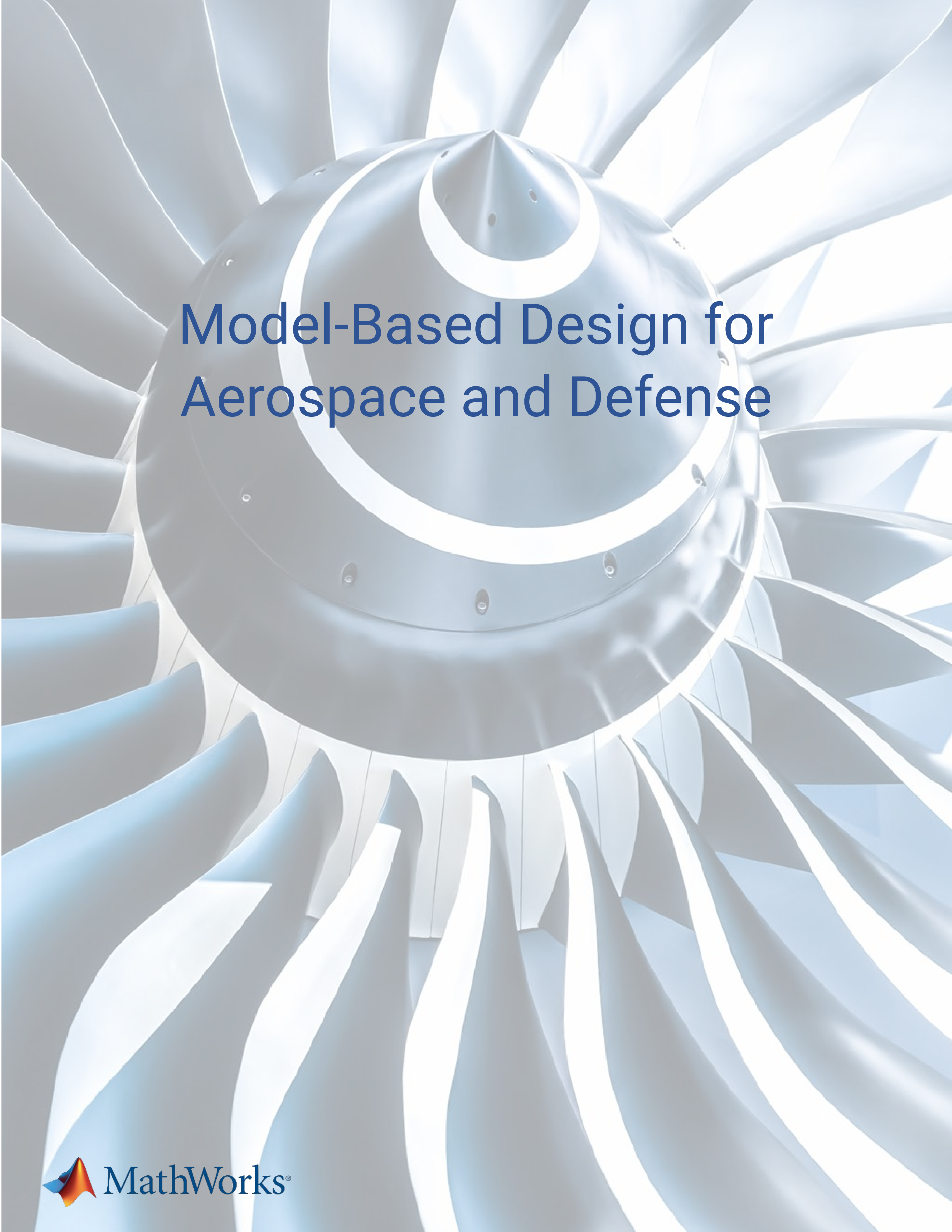


Model-Based Design for Aerospace and Defense

MathWorks®

Introduction

Aerospace and defense companies worldwide rely on MATLAB® and Simulink® across all technology readiness levels, from prototypes to their most important safety-critical and mission-critical systems. MathWorks tools are used in major programs across all domains, such as the aerial, naval, land, and space systems. MATLAB and Simulink are also used to accelerate research and development in areas like autonomous systems, hypersonics, advanced wireless systems, and hybridization and electrification of aircraft.

The added complexity in new aerospace and defense programs challenges traditional ways of design and collaboration. Having a unified digital environment becomes crucial to delivering high-quality systems quickly and cost-effectively. Aerospace and defense organizations use MathWorks tools as a foundation for digital transformation to create digital twins, a digital thread, and DevSecOps pipelines that work with interconnected digital infrastructures.

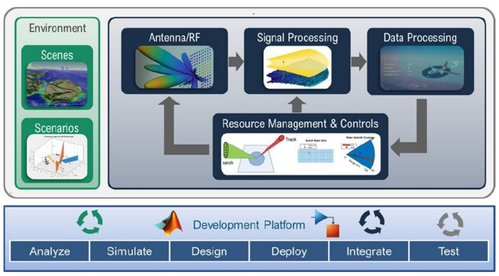
Table of Contents

MATLAB and Simulink for Aeronautics

Platform and Aerodynamics

Aerospace engineers use MathWorks tools to model, simulate and analyze high-fidelity aircraft, rotorcraft and VTOL platforms. The features include vehicle dynamics, validated models of the flight environment, and blocks for pilot behavior, actuator dynamics, and propulsion.   Engineers can visualize and understand aerospace vehicle dynamics by using cockpit flight instruments, connecting to the FlightGear flight simulator, or connecting the simulation to a photorealistic 3D environment with Unreal Engine®

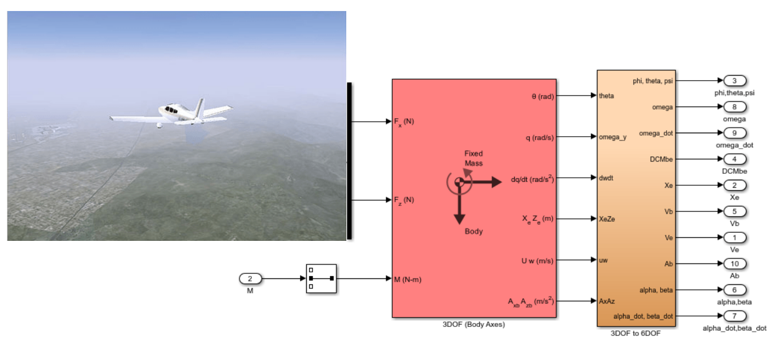
Sensors and Avionics



Engineers design, prototype, and test architectures, and algorithms of the next generation Avionics systems using MATLAB and Simulink. Whether working on radar, radio, flight or engine controls, flight computer, navigation and EW systems, engineers use MATLAB and Simulink to rapidly prove viability of new technology concepts, eliminate design problems early in the development cycle, streamline design verification, and qualify to safety standards like DO-178C – all within the same environment.

Guidance, Navigation and Controls

Control systems engineers use MATLAB and Simulink at all stages of development – from plant modeling to designing and tuning control algorithms and supervisory logic, all the way to deployment with automatic code generation and system verification, validation, and test.



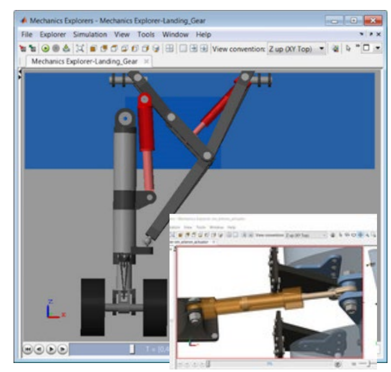
Propulsion Systems

Engineers rely on MathWorks products to design Full Authority Digital Engine Control (FADEC) systems for jet engines, and other propulsion systems that meet rigorous fuel-efficiency and performance requirements. With MATLAB, Simulink, and Stateflow® they can work in one environment to simulate the effect of design changes on the entire system, and quickly visualize and analyze engine-test results.

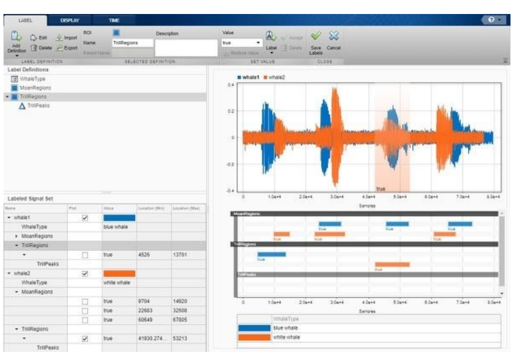
MATLAB and Simulink offer modeling and simulation of electric and hybrid electric aircraft architectures against design criteria such as flight range and flight duration.

Multidomain Physical Systems

Using Simulink, engineers model physical systems spanning across multiple domains such as mechanical, electrical, and hydraulics etc. They build models based on physical connections that directly integrate with block diagrams and other modeling paradigms and perform multibody dynamics in one environment using MathWorks tools.



Artificial Intelligence for Aeronautics



MATLAB and Simulink provide a comprehensive platform for AI applications from predictive maintenance to complex tasks like multimodal target identification.

- Optimize vehicle fleet service using predictive maintenance and digital twin capabilities; develop algorithms for diagnosis and prognosis
- Generate simulation-based training and test data
- Employ deep learning and machine learning algorithms to create accurate models from various datatypes
- Deploy models anywhere including embedded GPUs and CPUs, enterprise systems, or the cloud

MATLAB and Simulink for Naval Systems

Naval engineers use MATLAB and Simulink as a common integration environment throughout the design of surface water or under water systems. From systems engineering to platform modeling, environment simulation, and autonomy algorithm design, Model-Based Design helps you reduce risk and build confidence in system performance well in advance of the sea trial by providing environments for simulating synthesized sensor data such as Unity®, Unreal Engine, and Cuboid. With middleware like DDS and ROS, components and applications can share information and work together as the design matures.

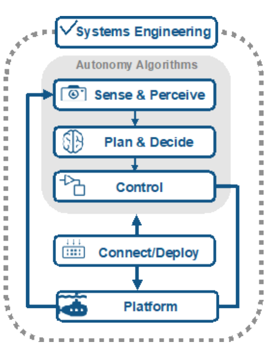
Naval Platform Dynamics and Electromechanical Behaviors

Engineers use MATLAB and Simulink to build powerful yet efficient multidomain models of naval platforms. Physical modeling with Simscape™ and Simscape Multibody™ allows the integration of hydrodynamics, fluid effects, dynamic behaviors, and inertial effects from CAD models. Simscape Electrical™ enables you to build models of power systems with electronic and mechatronic components like batteries and thrusters. With a realistic electromechanical plant model, engineers simulate component failures and evaluate system-level performance.

Control Systems

Engineers use Model-Based Design to design, iterate, and optimize motion planning and path following controllers for ocean vehicles. Engineers can model, simulate and observe coupling effects of the ocean vehicle’s motion in different axes in 2D and 3D.

Sensors and Autonomy

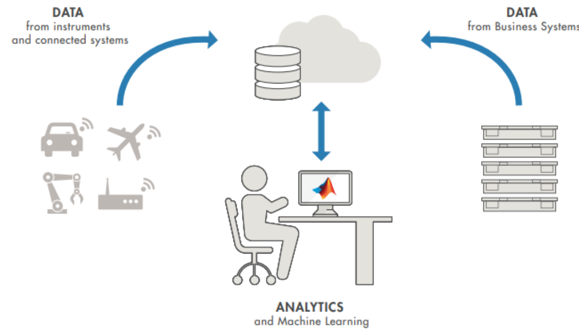


Engineers model sensors, such as sonar, phased arrays, and inertial measurement units (IMU) to prototype how the system senses an environment for sensor fusion, localization, mapping, and tracking. Built-in capabilities of MathWorks tools allows development and integration of latest technologies like deep learning to enhance the vehicle's level of autonomy.

Predictive Analytics

Engineers and scientists use MATLAB to organize, clean, and analyze complex data sets for diagnosis and prognosis applications.

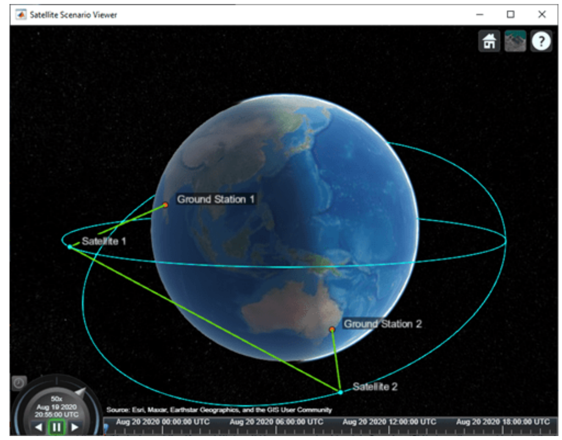
MATLAB provides:



- Datatypes and preprocessing capabilities designed for engineering data
- Interactive and highly customizable data visualizations
- Thousands of prebuilt functions for statistical analysis, machine learning, and signal processing
- Expanded analysis to big data without big code changes
- Automatic packaging of analysis into freely distributable software components or embeddable source code without manually recoding algorithms
- Sharable reports automatically generated from your analysis

MATLAB and Simulink for Space Systems

MATLAB and Simulink provide aerospace engineers with capabilities that speed the development process and improve communication between teams. Engineers use MATLAB and Simulink to:



- Model, simulate, visualize and analyze the motion and dynamics of a spacecraft
- Propagate the orbits of a constellation of satellites
- Perform requirements-based mission analysis
- Conduct trade studies for spacecraft sizing and hardware selection
- Waveform generation, signal recovery, and end-to-end satellite communications link modeling
- Analyze spacecraft telemetry and payload data
- Design detailed guidance, navigation, and control (GNC) algorithms
- Model photo-voltaic (PV) power subsystems and design power electronics components
- Analyze RF and digital communications subsystems and deploy the algorithms on FPGAs
- Generate embedded C and C++ code following space industry standards
- Perform flight software verification and validation

Guidance, Navigation, and Control (GNC)

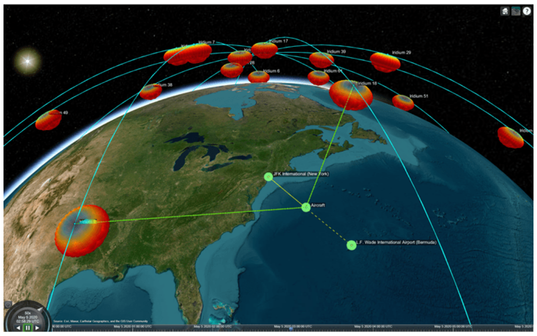
Using MATLAB and Simulink, space engineers test their control algorithms with plant models before implementation to achieve complex designs without using expensive prototypes. In a single environment, you can work on:

- Building and sharing GNC models
- Integrating and simulating system-level effects of controls and mechanical design changes
- Reusing automatically generated flight code and test cases
- Integrating new designs with legacy designs and tools

Power Systems

Space engineers use Model-Based Design for tasks like running simulations for mission power profile analysis, predicting the system impacts of battery aging, and performing detailed design of electrical components such as DC-DC converters. Using MATLAB and Simulink, engineers can also include thermal and attitude effects in their models to perform multidomain simulation within one environment.

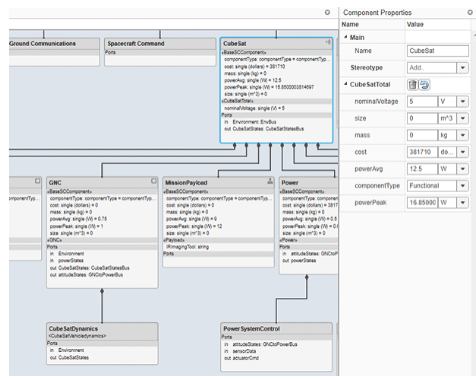
Communications and Radar Systems



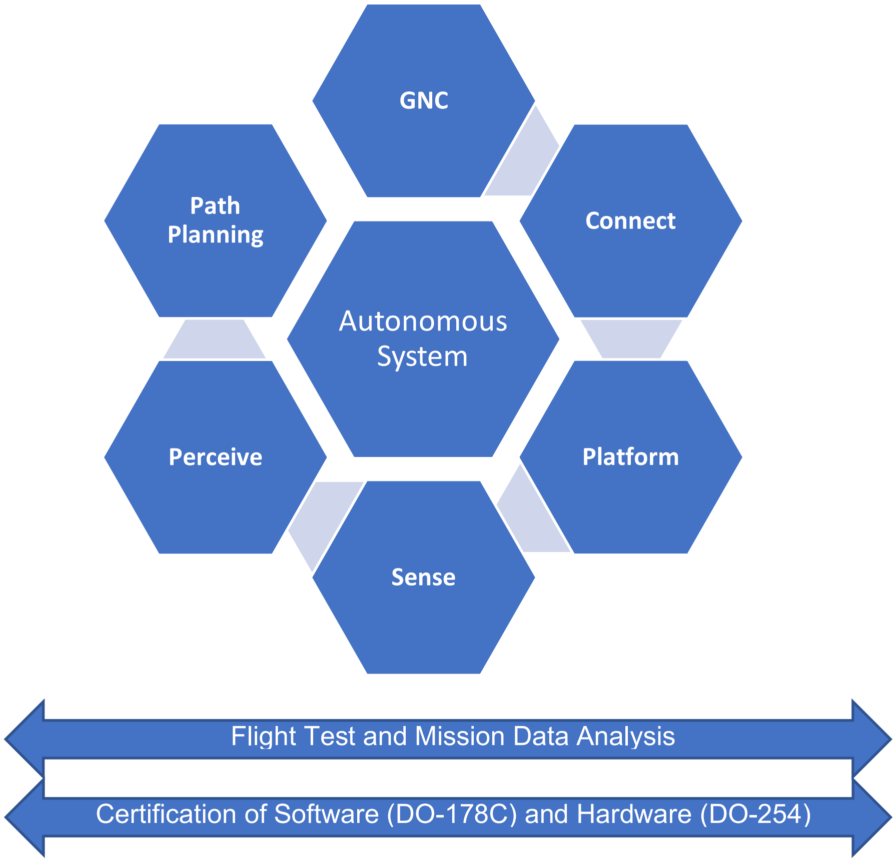
Space engineers use MATLAB and Simulink as a common design environment to develop, analyze, and implement spacecraft radar and communications systems. You can model and visualize satellite orbits, perform link analysis, and access calculations. MATLAB and Simulink help you prototype signal chain elements—including RF, antenna, and digital elements—and combine the work of multiple teams as a system-level executable model.

Systems Engineering

Model-Based Design enables engineers to create space and ground system architectures, define interfaces, and perform trade studies to evaluate their designs. Engineers can trace between levels of requirements and architectures and perform requirements allocation. Engineers can insert executable models into the architecture and can add fidelity to the underlying system behaviors with executable multidomain spacecraft and ground system models to verify and validate requirements, providing insights into system-level behavior and performance that cannot be obtained by static analysis alone.



MATLAB and Simulink for Autonomous Systems



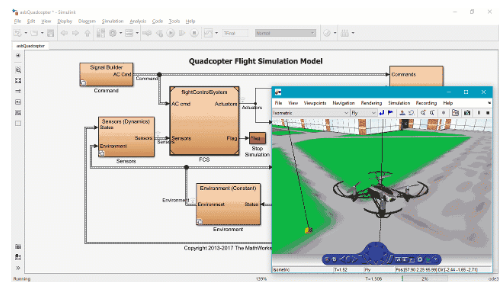
Engineers and researchers use MATLAB and Simulink to design and tune algorithms, model real-world systems, automatically generate and verify the code – all from one software environment.

MATLAB and Simulink enable users to:

- Model and analyze an autonomous system architecture
- Design flight control algorithms and simulate with a plant model while including environmental factors
- Develop perception and motion planning systems for autonomous flight using prebuilt algorithms, sensor models, and apps for computer vision, lidar and radar processing, and sensor fusion
- Evaluate vehicle performance in a closed-loop 3D simulation environment
- Automatically generate production code to deploy to flight controllers and onboard compute boards
- Connect to and control the vehicle from MATLAB and Simulink
- Analyze UAV flight telemetry and payload data

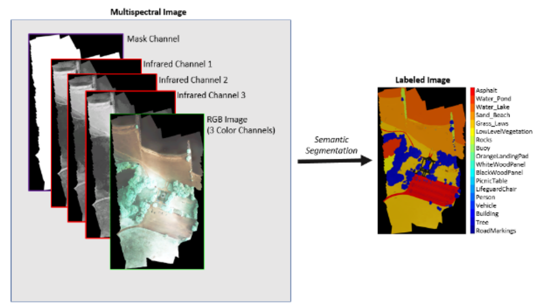
Guidance, Navigation, and Control

Develop high-integrity flight control software for UAVs and verify the software throughout development using a variety of techniques, including simulation, unit tests, formal tests, and hardware-in-the-loop (HIL) simulations. Engineering teams can accelerate these verification steps, as well as the overall development of UAV flight control software, with Model-Based Design.



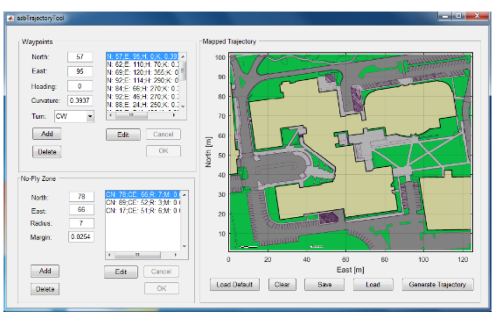
Sensor Data Acquisition

Sensors can be connected through ROS. Specific sensors, such as cameras, lidars, radars, and IMUs, have [ROS messages] that can be converted to MATLAB data types for analysis and visualization. Also, in-built models can be used to synthesize sensor data and test algorithms.



Perception

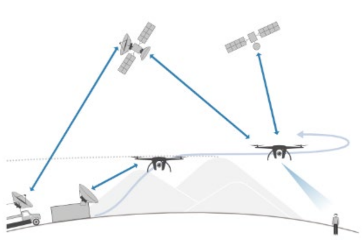
Built-in MATLAB apps enable interactively perform [object detection] and tracking, motion estimation, 3D point-cloud processing, and sensor fusion. [Deep learning can be used] for image classification, regression, and feature learning using convolutional neural networks (CNNs).



Path Planning

A map of the environment can be created using the lidar sensor data via [Simultaneous Localization and Mapping (SLAM)].
Navigate constrained environments by designing algorithms for [path and motion planning]. Use path planners to compute an obstacle-free path in any given map.

Connect and Communicate



- Connect to common UAV autopilots, such as PX4, and low-cost hardware like Raspberry Pi™
- Connect to UAV hardware using the Micro Air Vehicle Link (MAVLink) communication protocol
- Perform scenario modeling, end-to-end link-level, and system-level simulation

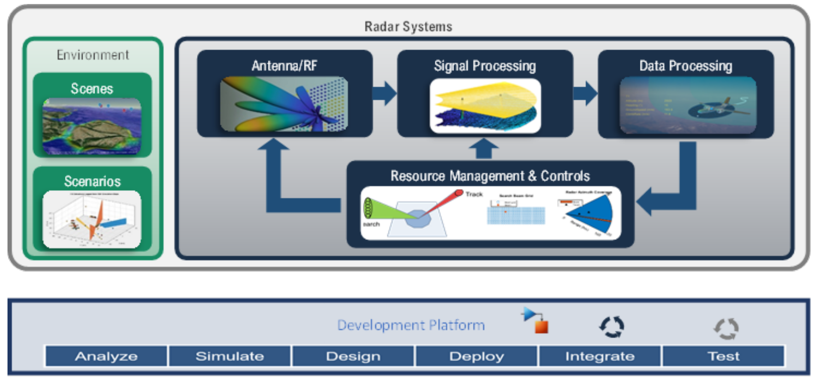
Flight Test and Mission Data Analysis

With MATLAB and related data analysis products, perform analyses and gain insight into data in a fraction of the time required with spreadsheets or traditional programming languages.

Flight test data algorithms can be implemented to use the raw data to calculate air speed, altitude, Mach number, and flight path acceleration, as well as the aircraft’s moments and products of inertia.

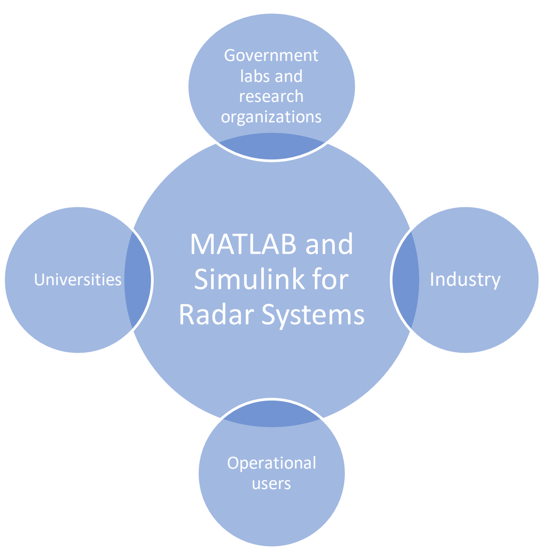
MATLAB and Simulink for Radar, Communications, and Electronic Warfare

MATLAB and Simulink are used to model complex radar systems and test with realistic scenarios that span across air, land, underwater, and space applications.



Engineers use MATLAB and Simulink to:

- Design and analyze multifunction, cognitive, and synthetic aperture systems interactively
- Model and simulate wireless systems at power level, measurement level, and waveform level
- Design end-to-end wireless systems, such as from the antenna array to radar signal processing to data processing and control
- Shorten development cycles by automating key steps such as reporting, coding, and verification
- Accelerate simulations and generate C/C++ and HDL code to target MCUs, GPUs, SoCs, and FPGAs
- Model coexistence of radar and communication systems
- Train, evaluate, and deploy deep learning models



Radar systems using Model-Based Design with MATLAB and Simulink improve collaboration across teams and organizations.

Premier
MATLAB and Simulink helped to create multidomain simulations, thus making it easy to pass the designs between different teams involved in the radar design.

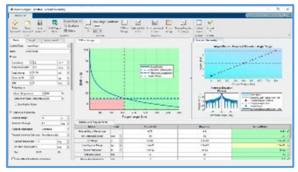
Faster
MathWorks tools for Model-Based Design enabled us to present artifacts to the certification authority much faster than previously possible.
\- **Leonardo**

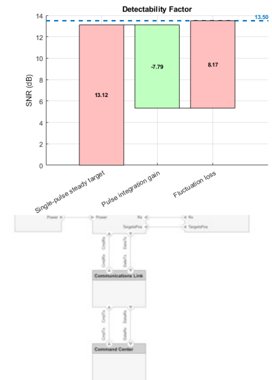
Better
With standalone online courses of MATLAB and Simulink training, we have full control of our tools to develop an underwater deep learning application.
\- **DRASS**

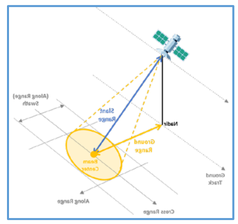
Jump Start Radar, Comms, and EW Systems Design with MATLAB and Simulink

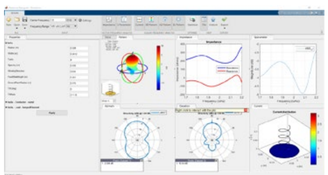
Systems Engineering

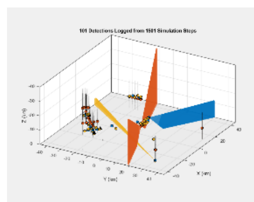
- Link budget analysis
- Feasibility analysis
- MTI performance analysis
- Statistics for detection and tracking
- System architecture
- Image formation for SAR

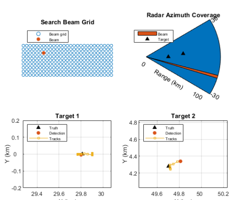


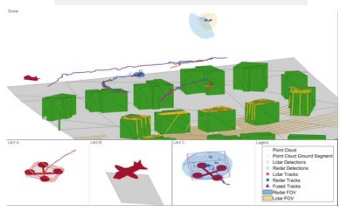










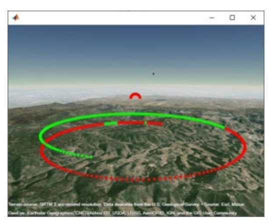


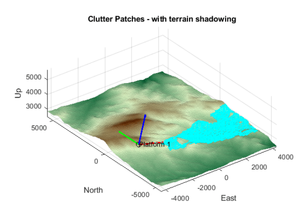
Subsystems

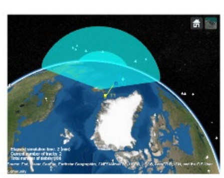
- Antenna array design and optimization
- RF budget analysis
- RF models for transceivers
- Beamforming and DOA estimation
- Detection and range and Doppler estimation
- Trackers for surveillance systems
- Adaptive tracking
- Multisensor fusion
- C/C++ and HDL code generation

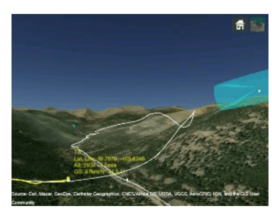
Scenario Generation

- Platforms and targets
- Waveform design
- Sensors and signal synthesis
- Land and sea clutter
- RF propagation
- 3D coverage analysis

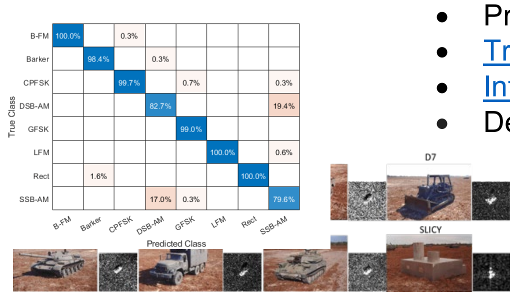








AI for Wireless Systems

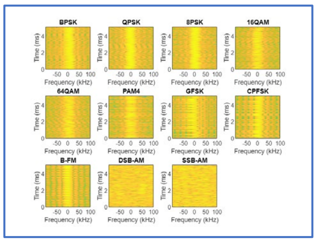


- Preprocess and label data
- Train and evaluate AI models
- Integrate with frameworks based on Python®
- Deploy code in embedded hardware or in the cloud

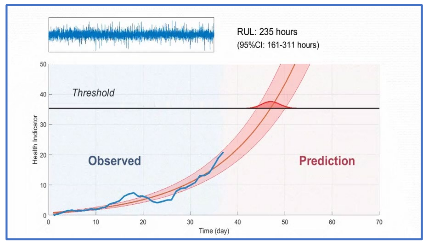
AI for Aerospace and Defense

MATLAB and Simulink provide a comprehensive platform for solving AI challenges from predictive maintenance to complex tasks like multimodal target identification. MATLAB empowers engineers even if they have limited AI experience. It helps teams better AI datasets, tackle integration challenges, reduce risk, and continuously test models in a system-wide context.

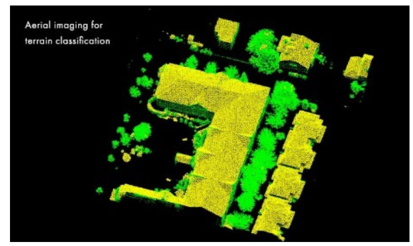
AI applications include:



AI-enabled Radar, Comms and EW Systems



Predictive Maintenance: Diagnosis and Prognosis



Autonomy: Perception, Planning, and Control

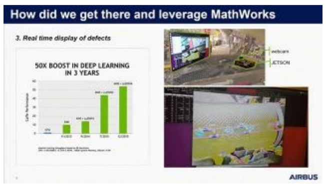
AI Application Workflow with MATLAB and Simulink

Data Preparation	AI Modeling	Simulation and Test	Deployment
Data cleansing and preparation	Model design and tuning	Integration with complex systems	Embedded devices
Human insight	Hardware accelerated training	System simulation	Enterprise systems
Simulation-generated data	Interoperability	System verification and validation	Edge, cloud, desktop

- Use a complete AI workflow with a unified MATLAB-based or Simulink-based framework
- Prepare data using apps for text, audio, signal, image, and video data
- Interactively design and select features from raw data
- Train and compare a range of AI models

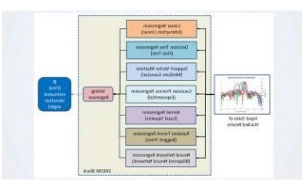
- Accelerate training of AI models
- Integrate AI models into Simulink and verify behavior
- Optimize product design using built-in AI techniques
- Test AI models in MIL/SIL/PIL mode
- Generate optimized C/C++/CUDA code from AI models for embedded hardware
- Verify compliance with DO-178C standard and EASA guidelines

AI Application Examples



[Airbus Uses AI and Deep Learning for Automatic Defect Detection]

[Edwards Air Force Base Accelerates Flight Test Data Analysis]



[Bharat Electronics Applies AI to Elevation Estimations from 3D Radar]

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