supernal

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Functional Simulator: A model-based simulation system of systems approach to emulating eVTOL aircraft.

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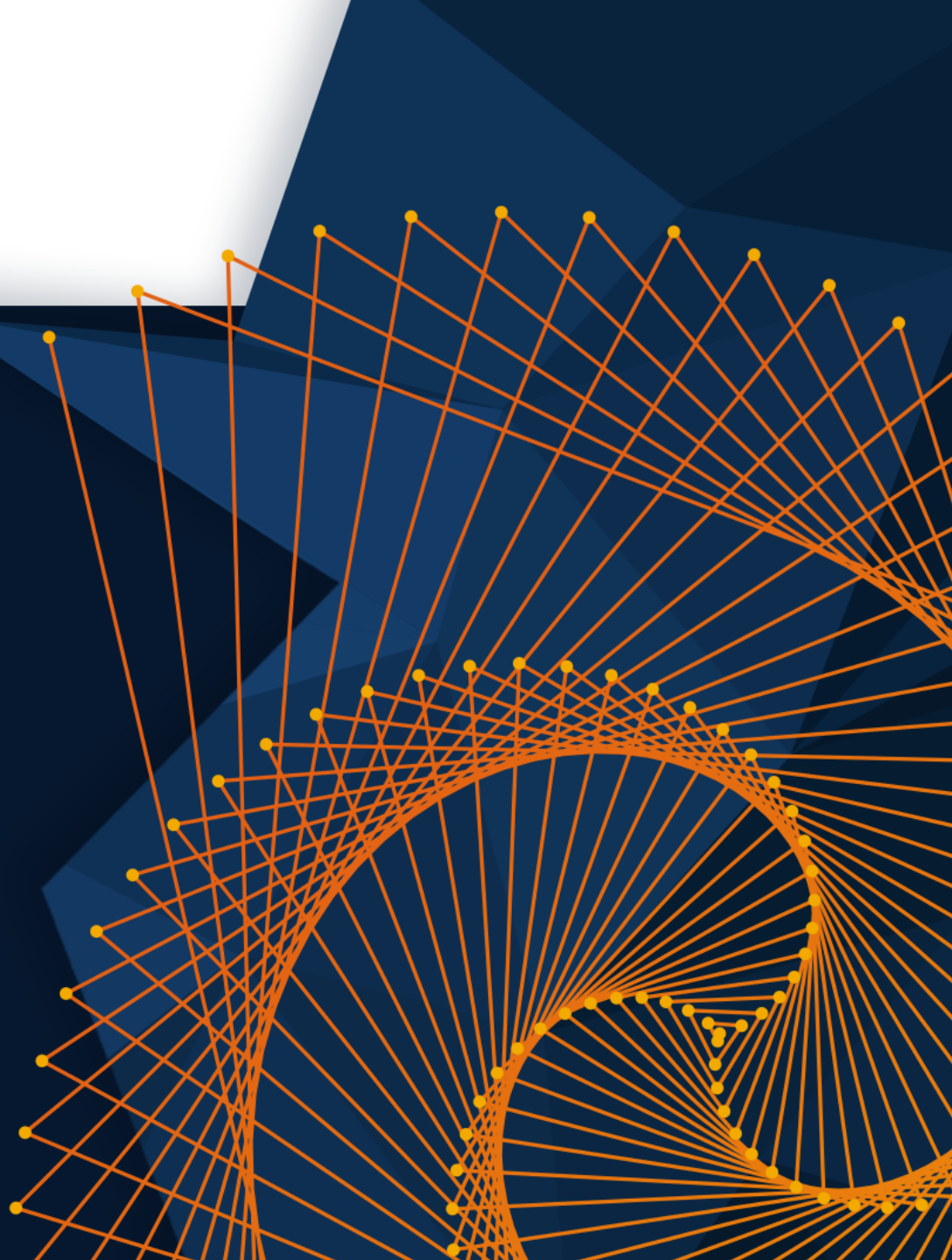
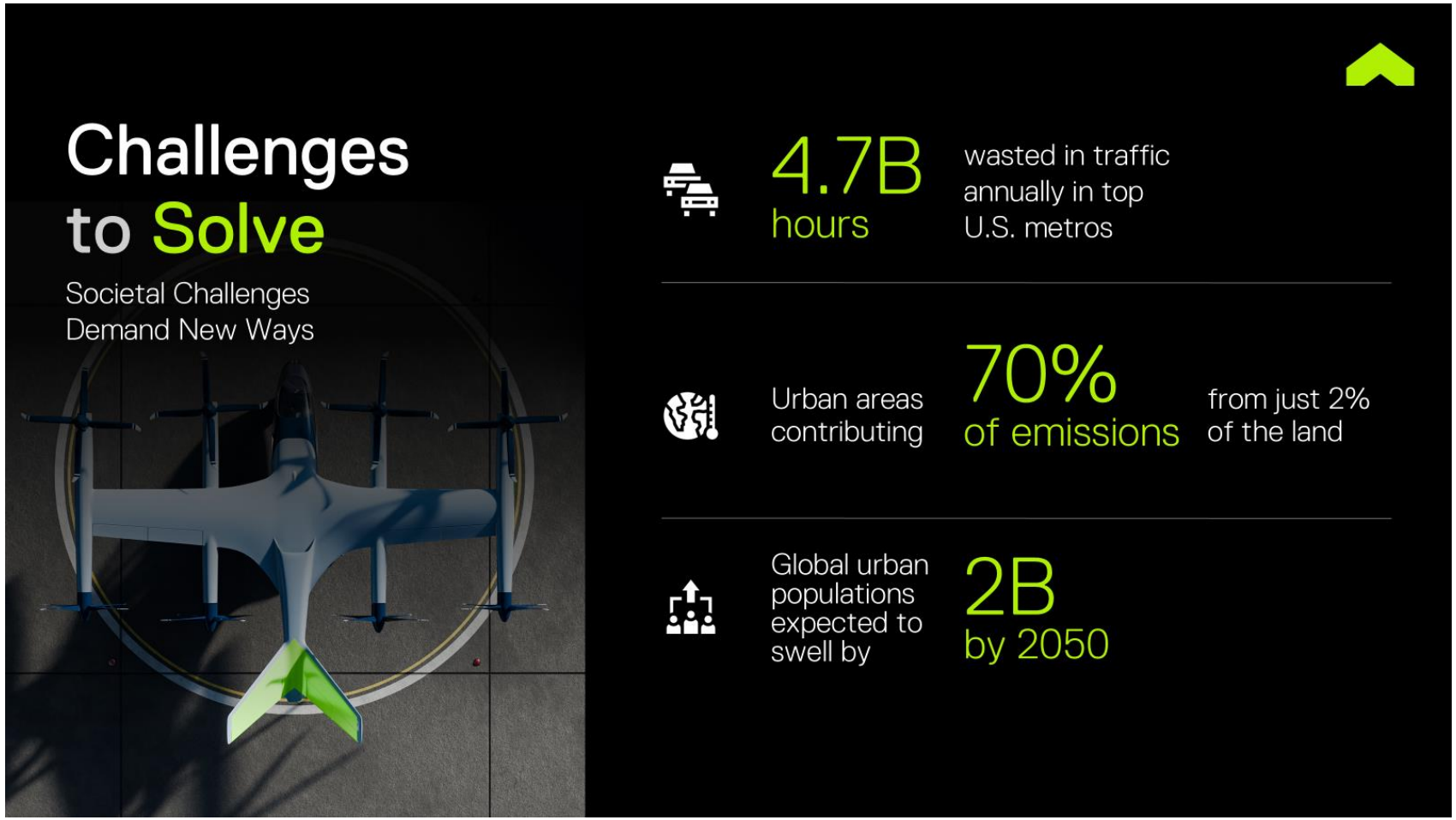
MATLAB EXPO



One of humanity’s biggest challenges in dense urban areas is billions of hours of our lives wasted in traffic every year

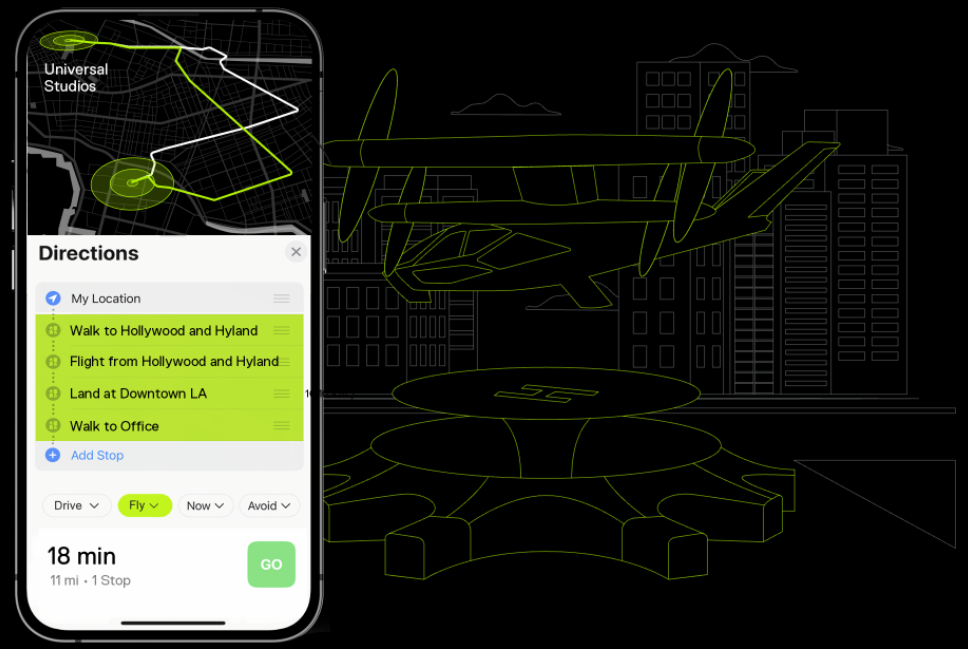


Sources:
World Bank Group
McKinsey & Co
Frontier Group

Advanced Air Mobility presents a promising opportunity to advance humanity and change how we live, move, and connect

AAM: A New Transportation Option

Similar to trains, subways and walking, eVTOL flights will be an **additional transportation option** travelers can choose from when charting their multi-modal journeys



A next-generation aerospace company inside a large conglomerate with a strong history of commitment to advance humanity

Supernal is the embodiment of Hyundai Motor Group's commitment to the future of transportation

We want to build **human-centered cities**

That leverage **innovative technology** advancements

To deliver **affordable and universal** mobility services

HYUNDAI MOTOR GROUP

GENESIS

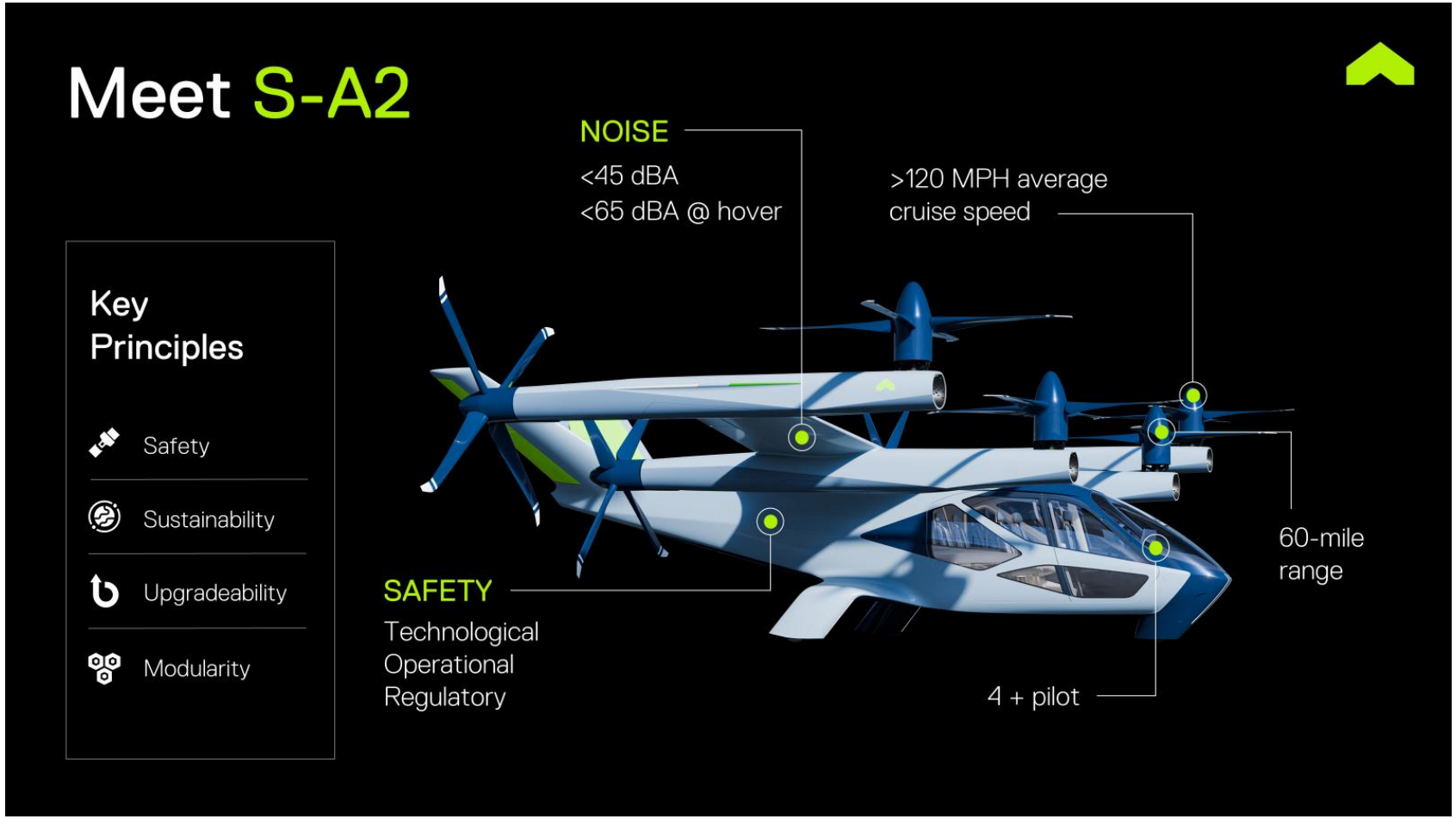
HYUNDAI

KIA

Boston Dynamics

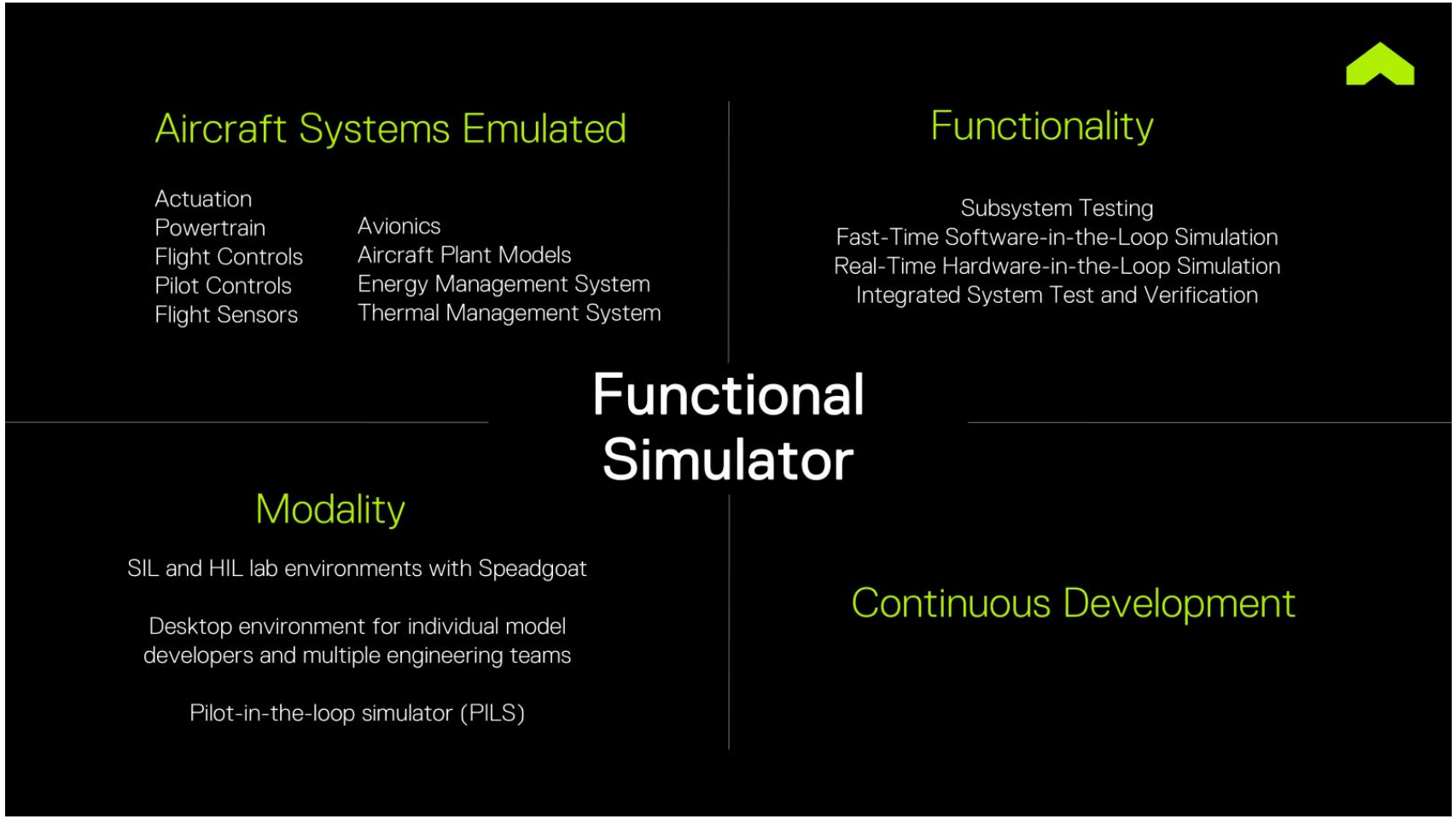
THE AI INSTITUTE

We are building an electric vertical take-off and landing (eVTOL) aircraft and a culture of simulation-driven engineering



We need simulation systems more than ever before as complexity of building an electric aircraft far outpaces that of a non-electric aircraft.

We built Functional Sim to be the integrated simulation system of systems capable of emulating all systems of our aircraft in a variety of technical settings



We built Functional Sim with Simulink and MATLAB product family tools coupled with internal and external tools

Flight Dynamics using **Simulink** and external/internal tools
- Aerospace Blockset
- Runs in “real-time” mode

Simulink, Stateflow & MATLAB functions for most native models
- MATLAB-function is particularly suited to fill gaps for rapid prototyping logical functions

Actuation and Powertrain system hardware model using vendor compiled Simulink model
- Closed model: runnable but not browsable

Interface Modeling using **Speedgoat** to support HWIL use cases

Thermal & Fluid sim using external **multi-physics systems simulation tool**, tied in with Simulink
- Full model needs model reduction to run 1x time

How we use Functional Sim is driven by use-cases, which are tied to our development lifecycle for system maturity

1 Software-in-the-loop Simulation (non-real-time)

Fully simulate aircraft subsystems and plant models in MATLAB Simulink

2 Hardware-in-the-loop Simulation (real-time)

Increase fidelity with Speedgoat stimulating various subsystems software hosted on target hardware

3 Pilot-in-the-loop Simulation (real-time)

Exercise aircraft subsystems with realistic test inputs in a dynamic environment to flesh out potential flight test anomalies

Functional Sim system design considerations

Modular

- Swappable components

Realistic

- High-fidelity models
- Real-time hardware-in-the-loop simulation

Configurable

- Dynamic scenarios
- System and subsystem level configuration

Performant

- Fast-time simulation

Functional Sim's modeling capabilities

Energy Management System

- System Software
- Battery Pack Model
- High/Low-Voltage Systems

Thermal Management System

- System Software
- Thermal Dynamics
- Cooling Loop

Flight Control System

- Control Software
- Flight Dynamics and Landing Gear

Flight Sensor Systems

- Navigation Sensors

Powertrain and Actuation Systems

- Motor and Actuator Models
- Prop/Lift Rotor and Swashplate Models

Functional Sim's modeling capabilities (Cont.)

Pilot Control
- Inceptor
- Cockpit Switches

Scenario Configuration
- Flight Profile
- System and Subsystems Configuration

Fault Modeling
- Subsystems Fault Injection

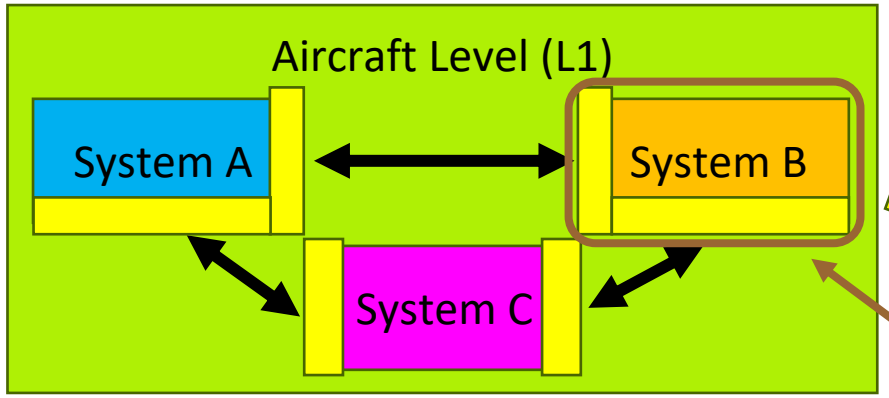
Analytics
- Data Recording and Plots
- Monte-Carlo Simulation

Real-Time Hardware-in-the-Loop Execution
- Speedgoat

Visualization
- Common Image Generator Interface (CIGI)

Systems testing driven by L2 system requirements

- System level test is the testing of individual system at L2 level, i.e. powertrain
  - Testing of multiple such systems in combination is testing at L1 “aircraft level”
- System level tests are against L2 requirements written for that system
  - L2 requirements generally don’t span multiple systems
- Functional Simulator is especially useful for L2 level testing
  - Many L2 tests implicitly require interactions with adjacent systems
    - **Most traditional L2 tests avoid requiring closed loop simulation**
  - Speedgoat interfaces provide wrap-around coverage of “system under test”

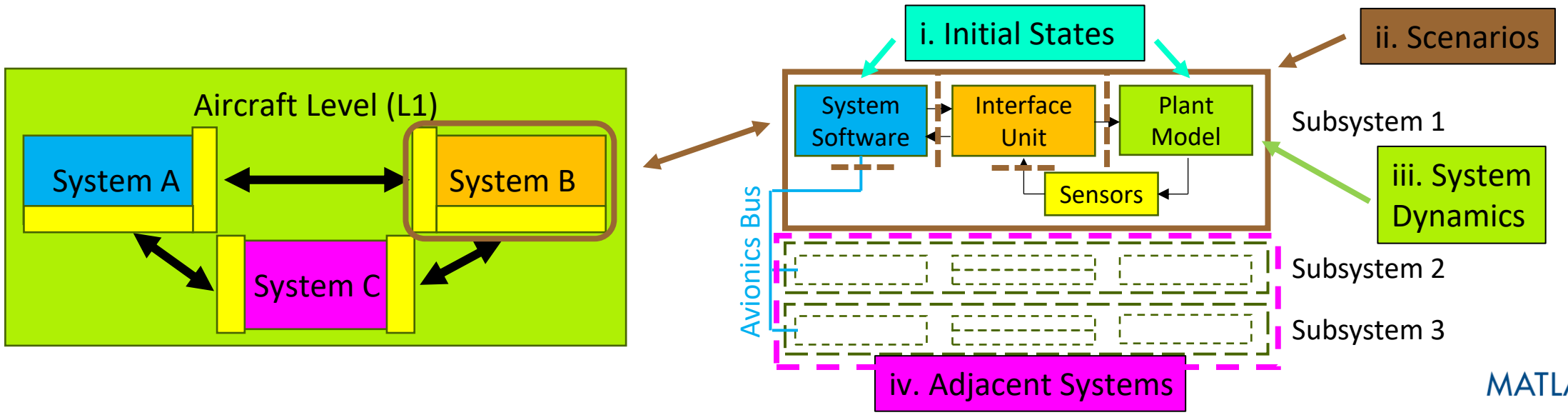


Speedgoat Interface Sim:
1. Provides simulated data traffic to targeted system
2. Verifies output data traffic from targeted system

L2 tests usually only target one system at a time. Adjacent system interactions are either simulated or prescribed (i.e. recorded)

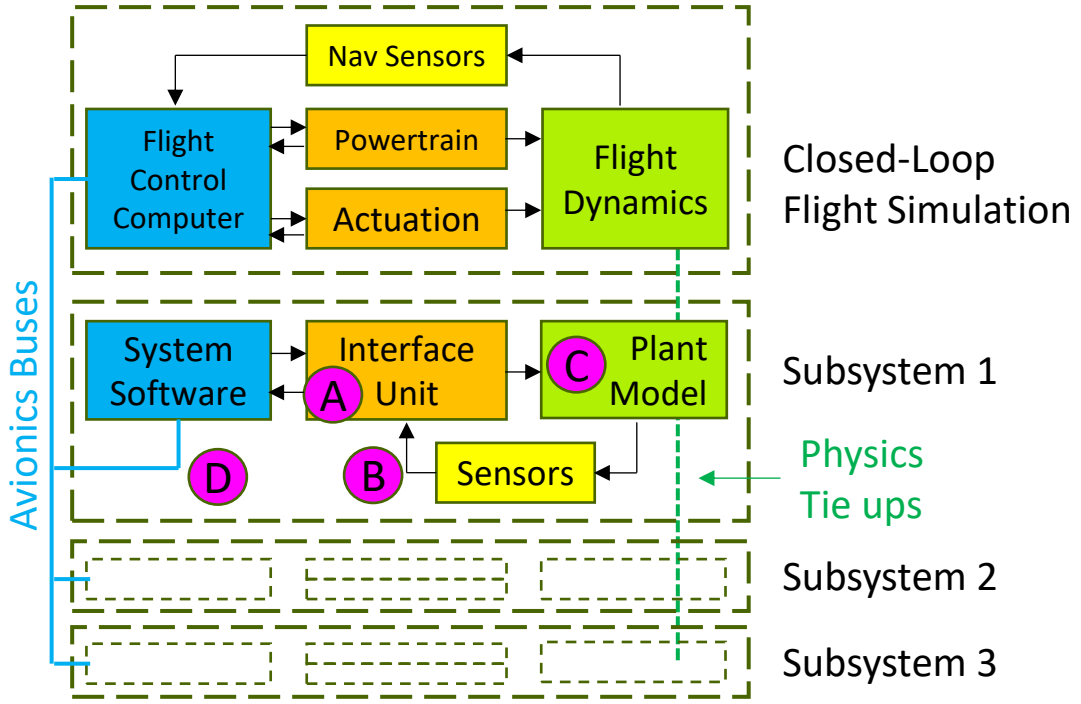
Functional Sim provides wrap-around coverage of “system under test”

1. Hardware interface allow testing of external and intermediate interfaces
2. Modeling of multiple system dynamics and populating interfaces by providing:
   i. Internal initial states for targeted system (start of test)
   ii. Scenario driver for adjacent systems and/or inputs for stimulation
   iii. Physical dynamical response integral to targeted system
   iv. Adjacent systems response in open or closed loop feedback to targeted system

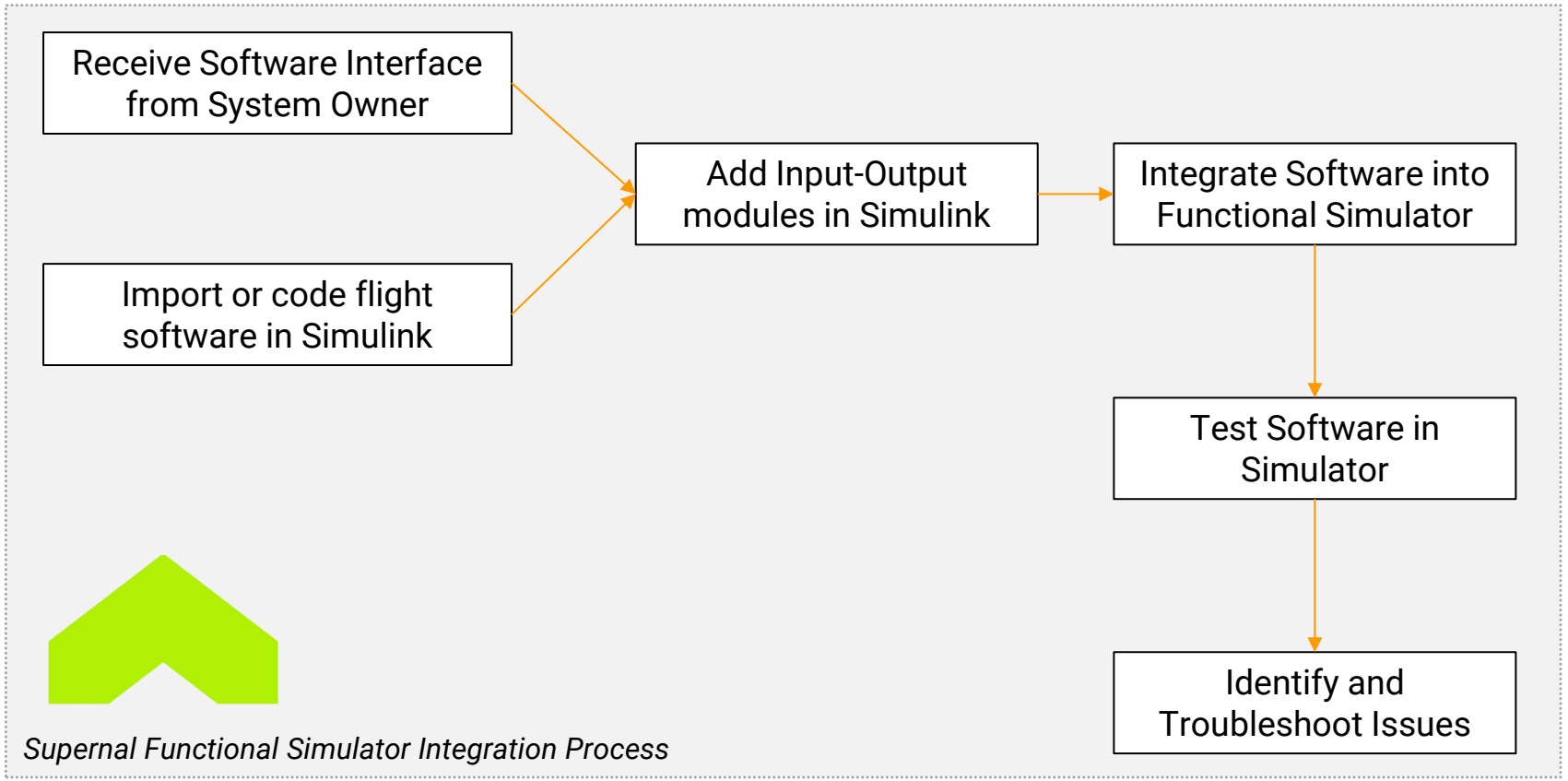


Functional Sim for system testing

- System test comprises a collection of test cases
  - Each test case tests a distinct part of the system
  - Each test case may require a number Functional Sim components
    - Most tests require only a single component
    - Most tests can be done open loop
    - **Closed loop simulation is a potential game changer for system tests**
- Functional Sim components serve to:
  - A. Simulate IO from system software to interface unit
  - B. Simulate sensor output feeding into interface units
  - C. Monitor system command to hardware
  - D. Simulate interfaces between adjacent systems

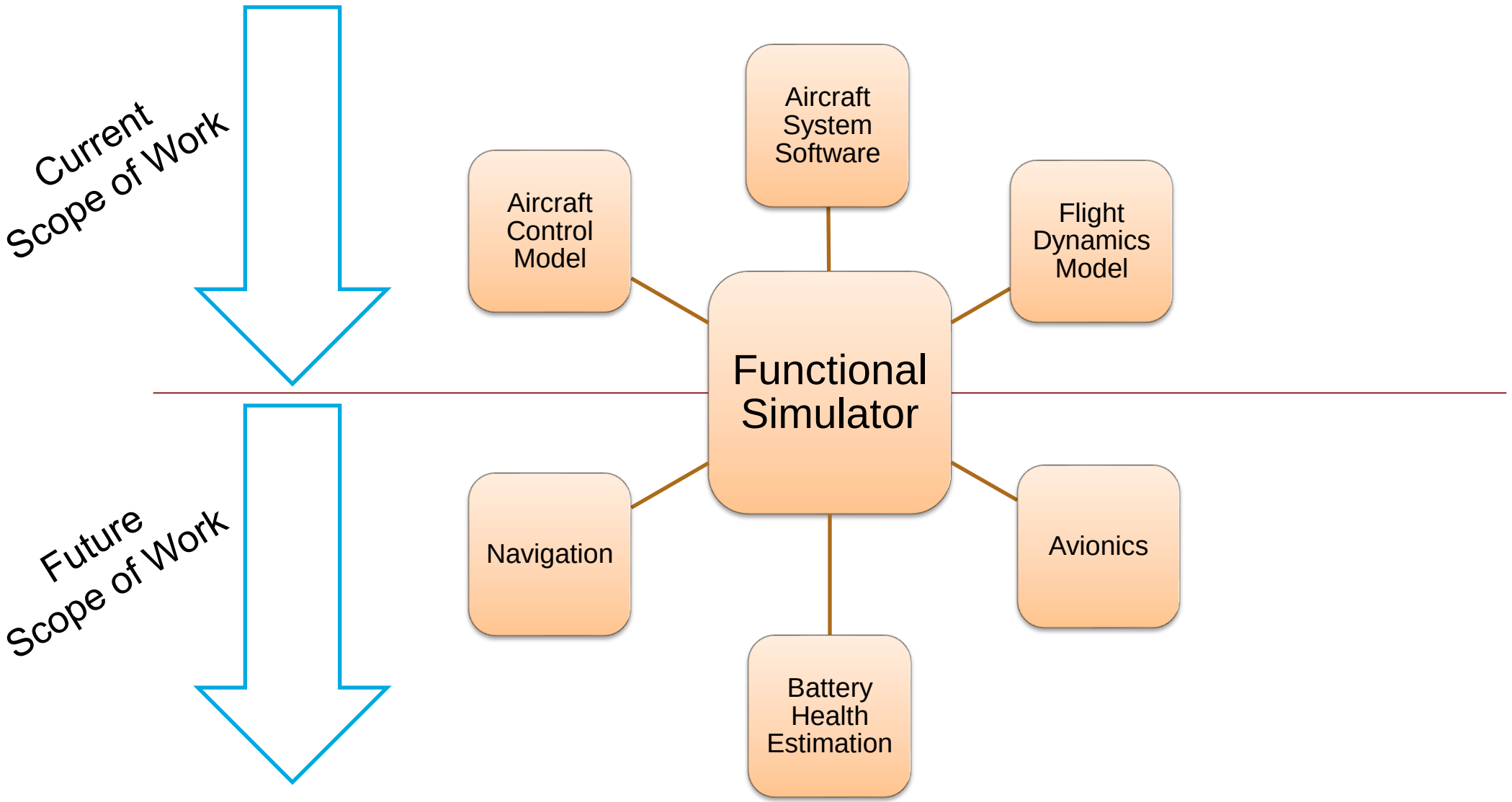


Engineering process through which new modules are added to the Functional Sim



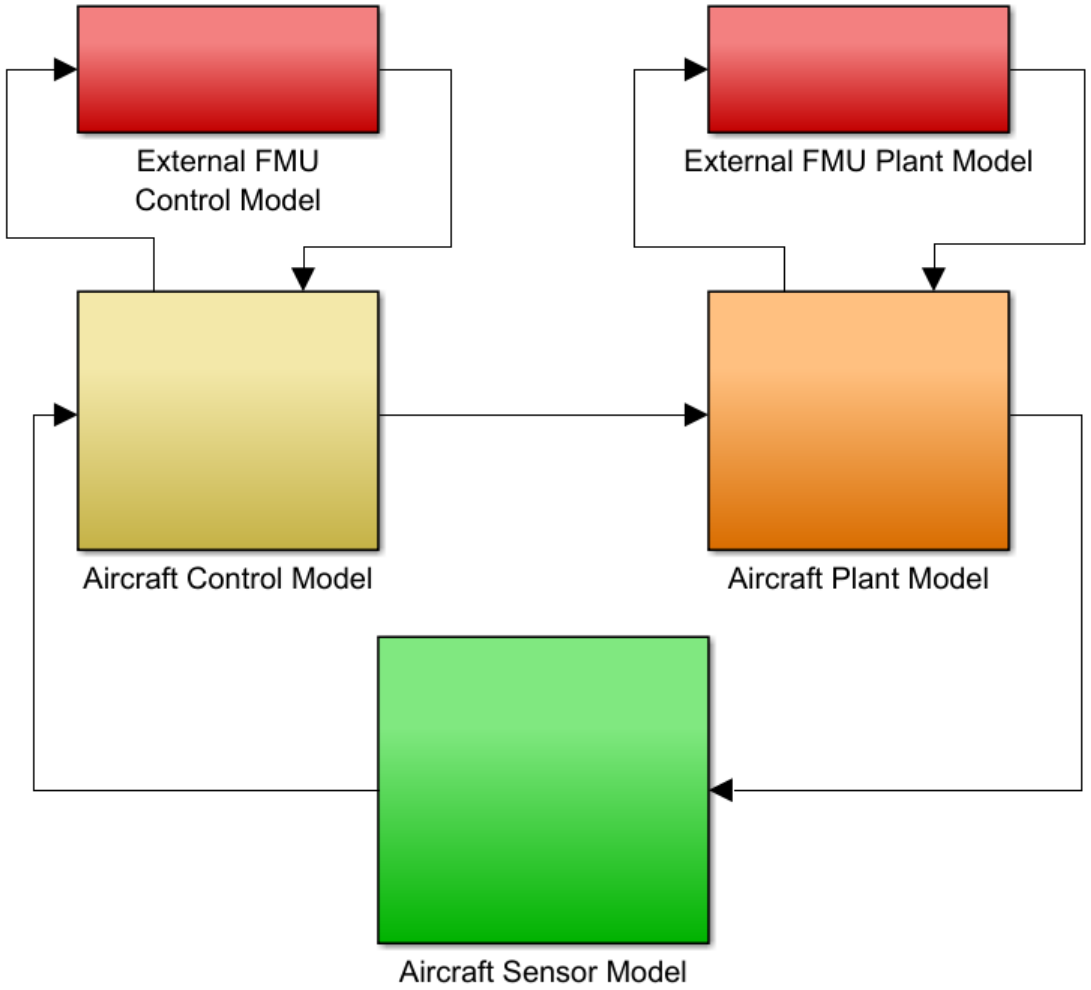
Supernal Functional Simulator Integration Process

Functional Sim 2.0: going beyond flight dynamics and aircraft systems software

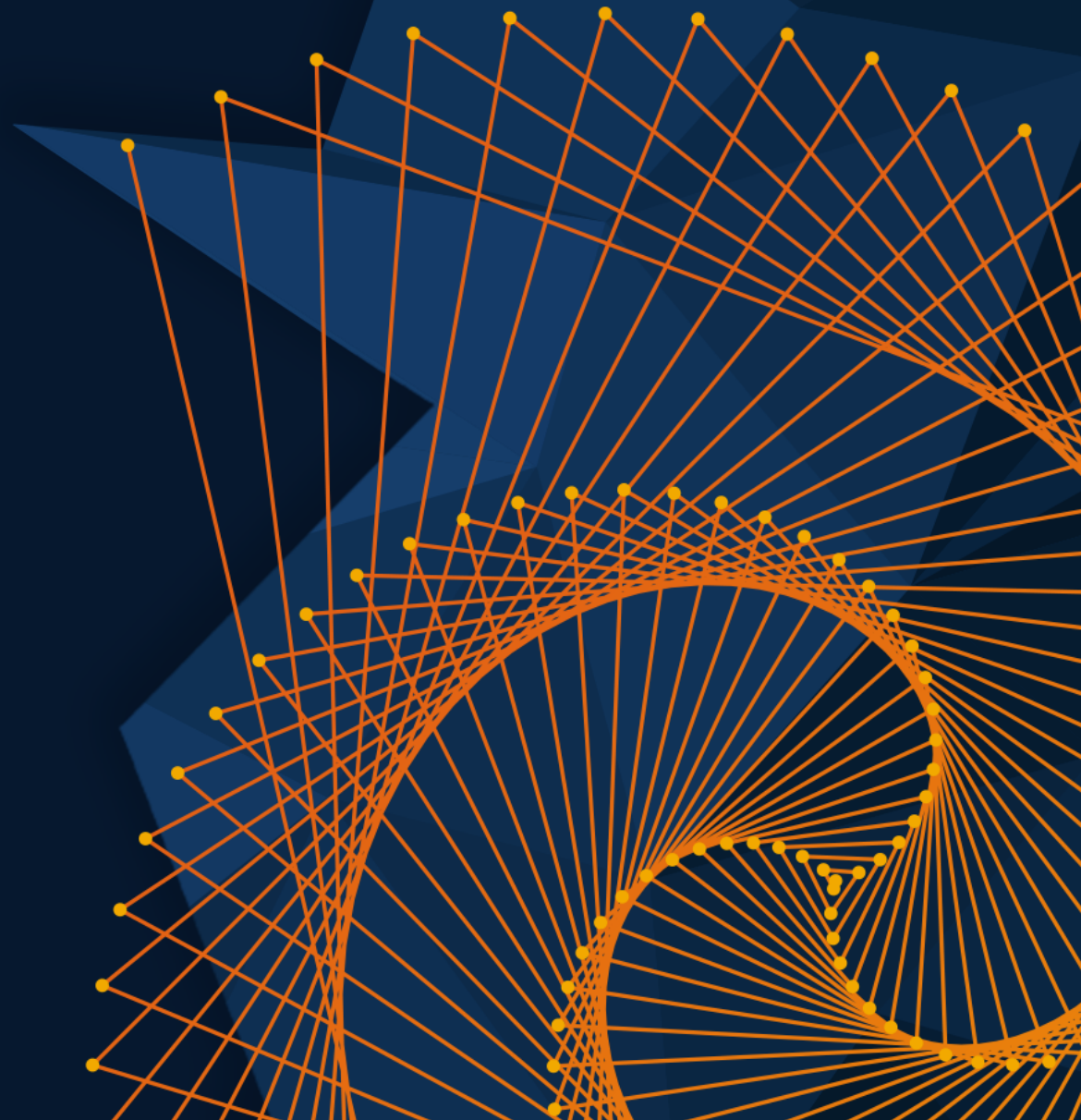


Increasing cross-org collaboration and ecosystem participation by adding Functional Mock-up Unit (FMU) co-simulation modality

Functional Mock-Up Interface



MATLAB EXPO



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