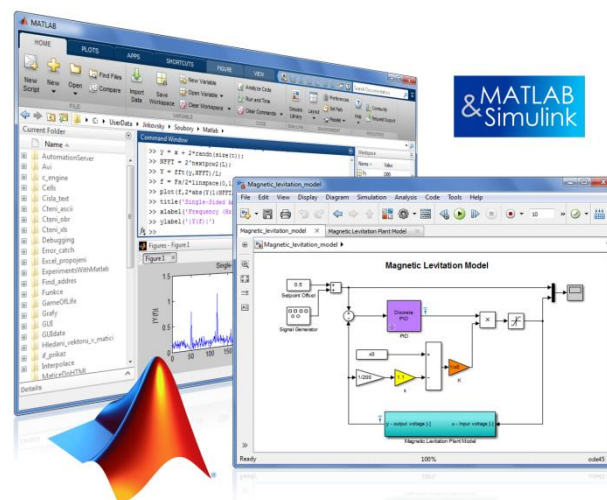


5.9.2019 Brno

TCC 2019

Produktivita a System Engineering při vývoji SW a HW v prostředí Simulink



Jaroslav Jirkovský

jirkovsky@humusoft.cz

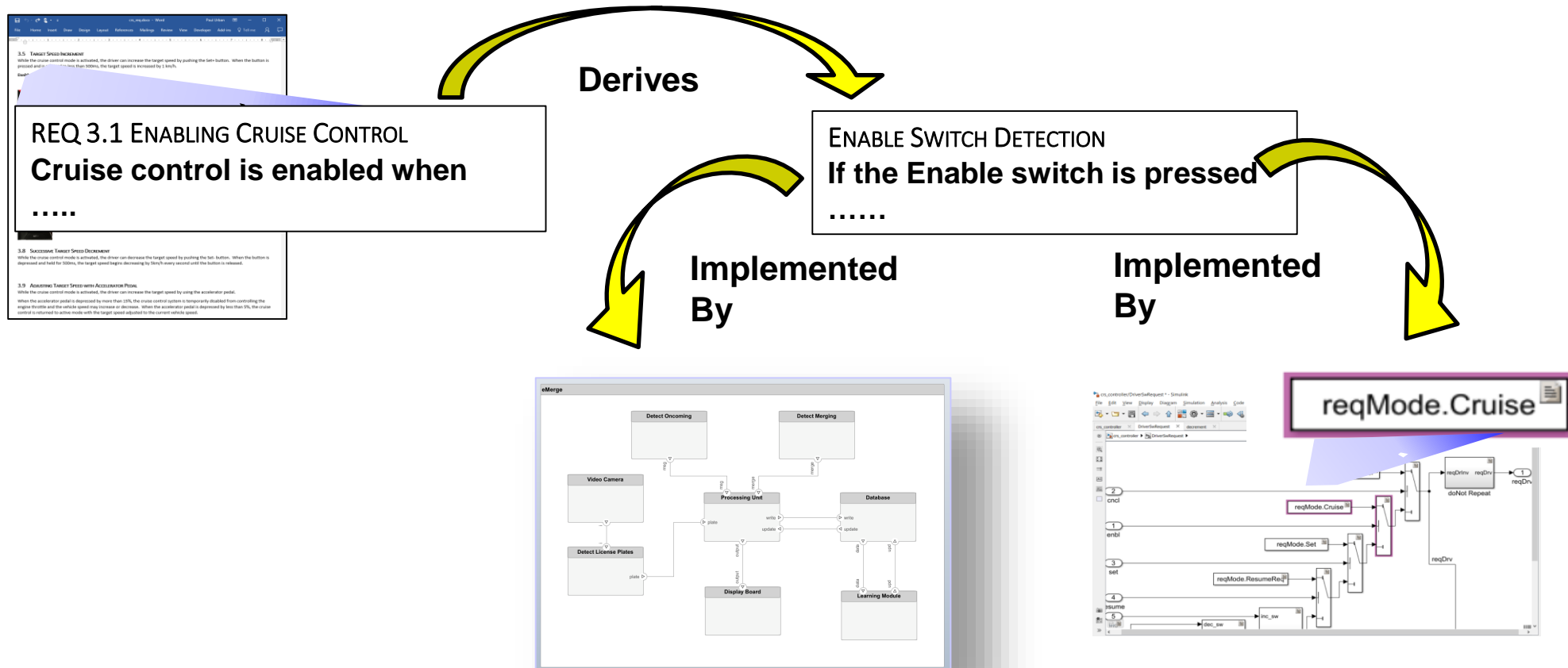
www.humusoft.cz

info@humusoft.cz

www.mathworks.com

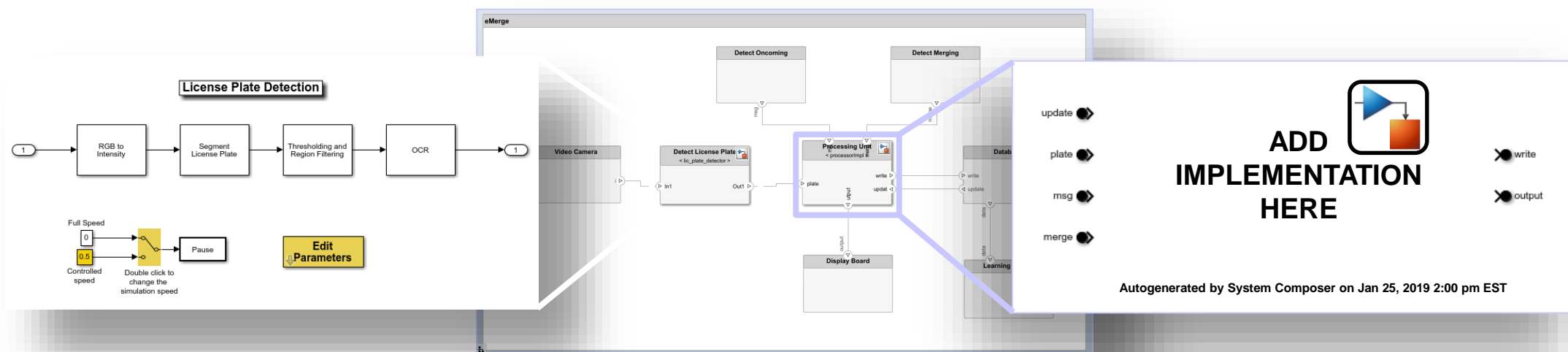
Key Takeaways

- Digital thread providing traceability between requirements, architecture, and design



Key Takeaways

- Digital thread providing traceability between requirements, architecture, and design
- Connected environment for designing and analyzing architectures and designs

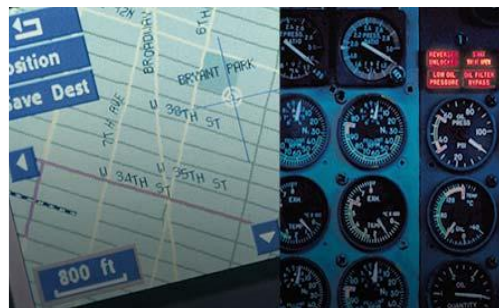


Key Takeaways

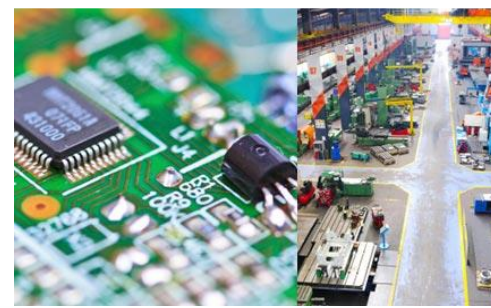
- **Digital thread providing traceability between requirements, architecture, and design**
- **Connected environment for designing and analyzing architectures and designs**
- **Integrated platform for analyzing all parts of your architecture in one multi-domain environment**



Dynamic Systems



State Machines



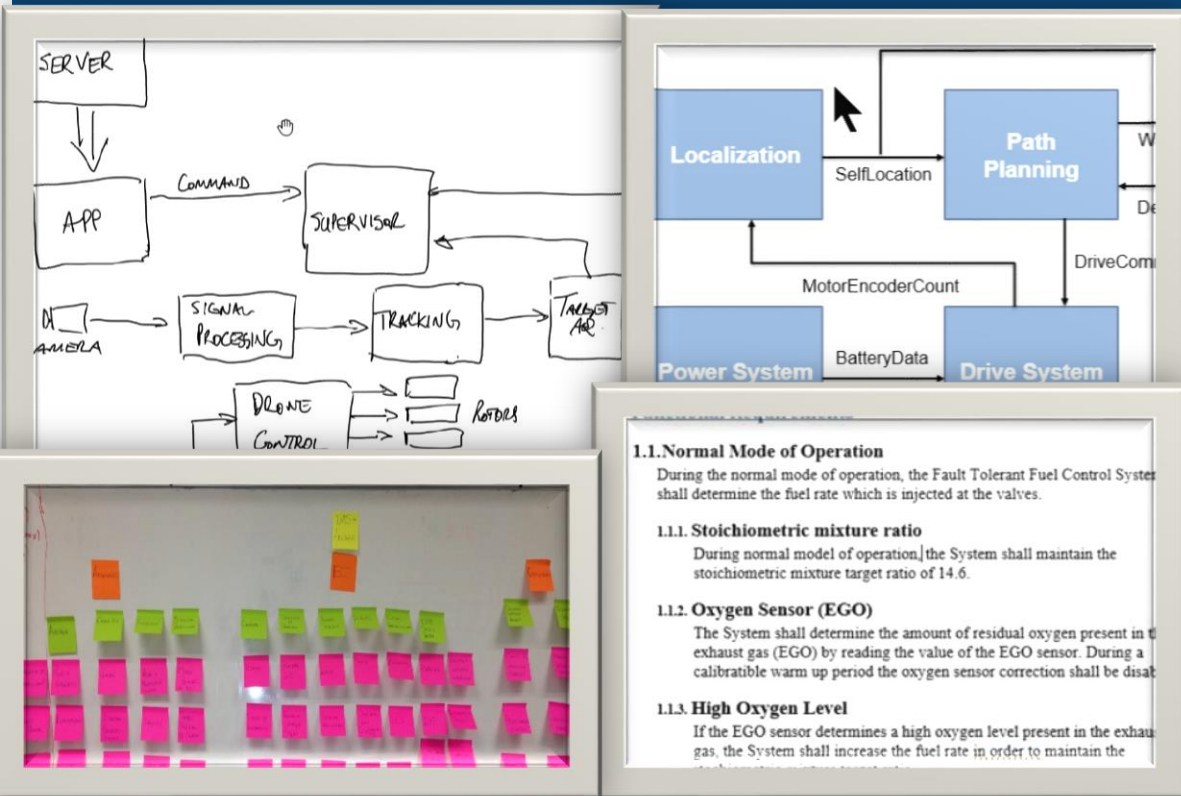
Discrete-Event



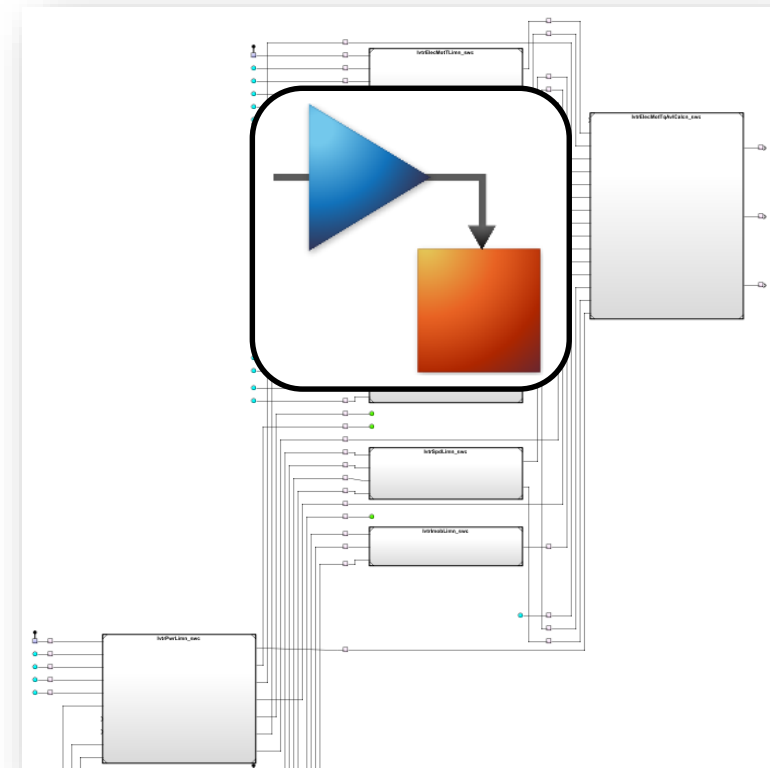
Physical Modeling

What does that mean?

Early in the Process Concepts/Descriptions



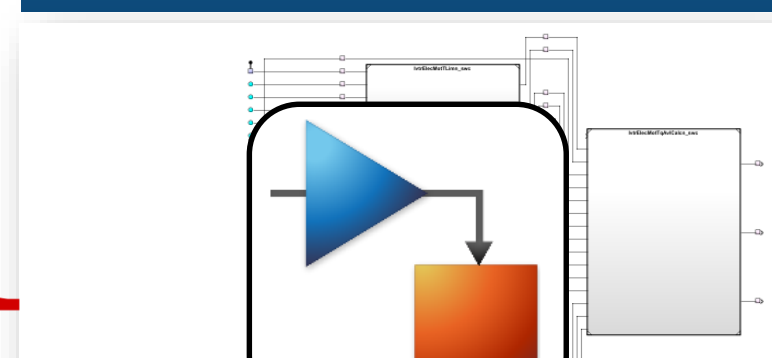
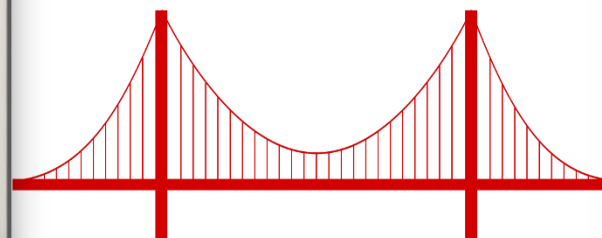
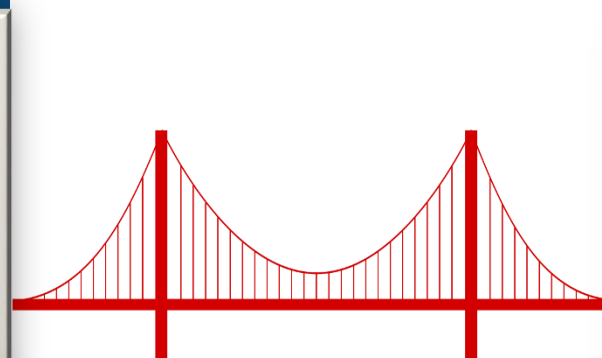
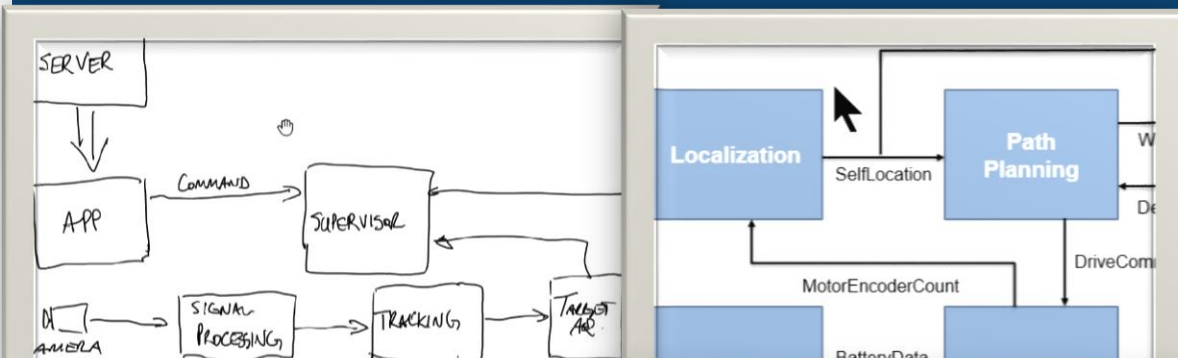
Later in the Process Models



What is the Gap?

Early in the Process
Concepts/Descriptions

Later in the Process
Models



Digital Thread
Connected Environment
Analysis & Simulation Platform

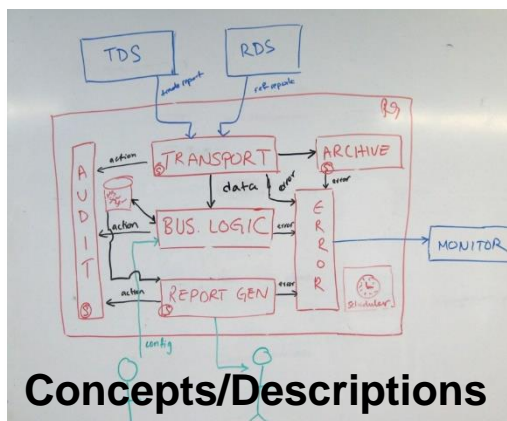
What goes into the bridge?

Be Intuitive

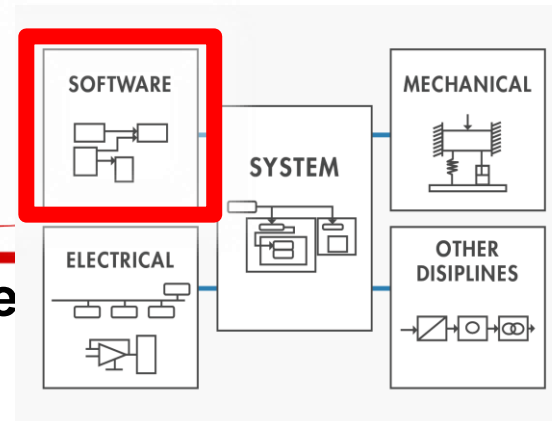
Facilitate Analysis

Tackle Complexity

Enable Implementation



VEHICLE COMPONENT	MASS(kg)	POWER(W)
• COMMUNICATION SUBSYS.	→ 2.63	58
- ADSB	→ 0.05	5
- KU/KA RADIO	→ 2.05	2
- RADIO RX PPM/PWM	→ 0.01	50
• ELECTRICAL SUBSYS	→ 0.02	0.85
- ACTUATOR POWER	→ 533.15	1
- POWER DISTRIBUTION	8	353000
- POWER MONITORING	10	200
- POWER SOURCE	→ 300	1000
- PROPULSION POWER	50	350000
- VEHICLE POWER	5	50
- AUTOPILOT REGULATOR	0.05	1.07
- COMMS REGULATOR	0.05	2
• MONITORING + CONTROL SUBS.	3.55	1.150
- AUTOPILOT	0.6	1



Digital Thread for Traceability

1. Functional Requirements

1.1. Normal Mode of Operation

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

I

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)

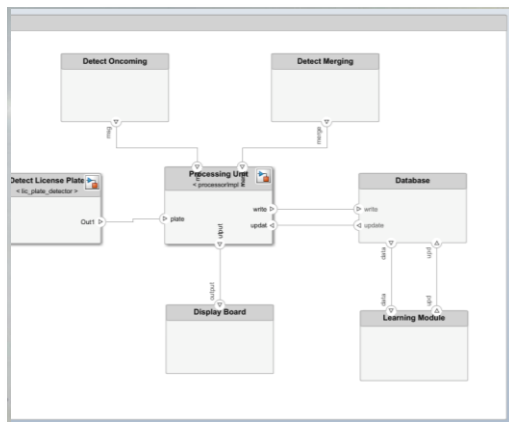
MathWorks Solution: System Composer R2019a and

✓ Be Intuitive

✓ Facilitate Analysis

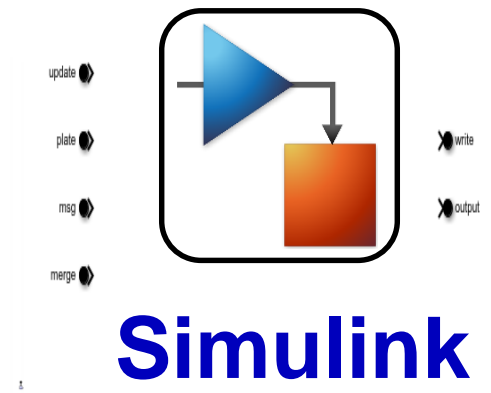
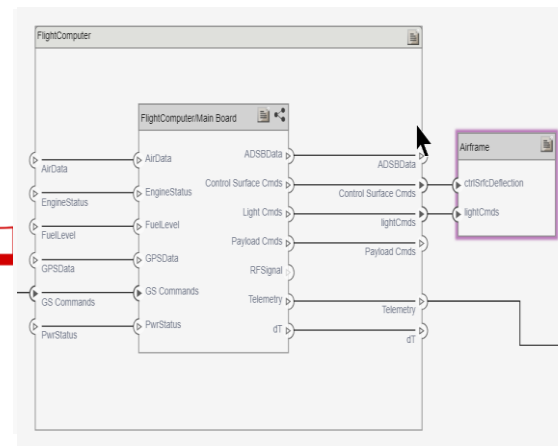
✓ Tackle Complexity

✓ Enable Implementation



VEHICLE COMPONENT

	MASS(kg)	POWER(W)
• COMMUNICATION SUBSYS.	→ 2.63	58
- ADSB	→ 0.05	5
- KU/Ka RADIO	→ 2.5	2
- RADIO RX PPM/PWM	→ 0.01	50
	→ 0.02	0.85
• ELECTRICAL SUBSYS	→ 533.15	1
- ACTUATOR POWER	8	353000
- POWER DISTRIBUTION	10	200
- POWER MONITORING	0.1	1000
- POWER SOURCE	→ 300	350000
- PROPULSION POWER	50	50
- VEHICLE POWER	5	0.02
- AUTOPILOT REGULATOR	0.05	1.07
- COMMS REGULATOR	0.05	1.07
• MONITORING + CONTROL SUBSYS.	→ 0.05	1.150
- AUTOPILOT	0.5	1



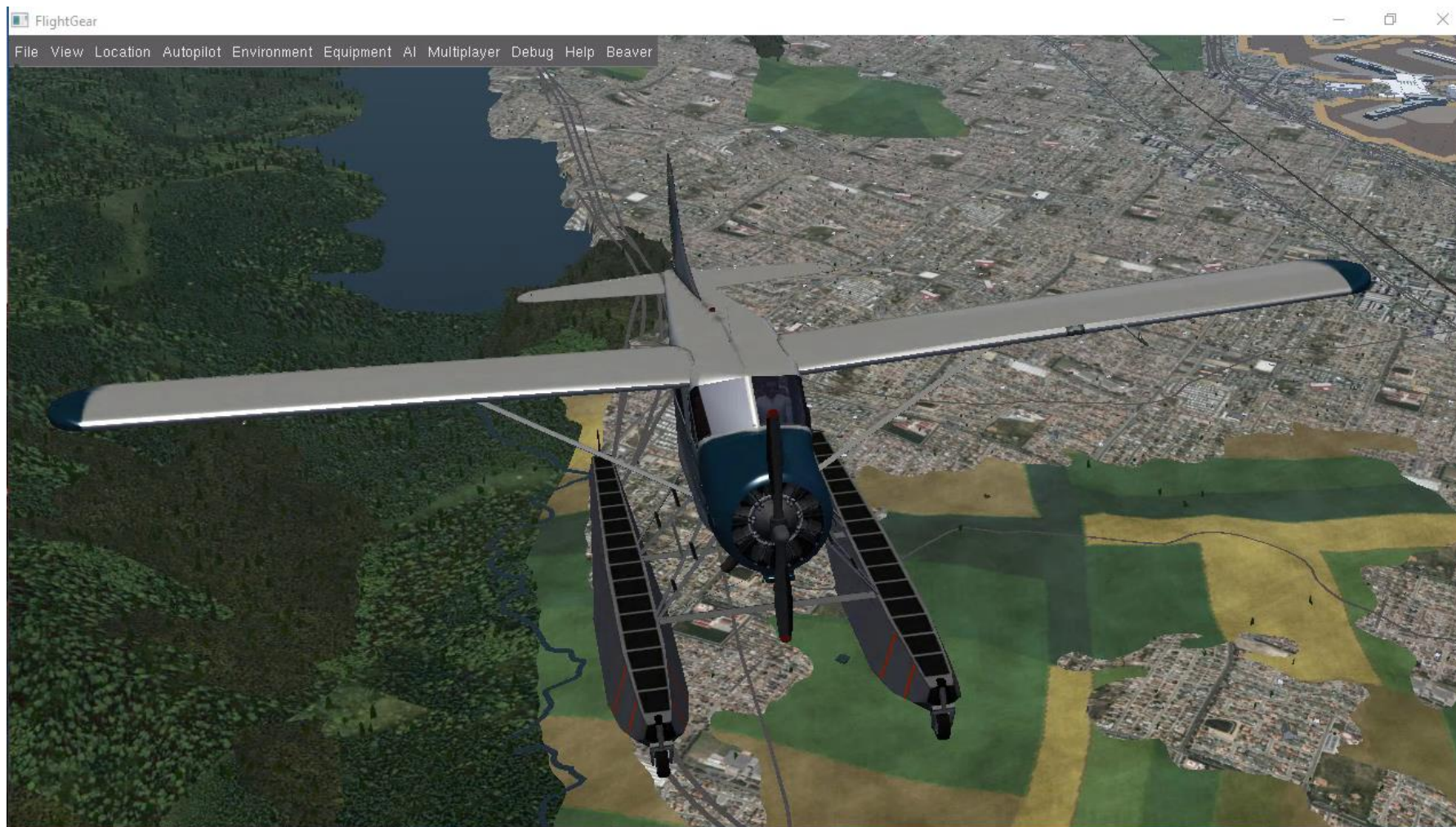
Requirements Coverage Reporting and Impact Analysis

Simulink Requirements

Index	Summary
> 1.1	Airworthiness
> 1.2	Communications
▼ 1.3	Payload Capabilities
1.3.1	Carrying Capacity
1.3.2	Payload Bay Capacity
1.3.3	Default Payload
1.3.4	Payload Protection

Implemented progress bar showing completion status for each requirement.

Now let's see it in action



Requirements Editor

File Edit Display Analysis Report Help

View: Requirements · Search

Index	Summary
UAS_reqs*	
> 1	Aircraft Capabilities
2	Ground Station Capabilities
3	BLOS Capabilities

Properties

Filepath: \\fs-56-ah\vmgr\$\home06\rboldt\Do...
Revision: 23
Created by: mlizarra
Created on: 07-Dec-2018 15:50:34
Modified by: gdrayera
Modified on: 12-Mar-2019 15:36:22
Description:

Custom Attribute Registries

Toolbar with icons for file operations, navigation, simulation, and analysis. Includes a numerical input field with the value 10.0 and a dropdown menu set to Normal.

Model Browser

UAS_ref_arch

Main workspace area showing a diagram titled 'UAS_ref_arch'. The diagram content is currently blank. A mouse cursor is hovering over a blue square icon in the left-hand toolbar.

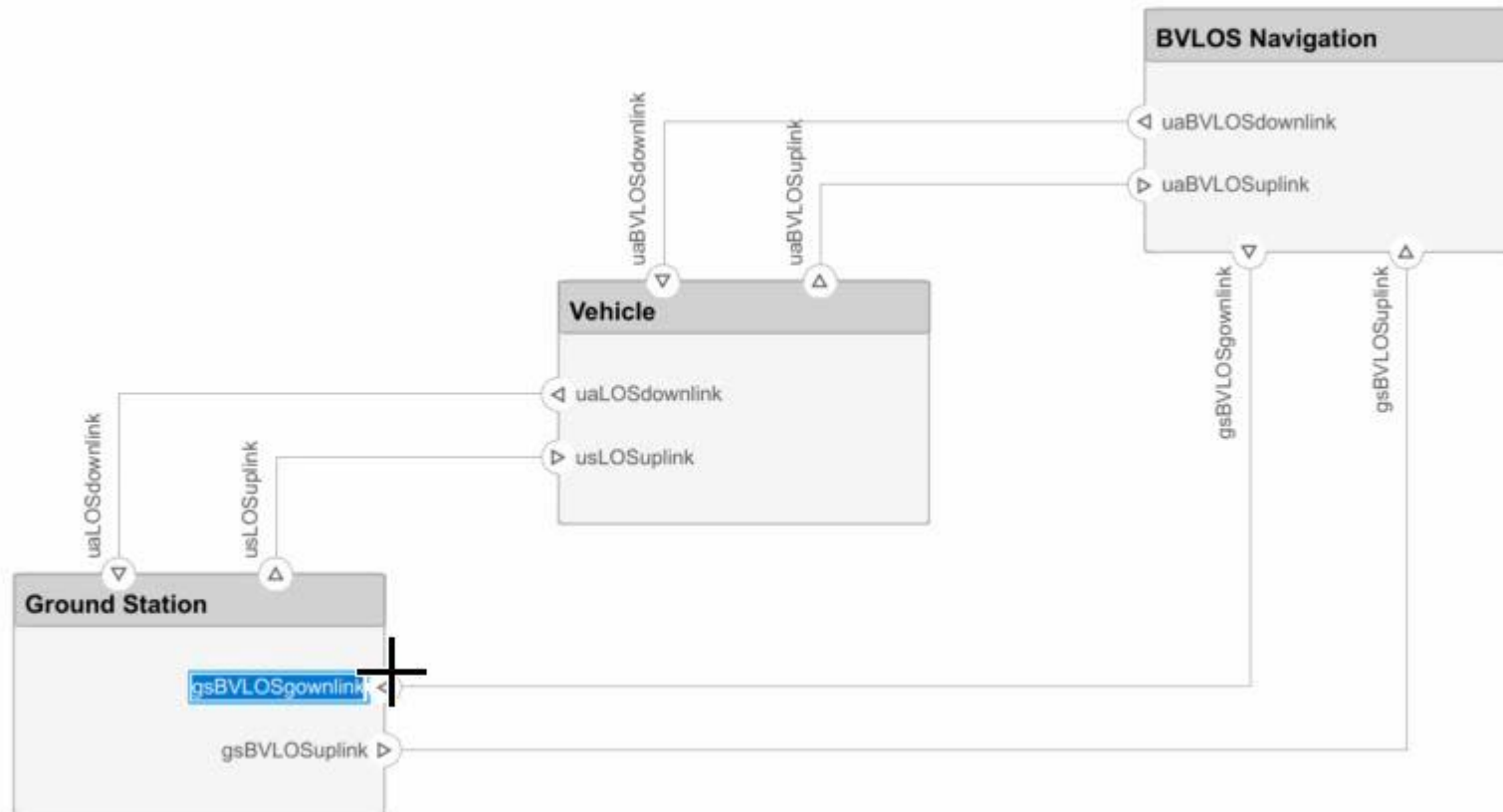
Property Inspector Interfaces

Model Browser

UAS_ref_arch

UAS_ref_arch

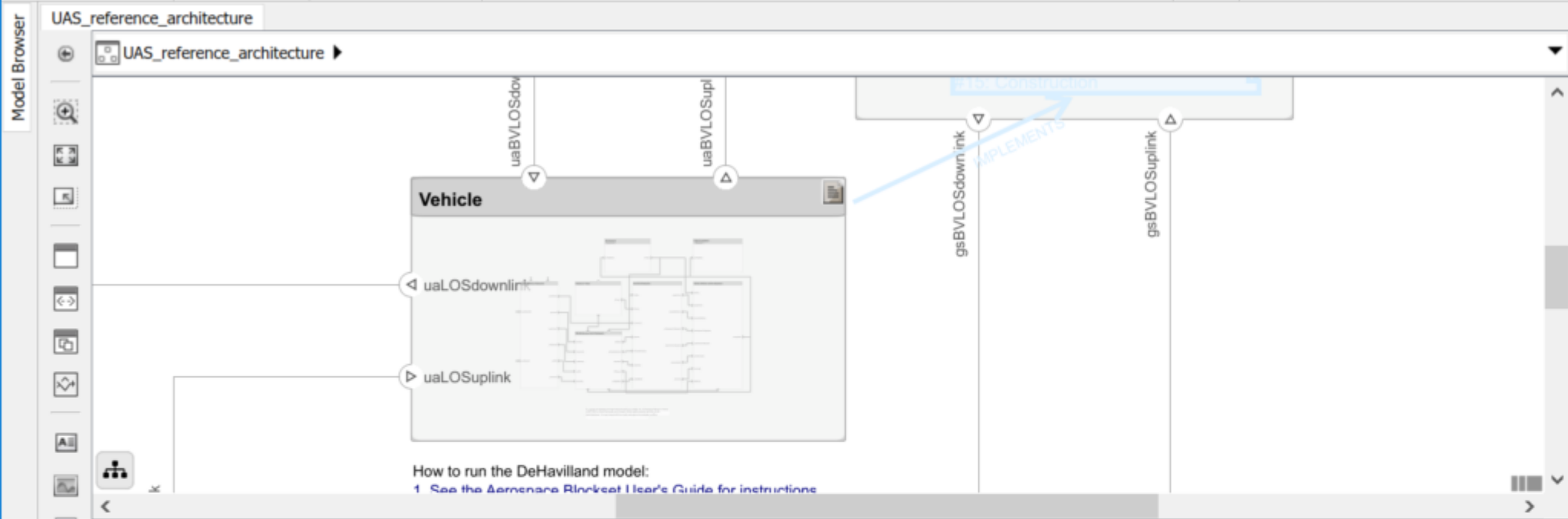
UAS_ref_arch



Property Inspector

Interfaces

60 Normal



Property Inspector

Requirement Set

Details

Properties

Filepath: \\fs-56-ah\vmgrs\home06\rboldt
 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

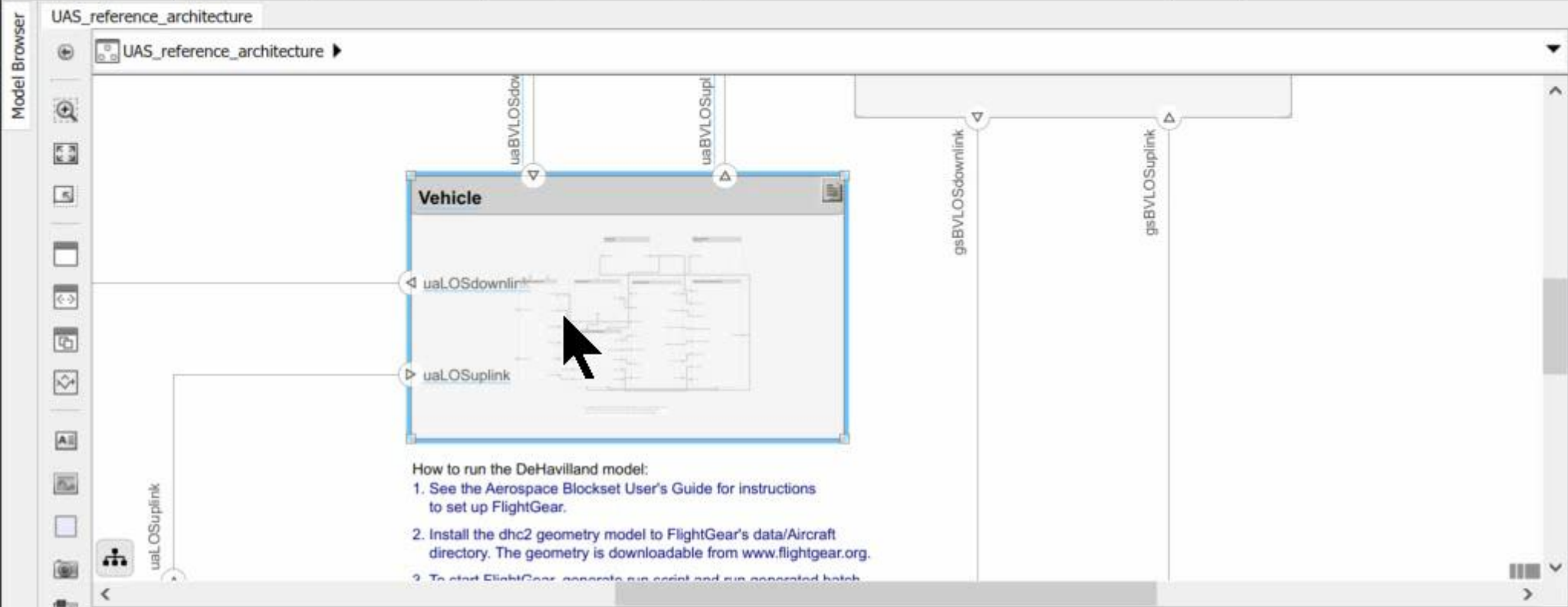
Requirements - UAS_reference_architecture

View: Requirements

Search

Index	Summary	Implemented
> 1.2	Communications	[Full Blue Bar]
> 1.3	Payload Capabilities	[Full Blue Bar]
▼ 1.4	Construction	[Partial Blue Bar]
1.4.1	Modularity	[Full Blue Bar]
1.4.2	Propulsion Power	[Empty Bar]
> 1.5	Flying Qualities	[Full Blue Bar]
2	Ground Station Capabilities	[Full Blue Bar]
3	BLOS Capabilities	[Full Blue Bar]

60 Normal



How to run the DeHavilland model:
 1. See the Aerospace Blockset User's Guide for instructions to set up FlightGear.
 2. Install the dhc2 geometry model to FlightGear's data/Aircraft directory. The geometry is downloadable from www.flightgear.org.
 3. To start FlightGear, execute run script and run generated batch

Property Inspector

Component

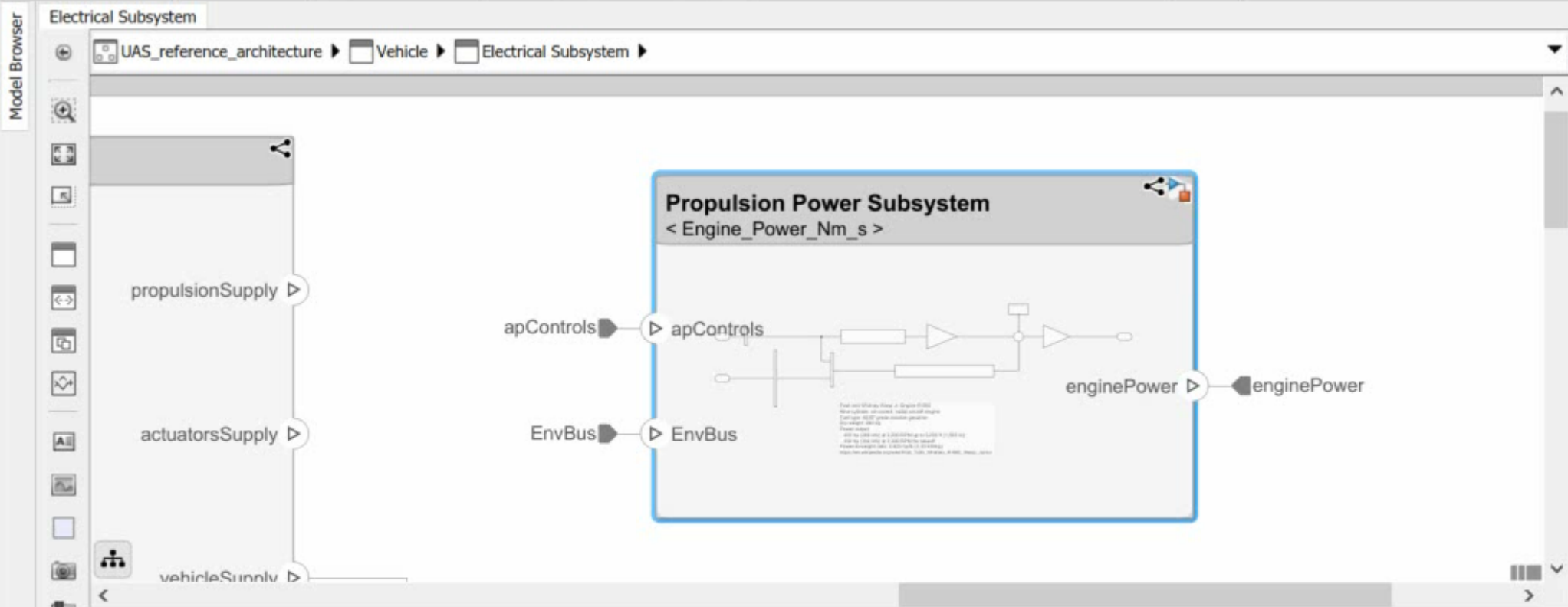
Architecture Info

NAME	VALUE
Name	Vehicle
Stereotype	Add..

Requirements - UAS_reference_architecture

View: Requirements Search

Index	Summary	Implemented
> 1.2	Communications	[Blue bar]
> 1.3	Payload Capabilities	[Blue bar]
▼ 1.4	Construction	[Blue bar]
1.4.1	Modularity	[Blue bar]
1.4.2	Propulsion Power	[White bar]
> 1.5	Flying Qualities	[Blue bar]



Property Inspector

Requirement: #35

Details

Properties

Type: Functional

Index: 1.4.2

Custom ID: #35

Summary: Propulsion Power

Description Rationale

Arial 14 B I U

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

Requirements - UAS_reference_architecture

View: Requirements

Index	Summary	Implemented
> 1.2	Communications	[Progress bar]
> 1.3	Payload Capabilities	[Progress bar]
▼ 1.4	Construction	[Progress bar]
1.4.1	Modularity	[Progress bar]
1.4.2	Propulsion Power	[Progress bar]
> 1.5	Flying Qualities	[Progress bar]

Keywords:

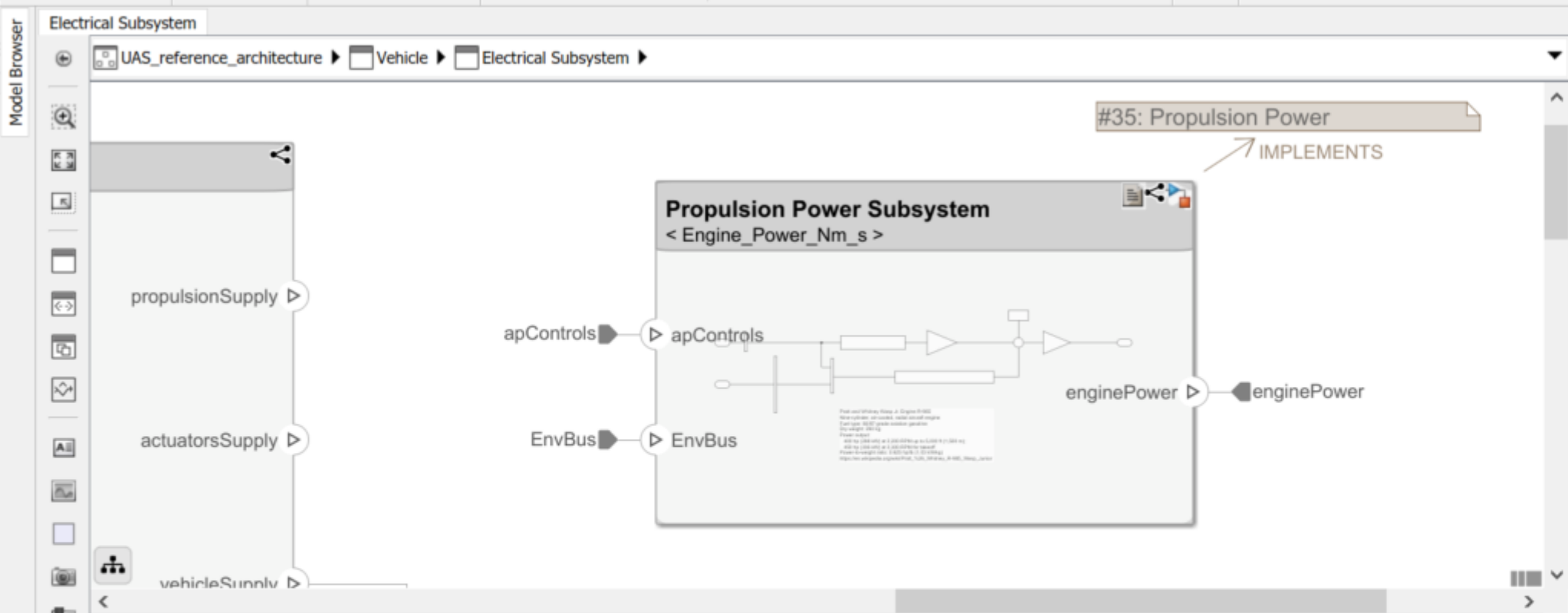
Revision information:

Links

No links

Comments

60 Normal



Property Inspector

Requirement Set

Details

Properties

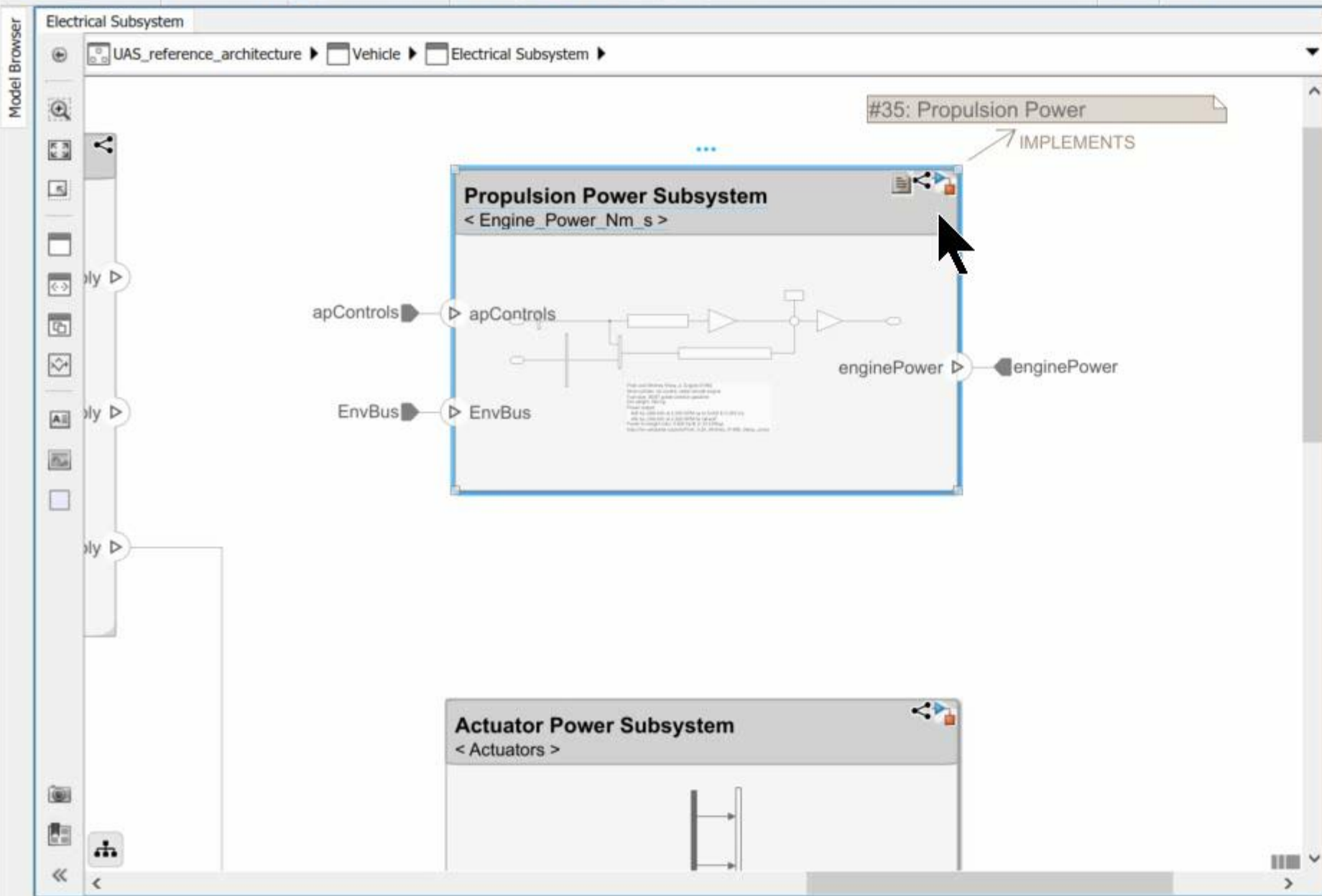
Filepath: \\fs-56-ah\vmgrs\home06\rboldt
 Revision: 24
 Created by: mlizarra
 Created on: 07-Dec-2018 15:50:34
 Modified by: rboldt
 Modified on: 20-Mar-2019 16:06:56
 Description:

Custom Attribute Registries

Requirements - UAS_reference_architecture

View: Requirements

Index	Summary	Implemented
UAS_reqs		
1	Aircraft Capabilities	Implemented: 27, Justified: 0, None: 0, Total: 27
1.1	Airworthiness	
1.1.1	Range	
1.1.2	Rain Conditions	
1.1.3	Power	



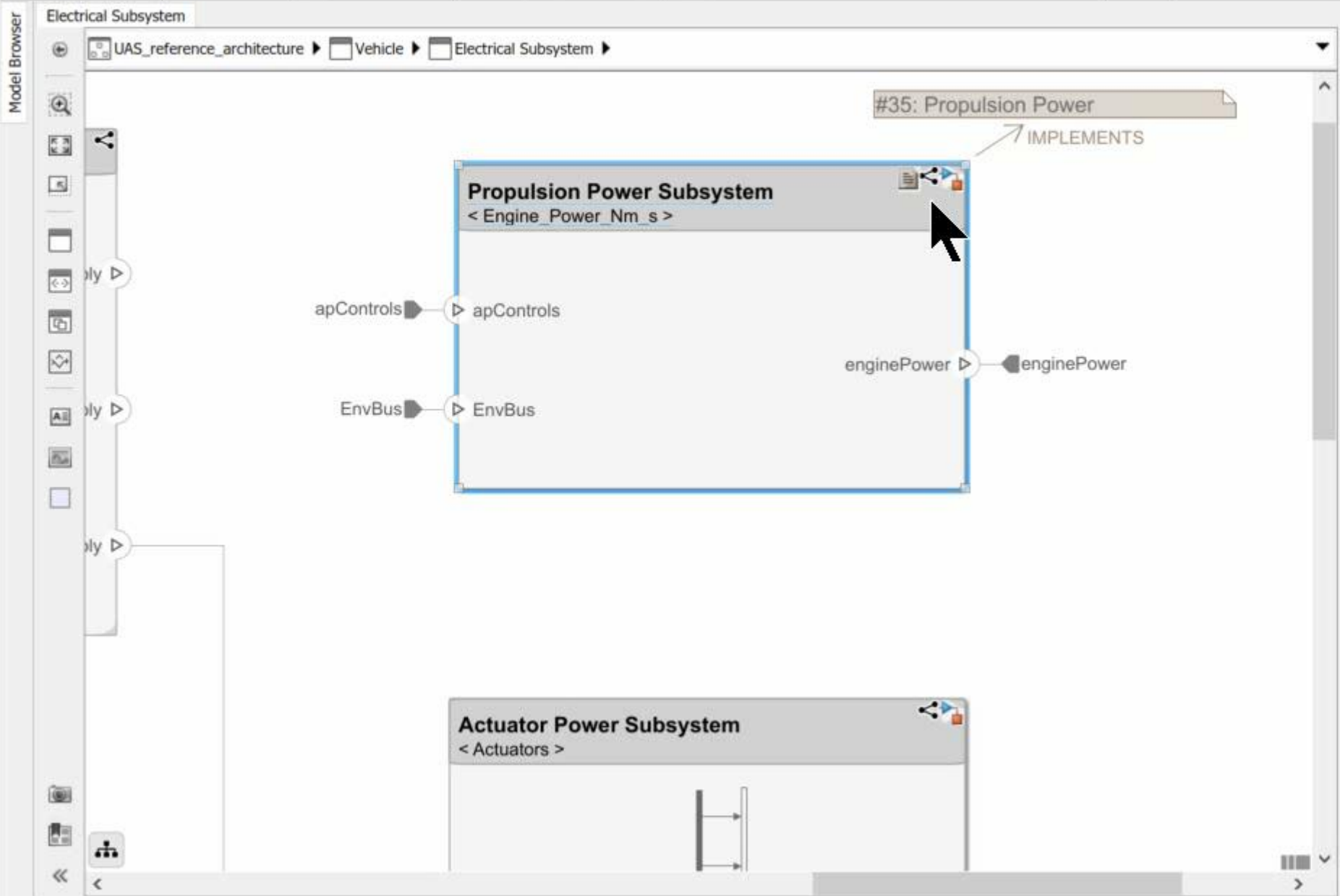
Property Inspector

Component

Architecture Info

NAME	VALUE
Main	
Name	Propulsion Power Subsystem
Stereotype	Add..
SubsystemBudget	
	Select

60 Normal



Property Inspector

Component	
Architecture	Info
NAME	VALUE
▼ Main	
Name	Propulsion Power Subsystem
Stereotype	Add..
> SubsystemBudget Select	

UAS_reference_architecture/Vehicle - Simulink

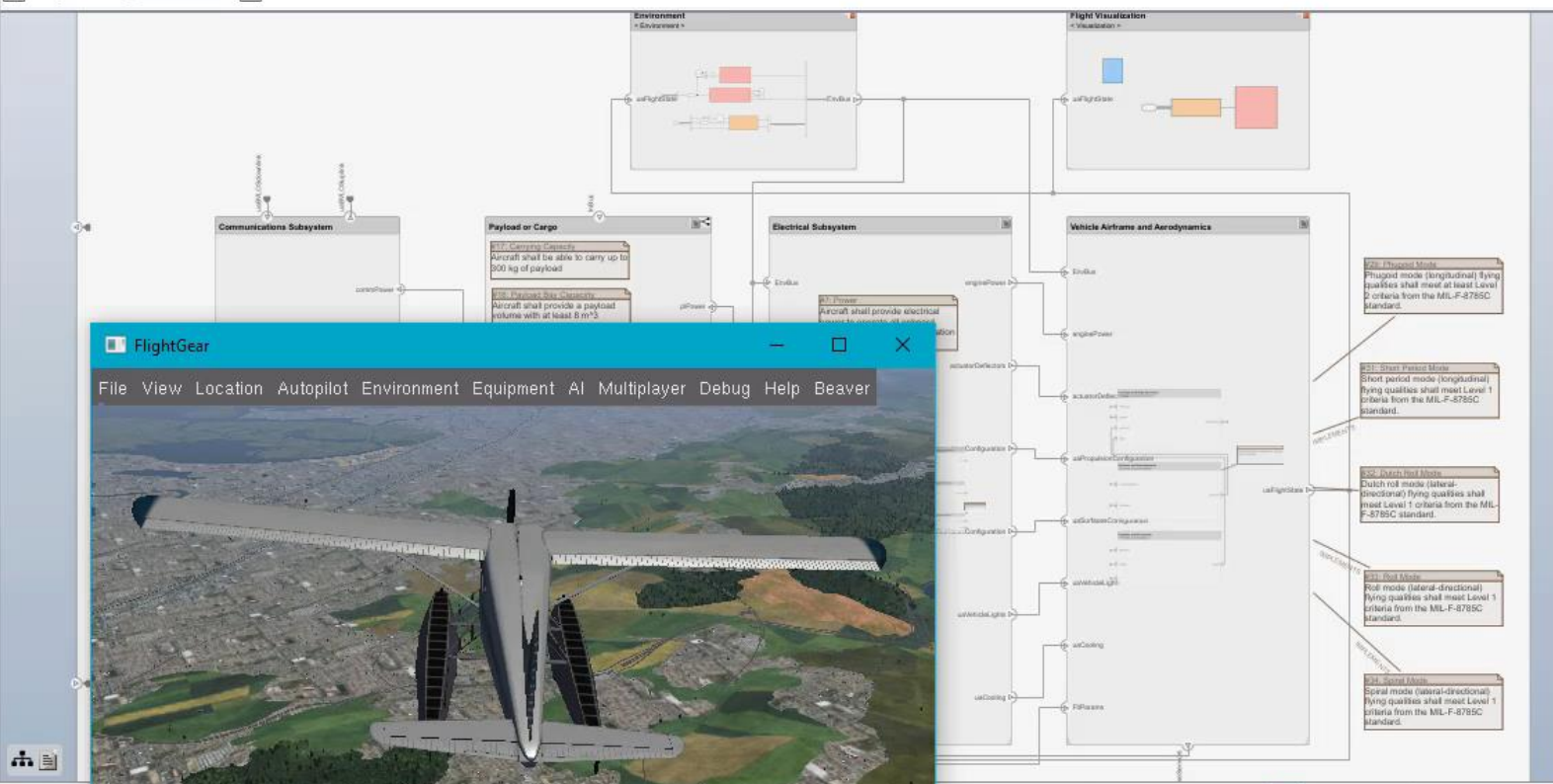
File Edit View Display Architecture Simulation Analysis Code Tools Help

60 Normal

Model Browser


Vehicle

UAS_reference_architecture ▶ Vehicle ▶



Running

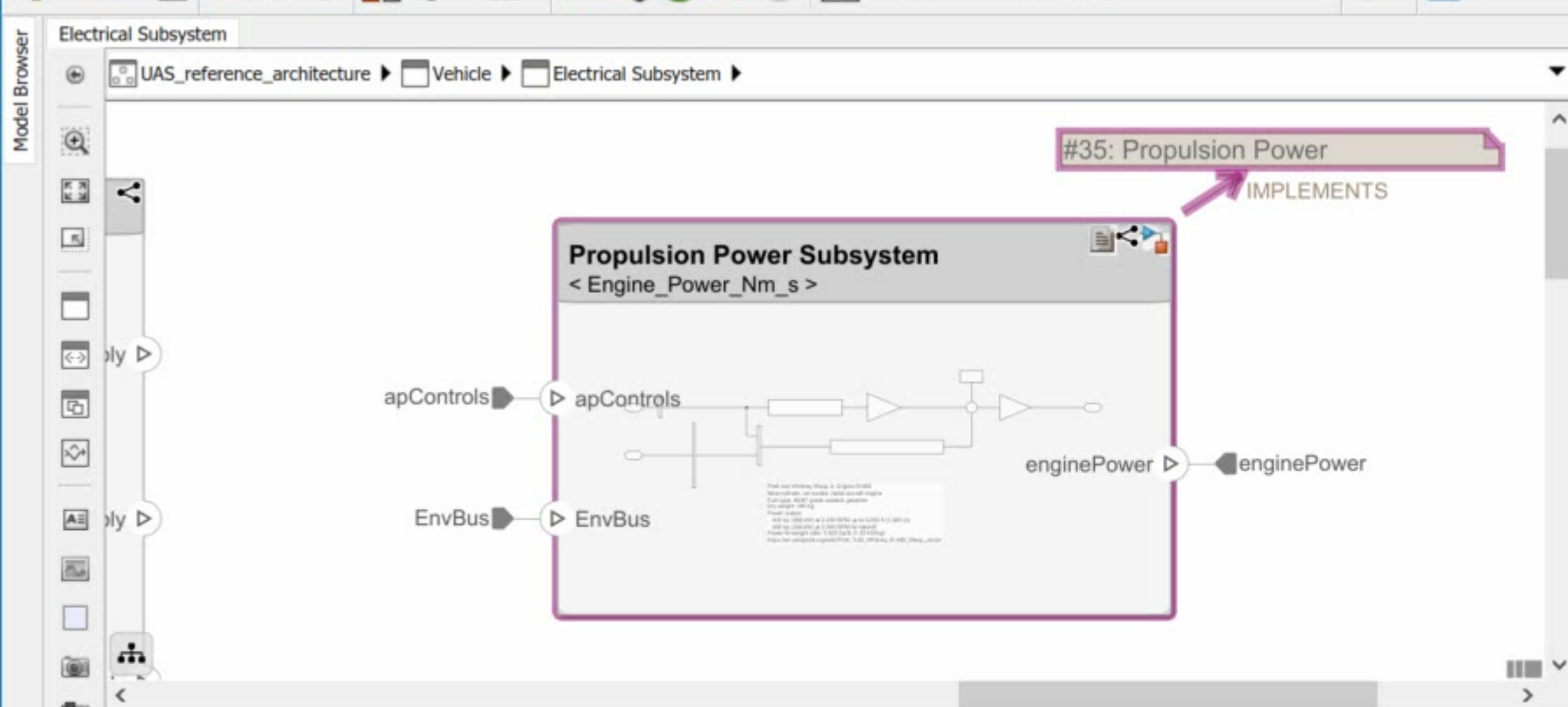
50% T=15.600 26% auto(ode23t)



FlightGear

File View Location Autopilot Environment Equipment AI Multiplayer Debug Help Beaver

- 201 - Thrust Mode**
 Thrust mode (longitudinal) flying qualities shall meet at least Level 2 criteria from the MIL-F-8785C standard.
- 202 - Short Period Mode**
 Short period mode (longitudinal) flying qualities shall meet Level 1 criteria from the MIL-F-8785C standard.
- 203 - Dutch Roll Mode**
 Dutch roll mode (lateral-directional) flying qualities shall meet Level 1 criteria from the MIL-F-8785C standard.
- 204 - Roll Mode**
 Roll mode (lateral-directional) flying qualities shall meet Level 1 criteria from the MIL-F-8785C standard.
- 205 - Spiral Mode**
 Spiral mode (lateral-directional) flying qualities shall meet Level 1 criteria from the MIL-F-8785C standard.



Property Inspector

Requirement: #35

Details

Properties

Type: Functional

Index: 1.4.2

Custom ID: #35

Summary: Propulsion Power

Description Rationale

Engine: Nine-cylinder, air-cooled, radial aircraft engine
 Fuel type: 80/87 grade aviation gasoline
 Dry weight/lb (1.03 kW/kg): 290 kg
 Power output: 400 hp (298 kW) at 2,200 RPM up to 5,000 ft (1,500 m)

Keywords:

Revision information:

Links

Implemented by:

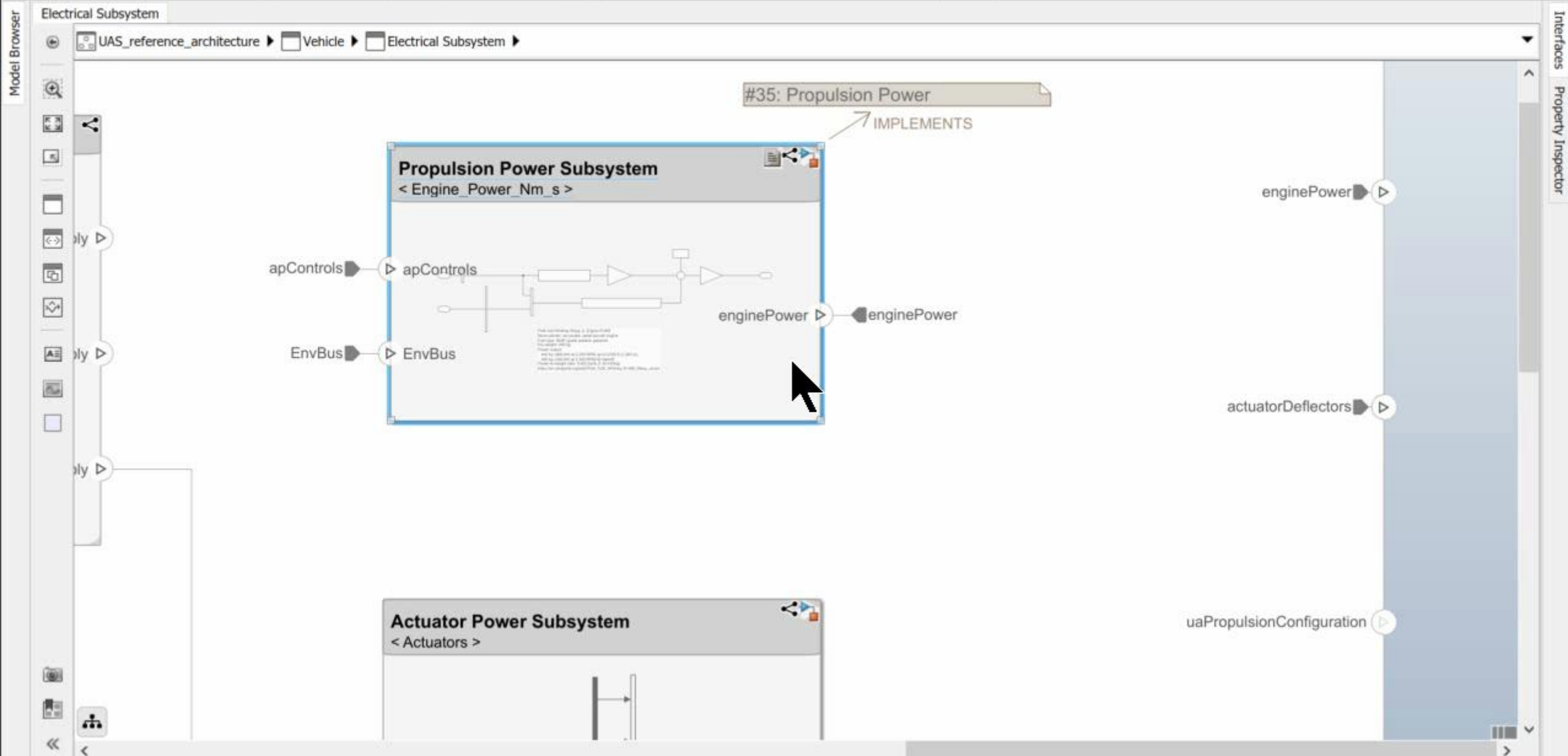
- Propulsion Power Subsystem

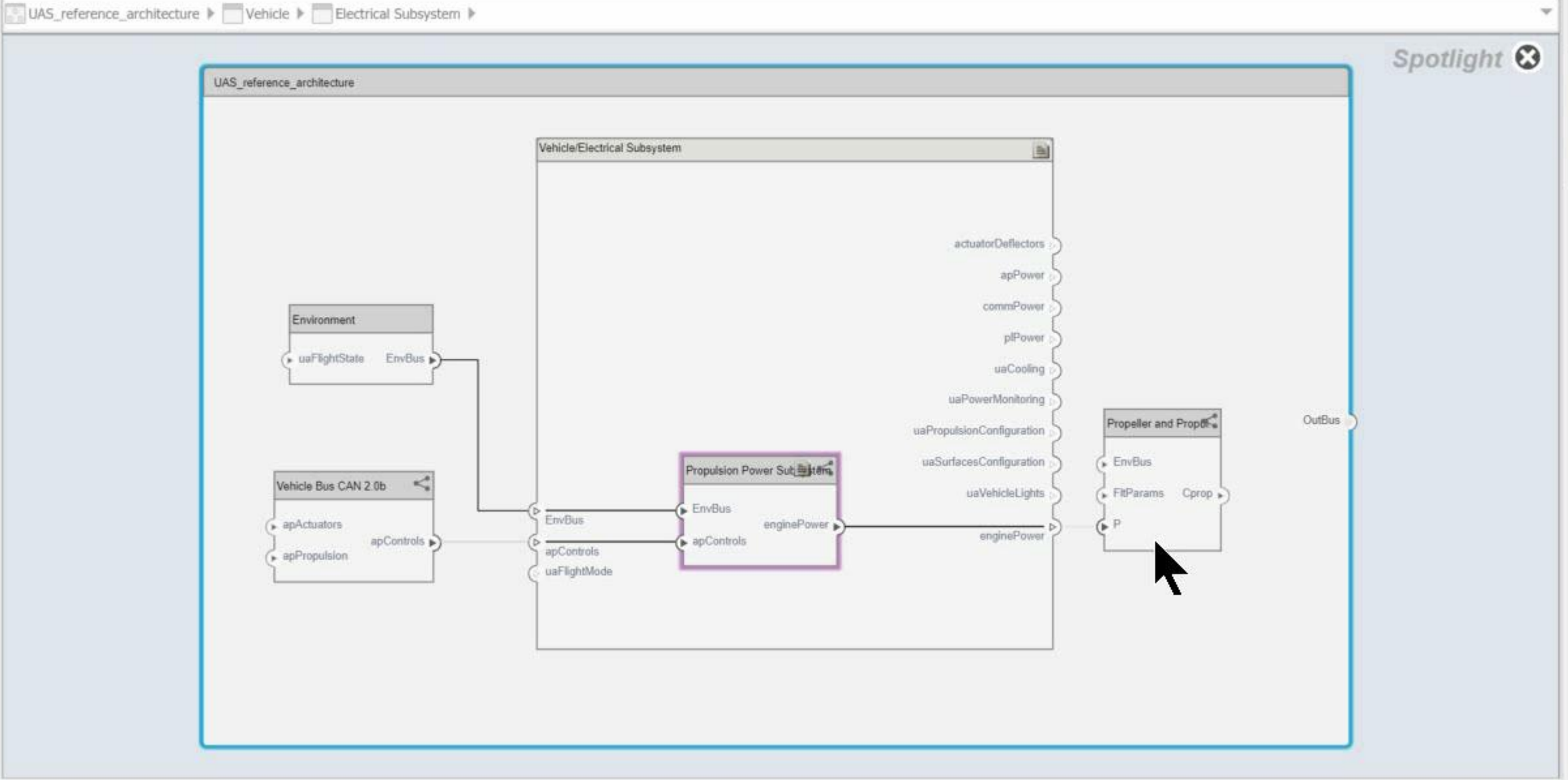
Comments

Requirements - UAS_reference_architecture

View: Requirements

Index	Summary	Implemented
1.4	Construction	████████████████████
1.4.1	Modularity	████████████████████
1.4.2	Propulsion Power	████████████████████
1.5	Flying Qualities	████████████████████
2	Ground Station Capabilities	████████████████████





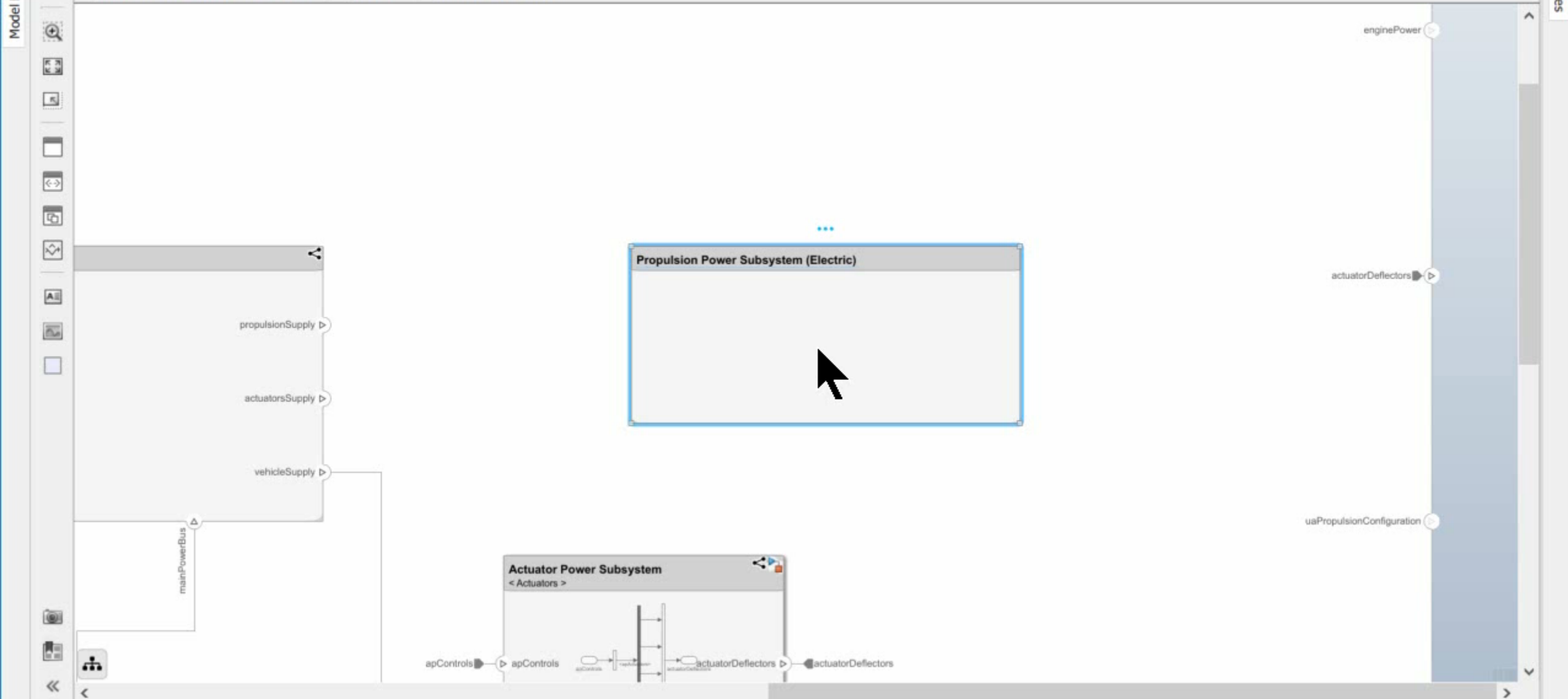
Spotlight

Interfaces
Property Inspector

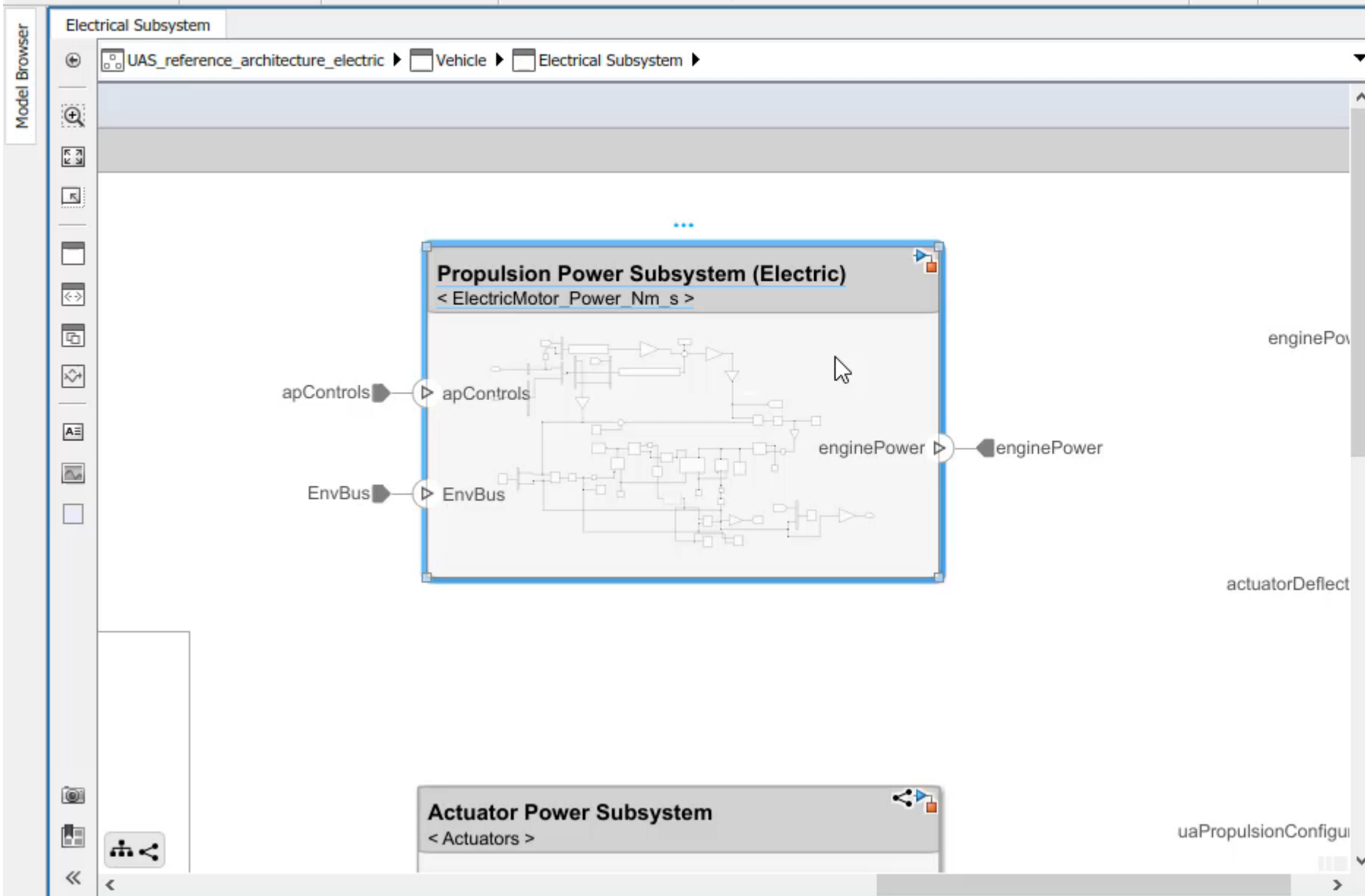
Toolbar with icons for file operations, navigation, simulation, and a numeric input field set to 60. A dropdown menu is set to 'Normal'.

Electrical Subsystem

UAS_reference_architecture_electric > Vehicle > Electrical Subsystem



60 Normal



Property Inspector

Component

Architecture Info

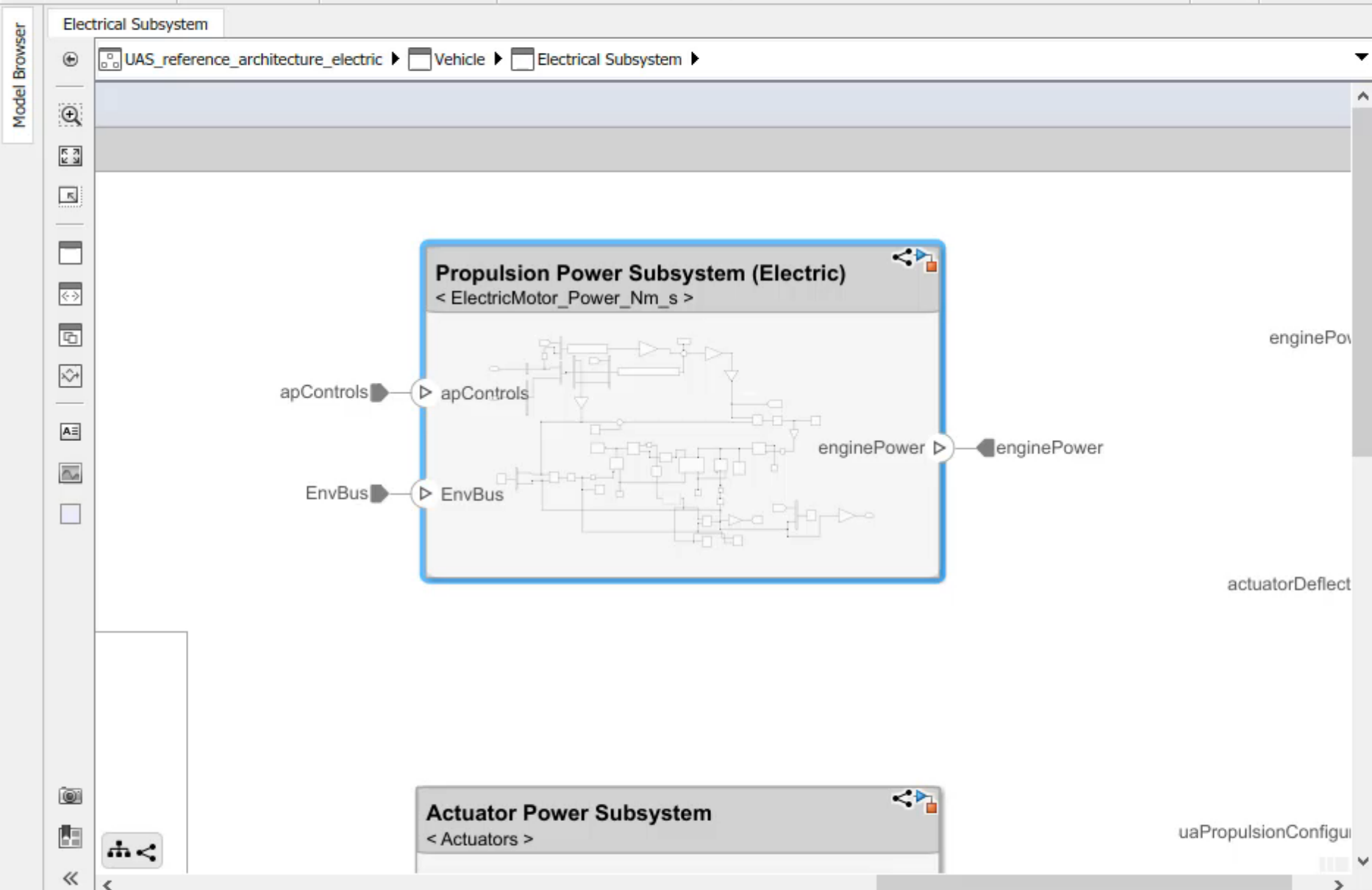
NAME	VALUE
Main	
Name	Propulsion Power S...
Stereotype	Add..

enginePow

actuatorDeflect

uaPropulsionConfig

60 Normal








Property Inspector

Component

Architecture Info

NAME	VALUE
Main	
Name	Propulsion Power S...
Stereotype	Add..
SubsystemBudget	
Mass	100 kg
Power	175000000 mW

HOME

     Continuous
 Arguments ▾
 BottomUp ▾

Automatic
 Overwrite

Update

INSTANCE MODEL ANALYSIS UPDATE

Instances	Mass	Power
UAS_reference_architecture_electric_budgetRollup	392.33	175614300
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	175614300
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	175355090
Actuator Power Subsystem	8	300000
Power Distribution	10	1000
Power Monitor	0	0
Power Source	20	1000
Propulsion Power Subsystem (Electric)	100	175000000
Vehicle Power Subsystem	5	50000
apRegulator	0.05	20
commRegulator	0.05	1070
piRegulator	0.05	2000
Environment	0	0

INSTANCE PROPERTIES

NodeInstance: Propulsion Power Subsystem (Electric)

Property	Units	Value	Edit
SubsystemBudget			
Mass	kg	100	
Power	mW	175,000,000	

UAS_reference_architecture_electric/Vehicle - Simulink

File Edit View Display Architecture Simulation Analysis Code Tools Help

60 Normal

Model Browser

Vehicle

UAS_reference_architecture_electric > Vehicle

Communications Subsystem

Payload or Cargo

- #17: Carrying Capacity
Aircraft shall be able to carry up to 300 kg of payload
- #18: Payload Bay Capacity
Aircraft shall provide a payload volume with at least 8 m³
- #19: Default Payload

Electrical Subsystem

- #7: Power
Aircraft shall provide electrical power to operate all onboard systems for the complete duration of the flight.

Vehicle Airframe

FlightGear

File View Location Autopilot Environment Equipment AI Multiplayer Debug Help Beaver

Running

Power Variables

File Tools View Simulation Help

VDC

Volts

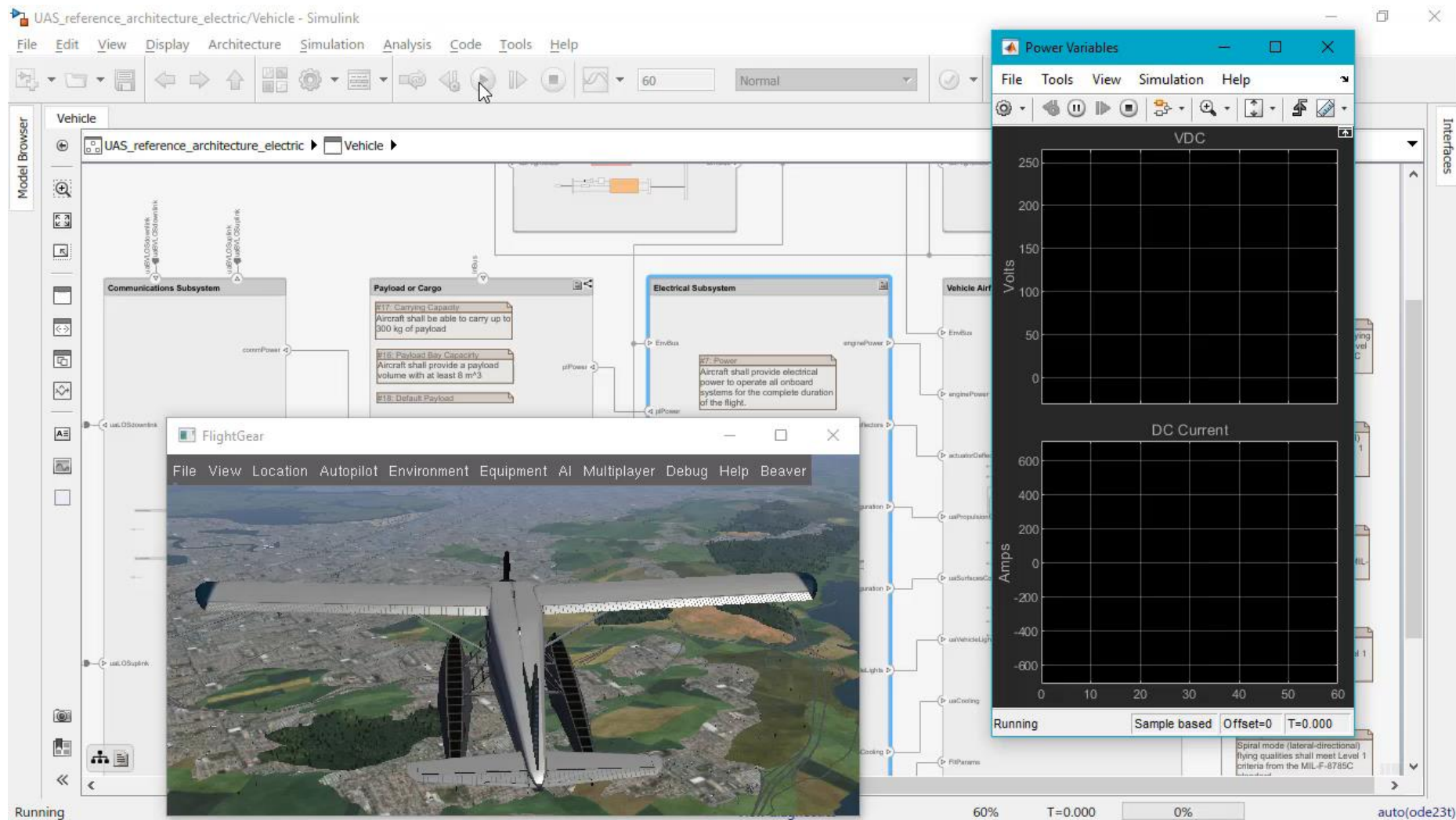
DC Current

Amps

Running Sample based Offset=0 T=0.000

Spiral mode (lateral-directional) flying qualities shall meet Level 1 criteria from the MIL-F-8785C

60% T=0.000 0% auto(ode23t)



Simulink Requirements


Digital Thread from Requirements to Architecture and Design

Author requirements or view from external source

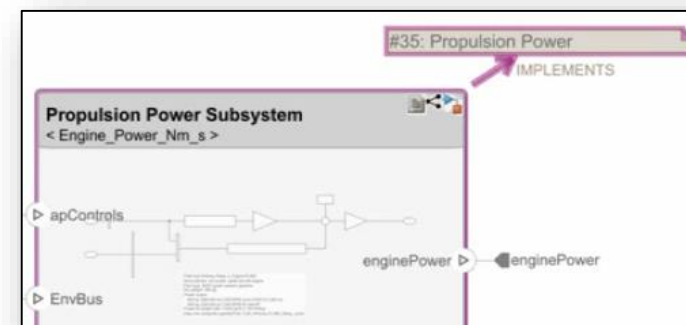
Summary: Range

Description Rationale

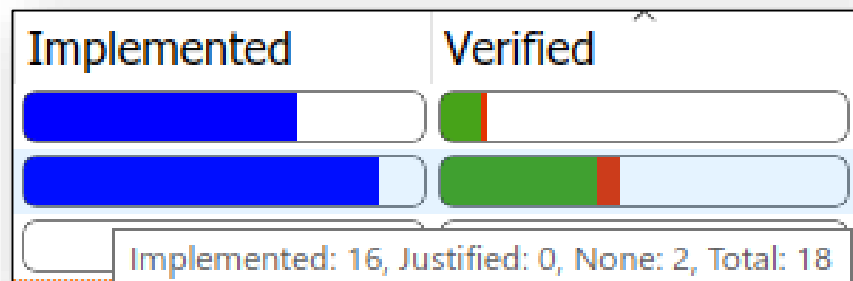
The aircraft shall be controllable for all distances within line-of-sight



Link requirements, architectures, design, code and test



Identify gaps in architecture or design



Identify impact of requirement changes

Implemented by:

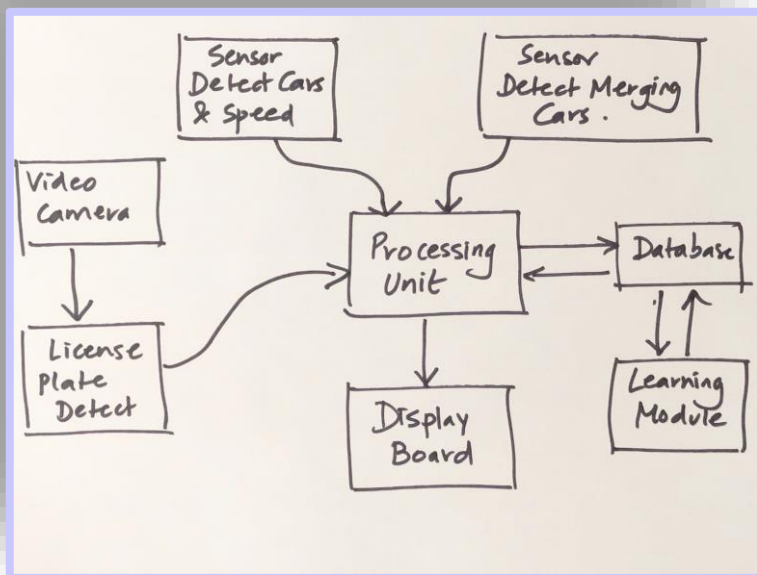
counter

Issue: Destination Changed.

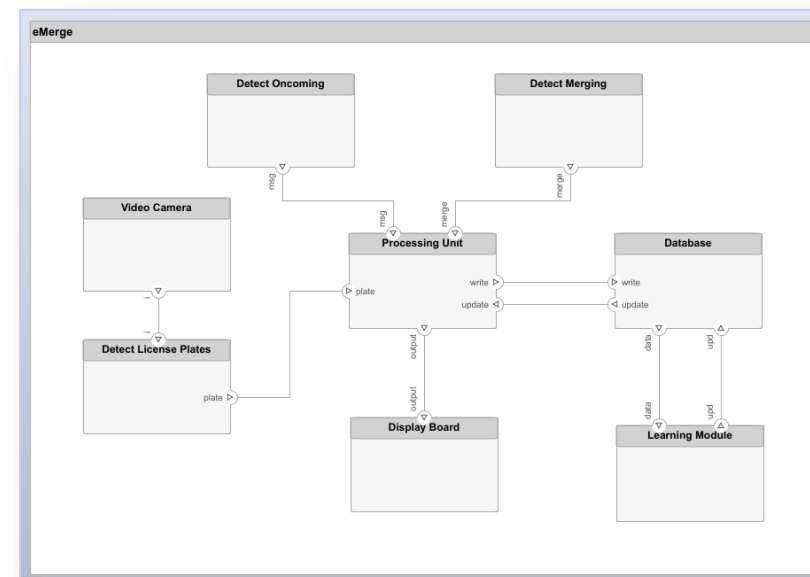
System Composer

Intuitively design system and software architectures

R2019a



Description
 ==
Architecture

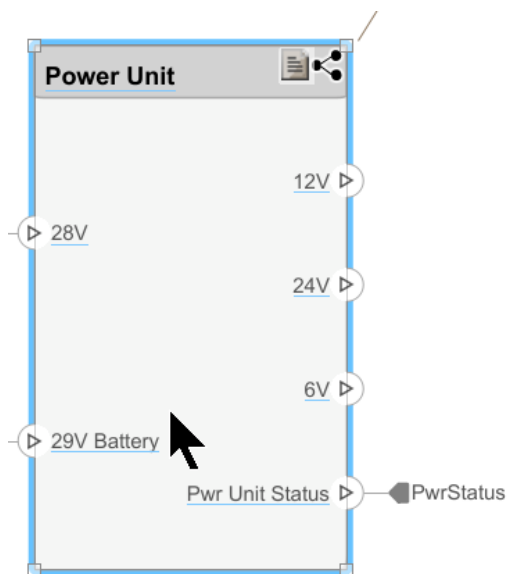


System Composer

Perform trade studies based on data driven analysis to optimize architectures

R2019a

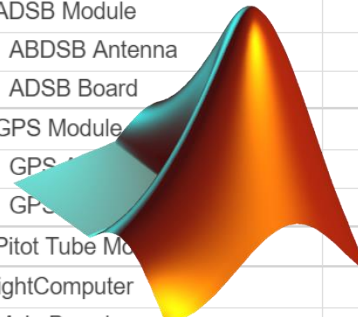
Add custom data



Architecture	Info
NAME	VALUE
▼ Main	
Name	Power Unit
Stereotype	Add..
▼ OnboardElement Select	
Mass	0.217 kg
Power	0 mW
RFHarnessLength	0 cm

Create analysis model

Instances	Mass(kg)
SmallUAV	0
Airframe	0
Fuselage	1.7
LandingGear	1.65
Tail and Boom	2.7
Wings	3.2
Flight Support Components	0
ADSB Module	0
ABDSB Antenna	0.058
ADSB Board	0.098
GPS Module	0
GPS Antenna	0.128
GPS Board	0.27
Pitot Tube Module	0.075
FlightComputer	0
Main Board	0.145
Protective Case	0.195



Calculate mass roll-up data

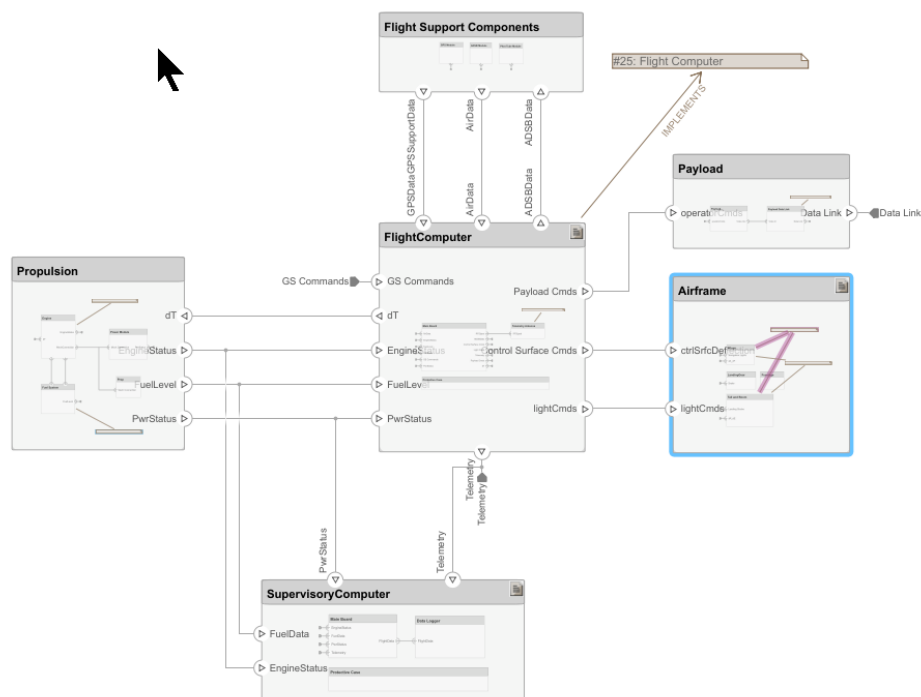
Instances	Mass(kg)
SmallUAV	15.932
Airframe	9.25
Fuselage	1.7
LandingGear	1.65
Tail and Boom	2.7
Wings	3.2
Flight Support Components	0.629
ADSB Module	0.156
ABDSB Antenna	0.058
ADSB Board	0.098
GPS Module	0.398
GPS Antenna	0.128
GPS Board	0.27
Pitot Tube Module	0.075
FlightComputer	0.388
Main Board	0.145
Protective Case	0.195

System Composer

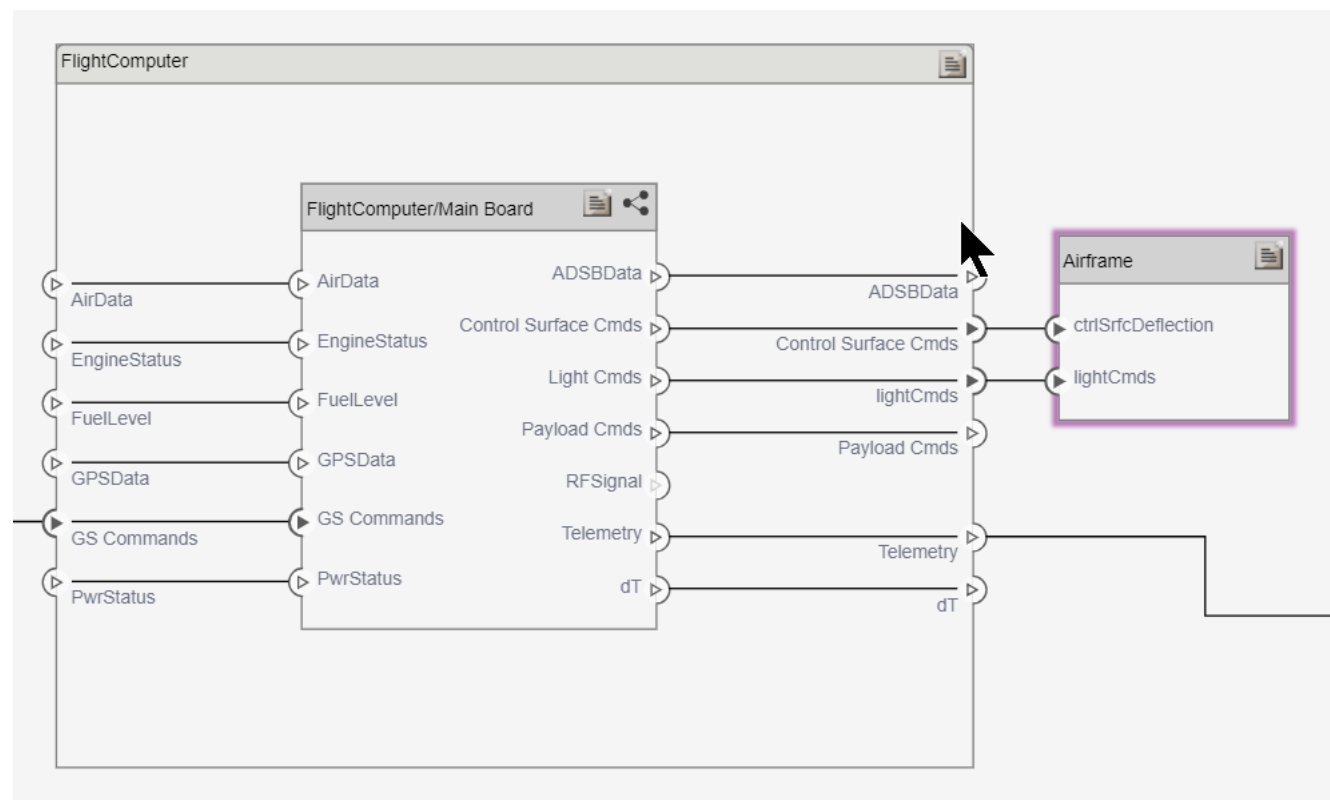
Tackle Architecture complexity with spotlight views

R2019a

Composition



Spotlight



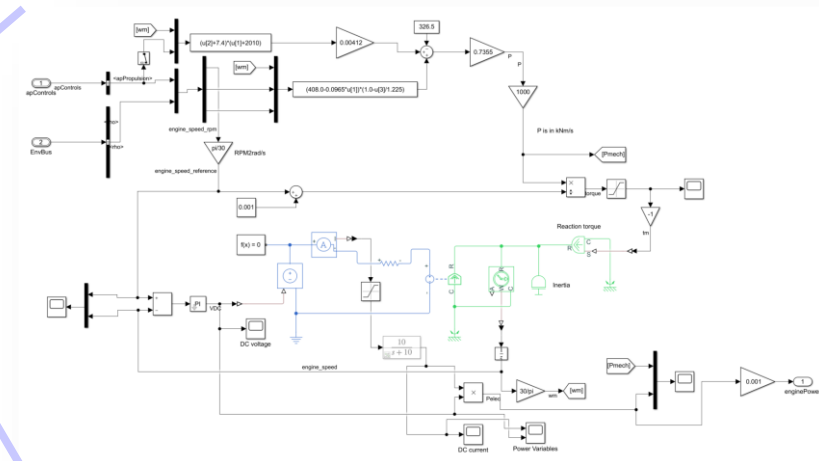
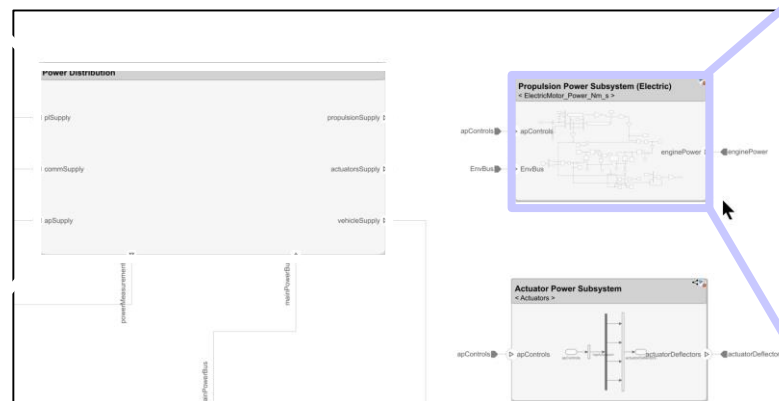
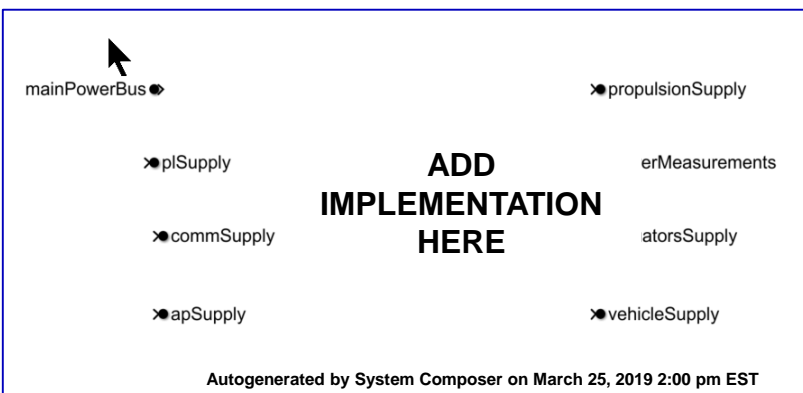
System Composer

System and software architectures connected to implementations in Simulink

R2019a

Generate Simulink models from architecture components

Link Simulink models to architecture components



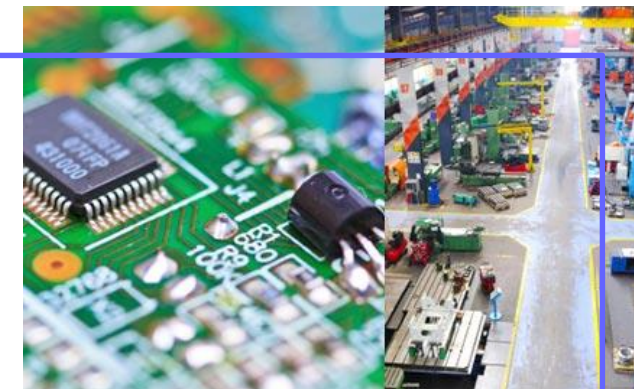
Simulink: A Multi-Language Simulation Environment



Dynamic Systems



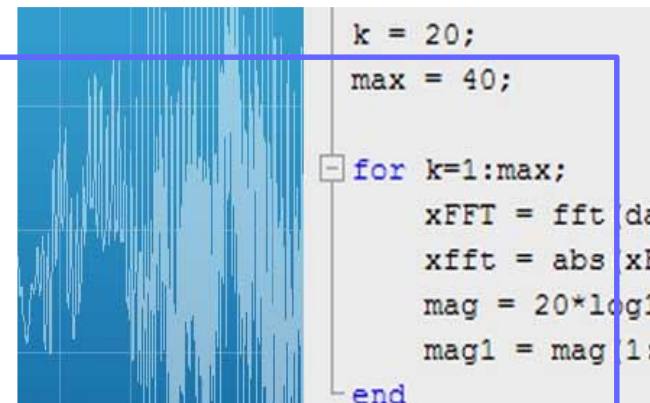
State Machines



Discrete-Event Systems



Physical Modeling



Object-Oriented

Děkuji za pozornost