

MATLAB CONFERENCE 2017

Simulink as Your Enterprise Simulation Platform

Daryl Ning
Applications Engineer
MathWorks Australia

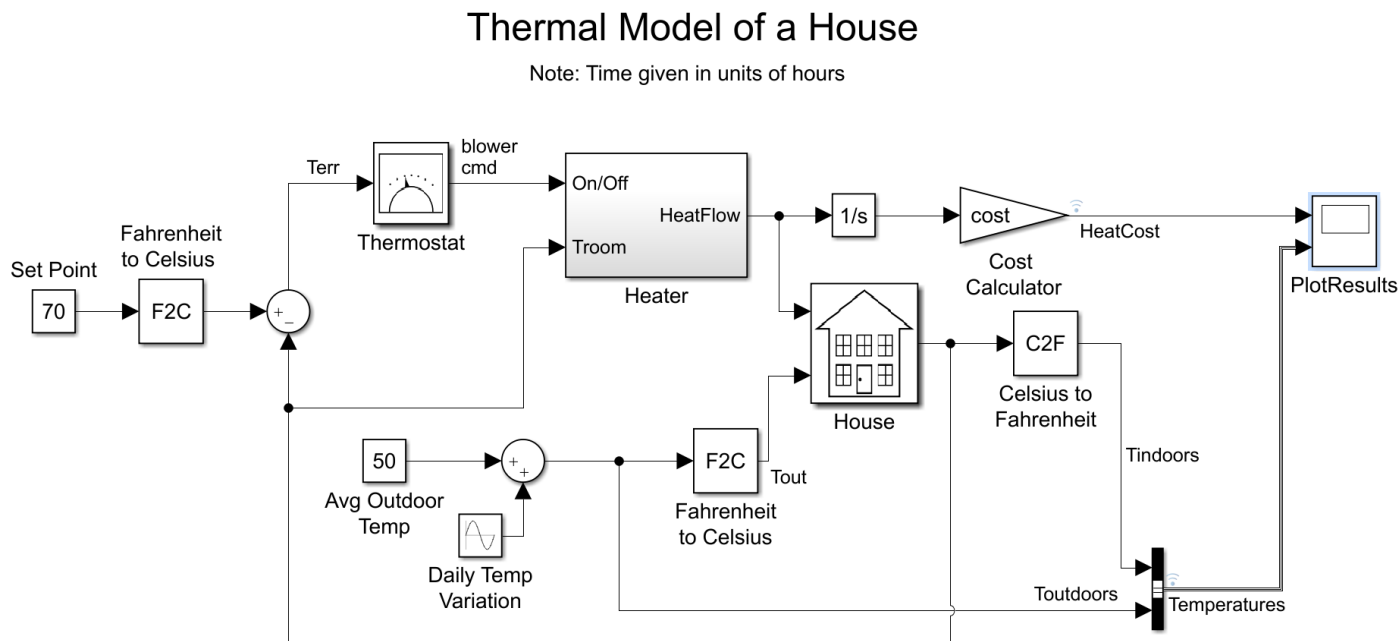


What is an Enterprise Simulation Platform?

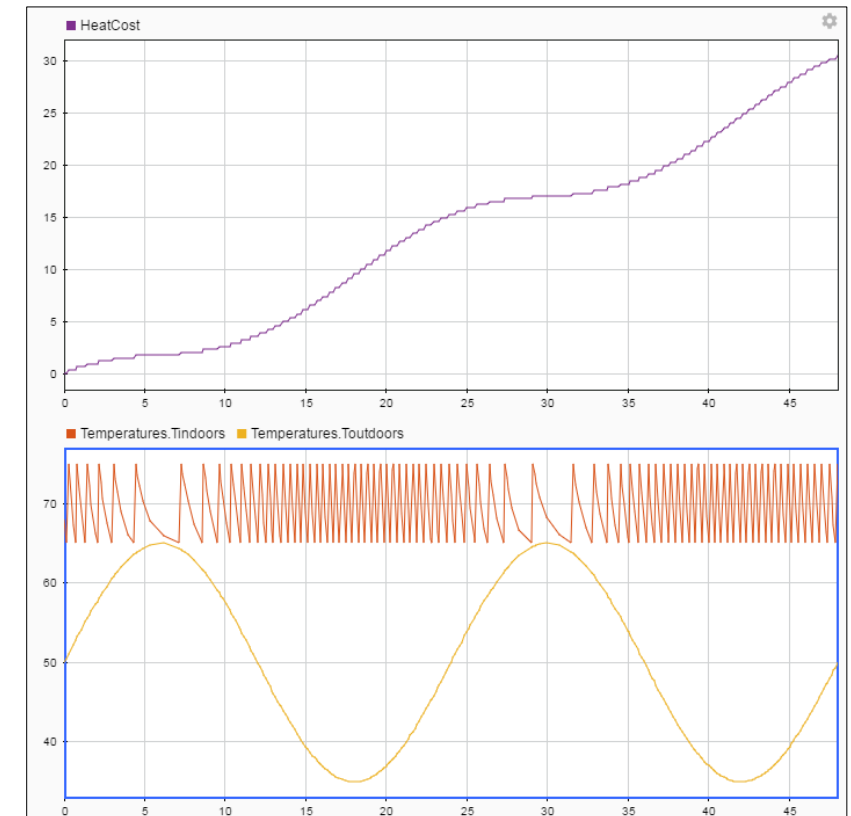
- Enterprise – Any size business or project. Small or large.
- Simulation – Evaluating system behavior through computation
- Platform – Scalable environment for multi-disciplinary collaboration

What is Simulink?

- A block diagram environment to **model** and **simulate** dynamic systems
- Block libraries are available to help you build your model



RUN



Simulink can be used as your Enterprise Simulation Platform

Carnegie Wave Energy

Designs and Builds the World's First Operating Wave Farm

Harness the power of ocean waves to generate electricity!

- Large submerged buoys (11m diameter)
- Buoy motion actuates pumps to pressurize water
- Water drives hydroelectric conversion devices



Challenges

- Multidomain problem: mechanical, hydraulic and electrical components
- Integrating a large multi faceted project for system level analysis
- Test under many different conditions

Solution

- Leverage Simulink as a simulation platform

Carnegie Wave Energy

Designs and Builds the World's First Operating Wave Farm

Crucial Design Insights Gained

“As engineering tools, MATLAB and Simulink provide significant value...they enable us to quickly test ideas that we would otherwise never try.”

Jonathan Fiévez, CTO

“Simulink revealed system behaviours that we didn't anticipate.”

Alex Pichard, Analysis Engineer

Sensitivity Studies Accelerated

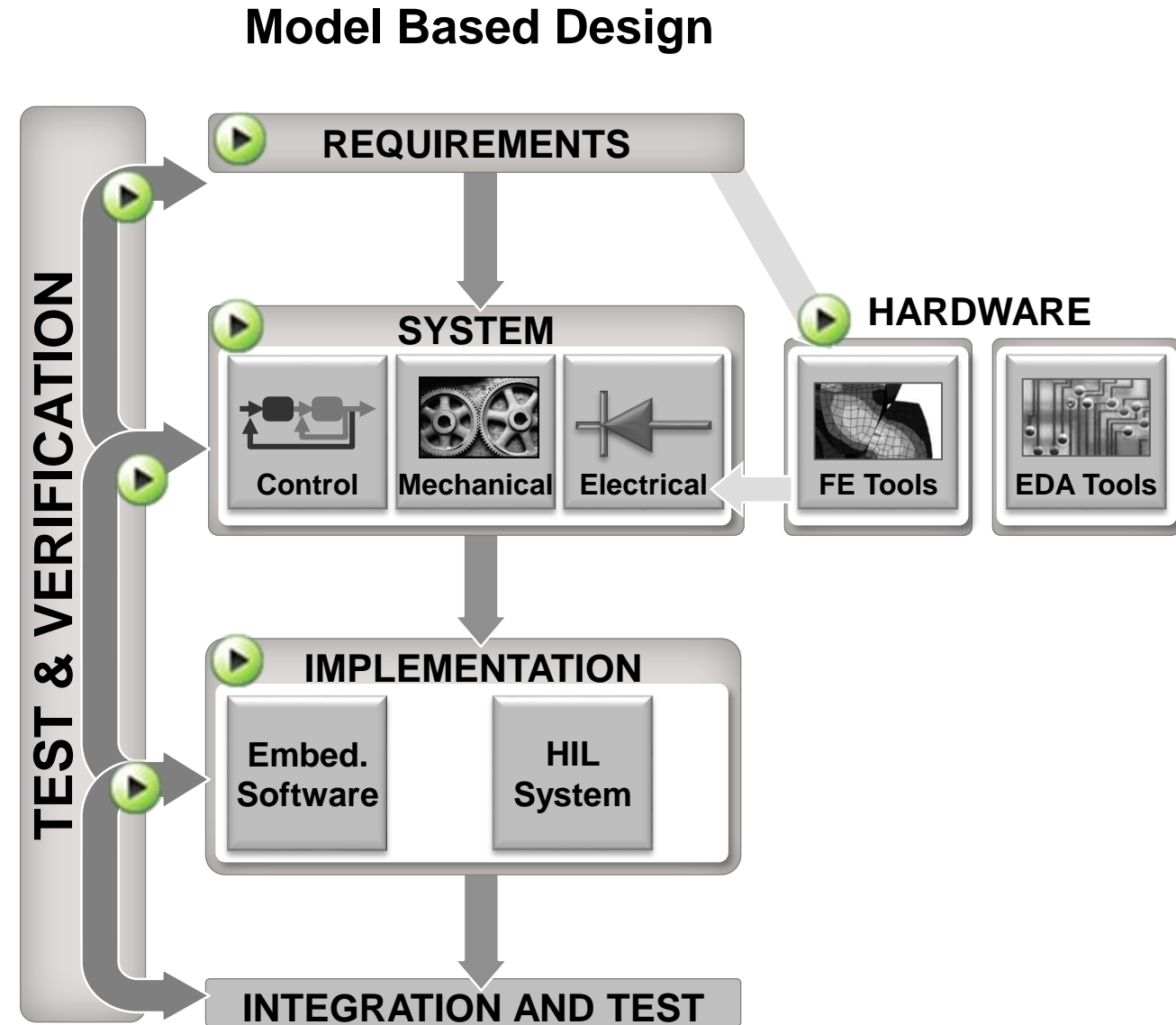
“...we typically simulate 15 to 20 sea states for each parameter value we vary. With Parallel Computing Toolbox we can run simulations in parallel, and with a twelve-core computer we see an almost twelvefold increase in speed.”

Jack Jorgensen, Analysis Engineer.

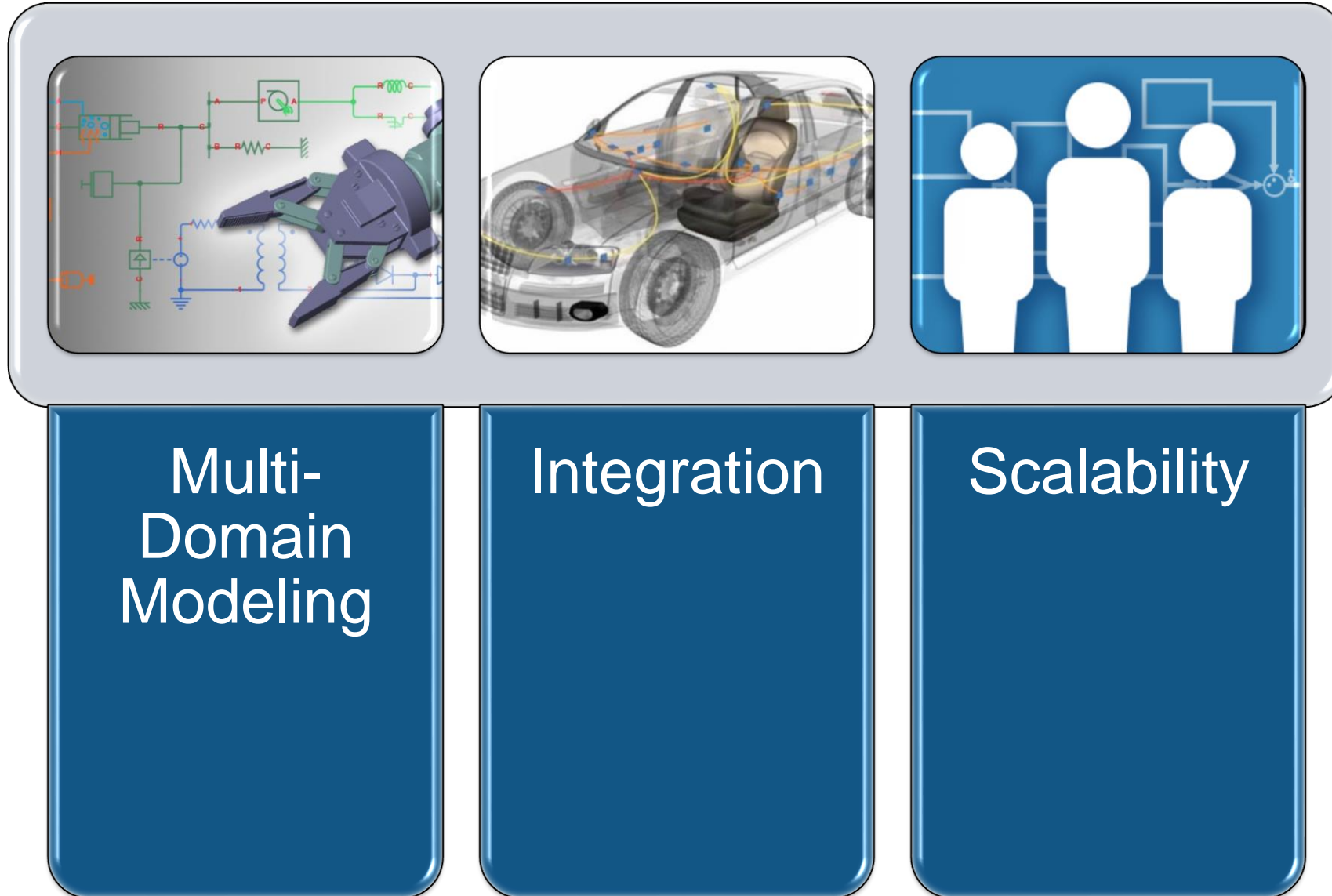
Enterprise Simulation Platform

- Enterprise - Any size business or project
- Simulation – Evaluating system behavior through computation
- Platform – Scalable environment for multi-disciplinary collaboration

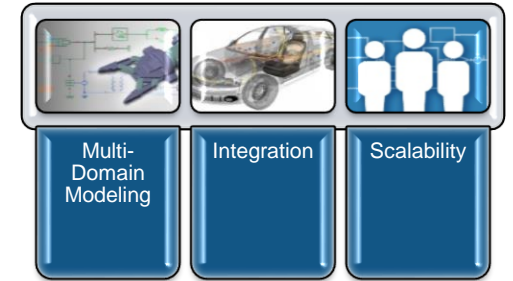
Simulation



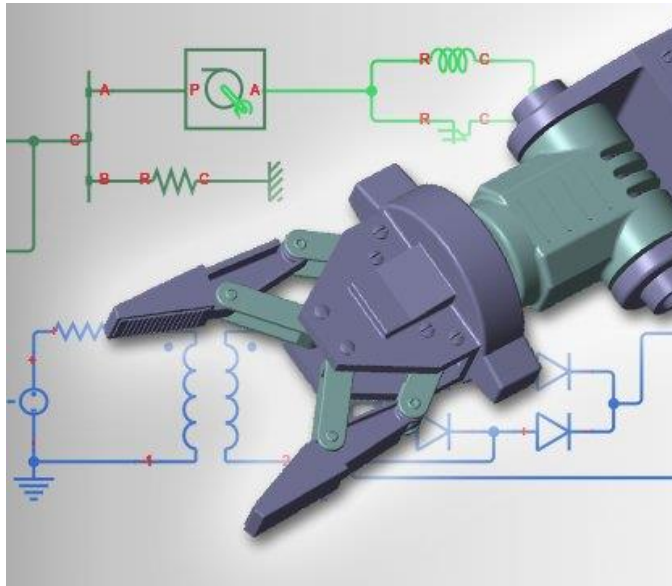
Enterprise Simulation Platform Enablers



Enterprise Simulation Platform Enablers



1. Multi-Domain Modeling



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Multi-Domain Modeling in Simulink



Dynamic Systems



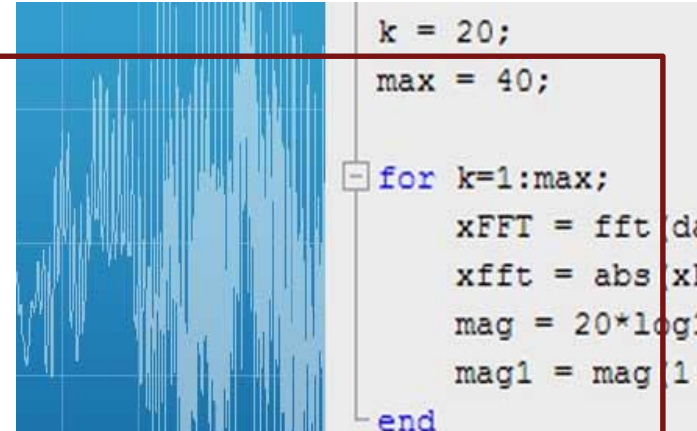
State Machines



Discrete-Event Systems



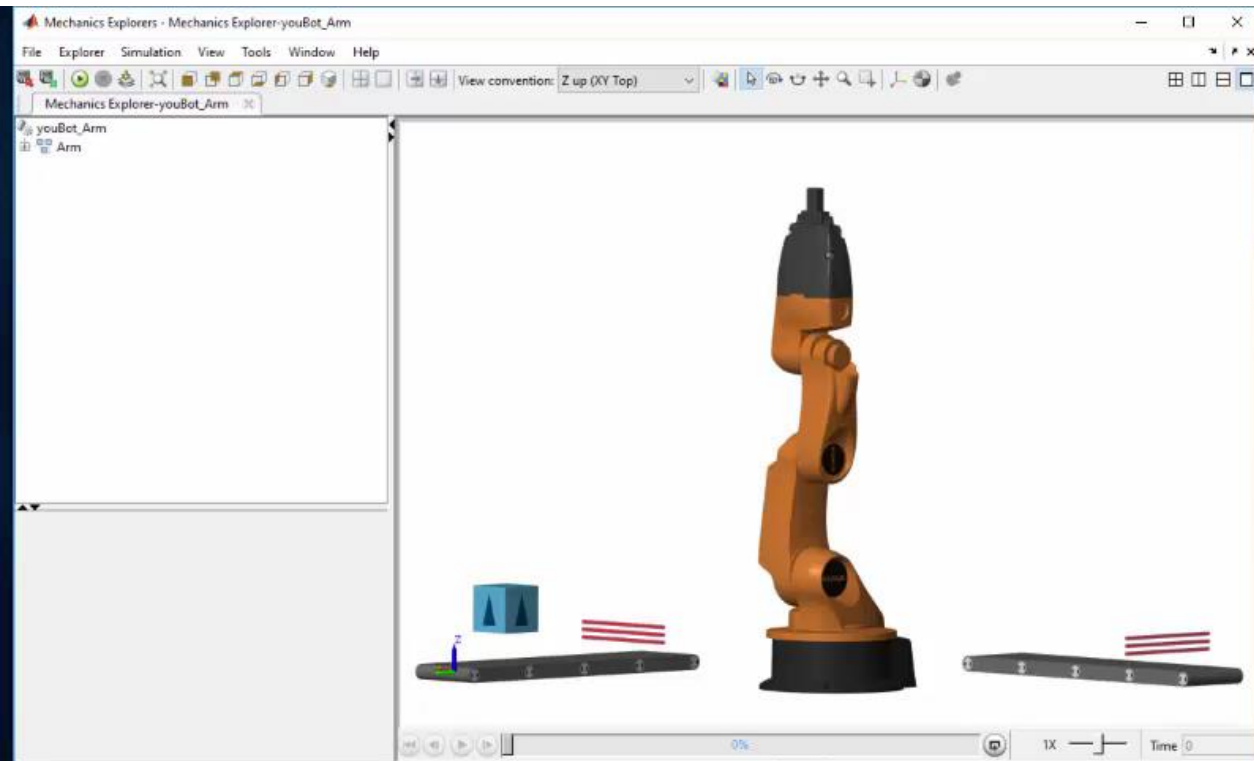
Physical Modeling



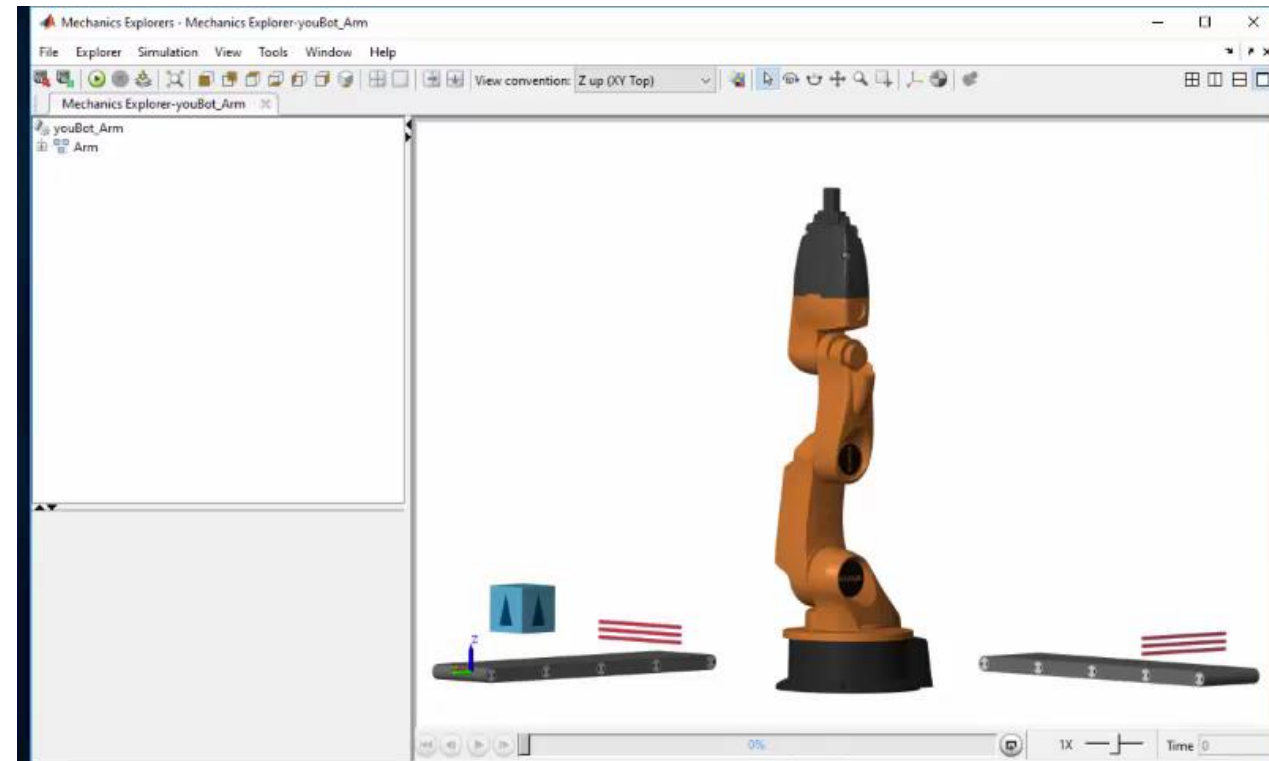
Code

Robot Arm Multi-Domain Simulation

Without Network Model



With Network Model



Multi-Domain Model

youBot Arm

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [sscexplore](#)
5. Plot optimization results: [Friction, No Friction \(code\)](#)
6. [Compare](#) optimization results [\(code\)](#)
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

Configure Test : [Default \(code\)](#)
 Box Transfer only: [Linear](#); Splines: [Manual](#), [Optim \(friction\)](#), [Optim \(no friction\)](#)
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#), [Wrist](#), [Max Torque](#), [All 35](#)

Run optimization: [Friction, No Friction \(code\)](#)

Ready 123% ode15s

State Charts and System Dynamics

The image displays a Simulink workspace for a robot arm control system. It includes a main block diagram of the robot arm, a Stateflow logic chart for the control logic, and a block diagram for joint commands.

youBot Arm

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [ssexplore](#)
5. Plot optimization results: [Friction](#), [No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

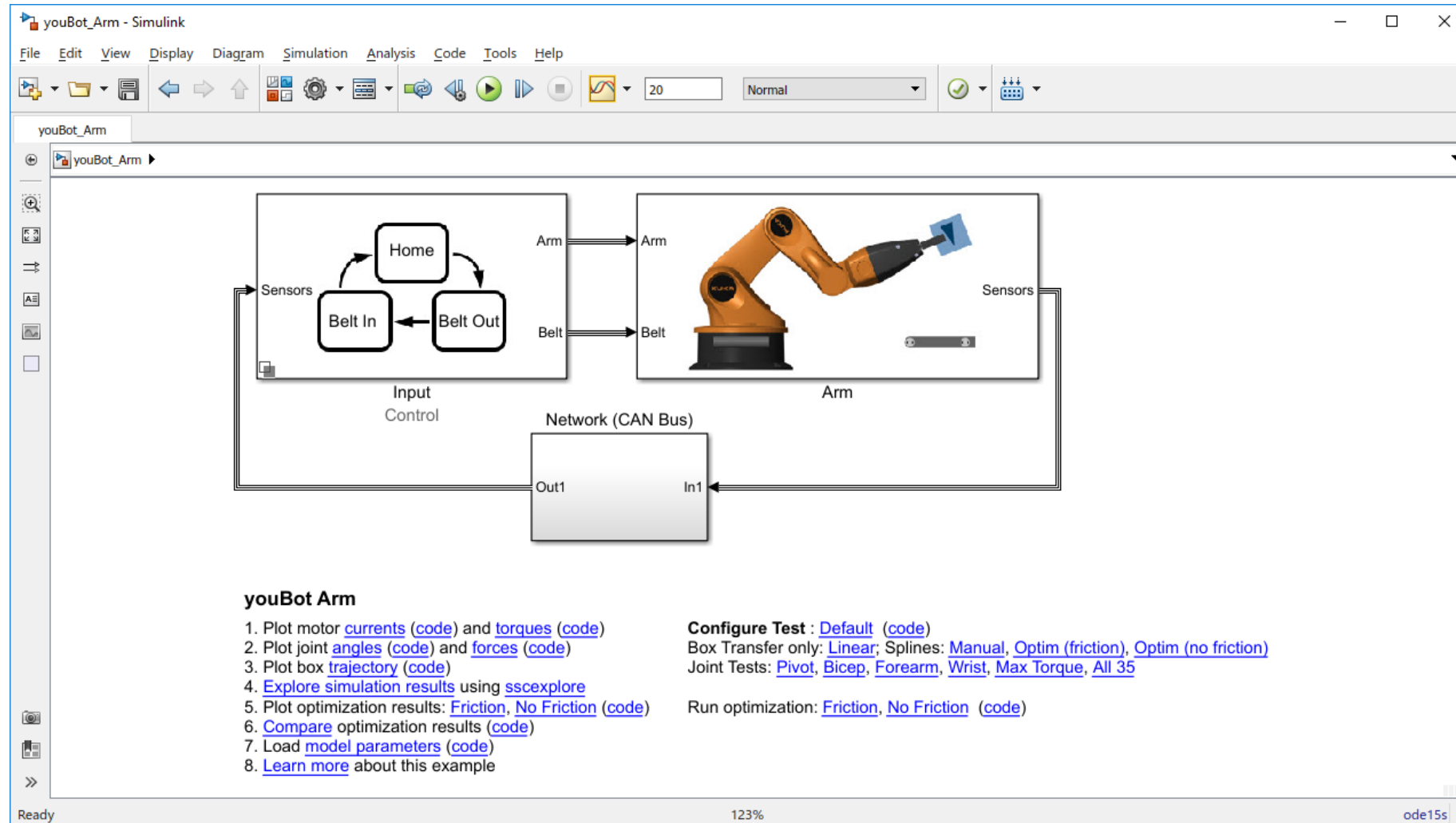
Configure ... (code)
 Box Transfer only: [Manual](#), [Optim](#)
 Joint Tests: [Pivot](#), [B](#), [Wrist](#), [Max Tor](#)
 Run optimization: [Friction](#), [No Friction \(code\)](#)

Stateflow Logic Charts:

- BeltIn:** States include Empty (entry: BeltIn_En = 0), On (entry: BeltIn_En = 1), BoxReady (entry: Robot.GetBox, BeltIn_En = 0), and WaitClear (entry: after(delayBeltClear, sec)).
- Robot:** States include StartHome (entry: Way = 0), GoBeltIn (entry: Gripper.OpenGrip, Way = 1), MoveBox (entry: Gripper.GripBox), GoBeltOut (entry: Way = 2), BeltOut (entry: Gripper.DropBox), GoHome (entry: Way = 3), and Home (entry: Gripper.Close).
- Gripper:** States include Closed (entry: Grip = 0), Open (entry: Grip = 1), Tighten (entry: Grip = 2), and Release (entry: Grip = 1).
- BeltOut:** States include Empty (entry: BeltOut_En = 0), WaitRelease (entry: ShipBox), On (entry: BeltOut_En = 1), BoxReady (entry: Robot.GoHome, BeltOut_En = 0), and WaitClear (entry: after(delayBeltClear, sec)).

Joint Commands: This block diagram shows the control logic for the robot's joints, including a Way selector, an Integrator, a Unit Delay, and a Rate Limiter, all connected to a bus.

Multi-Domain Model



Physical Modeling

youBot_Arm - Simulink

File Edit View Display Diagram Simulation Analysis Code Tools Help

youBot_Arm

youBot_Arm

Input Control

Network (CAN Bus)

Arm

Sensors

Home

Belt In

Belt Out

Arm

Sensors

In1

World

Belt

Environment

Sensors

Finger A

Finger B

Actuation Motion

Configure Actuation: [Motion](#), [Motor](#)

116%

ode15s

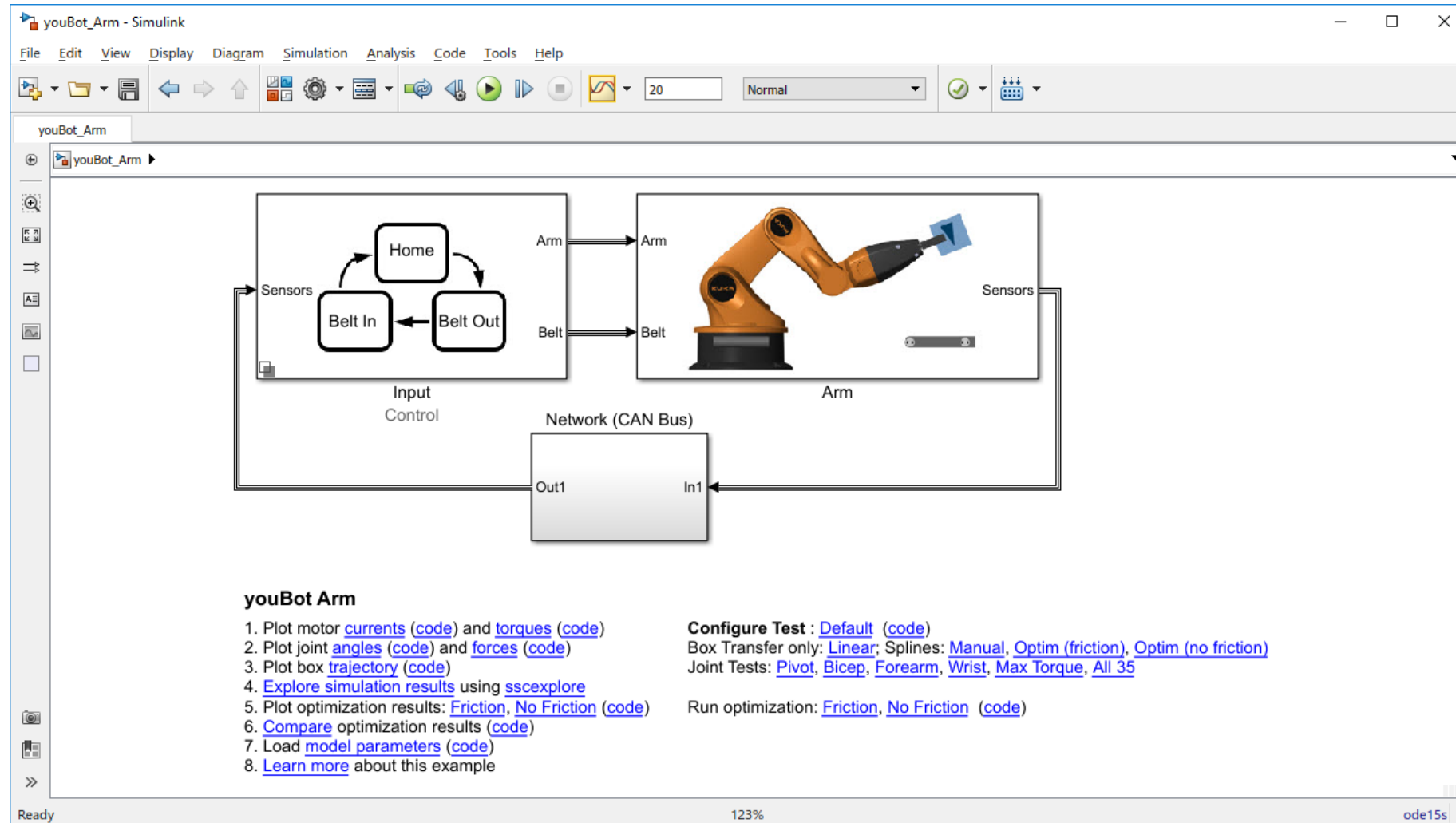
123%

ode15s

Configure Test : [Default](#) (code)
 Box Transfer only: [Linear](#); Splines: [Manual](#), [Optim \(friction\)](#), [Optim \(no friction\)](#)
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#), [Wrist](#), [Max Torque](#), [All 35](#)

) Run optimization: [Friction](#), [No Friction](#) (code)

Multi-Domain Model



Discrete-Event Modeling

youBot Arm

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [ssxexplore](#)
5. Plot optimization results: [Friction](#), [No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

Configure Test : [Default \(code\)](#)
 Box Transfer only: [Linear](#); Splines: [Ma](#)
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#), [Wr](#)

Run optimization: [Friction](#), [No Friction](#)

Transmitter

Signal To CAN Message → Drop Dated Message upon Buffer Overflow → By ID → Message Release Control → ReTx → Re-Transmission Control → ToBus → Send Message to Bus

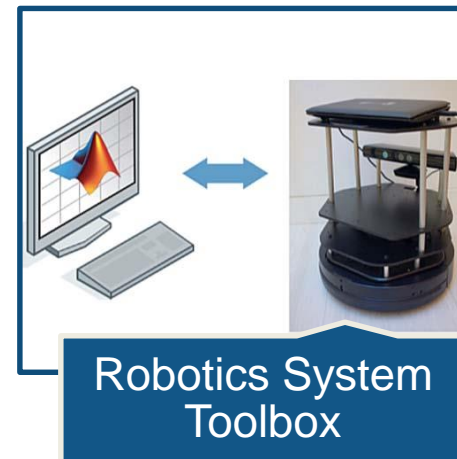
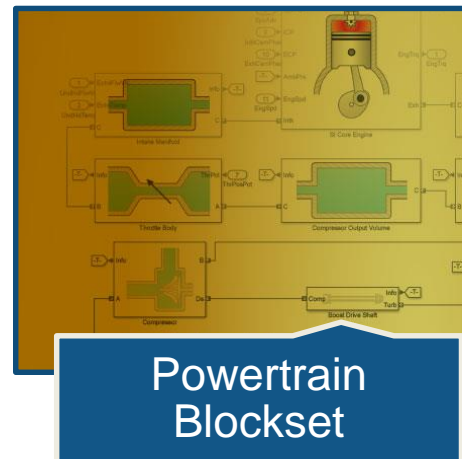
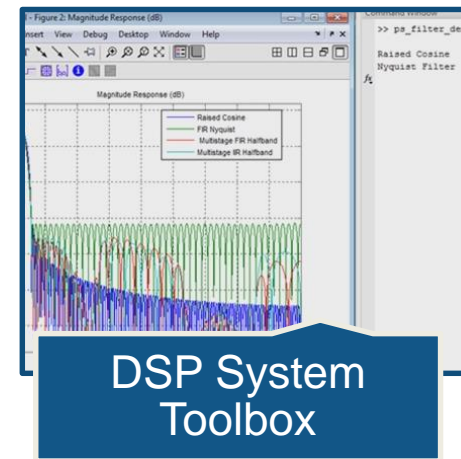
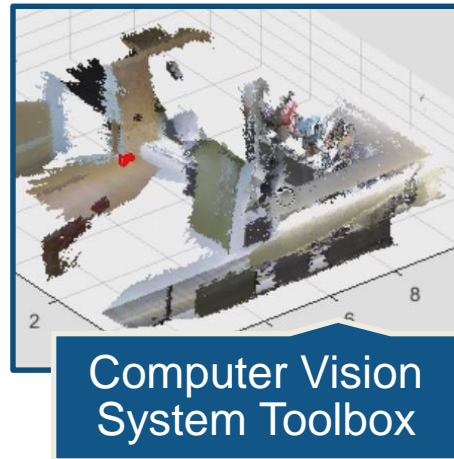
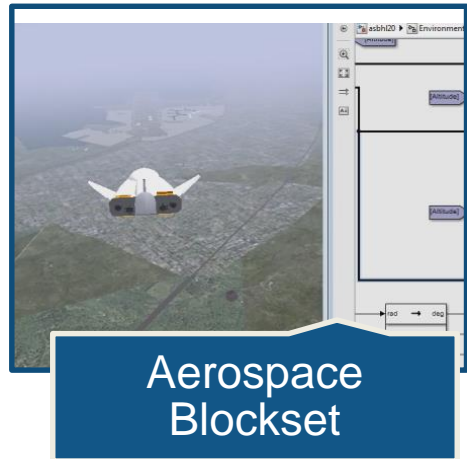
Receiver

Message from Bus → FIFO From Bus → Entity Replicator → Received Message → Reception Control → Success → ReTx → Re-Transmission Control → ToBus → Send Message to Bus

Reception Control → Subscribed Message → Unsubscribed Message → Damaged Message

Domain-Specific Blocksets and Toolboxes

Simulink has numerous domain-specific tools, for example:



Customer Success in Multidomain Modeling

ABB, Deltamarin, and VTT Simulate and Optimize Energy Flows for large ships

Challenge

- Increase the energy efficiency of large vessels

Solution

- Use Simulink to model, simulate, and optimize ship energy flow
- Included mechanical, electrical, thermal, pneumatic, hydraulic and custom (e.g. steam) domains

Results

- Identified design improvements to save on cost and annual fuel usage
- Testing costs reduced by tens of thousands of euros



Customer Success in Multidomain Modeling

“While basic machinery can be modelled in spreadsheets, we could not achieve all our goals in Excel. **Simulink and Simscape enable us to run multidomain simulations ... and to perform energy optimization** for today’s ships and future ships.”

Mia Elg, Deltamarin



Solution

- Use Simulink to model, simulate, and optimize ship energy flow
- Included mechanical, electrical, thermal, pneumatic, hydraulic and custom (e.g. steam) domains

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Lockheed Martin Builds Discrete-Event Models to Predict F-35 Fleet Performance



F-35s ready for flight.

Challenge

Predict F-35 fleet performance to minimize life-cycle costs and maximize mission readiness

Solution

Build a discrete-event model of the fleet with Simulink and SimEvents, use MATLAB Distributed Computing Server to accelerate thousands of simulations, and interpolate the results with Neural Network Toolbox

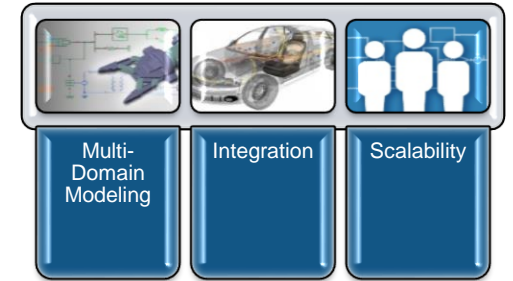
Results

- Simulation setup time reduced from months to hours
- Development effort lessened
- Simulation time cut by months

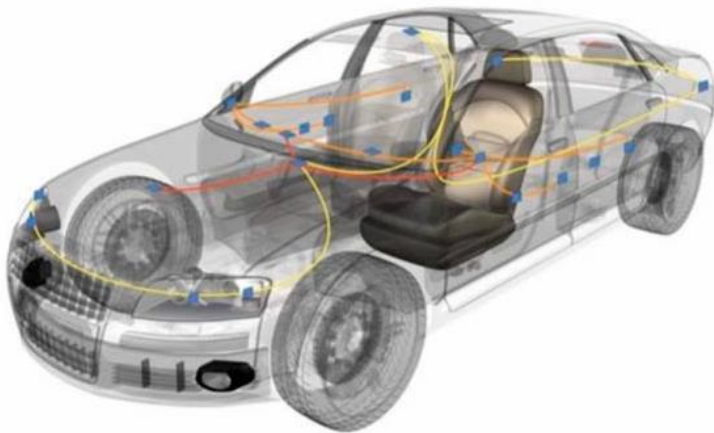
“By building a model with Simulink and SimEvents and running discrete-event simulations on a computer cluster, we rapidly identified many opportunities to maximize F-35 fleet performance while minimizing development and execution efforts.”

Justin Beales
Lockheed Martin

Enterprise Simulation Platform Enablers

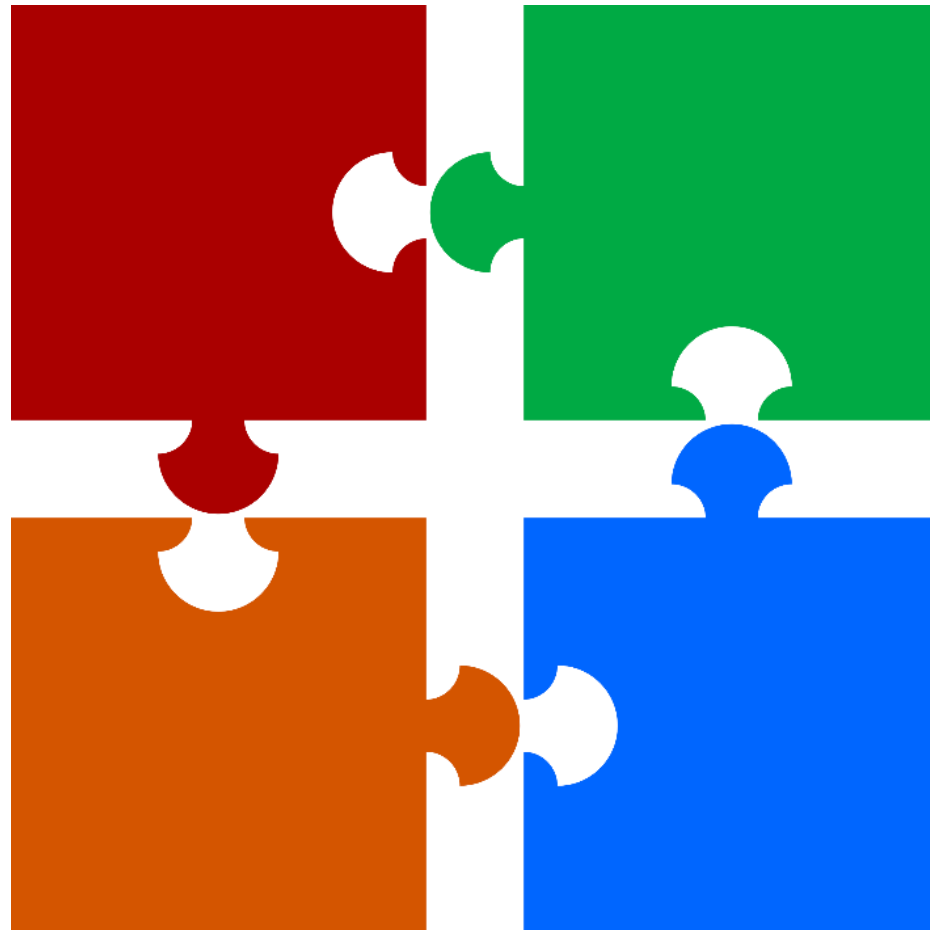


2. Simulation Integration



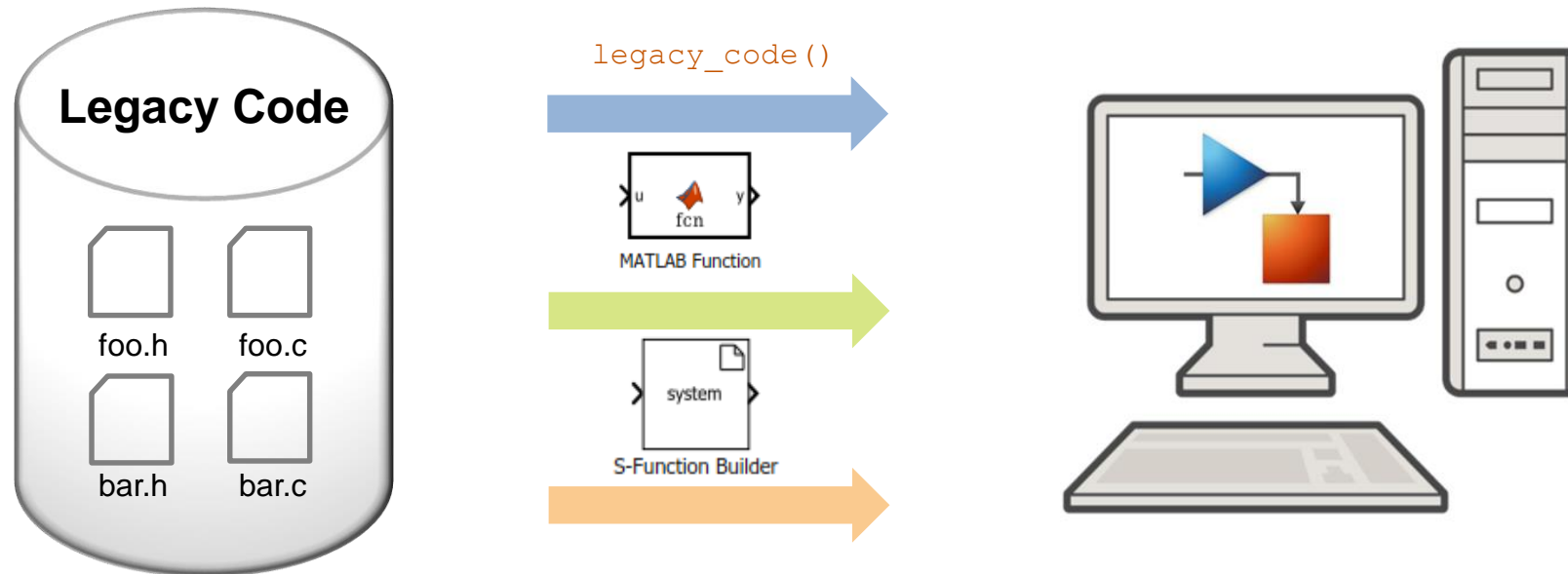
Disconnected Component Intellectual Property (IP)

Your IP exists in many forms and in many locations, making integration difficult

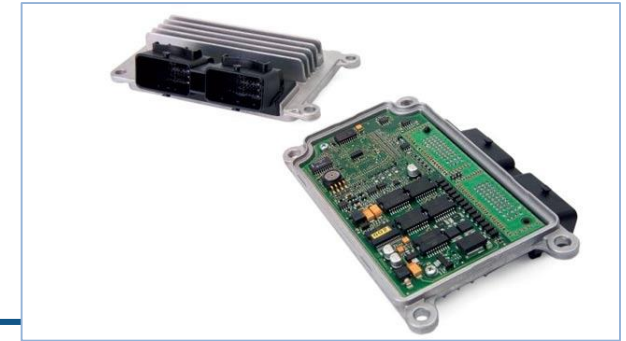


Integrating Your Code

Multiple ways to reuse your legacy code with Simulink



Lotus Engineering Develops Control Systems Software to Reduce Diesel Emissions



Emission control system

Challenge

To develop control systems that enable diesel engines to run cleaner and meet EPA standards for diesel emissions

Solution

Use MathWorks tools for Model-Based Design to model and simulate control systems for emission-reducing components, then generate fixed-point, production-intent code for on-track validation tests

Results

- Proof-of-concept delivered rapidly
- Development time reduced by 30%
- High-quality, production-intent code generated

“Using MathWorks tools to model our control systems has enabled us to manage the complexity of new emissions technologies. I integrated legacy code into the model so I knew I was simulating with the real algorithms”

Roger Tudor
Lotus Engineering

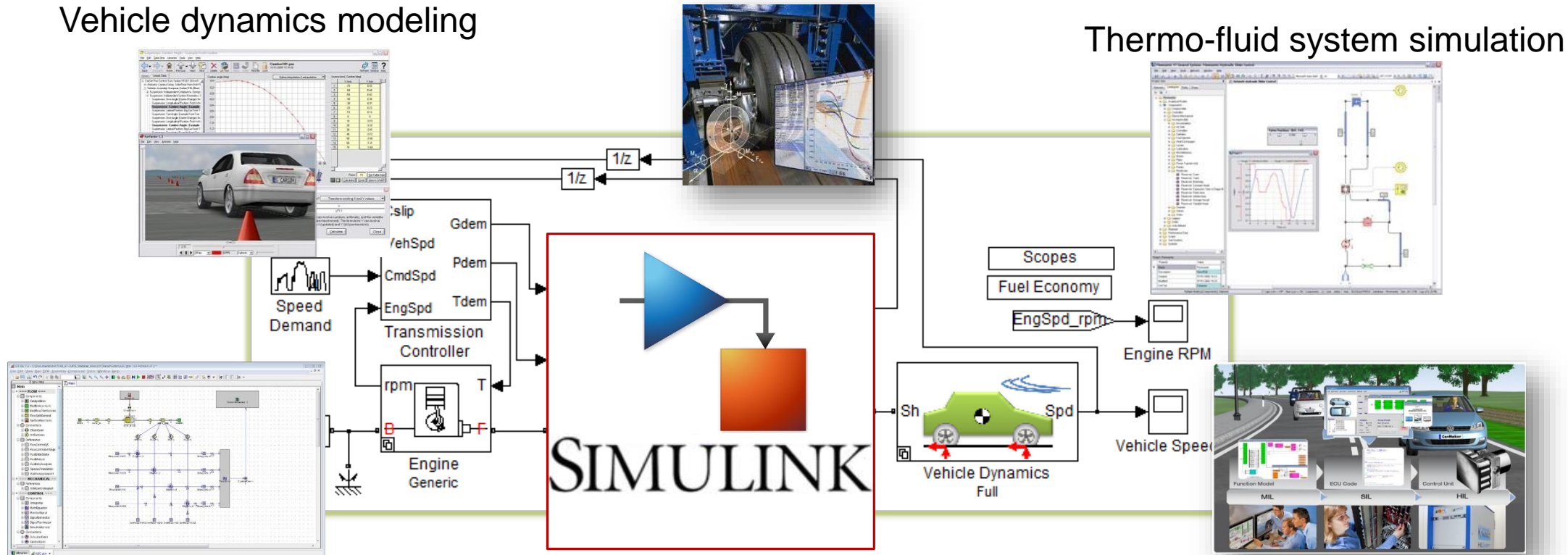
Integrating Third-Party Simulation Tools

- Mature and extensive APIs for third-party tool integration

Tire behavior assessment

Vehicle dynamics modeling

Thermo-fluid system simulation



1D / 3D engine /exhaust simulation

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Partner Ecosystem

Numerous partners provide interfaces to Simulink

The screenshot shows the MathWorks website's 'Third-Party Products & Services' section. It features a navigation menu with 'Products', 'Solutions', 'Academia', 'Support', and 'Community'. The main content area is titled 'Third-Party Products & Services' and includes a search bar and filters for 'Refine by Product Type' and 'Refine by Task'. A list of products is displayed, each with a title, description, and the provider's name. Some products are highlighted with a yellow box.

Product Name	Provider
CarSim, TruckSim, BikeSim	Mechanical Simulation Corporation
CISC RFID ASD Kit+Library	CISC Semiconductor
FIPER (Federated Intelligent Product EnviRonment)	Dassault Systèmes Simulia Corporation
Flowmaster	TASS International
MagNet	Synopsys, Inc
Saber	SIDLAB HB
SIDLAB	SIDLAB HB
SIMPACK	SIMPACK AG
SimulationX	Presagis
VAPS XT	Presagis
veDYNA	TESIS DYNAware GmbH
Vehicle Dynamics for use with MATLAB/Simulink	Milliken Research Associates, Inc.
Virtual Lab Motion	LMS Headquarters
Thermolib	Ricardo
WAVE	Ricardo
Wind River Simics	Wind River
Working Model 2D	Design Simulation Technologies
UniPhi	SimuQuest, Inc.

Customer Success in Simulation Integration

Autoliv Develop Integrated Vehicle Safety Applications

Challenge

- Design and validate safety-critical control algorithms
- Integrate with several 3rd party domain specific tools

Solution

- Leverage Simulink as a platform by integrating third-party software

Results

- Industry first integration of stability control inertial sensor into airbag control unit
- Restraint control module software development time reduced by 30%



Customer Success in Simulation Integration

“Seamless integration with third party software solutions enables rigorous development in a safe environment... it is very useful that you can export these complex third-party tool functionalities in the form of S-functions and run co-simulation.”

Siddharth D’Silva, Autoliv



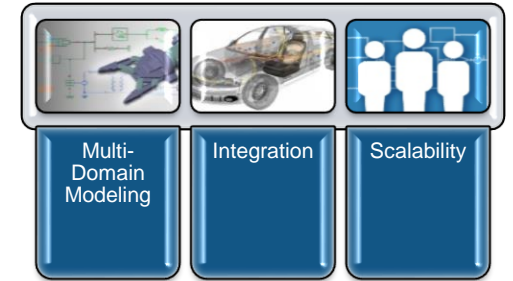
Solution

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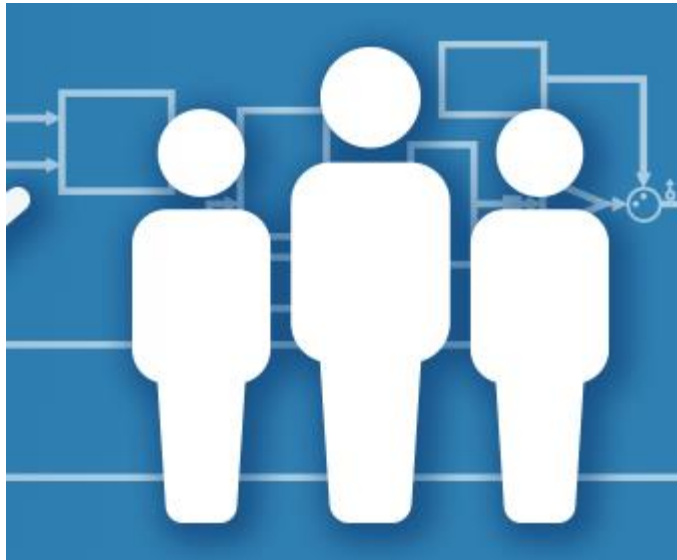
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Enterprise Simulation Platform Enablers

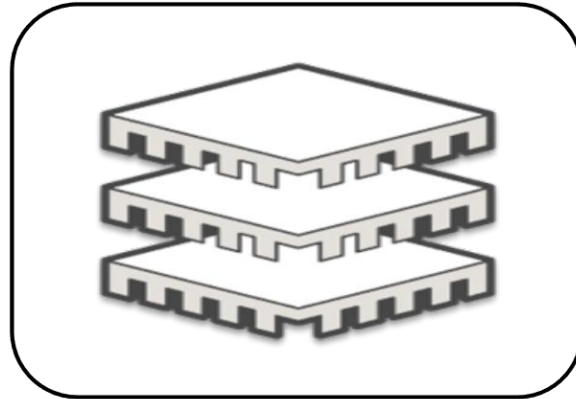


3. Scalability

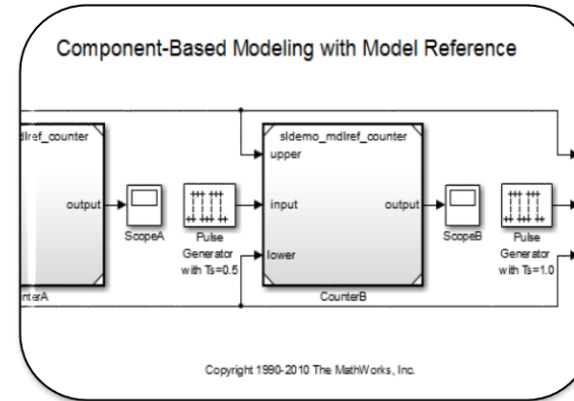


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Scalability Challenges



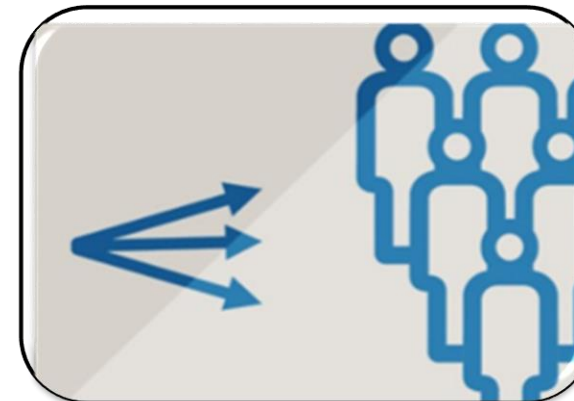
Performance



Componentization



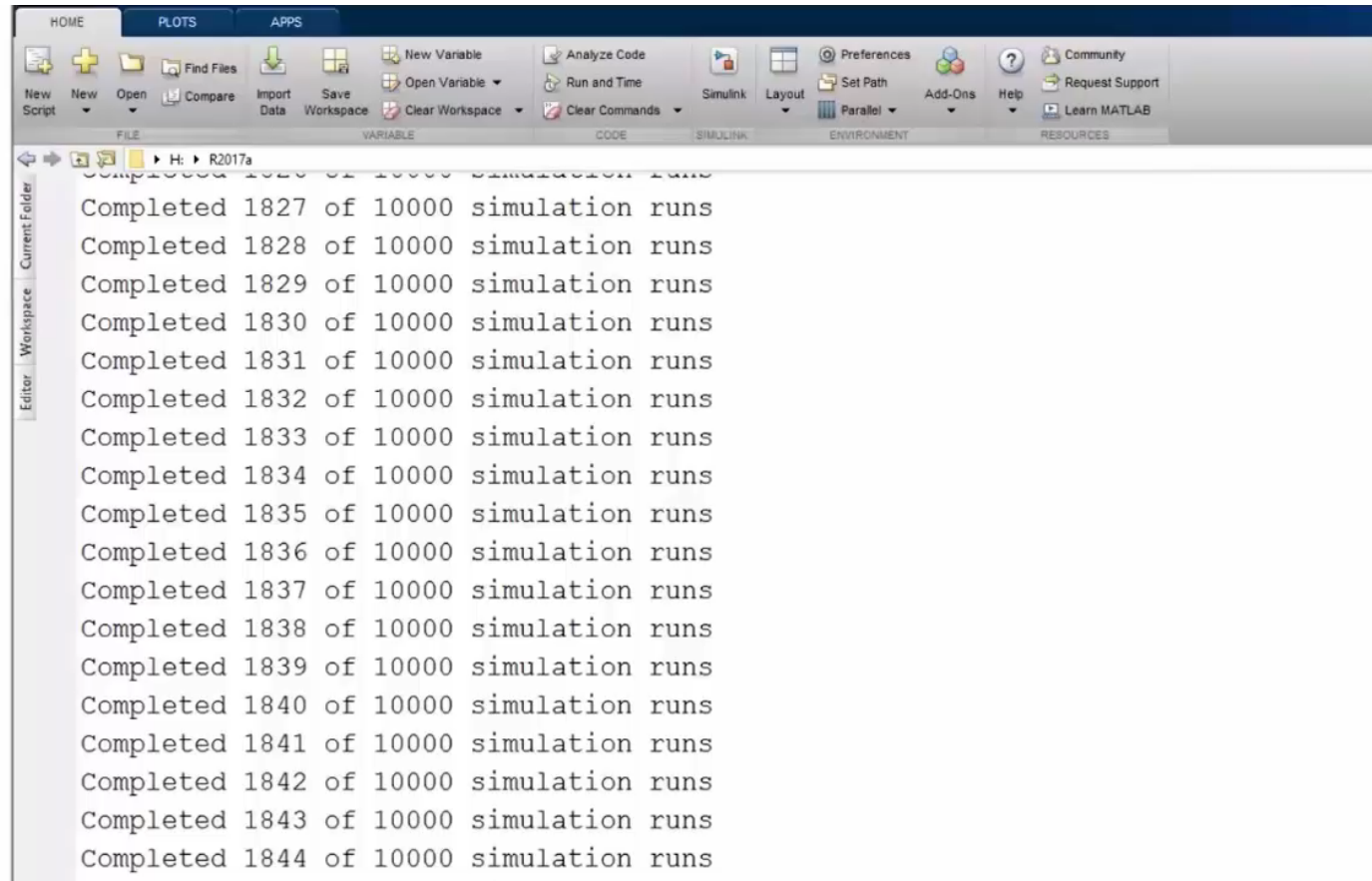
Team Workflows



Sharing

Performance Scalability

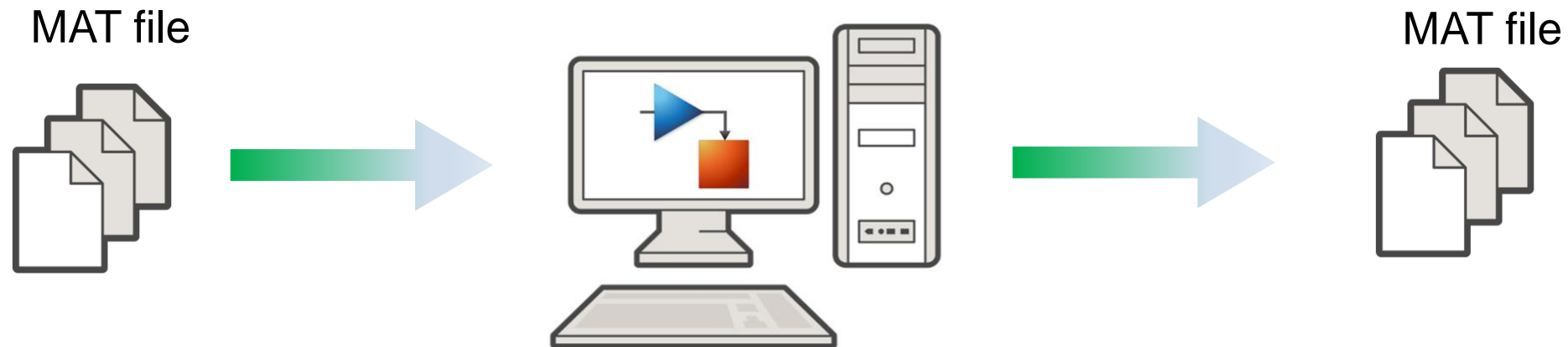
Easy scalability to multicore or cluster/cloud computation environment



Performance Scalability

Big data workflow

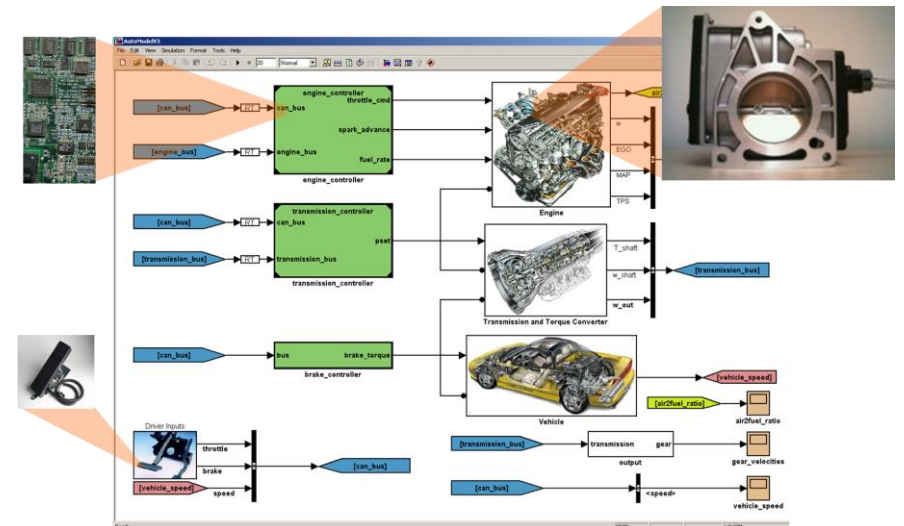
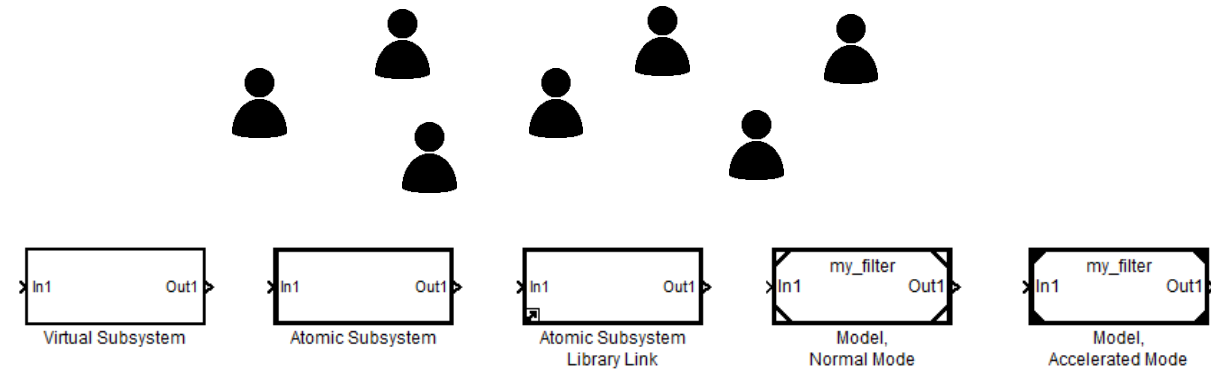
- Processing large amount of simulation inputs / outputs



Complex Design Development through Componentization

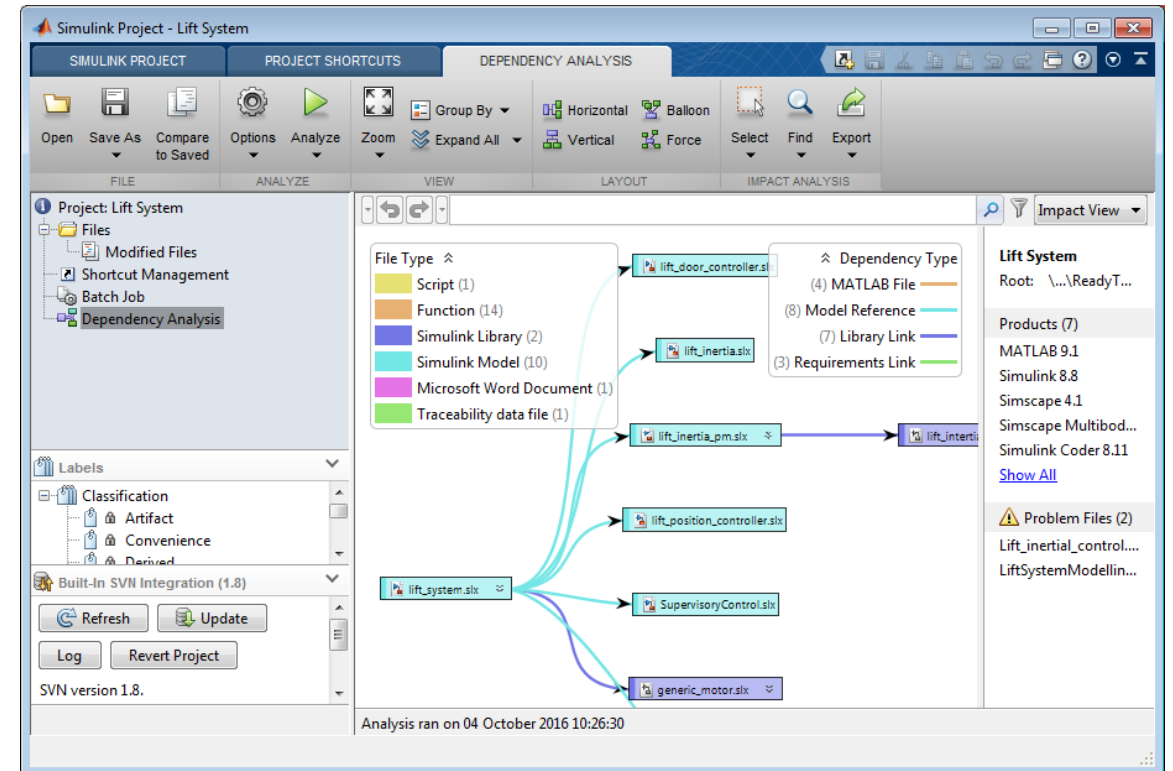
- Supporting team workflows
 - Faster modular development
 - More effective verification
 - Increased reusability

- Improving performance
 - Incremental loading and code generation
 - Simulation speed
 - Memory usage

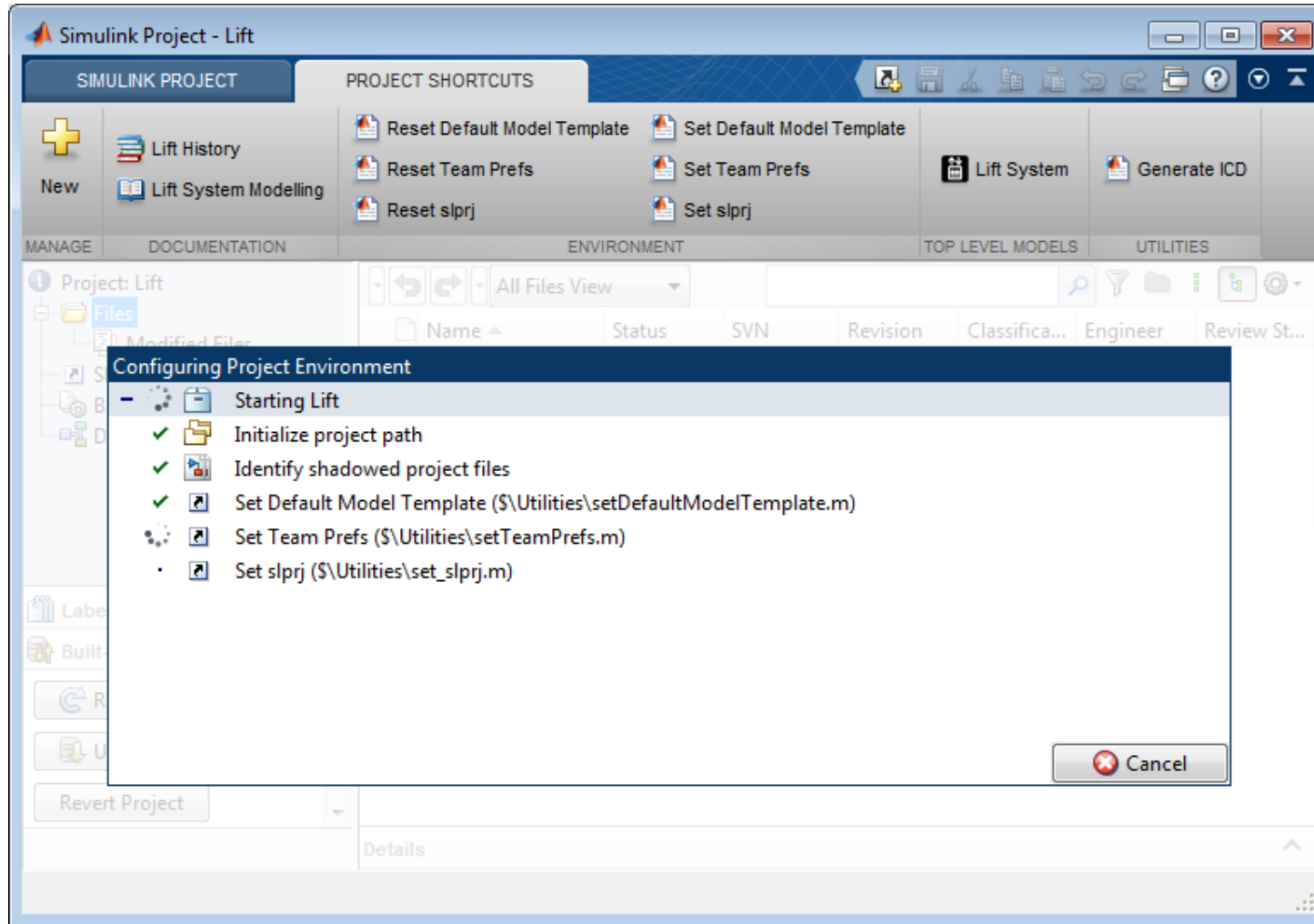


Capabilities Enabling Team Workflows

- Simulink Projects
- Source control
- Design comparison and merging
- Dependency analysis



Manage team development with Simulink Projects



*“It works on my computer,
but not on someone
else’s ...”*

- Simulink projects help with
- File management
 - Paths
 - Startup/Shutdown scripts
 - Source control interaction
 - Simulink customisation

Source Control Integrations



Microsoft Team Foundation Server (TFS) integration available now from MathWorks File Exchange



[Products](#)
[Solutions](#)
[Academia](#)
[Support](#)
[Community](#)
[Events](#)

File Exchange

TFS Version Control Integration

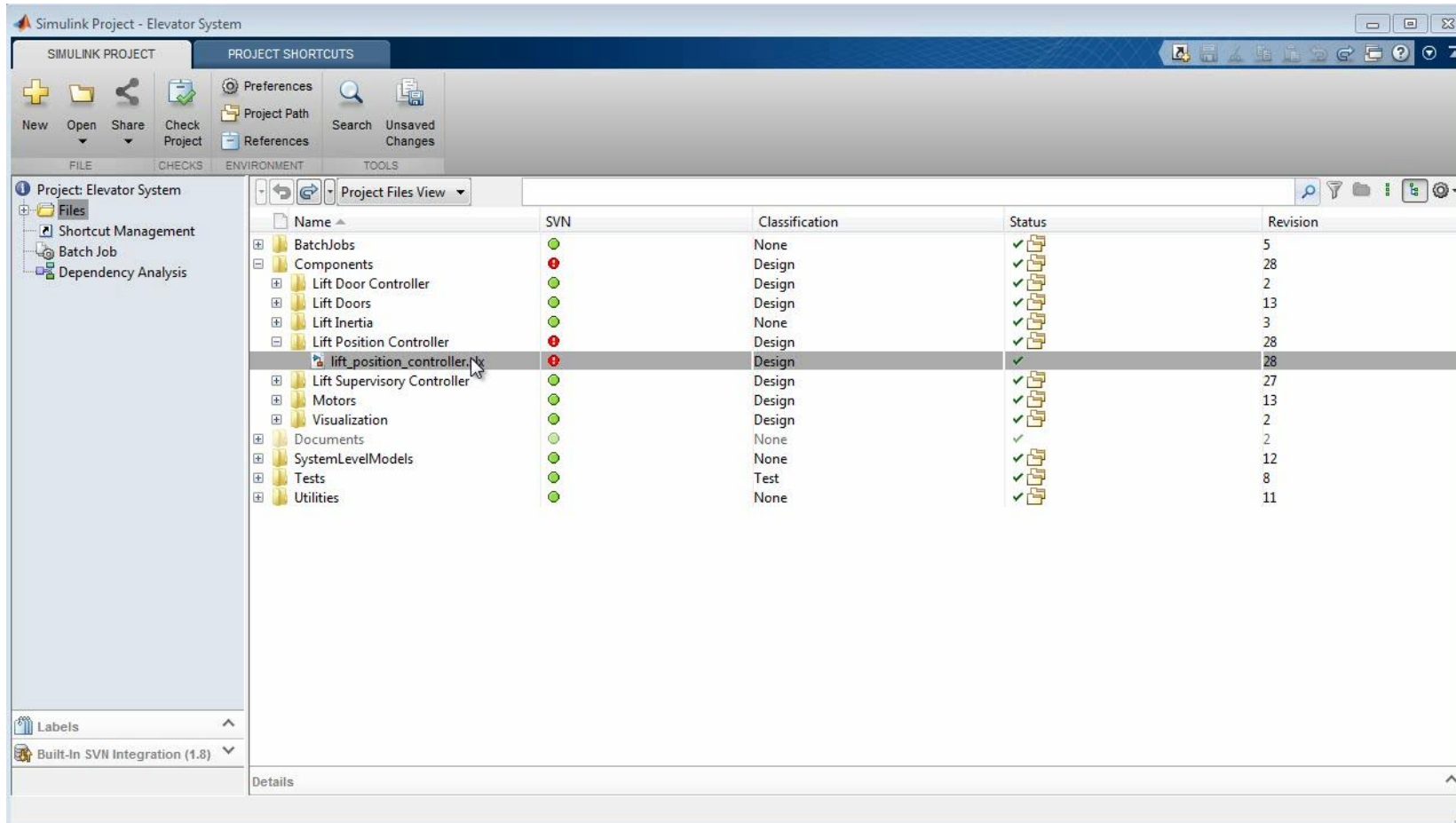
by [Jasper Schneider](#)

17 May 2016 (Updated 26 May 2016)

TFS Version Control integration in MATLAB and Simulink

[Watching this File](#)

Manage Concurrent Design Conflicts – 3 Way Merge



- Supports concurrent engineering
- Identify conflicts in design
- Automatically merge changes

Dependency Analysis – Modular Development

Simulink Project - Elevator System

SIMULINK PROJECT PROJECT SHORTCUTS

+ New Lift History Lift System Modelling
 Reset Default Model Template Set Default Model Template
 Reset Team Prefs Set Team Prefs Lift System Generate ICD
 Reset slprj Set slprj

MANAGE DOCUMENTATION ENVIRONMENT TOP LEVEL MODELS UTILITIES

Project: Elevator System

Files
 Shortcut Management
 Batch Job
 Dependency Analysis

Project Files View

Name	Path	Status	Classification
Lift	\$\Tests	✓	Test
Lift Door Controller	\$\Components	✓	Design
Lift Door Controller	\$\Tests	✓	Test
Lift Doors	\$\Components	✓	Design
Lift Doors	\$\Tests	✓	Test
Lift Inertia	\$\Components	✓	None
Lift Motor	\$\Tests	✓	Test
Lift Position Controller	\$\Components	✓	Design
Lift Position Controller	\$\Tests	✓	Test
Lift Supervisory Controller	\$\Components	✓	Design
Lift Supervisory Controller	\$\Tests	✓	Test
Motors	\$\Components	✓	Design
SystemLevelModels	\$\	✓	None
Tests	\$\	✓	Test
Utilities	\$\	✓	None
Visualization	\$\Components	✓	Design
Visualization	\$\Tests	✓	Test
basic_animation.slx	\$\Components\Visualization	✓	Design
ElevatorTemplate.slx	\$\Utilities	✓	Other
exportToR2016a.m	\$\BatchJobs	✓	Design
generateBillOfMaterials.m	\$\BatchJobs	✓	Design
generateICD.m	\$\Utilities	✓	Design
generic_motor.slx	\$\Components\Motors	✓	Design
history.m	\$\Utilities	✓	Design
lift_door.req	\$\Components\Lift Doors	✓	Design
lift_door.slx	\$\Components\Lift Doors	✓	Design
lift_door_controller.slx	\$\Components\Lift Door Controller	✓	Design

Labels

Details

Dependency Analysis – Modular Development

List products required

Show model structure

Highlight issues

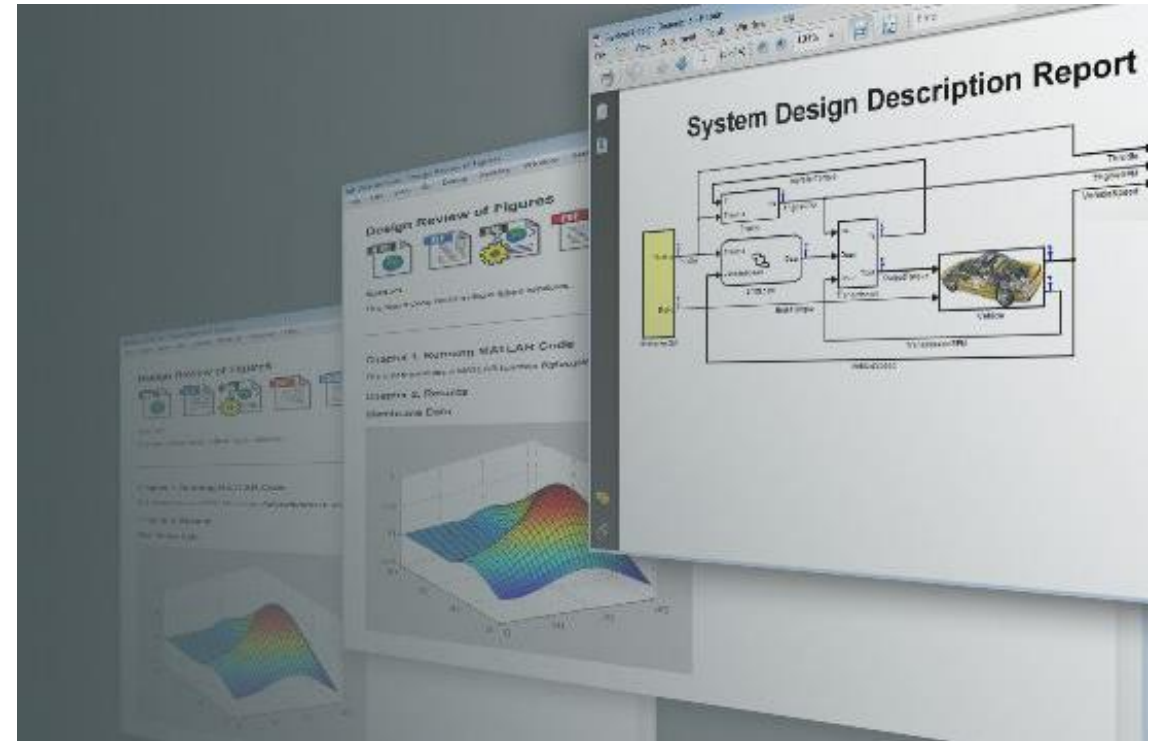
lift_system_orig
Root: \\UK-GWALKER-LT\
Products (7)
MATLAB 9.1
Simulink 8.8
Simscape 4.1
Simscape Multibody 4.9
Simulink Coder 8.11
[Show All](#)
Problem Files (1)
LiftSystemModelling.docx

Sharing Outside Your Team

Quick File
Packaging

Model Protection
(IP Management)

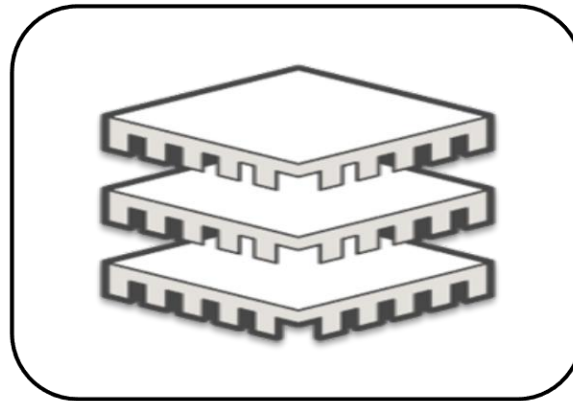
Reporting and
Documentation



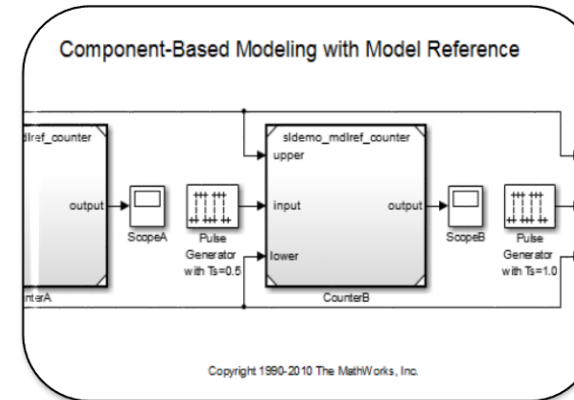
Simulink Addresses Scalability Challenges

Parallel Simulations

Big Data



Performance



Componentization

Modular design

Performance Improvements

Simulink Projects

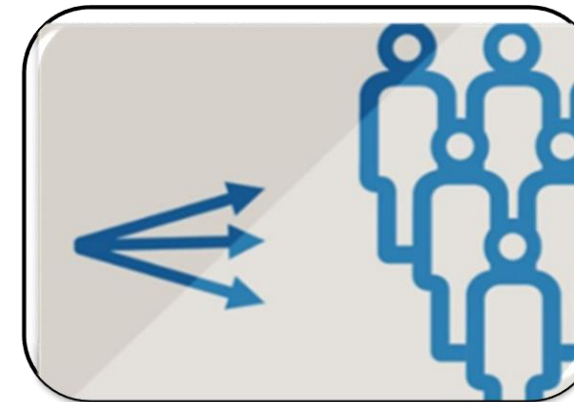
Source Control

3 Way Merge

Dependency Analysis



Team Workflows



Sharing

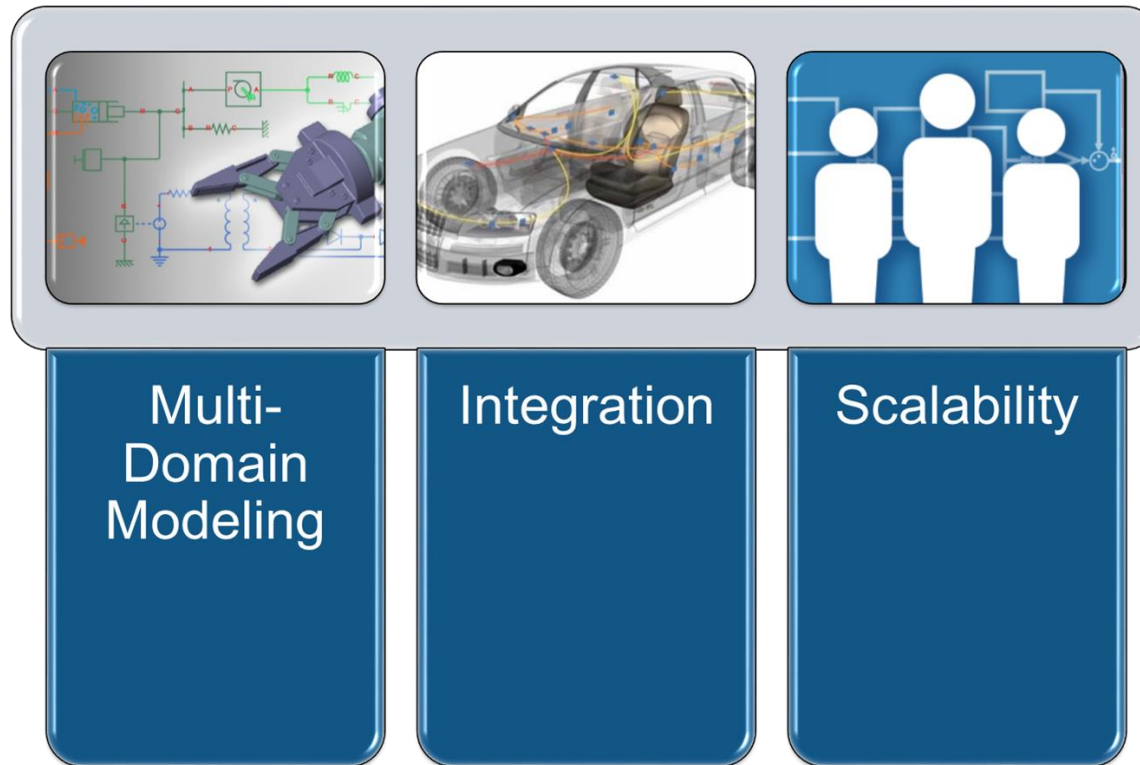
Simulink Projects

IP Protection

Reports

Web Views

Simulink can be used as your Enterprise Simulation Platform



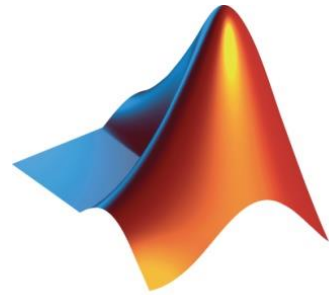
Simulink as Enterprise Simulation Platform

“It would be horrendously complex to build a scale model of our full system for all the different variants we considered in the design phase.”

*“**With Simulink ... we built virtual prototypes that enable us to predict system performance** under various sea conditions, simulate failure cases, and analyze loads **so we can select the best design and accurately specify component requirements** to our suppliers.”*



*Jonathan Fiévez, CTO
Carnegie Wave Energy*



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