基于福特自动化系统仿真工具链的MBD敏捷开发

Model-Based Agility with Ford Automated System Simulation Toolchain

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- *On behalf of* ***Ford FASST Core Team***

MATLAB EXPO 2021

目录

- 为什么需要 FASST
- 什么是 FASST
- FASST 概览
- FASST 与持续集成（Continuous Integration)
- FASST 面对的挑战
- 总结

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为什么需要FASST？

Go Further

机电系统软件开发面临的挑战

“软件和数字系统提供了强大的能力以构建过去难以实现的复杂系统，但是这种能力的提升却伴随着代价，即庞大的软件系统极难完全正确，且构建此类软件的难度常常被工程师所低估”.

“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

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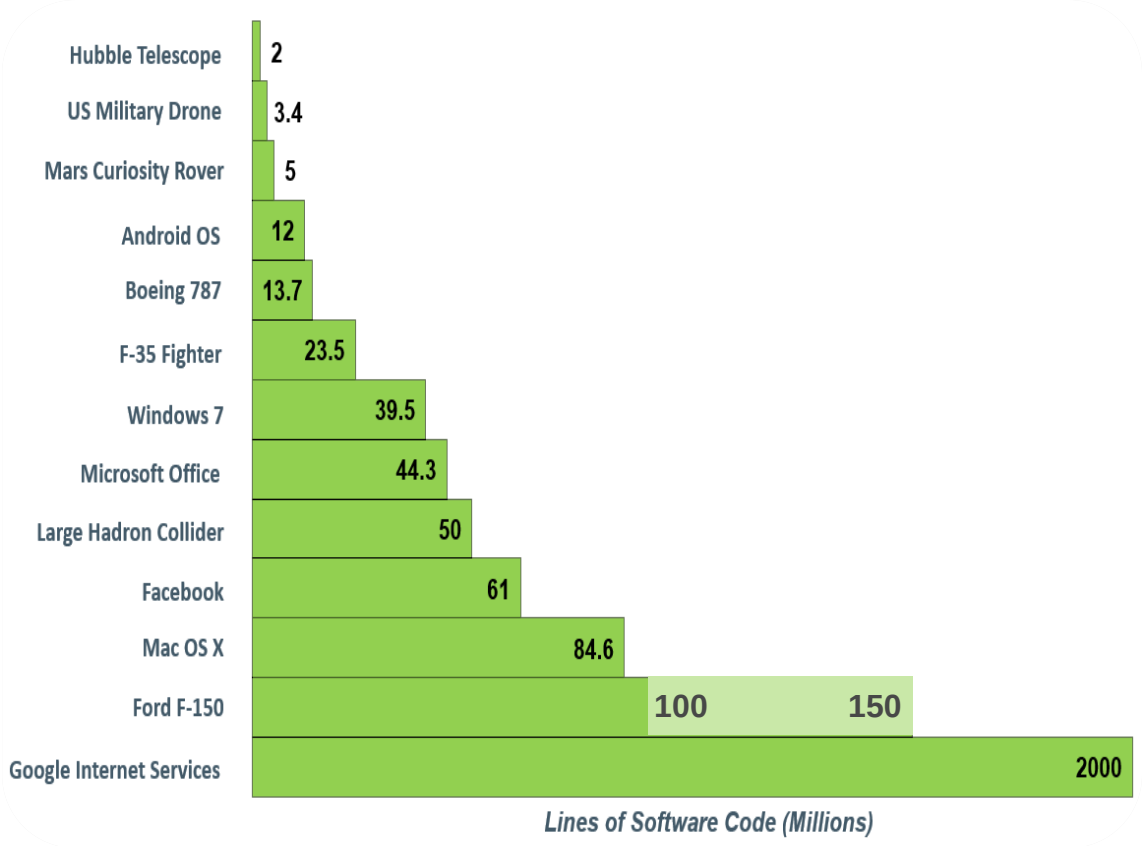
当前汽车软件开发的复杂性



2016MY Pro Trailer Backup Assist

在开发福特2016款F-150拖车后向辅助功能过程中，发现其中41%的软件问题和需求相关，38%的软件问题和系统相关。

汽车是量产机电一体化系统中极其复杂的产品之一

很大比重的问题来自于汽车软件系统

Sources:
https://informationisbeautiful.net/visualizations/million-lines-of-code/

Rolfes, N., "Requirement Modeling of Pro Trailer Backup Assist™," SAE Int. J. Passeng. Cars – Electron. Electr. Syst. 10(1):2017, doi:10.4271/2017-01-0002.

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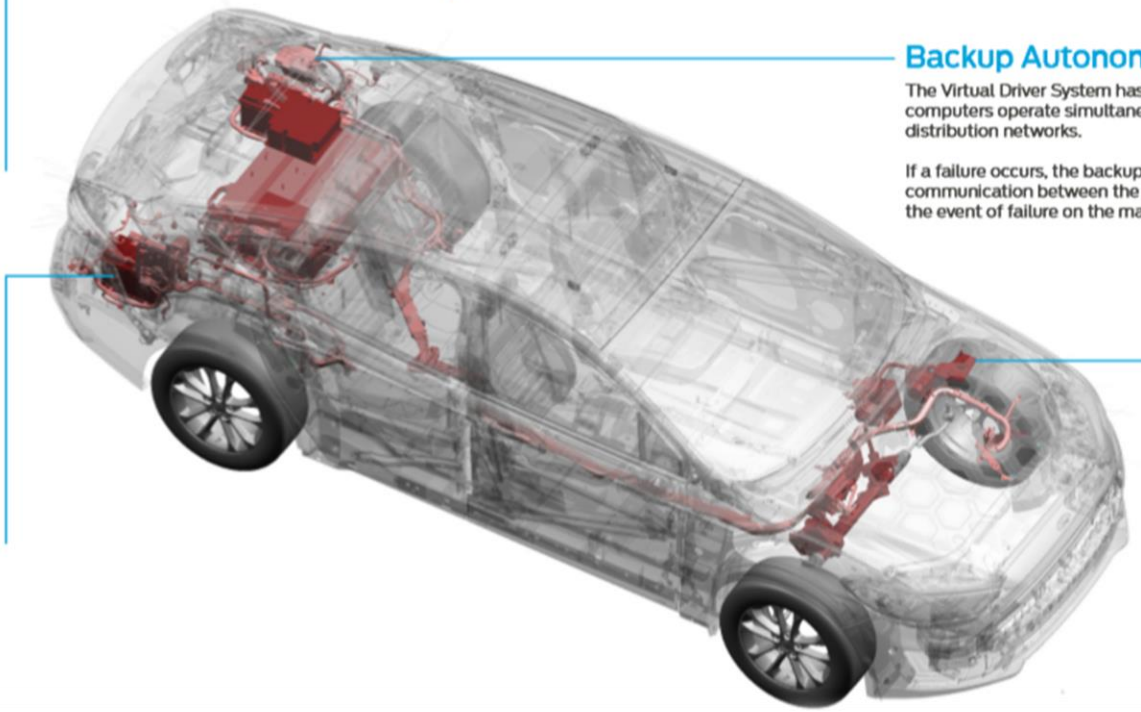
下一代汽车系统

Released: Aug 16, 2018

Diagnostics and Vehicle Health Monitoring

A sophisticated vehicle health monitoring strategy employs diagnostics integrated across multiple systems within the vehicle to determine vehicle health and perform fallback maneuvers when needed.

In addition to diagnostics, we also monitor the vehicle to determine its readiness, such as if all doors are closed.



Backup Autonomous Driving System

The Virtual Driver System has both main and backup computing systems. These two computers operate simultaneously while sharing information yet are on separate power distribution networks.

If a failure occurs, the backup system will bring the vehicle to a controlled stop. In addition, communication between the sensors, computers, and actuators have an alternate path in the event of failure on the main system.

Electrical Power Systems

While main power to the vehicle is provided from the high voltage battery, there are backup electrical power sources and distribution to several critical components. In the case of a power failure, the backup powernets are able to provide low voltage power to the computers, sensors, braking and steering systems to bring the vehicle to a controlled stop.

Redundant Braking and Steering Systems

Backup braking and steering systems exist on separate power distribution networks. This redundancy allows the system to bring the vehicle to a controlled stop if a system fails.

随着整车机电系统复杂度增加，更早地发现软件问题也变得越来越重要

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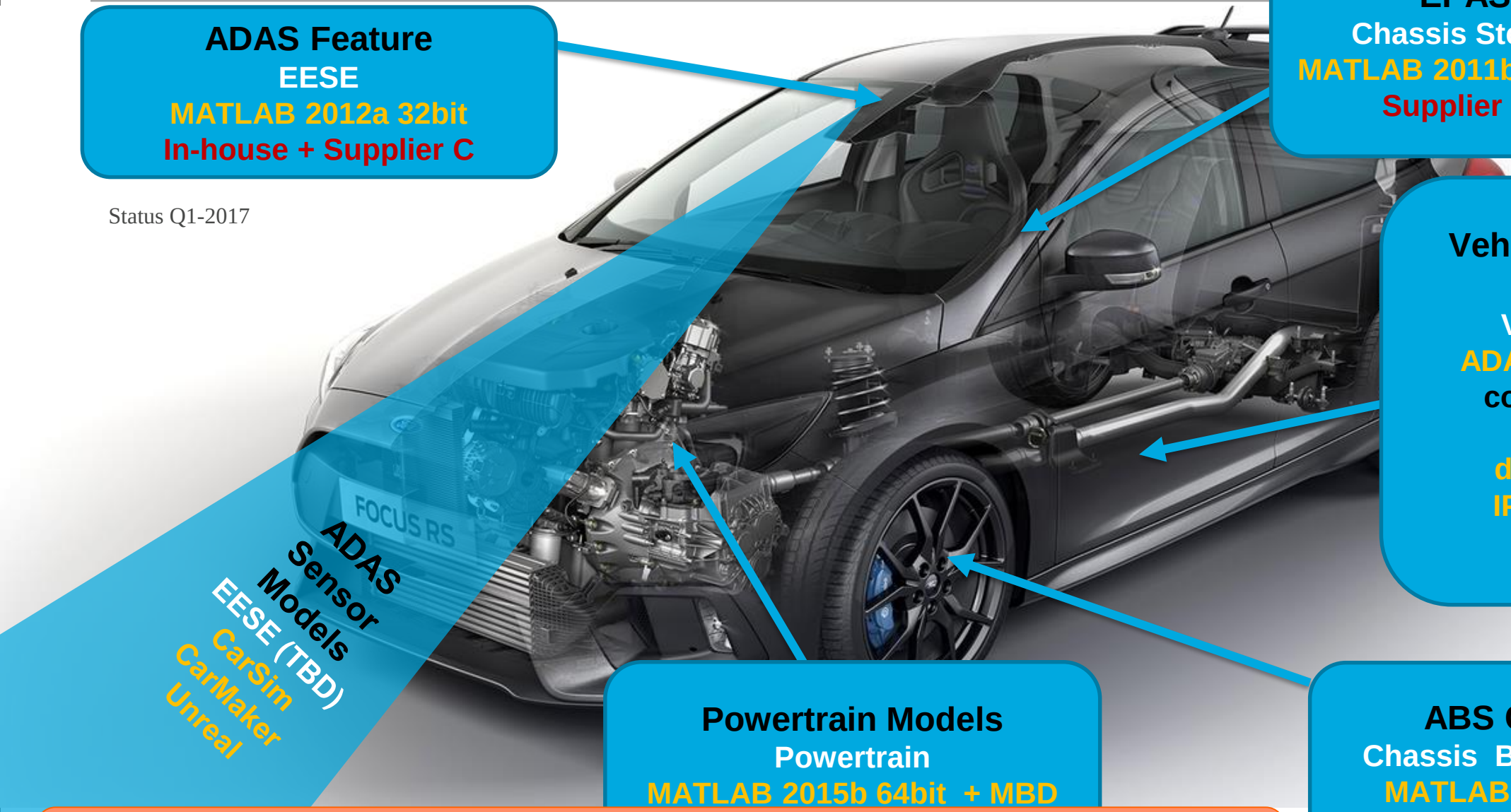
整车仿真面临的挑战

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

Status Q1-2017

EPAS controls
Chassis Steering controls
MATLAB 2011b 32bit +TargetLink
Supplier A + In-house

Vehicle Dynamics Models
VehDyn CAE
ADAMS (MASTER)
converted into:
CarSim
dSPACE ASM
IPG-CarMaker



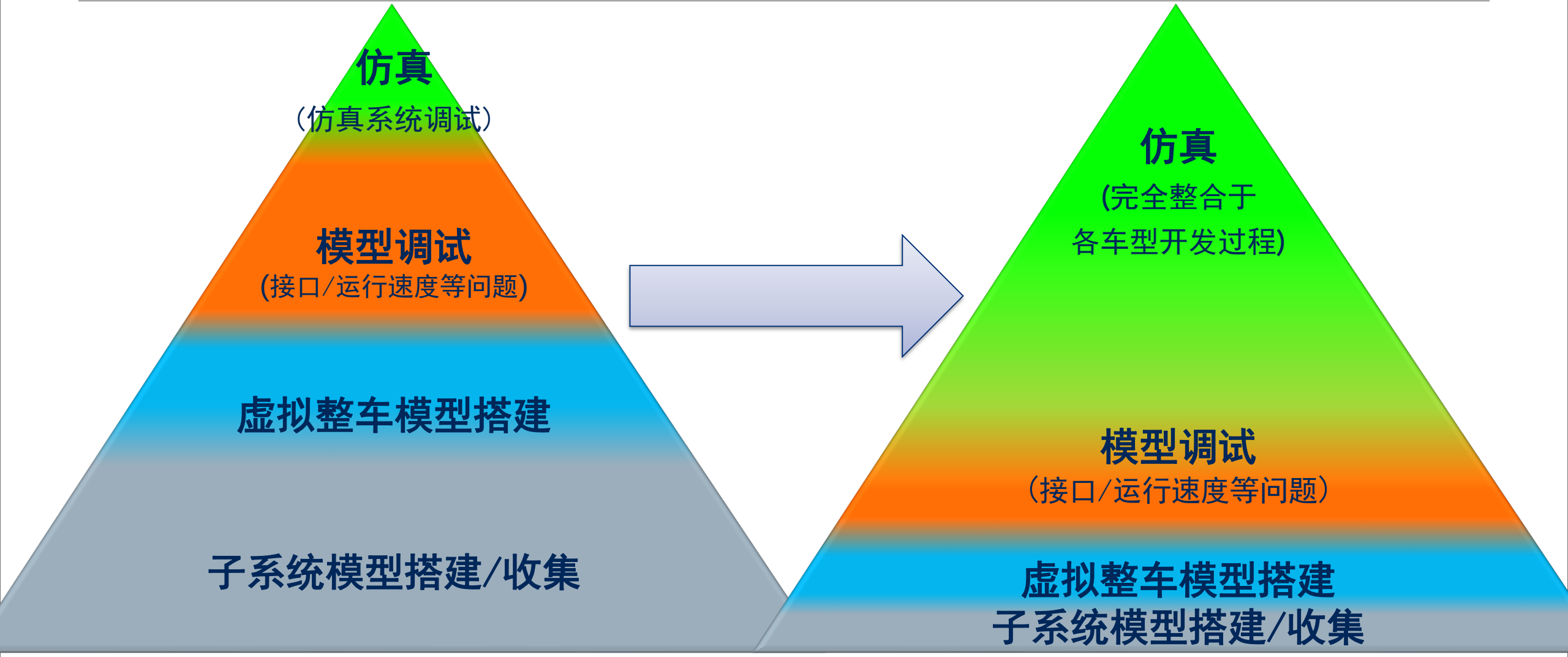
ADAS Sensor Models
EESE (TBD)
CarSim
CarMaker
Unreal

Powertrain Models
Powertrain
MATLAB 2015b 64bit + MBD

ABS Controls
Chassis Brake controls
MATLAB 2014b 32bit
Supplier B + In-house

所有团队必须紧密协作以推动整车分布式系统的虚拟开发

整车仿真效率问题



FASST 是整车仿真开发效率提升的助推器

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什么是FASST?

Go Further

FASST - 福特自动化系统仿真工具链

GitHub

40 million+ Global Users

Enterprise @ 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

A Smart Cross Organizational team

FASST

600+ Members / Passive Users
100+ Active Users
~30 Members on “DevOps” Team

Go Further

FASST - 福特自动化系统仿真工具链

跨部门CAE开发的
技术支撑

实现虚拟整车模型快速搭建
（不再像以前需要数月时间）

助力先期CAE开发
和控制开发

公司跨部门仿真工作
团队协作的助推器

不同颗粒度模型
可集成于整个V流程

基于MATLAB &
Simulink
虚拟整车开发

FASST子模型可应用于V
模式(包括HIL)全流程

兼容公司内部
工程设计环境

定义标准 &
促进共识

遵循MBD开发
工具和敏捷思想

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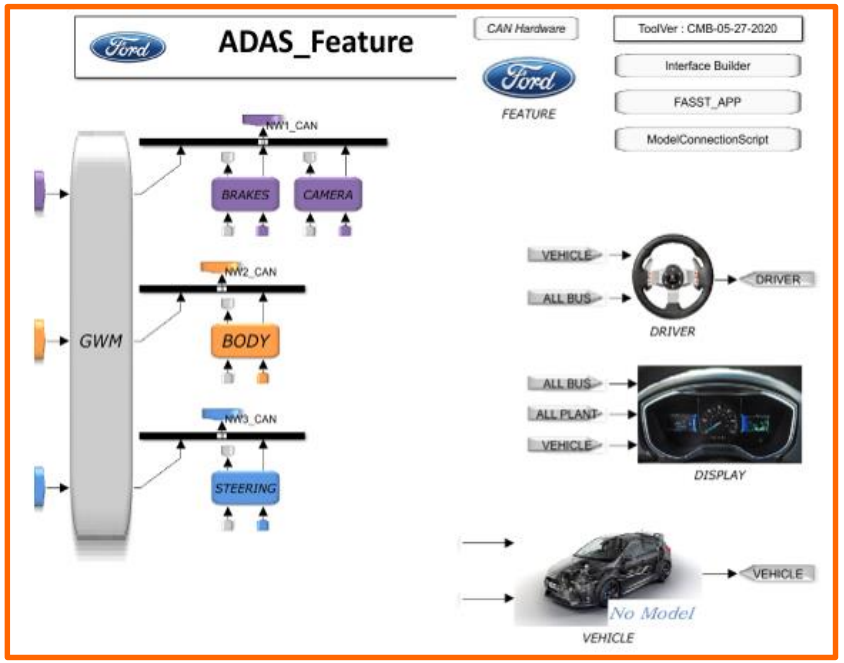
FASST - 创建整车框架模型

+

<metadata>	
Program_Name	ADAS
Feature_Name	Feature
Variant_Name	
Model Parts	GitHub Organization and Repository
<components>	
BRAKES	FASST/BRAKES
CAMERA	FASST/CAMERA
BODY	FASST/BODY
STEERING	FASST/STEERING
FEATURE	FASST/FEATURE
DISPLAY	FASST/DISPLAY
DRIVER	FASST/DRIVER

=



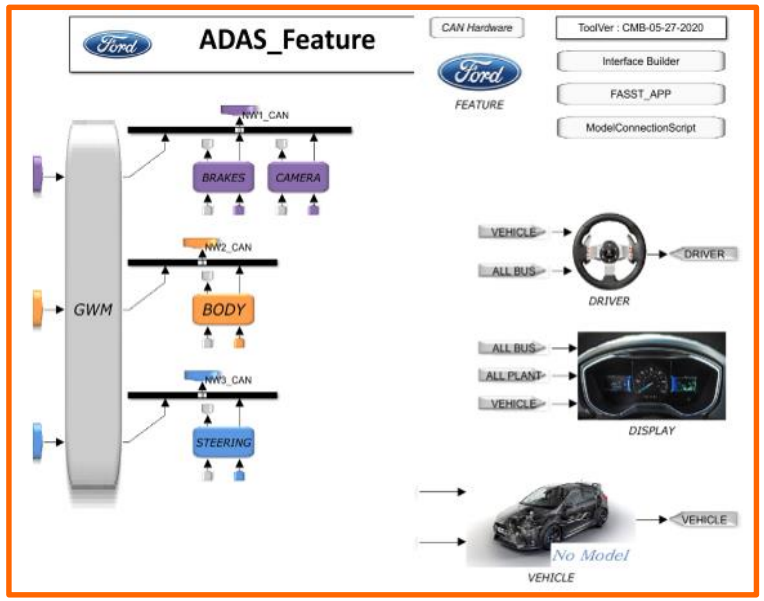
整车控制架构
(由DBC文件建立整车控制网络框架)

模型配置文件
(定义仿真模型系统配置文件)

整车框架模型
(未填充完整的子系统模型)

Go Further

FASST - 填充整车框架模型



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GitHub

MODEL REPOSITORY

Populate ECU contents from functional software model developers

Brakes | **Camera**

Steering | **…**

VEHICLE

- **VDBS**
- **CarSim**
- **Carmaker**
- **…**

=

整车框架模型

子系统模型

整车模型

Go Further

FASST - 实现虚拟开发及验证






There is no single virtual vehicle

+

DVM/DVP
测试

or

Explorative
testing

测试计划

=

整车虚拟开发

Go Further

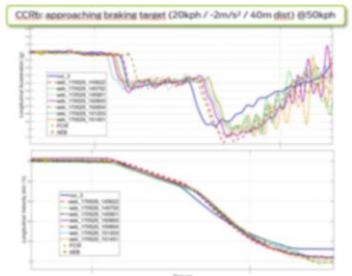
FASST - 实现虚拟开发及验证

整车控制架构

功能模型BOM文件

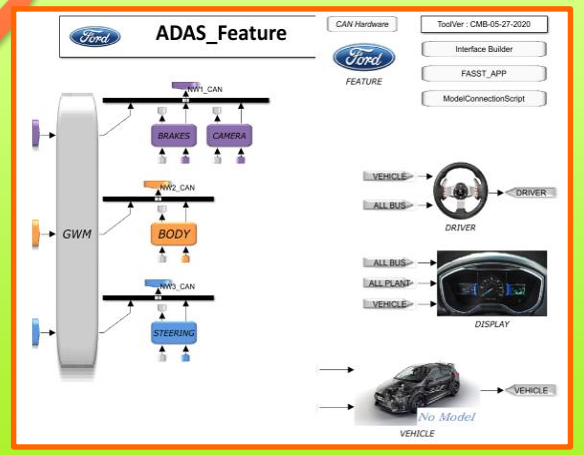
FASST USER

FASST



整车虚拟开发及验证

创建系统框架模型
&
填充子系统模型



GitHub

模型仓库(Model Repository)
(子系统模型从Github云端
模型仓库中抽取)

Brakes

Camera

Steering

…

VEHICLE

- VDBS
- CarSim
- Carmaker
- …

FASST实现整车虚拟模型构建从数月大幅缩减至数分钟

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FASST 概览

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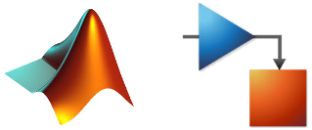
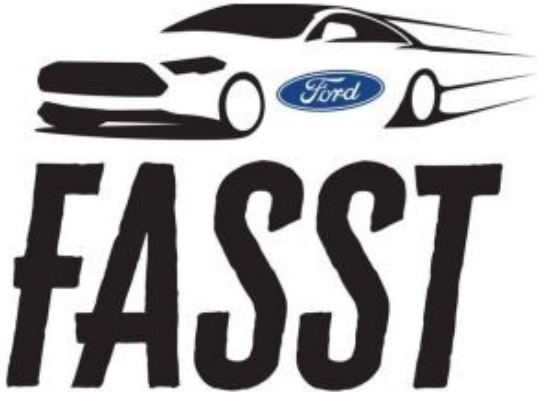
FASST 模型构建要素

基于云端
分布式版本控制



ECU 模型 &
子系统模型

模型配置
文件



整车物理模型

ECU架构
(DBC)

物理模型
接口配置表

Go Further

FASST 模型BILL OF MODELS (BOM)文件

模型BOM*

<metadata>		
Program_Name	ADAS	
Feature_Name	Feature	
Variant_Name		
Model Parts	GitHub Organization and Repository	Branch/Tag
<components>		
BRAKES	FASST/BRAKES	BehvM
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

项目名称
功能模块名称
变体名称

ECU/子系统模型

模型版本GitHub路径

模型类型/Release Tag

整车模型选择

网络/ECU架构

*其他未展示部分:

- Build选项
- 系统模型
- 测试规程
- 可选工具
- 文档
- 测试结果
- 其他

模型BOM文件用于定义虚拟整车所有的配置信息

Go Further

FASST “一键”生成整车系统模型

模型配置 BOM

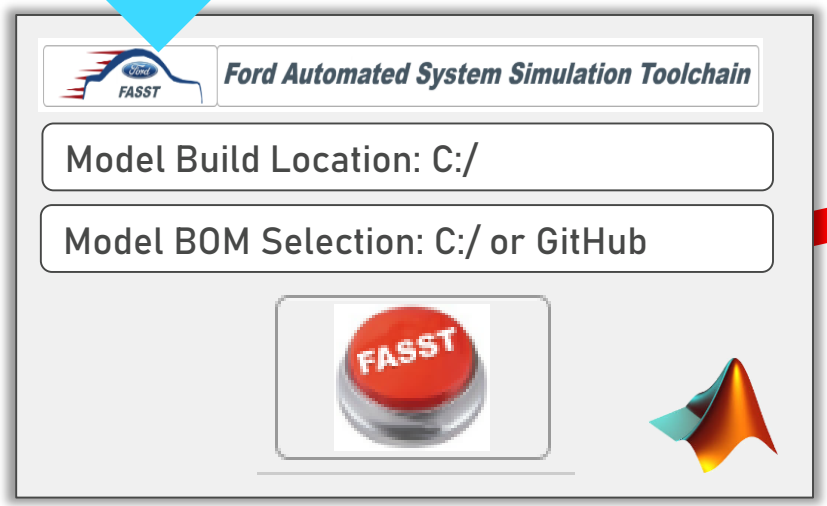
基于云端 分布式版本控制

ECU 架构 (DBC)

ECU 模型 & 子系统模型

物理模型 接口配置表

整车 物理模型



CAN Model Builder

GitHub Repo Browser

Vehicle Plant Interface Builder

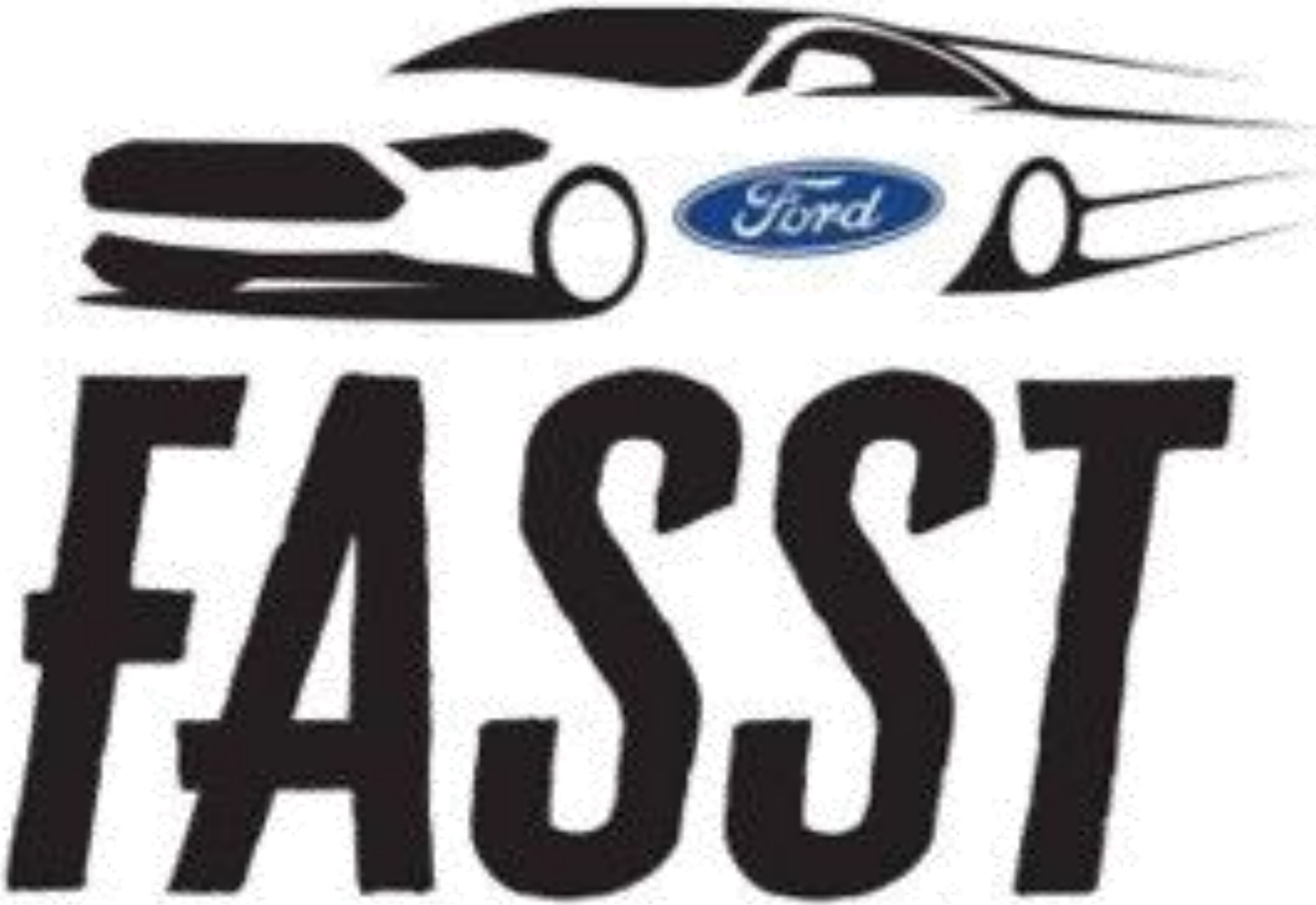
Connect ECU and Driver Models to Vehicle Model

FASST Virtual Vehicle

FASST能自动集成多个工具集以链接分布存储于GitHub云端的子系统模型 进而构建起完整的车辆仿真系统模型

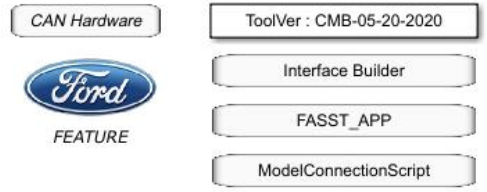
Go Further

FASST 系统模型生成DEMO

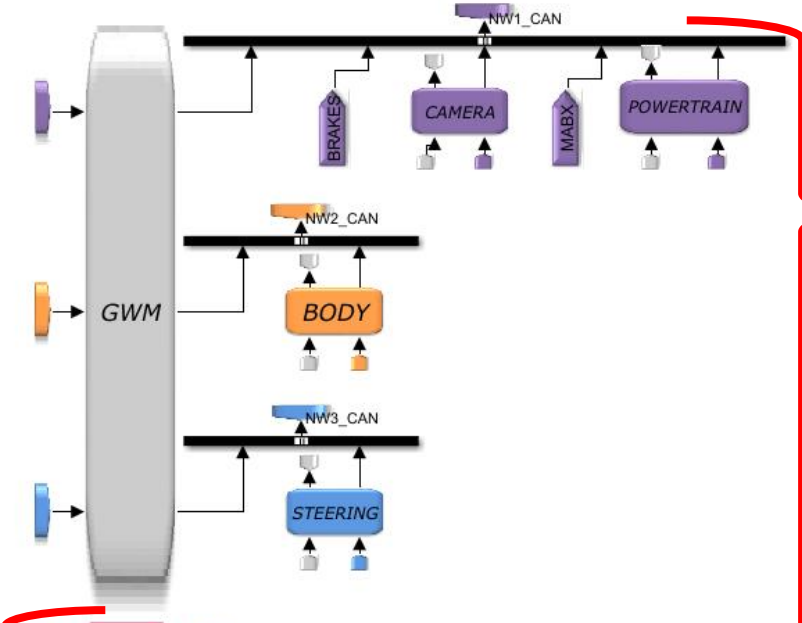


FASST SIMULINK模型

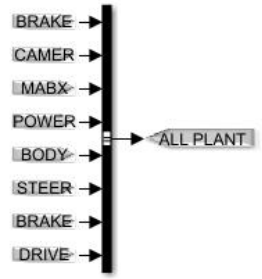
项目及
功能名称



FASST
相关工具
快捷按钮

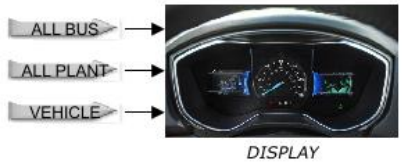


虚拟ECU
“面包板”
支持XiL



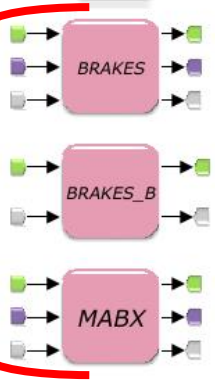
驾驶员模型

信号监测及显示

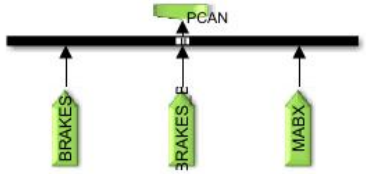


整车物理模型

ECU多路
CAN通讯



支持私有CAN



通用的模型架构能兼容多种应用场景，利于跨部门协作

Go Further

整车物理模型

为什么需要支持多种整车物理模型？选择何种整车物理模型？

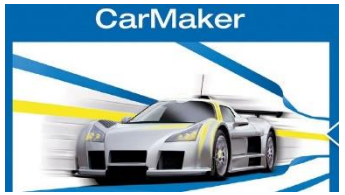
- 仿真速度
- 软件成本
- 用户体验
- 部门偏好
- 模型保真度

FASST 支持集成多种整车物理模型

User Model

VEHICLE DYNAMICS BLOCK SET

carSIM MECHANICAL SIMULATION

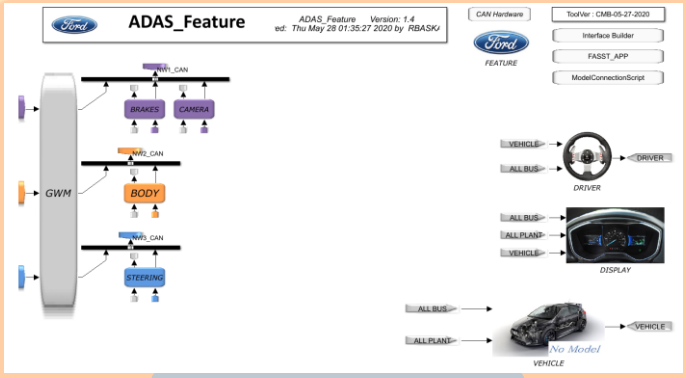


MSC Software Simulating Reality, Delivering Certainty

ADAMS

物理模型信号数据库

FASST 整车物理模型生成过程



FASST 模型

Generates

BODY CAMERA BRAKES

物理模型
信号数据库

ECU-to-Vehicle
接口mapping文档

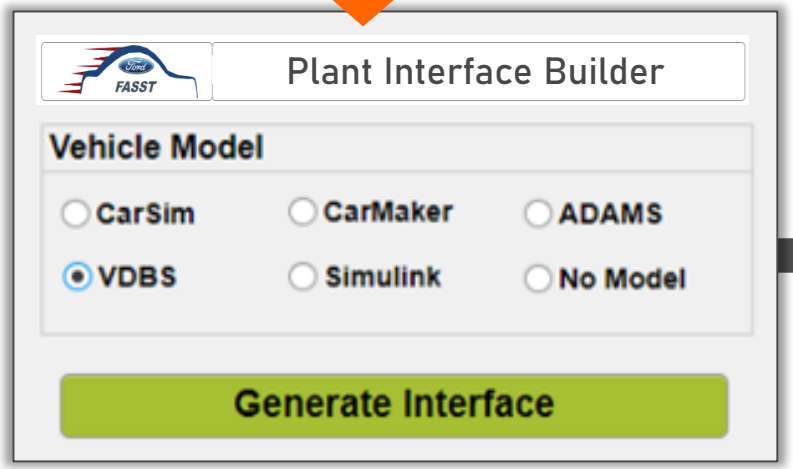
IPG AUTOMOTIVE

carSIM

MSC Software

VEHICLE DYNAMICS BLOCK SET

整车物理模型



Detect Plant Signals in Model

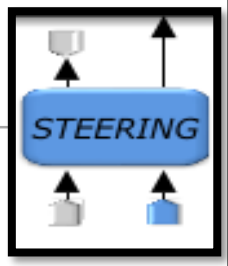
Generate ECU-to-Vehicle Interfaces

Add Vehicle Model

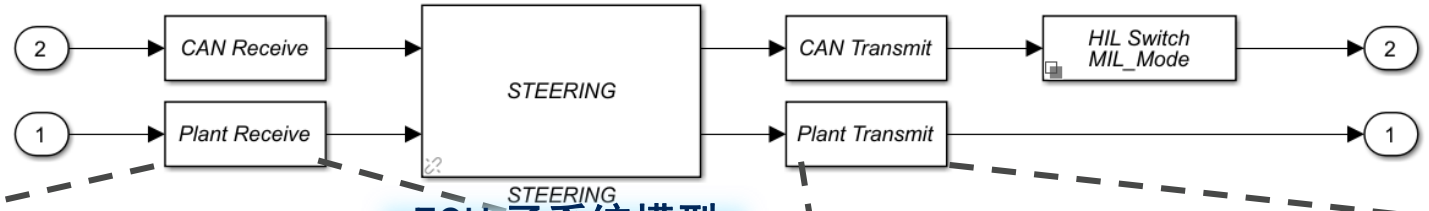
Connect ECU and Driver Models to Vehicle Model

Ford Go Further

FASST ECU子系统模型

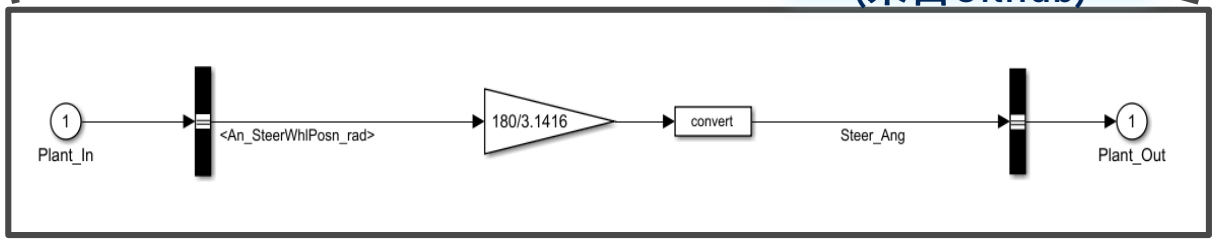


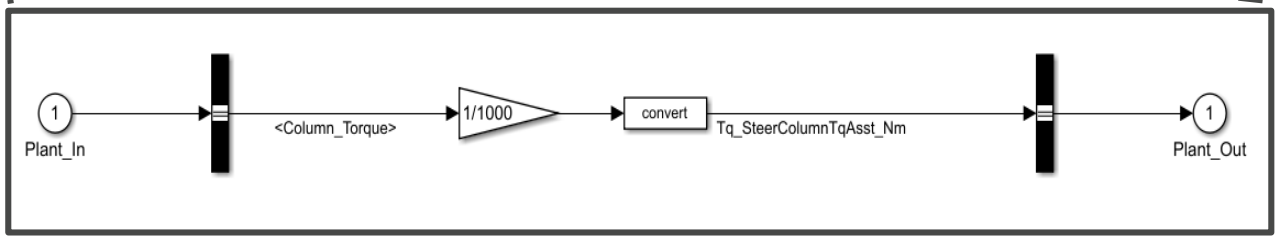
ECU 输入 (CAN & Plant)



ECU 输出 (CAN & Plant)

ECU 子系统模型 (来自Github)





GPSDB Name → Controller Name

Controller Name → GPSDB Name

转向系统

ECU-to-Vehicle接口信号mapping表

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)

物理模型信号数据库

ECU子系统模型

VEHICLE DYNAMICS BLOCK SET

IPG AUTOMOTIVE

carSIM

Ford Go Further

FASST与持续集成
CONTINUOUS INTEGRATION (CI)

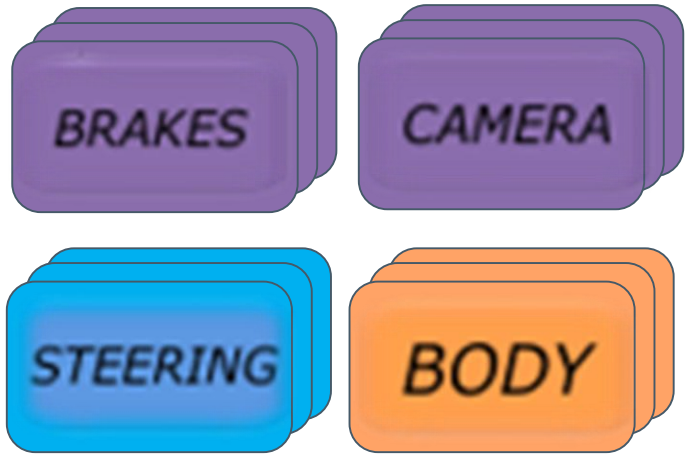
持续集成(CI) - 验证子系统

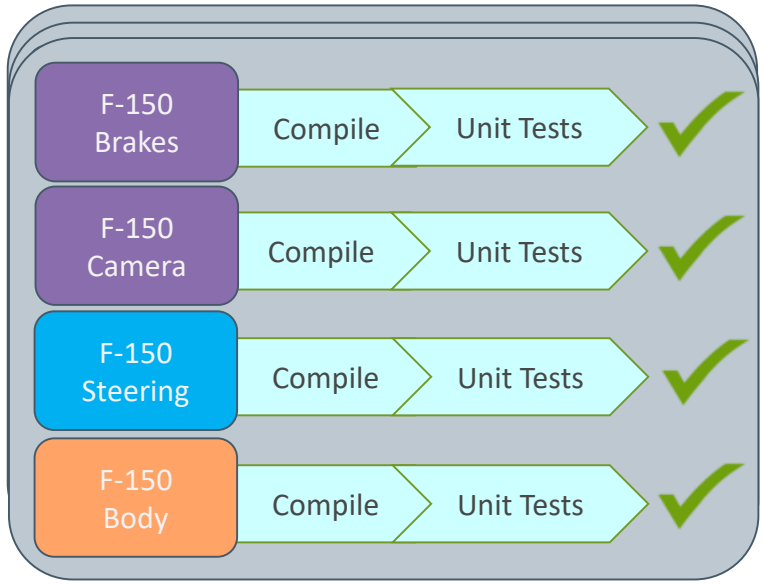
GitHub

Jenkins

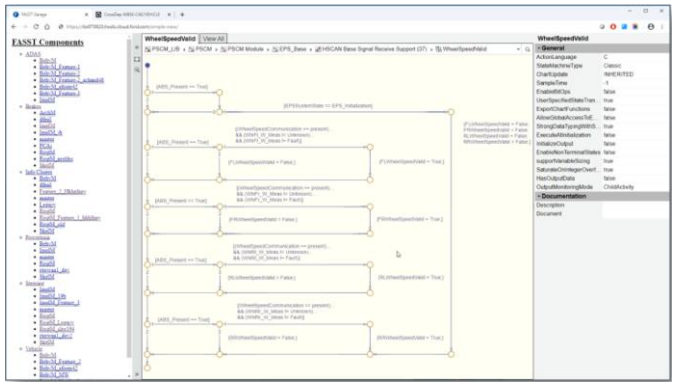
FASST Garage

ECU子系统模型仓库





At least 10 carlines ✕ 30 ECUs
Tests run daily & nightly



250+ tested models are viewable from a browser

持续集成(CI) - 系统模型自动创建及验证

ECU 架构(DBC)

模型 BOM
配置文件

ECU 模型 &
子系统模型

GitHub

\+

Enterprise
&
Program
complexity

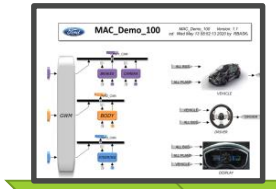
=

Jenkins

kubernetes

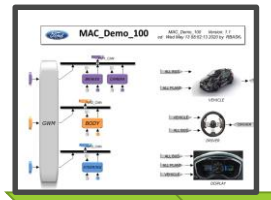
docker

vmware



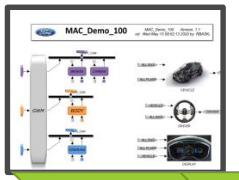
F-150 Lane Assist

FASST → Clone → Build → System Tests



F-150 Park Assist

FASST → Clone → Build → System Tests



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FASST → Clone → Build → System Tests

一个完整的功能模型CI流程
可能耗时10分钟~1小时

每天40+小时用于大量BOM创建
及其CI自动化并发测试

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FASST面临的挑战?

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模型保真度问题

"ALL MODELS ARE WRONG…
SOME ARE USEFUL"

- George E.P. Box

"WHICH MODELS ARE USEFUL ?
DEPENDING ON THE USE CASE"

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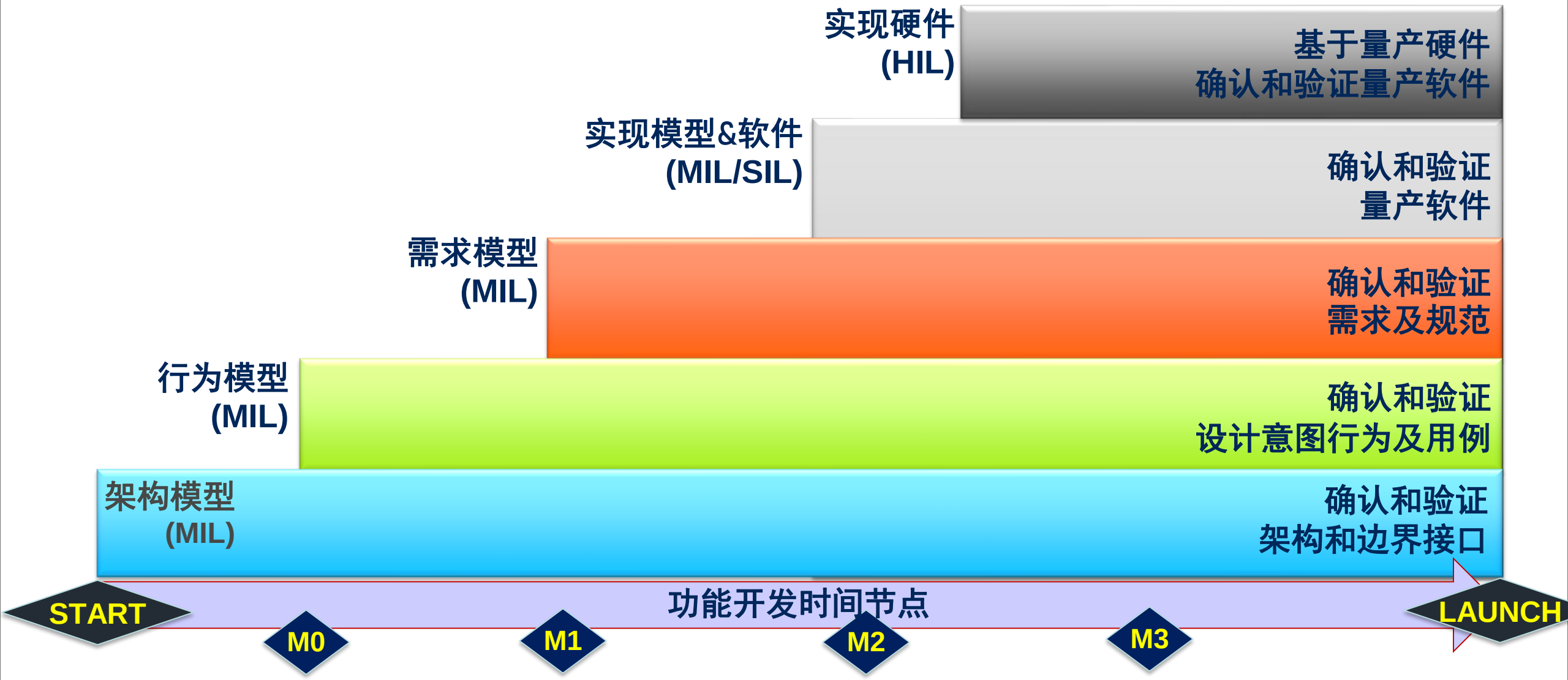
模型保真度问题



相较于直接实现量产模型/软件，渐进式模型/软件更新迭代更容易且风险更少

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总结

总结

- **FASST 自动化系统仿真工具链：**
  - 是基于MATLAB & Simulink的、团队协作的、前沿的、内部开源的敏捷开发模式
  - 能帮助发现开发过程中的系统问题
  - 能实现整车虚拟模型构建从数月缩减至数分钟
  - 自动化流程能消除模型集成过程中的错误
  - 结合CI能确保建模及仿真的扩展性满足开发过程的不同需求

- **“所有的模型都是错误的，其中有些是有用的”挑战仍然存在**

- **“即插即用”内部开源的子系统模型是项目成功的关键**

FASST并不能解决所有问题，但是却能提升工程师的日常工作效率
并助力跨组织协同

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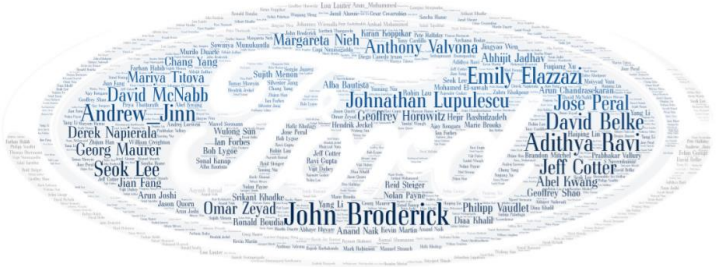
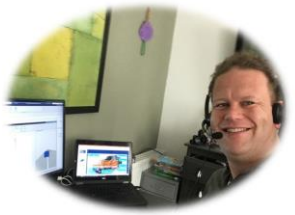
特别感谢FORD FASST团队





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NICK ADAMS

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THANK YOU
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Q&A
GT
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Thank you

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