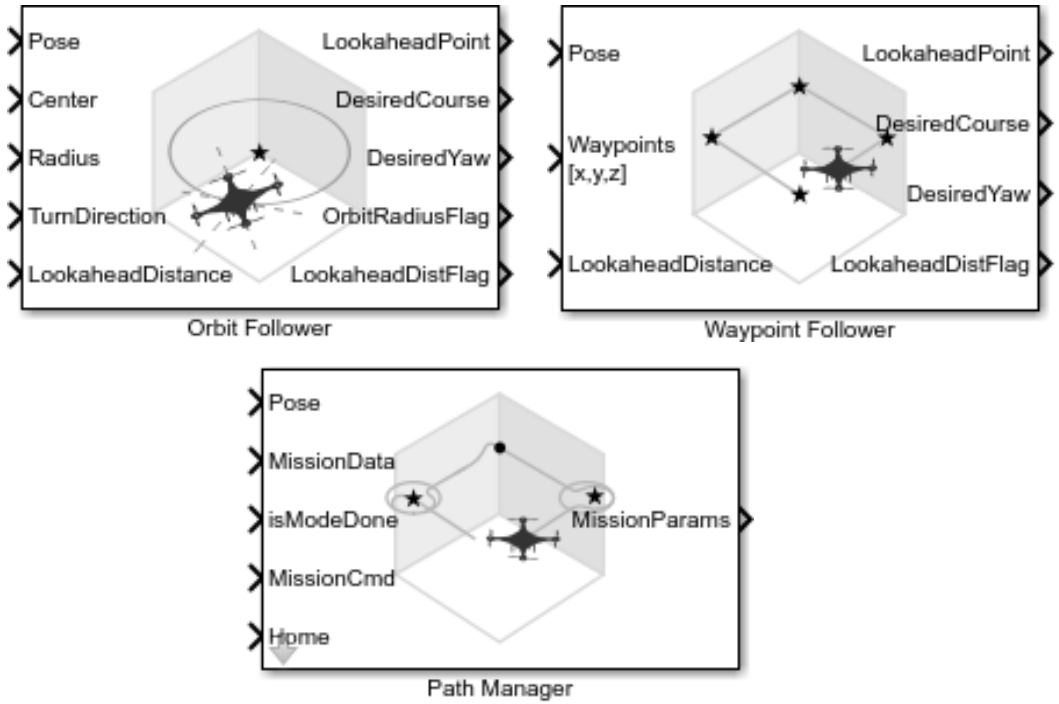
Recognition, Object Detection, and Semantic Segmentation

Tracking and motion estimation

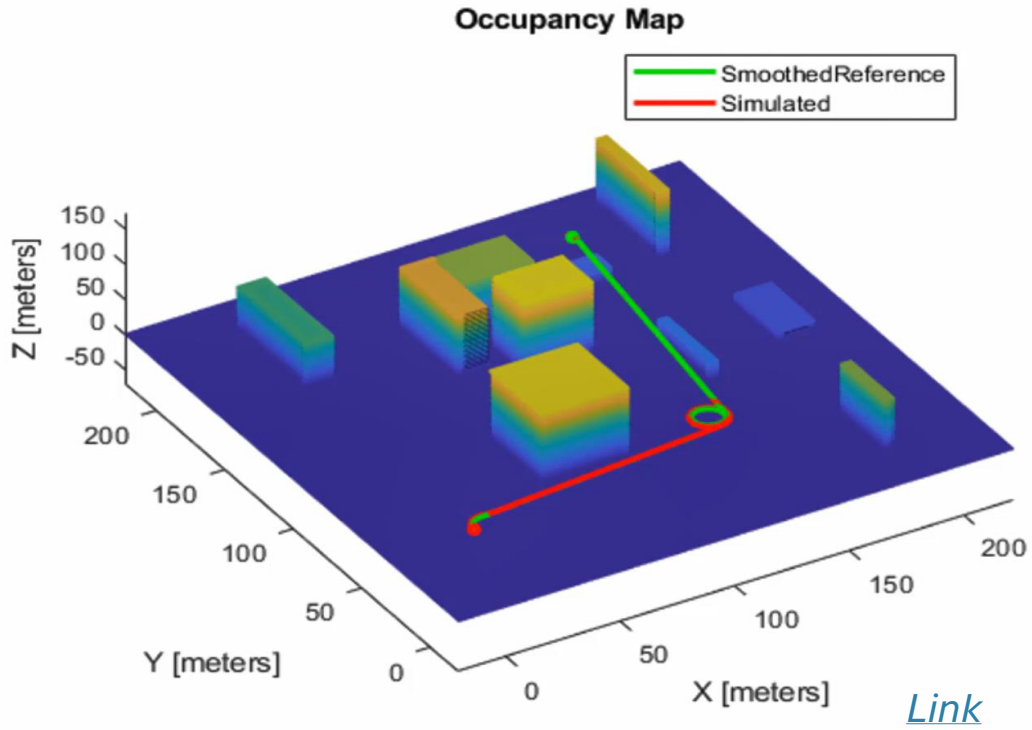


Tvorba algoritmov autonómnych systémov

Perception | **Planning & Decision** | Control



UAV misie pomocou algoritmov sledovania bodov a trajektórií



Link

Plánovanie pohybu UAV s pokročilými plánovačmi trás

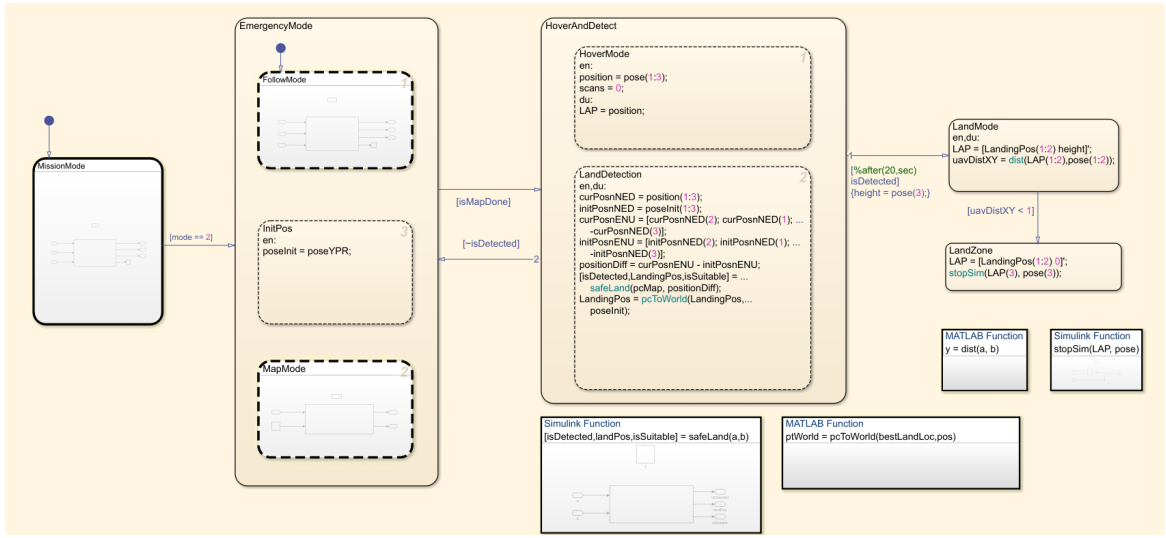
UAV Toolbox, Navigation Toolbox

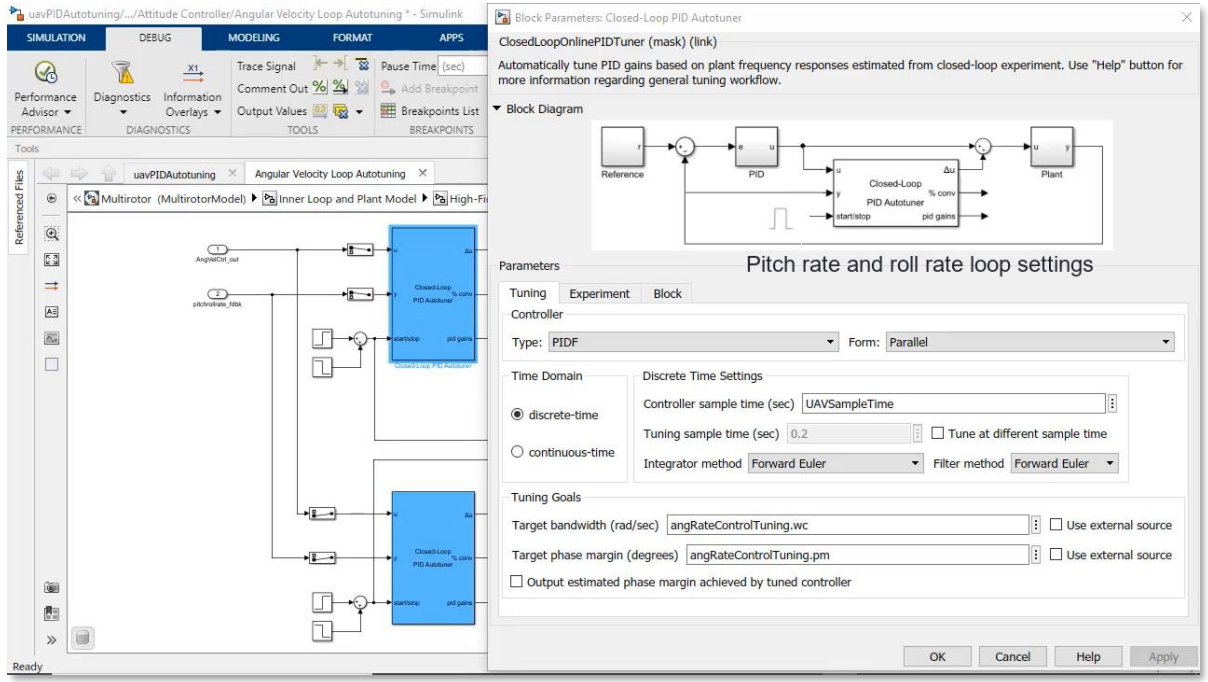
Tvorba algoritmov autonómnych systémov

Perception

Planning & Decision

Control





Nadradená rozhodovacia logika pre bezpečné pristátie

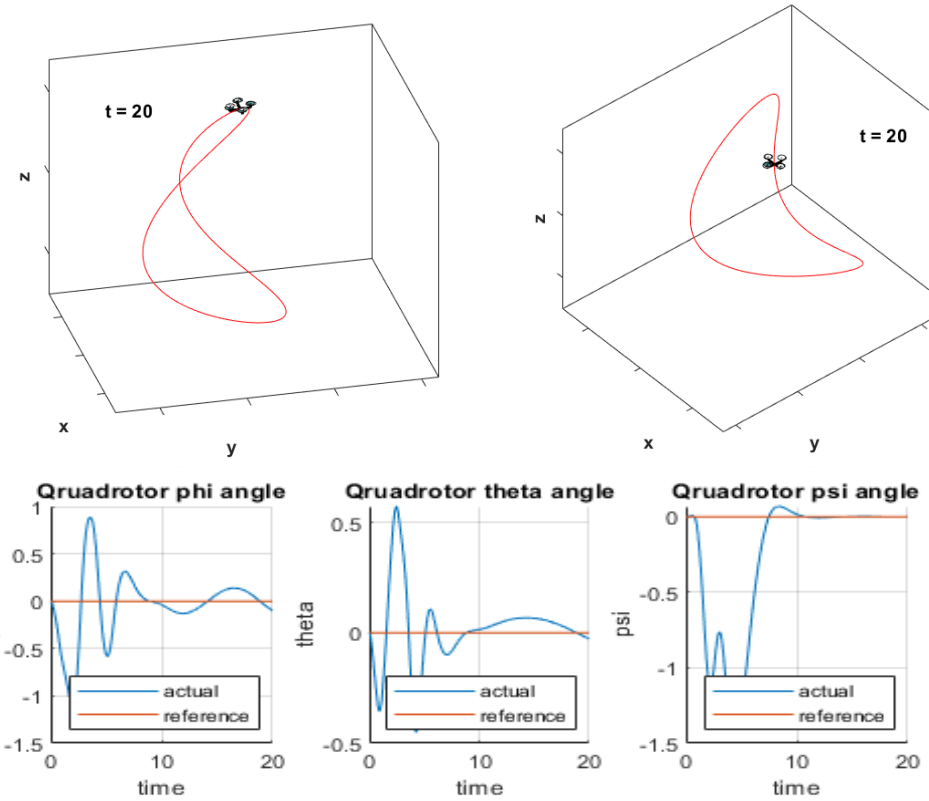
Automatické ladenie viacerých PID regulátorov

Tvorba algoritmov autonómnych systémov

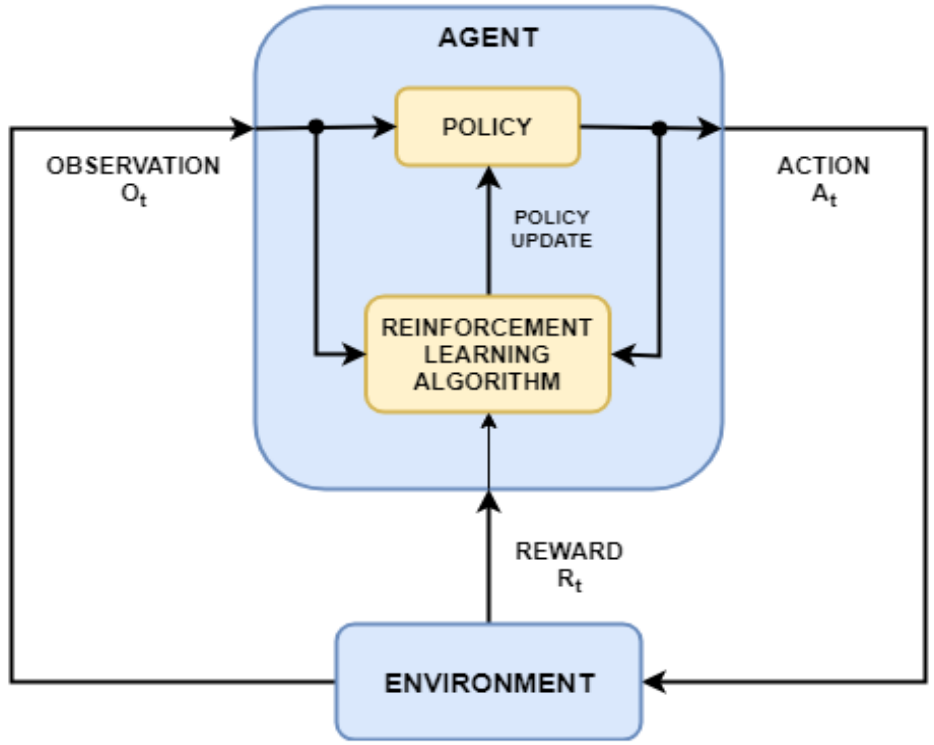
Perception

Planning & Decision

Control



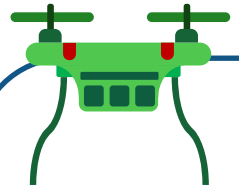
Sledovanie trajektórie s nelineárnym prediktívnym riadením (MPC)



Generovanie trajektórií pomocou metódy Reinforcement Learning

Model Predictive Control Toolbox, Reinforcement Learning Toolbox

Model-Based Design pre UAV aplikácie

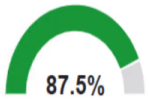


MATLAB®

Simulink®

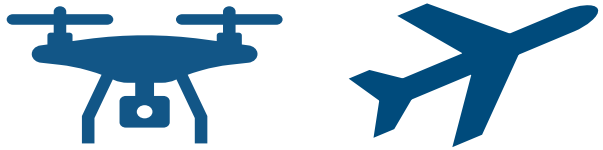
System Architecture

Verification & Validation



DO-178

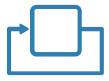
Model UAV



Design Algorithms

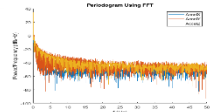
Perception

Planning & Decision

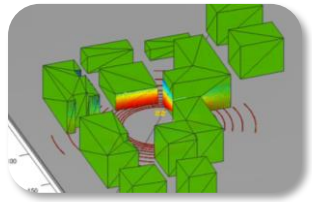


Control

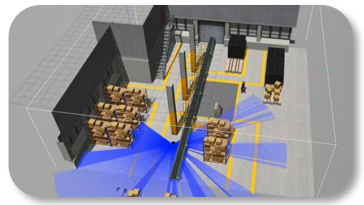
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

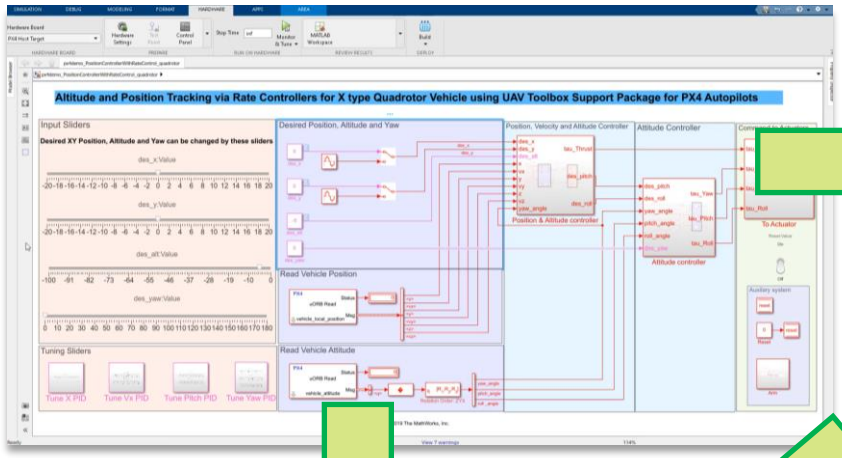
Connect

Connect

UAV

Ground Control Station

Automatické generovanie kódu pre hardvérovú implementáciu



Nasadenie riadenia do hardvéru autopilota

CPU

FPGA

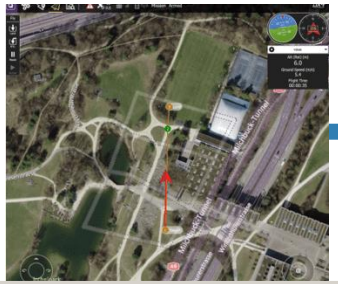
GPU

ROS

Nasadenie autonómnych algoritmov do palubných počítačov

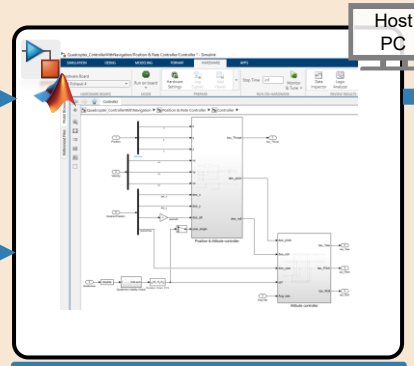
MIL, SIL a HIL pre simuláciu UAV

Inputs



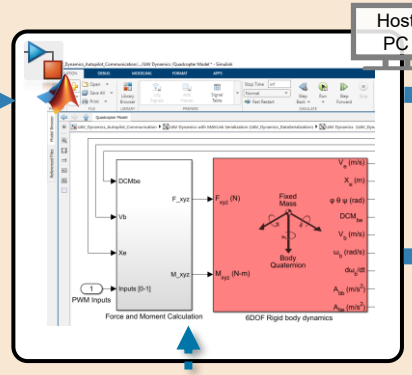
Ground Control Station

Flight Controller



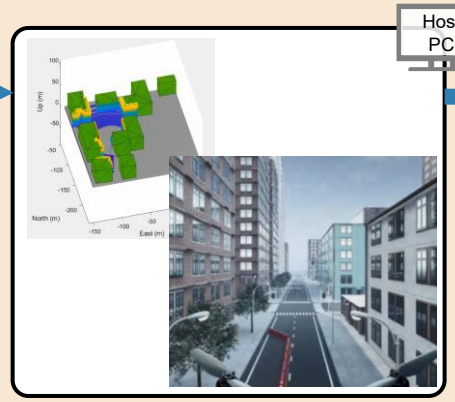
Model-in-the-Loop

Plant Model

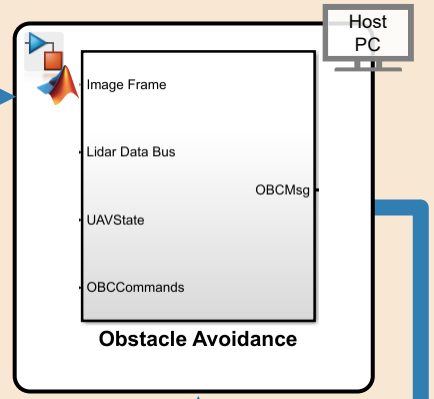


TCP/IP or UDP

Scenario Simulation



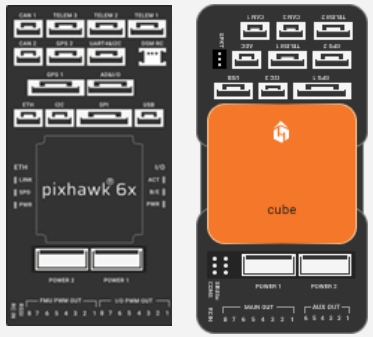
Onboard Autonomy



C++ EXE on Host PC

Software-in-the-Loop

Deploy on Hardware



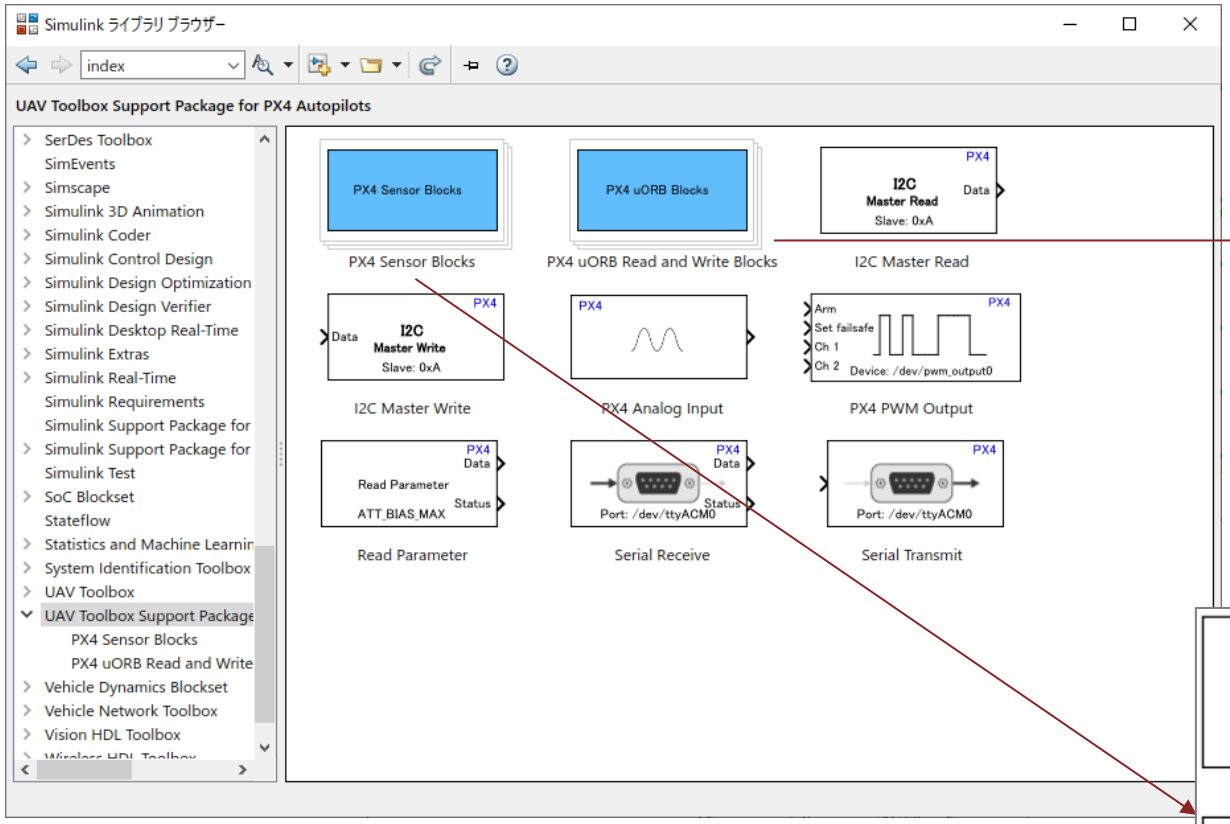
Hardware-in-the-Loop

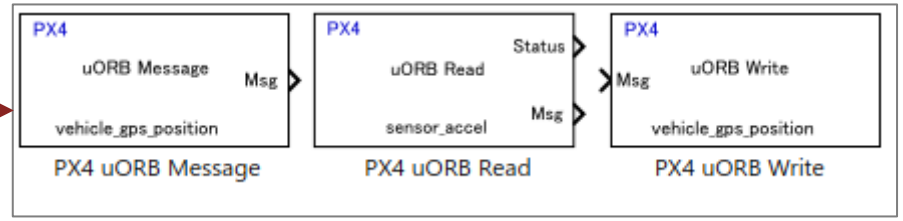
Deploy on Hardware

Deploy on Hardware

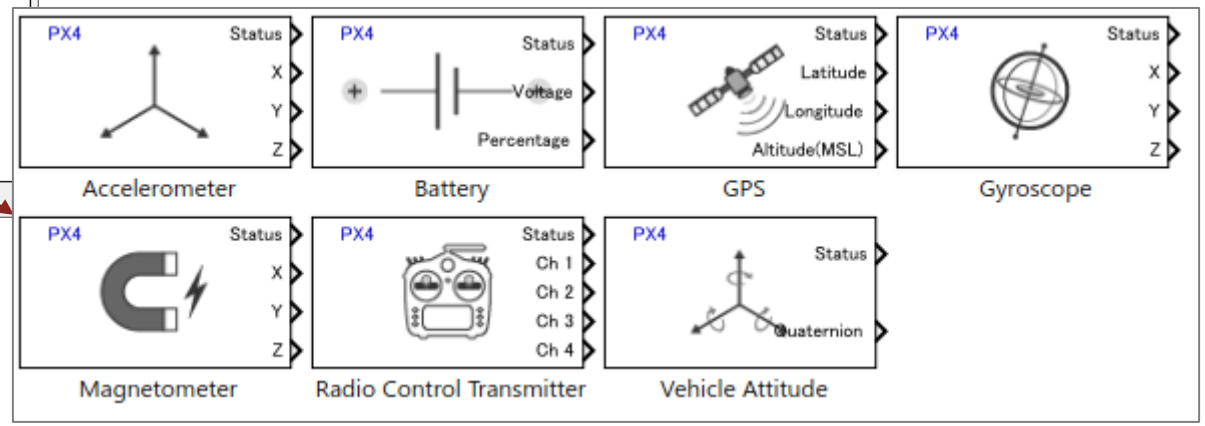
NVIDIA® Jetson™

UAV Toolbox Support Package for PX4 Autopilots

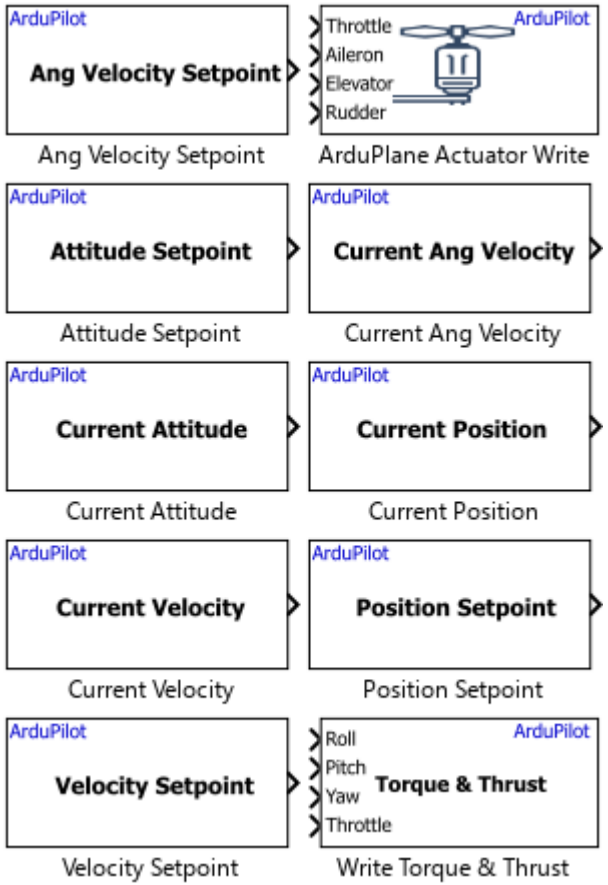




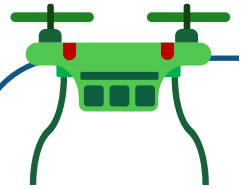
uORB: Asynchronous pub/sub messaging API (middleware)



UAV Toolbox Support Package for ArduPilot Autopilots



Model-Based Design pre UAV aplikácie

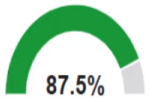


MATLAB®

Simulink®

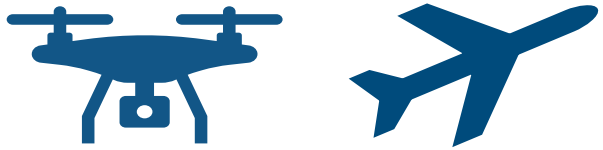
System Architecture

Verification & Validation



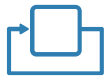
DO-178

Model UAV



Design Algorithms

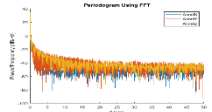
Perception



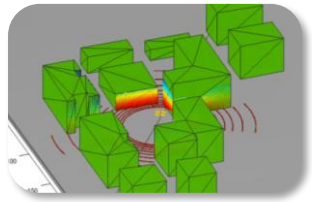
Control

Planning & Decision

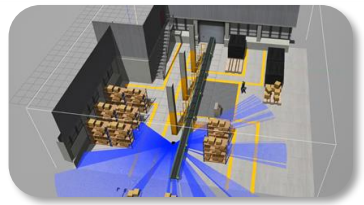
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

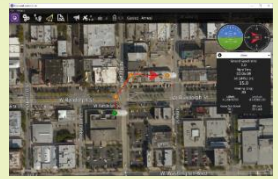
PX4®

NVIDIA® Jetson®

Connect

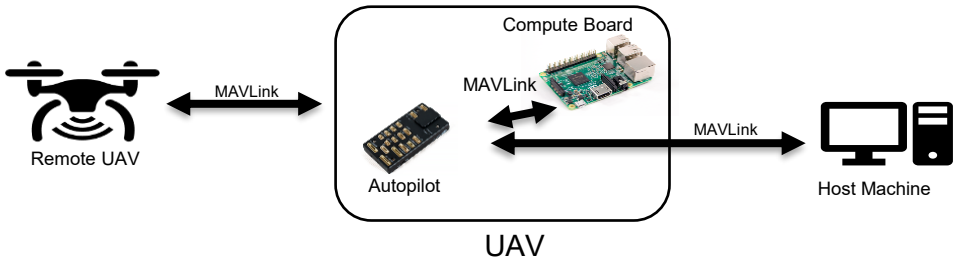
Connect

UAV

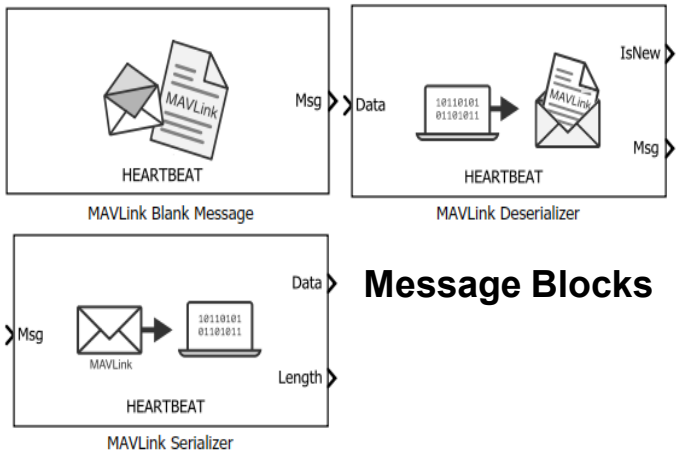


Ground Control Station

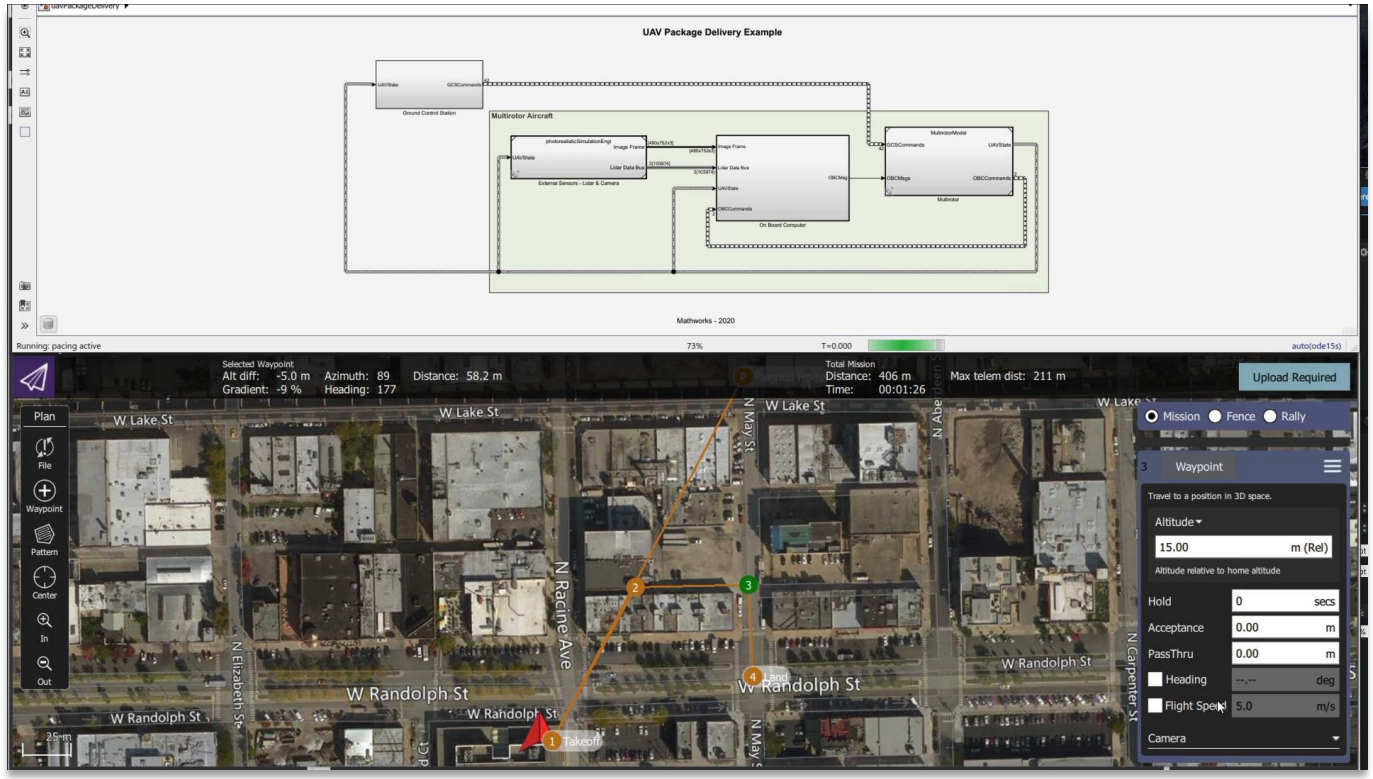
Pripojenie pomocou MAVLink



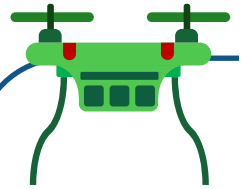
MAVLink Connectivity



Message Blocks



Model-Based Design pre UAV aplikácie

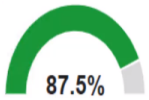


MATLAB®

Simulink®

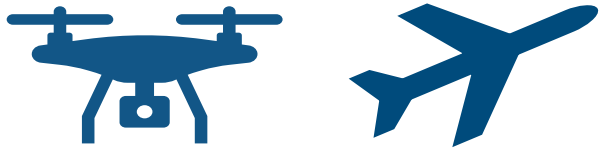
System Architecture

Verification & Validation



DO-178

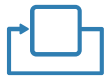
Model UAV



Design Algorithms

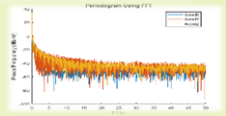
Perception

Planning & Decision

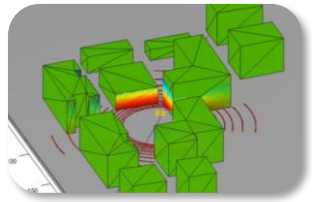


Control

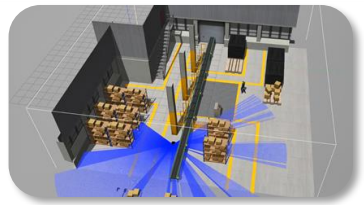
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

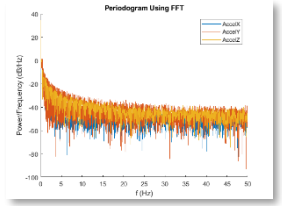
Connect

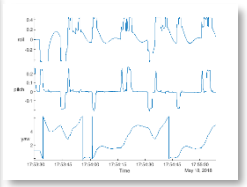
UAV

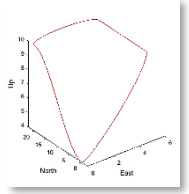
Ground Control Station

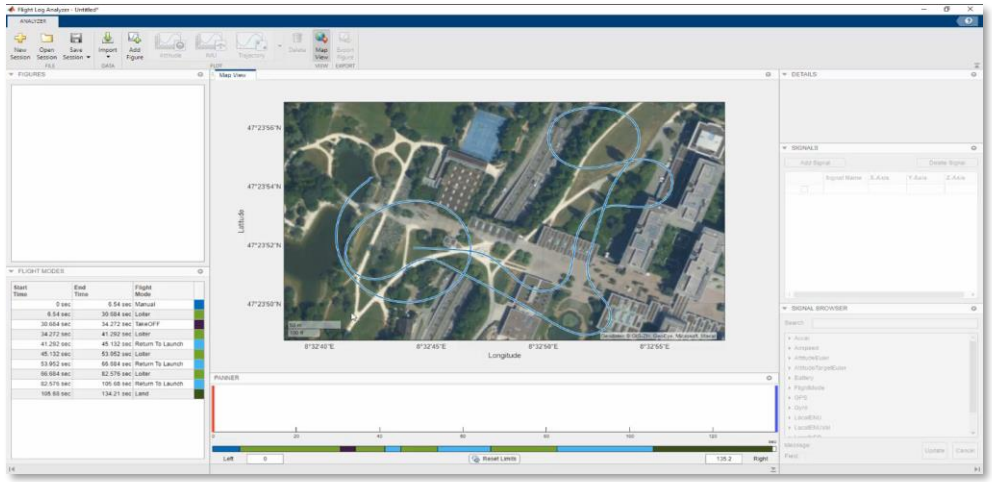
Analýza údajov po lete

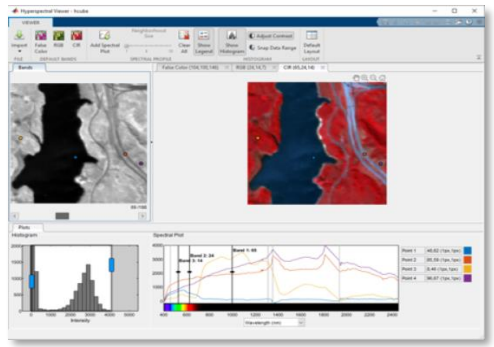
Analýza letu → **Analýza dát**

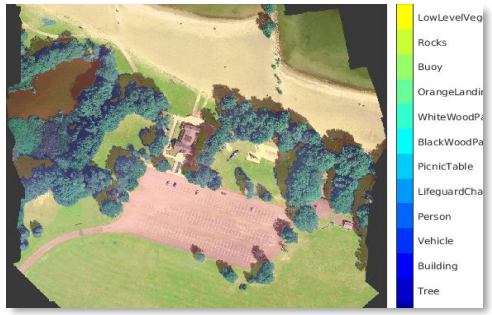






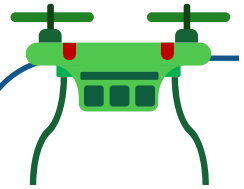






UAV Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

Model-Based Design pre UAV aplikácie

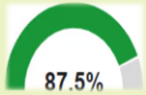


MATLAB®

Simulink®

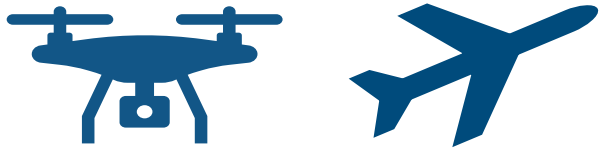
System Architecture

Verification & Validation



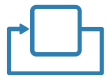
DO-178

Model UAV



Design Algorithms

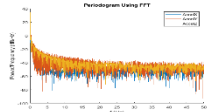
Perception



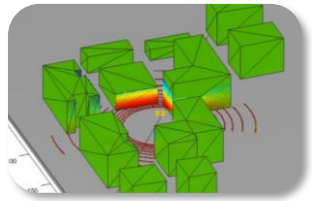
Control

Planning & Decision

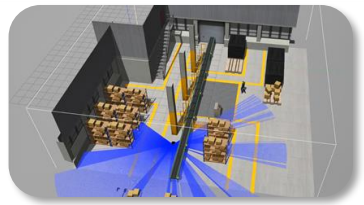
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

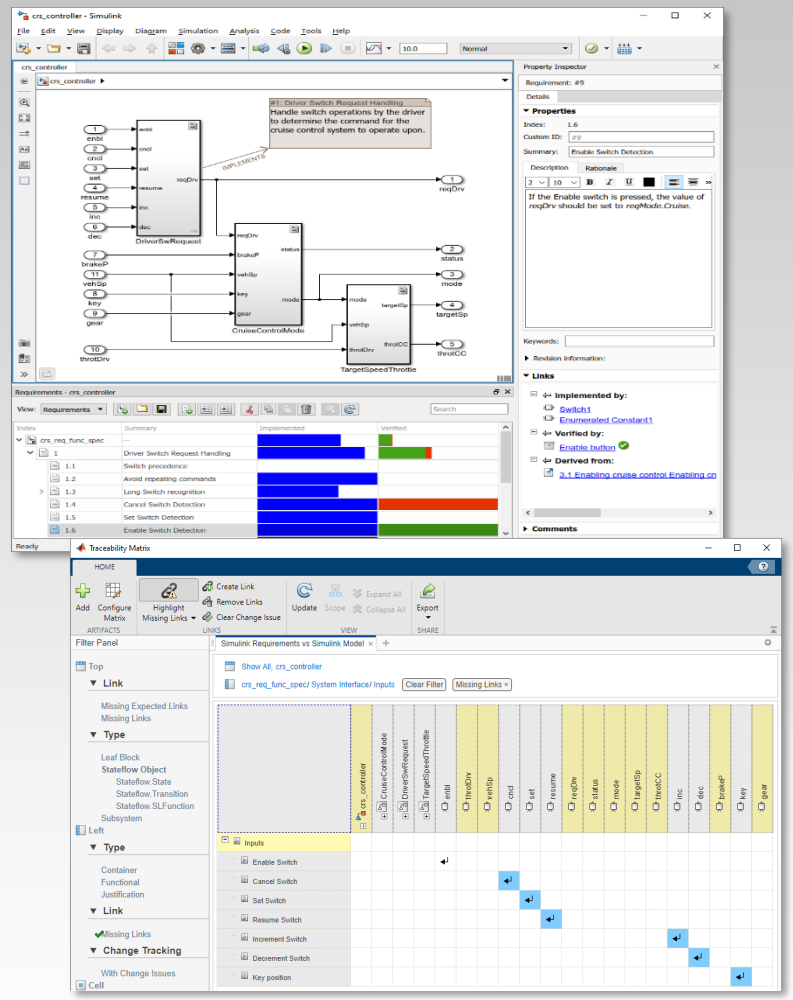
Connect

UAV

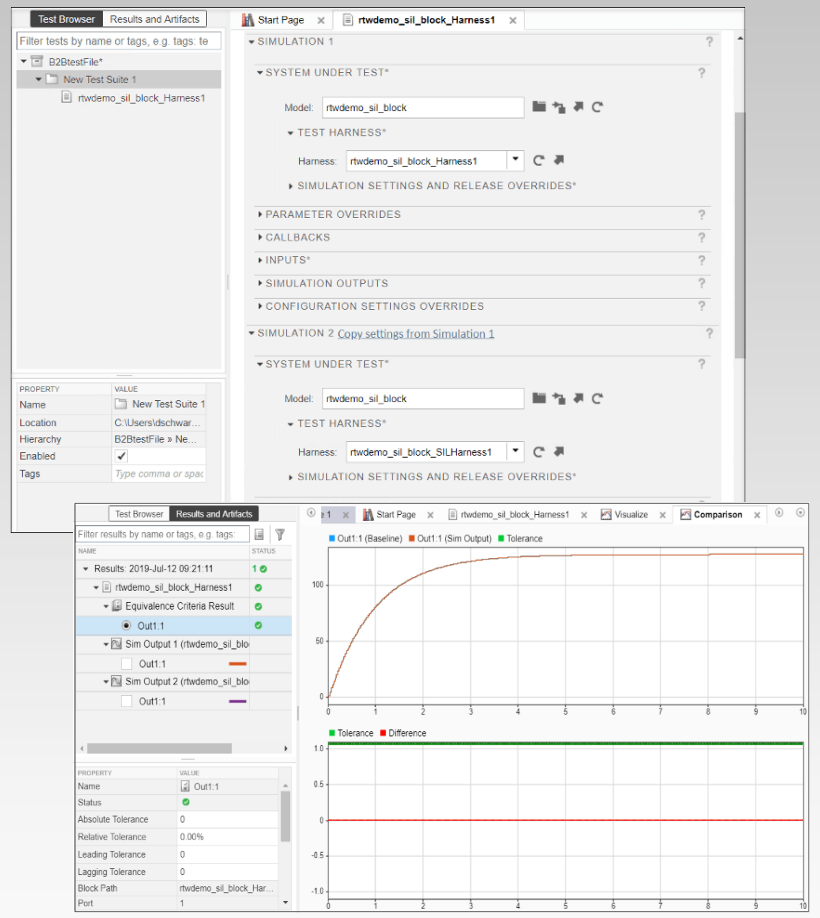
Ground Control Station

Sledovanie a automatizácia verifikácie a validácie

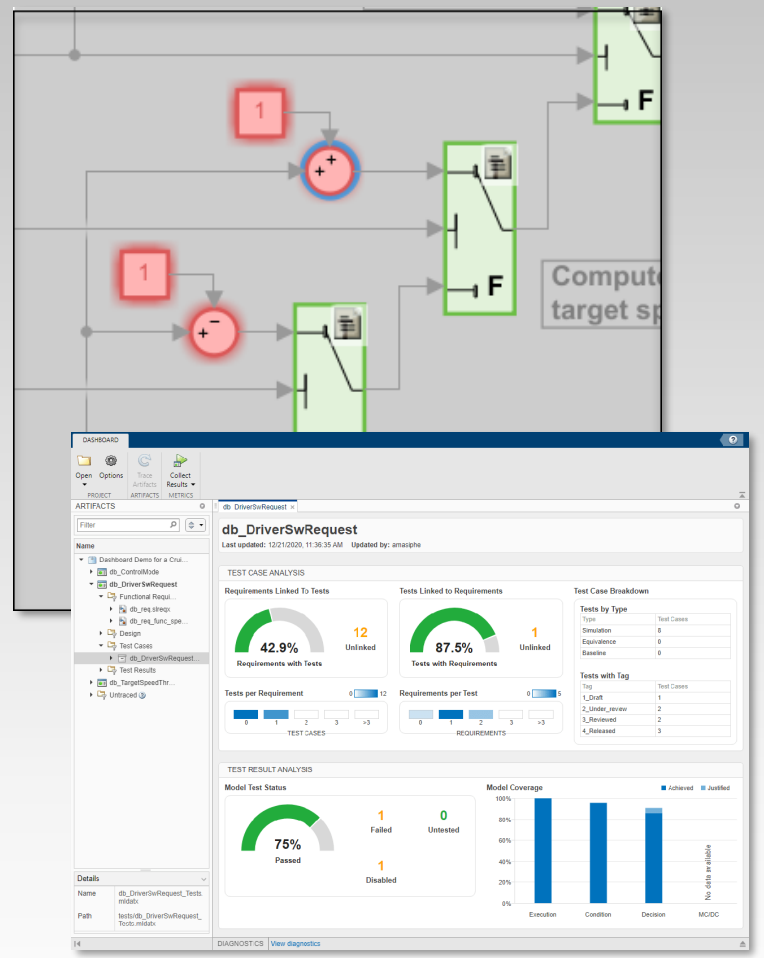
Sledovanie požiadaviek



Správa a automatizácia testov

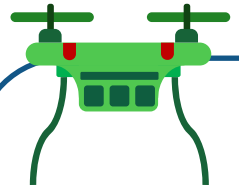


Kvalita a štandardy



Simulink Requirements, Simulink Test, Simulink Coverage, Simulink Check

Model-Based Design pre UAV aplikácie

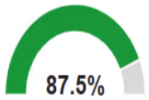


MATLAB®

Simulink®

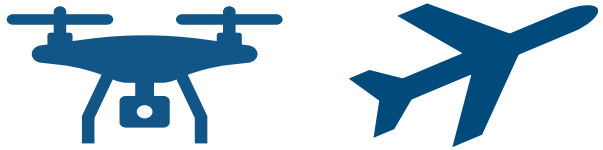
System Architecture

Verification & Validation



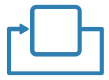
DO-178

Model UAV



Design Algorithms

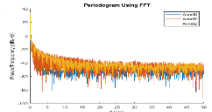
Perception



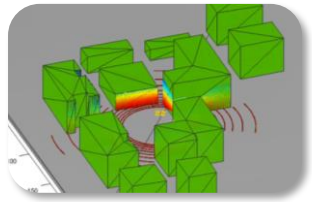
Control

Planning & Decision

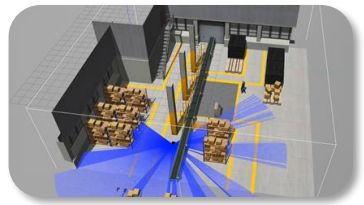
Analyze Data



Simulate with Sensor Models



Cuboid



Gazebo

Unreal Engine

Implement

Deploy to Hardware

PX4®

NVIDIA® Jetson®

Connect

Connect

UAV

Ground Control Station

Ďakujem za pozornosť