Connecting System Architecture to Model-Based Design

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Application Engineer
MathWorks
Plano, TX

Agenda

- MathWorks Overview
- System Architecting and Model-Based Design
  - User Needs
  - Current workflows
  - MathWorks solution
  - Example
- Summary
- Resources

Background

- University of Illinois at Urbana-Champaign
  - B.S, M.S. Aerospace Engineering
- SpaceX Rocket Development Facility
  - Test Engineer
  - Lead Engineer, Integration & Test
- Eaton Aerospace, Fuel and Motion Controls
  - Lead Aerospace Systems Engineer
- MathWorks, Application Engineering Group
  - Lead Engineer, Aerospace applications

MathWorks at a Glance

- Privately held
- 4500 employees worldwide
- More than 4 million users in 185 countries

Earth's topography on a Miller cylindrical projection, created with MATLAB and Mapping Toolbox.

- Office locations
- Distributors serving 16 countries

Key Industries

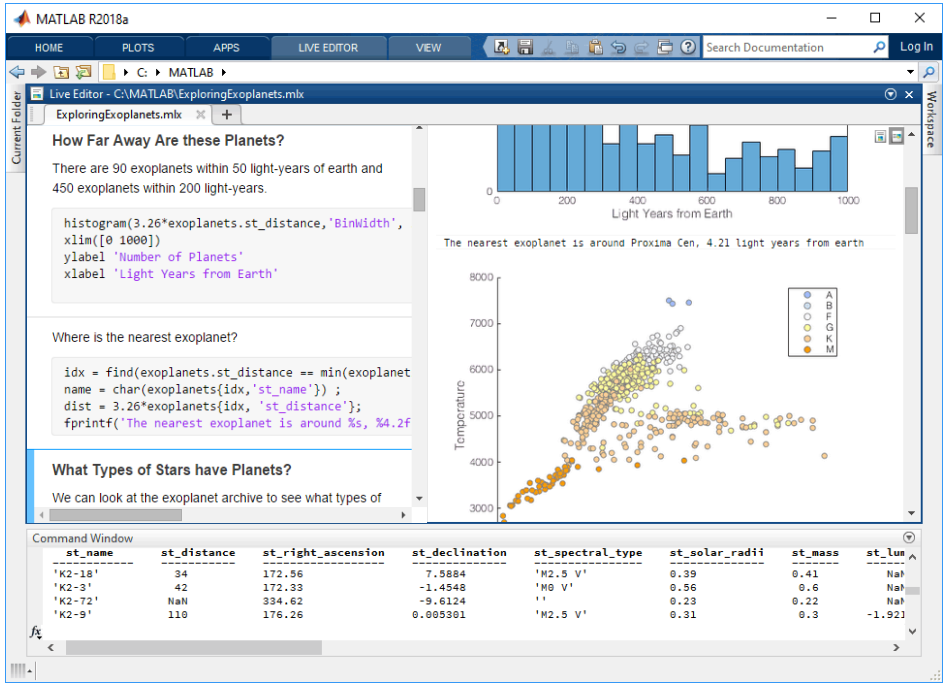
- Aerospace and defense
- Automotive
- Biological sciences
- Biotech and pharmaceutical
- Communications
- Electronics
- Energy production
- Financial services
- Industrial automation and machinery
- Medical devices
- Metals, materials, and mining
- Neuroscience
- Railway systems
- Semiconductors
- Software and internet

Core MathWorks Products

MATLAB®

Math. Graphics. Programming.

- Designed for engineers and scientists
- Professionally developed, tested, and documented
- Toolboxes for:
  - Machine learning, data analytics, deep learning, image processing and computer vision, signal processing and communications, computational finance, robotics and control systems
- Interactive apps that automatically generate programs
- Easily scales to clusters, GPUs, and clouds
- Direct deployment to production enterprise applications
- Automatic conversion to embeddable C and CUDA code
- Integrates with Simulink to support Model-Based Design



Core MathWorks Products

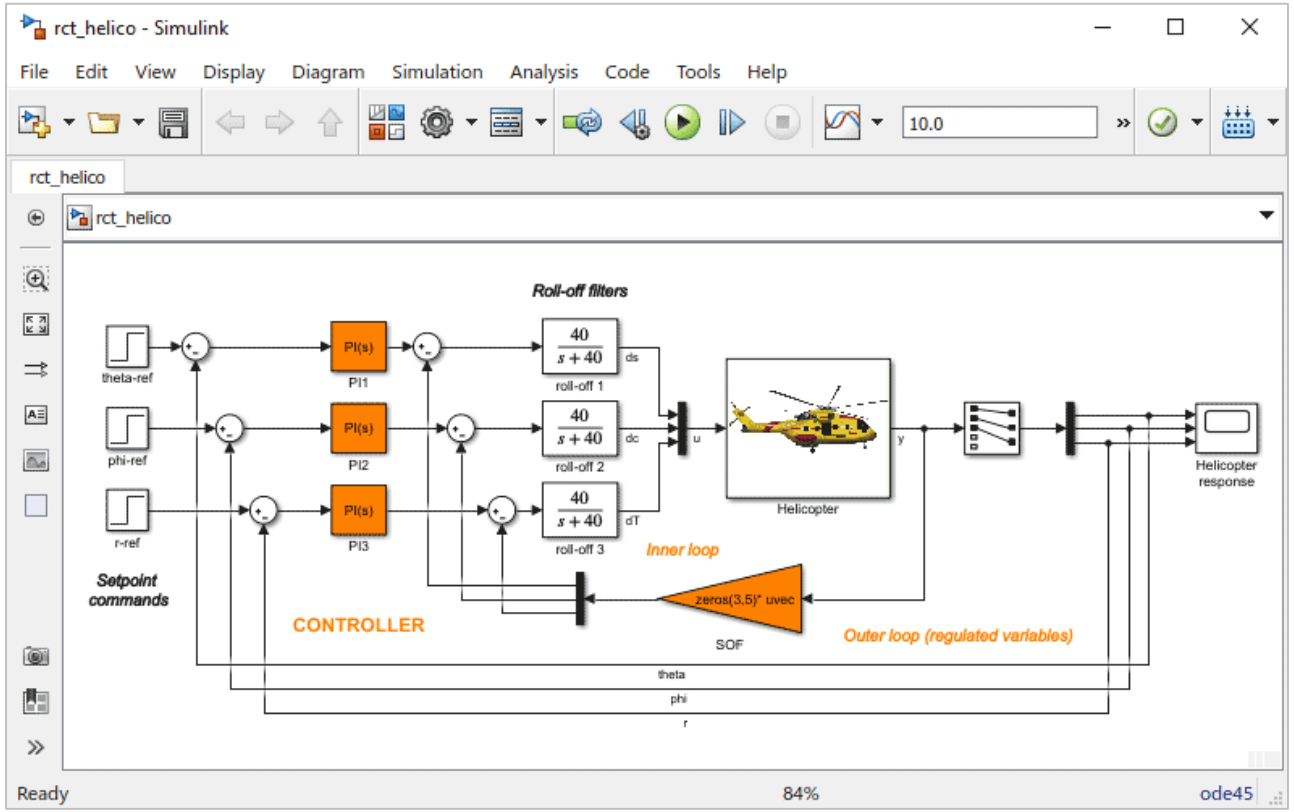
SIMULINK®

Simulation and Model-Based Design

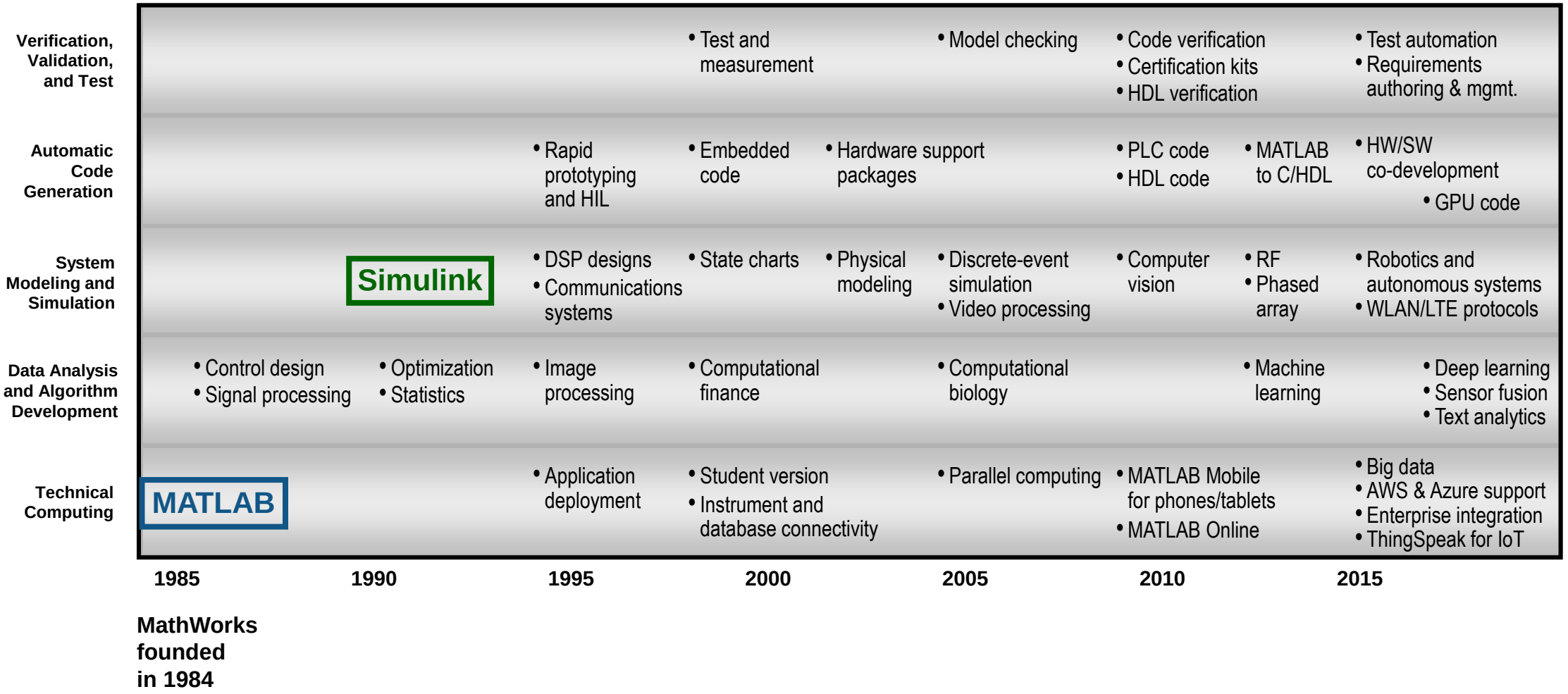
Model and simulate your system
- Use one multi-domain environment
- Model the system under test and the plant
- Simulate how all parts of the system behave

Test early and often
- Test your system under all conditions
- Validate your design with real-time testing
- Trace from requirements to design to code

Automatically generate code
- Generate production-quality C and HDL code
- Deploy directly to embedded processors or FPGA's/ASIC's

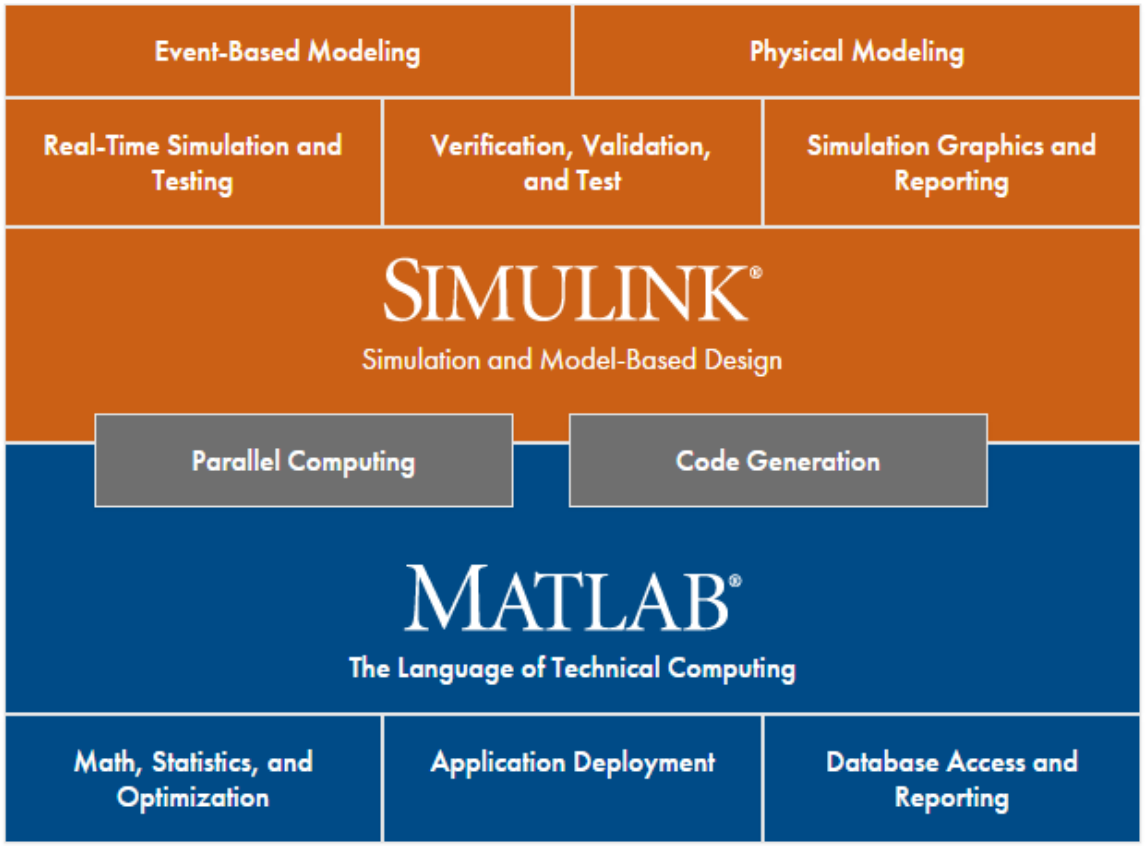


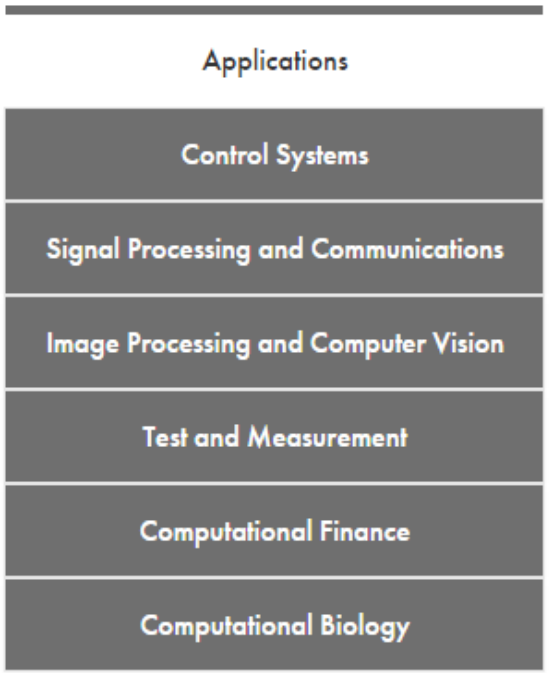
Key capabilities for engineers and scientists



MathWorks founded in 1984

MathWorks Product Overview





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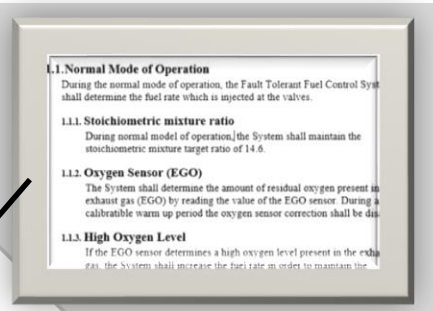

1.1. Normal Mode of Operation

During the normal mode of operation, the Fault Tolerant Fuel Control Syst shall determine the fuel rate which is injected at the valves.

1.1.1. Stoichiometric mixture ratio

During normal model of operation, the System shall maintain the stoichiometric mixture target ratio of 14.6.

1.1.2. Oxygen Sensor (EGO)

The System shall determine the amount of residual oxygen present in exhaust gas (EGO) by reading the value of the EGO sensor. During a calibratible warm up period the oxygen sensor correction shall be dis

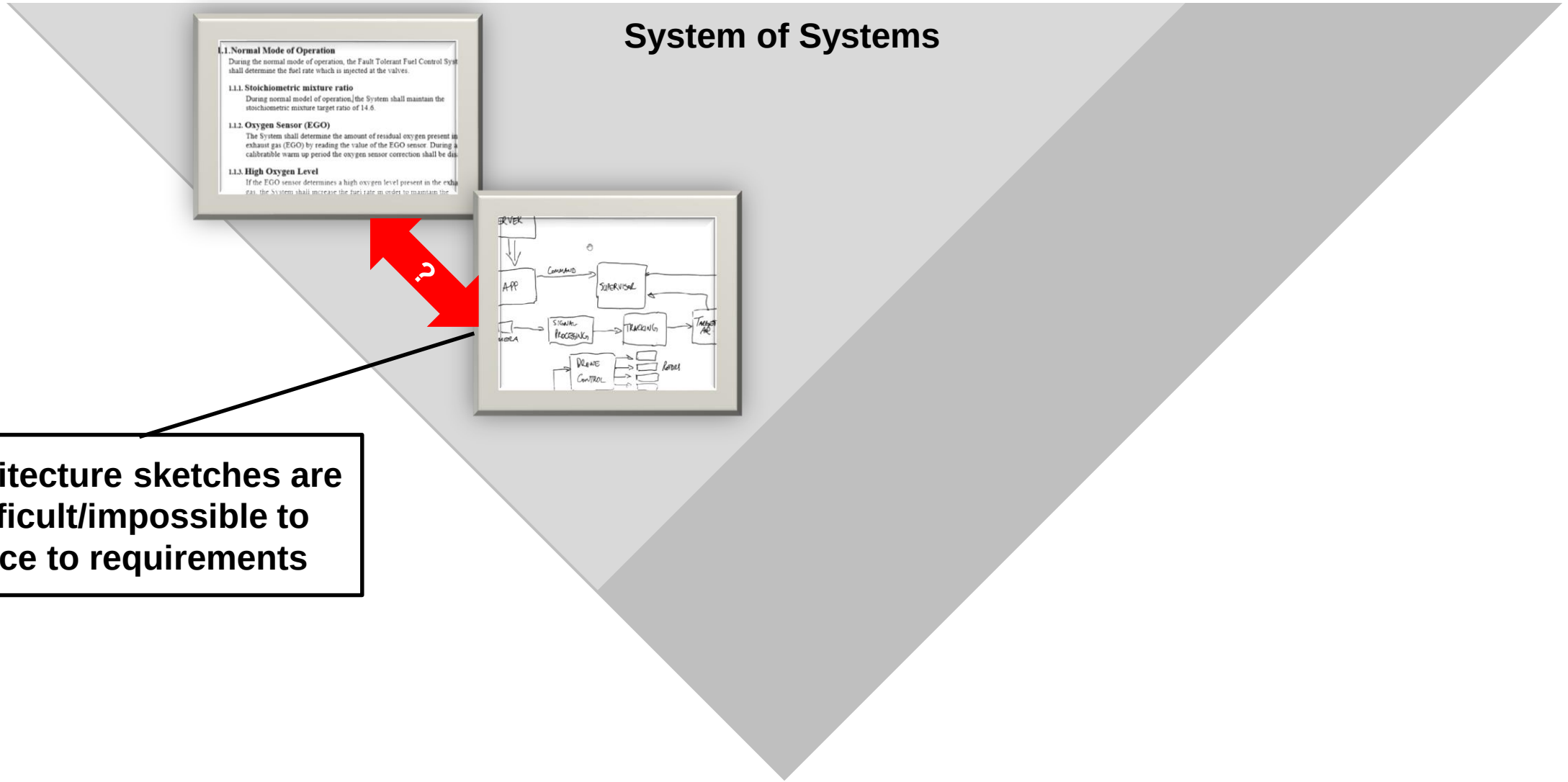
1.1.3. High Oxygen Level

If the EGO sensor determines a high oxygen level present in the exha gas, the System shall increase the fuel rate in order to maintain the

Textual requirements

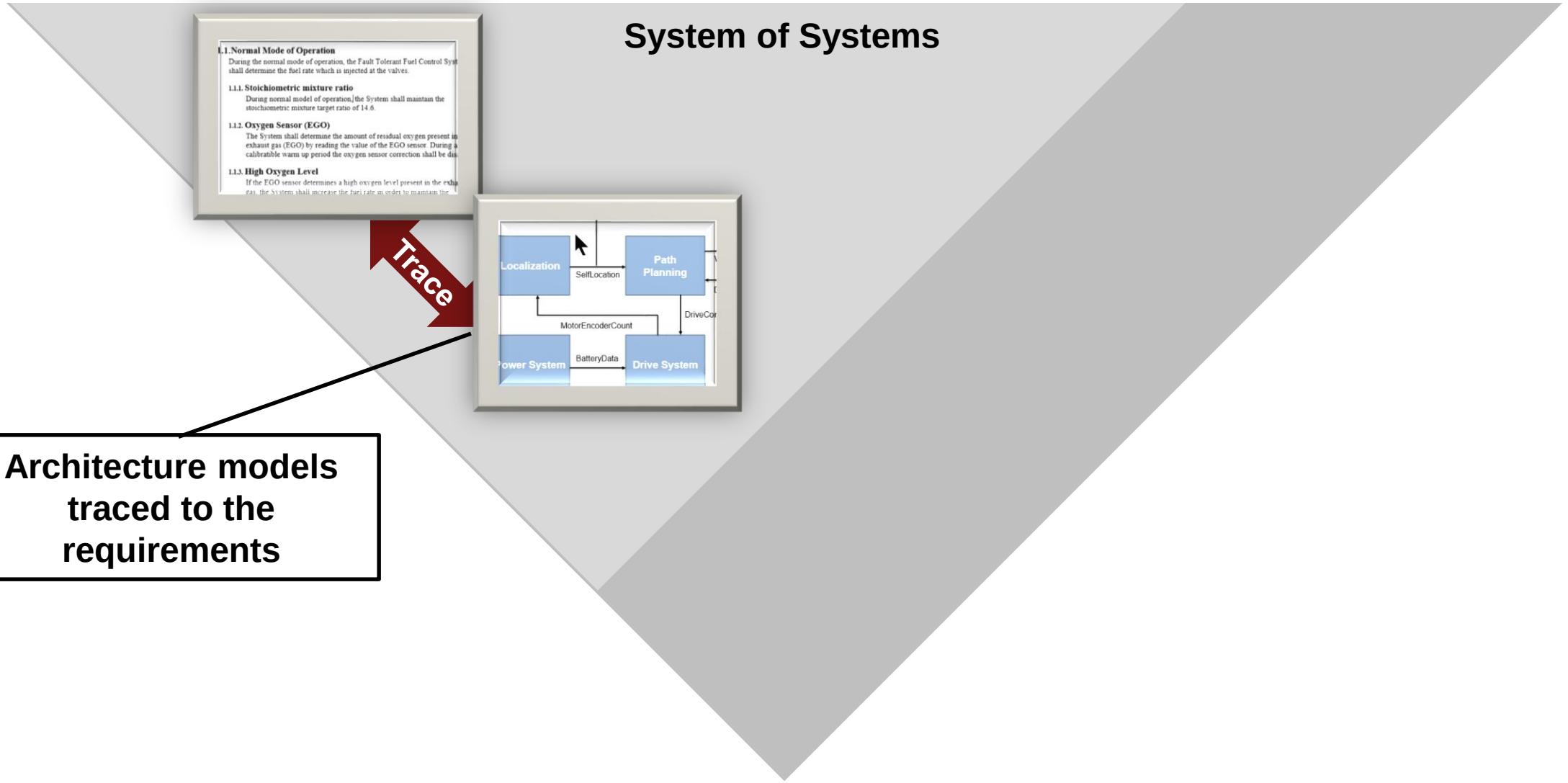
System of Systems

How is this done today?



Architecture sketches are difficult/impossible to trace to requirements

How is this done today?



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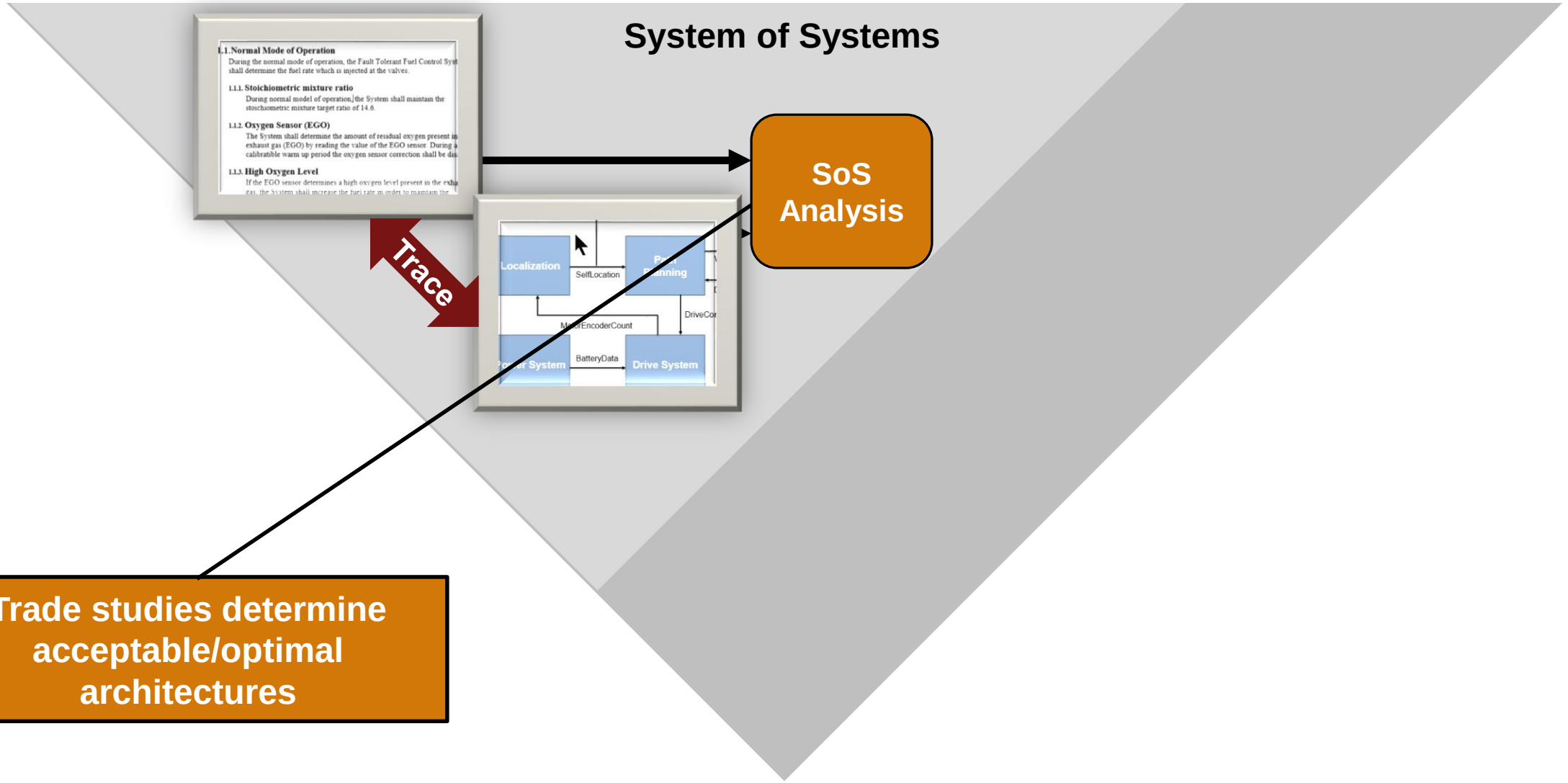

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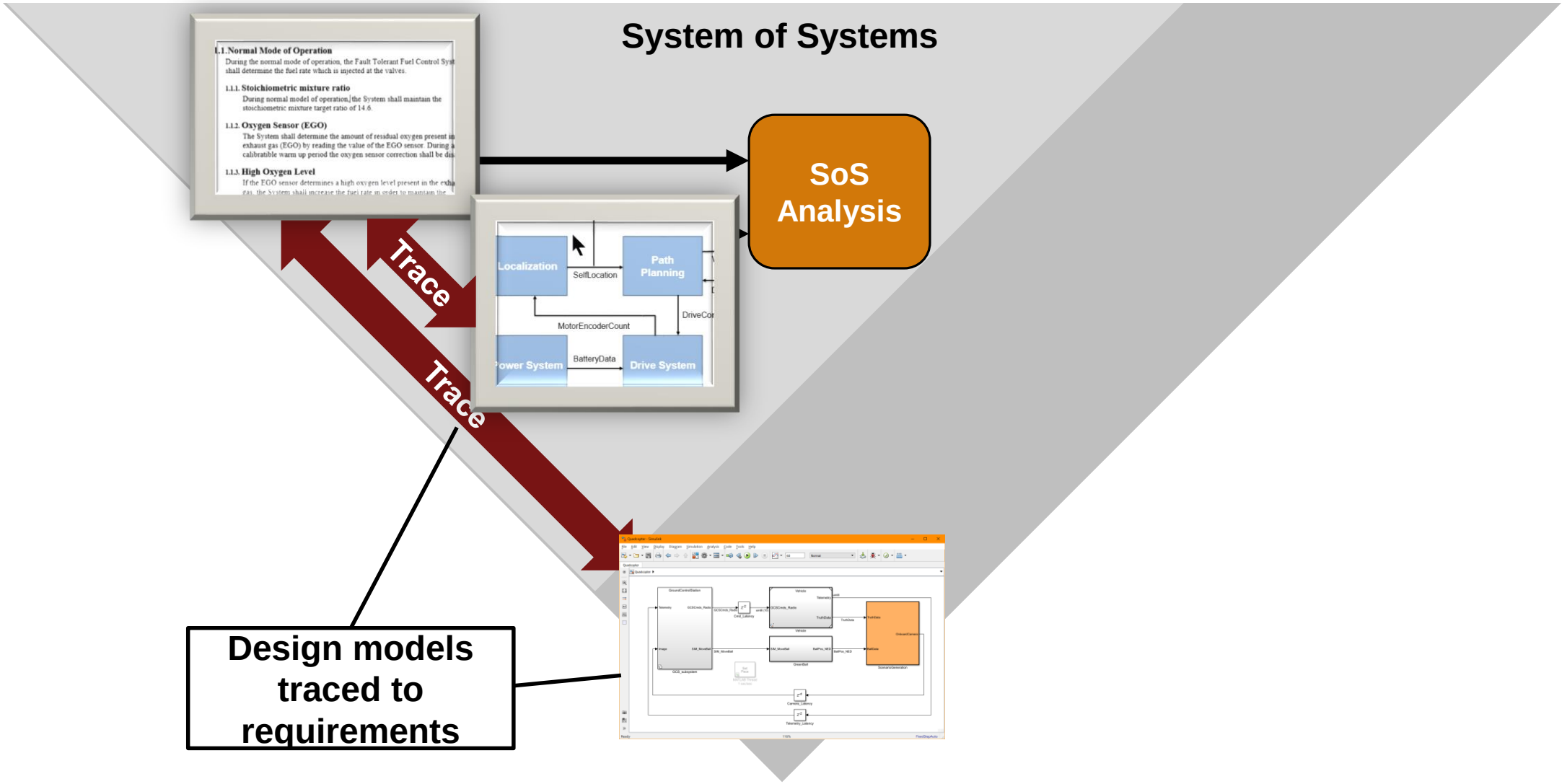

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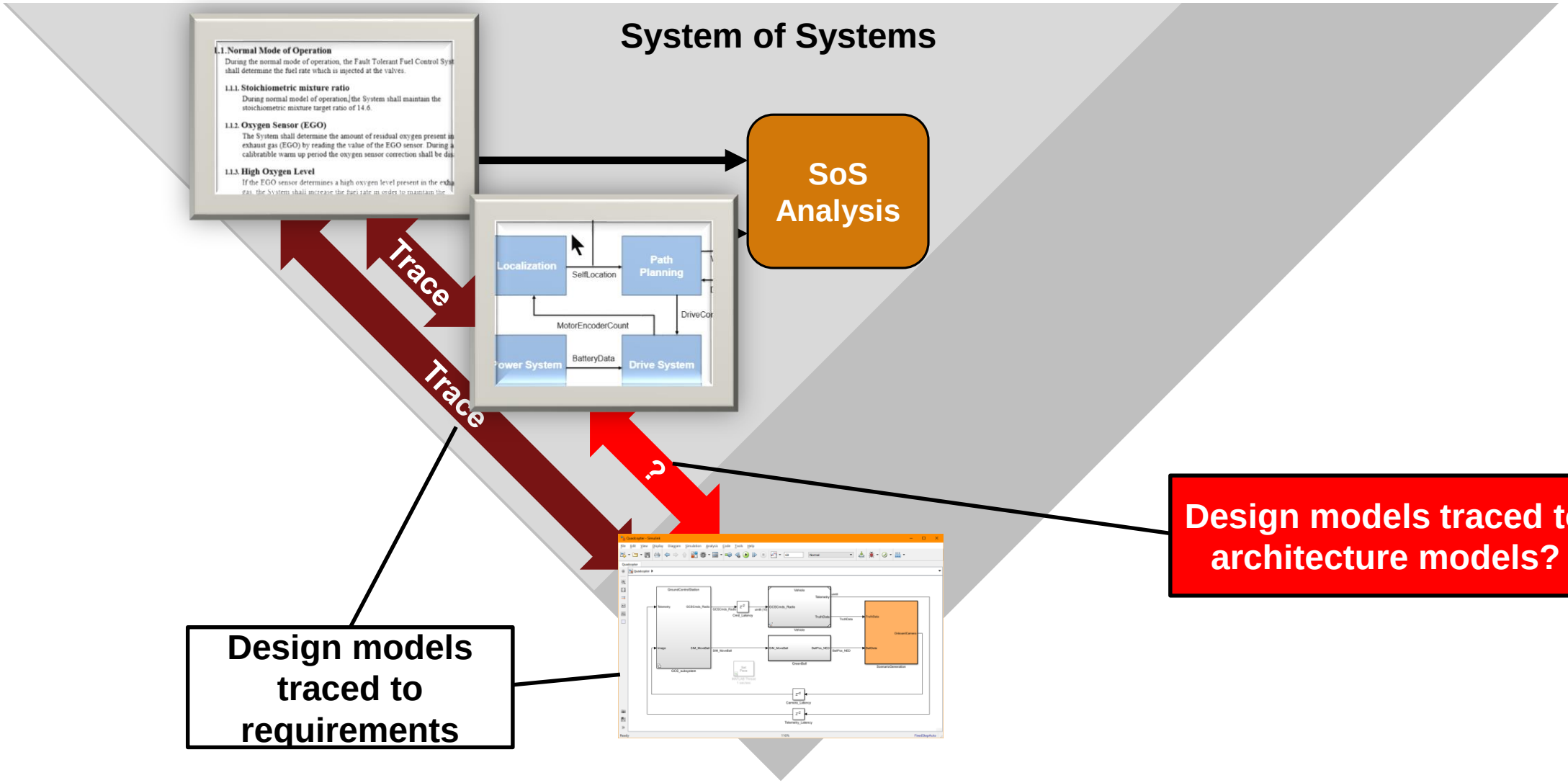

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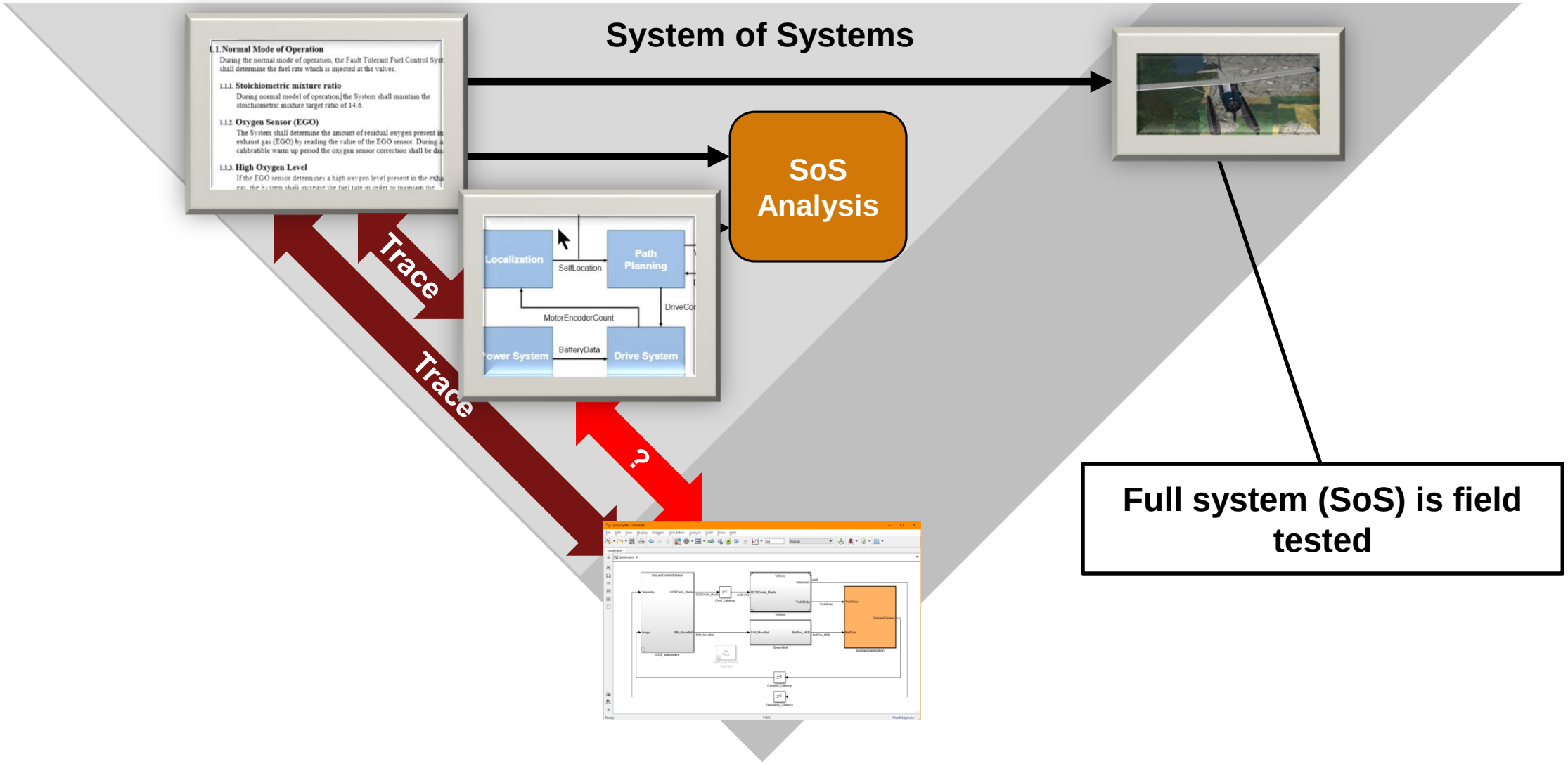
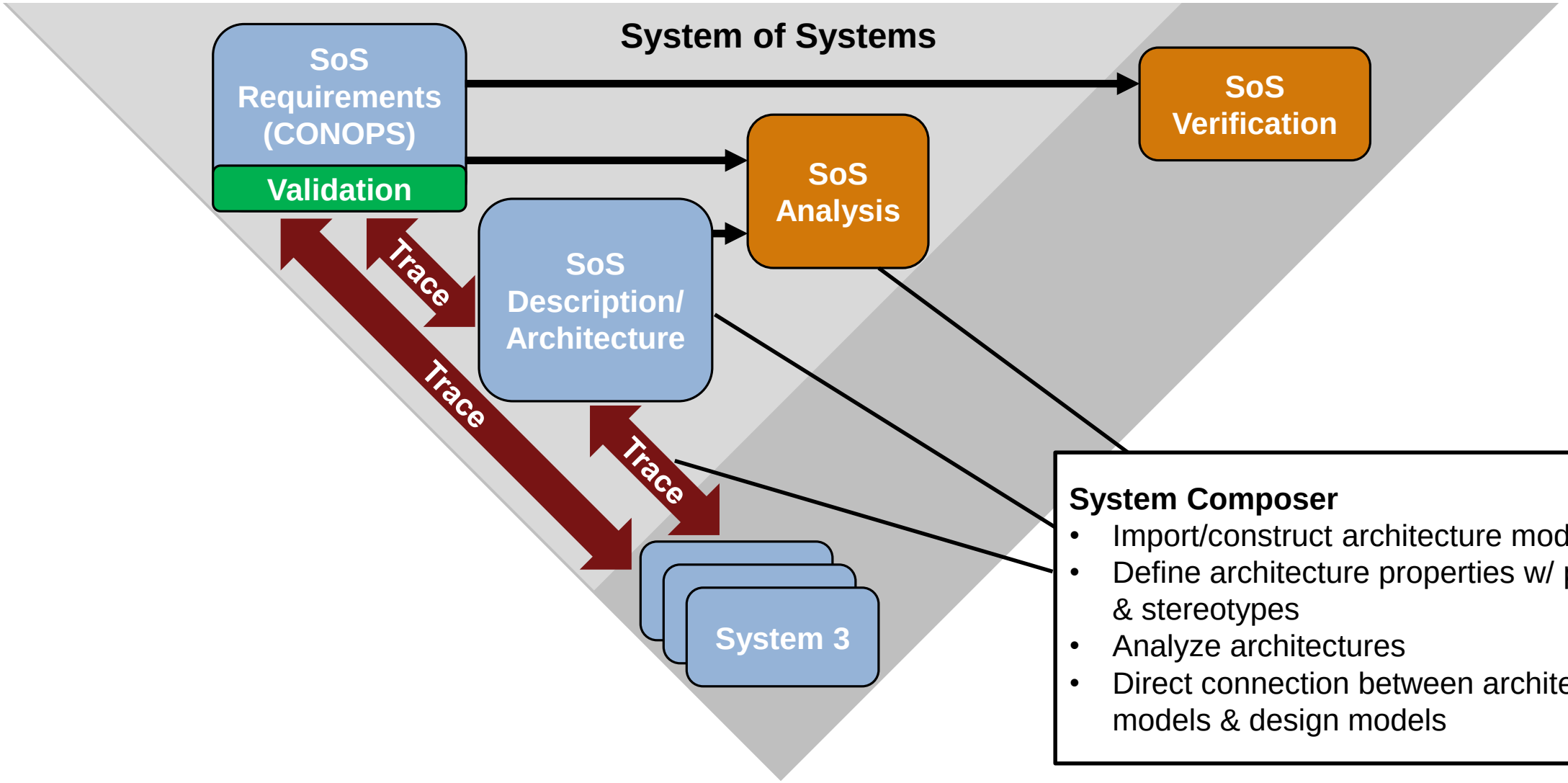


How can MathWorks address the gap?

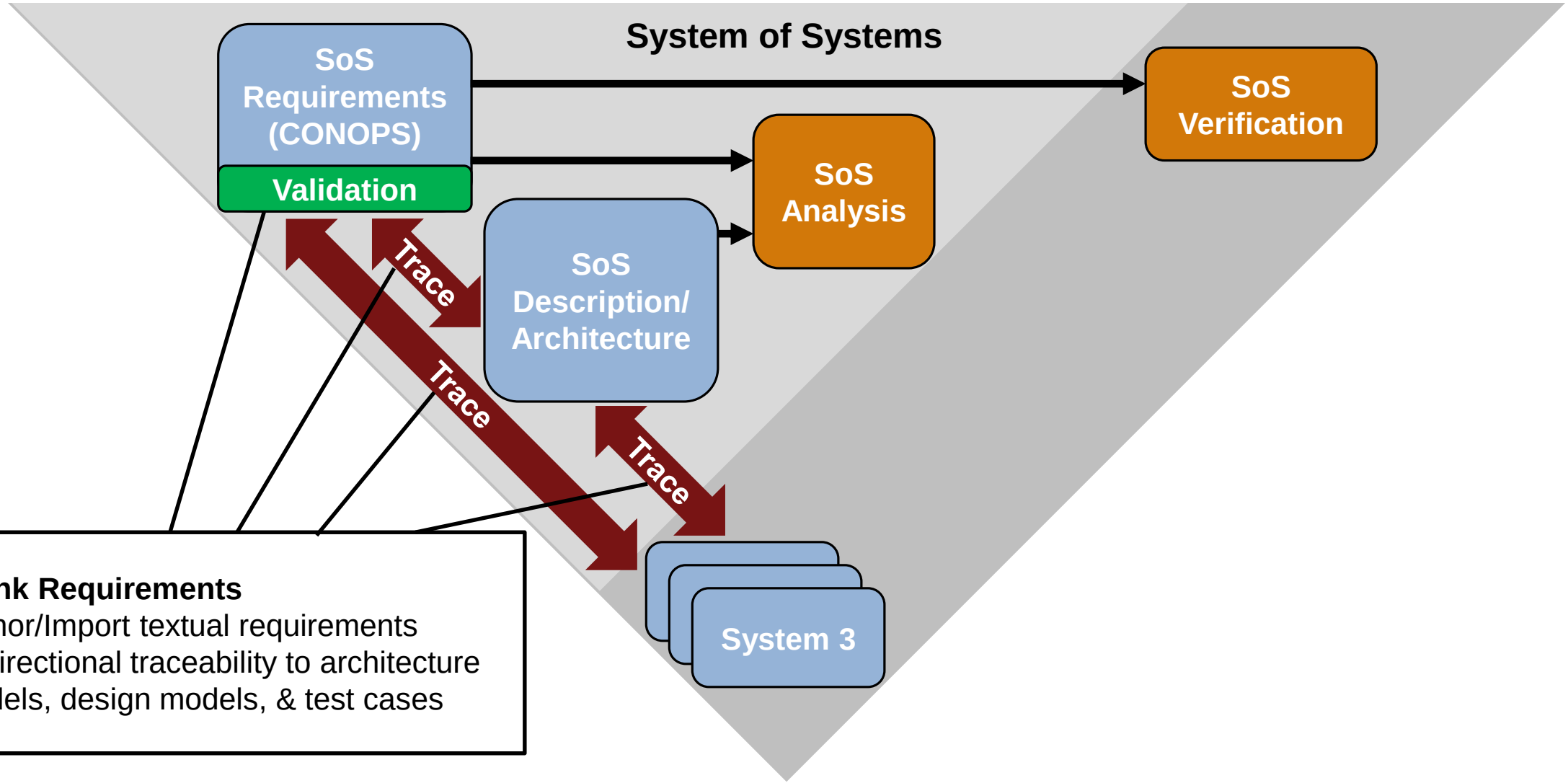
System Architecting & Technical Analysis



System Composer

- Import/construct architecture models
- Define architecture properties w/ profiles & stereotypes
- Analyze architectures
- Direct connection between architecture models & design models

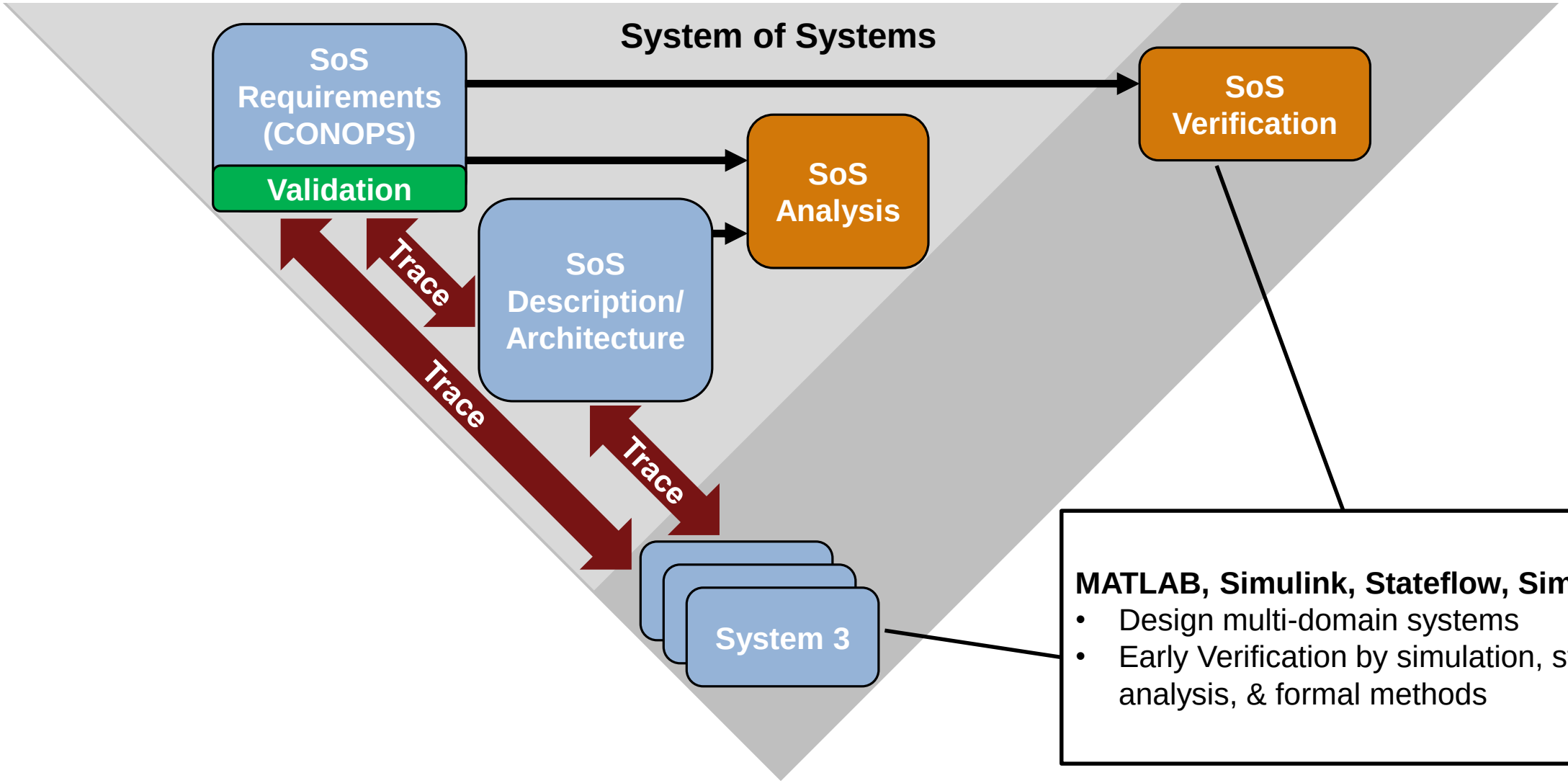
Requirements Management



Simulink Requirements

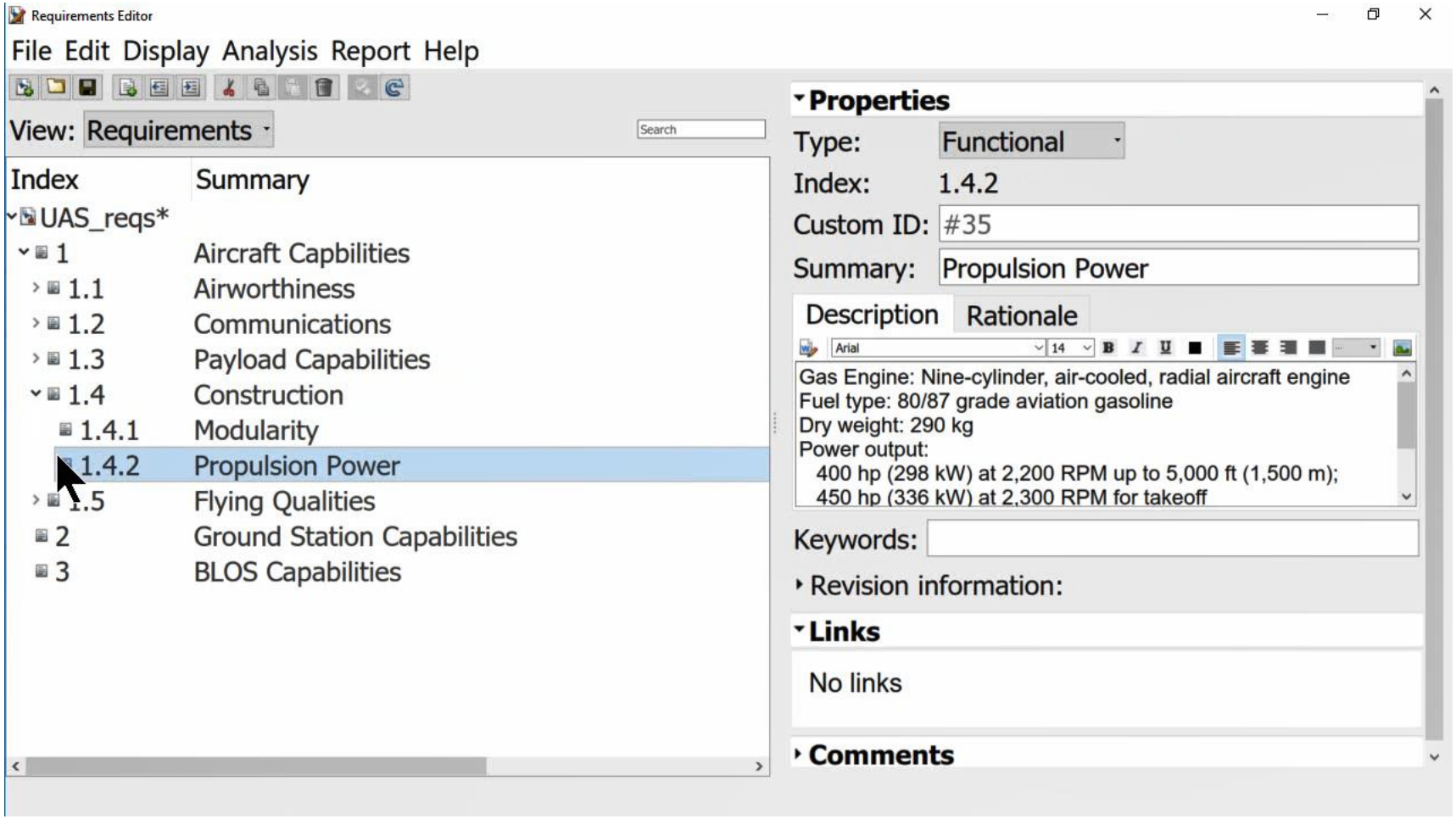
- Author/Import textual requirements
- Bi-directional traceability to architecture models, design models, & test cases

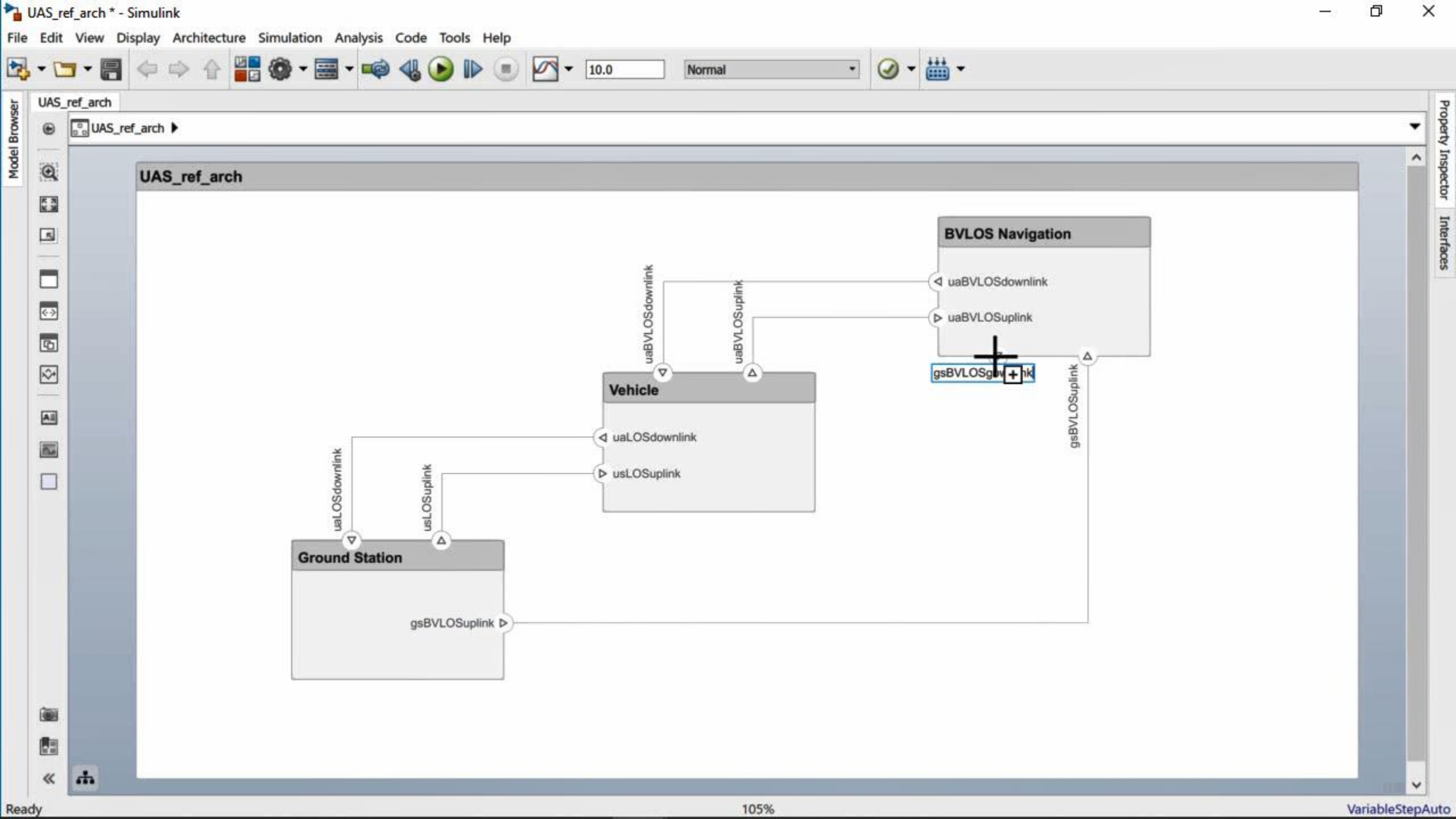
Verification & Validation



Now let’s see it in action


FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help Beaver


Requirements Editor
File Edit Display Analysis Report Help
View: Requirements
Search
Index
Summary
UAS_reqs*
1 Aircraft Capbilities
1.1 Airworthiness
1.2 Communications
1.3 Payload Capabilities
1.4 Construction
1.4.1 Modularity
1.4.2 Propulsion Power
1.5 Flying Qualities
2 Ground Station Capabilities
3 BLOS Capabilities
Properties
Type: Functional
Index: 1.4.2
Custom ID: #35
Summary: Propulsion Power
Description
Rationale
Arial
14
Gas Engine: Nine-cylinder, air-cooled, radial aircraft engine
Fuel type: 80/87 grade aviation gasoline
Dry weight: 290 kg
Power output:
400 hp (298 kW) at 2,200 RPM up to 5,000 ft (1,500 m);
450 hp (336 kW) at 2,300 RPM for takeoff
Keywords:
Revision information:
Links
No links
Comments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Property Inspector
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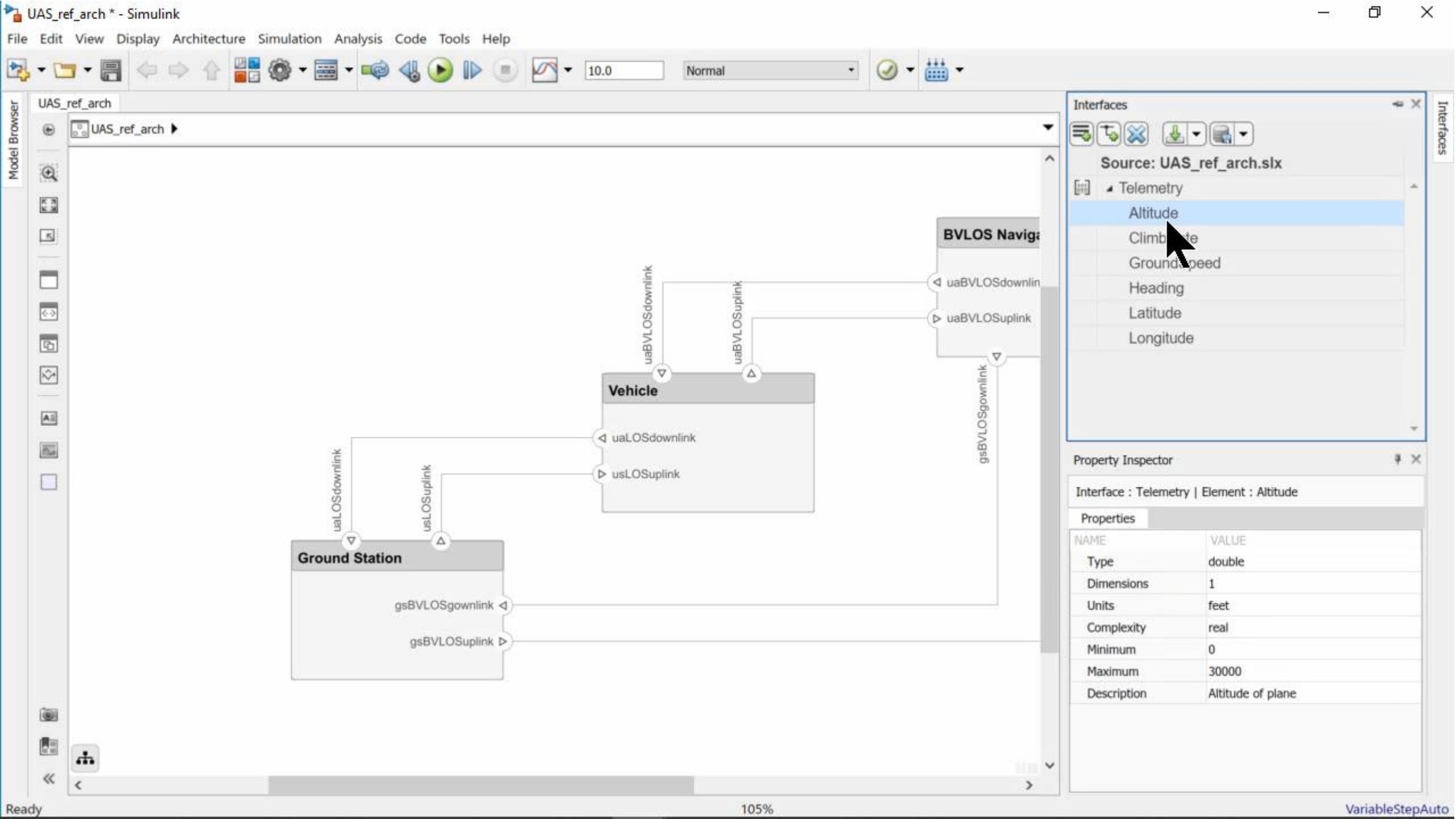
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Ground Station
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Interfaces
Source: UAS_ref_arch.slx
Telemetry
Altitude
Heading
Latitude
Longitude
Property Inspector
Interface : Telemetry | Element : Altitude
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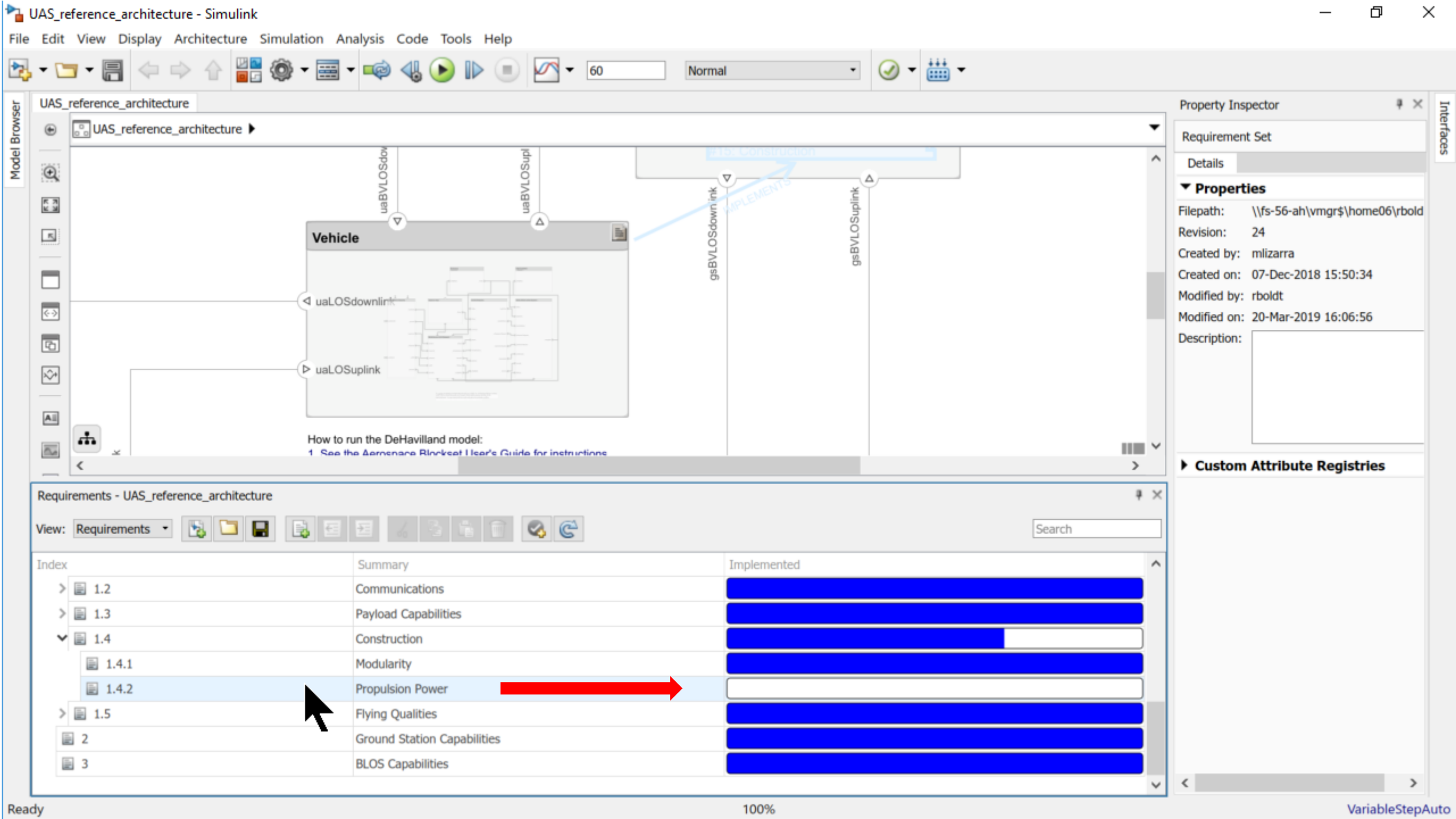
UAS_reference_architecture - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
Model Browser
UAS_reference_architecture
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Vehicle
uaLOSdownlink
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How to run the DeHavilland model:
1. See the Aerospace Blockset User's Guide for instructions
Property Inspector
Requirement Set
Details
Properties
Filepath: \\fs-56-ah\vmgr$\home06\rbold
Revision: 24
Created by: mlizarra
Created on: 07-Dec-2018 15:50:34
Modified by: rboldt
Modified on: 20-Mar-2019 16:06:56
Description:
Custom Attribute Registries
Interfaces
Requirements - UAS_reference_architecture
View: Requirements
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Index
Summary
Implemented
1.2 Communications
1.3 Payload Capabilities
1.4 Construction
1.4.1 Modularity
1.4.2 Propulsion Power
1.5 Flying Qualities
2 Ground Station Capabilities
3 BLOS Capabilities
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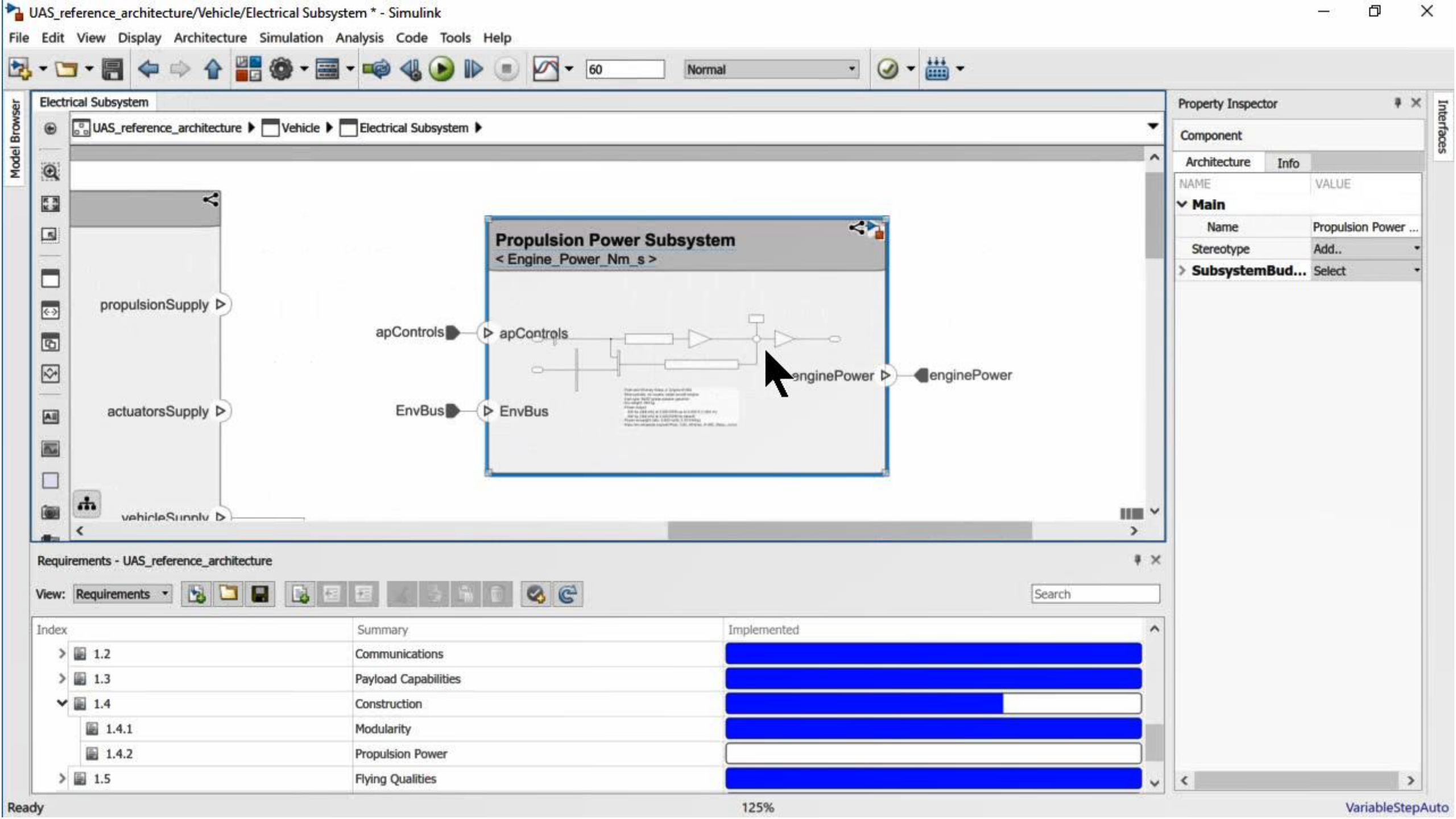
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Normal
Model Browser
Electrical Subsystem
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Vehicle
Electrical Subsystem
propulsionSupply
actuatorsSupply
vehicleSupply
Propulsion Power Subsystem
< Engine_Power_Nm_s >
apControls
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EnvBus
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enginePower
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Property Inspector
Component
Architecture
Info
NAME
VALUE
Main
Name
Propulsion Power ...
Stereotype
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SubsystemBud...
Select
Interfaces
Requirements - UAS_reference_architecture
View:
Requirements
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Summary
Implemented
1.2
Communications
1.3
Payload Capabilities
1.4
Construction
1.4.1
Modularity
1.4.2
Propulsion Power
1.5
Flying Qualities
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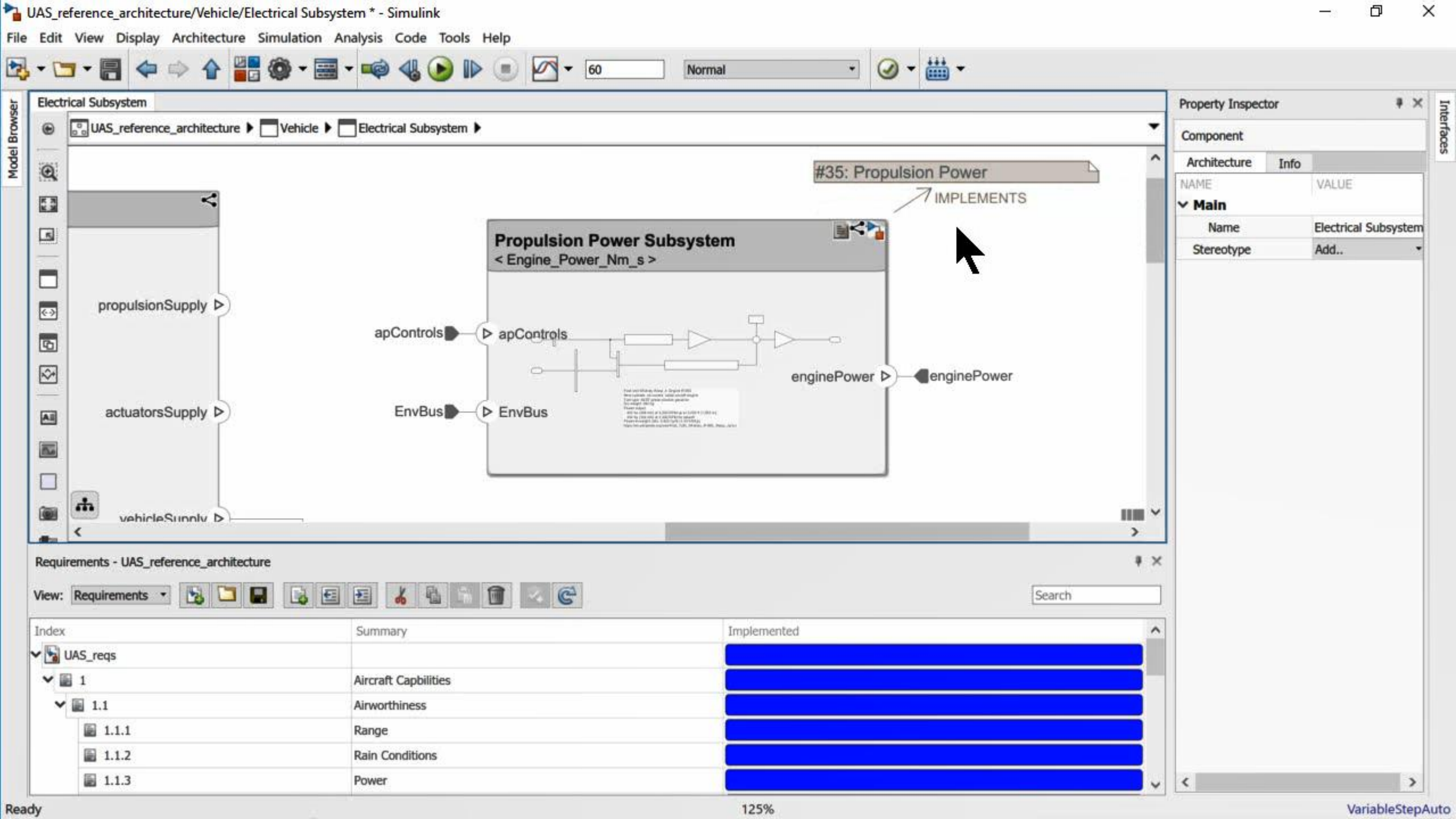
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Vehicle
Electrical Subsystem
#35: Propulsion Power
IMPLEMENTS
Propulsion Power Subsystem
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actuatorsSupply
vehicleSupply
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enginePower
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Architecture
Info
NAME
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View:
Requirements
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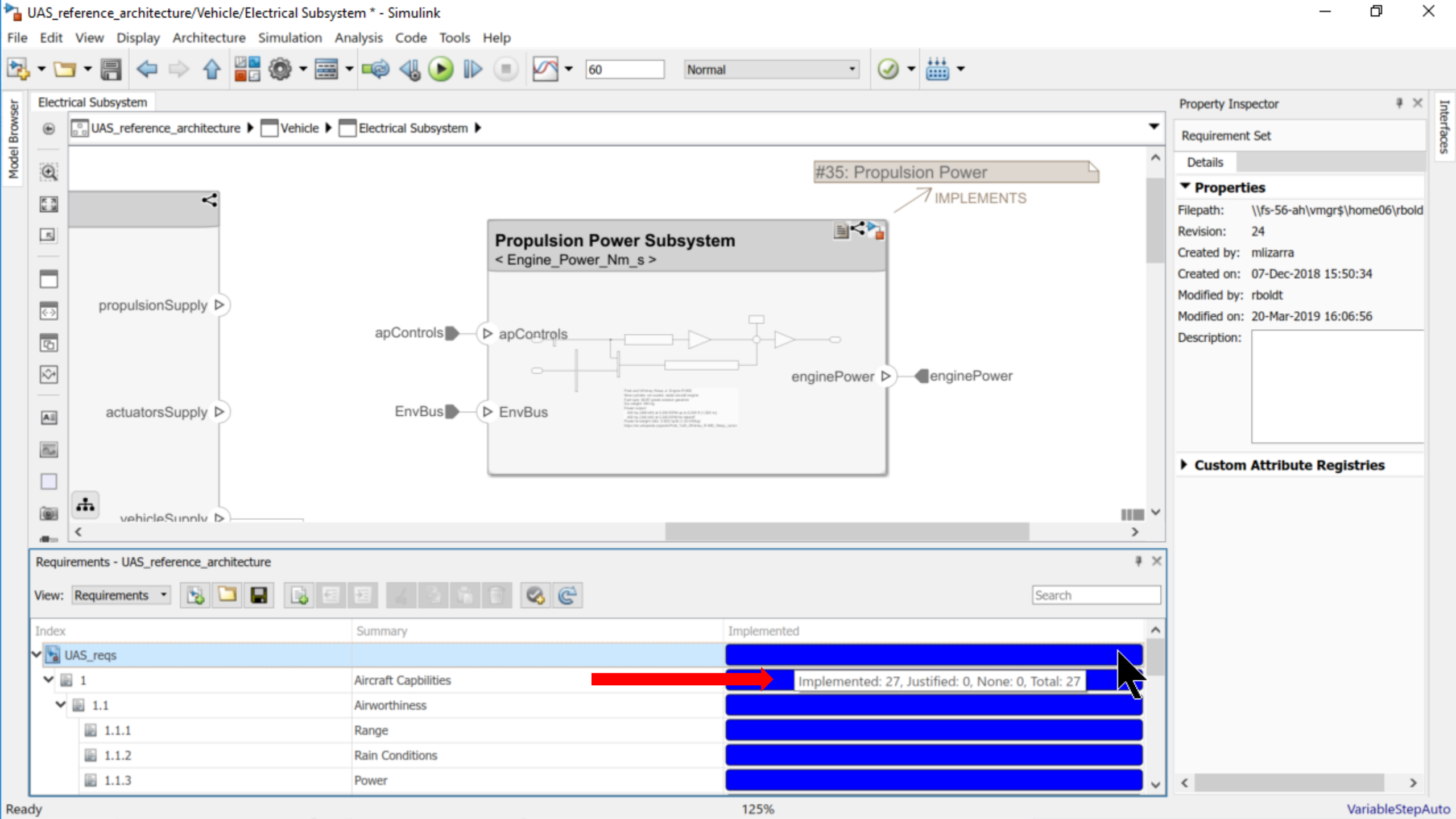
Index
Summary
Implemented
UAS_reqs
1
Aircraft Capbilities
1.1
Airworthiness
1.1.1
Range
1.1.2
Rain Conditions
1.1.3
Power
Ready
125%
VariableStepAuto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Model Browser
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Electrical Subsystem
#35: Propulsion Power
IMPLEMENTS
Propulsion Power Subsystem
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actuatorsSupply
vehicleSupply
apControls
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EnvBus
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enginePower
enginePower
Property Inspector
Requirement Set
Details
Properties
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Created by: mlizarra
Created on: 07-Dec-2018 15:50:34
Modified by: rboldt
Modified on: 20-Mar-2019 16:06:56
Description:
Custom Attribute Registries
Interfaces
Requirements - UAS_reference_architecture
View: Requirements
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Summary
Implemented
UAS_reqs
1
Aircraft Capbilities
Implemented: 27, Justified: 0, None: 0, Total: 27
1.1
Airworthiness
1.1.1
Range
1.1.2
Rain Conditions
1.1.3
Power
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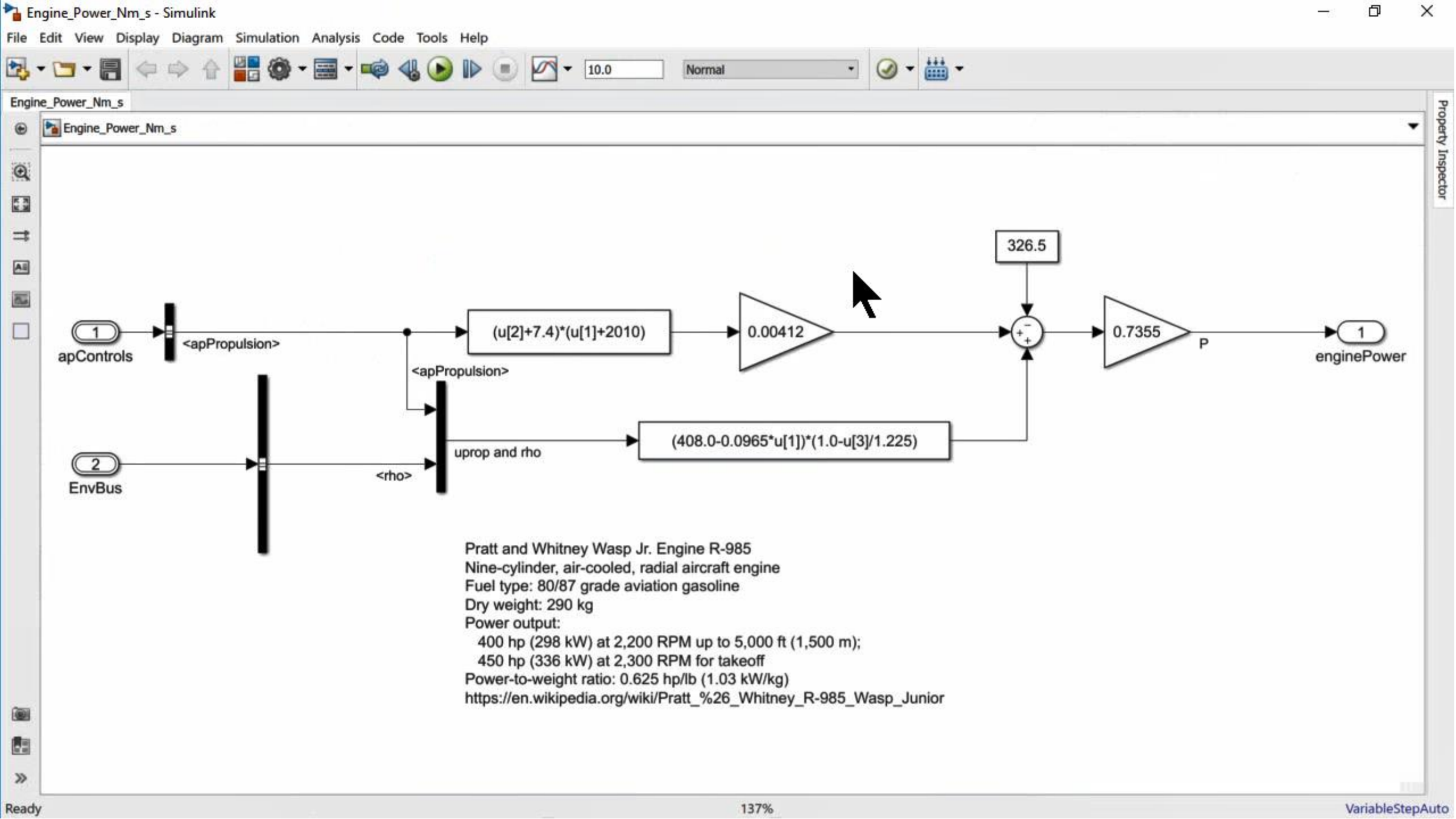
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Pratt and Whitney Wasp Jr. Engine R-985
Nine-cylinder, air-cooled, radial aircraft engine
Fuel type: 80/87 grade aviation gasoline
Dry weight: 290 kg
Power output:
400 hp (298 kW) at 2,200 RPM up to 5,000 ft (1,500 m);
450 hp (336 kW) at 2,300 RPM for takeoff
Power-to-weight ratio: 0.625 hp/lb (1.03 kW/kg)
https://en.wikipedia.org/wiki/Pratt_%26_Whitney_R-985_Wasp_Junior
Ready
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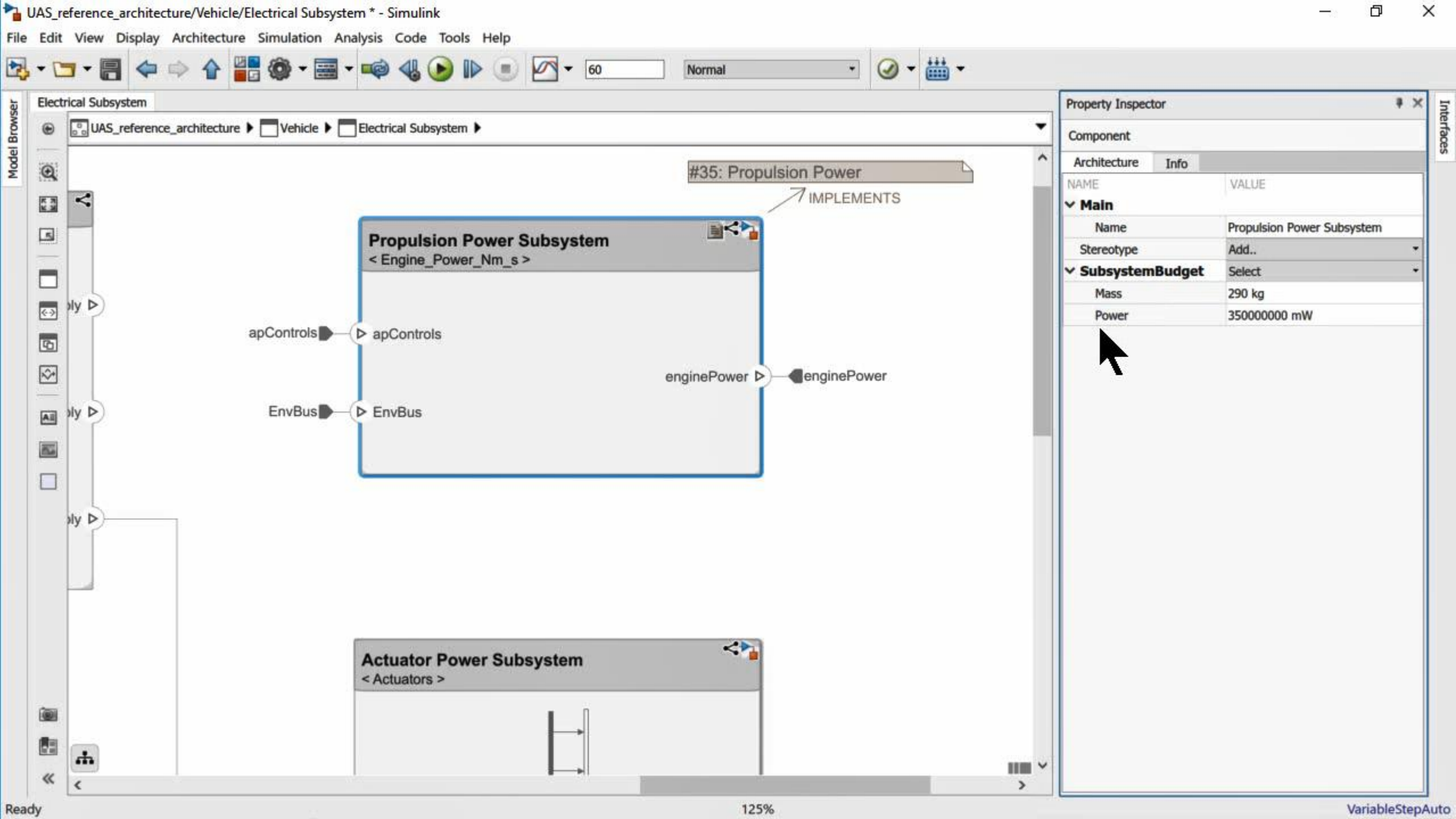
VariableStepAuto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Vehicle
Electrical Subsystem
#35: Propulsion Power
IMPLEMENTS
Propulsion Power Subsystem
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Actuator Power Subsystem
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Property Inspector
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Architecture
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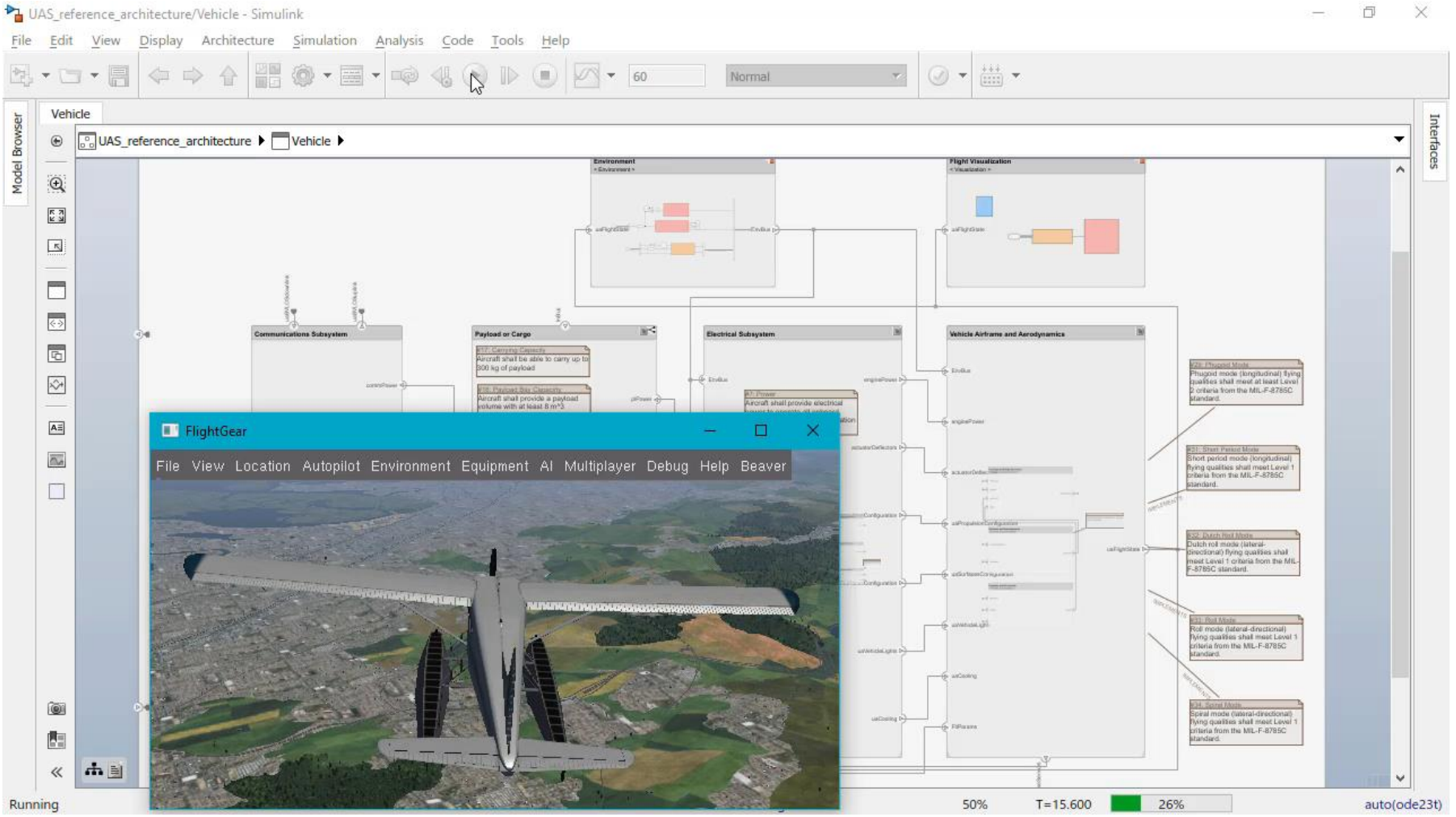
UAS_reference_architecture/Vehicle - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
Vehicle
UAS_reference_architecture
Vehicle
Model Browser
Interfaces
Environment
Flight Visualization
Communications Subsystem
Payload or Cargo
Electrical Subsystem
Vehicle Airframe and Aerodynamics
FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help Beaver
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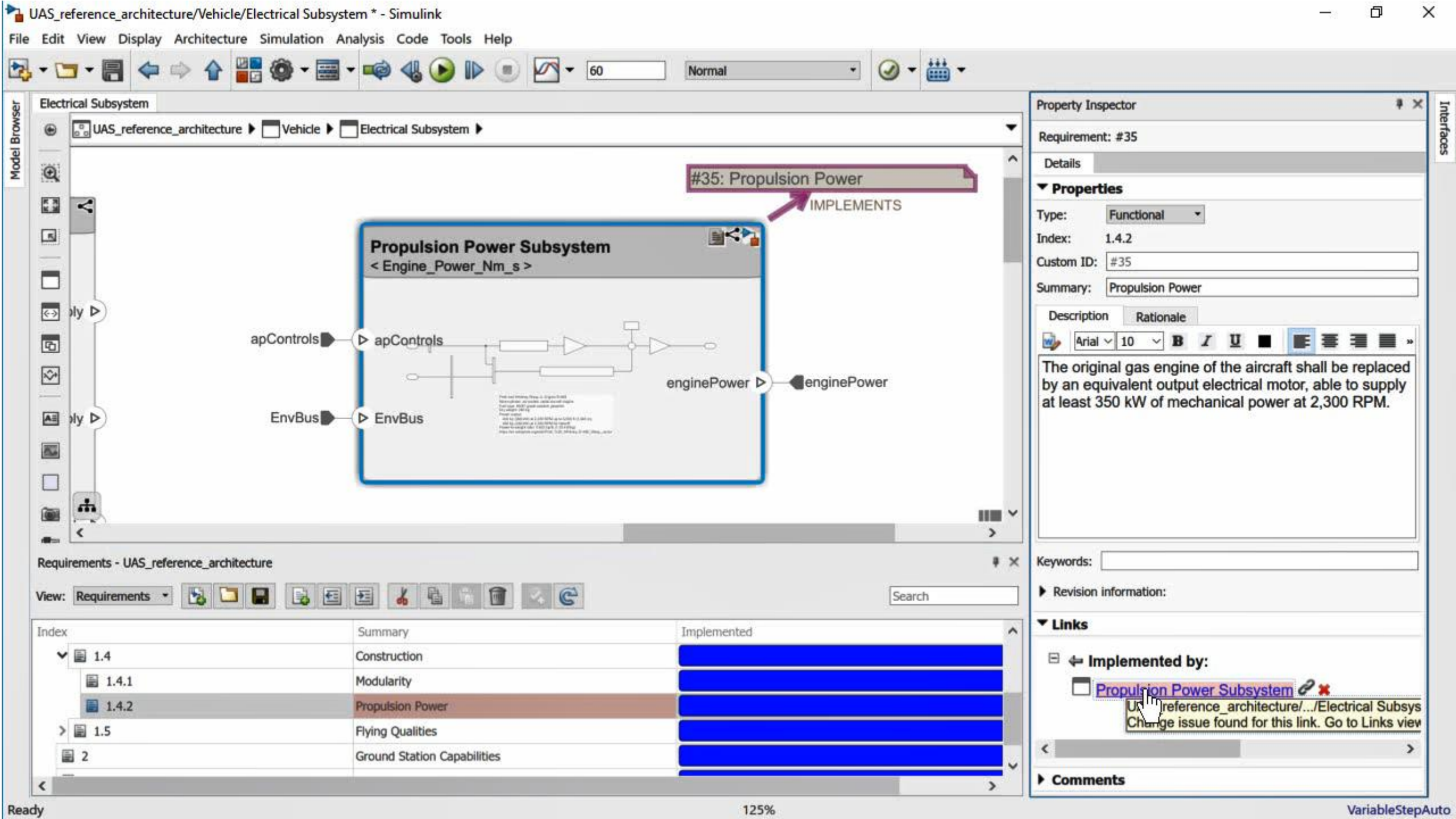
UAS_reference_architecture/Vehicle/Electrical Subsystem * - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
Model Browser
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Vehicle
Electrical Subsystem
#35: Propulsion Power
IMPLEMENTS
Propulsion Power Subsystem
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apControls
enginePower
enginePower
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EnvBus
Requirements - UAS_reference_architecture
View: Requirements
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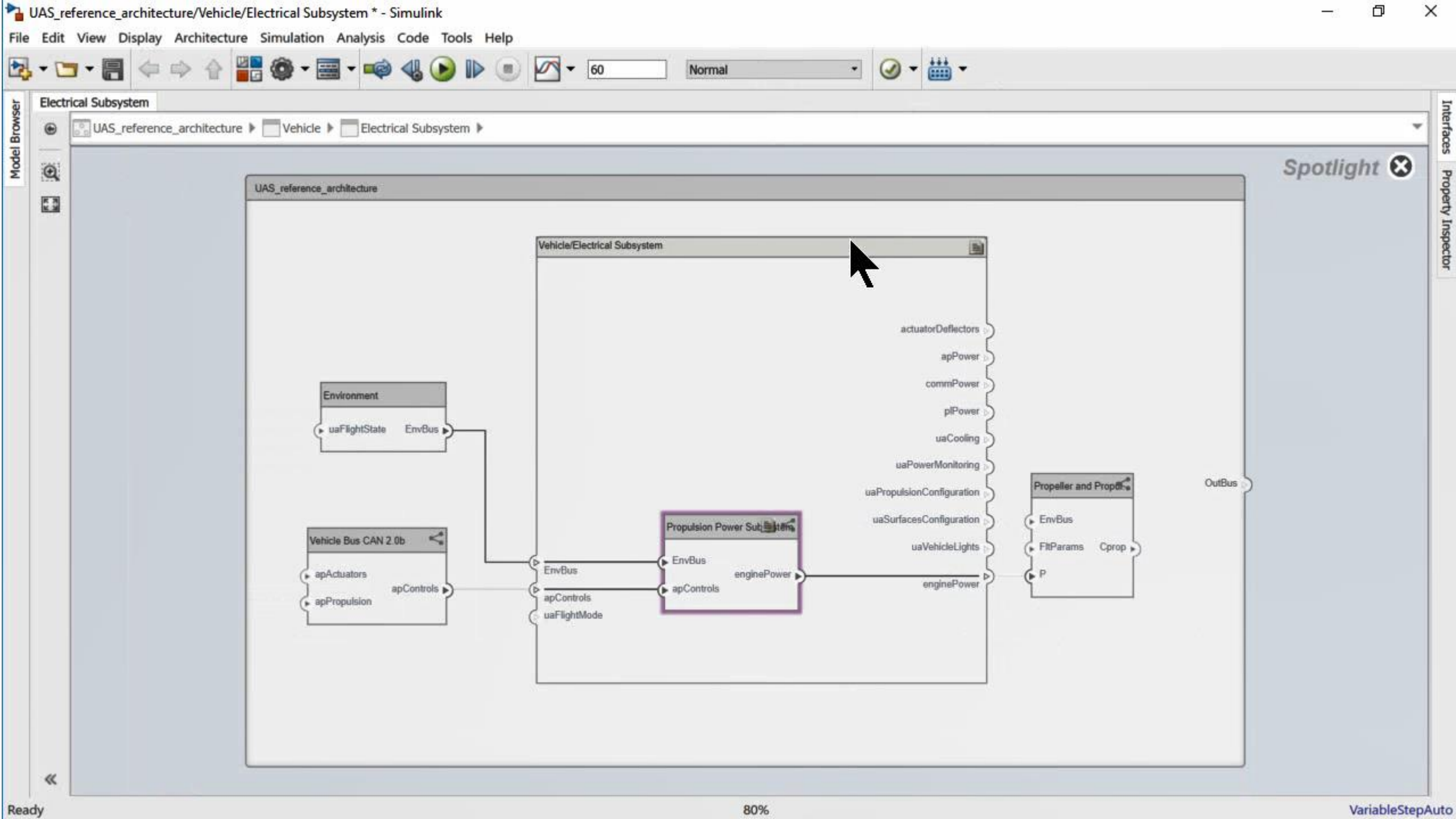
Implemented
1.4 Construction
1.4.1 Modularity
1.4.2 Propulsion Power
1.5 Flying Qualities
2 Ground Station Capabilities
Property Inspector
Requirement: #35
Details
Properties
Type: Functional
Index: 1.4.2
Custom ID: #35
Summary: Propulsion Power
Description
Rationale
Arial
10
The original gas engine of the aircraft shall be replaced by an equivalent output electrical motor, able to supply at least 350 kW of mechanical power at 2,300 RPM.
Keywords:
Revision information:
Links
Implemented by:
Propulsion Power Subsystem
reference_architecture/.../Electrical Subsys
Change issue found for this link. Go to Links view
Comments
Interfaces
Ready
125%
VariableStepAuto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Electrical Subsystem
UAS_reference_architecture
Vehicle
Electrical Subsystem
Model Browser
Interfaces
Property Inspector
Spotlight
UAS_reference_architecture
Vehicle/Electrical Subsystem
actuatorDeflectors
apPower
commPower
plPower
uaCooling
uaPowerMonitoring
uaPropulsionConfiguration
uaSurfacesConfiguration
uaVehicleLights
enginePower
Environment
uaFlightState
EnvBus
Vehicle Bus CAN 2.0b
apActuators
apPropulsion
apControls
EnvBus
apControls
uaFlightMode
Propulsion Power Subsystem
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enginePower
Propeller and Propeller
EnvBus
FltParams
Cprop
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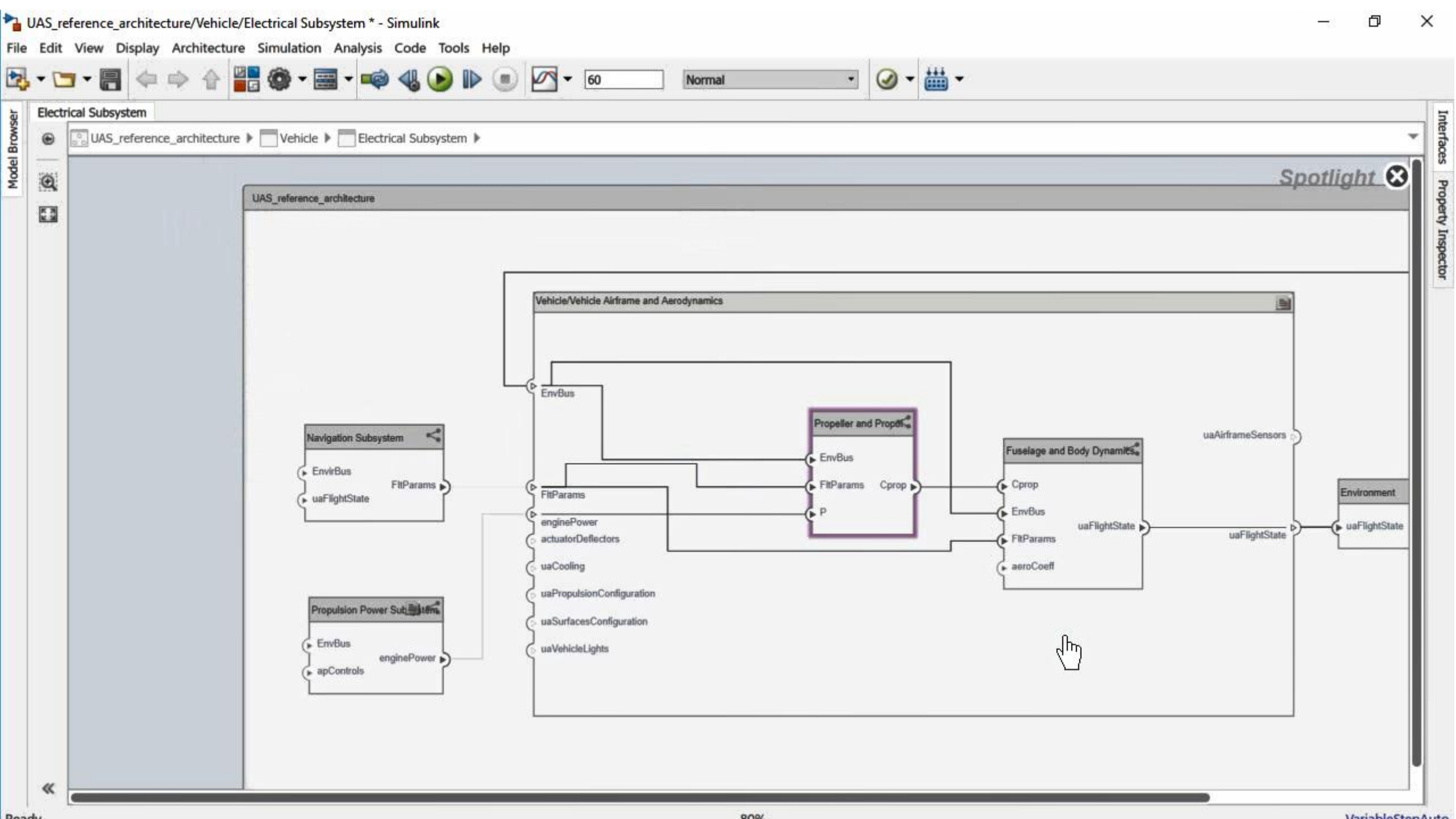
OutBus
Ready
80%
VariableStepAuto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Model Browser
Interfaces
Property Inspector
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UAS_reference_architecture
Vehicle/Vehicle Airframe and Aerodynamics
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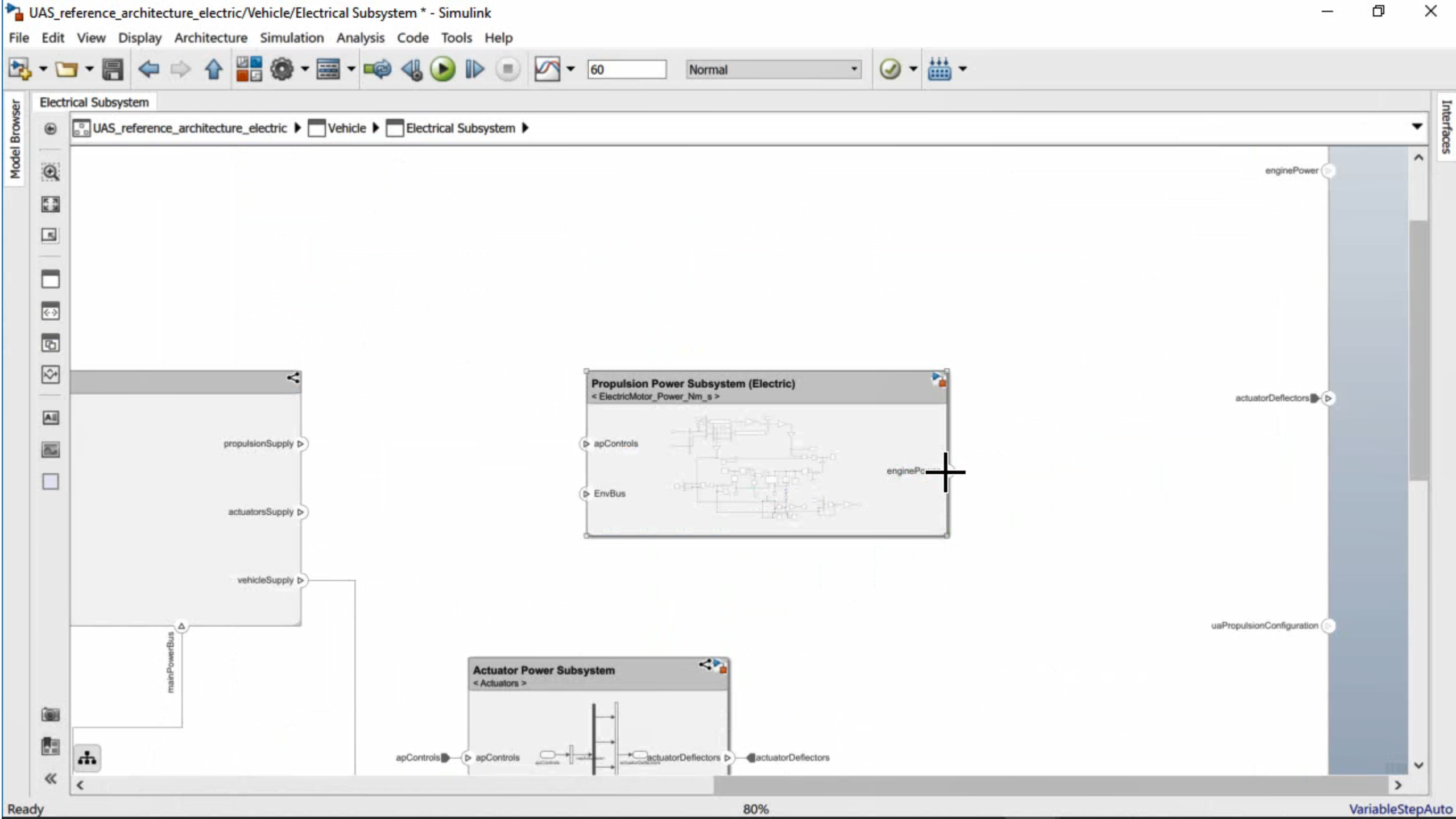
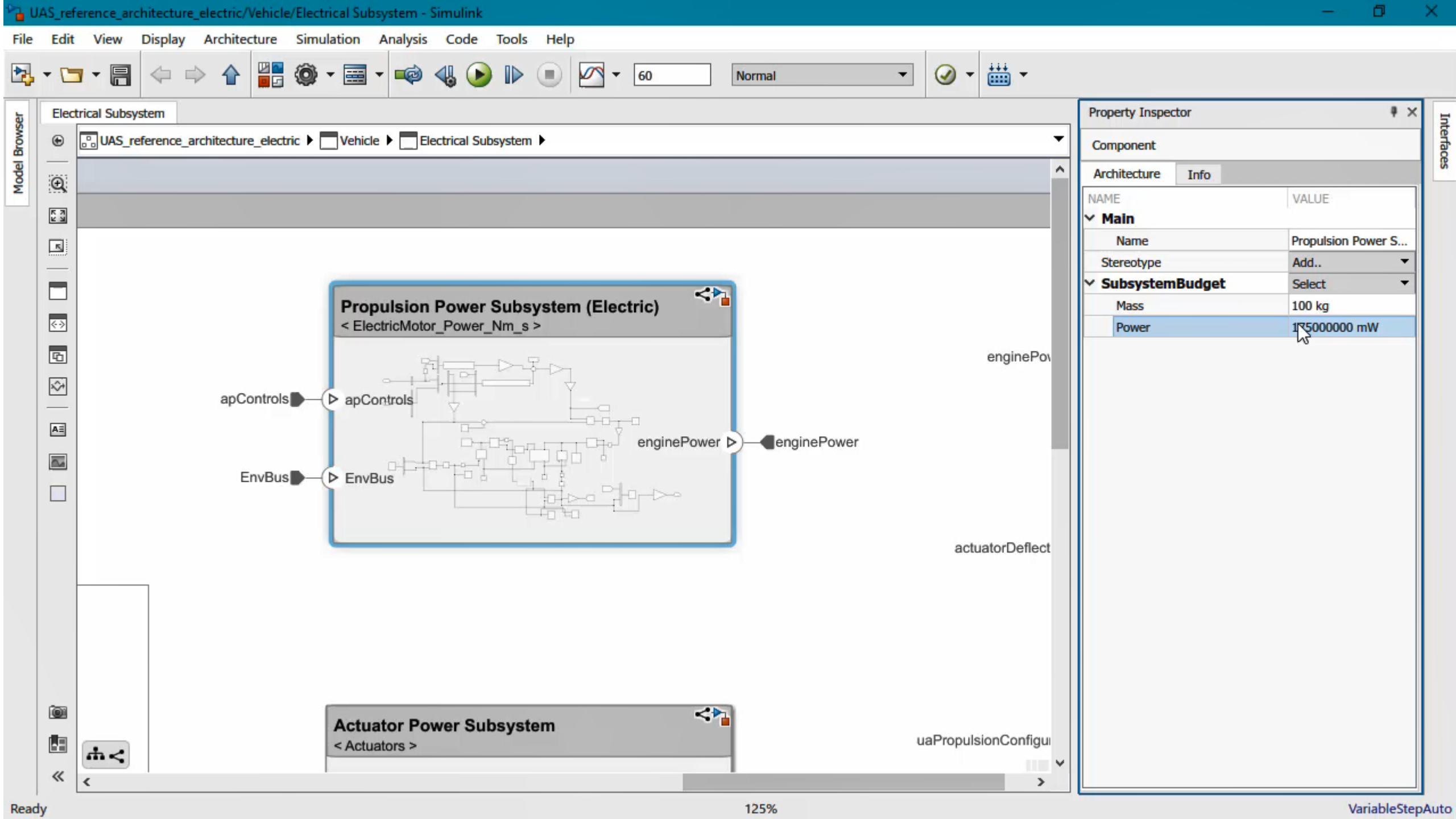
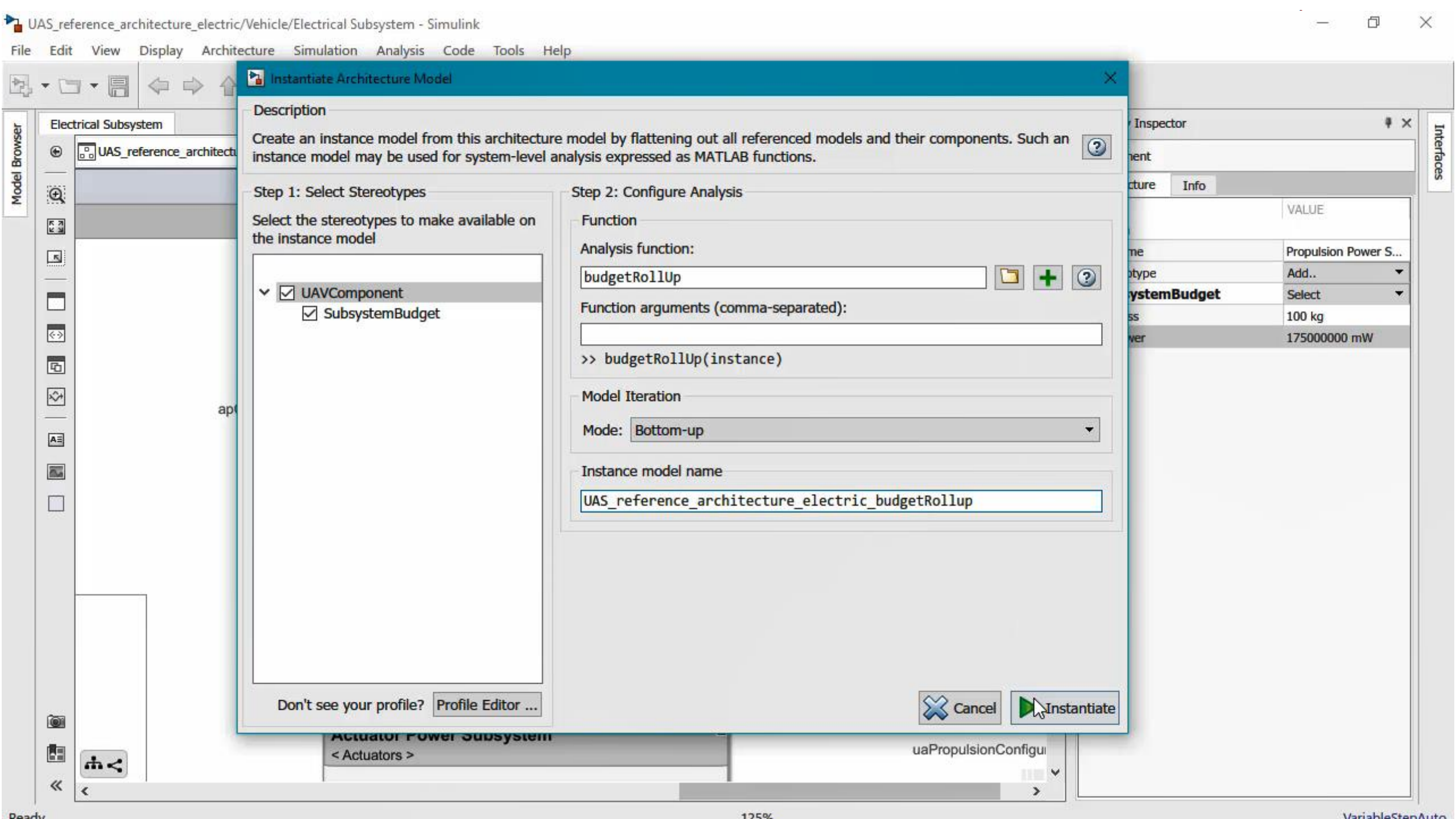
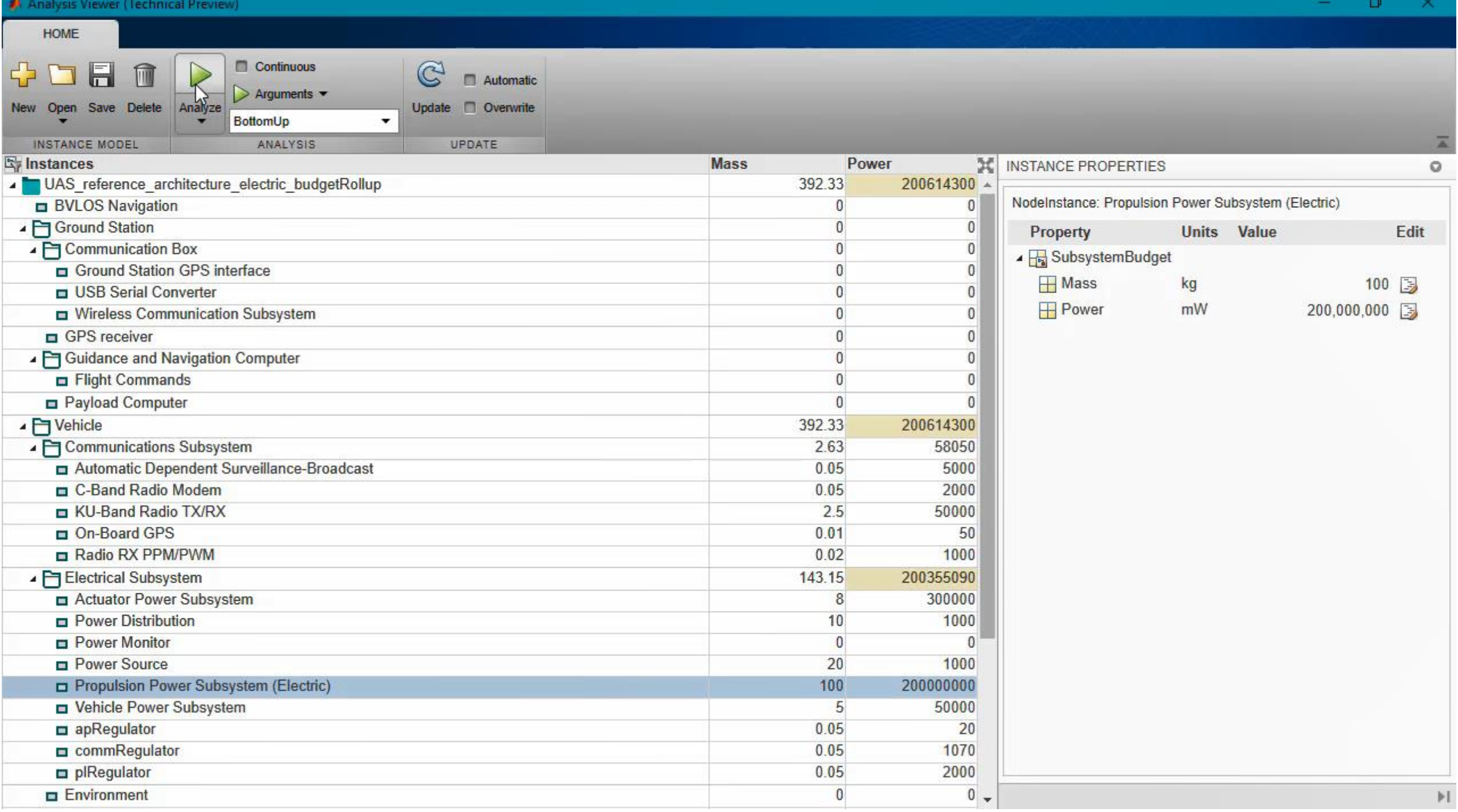
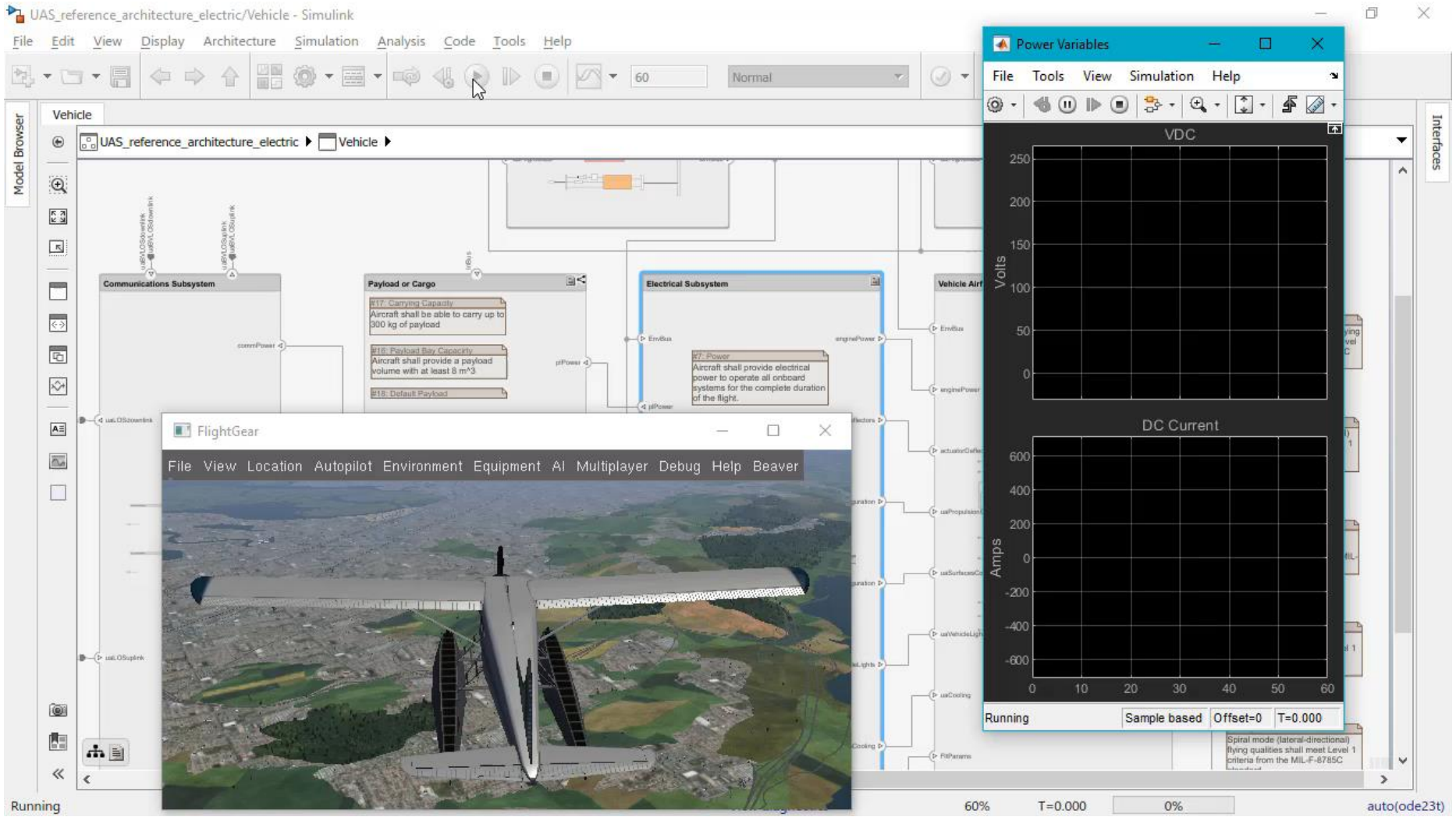
actuatorDeflectors
uaCooling
uaPropulsionConfiguration
uaSurfacesConfiguration
uaVehicleLights
Navigation Subsystem
EnvirBus
uaFlightState
FltParams
Propulsion Power Subsystem
EnvBus
apControls
enginePower
Propeller and Propeller
EnvBus
FltParams
P
Cprop
Fuselage and Body Dynamics
Cprop
EnvBus
FltParams
aeroCoeff
uaFlightState
uaAirframeSensors
uaFlightState
Environment
uaFlightState


UAS_reference_architecture_electric/Vehicle/Electrical Subsystem * - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
60
Normal
Model Browser
Interfaces
Electrical Subsystem
UAS_reference_architecture_electric
Vehicle
Electrical Subsystem
enginePower
actuatorDeflectors
uaPropulsionConfiguration
Propulsion Power Subsystem (Electric)
< ElectricMotor_Power_Nm_s >
apControls
EnvBus
propulsionSupply
actuatorsSupply
vehicleSupply
mainPowerBus
Actuator Power Subsystem
< Actuators >
apControls
apControls
actuatorDeflectors
actuatorDeflectors
Ready
80%
VariableStepAuto


UAS_reference_architecture_electric/Vehicle/Electrical Subsystem - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
60
Normal
Model Browser
Electrical Subsystem
UAS_reference_architecture_electric
Vehicle
Electrical Subsystem
Propulsion Power Subsystem (Electric)
< ElectricMotor_Power_Nm_s >
apControls
apControls
EnvBus
EnvBus
enginePower
enginePower
enginePo
actuatorDeflect
Actuator Power Subsystem
< Actuators >
uaPropulsionConfigu
Property Inspector
Component
Architecture
Info
NAME
VALUE
Main
Name
Propulsion Power S...
Stereotype
Add..
SubsystemBudget
Select
Mass
100 kg
Power
Interfaces
Ready
125%
VariableStepAuto


UAS_reference_architecture_electric/Vehicle/Electrical Subsystem - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
Instantiate Architecture Model
Description
Create an instance model from this architecture model by flattening out all referenced models and their components. Such an instance model may be used for system-level analysis expressed as MATLAB functions.
Step 1: Select Stereotypes
Select the stereotypes to make available on the instance model
UAVComponent
SubsystemBudget
Don't see your profile?
Profile Editor ...
Step 2: Configure Analysis
Function
Analysis function:
budgetRollUp
Function arguments (comma-separated):
>> budgetRollUp(instance)
Model Iteration
Mode:
Bottom-up
Instance model name
UAS_reference_architecture_electric_budgetRollup
Cancel
Instantiate
Electrical Subsystem
Model Browser
Inspector
Interfaces
Info
VALUE
Propulsion Power S...
Add..
Select
100 kg
175000000 mW
< Actuators >
Ready

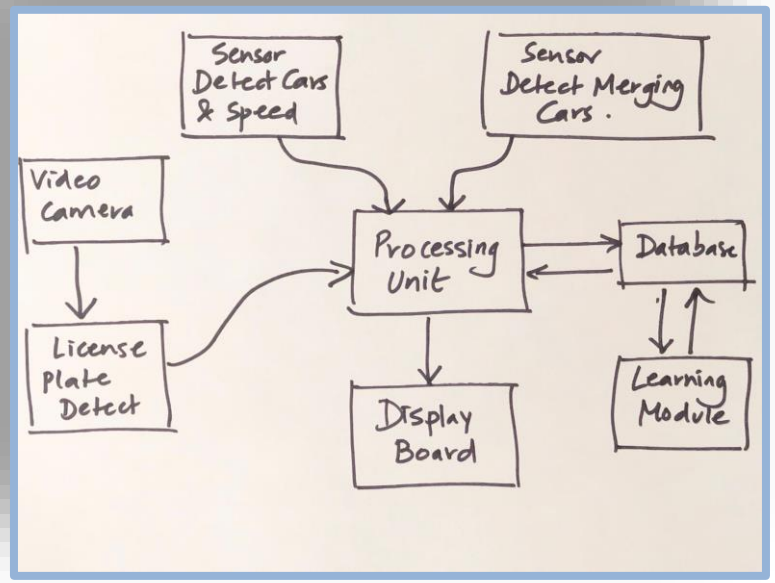

Analysis Viewer (Technical Preview)
HOME
New
Open
Save
Delete
INSTANCE MODEL
Analyze
Continuous
Arguments
BottomUp
ANALYSIS
Update
Automatic
Overwrite
UPDATE
Instances
Mass
Power
UAS_reference_architecture_electric_budgetRollup 392.33 200614300
BVLOS Navigation 0 0
Ground Station 0 0
Communication Box 0 0
Ground Station GPS interface 0 0
USB Serial Converter 0 0
Wireless Communication Subsystem 0 0
GPS receiver 0 0
Guidance and Navigation Computer 0 0
Flight Commands 0 0
Payload Computer 0 0
Vehicle 392.33 200614300
Communications Subsystem 2.63 58050
Automatic Dependent Surveillance-Broadcast 0.05 5000
C-Band Radio Modem 0.05 2000
KU-Band Radio TX/RX 2.5 50000
On-Board GPS 0.01 50
Radio RX PPM/PWM 0.02 1000
Electrical Subsystem 143.15 200355090
Actuator Power Subsystem 8 300000
Power Distribution 10 1000
Power Monitor 0 0
Power Source 20 1000
Propulsion Power Subsystem (Electric) 100 200000000
Vehicle Power Subsystem 5 50000
apRegulator 0.05 20
commRegulator 0.05 1070
plRegulator 0.05 2000
Environment 0 0
INSTANCE PROPERTIES
NodeInstance: Propulsion Power Subsystem (Electric)
Property
Units
Value
Edit
SubsystemBudget
Mass kg 100
Power mW 200,000,000


UAS_reference_architecture_electric/Vehicle - Simulink
File Edit View Display Architecture Simulation Analysis Code Tools Help
Vehicle
UAS_reference_architecture_electric
Vehicle
Model Browser
Interfaces
Communications Subsystem
Payload or Cargo
Electrical Subsystem
Power Variables
File Tools View Simulation Help
VDC
Volts
DC Current
Amps
Running
Sample based
Offset=0
T=0.000
FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help Beaver
Running
60%
T=0.000
0%
auto(ode23t)

System Composer

Intuitively design system and software architectures

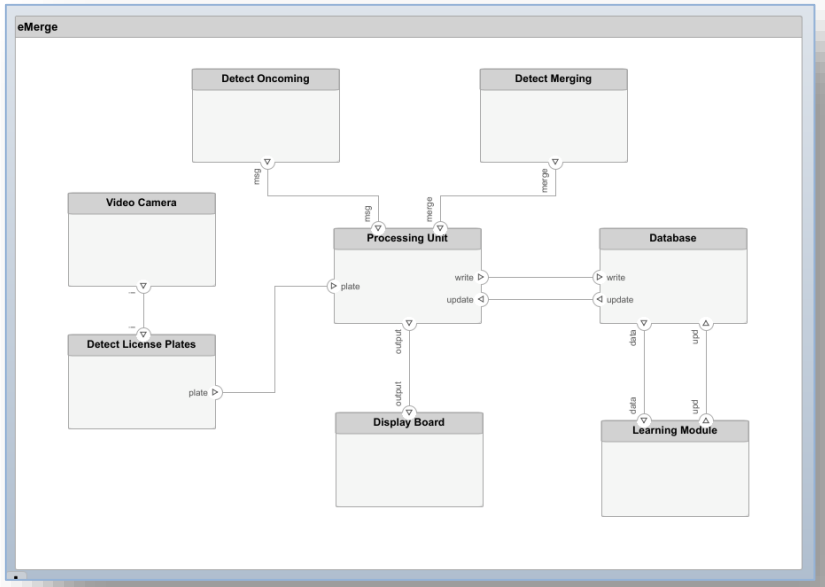
R2019a



Description

==

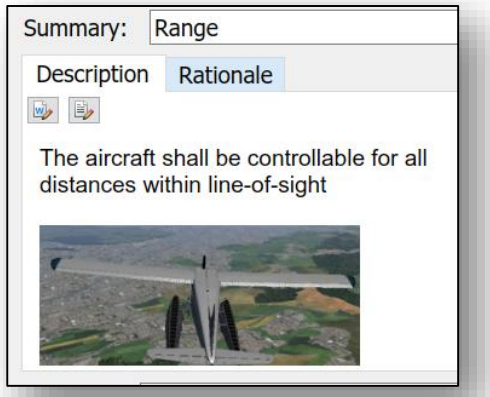
Architecture



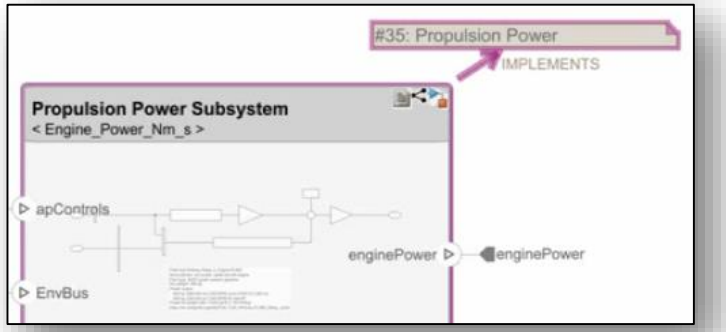
Simulink Requirements

Digital Thread from Requirements to Architecture and Design

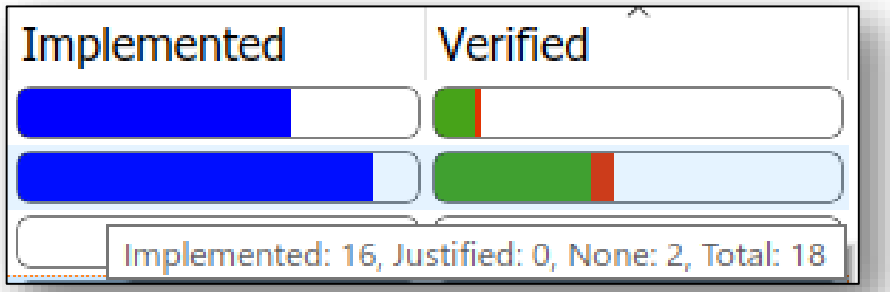
Author requirements or view from external source



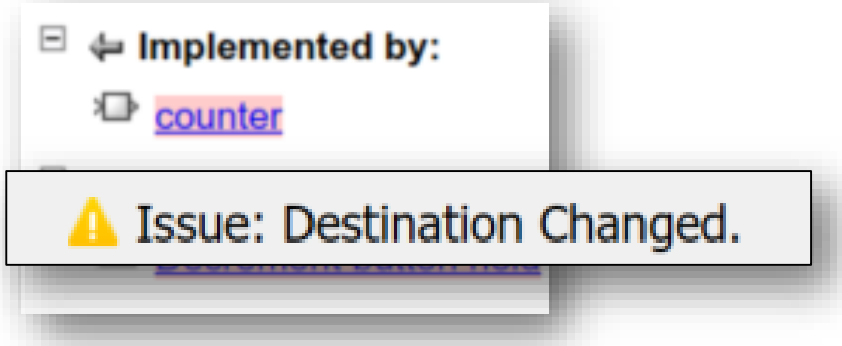
Link requirements, architectures, design, code and test



Identify gaps in architecture or design



Identify impact of requirement changes

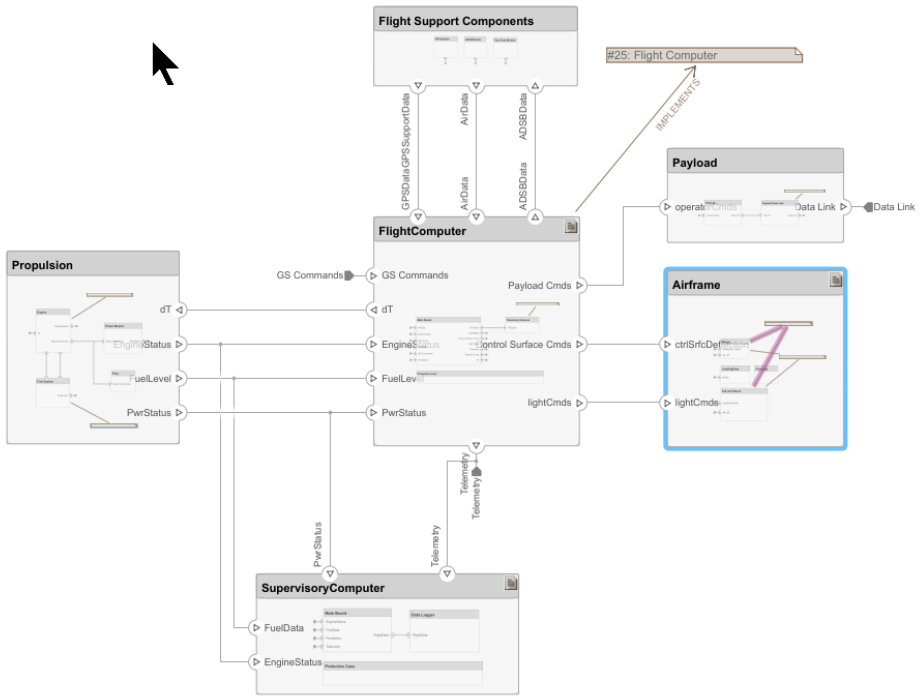


System Composer

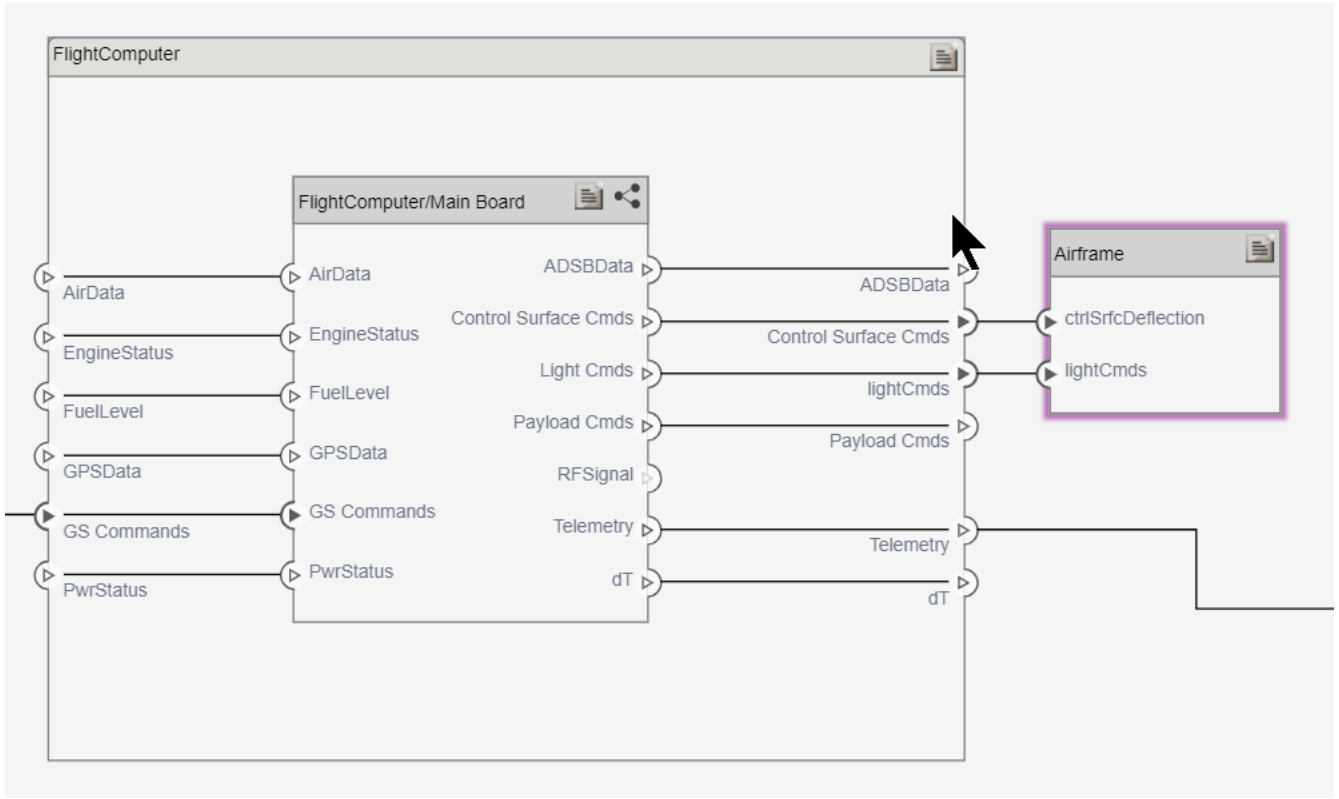
Tackle Architecture complexity with spotlight views

R2019a

Composition



Spotlight

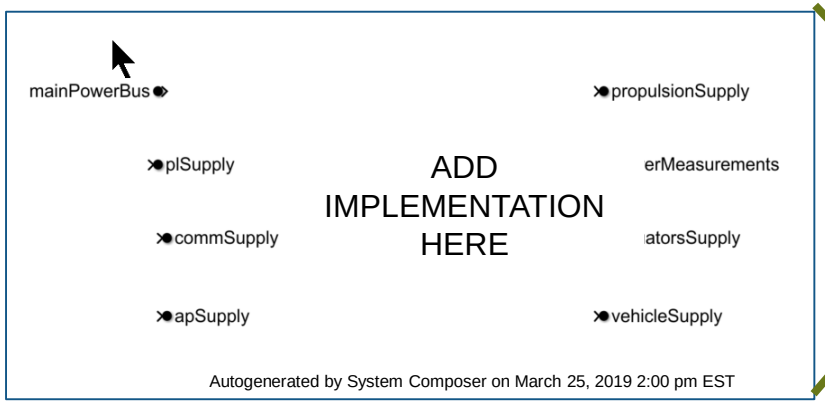


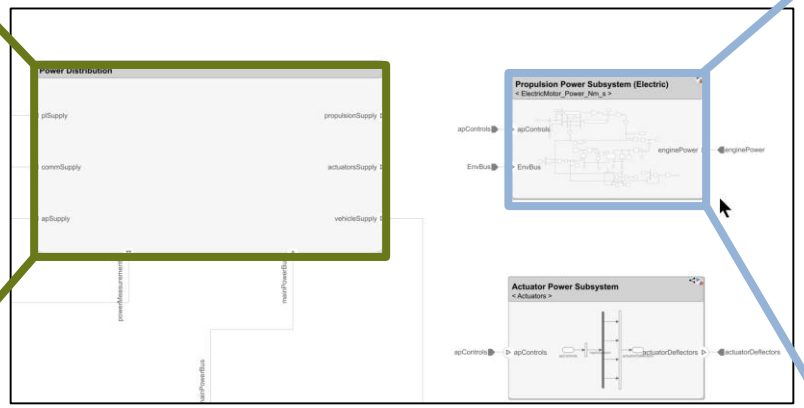
System Composer

R2019a

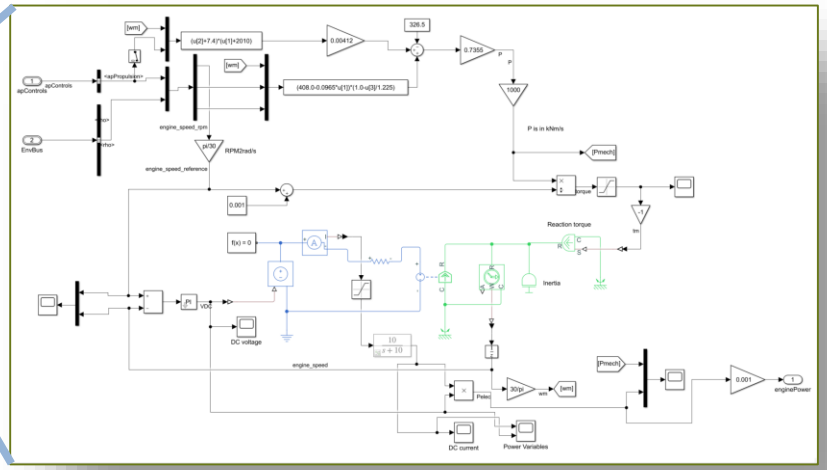
System and software architectures connected to implementations in Simulink

Generate Simulink models from architecture components





Link Simulink models to architecture components

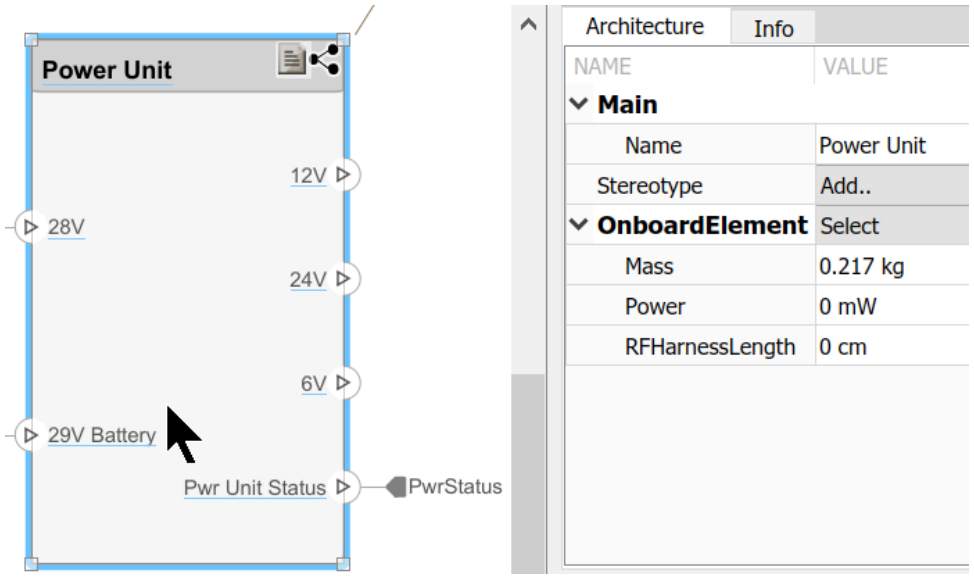


System Composer

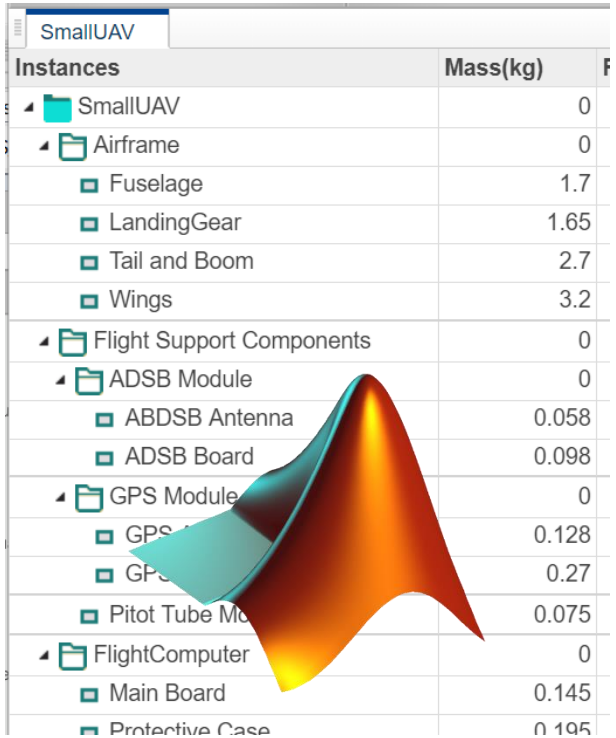
R2019a

Perform trade studies based on data driven analysis to optimize architectures

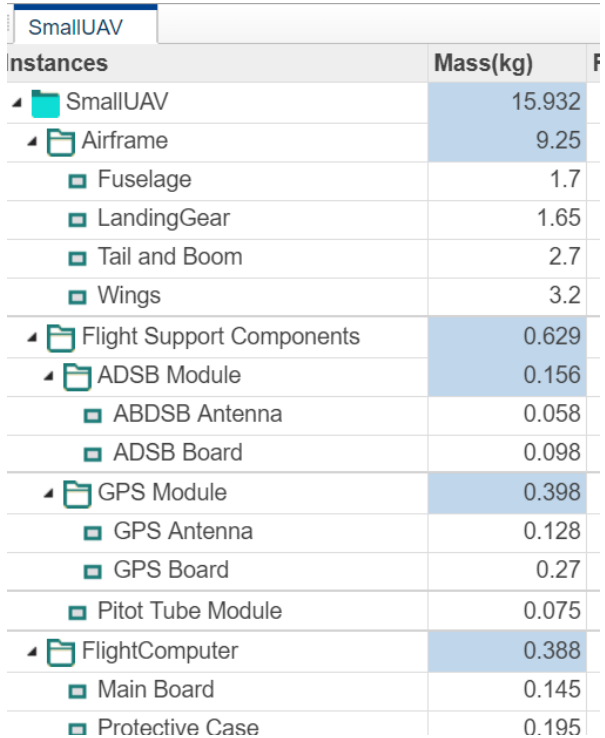
Add custom data



Create analysis model

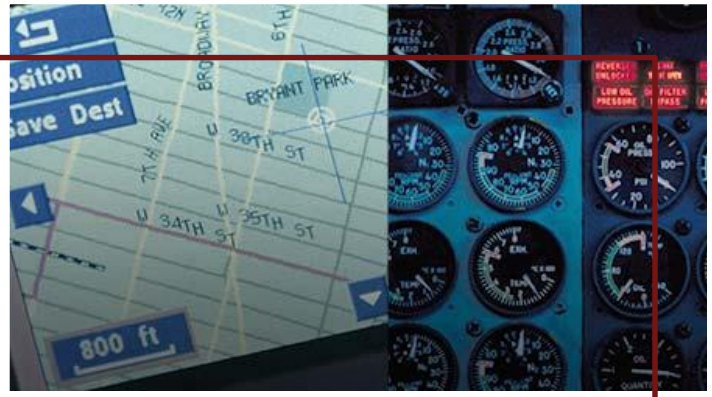


Calculate mass roll-up data



Simulink: A Multi-Language Simulation Environment

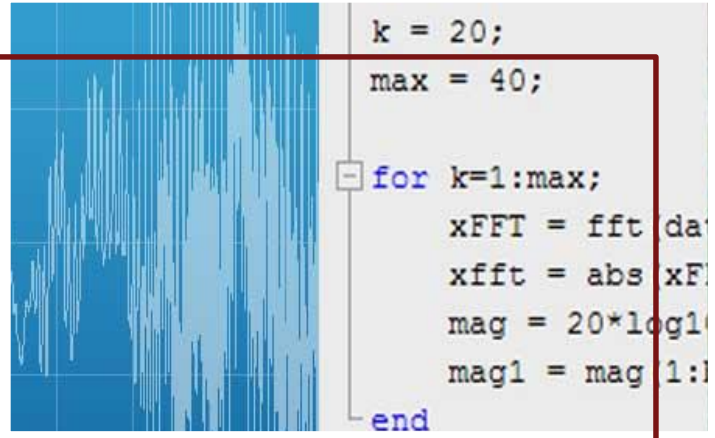
Dynamic Systems



State Machines

Discrete-Event Systems

Physical Modeling



Programming Languages

Learn More

- Simulink Requirement Webpage
- System Composer Webpage
- System Modeling and Simulation Webpage

- Trial

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508-647-7000

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