

Adoption of Model-Based Software for Vehicle Systems Development

Presented by:

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Crown Equipment Company

Material prepared for MathWorks Automotive Conference, May 9, 2017



One of the World's Largest Material Handling Companies



5 regional
headquarters



2.5 Billion USD
FY2014



12,000
employees



17 manufacturing
plants in 11 locations
worldwide



Over 500 retail
locations across
84 countries



Leader in material
handling innovation and
technology



Global line of trucks
designed to local
work practices



Innovative fleet
management
solutions



Family owned and
managed industry
leader since 1945

CROWN

 NEW TRACK  REDESIGNED OR UPDATED TRACK



Adopting Model Based Software

Agenda

- I. Initial Goals
- II. Architecture Decisions
- III. Code Generation Experience
- IV. Virtual Truck Simulations
- V. Performance Improvements
- VI. Verify, Test and Report

I. Model Based Software – Initial Goals

- Code Generation from Reusable Models for All Products
- Support Expansion of Features for New Technology



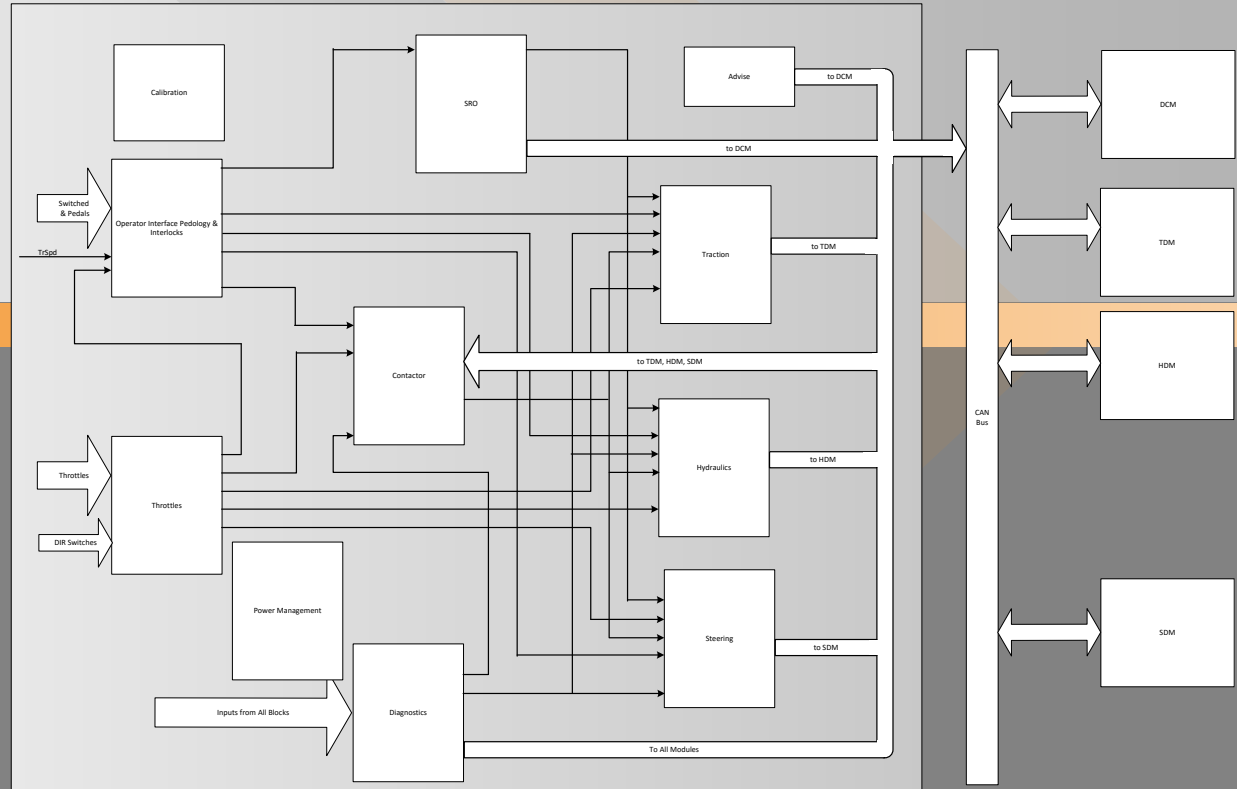
II. Model Based Software – Architecture Decisions

R2011b

Initial MBS Version:

- MATLAB
- Simulink
- Stateflow

Data Dictionary Concept
Shared Network Files
(8) Legacy MATLAB Users



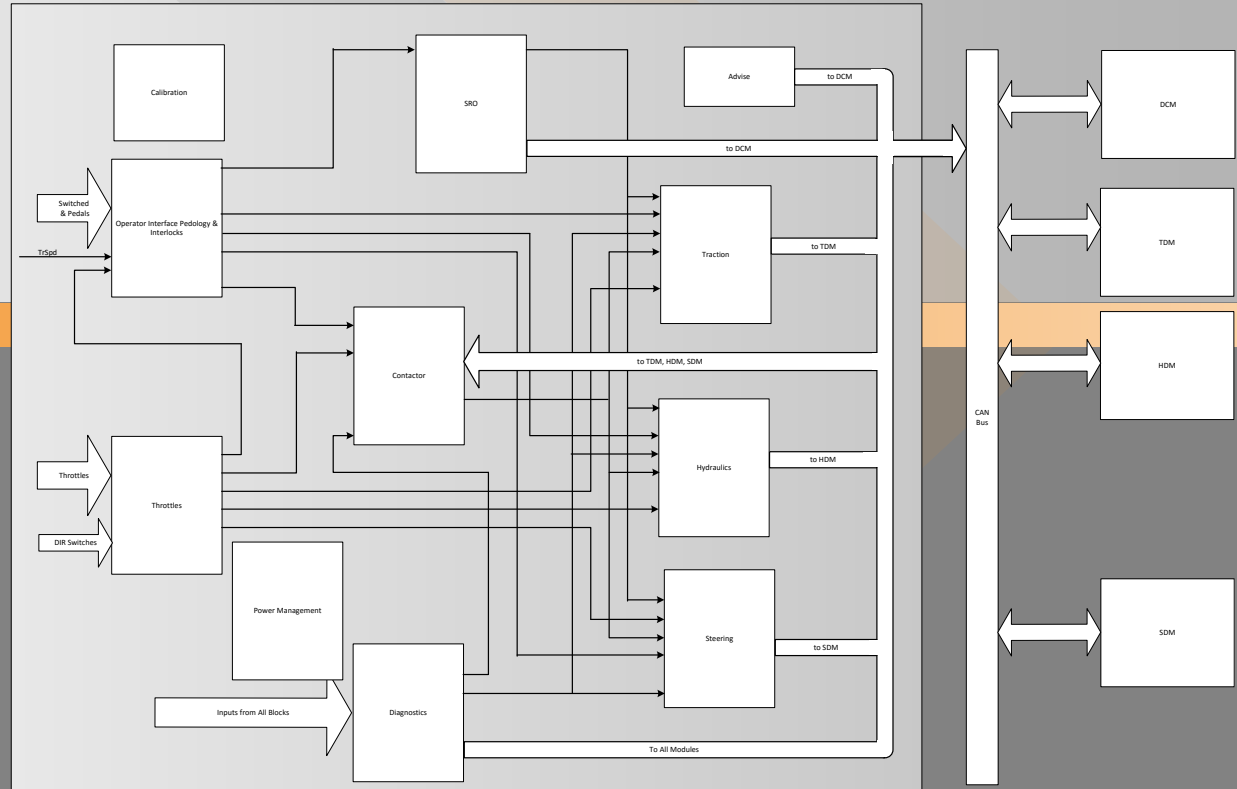
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III. Model Based Software – Code Generation

Modular Model Design

Initial Code Gen:

- MATLAB Coder
 - Simulink Coder
 - Embedded Coder
- (4) System Developers

R2011b

R2012b

Initial MBS Version:

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| Benefits | Virtual Subsystem | Atomic Subsystem | Model Reference |
|------------------------|-------------------|------------------|-----------------|
| Ease of Use | + | + | - |
| Readability | + | + | + |
| Traceability | | + | + |
| Reusability | | | + |
| Concurrent Development | | | + |
| Unit Testing | | | + |
| Performance | | | +, - |

III. Model Based Software – Code Generation

Initial Code Gen:

> 2 Hrs to Generate Code
Single Core - 8 GB RAM
SVN Source Control
(4) System Developers

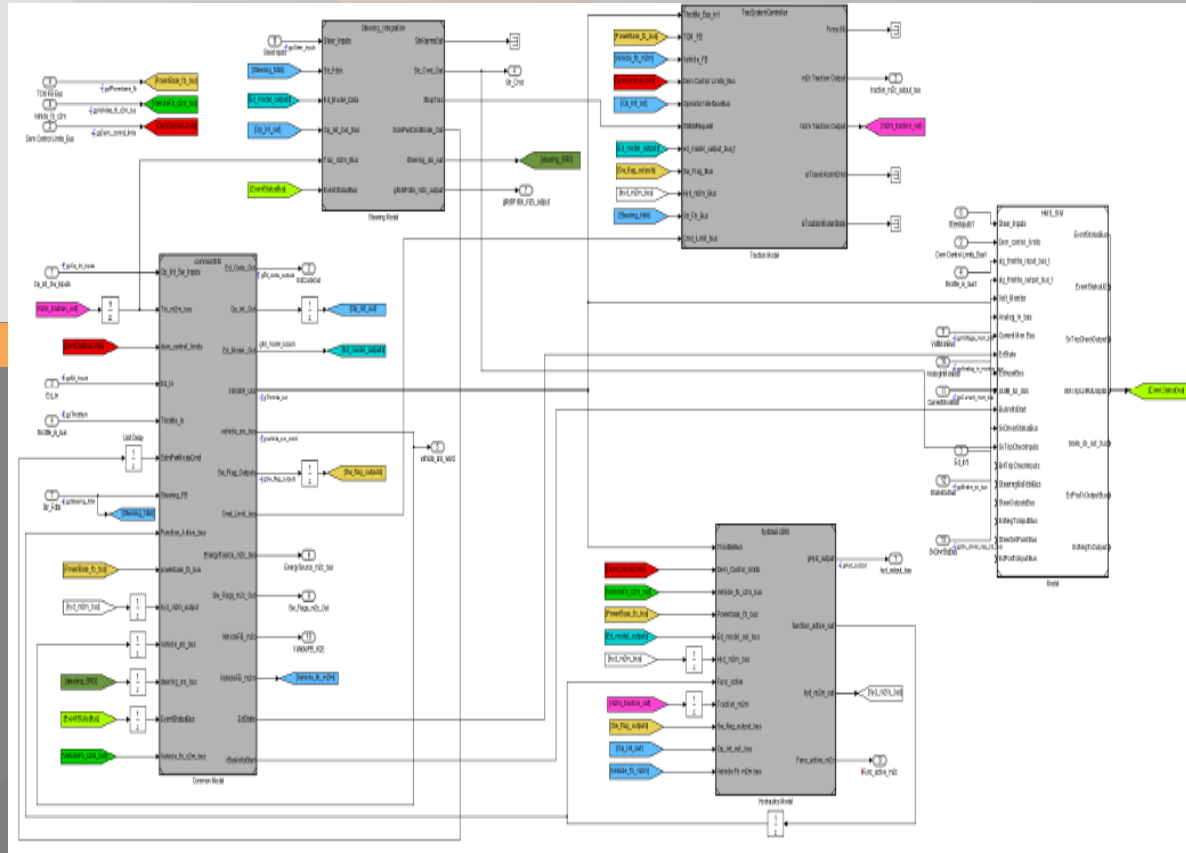
R2011b

R2012b

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Data Dictionary Concept
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III. Model Based Software – Signals and Parameters

[illegible]

III. Model Based Software – Code Generation

Initial Code Gen:

- MATLAB Coder
 - Simulink Coder
 - Embedded Coder
- (4) System Developers

Software environment

Code replacement library:

Shared code placement:

R2011b

R2012b

R2014a

Initial MBS Version:

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Data Dictionary Concept

Shared Network Files

(8) Legacy MATLAB Users

Individual Builds:

- Simscape
- MATLAB Report Generator
- Simulink Report Generator

Virtual Truck, HiL,

Shared Code Placement

Reference Config Sets

(8) System Developers

Normal
Normal
Accelerator
Rapid Accelerator
Software-in-the-Loop (SIL)
Processor-in-the-Loop (PIL)
External

commonSIMbuild
Model Workspace
Reference (Active)

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R2014a

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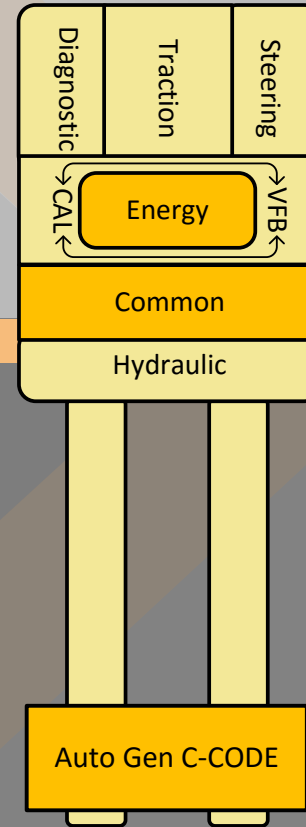
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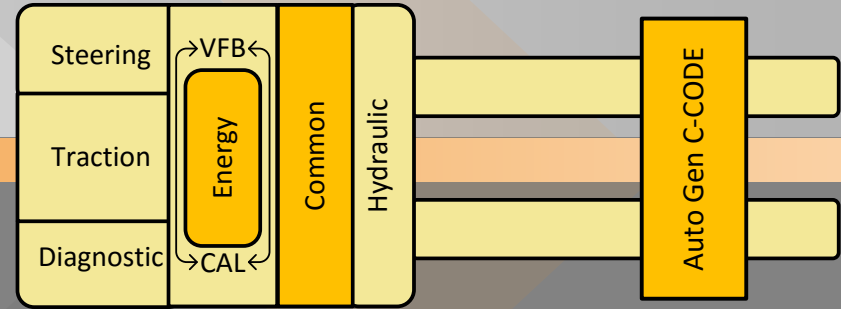
Initial MBS Version:

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Data Dictionary Concept
Shared Network Files
(8) Legacy MATLAB Users

Individual Builds:

10-20 Minute Code Gen
Single Core - 16 GB RAM
IBM's RTC Source Control
(8) System Developers



Vehicle Apps

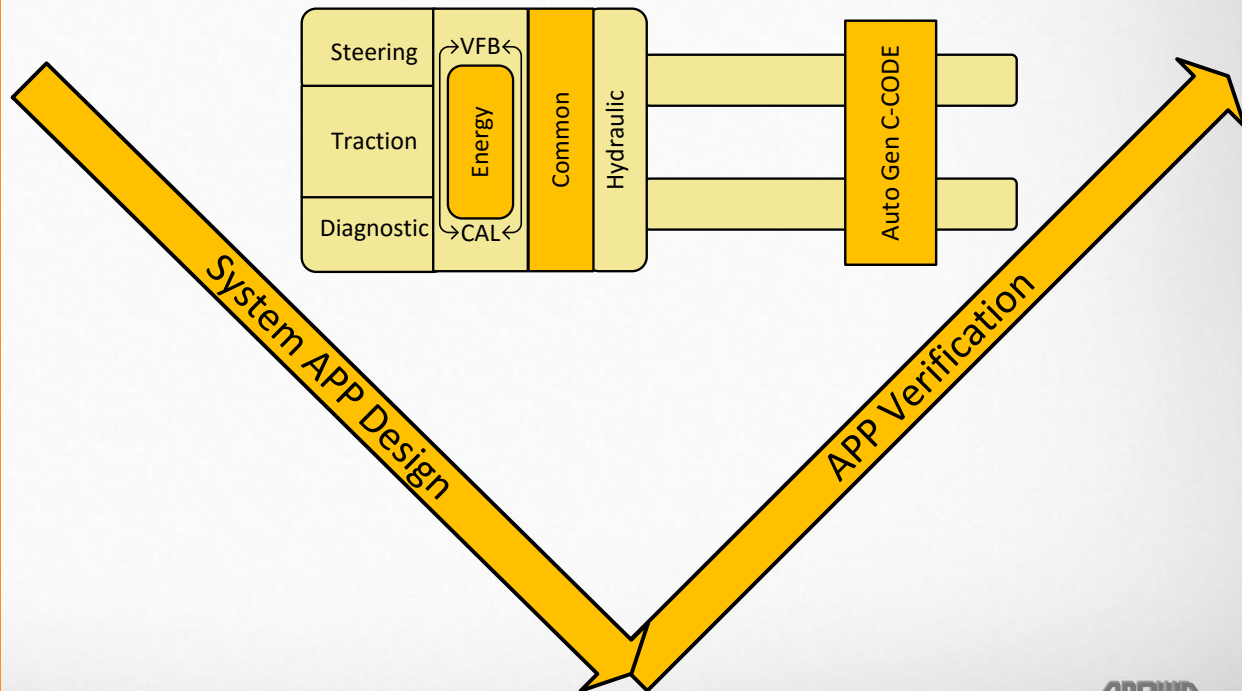
20 System Apps

200 Simulink Models

2000 Model Parameters

1 Auto Gen C-Code
325K Lines of Code

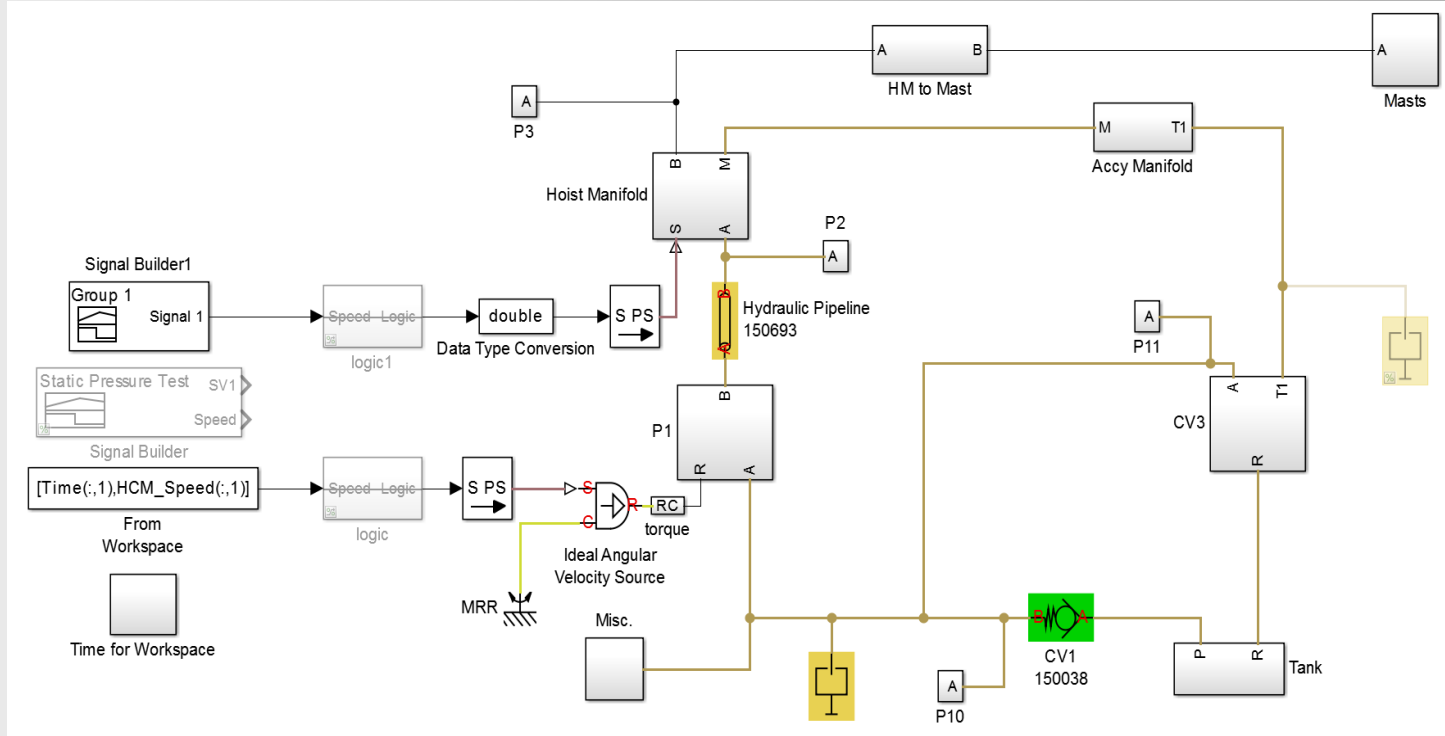
Model Based Vehicle System Apps



OnTrac™ Traction Control

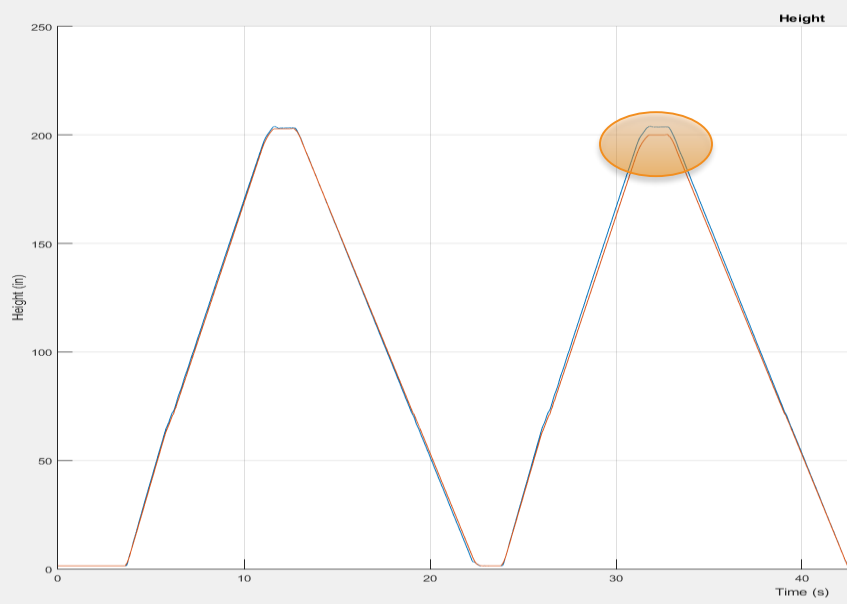


IV. Model Based Software – Virtual Truck

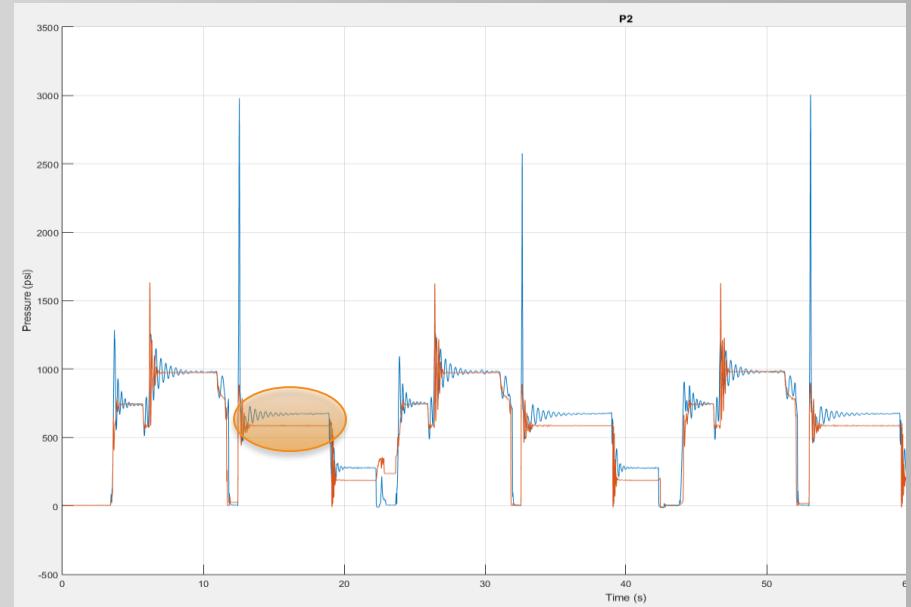


IV. Model Based Software – Virtual Truck

Lift Speed Correlation (test vs model)



Pressure Correlation (test vs model)



V. Model Based Software – Improved Performance

Initial Code Gen:

- MATLAB Coder
 - Simulink Coder
 - Embedded Coder
- (4) System Developers

Parallel Builds:

- Parallel Computing Toolbox
 - Polyspace Static Analysis
 - V&V Toolbox
- Parallel Simulation and Build
(12) System Developers

R2011b

R2012b

R2014a

R2015b

Initial MBS Version:

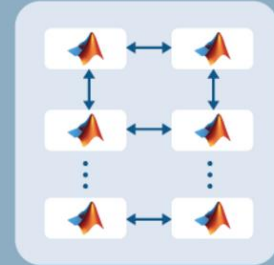
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Shared Code Placement
Reference Config Sets
(8) System Developers

Desktop

Parallel Computing Toolbox



Simulink,
Blocksets, and
Other Toolboxes

MATLAB®

V. Model Based Software – Improved Performance

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Parallel Builds:

5-10 Minute Code Gen
Quad Core - 32 GB RAM
GIT Distributed Source Control
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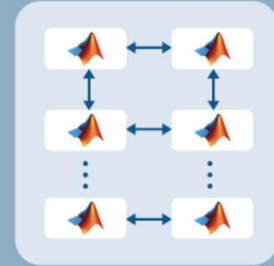
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VI. Model Based Software – Verify, Test & Report

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 - Embedded Coder
- (4) System Developers

Parallel Builds:

- Parallel Computing Toolbox
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- Parallel Simulation and Build
(12) System Developers

Test & Report:

- Simulink Test
 - MATLAB Compiler
- Bi-Directional Req's Links
(20) System Developers

R2011b

R2012b

R2014a

R2015b

R2016b

R2017?

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Verification:

- Dependency Analysis
Simulink Design Verifier
3-way compare and merge
(16) System Developers

VI. Model Based Software – Verify, Test & Report

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R2011b

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R2017?

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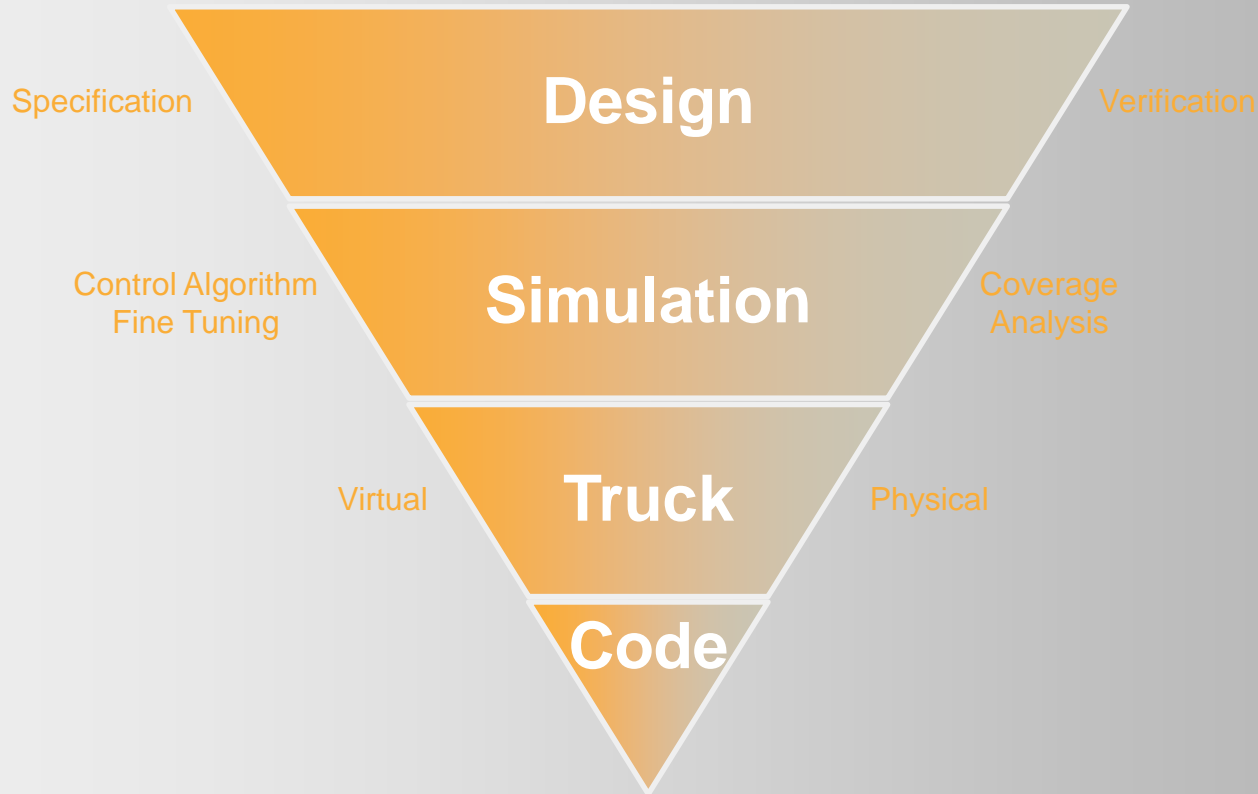
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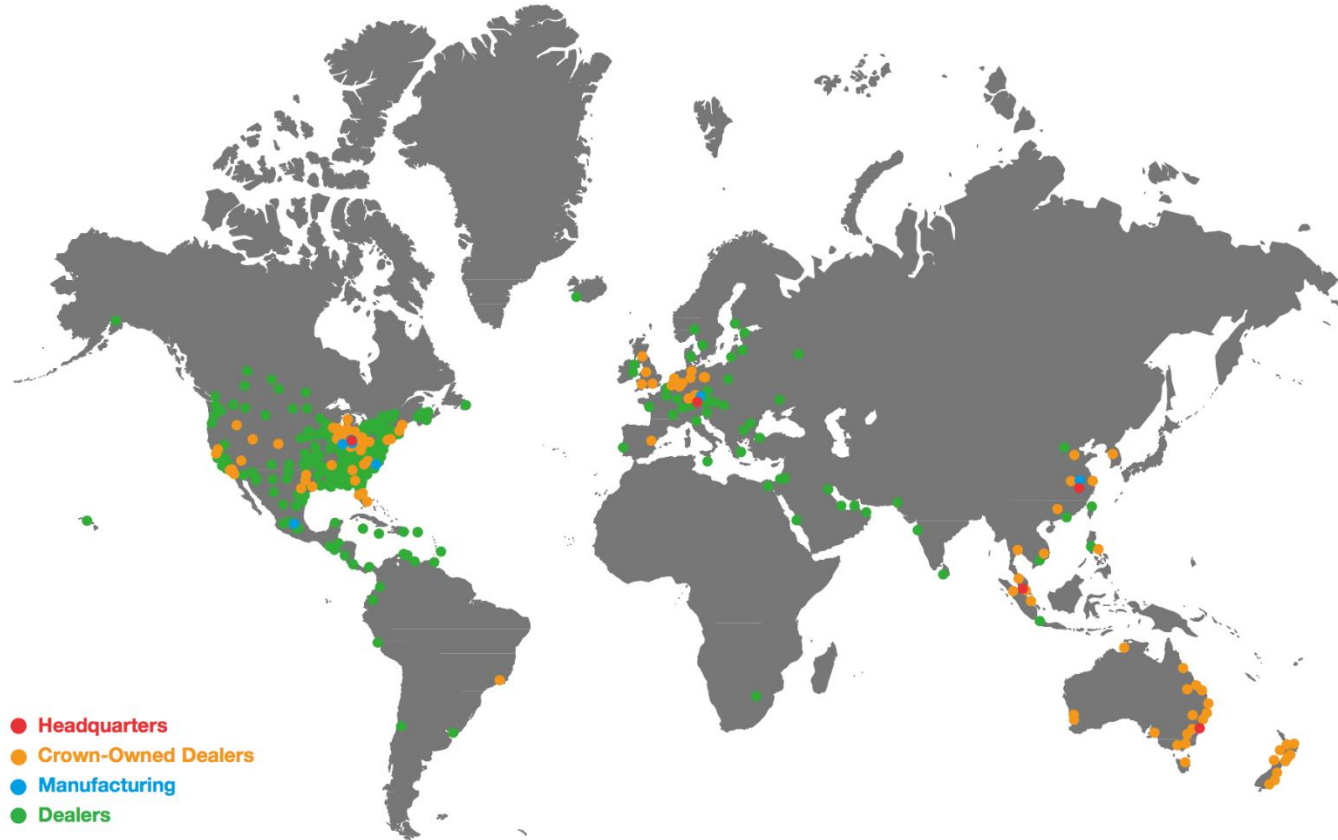
Verification:

5-10 Minute Code Gen
Quad Core with 32 GB RAM
GIT Distributed Source Control
(16) System Developers

VI. Model Based Software – Verify, Test & Report



Global Locations



USA

New Bremen, Ohio
New Castle, Indiana
Greencastle, Indiana
Kinston, North Carolina
Celina, Ohio
Minster, Ohio
New Bremen, Ohio
New Knoxville, Ohio

EUROPE

Munich, Germany
Roding, Germany

MEXICO

Querétaro

CHINA

Suzhou
Suzhou

AUSTRALIA

Sydney

SINGAPORE

Singapore

