
WELCOME
Ford
Model-Based Agility
with
FASST
Ford Automated System
Simulation Toolchain
Robert ter Waarbeek
Raghu Baskaran
Steven Foster
Nick Adams
Nate Rolfes
...and the Global FASST team !
VIRTUAL VEHICLE built in MINUTES instead of MONTHS

AGENDA

▪ Why & What is FASST	Robert ter Waarbeek
▪ How does it work	Raghu Baskaran
▪ Creating full Vehicle Simulation	Steven Foster
▪ Scaling to production	Nick Adams
▪ Inner Sourcing for Model Development	Nate Rolfes
▪ Closing Statement	Robert ter Waarbeek

WHAT IS FASST?

WHY DO WE NEED IT?

ROBERT TER WAARBEEK

WHY DO WE NEED FASST?

"Software and digital systems provide tremendous power in building complex systems not previously possible.

But this increase in power comes with a price – large software systems are fiendishly difficult to get correct.

The difficulty of building such software is often underestimated by engineers."

– Nancy Leveson, Professor of Aeronautics and Astronautics at MIT
Widely recognized as a preeminent expert in system and software safety

Automotive Vehicles are extremely complex mass produced mechatronics systems

with rising complexity its is essential to detect system issues early in development.

THE CHALLENGE OF FULL VEHICLE SIMULATION

ADAS Feature
EESE
Matlab 2012a 32bit
In-house + Supplier C

Status Q1-2017

Steering controls
Chassis
Matlab 2011b 32bit +target link
Supplier A + In-house

Vehicle Dynamics Models
VehDyn CAE
ADAMS
converted into:
CarSim
Dspace ASM
IPG-Carmaker
Mathworks-VDBS

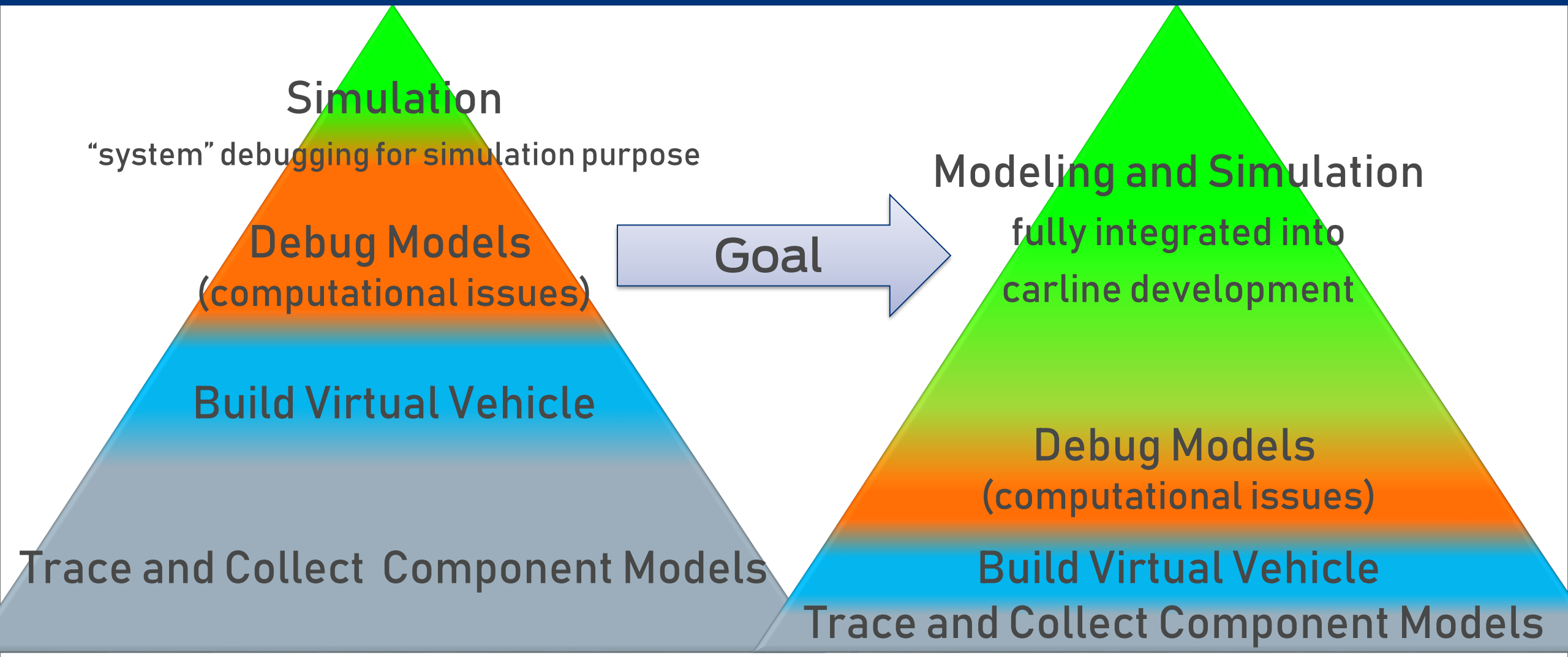
Brake Controls
Chassis
Matlab 2014b 32bit
Supplier B + In-house

Powertrain Models
Powertrain
Matlab 2015b 64bit + MBD
In-house

ADAS Sensor Models
EESE
CarSim
Carmaker
Unreal

For virtual development of distributed systems all teams have to work together

SIMULATION INEFFICIENCY



FASST is an enabler to work more effective

FORD AUTOMATED SYSTEM SIMULATION TOOLCHAIN (FASST)

GitHub

40 million+ Global Users

Ford: 10,000+ Users

git

Most widely used source control management tool

MATLAB® & SIMULINK®

3 million+ Global Users / 4,500 Employees / 31 Offices Globally

Ford: 7,000+ Matlab / 4,000+ Simulink Users

Ford

A Smart Cross Organizational team

FASST

500+ Members / Passive Users
100+ Active Users
~30 Members on "DevOps" Team

FASST leverages modern tools & standard

FASST: BUILDING THE SKELETON MODEL

+

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Feature_Name	Feature
Variant_Name	
Model Parts	GitHub Organization and Repository
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BRAKES	FASST/BRAKES
CAMERA	FASST/CAMERA
BODY	FASST/BODY
STEERING	FASST/STEERING
FEATURE	FASST/FEATURE
DISPLAY	FASST/DISPLAY
DRIVER	FASST/DRIVER

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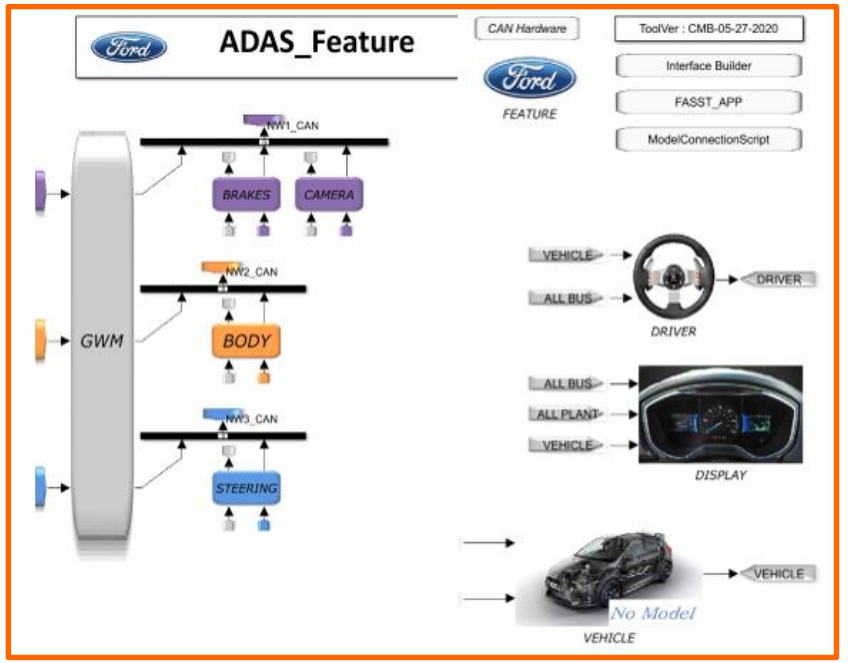
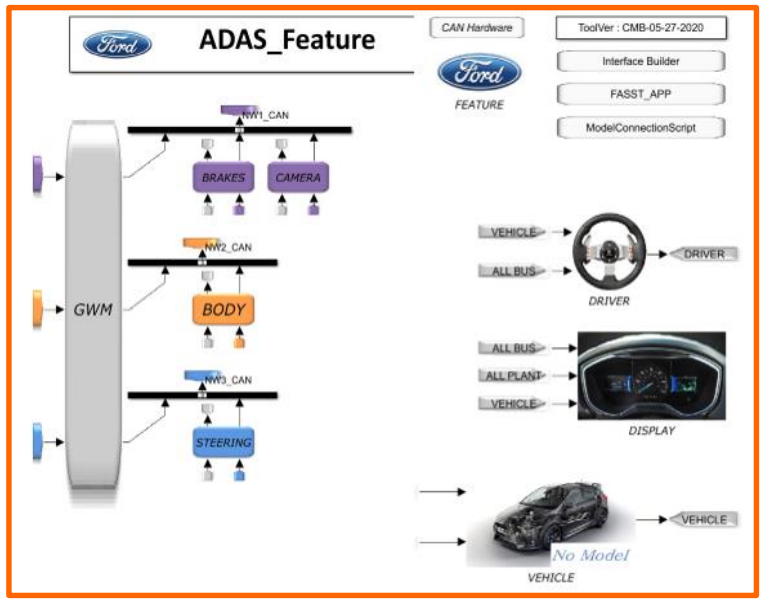


Vehicle controls architecture

Bill Of Models

Skeleton/System Model

FASST: CREATING A VEHICLE MODEL



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GitHub

MODEL REPOSITORY

Populate ECU contents from functional software model developers

- Brakes
- Camera
- Steering
- …

VEHICLE

- VDBS
- CarSim
- Carmaker
- …

=

Skeleton/System Model

Component Models

Vehicle models

FASST: VIRTUAL DEVELOPMENT

There is no single virtual vehicle

+

DVM,DVP with metrics

or

Explorative testing

Test Plan

=

Virtual development

FORD AUTOMATED SYSTEM SIMULATION TOOLCHAIN (FASST)

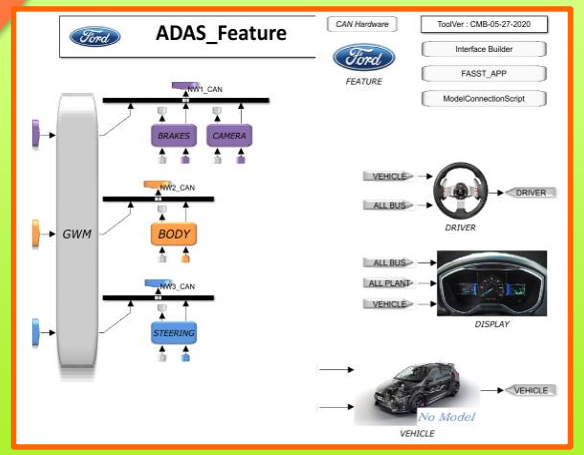
Vehicle controls architecture

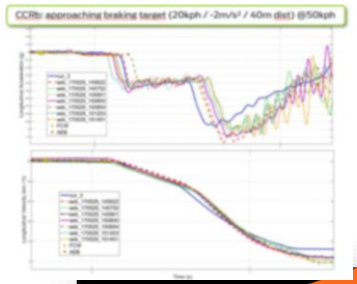
Feature model BOM (Bill Of Models)

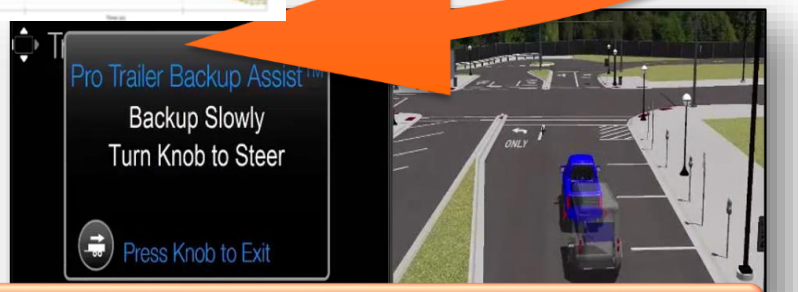
FASST USER

FASST

Build system/skeleton model & Include components







Virtual development & Verification

GitHub

MODEL REPOSITORY

Populate ECU contents from functional software model developers

- Brakes
- Camera
- Steering
- …

VEHICLE

- VDBS
- CarSim
- Carmaker
- …

FASST reduced virtual vehicle build from months into minutes

HOW DOES IT WORK?

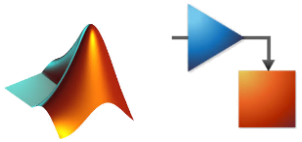
THE MECHANICS OF BUILDING A FASST MODEL

RAGHU BASKARAN

WHAT DO WE NEED TO BUILD A FASST MODEL?

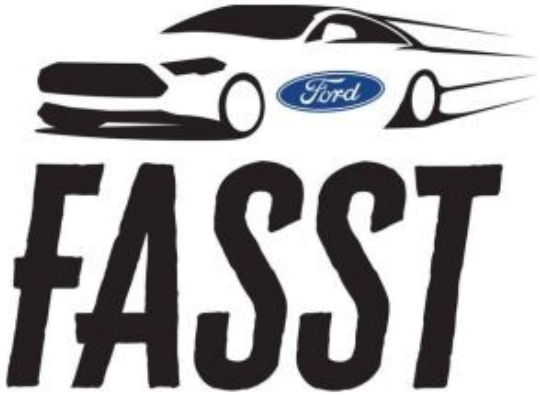
GitHub

Cloud-Based Distributed Version Control

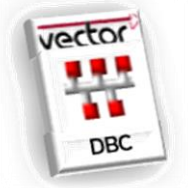


ECU Models & Components

Model BOM



Vehicle Plant Models



ECU Architecture (DBC)

Plant Interface Sheet

IT ALL STARTS WITH THE BILL OF MODELS

Model BOM*

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Feature_Name	*Feature*	
Variant_Name		
Model Parts	GitHub Organization and Repository	Branch/Tag
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CAMERA	*FASST/CAMERA*	*BehvM*
BODY	*FASST/BODY*	*SkelM*
STEERING	*FASST/STEERING*	*ReqtM*
FEATURE	*FASST/FEATURE*	*Feature1*
DISPLAY	*FASST/DISPLAY*	*Display1*
DRIVER	*FASST/DRIVER*	*Driver1*
</components> <vehicle>		
Vehicle	*FASST/Vehicle*	*BehvM*
CarSim		
CarMaker		
VDBS	*FASST/VDBS*	*BehvM*
Ford_PowerTrain		
ADAMS		
</vehicle> <network>		
DBC	*FASST/DBC*	*Latest_Architecture*

Program Name
Feature Name
Variant Name

ECU Component Models

Location in GitHub

Model Fidelity or Release Tag

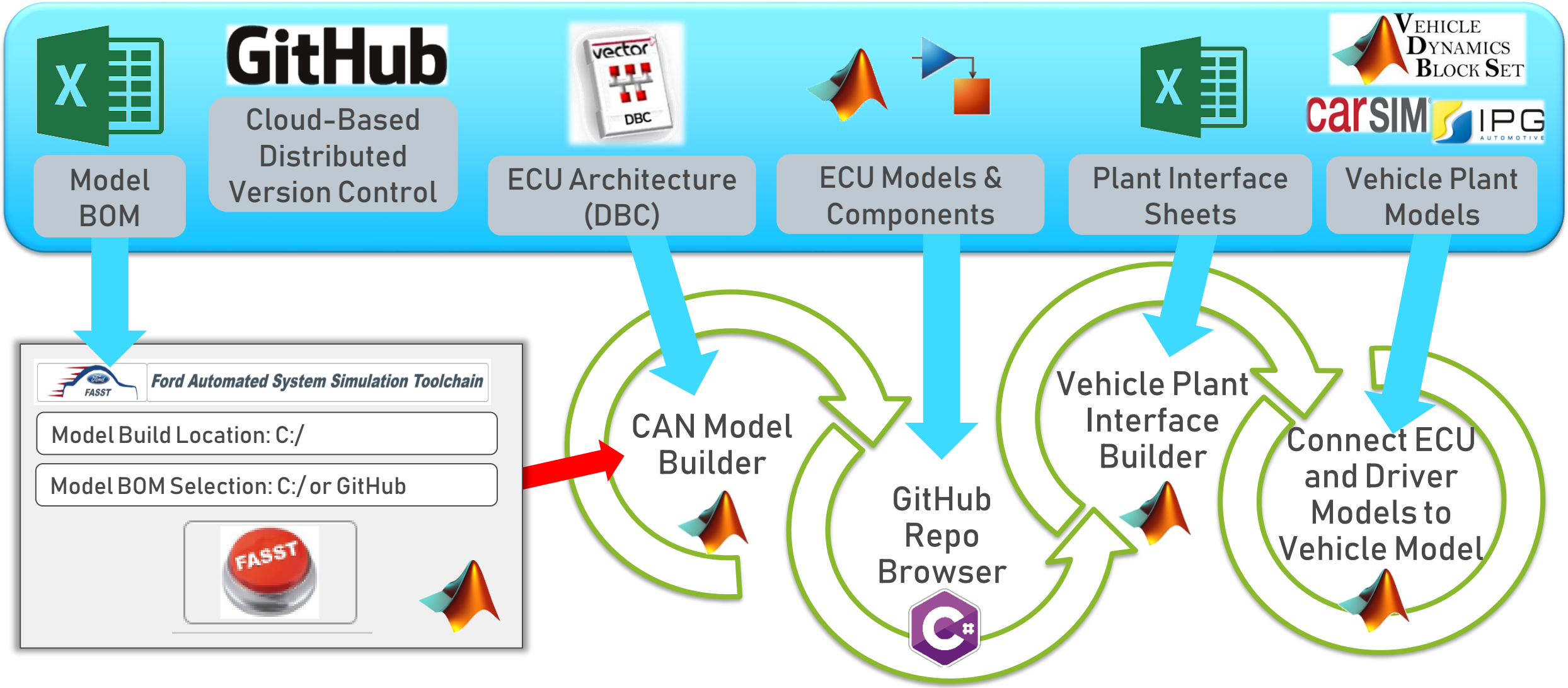
Vehicle Dynamics Model Selection

Network / ECU Architecture

*Additional sections (not shown) for:

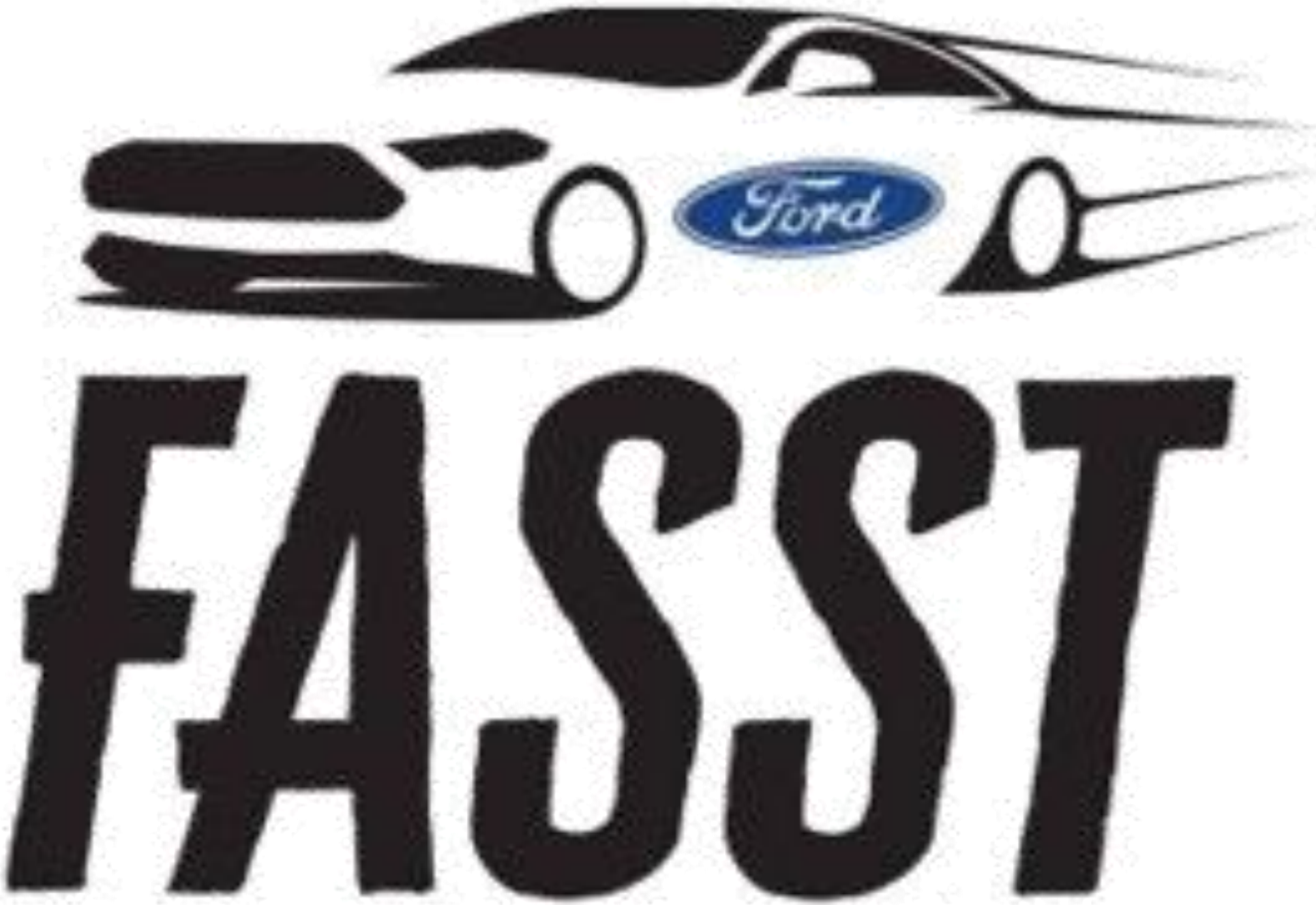
- Build Options
- System Model
- Test Procedures
- Optional Tools
- Documentation
- Test Results
- Miscellaneous

THE FASST "ONE CLICK" SYSTEM MODEL BUILD



FASST is an automation wrapper for several linked tools that builds the full system vehicle model from components in the GitHub cloud

FASST DEMONSTRATION VIDEO

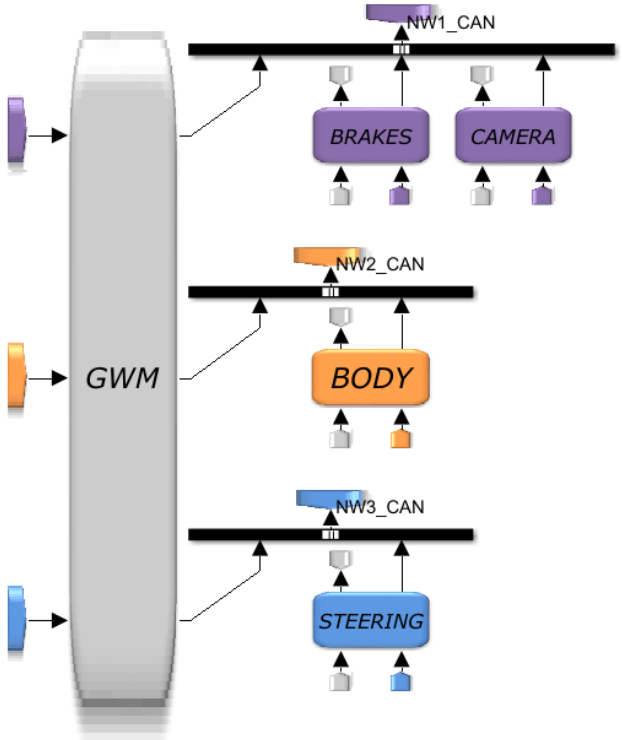


ANATOMY OF A FASST MODEL

Program & Feature Name

ADAS_Feature

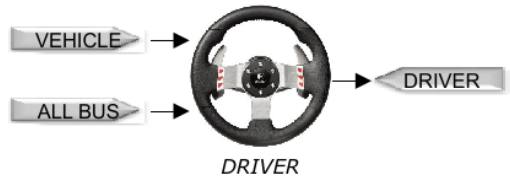
ADAS_Feature Version: 1.4
ed: Thu May 28 01:35:27 2020 by RBASKA



Virtual ECU "Breadboard" MIL, SIL, & HIL Ready

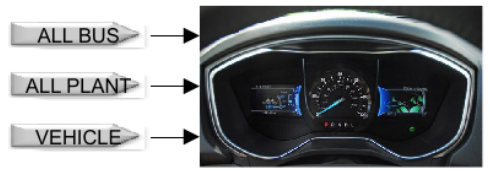
ToolVer : CMB-05-27-2020
Interface Builder
FASST_APP
ModelConnectionScript

Shortcut Buttons to FASST Tools



DRIVER

Driver Model



DISPLAY

Signal Monitors Displays

VEHICLE

Vehicle Model

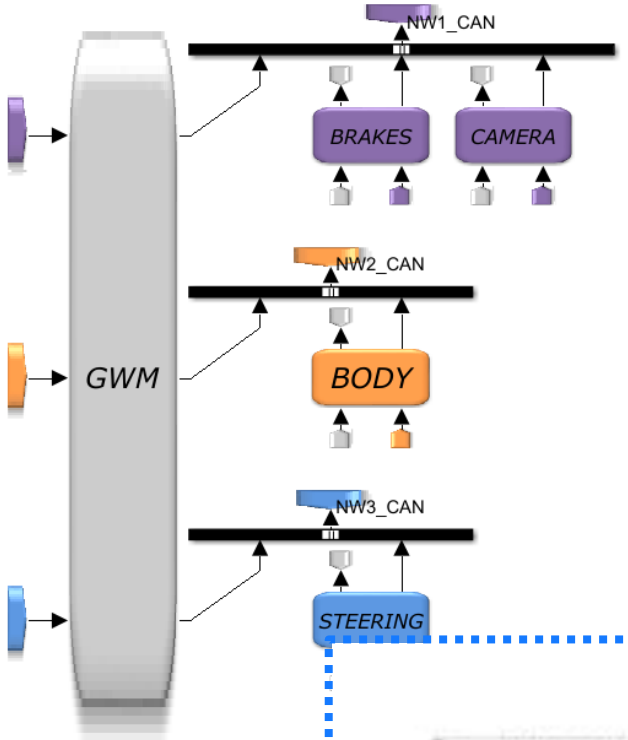
FASST generates an ECU framework model that can accept "plug and play" components to capture as many use cases as possible

ANATOMY OF A FASST MODEL

Program & Feature Name

ADAS_Feature

ADAS_Feature Version: 1.4
ed: Thu May 28 01:35:27 2020 by RBASKA



Virtual ECU "Breadboard" MIL, SIL, & HIL Ready

CAN Hardware

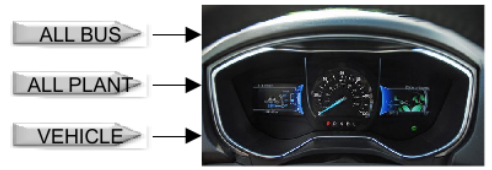
FEATURE

ToolVer : CMB-05-27-2020
Interface Builder
FASST_APP
ModelConnectionScript

Shortcut Buttons to FASST Tools

DRIVER

Driver Model



DISPLAY

Signal Monitors Displays

VEHICLE

Vehicle Model

CREATING FULL VEHICLE SIMULATION:

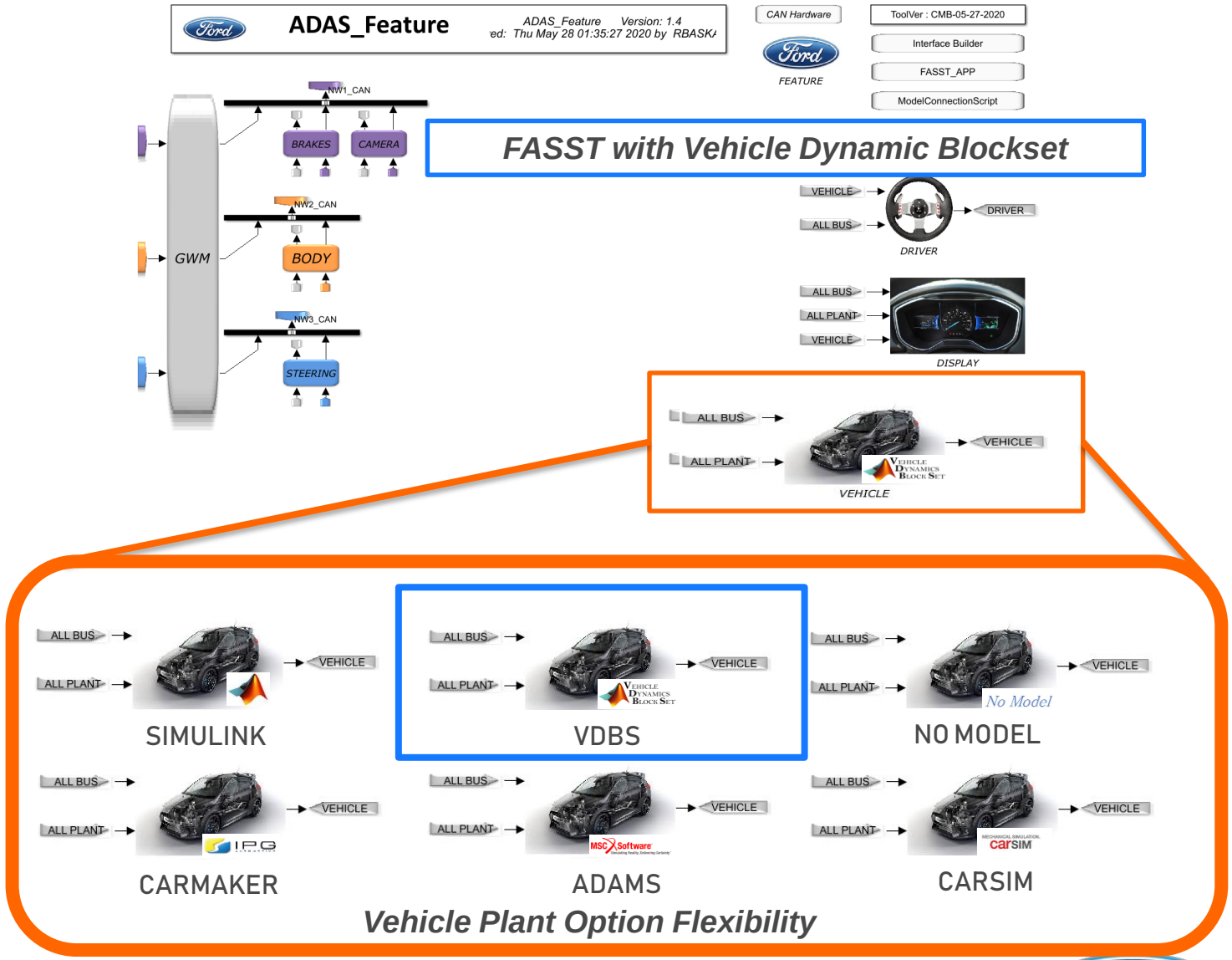
CONNECTING SYSTEM COMPONENTS TO THE VEHICLE MODEL

STEVEN FOSTER

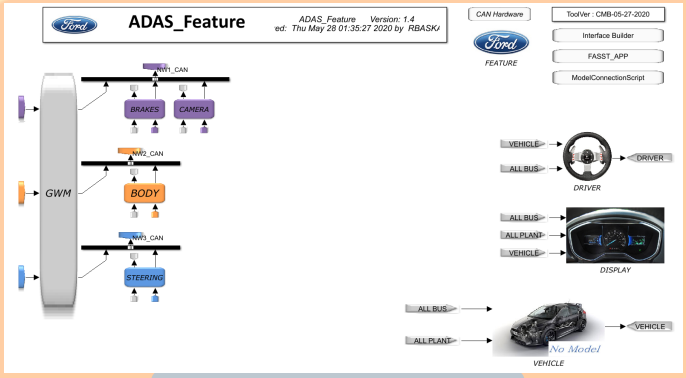
VEHICLE PLANT MODEL FLEXIBILITY IS CRITICAL

Why Support Multiple Vehicle Plant Models?

- Simulation Speed
- Licensing Cost / Availability
- User Experience
- Department Preference
- Model Fidelity



THE FASST PLANT VEHICLE BUILD PROCESS



FASST Model

Generates

Global Plant Signal Database

BODY CAMERA BRAKES

ECU-to-Vehicle Interface Sheets

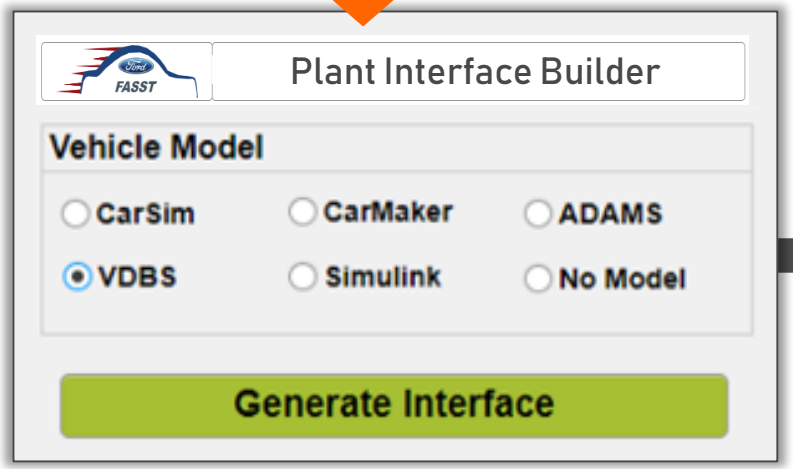
IPG AUTOMOTIVE

carSIM

MSC Software

VEHICLE DYNAMICS BLOCK SET

Vehicle Models



Detect Plant Signals in Model

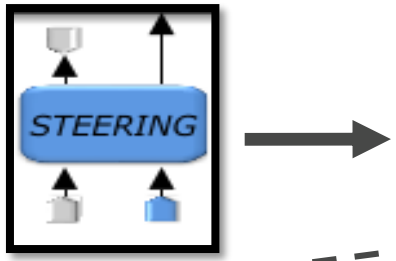
Generate ECU-to-Vehicle Interfaces

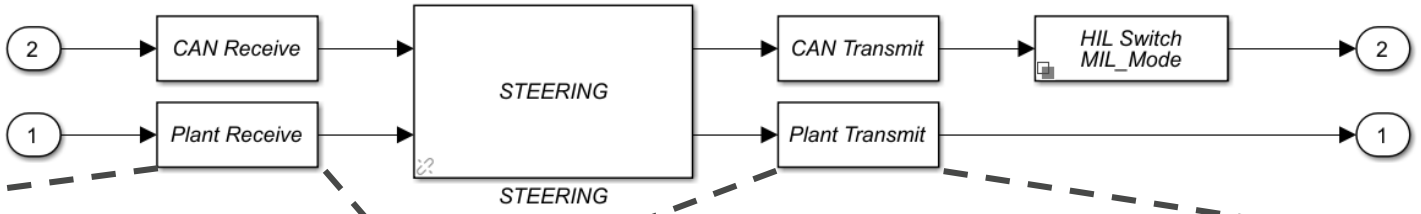
Add Vehicle Model

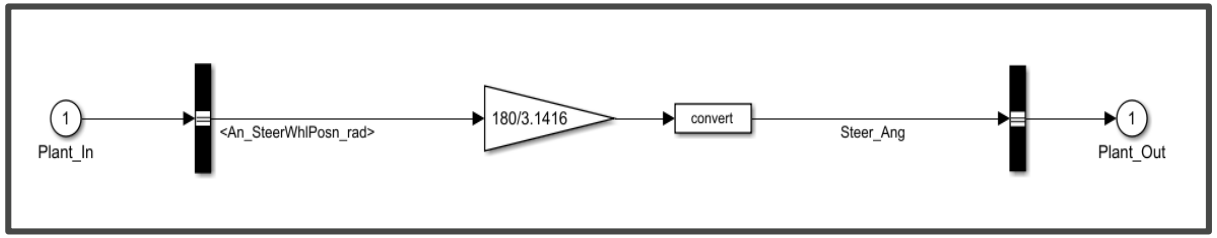
Connect ECU and Driver Models to Vehicle Model

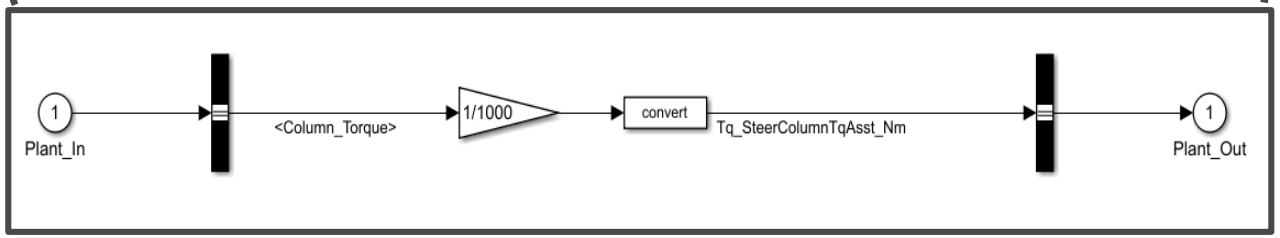
The Plant Interface Builder automates the connections within FASST

THE VEHICLE PLANT TO ECU CONNECTION INTERFACE









GPSDB Name → Controller Name

Controller Name → GPSDB Name

STEERING

ECU-to-Vehicle Interface Sheets

Interface	GPSDB Name	Controller Name	Unit Gain (GPSDB -> Controller)	Unit Gain (Controller -> GPSDB)	VDBS Name	Unit Gain (GPSDB -> VDBS)	Unit Gain (VDBS -> GPSDB)
Receive from Plant	An_SteerWhlPosn_rad	Steer_Ang	180/π (rad to deg)	π/180 (rad to deg)	AngIn	1 (rad to rad)	1 (rad to rad)
Transmit to Plant	Tq_SteerColumnTqAsst_Nm	Column_Torque	1000 (Nm to Nmm)	1/1000 (Nmm to Nm)	TrqIn	1 (Nm to Nm)	1 (Nm to Nm)

Global Plant Signal Database

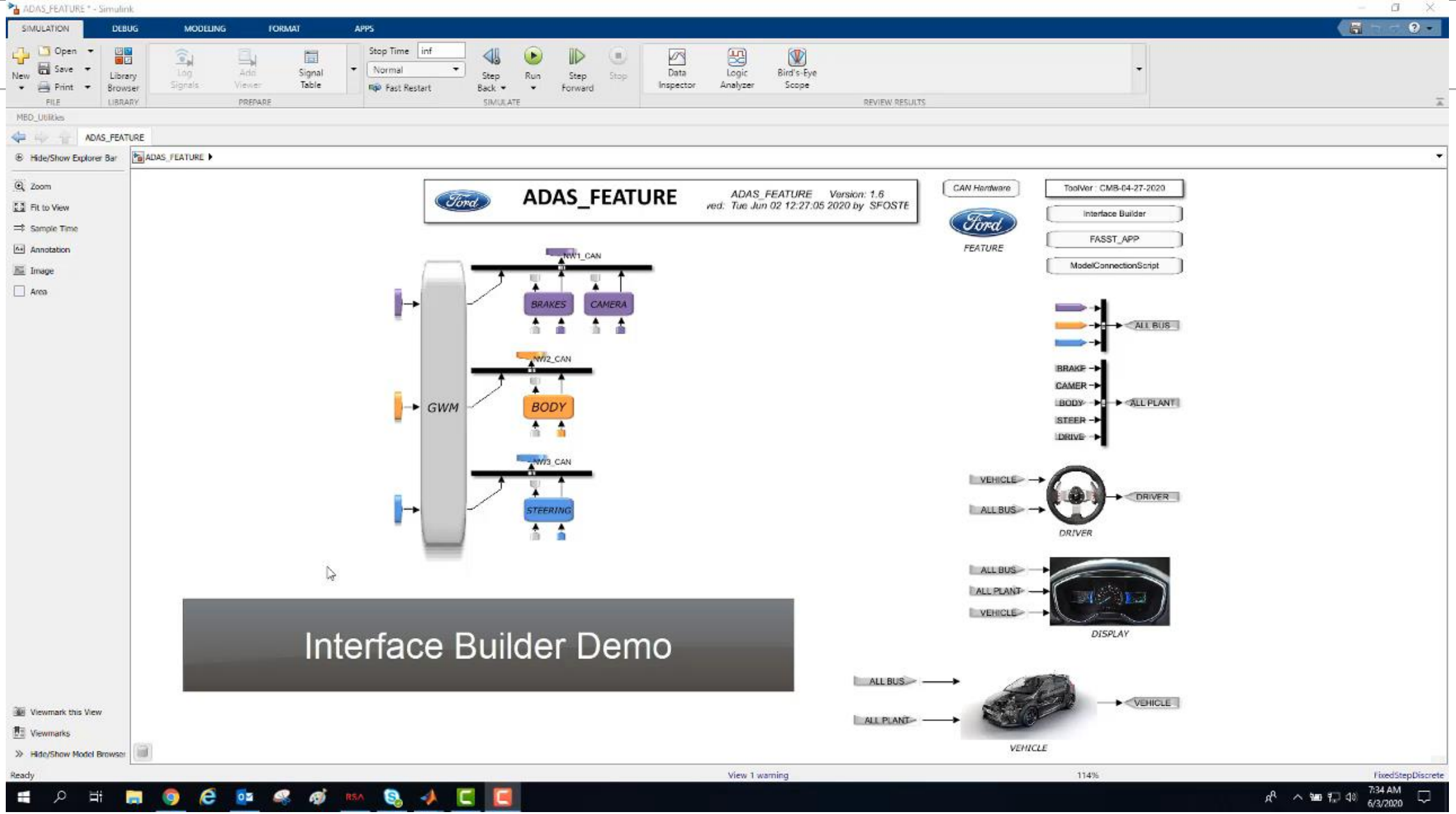
ECU Models & Components

VEHICLE DYNAMICS BLOCK SET

MathWorks

GPSDB –GLOBAL PLANT SIGNAL DATABASE
VDBS –VEHICLE DYNAMIC BLOCKSET

Ford Go Further


ADAS_FEATURE * - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
APPS
Open
Save
Print
New
Library Browser
Log Signals
Add Viewer
Signal Table
Stop Time
inf
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
Data Inspector
Logic Analyzer
Bird's-Eye Scope
FILE
LIBRARY
PREPARE
SIMULATE
REVIEW RESULTS
MBD_Utilities
ADAS_FEATURE
Hide/Show Explorer Bar
Zoom
Fit to View
Sample Time
Annotation
Image
Area
Viewmark this View
Viewmarks
Hide/Show Model Browser
ADAS_FEATURE
ADAS_FEATURE
ADAS_FEATURE Version: 1.6
mod: Tue Jun 02 12:27:05 2020 by SFOSTE
CAN Hardware
FEATURE
ToolVer : CMB-04-27-2020
Interface Builder
FASST_APP
ModelConnectionScript
NW1_CAN
BRAKES
CAMERA
NW2_CAN
BODY
NW3_CAN
STEERING
GWM
ALL BUS
BRAKE
CAMER
BODY
STEER
DRIVE
ALL PLANT
VEHICLE
ALL BUS
DRIVER
DRIVER
ALL BUS
ALL PLANT
VEHICLE
DISPLAY
ALL BUS
ALL PLANT
VEHICLE
VEHICLE
Interface Builder Demo
Ready
View 1 warning
114%
FixedStepDiscrete
7:34 AM
6/3/2020

SCALING TO PRODUCTION:

UNLEASHING THE POWER OF CONTINUOUS INTEGRATION(CI)

NICK ADAMS

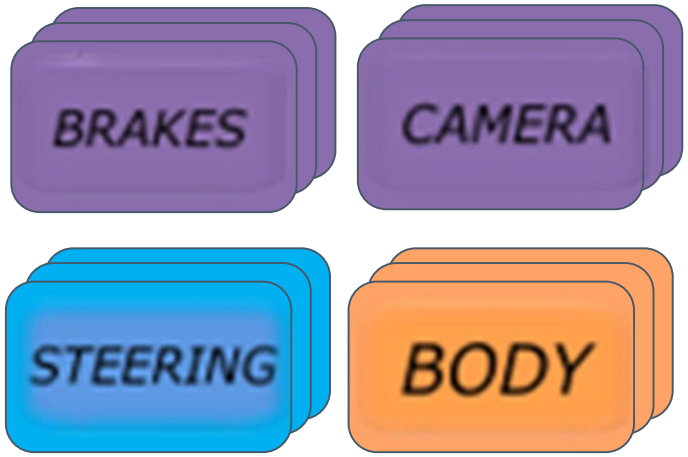
CONTINOUS INTEGRATION: JENKINS TO VALIDATE COMPONENTS

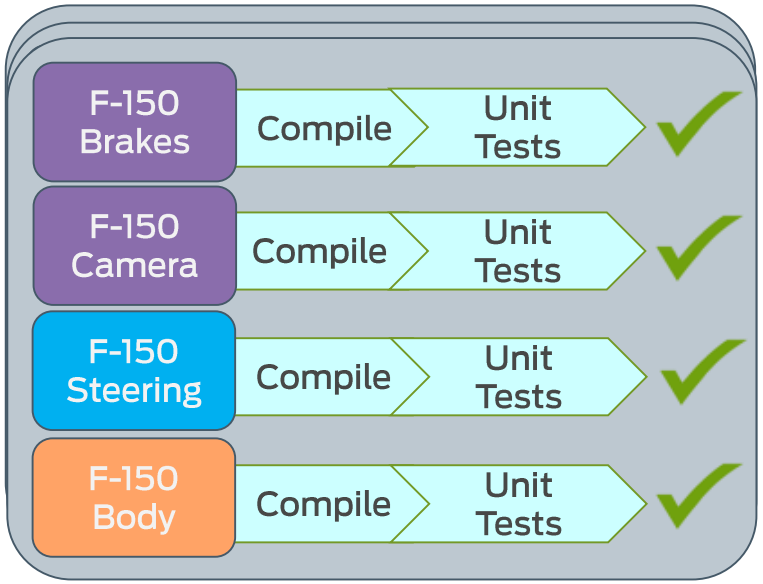
GitHub

Jenkins

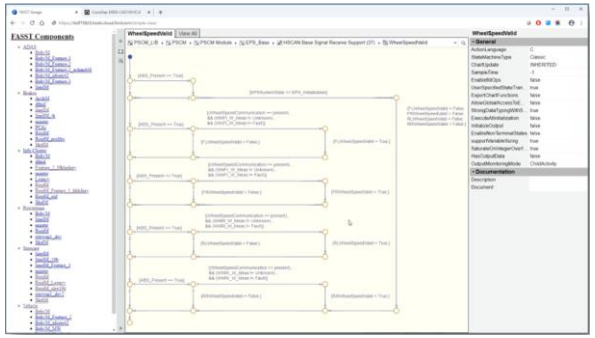
FASST Garage

Component ECU Repos



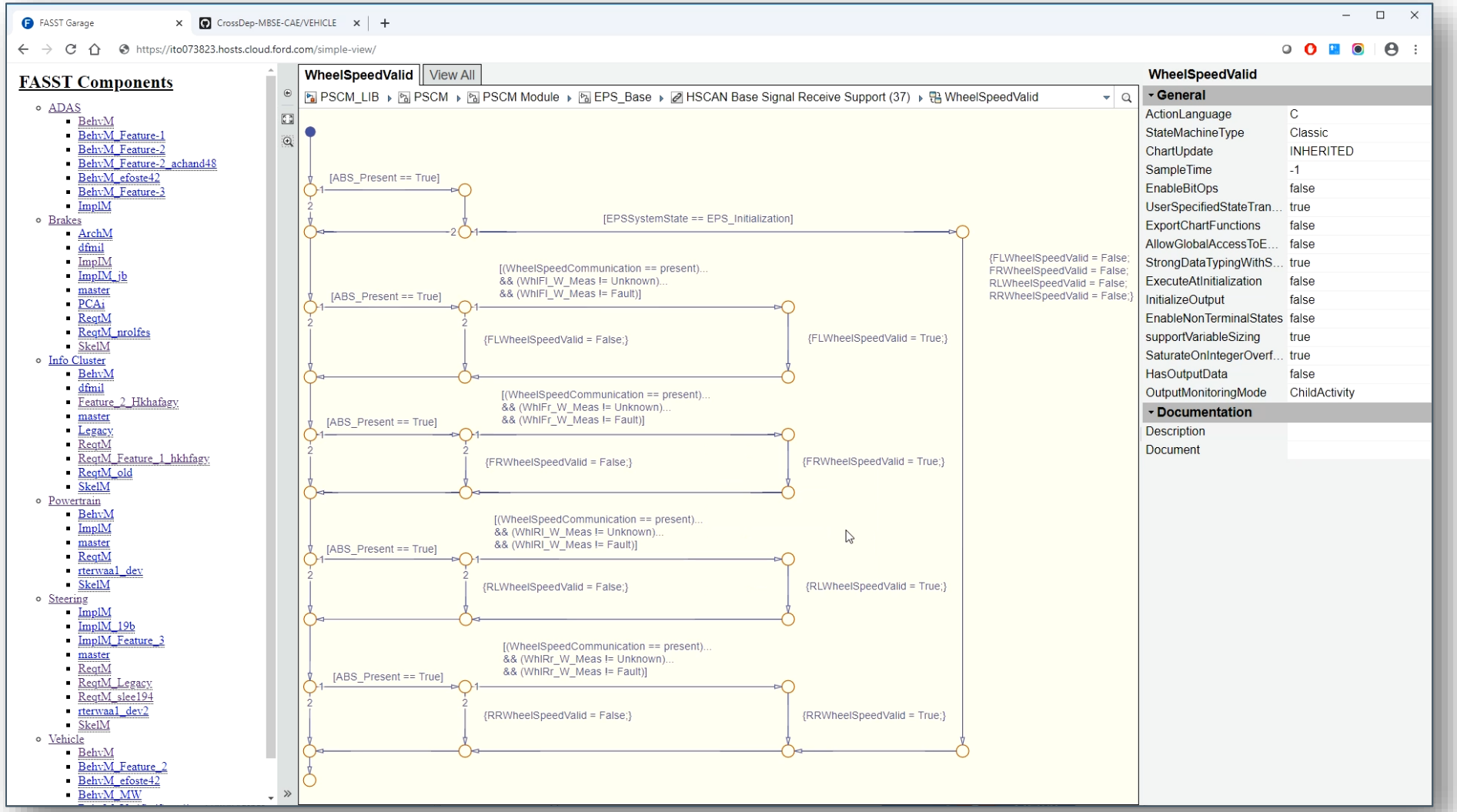


At least 10 carlines × 30 ECUs
Tests run nightly



250+ tested models are viewable from a browser

THE FASST GARAGE TO BROWSE COMPONENTS



FASST Garage is the enabler for finding the right model based on the use case and user's needs

CONTINOUS INTEGRATION: JENKINS TO AUTOMATE VEHICLE BUILDS

GitHub

Jenkins

kubernetes

docker

vmware

Bill of Models Library

Component ECU Repositories

BRAKES

CAMERA

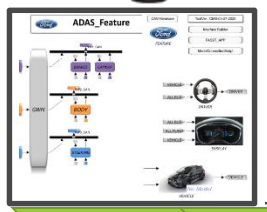
STEERING

BODY

ECU Network (DBC)

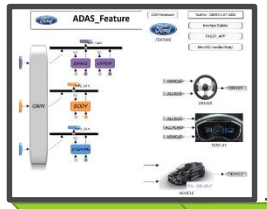
DBC

DBC



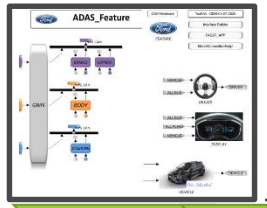
F-150 Lane Assist

FASST → Compile → Unit Tests → Feature Tests



F-150 Park Assist

FASST → Compile → Unit Tests → Feature Tests



F-150 Trailer Assist

FASST → Compile → Unit Tests → Feature Tests

Dozens of BOMs are built and tested in parallel for a combined total of 40+ hours each day

One pipeline takes between 10 min to over an hour

INNER SOURCING FOR MODEL DEVELOPMENT

NATE ROLFES

"All Models Are Wrong… Some are Useful"

- George E.P. Box

FASST AND THE POWER OF INNER SOURCING

Inner Source
is the adoption of open source software development best practices and establishment of open source culture within an enterprise.

Collaboration
Maximize the pool of engineering brainpower for advancing a project, meeting user needs, or finding and fixing bugs. Never start from scratch, always build upon others work!

Communication
Transparent, self-documenting, and "searchable" problem solving and decision-making creates trust & alignment in the goals and makes it easy for new users to get on-board and start contributing!

Egalitarian
Users are Developers & Developers are Users leads to a culture void of "politics" as recognition is inherently merit-based. Can work around organizational barriers and provide everyone the opportunity to influence the project direction and success!

The "Plausible Promise"
"Your program can be crude, buggy, incomplete, and poorly documented. What it must not fail to do is (a) run, and (b) convince potential co-developers that it can be evolved into something really neat in the foreseeable future."

- Eric S. Raymond, The Cathedral and the Bazaar

Establishing standard interfaces, terminology, and metrics around model types & capabilities is critical to gain traction for inner source

MODEL FIDELITY: SIMPLIFIED AND FUNCTIONAL MODELS

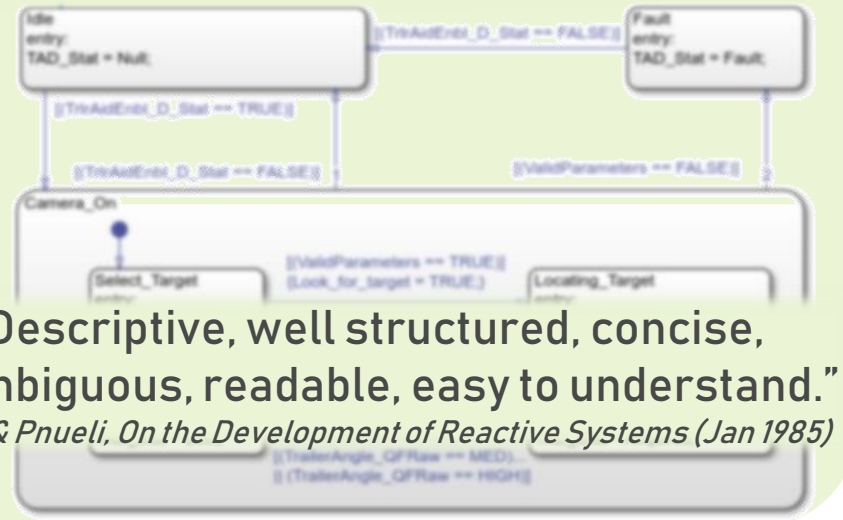
Skeleton Model

Interfaces (I/O) with Changeable Outputs (No behavior or logic)

The three diagrams are for the same model to demonstrate scaled fidelity!

Behavior Model

Design Intent Behavior

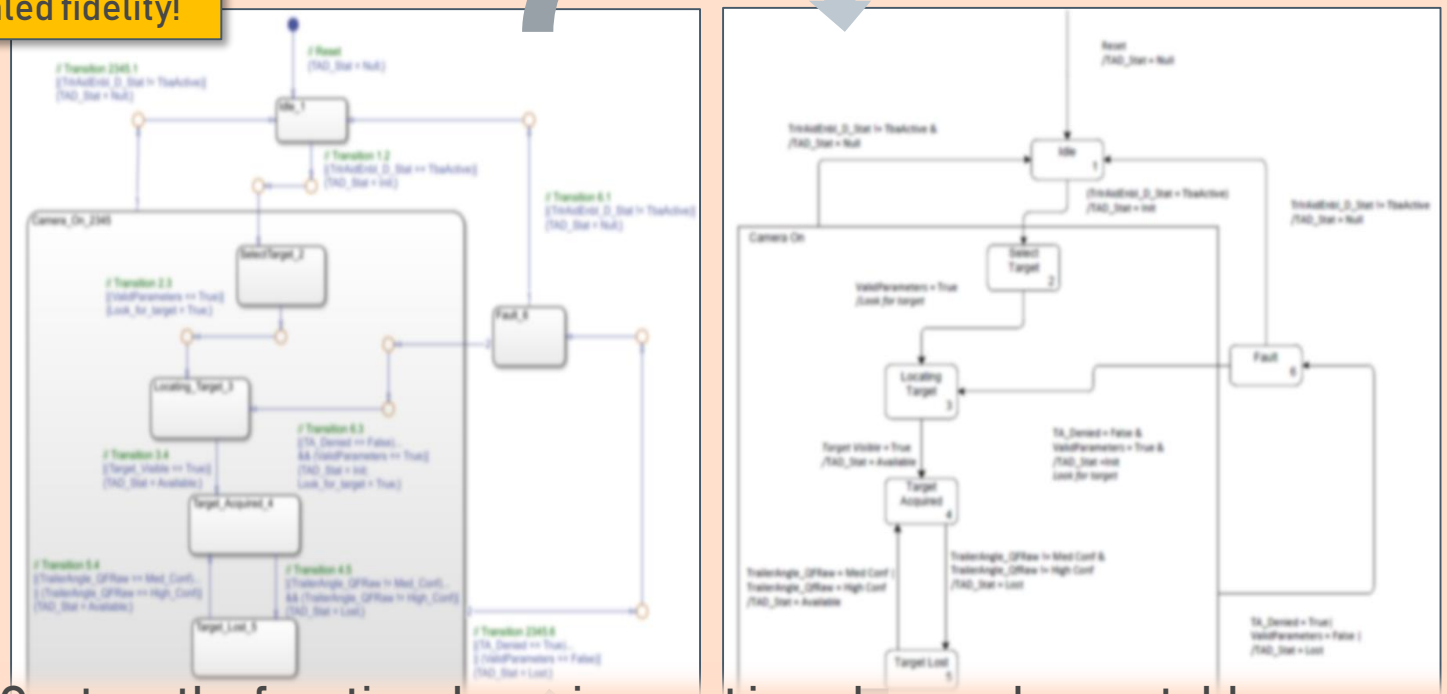


"Descriptive, well structured, concise, unambiguous, readable, easy to understand."

Harel & Pnueli, On the Development of Reactive Systems (Jan 1985)

Requirement Model

Executable representation of functional design requirements and specifications

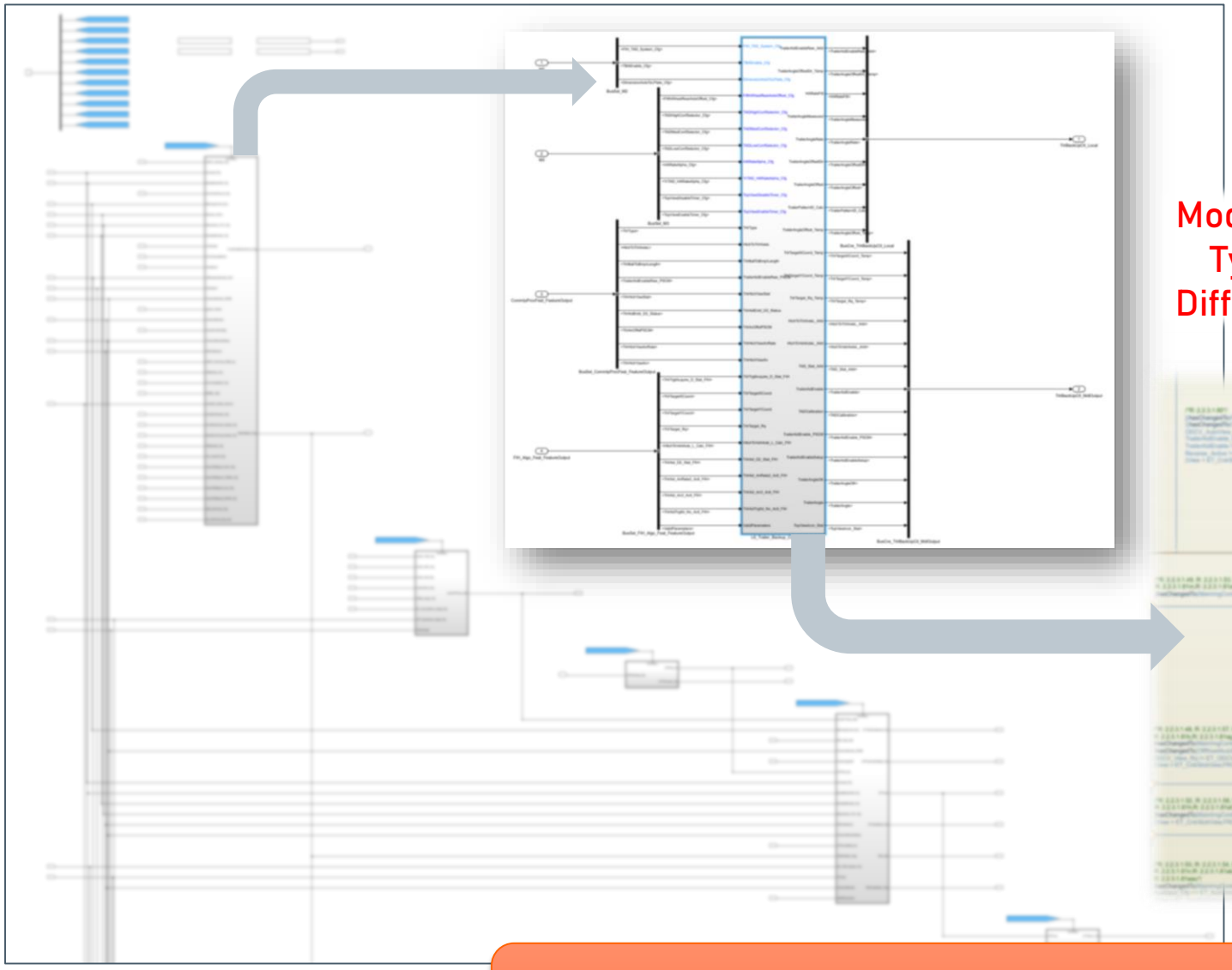


"Capture the functional requirement in a clear and executable manner."

Lee & Friedman, Requirements Modeling & Automated Requirements-Based Test Generation (2014)

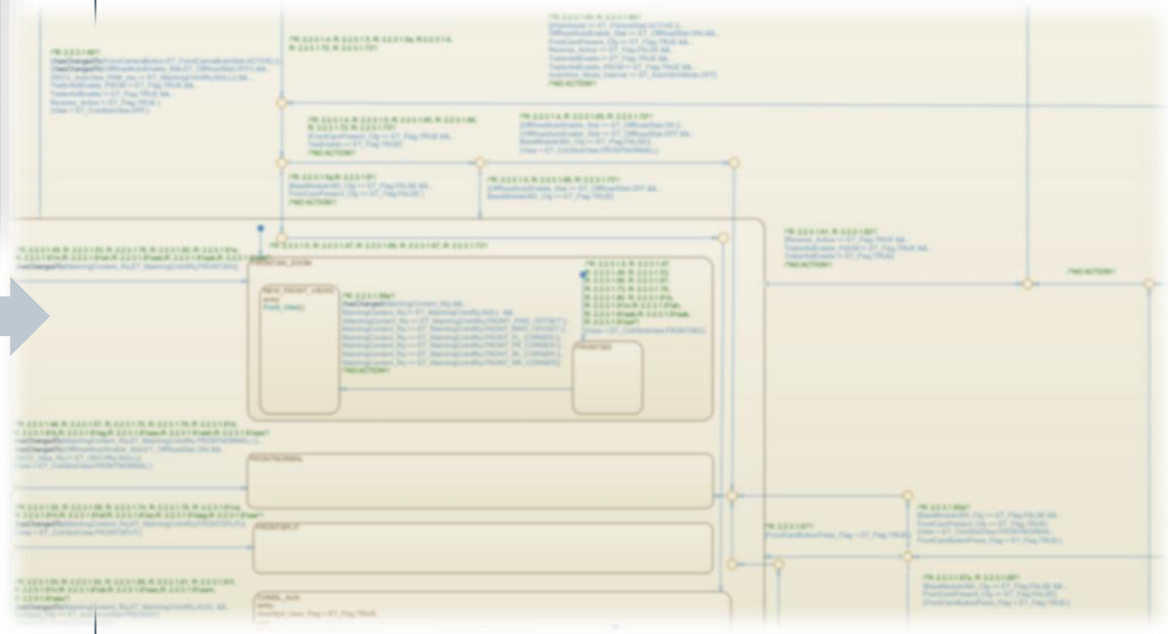
Evidence indicates that over 60% of System software issues emerge from these three phases!

MODEL FIDELITY: THE PRODUCTION IMPLEMENTATION MODEL



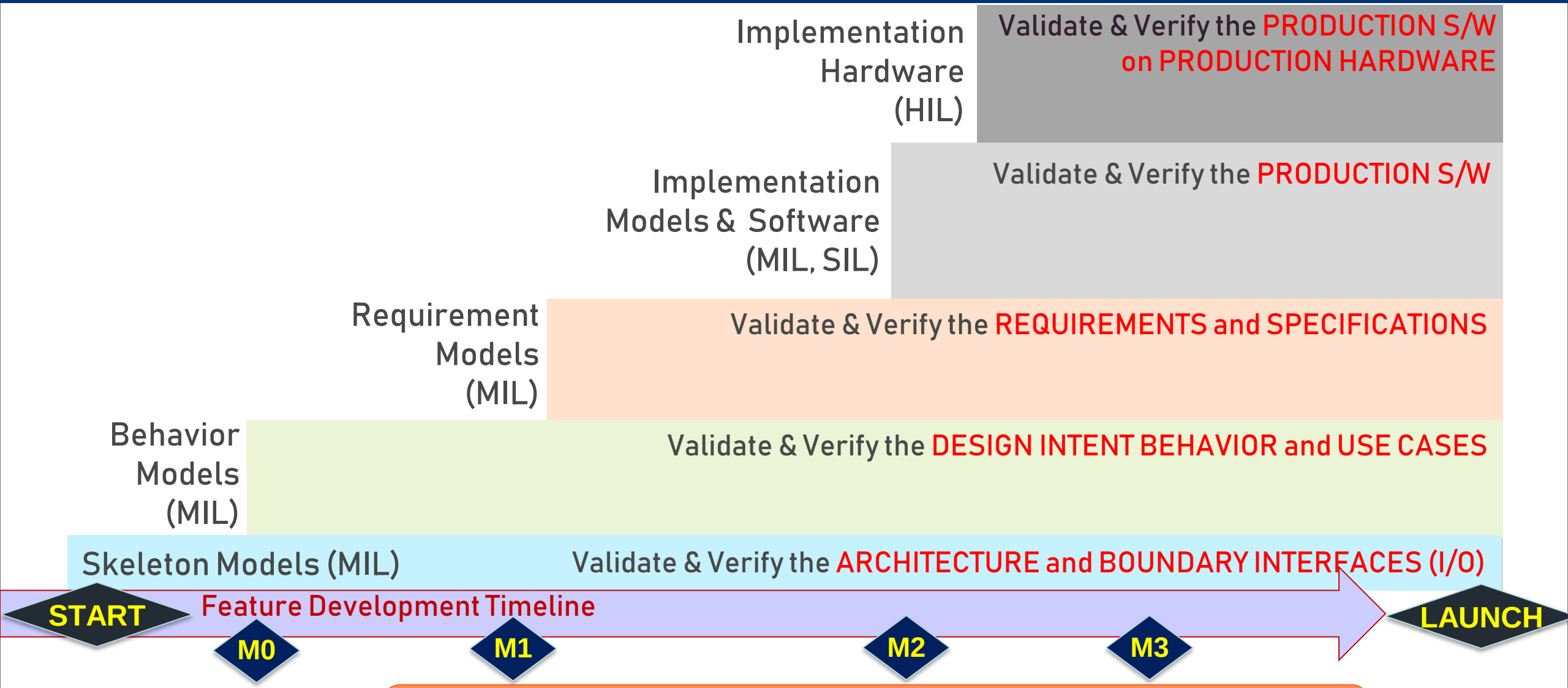
Implementation Model / Production Code

Model-Based Implementation of the production code model.
Typically only available for in-house model-based code.
Difficult to obtain for supplier written code (use HIL instead).



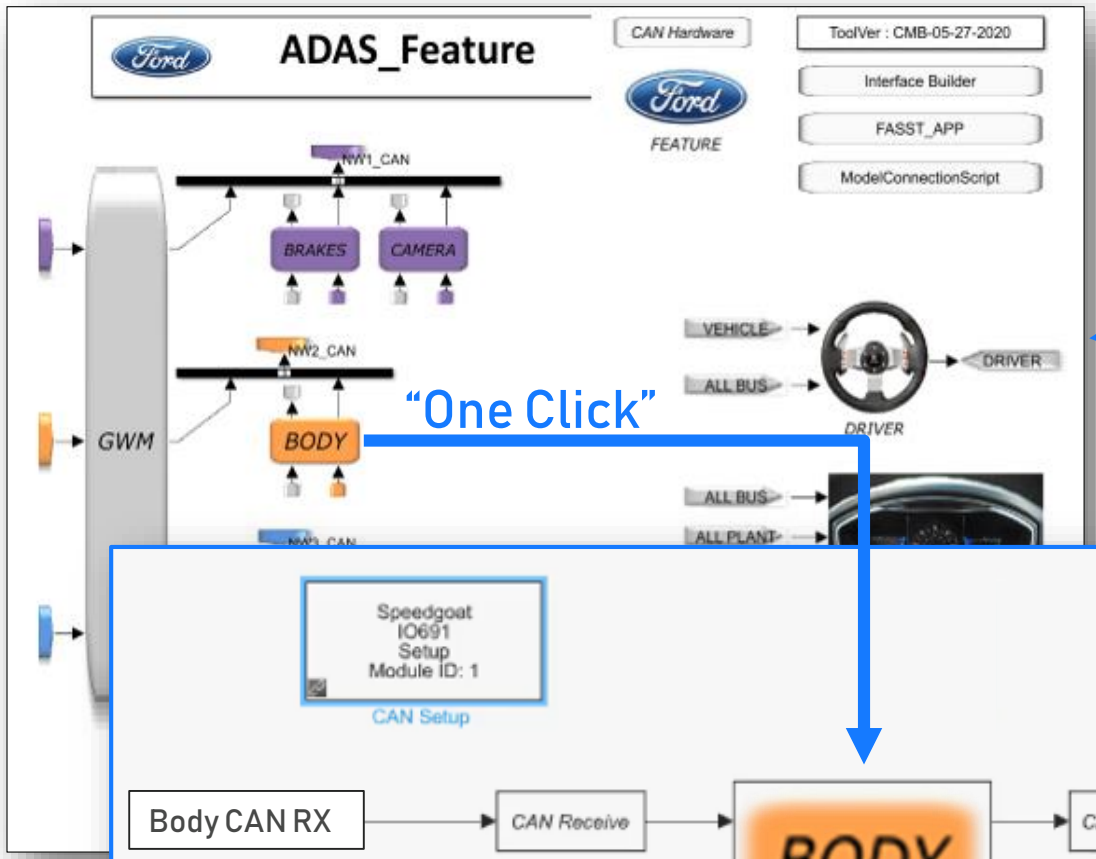
System simulations which utilize Implementation Models can take dozens of minutes to compile and don't simulate at real-time speeds!

THE IMPLEMENTATION MODEL CLIFF! vs the MODEL FIDELITY STAIRSTEP



Continuous Modeling Integration using scaled modeling fidelities is critical to ensure the systems work correctly the first time!

FASST "TO GO": QUICK DEPLOYMENT TO SPEEDGOAT



"One Click"

MathWorks

Vehicle Network Toolbox

HIL Mode
CAN RX/TX

Speedgoat "Unit"
Target Machine

Binary hex file
Can be uploaded via
Ethernet or USB stick

"One Click"

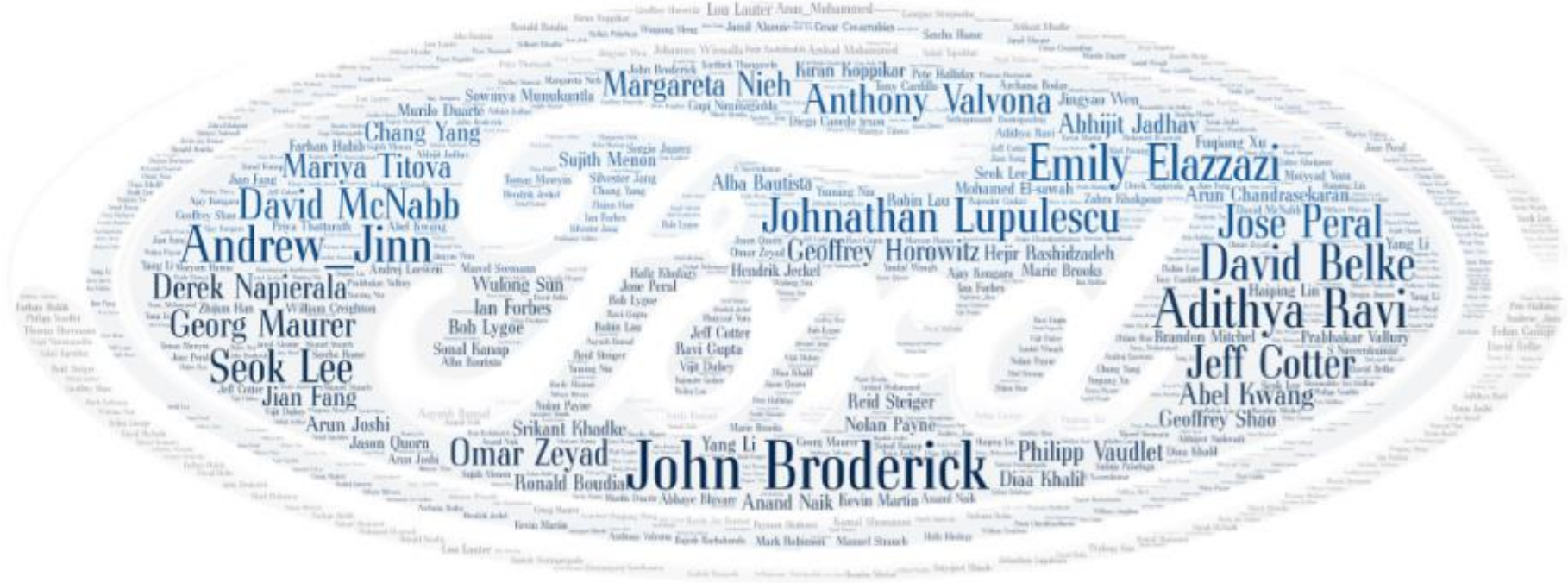
FASST "To Go" Provides flexible options for offloading model components to real-time hardware as well as an easy method to pass protected binary files to breadboard teams and suppliers

Summary

- FASST toolchain…
  - … is developed in collaborative, modern, inner source and agile fashion, together with the MathWorks
  - … helps to detect system Issues through out the development
  - … reduced Virtual Vehicle build time from months to minutes
  - … the automated processes eliminate modeling mistakes
  - … in combination with CI enables scaling up modeling and simulation to enterprise level.
- The challenge of *"All models are wrong , but some of them are useful"* will always stay
- "Plug and Play" components are a critical key to success

FASST doesn't solve all the issues,
but makes the daily life of an engineer more effective and enabled
Cross Organizational Collaboration

With special thanks to the entire FASST team:




THANK YOU
Ford.
YHV 810