# PC-Based Validation of ECU Software

Sean Wyatt - ETAS, Inc.

**Embedded System Workshop**

IEEE
Southeastern
Michigan

**Venue: Oakland University School of Engineering and Computer Science, Rochester, MI**

**Date: October 13, 2012**

DRIVING | EMBEDDED EXCELLENCE

ETAS

# What you will learn

- Motivation for PC-Based Development
- How to create MiL and SiL platforms using ETAS INTECRIO software;
- How to calibrate C-code using production tools like ETAS INCA;
- How to improve productivity, reduce cost by leveraging the PC platform;

# Agenda

- Why PC-based Development
- Definitions
- What is INTECRIO?
- Model-in-the-loop with INTECRIO
- Software-in-the-loop with INTECRIO
- Other ETAS Solutions
- Summary

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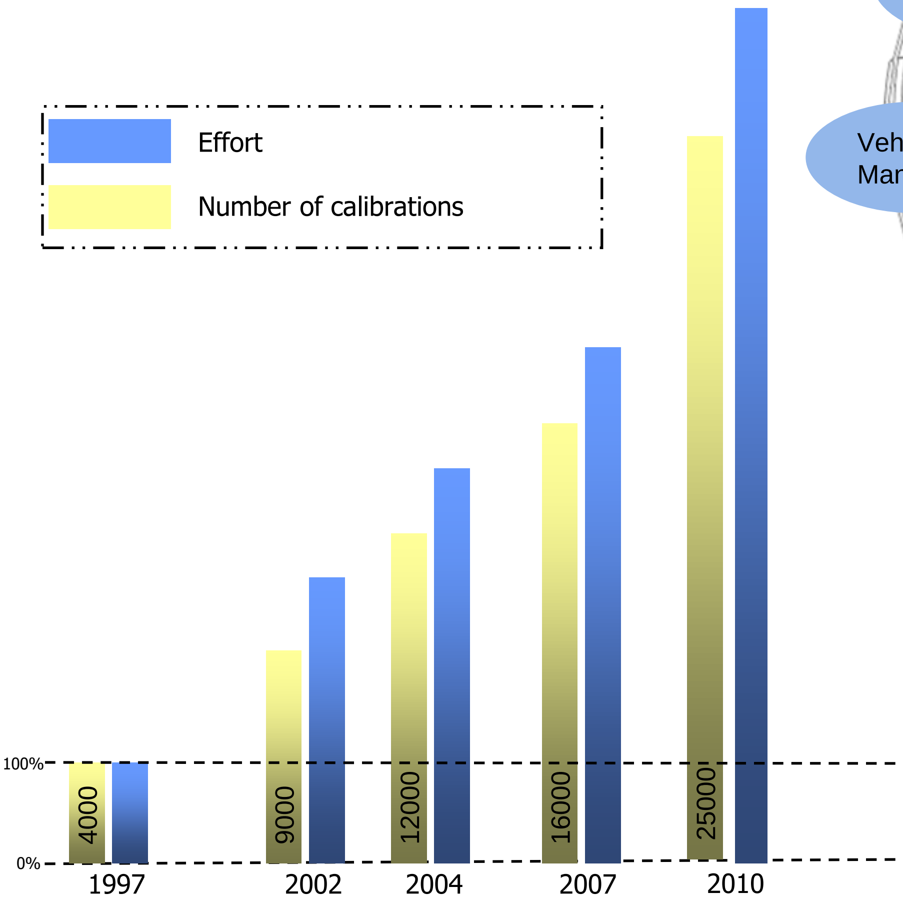
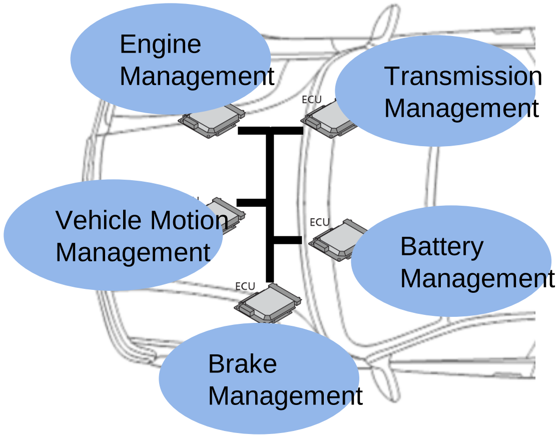
# Why PC-Based Development?

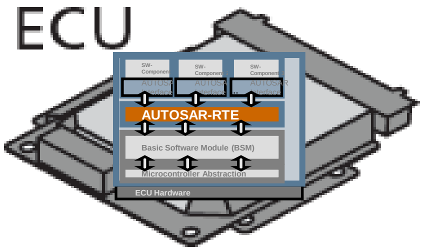
Consumption and emission requirements



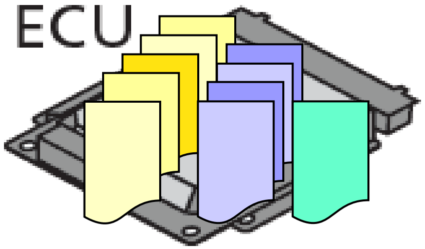
Engine control complexity



Increased inter domain connectivity

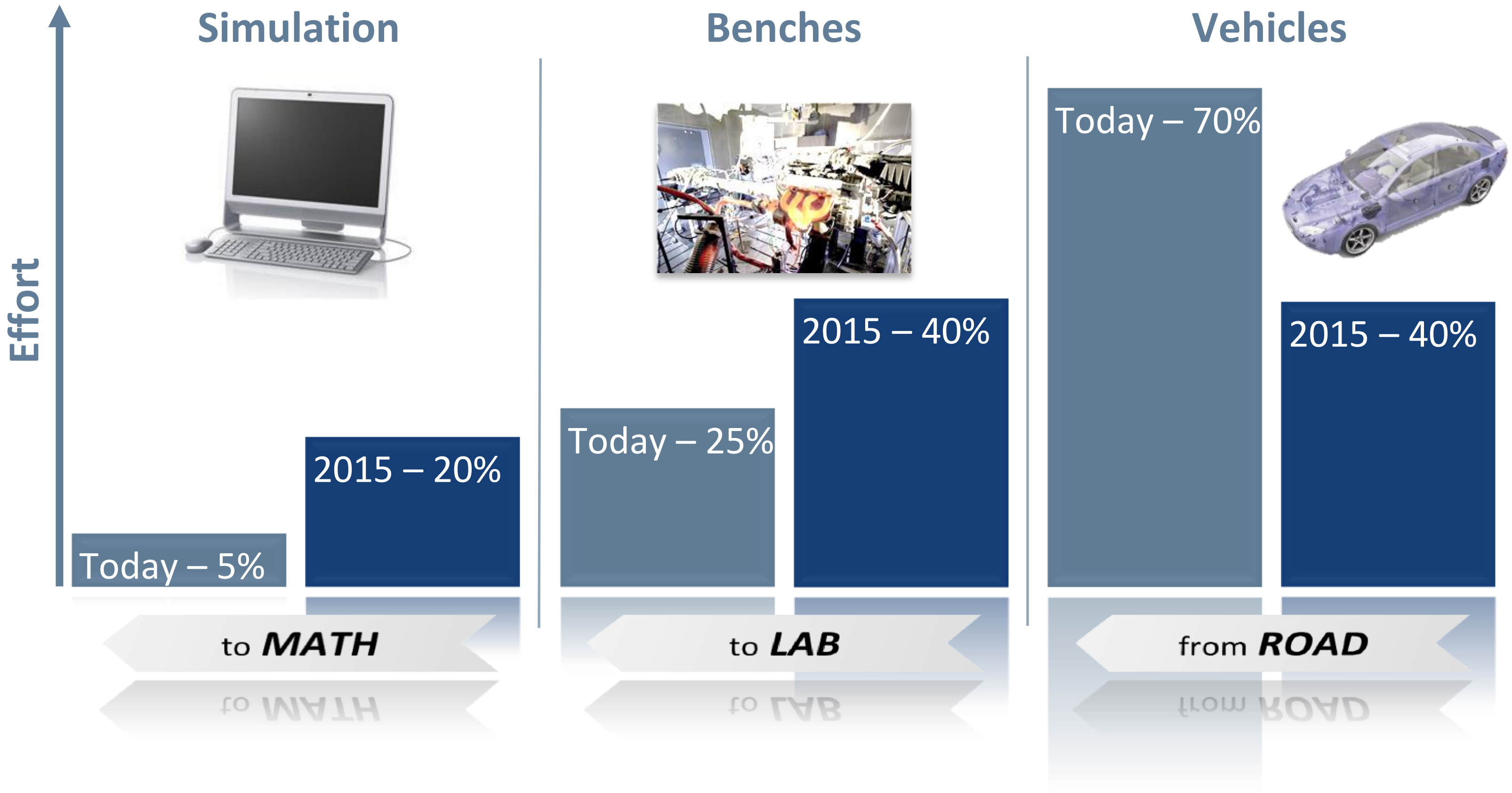


New layered standard architecture



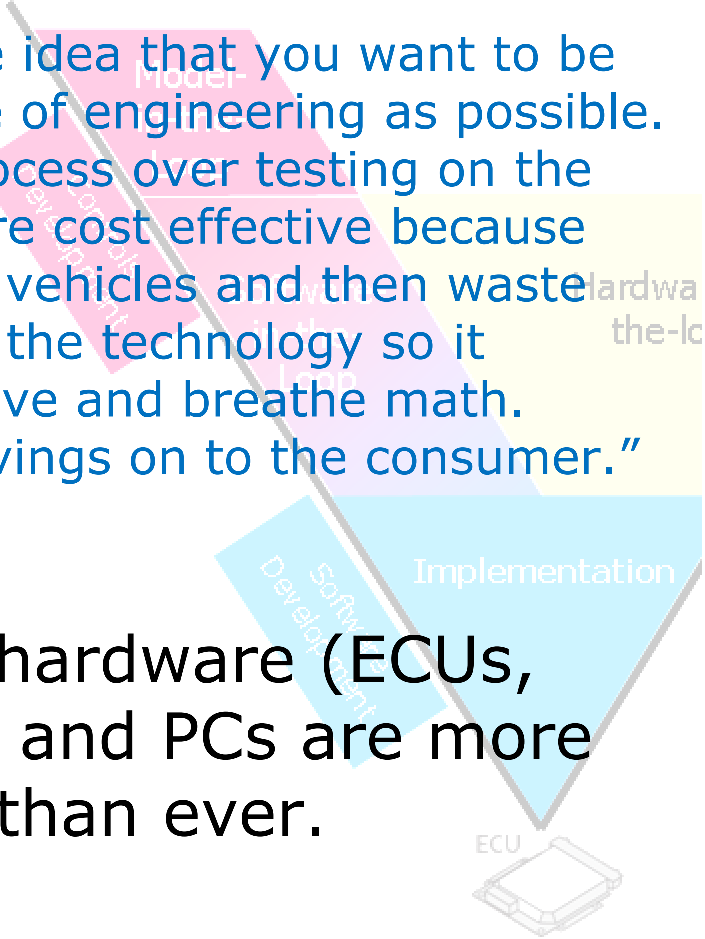
New functions and variants

# Why PC-Based Development?



# Why PC-Based Development?

“**Road to lab to math** is basically the idea that you want to be as advanced on the evolutionary scale of engineering as possible. Math is the next logical step in the process over testing on the road and in the lab. Math is much more cost effective because you don’t have to build preproduction vehicles and then waste them. We’ve got to get out in front of the technology so it doesn’t leave us behind. We have to live and breathe math. When we do that, we can pass the savings on to the consumer.”
- A senior auto executive

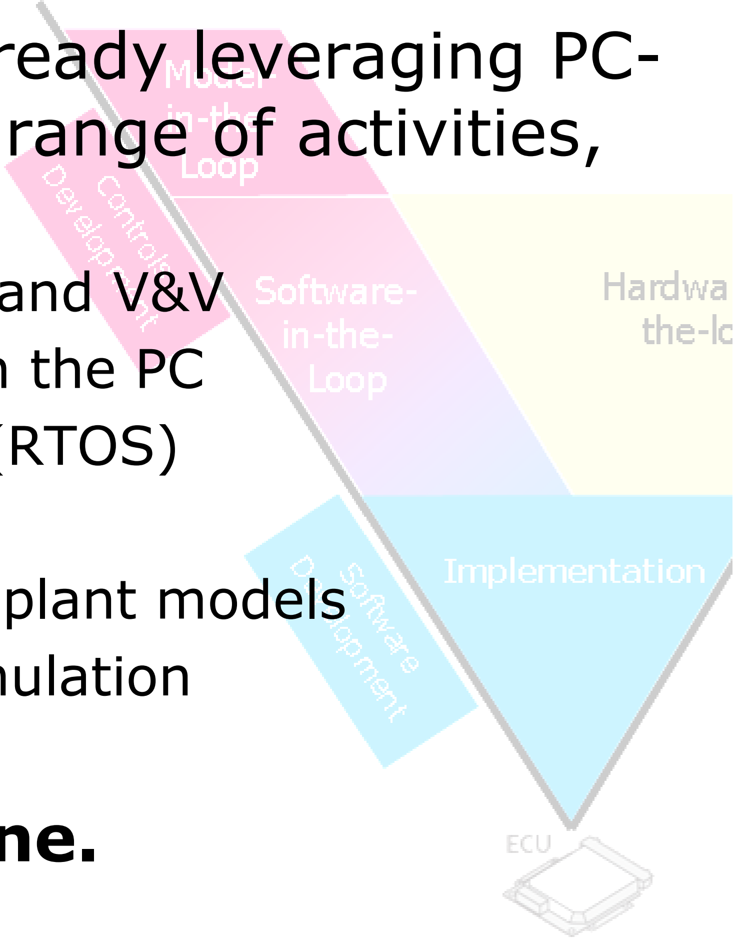


- **Summary**: Development hardware (ECUs, vehicles etc.) is expensive and PCs are more powerful and inexpensive than ever.

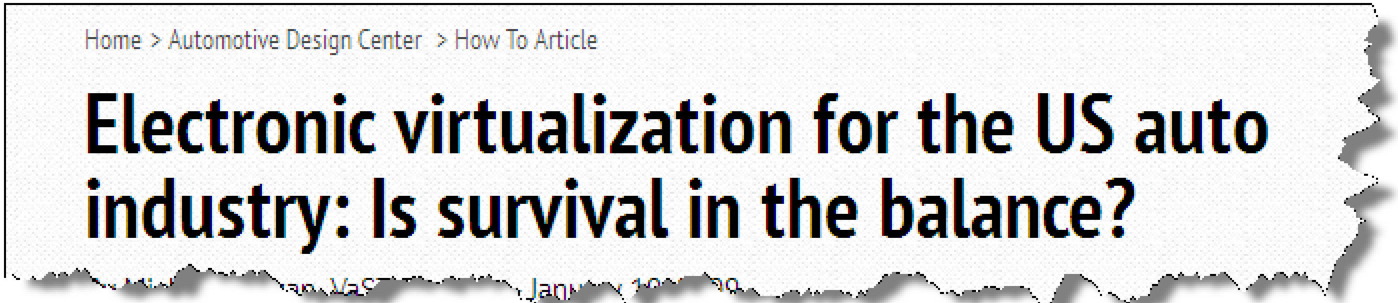
# Why PC-Based Development?

- Automotive industry is already leveraging PC-based development for a range of activities, e.g.:
  - software functional testing and V&V
  - legacy c-code simulation on the PC
  - target-like timing analysis (RTOS)
  - calibration development
  - system development using plant models
  - complete ECU hardware emulation

→ **But more can be done.**

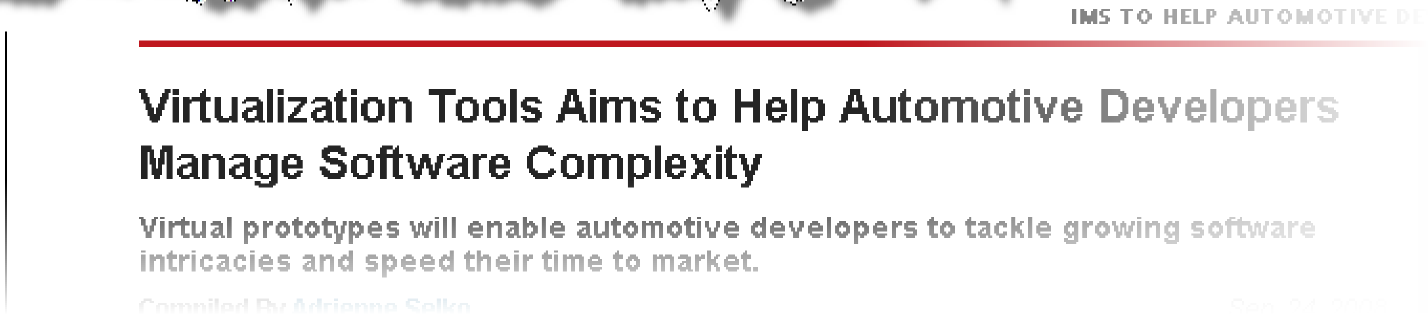


# Several studies..



Home > Automotive Design Center > How To Article

Electronic virtualization for the US auto industry: Is survival in the balance?

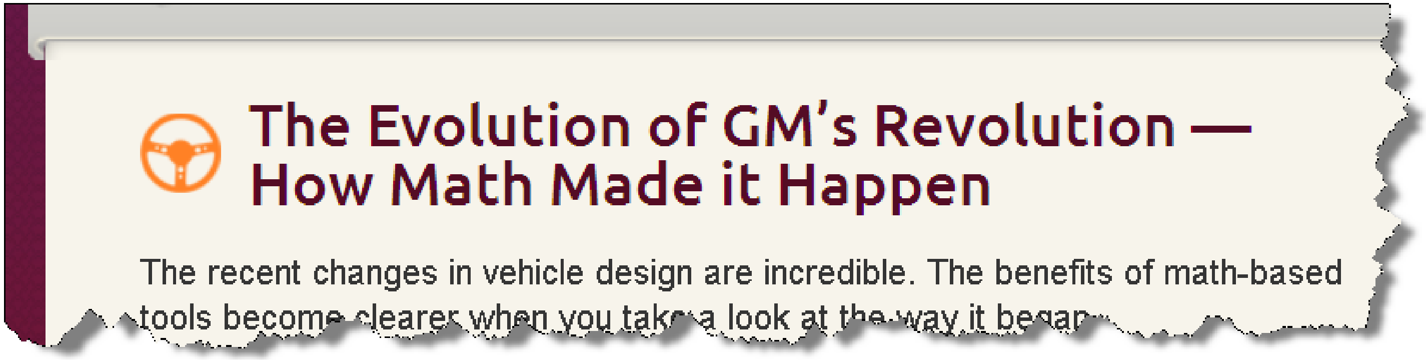


IMS TO HELP AUTOMOTIVE DE

Virtualization Tools Aims to Help Automotive Developers Manage Software Complexity

Virtual prototypes will enable automotive developers to tackle growing software intricacies and speed their time to market.

Compiled By Adrienne Selko



The Evolution of GM's Revolution — How Math Made it Happen

The recent changes in vehicle design are incredible. The benefits of math-based tools become clearer when you take a look at the way it began

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- **Definitions**
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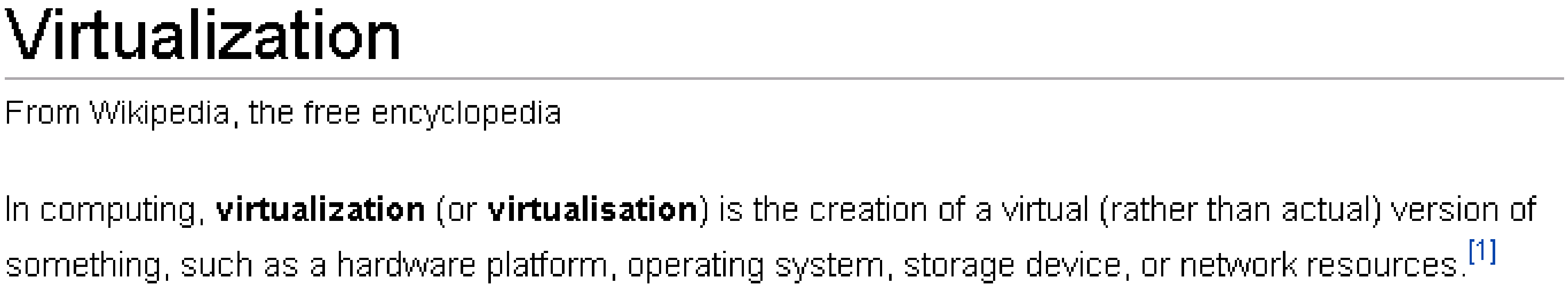
# Definitions



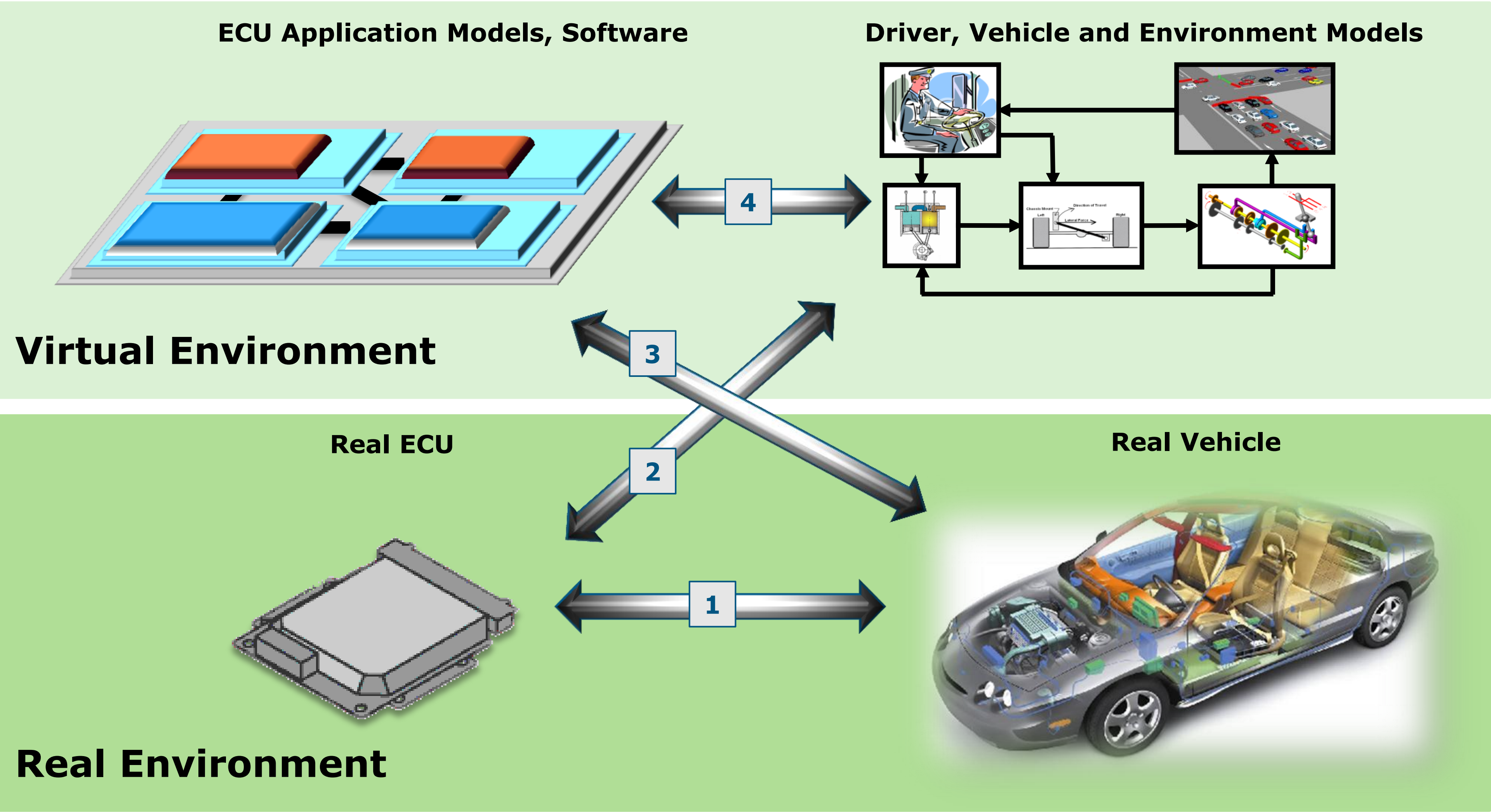
## Virtualization

From Wikipedia, the free encyclopedia

In computing, **virtualization** (or **virtualisation**) is the creation of a virtual (rather than actual) version of something, such as a hardware platform, operating system, storage device, or network resources.[1]

**Our Definition**: A virtual ECU development environment is characterized by the absence of physical hardware, i.e. PC-based representation of all components, with or without real-time execution

# Evolution of Virtualization



ECU Application Models, Software

Driver, Vehicle and Environment Models

Virtual Environment

Real ECU

Real Vehicle

Real Environment

# What’s included for today?

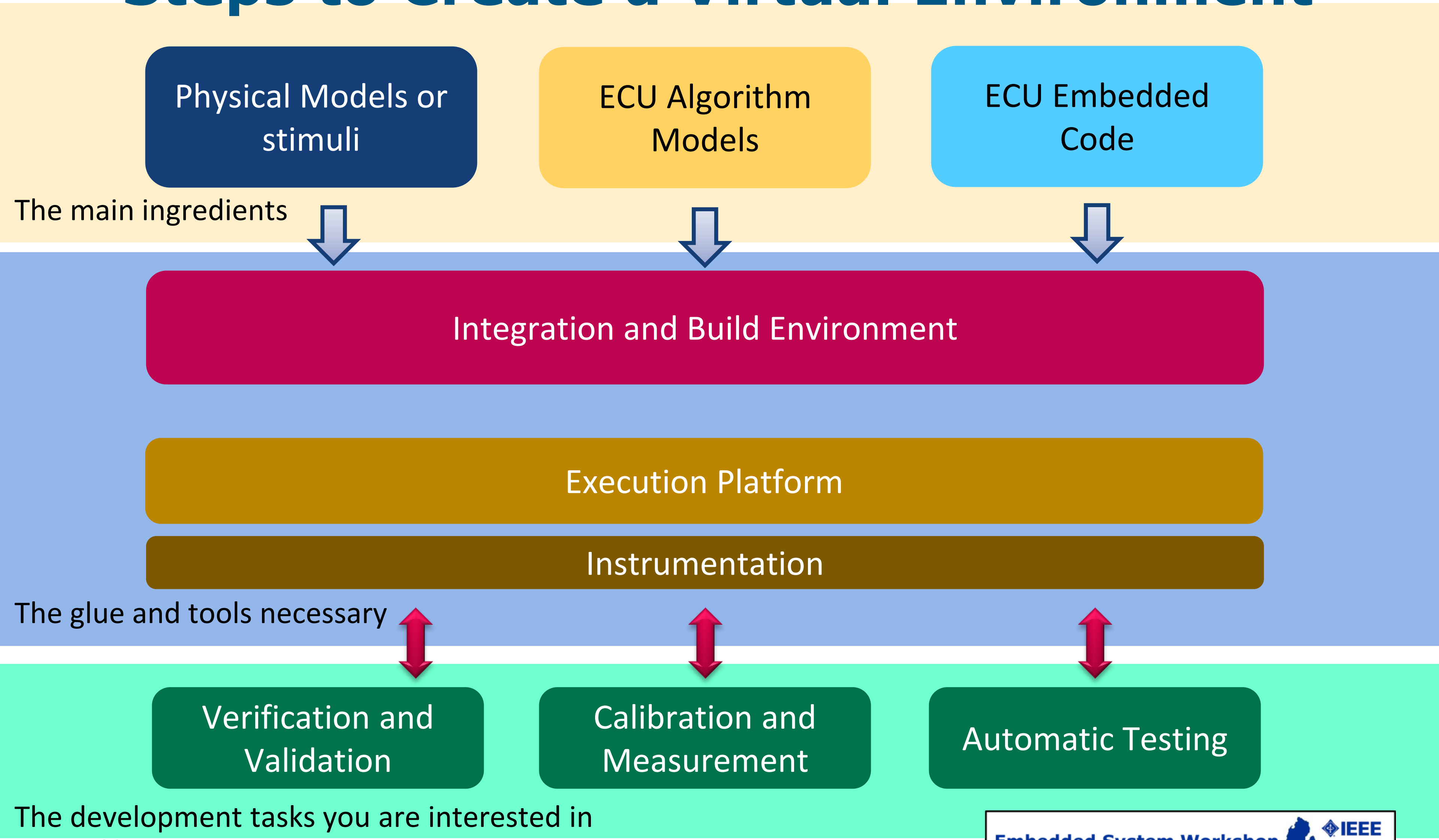
**Included:**

- ECU algorithm models or embedded code
- ECU real-time operating system (RTOS) and other basic software components
- Physical systems (e.g. engine, transmission, body, chassis, driver, environment models)

**Not included:**

- Virtualization of the ECU hardware (e.g. microcontroller, peripherals)
- Virtualization of the physical buses (e.g. CAN, FlexRay)

# Steps to Create a Virtual Environment



Physical Models or stimuli

ECU Algorithm Models

ECU Embedded Code

The main ingredients

Integration and Build Environment

Execution Platform

Instrumentation

The glue and tools necessary

Verification and Validation

Calibration and Measurement

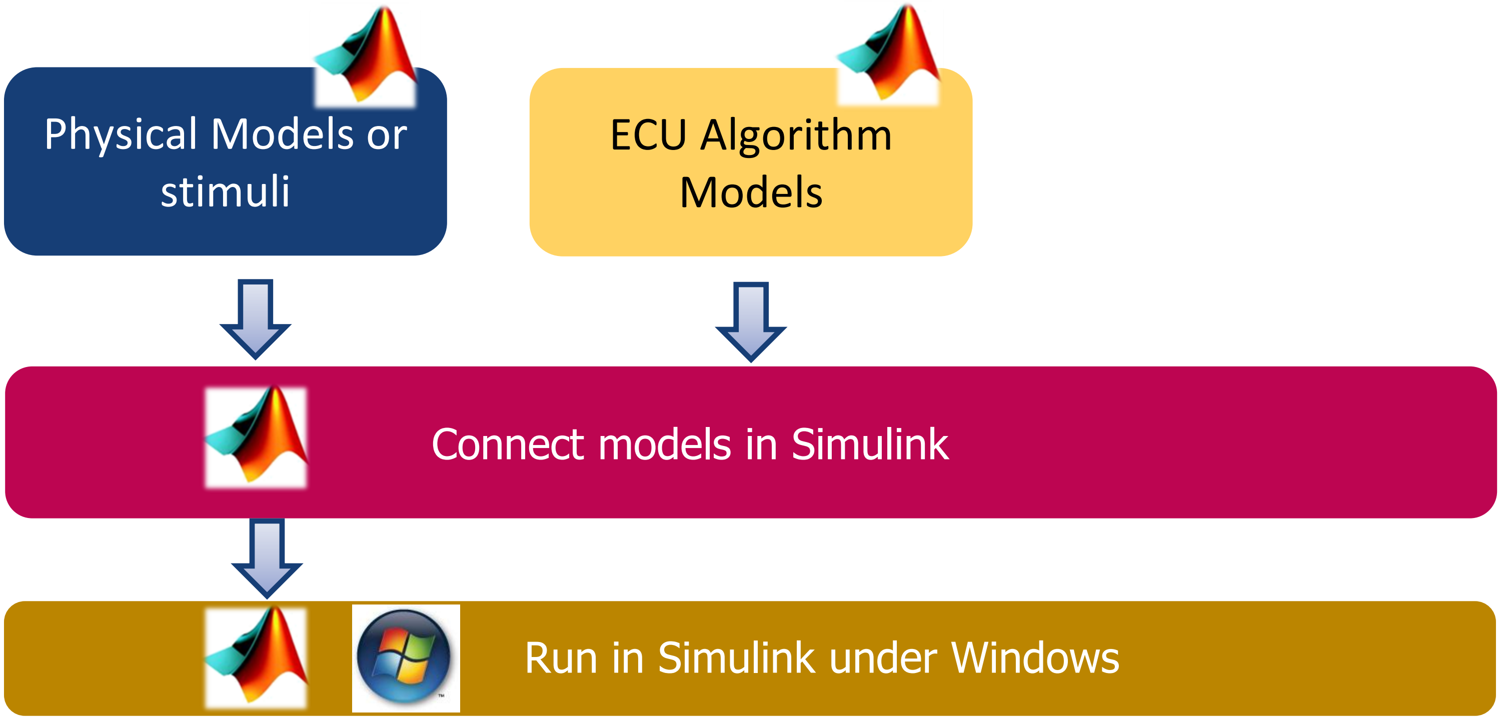
Automatic Testing

The development tasks you are interested in

# Model-in-the-Loop (MiL) Simulation

- Defined as the ECU algorithm model "in-the-loop" with the plant models

– May be run within the modeling environment, or



Physical Models or stimuli

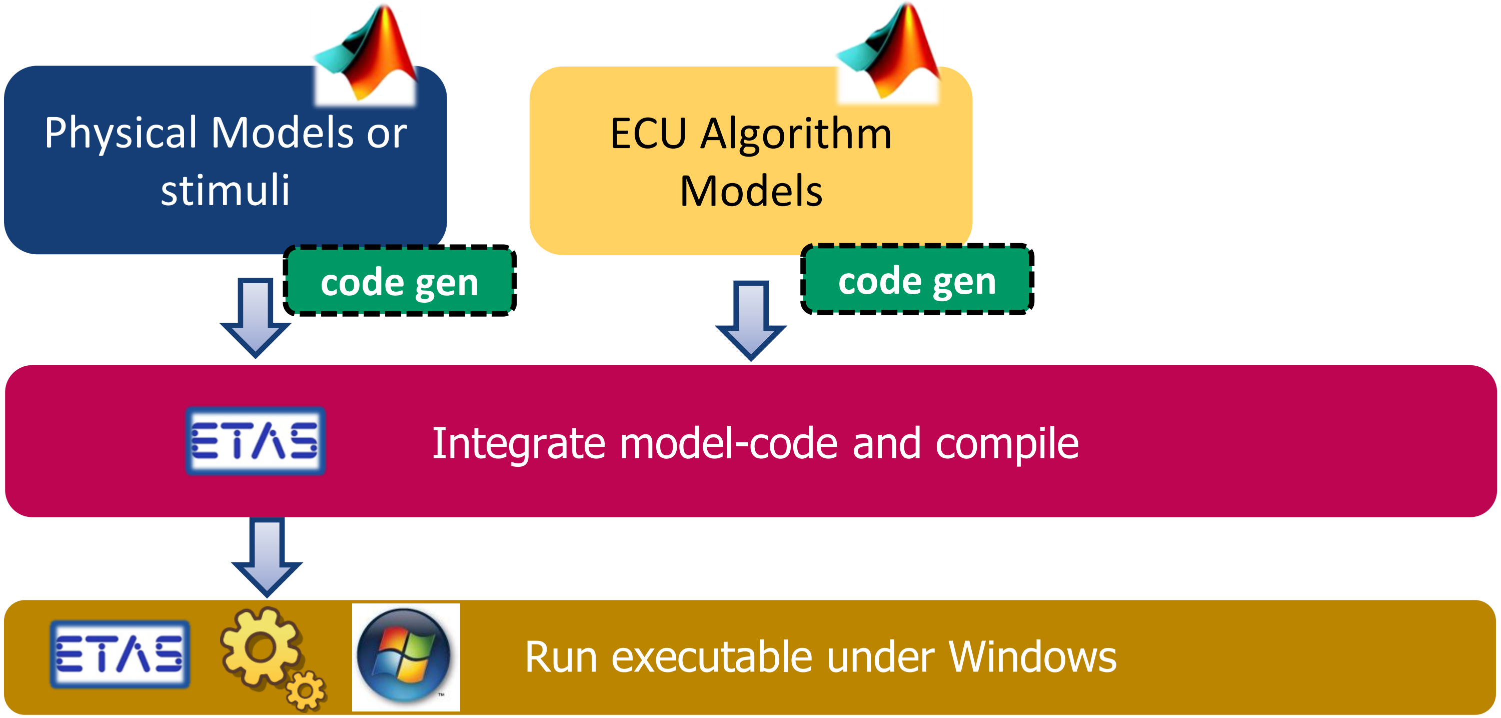
ECU Algorithm Models

Connect models in Simulink

Run in Simulink under Windows

# Model-in-the-Loop (MiL) Simulation

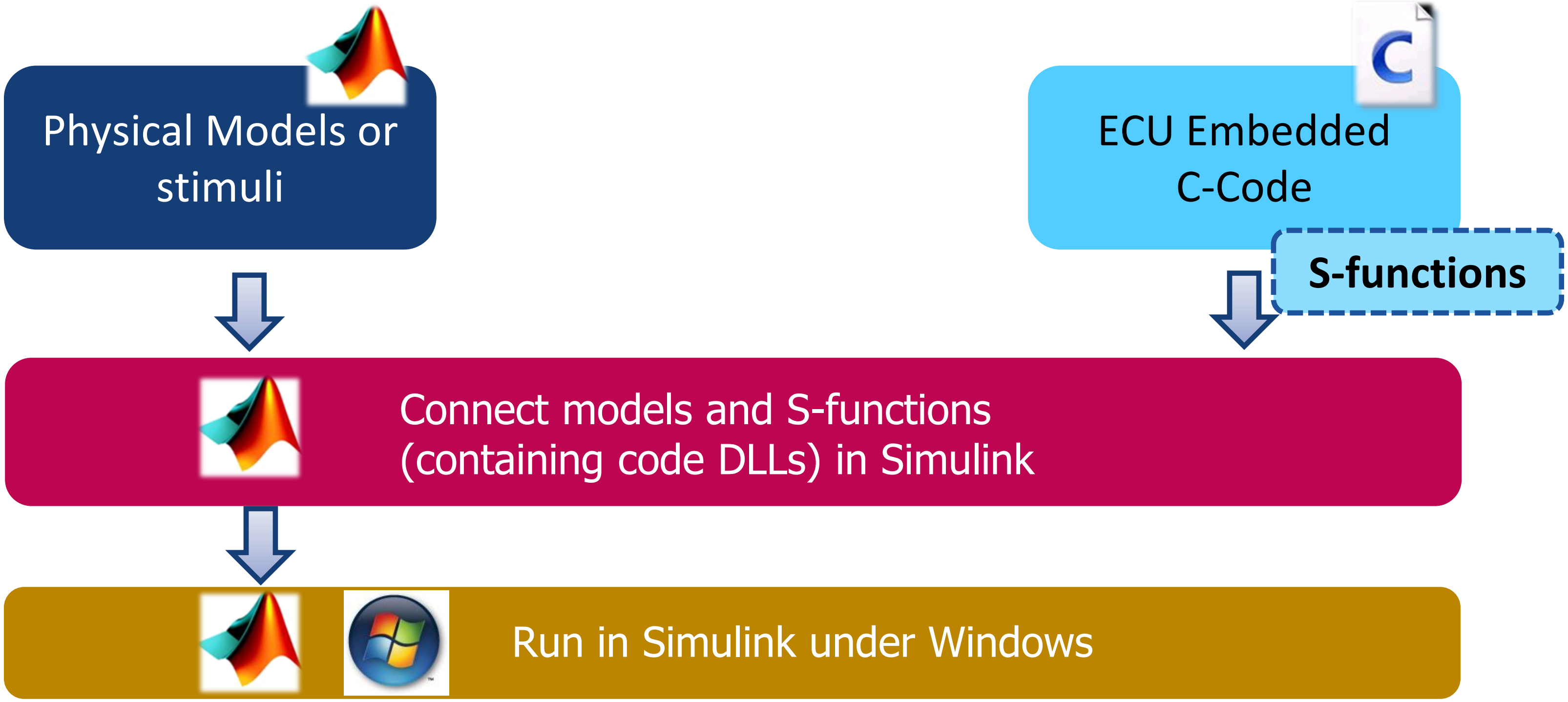
- Defined as the ECU algorithm model "in-the-loop" with the plant models
- – May be run within the modeling environment, or
- – Run as an executable under Windows - from model-generated code


Physical Models or stimuli
ECU Algorithm Models
code gen
code gen
ETAS
Integrate model-code and compile
ETAS
Run executable under Windows

# Software-in-the-Loop (SiL) Simulation

- Defined as the ECU embedded software “in-the-loop” with the plant models

– May be run within the modeling environment, or



Physical Models or stimuli

ECU Embedded C-Code

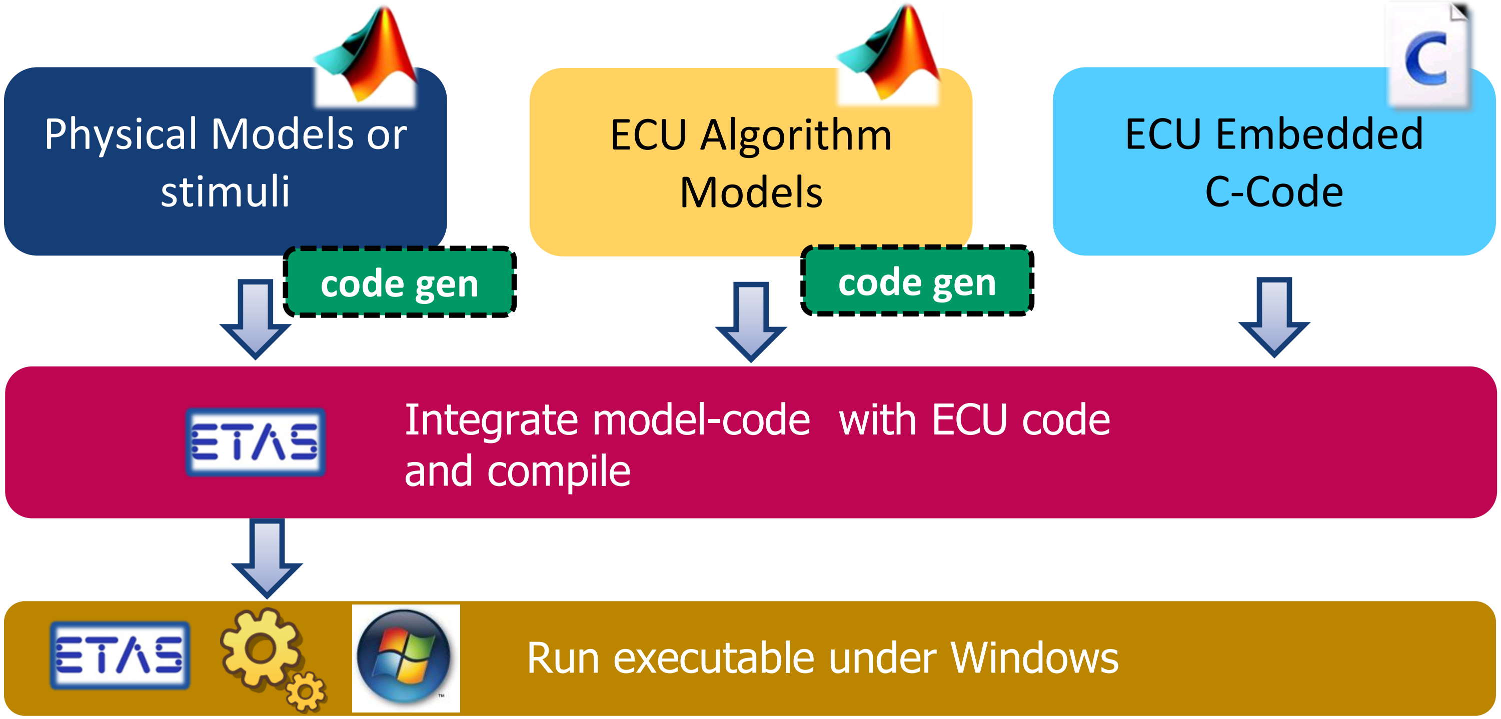
**S-functions**

Connect models and S-functions (containing code DLLs) in Simulink

Run in Simulink under Windows

# Software-in-the-Loop (SiL) Simulation

- Defined as the ECU embedded software "in-the-loop" with the plant models
– May be run within the modeling environment, or
– Run as an executable under Windows


Physical Models or stimuli
ECU Algorithm Models
ECU Embedded C-Code
code gen
code gen
ETAS
Integrate model-code with ECU code and compile
ETAS
Run executable under Windows

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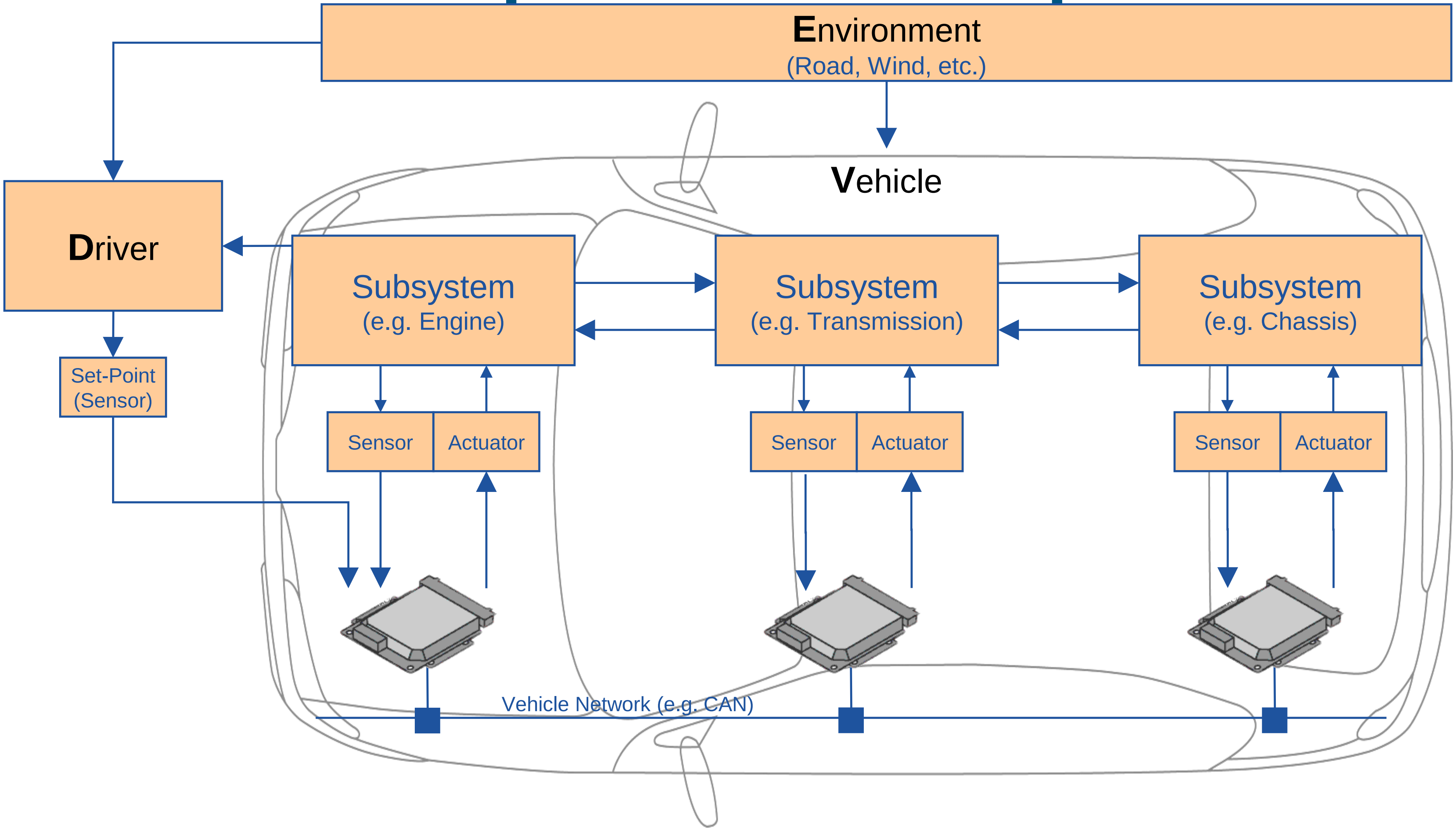
# Virtual Setup for ECU Development



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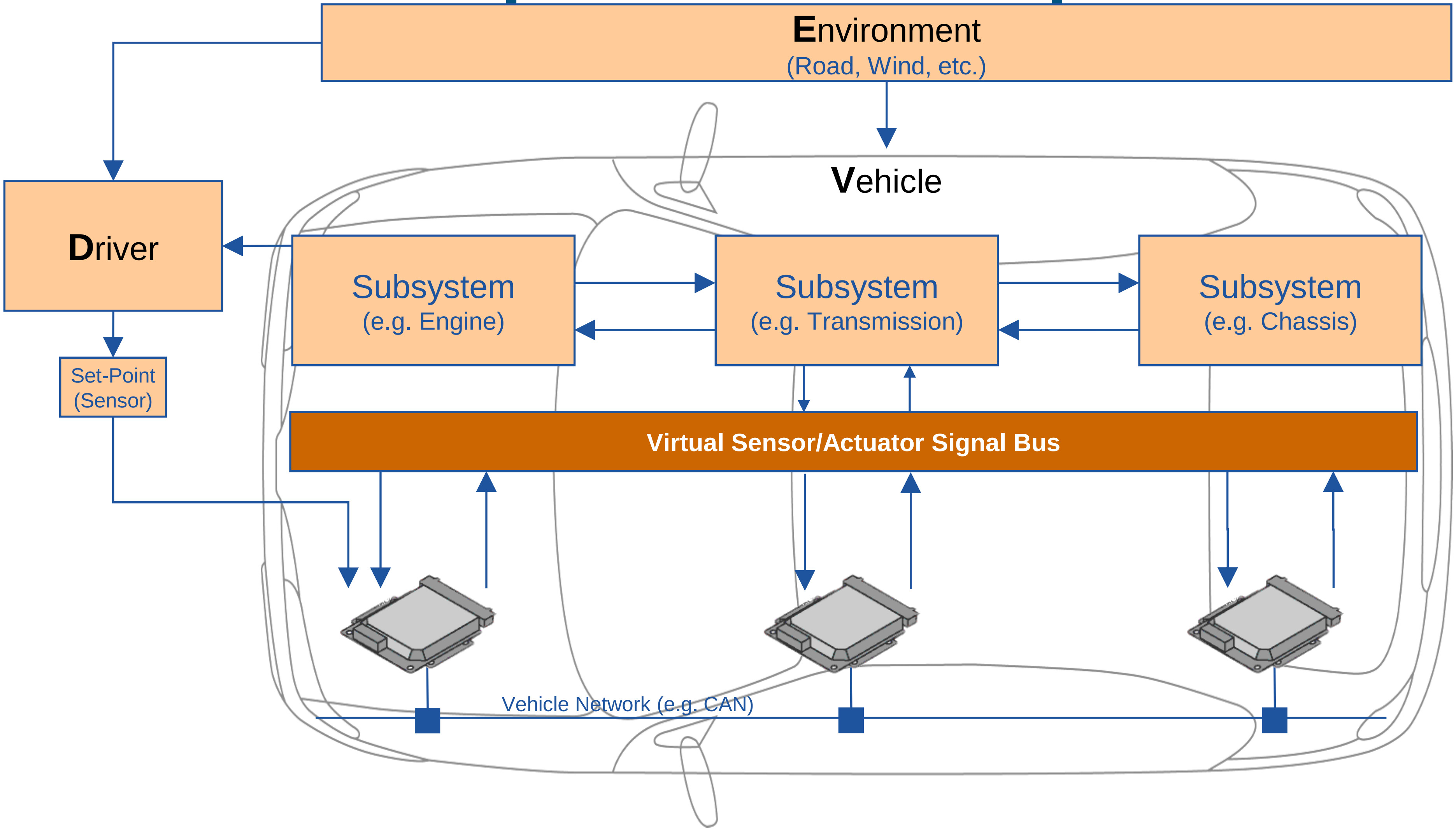

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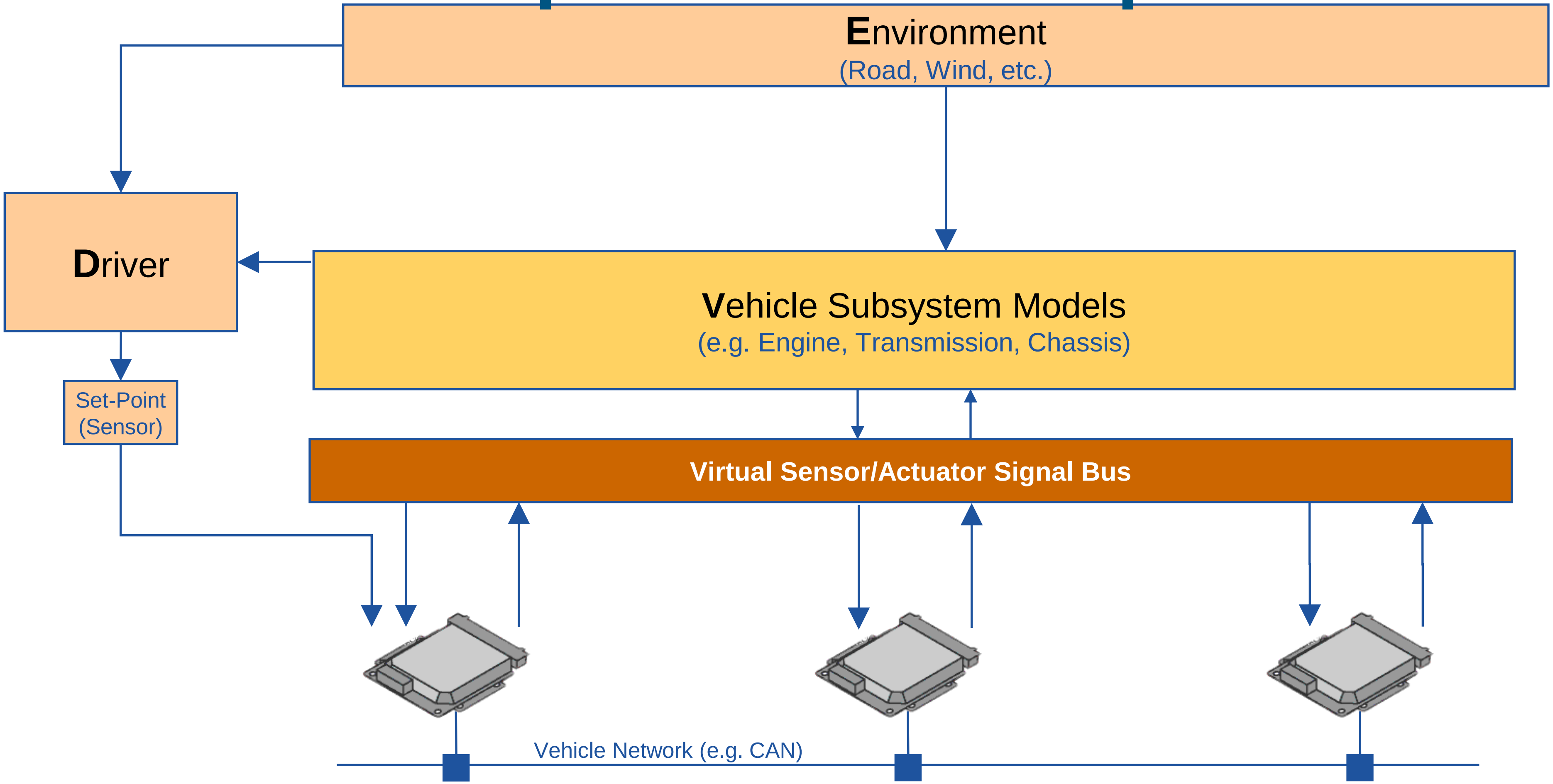
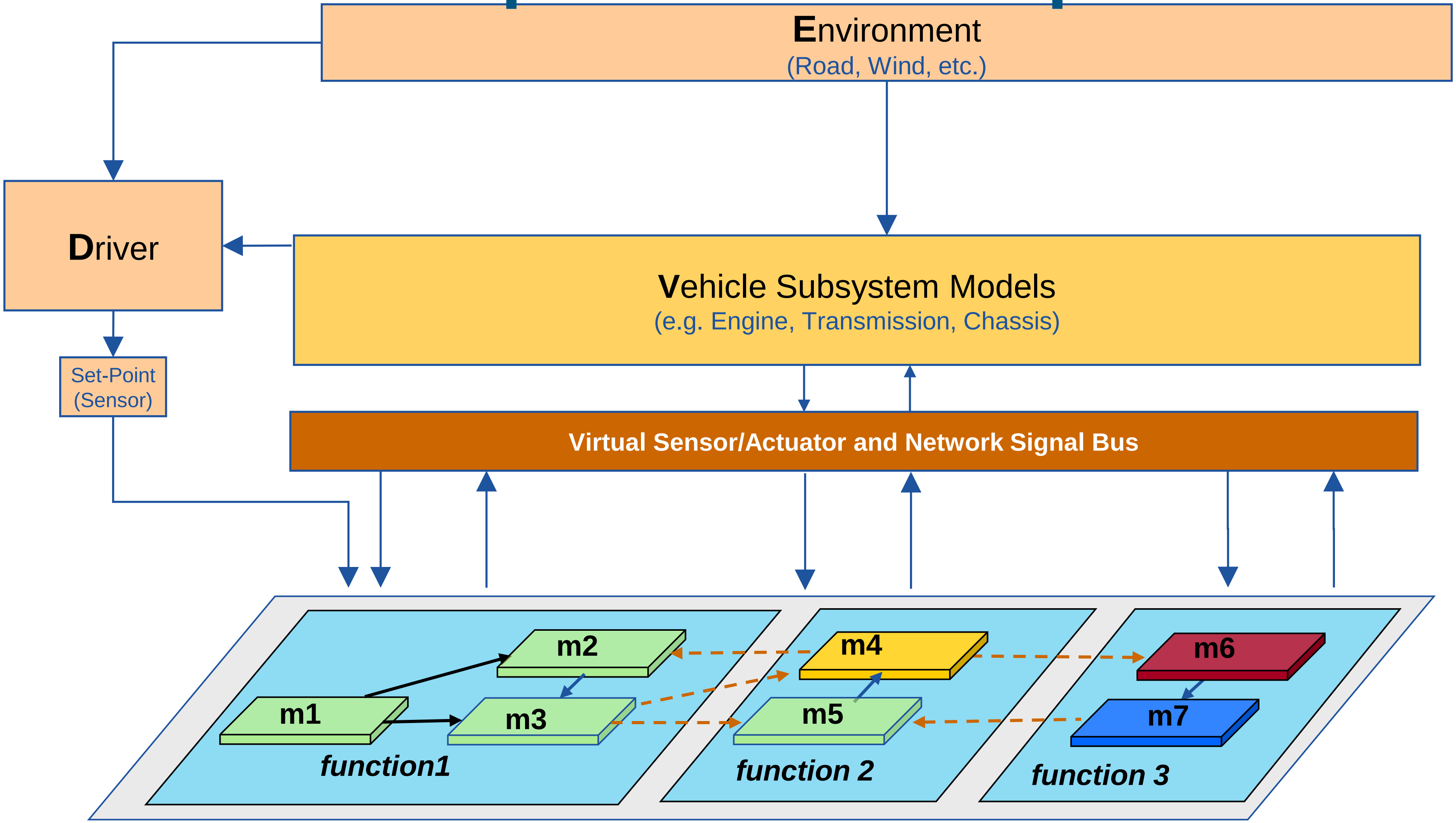


Environment
(Road, Wind, etc.)
Driver
Vehicle Subsystem Models
(e.g. Engine, Transmission, Chassis)
Set-Point
(Sensor)
Virtual Sensor/Actuator Signal Bus
Vehicle Network (e.g. CAN)

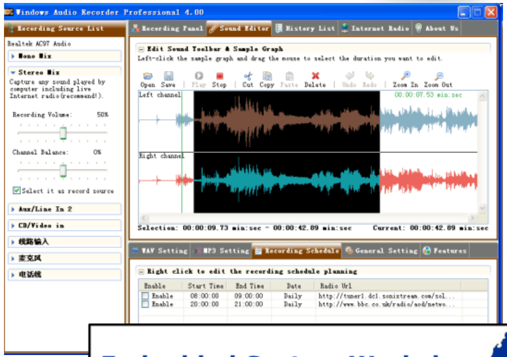
# Virtual Setup for ECU Development



SUPER CHROME CLASS
UX-S
90
SONY
A
BASF
CHROME EXTRA II
90

Music
10:26 pm
sansa
menu
SanDisk

AUDIO MIXER



Windows Audio Recorder Professional 4.00

Realtek AC97 Audio

- Mono Mix
- Stereo Mix

Capture any sound played by computer including live Internet radio(recommend!).

Recording Volume: 50%

Channel Balance: 0%

☑ Select it as record source

- Aux/Line In 2
- CD/Video in
- 线路输入
- 麦克风
- 电话线

Edit Sound Toolbar & Sample Graph

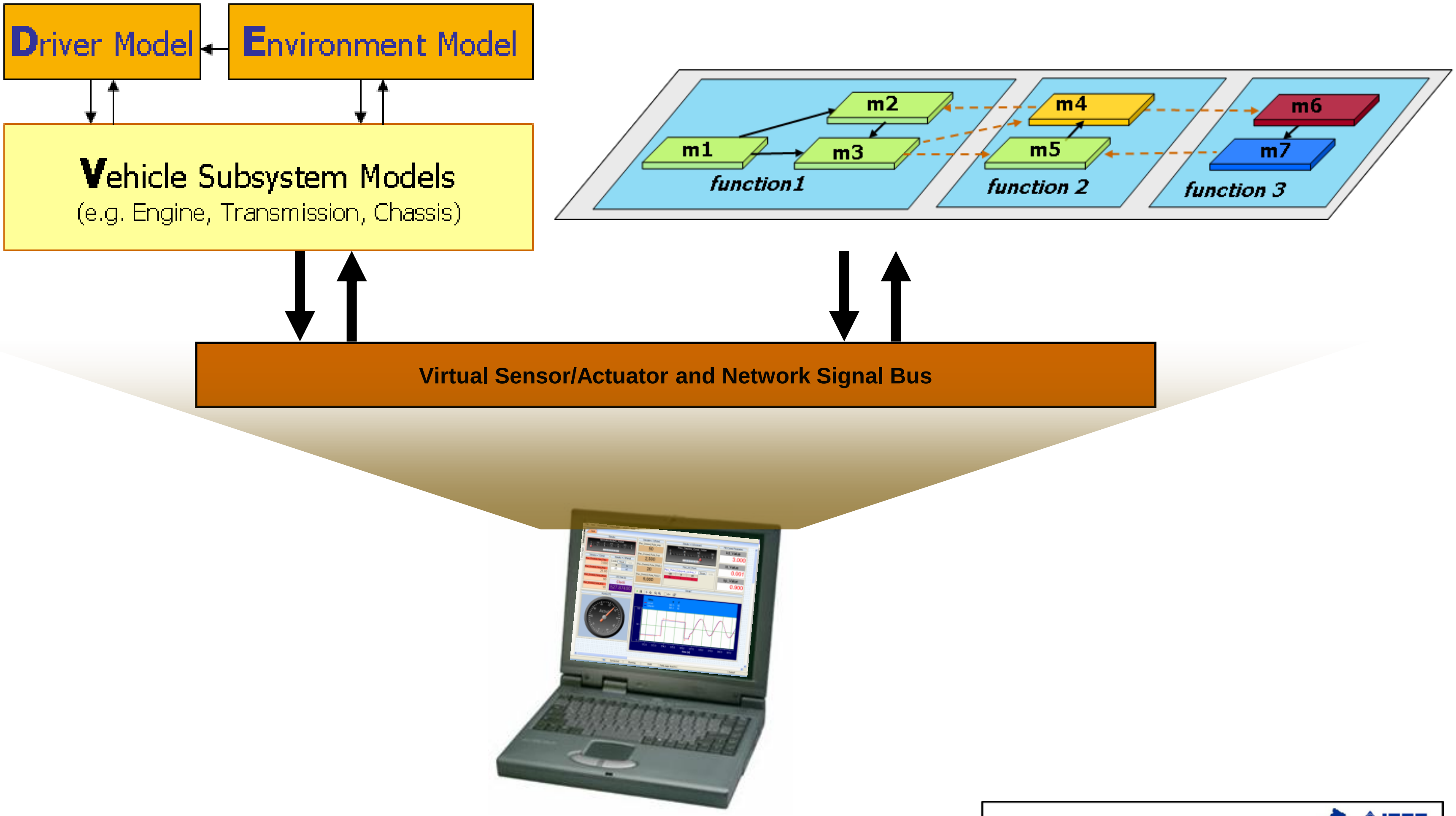
Left-click the sample graph and drag the mouse to select the duration you want to edit.

Selection: 00:00:09.73 min:sec - 00:00:42.89 min:sec Current: 00:00:42.89 min:sec

Right click to edit the recording schedule planning

| Enable | Start Time | End Time | Date | Radio Url |
|---|---|---|---|---|
| □ Enable | 08:00:00 | 09:00:00 | Daily | http://tuner1.dc1.sonixtream.com/sol... |
| □ Enable | 20:00:00 | 21:00:00 | Daily | http://www.bbc.co.uk/radio/aod/netwo... |

# What is INTECRIO?



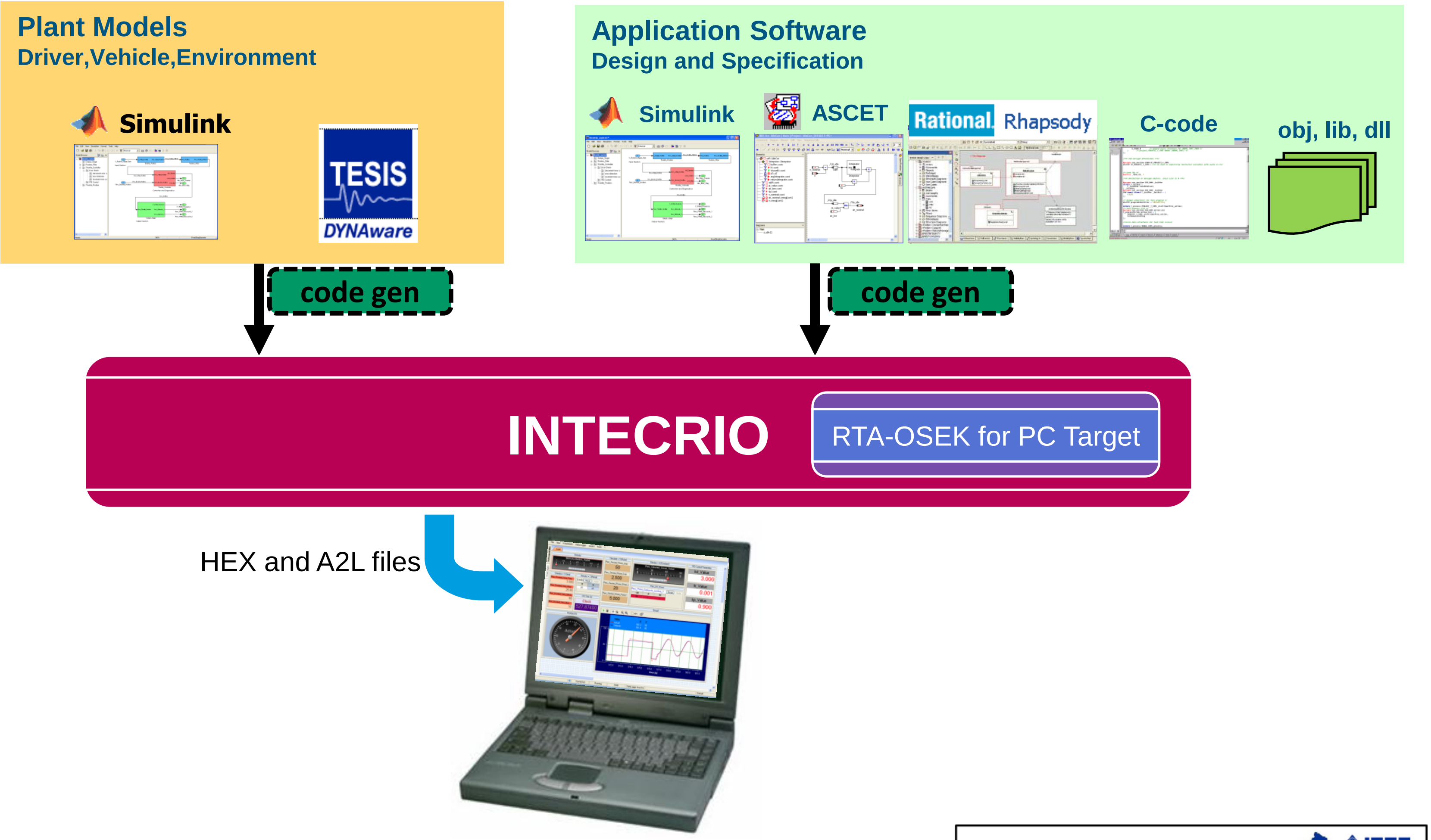
Driver Model

Environment Model

Vehicle Subsystem Models
(e.g. Engine, Transmission, Chassis)

Virtual Sensor/Actuator and Network Signal Bus

# What is INTECRIO?



Plant Models
Driver,Vehicle,Environment

Simulink

TESIS DYNAware

Application Software
Design and Specification

Simulink

ASCET

Rational Rhapsody

C-code

obj, lib, dll

code gen

code gen

INTECRIO

RTA-OSEK for PC Target

HEX and A2L files

# Key Takeaways

- PC-based development of ECU software is becoming more widespread due to cost and performance advantages
- INTECRIO is a versatile platform for PC-based verification and validation (e.g. in MiL and SiL phases)

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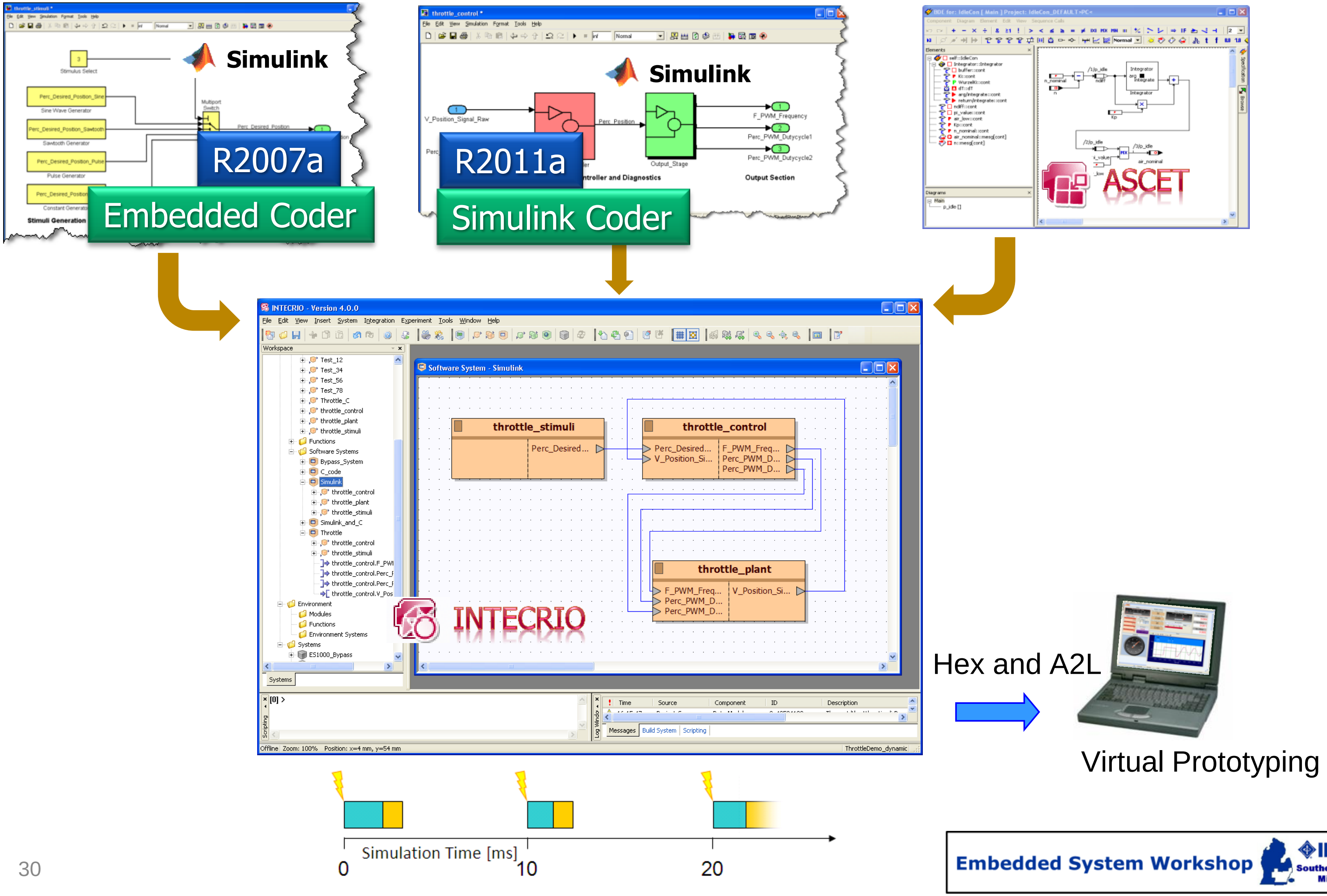
# INTECRIO for MiL



Hex and A2L

Virtual Prototyping

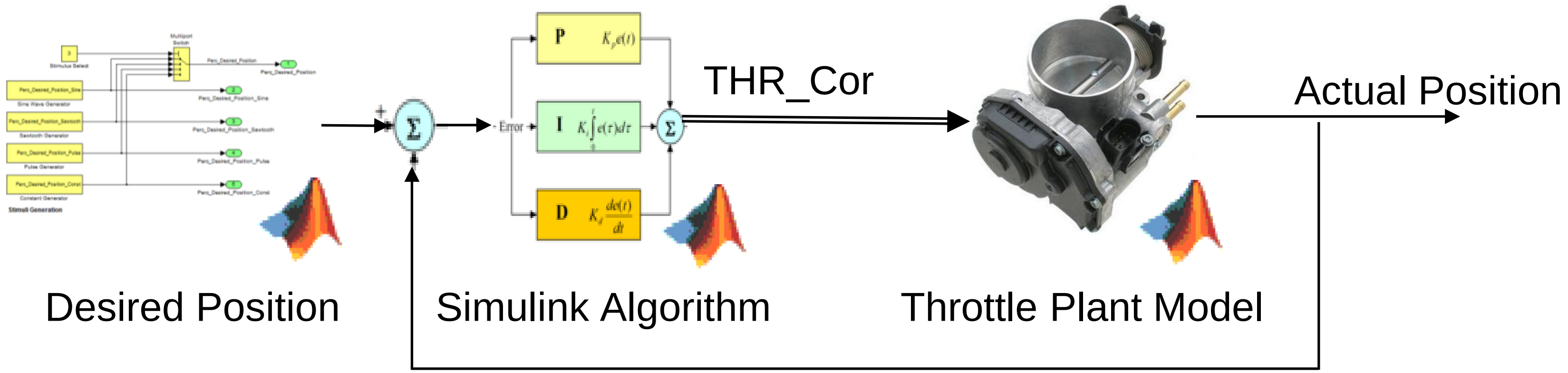
Simulation Time [ms]

0 10 20

# INTECRIO for MiL

# INTECRIO for MiL: Demo Setup

- Goal: Simulate a Simulink-based plant (throttle) + Simulink throttle controller specification.



THR_Cor

Actual Position

Desired Position

Simulink Algorithm

Throttle Plant Model

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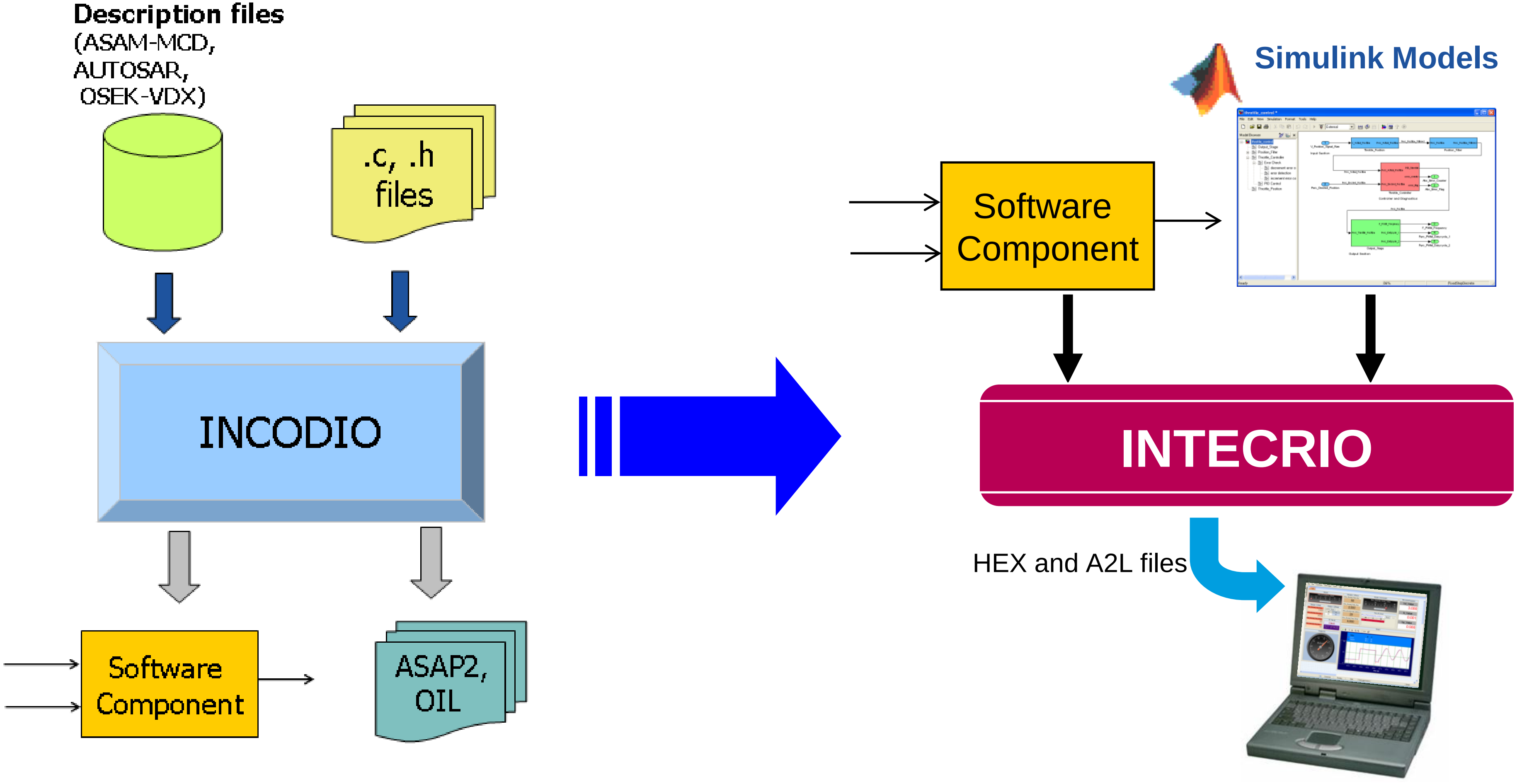
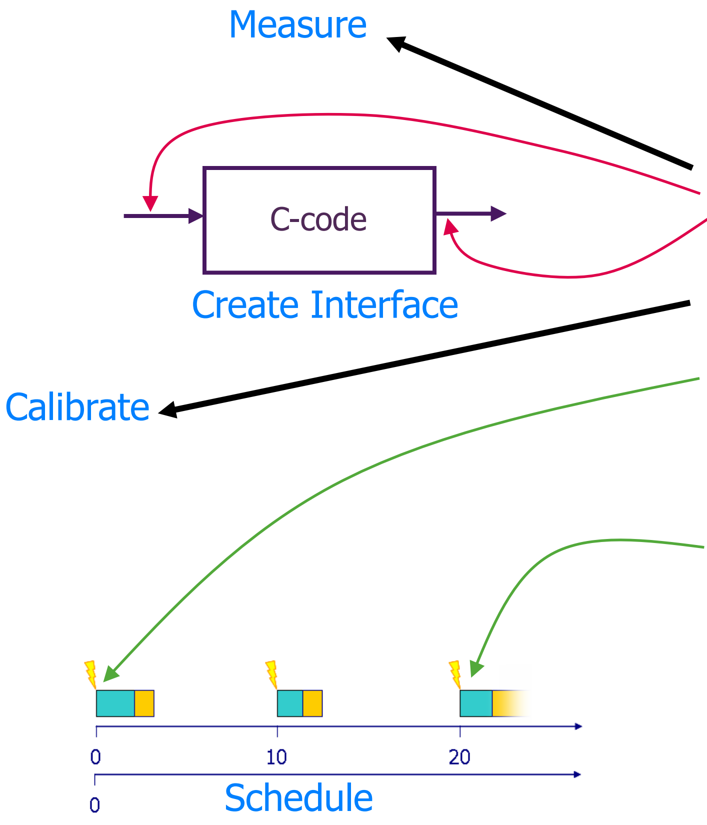
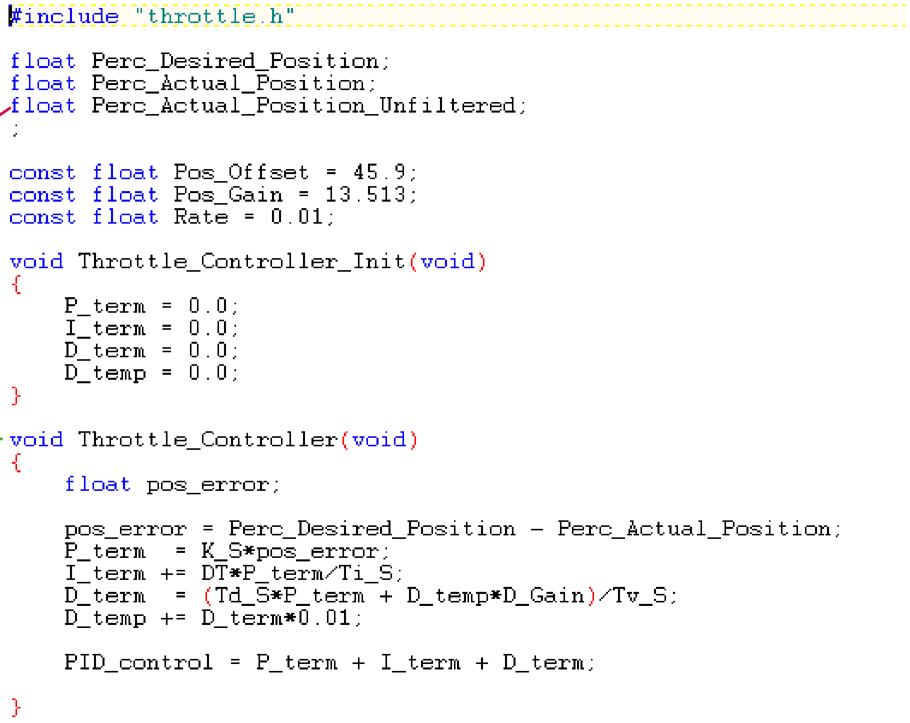
# INTECRIO for SiL – 2 steps



# INTECRIO for SiL – Step 1 with INCODIO



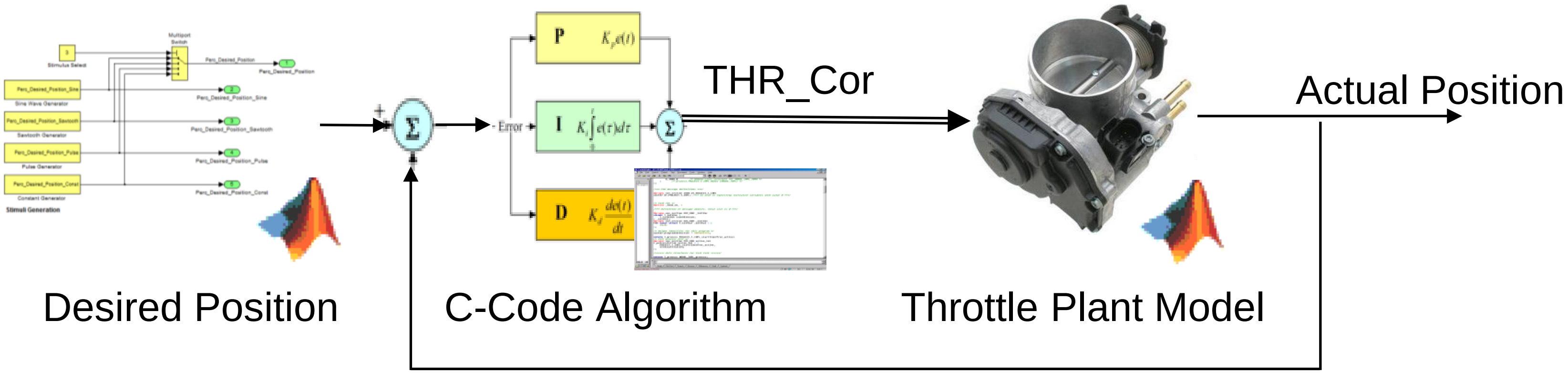


```
#include "throttle.h"

float Perc_Desired_Position;
float Perc_Actual_Position;
float Perc_Actual_Position_Unfiltered;
;

const float Pos_Offset = 45.9;
const float Pos_Gain = 13.513;
const float Rate = 0.01;

void Throttle_Controller_Init(void)
{
     P_term = 0.0;
     I_term = 0.0;
     D_term = 0.0;
     D_temp = 0.0;
}

void Throttle_Controller(void)
{
     float pos_error;

     pos_error = Perc_Desired_Position - Perc_Actual_Position;
     P_term  = K_S*pos_error;
     I_term += DT*P_term/Ti_S;
     D_term  = (Td_S*P_term + D_temp*D_Gain)/Tv_S;
     D_temp += D_term*0.01;

     PID_control = P_term + I_term + D_term;

}
```

# INTECRIO for SiL

# INTECRIO for MiL + SiL: Demo Setup

- Goal: Verify that the C-code implementation of the Throttle Controller matches specification, reusing the stimulus and plant Simulink models.



# Calibration of C-code with INCA

# Key Takeaways

- **MiL**: INTECRIO integrates one or more Simulink models at the code level, adds scheduling information and compiles for PC target.

- **SiL**: INCODIO parses C-code and makes it visible to INTECRIO for integration with models or other C-code.  INTECRIO adds scheduling information and compiles for PC target.

- **Calibration**: An industry standard tool like INCA can be used to pre-calibrate ECU software in the SiL environment

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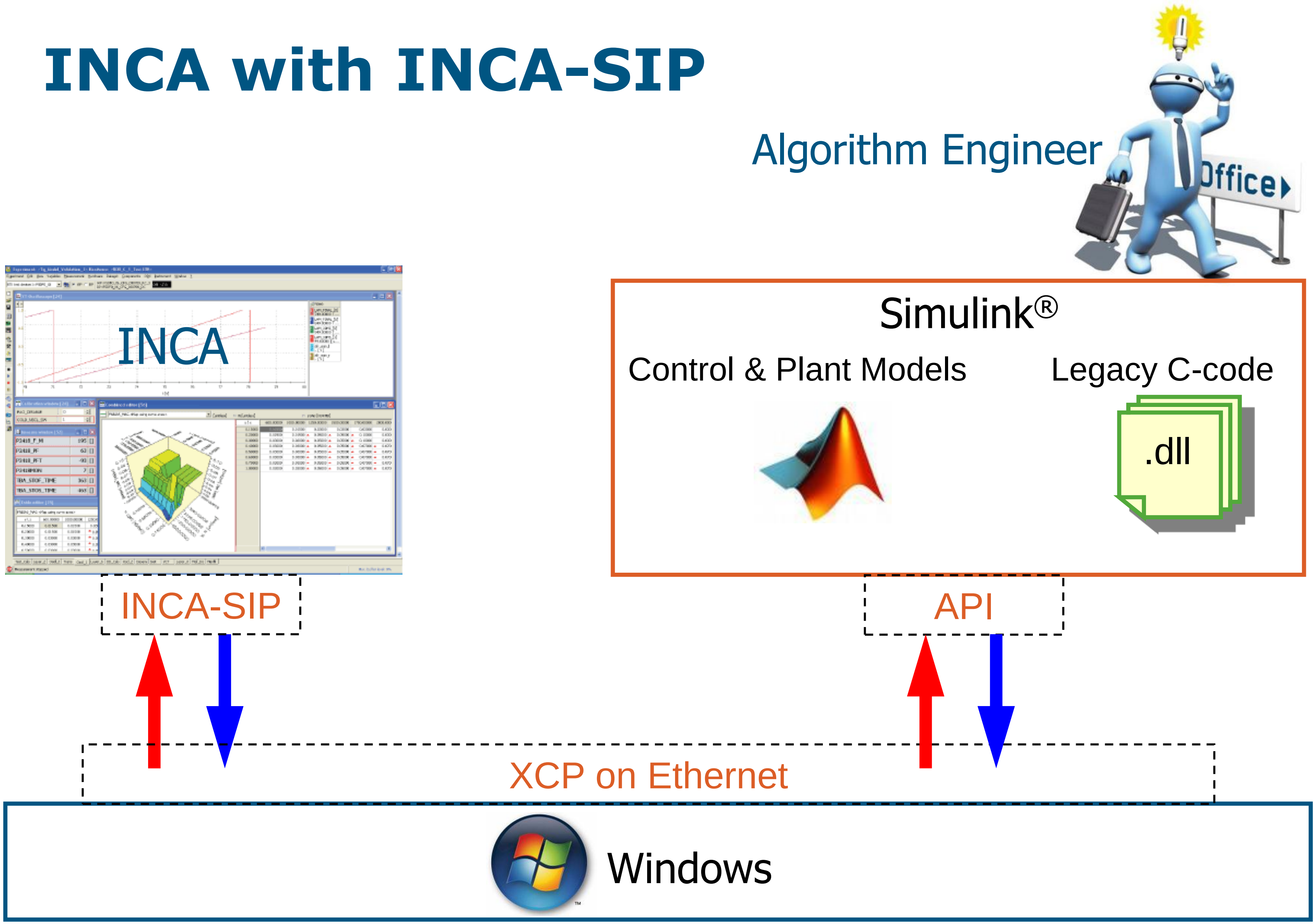
# INCA with INCA-SIP



Algorithm Engineer

INCA

INCA-SIP

Simulink®

Control & Plant Models

Legacy C-code

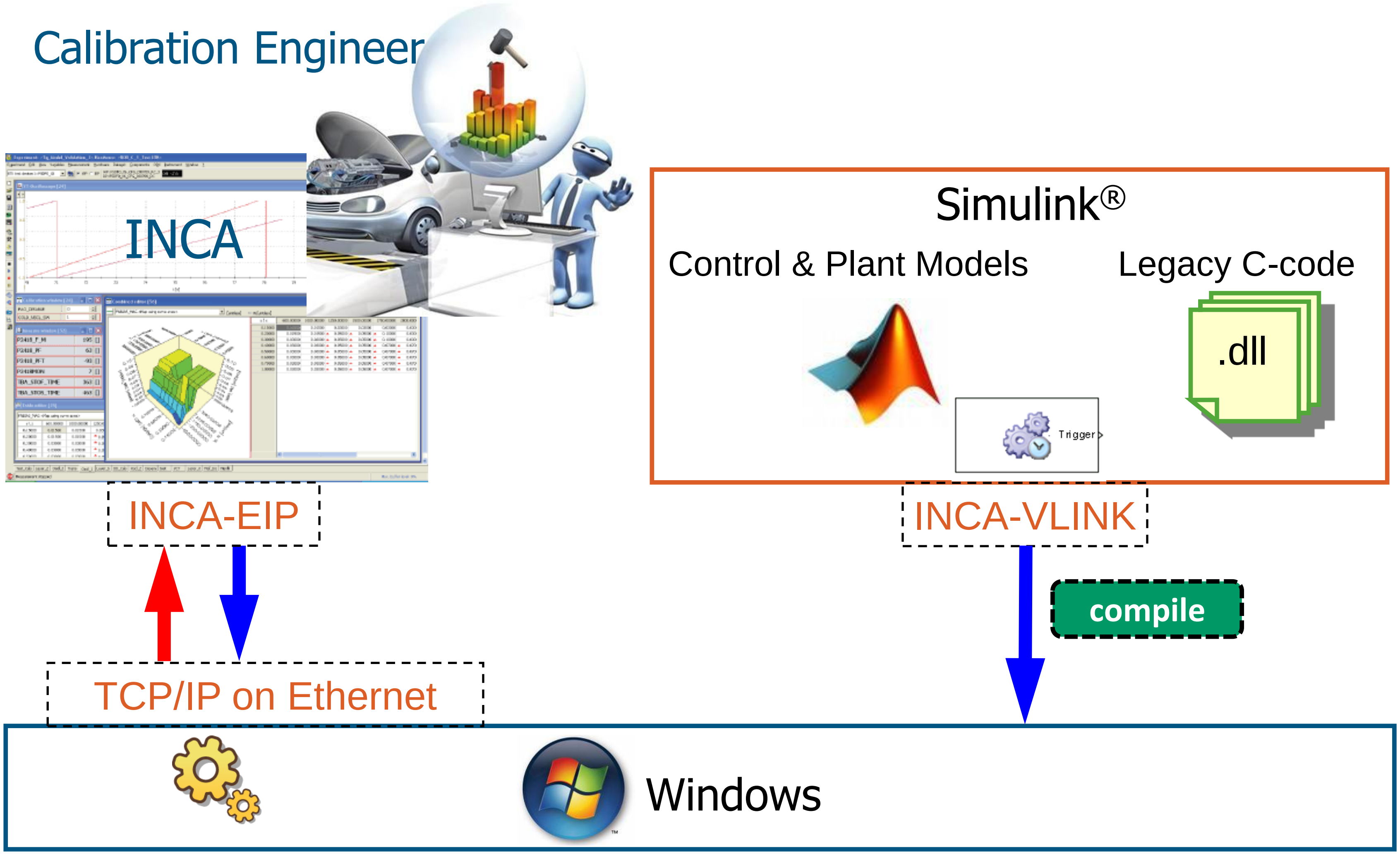
.dll

API

XCP on Ethernet

Windows

# INCA with INCA-VLINK



Calibration Engineer

INCA

Simulink®

Control & Plant Models

Legacy C-code

INCA-EIP

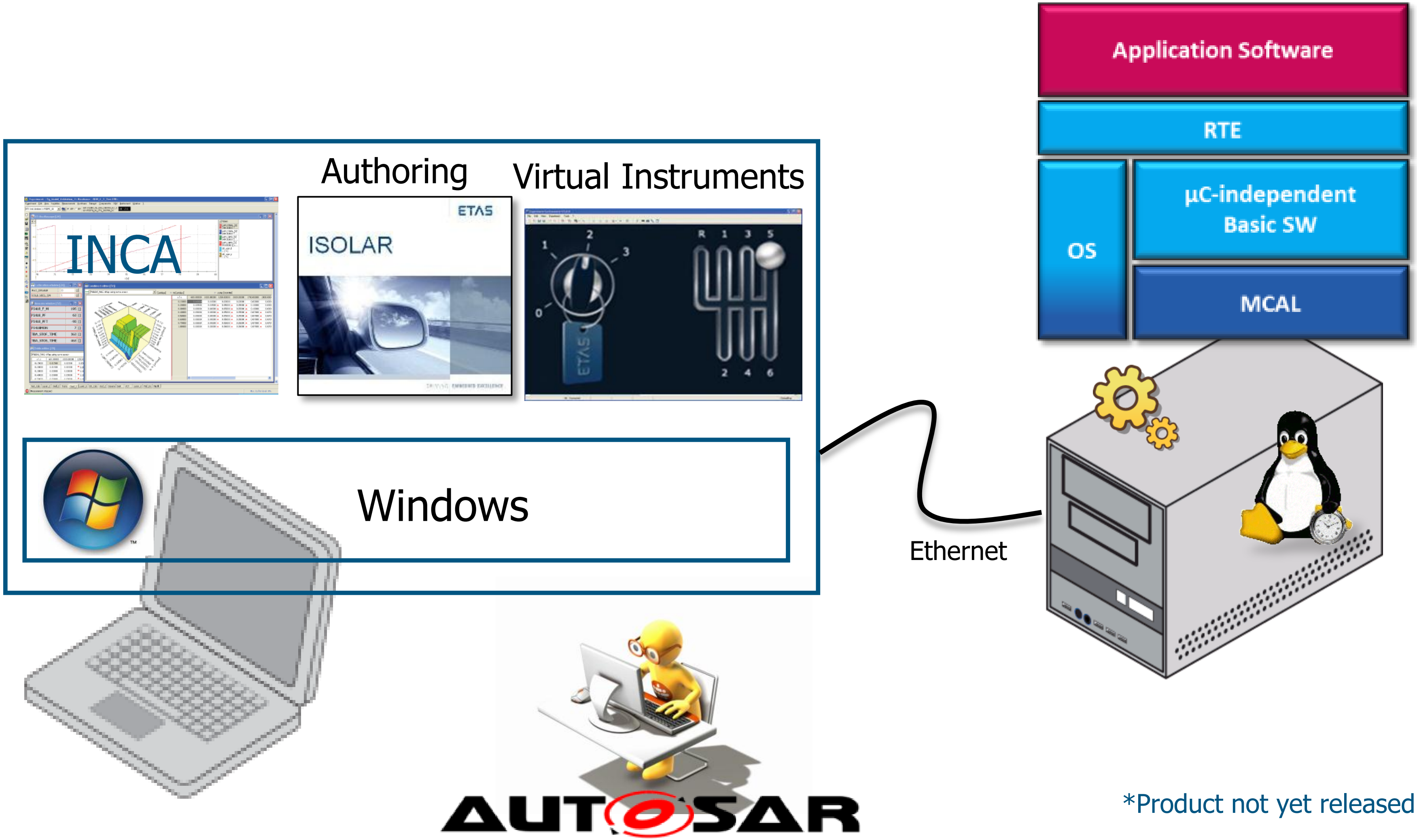
INCA-VLINK

compile

TCP/IP on Ethernet

Windows

# ISLOAR-EVE* (ETAS Virtual ECU)



*Product not yet released

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# Summary

- Virtual techniques can substantially lower the cost of verification and validation of ECU control models and software.
- Calibrators can use the same tools in the virtual environment as in the vehicle.
- Re-use of test cases, models and calibration data across the development cycle further optimizes cost and effort.
- AUTOSAR architecture further enables validation of ECU software on the PC platform

# Where to find more information?

1. Virtualization in Automotive Embedded Systems
   http://www.slideshare.net/REALTIMEATWORK/rts10-virtualization

2. Automotive: The Next Frontier for Virtualization
   http://www.ok-labs.com/blog/entry/automotive-the-next-frontier-for-virtualization/

3. Virtualization Technologies for Cars
   http://marko-wolf.de/files/PeWoWo08_ECU_Virtualization_EN.pdf

4. Road-to-lab-to-math: a new path to improved product
   www.sae.org/automag/features/futurelook/05-2005/1-113-5-78.pdf

5. SAE papers:
   - **2010-01-0660**: Maximizing Test Asset Re-use across MiL, SiL and HiL Development Platforms
   - **2010-01-0431**: Advanced Techniques for Simulating ECU C-code on the PC
   - **2012-01-0961:** Model-Based Verification and Validation of Electronic Engine Control

# Skills and Networking Opportunities

1. Skills required to leverage PC-based development:
   - Controls development (e.g. MATLAB/Simulink®)
   - Software development (e.g. ASCET, C-code)
   - Plant modeling (i.e. physical systems)
   - Verification and validation (i.e. testing of embedded software)
   - Understanding of AUTOSAR architecture

2. Networking opportunities:
   - Testing Expo (Novi): Oct 23-25, 2012
   - SAE World Congress (Detroit): April 16-18, 2013

# Thank you !

谢谢

감사합니다.

有難うございました

Merci

Vielen Dank