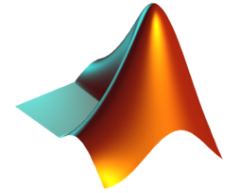




GEEDS - Group Electronics Expertise and Development Services



Live Debugging of Stateflow Charts While Running on ECU

Amjad Elshenawy & Mohammad Raouf

*Mathworks Automotive Conference 2015
Stuttgart, Sep., 24th 2015*

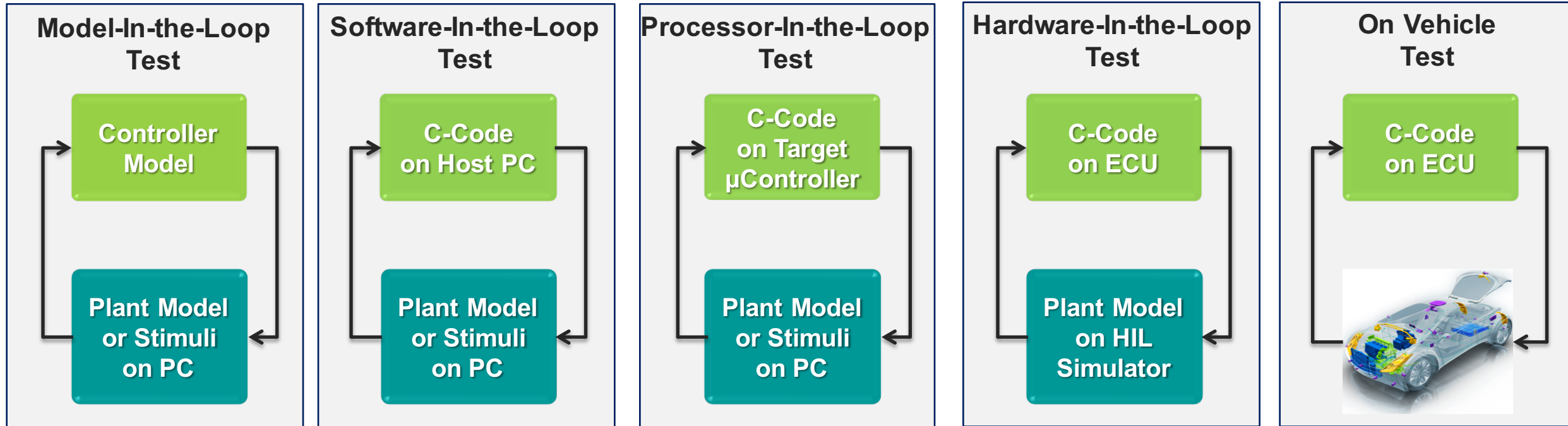
September 2015

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1	Testing & Debugging Techniques in MBD	3
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Testing in Model Based Design

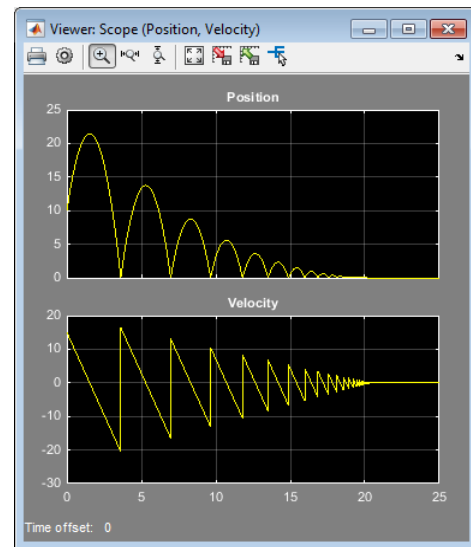


- What happens if a test case fails?
- How to debug in X-In-the-Loop testing?
- How to debug on Vehicle?

Debugging in Model-In-the-Loop (MIL) Testing

Simulink Blocks

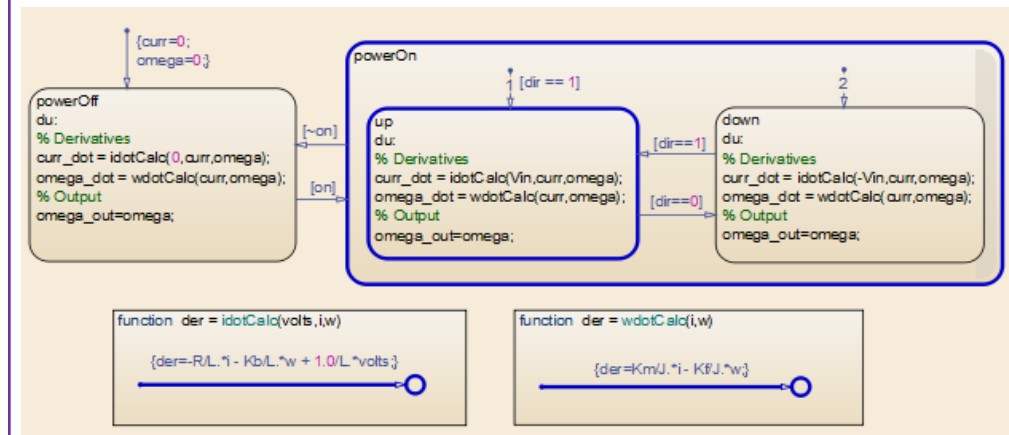
- Signal Analysis
 - Scopes and Signal Viewers
 - Signal Logging
 - etc ...



The figure shows the 'Break Points' configuration window in Simulink. It is titled 'Simulation Loop'. Under 'Break/Display points', there is a table with one row labeled 'Blocks'. Below this is a 'Remove selected point' button. Under 'Break on conditions', there are four checkboxes: 'Zero crossings', 'Step size limited by state', 'Solver Error', and 'NaN values'. At the bottom, there is a 'Break at time' field.

Stateflow Charts

- Stateflow Chart Animation
- Stateflow Breakpoints and Watch Data



Debugging in Software-In-the-Loop (SIL) & Processor-In-the-Loop (PIL) Testing

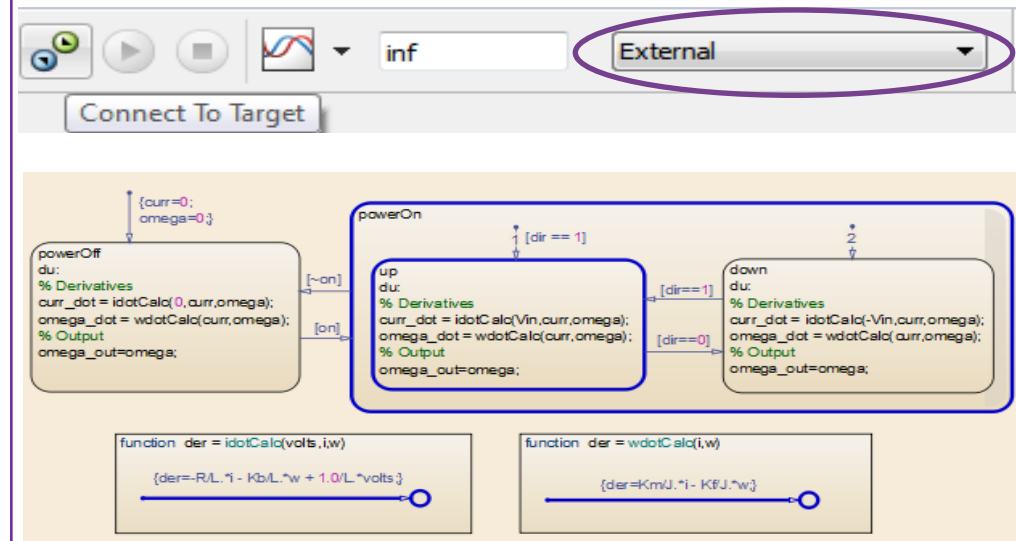
Simulink Blocks

- Signal Analysis
 - Scopes and Signal Viewers
 - Signal Logging
 - etc ...

Some Limitations Exist for
internal Signal Logging

Stateflow Charts

- Stateflow Chart Animation in “External Mode”
 - Chart local data can be viewed on signal viewers by designating them to be test points

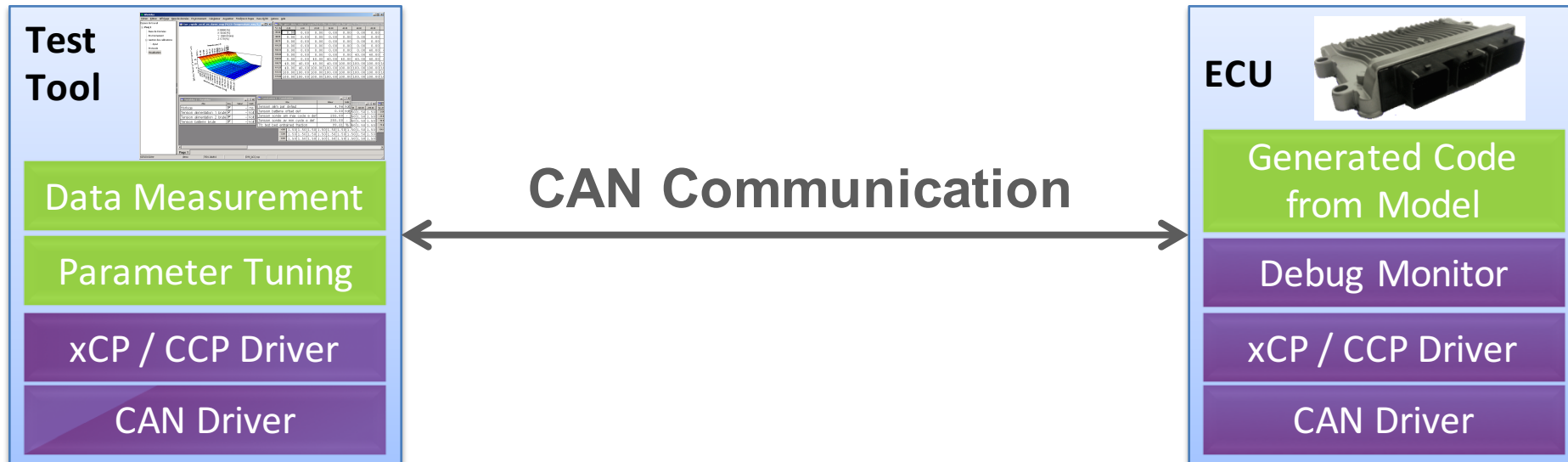


Debugging in Hardware-In-the-Loop (HIL) & On Vehicle Testing

- Design phase

- Identify debugging variables
- Declare debugging variables as “Global Variables” (they will have Fixed Memory Address)

- Validation phase



Debugging in Hardware-In-the-Loop (HIL) & On Vehicle Testing

Simulink Blocks

- Data acquisition and signal plotting
- Parameter tuning

The screenshot displays the WinAdeS software interface. The main window shows a 3D surface plot titled 'Corr_rapide_accel_en_duree_map (%) X=Temperature_eau, Y=...'. The plot shows a surface with a color gradient from blue (low) to red (high). The axes are labeled 'Temperature_eau [C]', 'Duree_accel [ms]', and 'Corr_rapide_accel_en_duree_map [%]'. A data table is visible on the right side of the plot window.

Below the 3D plot is a 2D line graph showing 'Engine_load' and 'Av_dr_deg_rendement_totale' over time. The x-axis represents time from 15 to 75. The y-axis represents values from 0 to 100. Two data series are plotted: a blue line for 'Engine_load' and a green line for 'Av_dr_deg_rendement_totale'. Two callout boxes provide specific data points:

- At time 21: Temps: 34.22, Engine_load: 35.390991, Av_dr_deg_rendement_totale: 1
- At time 63: Temps: 58.52, Engine_load: 61.952547, Av_dr_deg_rendement_totale: 0

At the bottom of the interface, there is a 'Constantes' window with a table of parameters:

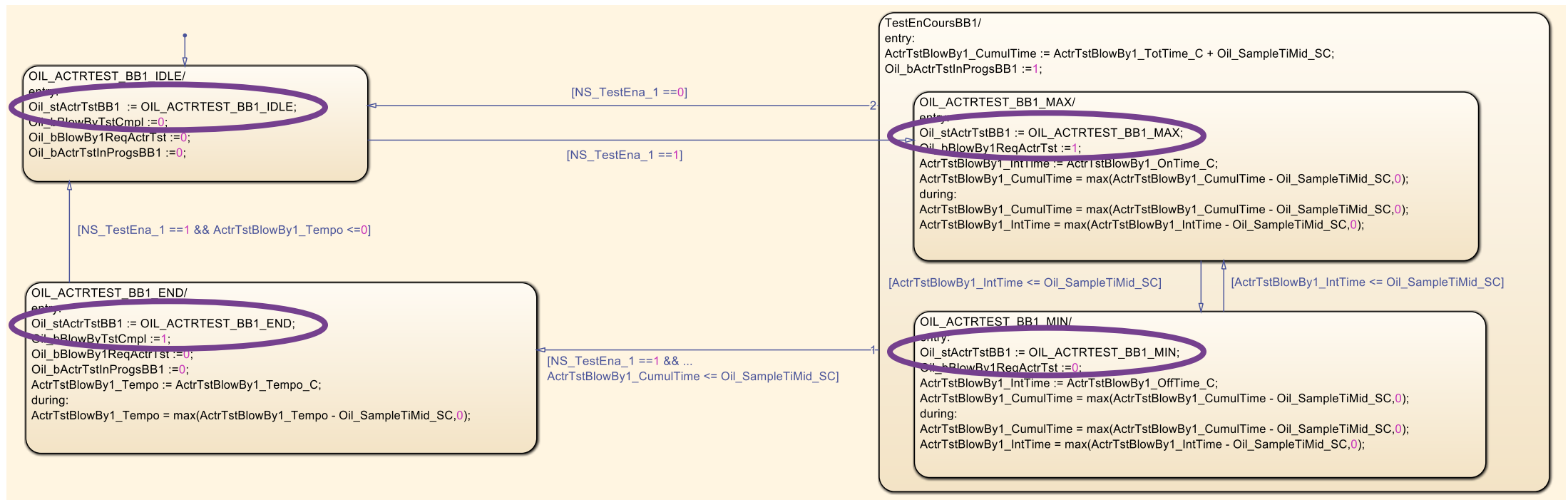
Nom	Valeur	Unité
ion alim par defaut	4.96	Volt
ion batterie offset def	0.00	Volt
ion sonde am max cycle e def	255.00	-
ion sonde av min cycle e def	255.00	-
rest bed entrained fraction	99.61	%



Debugging in Hardware-In-the-Loop (HIL) & On Vehicle Testing

Stateflow Charts – The Classical Way

- Manually create a debugging variable representing chart states

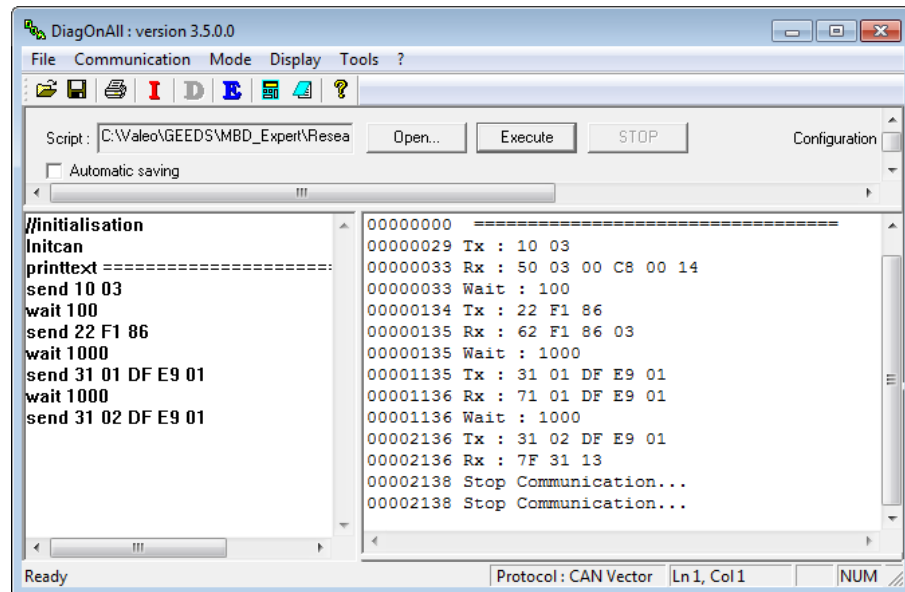


Debugging in Hardware-In-the-Loop (HIL) & On Vehicle Testing

Stateflow Charts – The Classical Way

- Visualize the value of the state variable using the test tool
- Run the test case and monitor the state variable

Name	Acq.	Value	Unit
Oil stActrTstBB1	<input checked="" type="checkbox"/>	-	-
Oil bActrTstInProgsBB1	<input checked="" type="checkbox"/>	-	bool
Oil bBlowBy1ReqActrTst	<input checked="" type="checkbox"/>	-	bool



Name	Acq.	Value	Unit
Oil stActrTstBB1	<input checked="" type="checkbox"/>	2.00	-
Oil bActrTstInProgsBB1	<input checked="" type="checkbox"/>	0	bool
Oil bBlowBy1ReqActrTst	<input checked="" type="checkbox"/>	0	bool

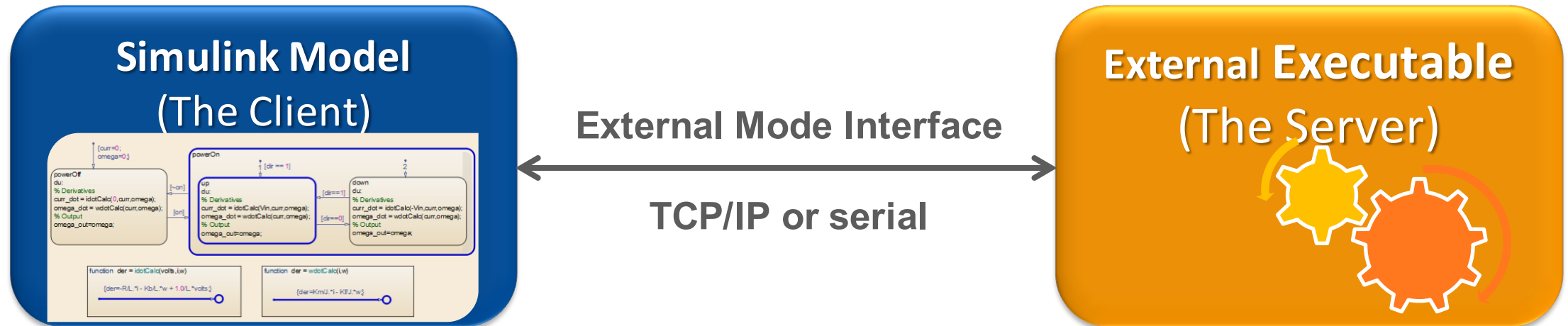
Stateflow Charts – The Classical Way

- Drawbacks of the Classical Way of Debugging Stateflow Charts
 - Manually Define State Variables
 - Extra development effort is required
 - Additional memory consumption
- Poor Visualization of Statecharts; No Statechart Animation
- Isn't there a better way to debug Stateflow charts running on ECU?
 - Valeo solution with visualization and animation of Stateflow models based on “Simulink External Mode” will be presented

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Overview of Simulink External Mode

- In “External Mode”, Simulink algorithm is executed outside Simulink environment. Simulink is merely a GUI for:
 - Visualizing Data
 - Acquiring Signals
 - Tuning Parameters (Provided that parameters are not inlined)



Configure Code Generation in External Mode

- In the model «Code Generation» configuration, configure:
 - « System target file » as « ert.tlc »
 - « Interface » as « External Mode »
 - « Transport Layer » as « tcpip » or « RS-232 (serial) »

Interface: External mode

Host/Target interface

Transport layer: tcpip MEX-file name: ext_comm

MEX-file arguments:

Memory management

Static memory allocation

Steps to start External Mode communication

1 Build the Target Executable

- Both code and external executable are generated

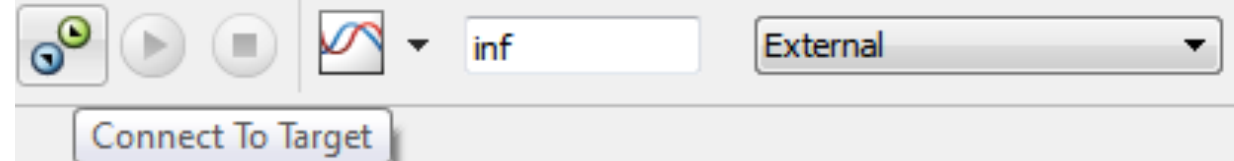
Generate code only

Build

2 Run the External Executable

```
C:\>external_executable.exe
```

3 Select Simulink simulation as “External” Mode



4 Connect to the Target

5 Start Simulation in External Mode

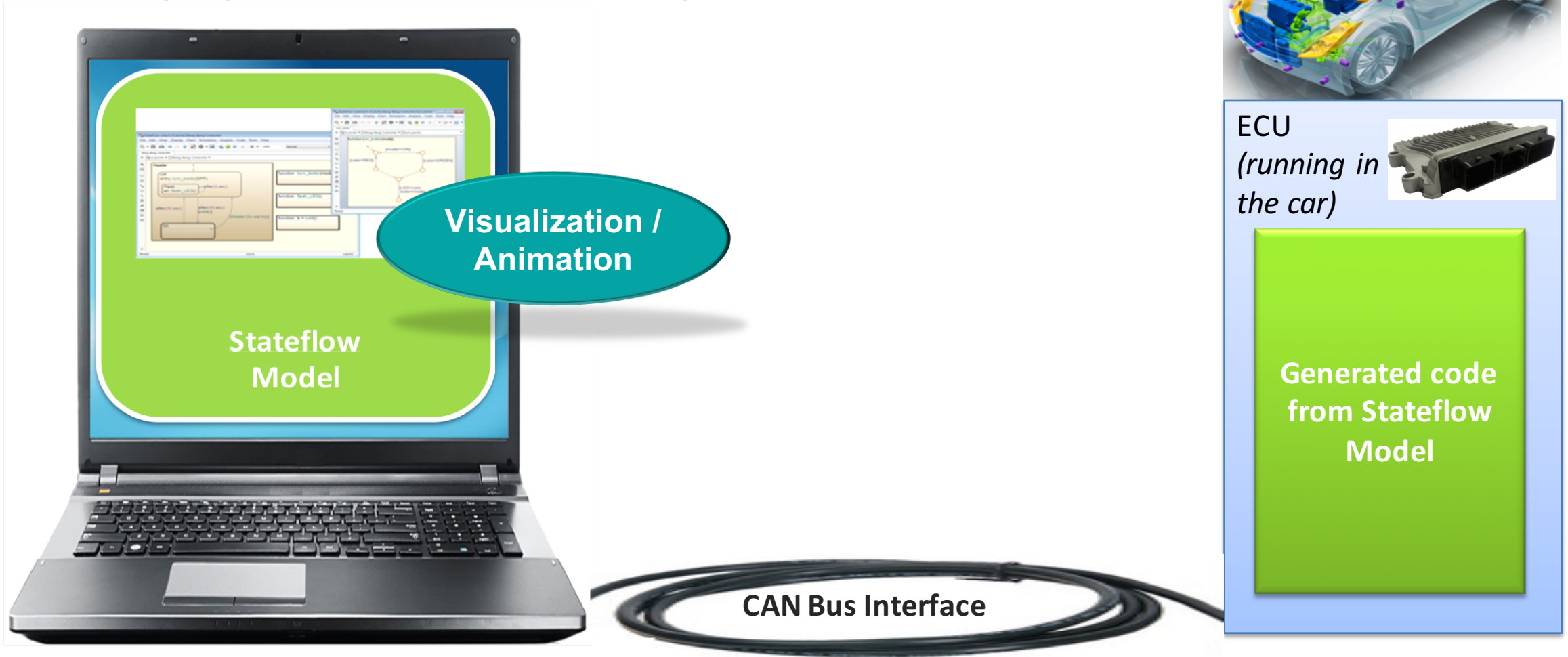
External Mode Remarks

- External mode uses “**Code Instrumentation**”
 - Includes extra header files
 - Adds code for data exchange and for transport layer
 - Adds extra variables
- ERT supports only two transport layers, namely, TCP/IP and RS-232 (serial).
No direct support for automotive communication protocols.

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Valeo Solution in Details

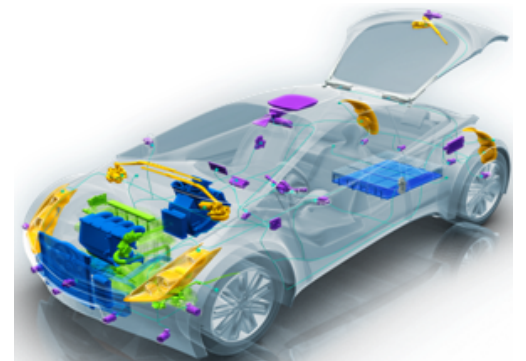
- To prepare environment, 3 steps are needed



Model State info on ECU

- Use Embedded Coder (ert.tlc) to generate a Global structure “DW_<modelName>”, containing active state of each state machine.

```
typedef struct {  
    ...  
    uint8_T is_StateChart_1;      /* ... */  
    uint8_T is_StateChart_2;      /* ... */  
    uint8_T is_StateChart_3;      /* ... */  
    uint8_T is_StateChart_4;      /* ... */  
    ...  
} DW_<modelName>;
```

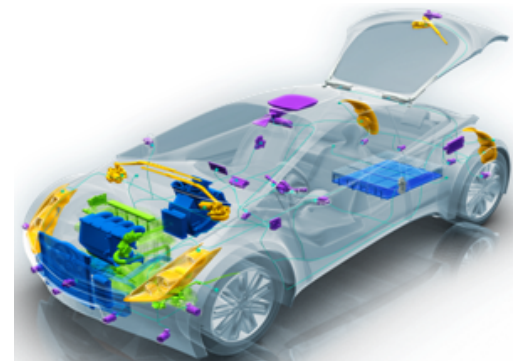


ECU
(running in the car)

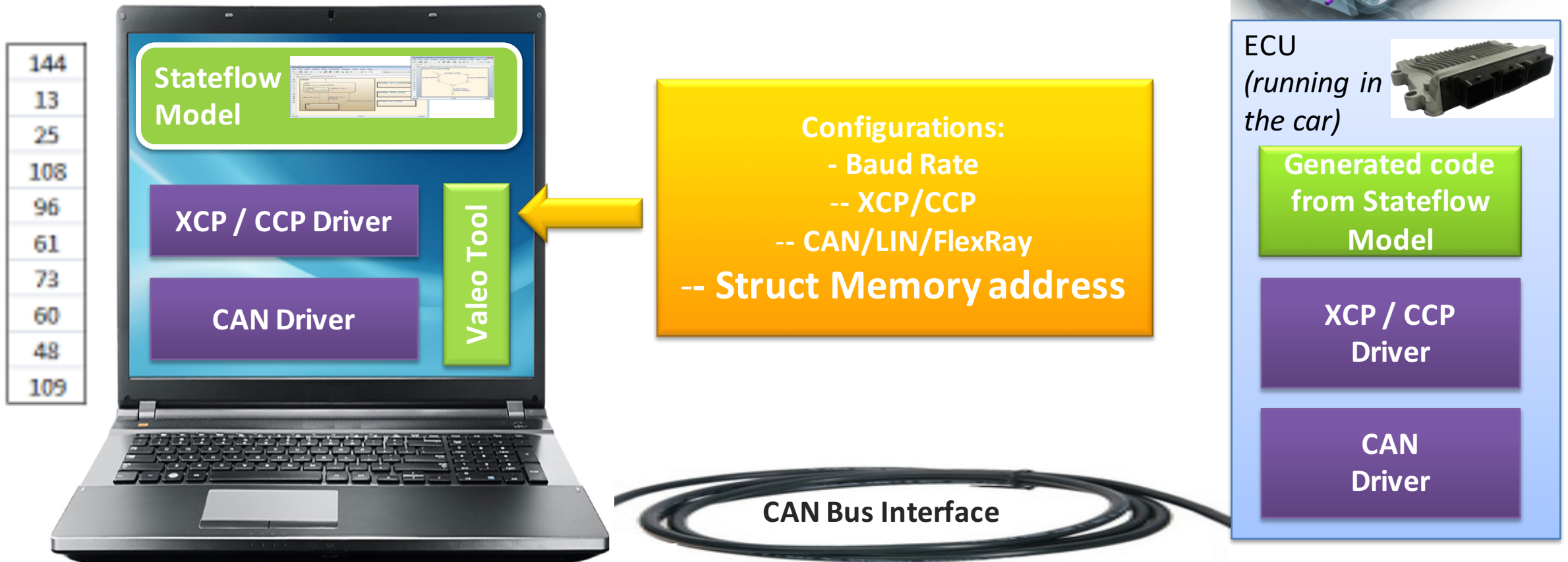
Generated code from Stateflow Model

No need for code instrumentation on Target !

1st Step: Exchanging Model States Info from ECU to PC

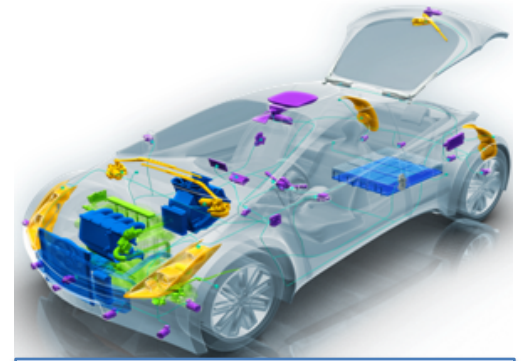


- Add XCP/CCP and CAN drivers on laptop
- Configure reception of data in Valeo Tool

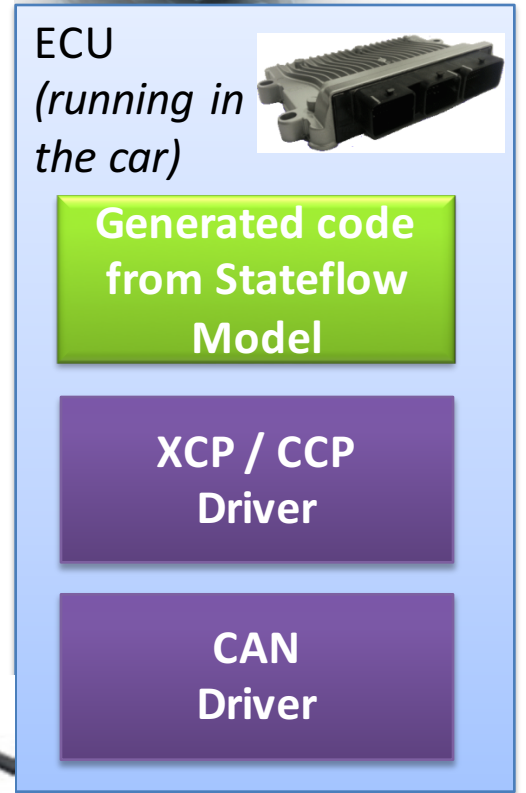


2nd Step: Exchange Received States Info to Simulink Model

- Modify generated External-Mode files:



144
13
25
108
96
61
73
60
48
109



2nd Step: Exchange Received States Info to Simulink Model

- Modifications in details:

- Comments all direct assignation to the states values
- Generates additional C files that directly update the states value with the values received from ECU



```
/* Entry: ActrTstBlowBy/F02_BlowBy2Tst/F01_BlowBy2TstChart */
/* ValeoTool Comment: ActrTstBlowBy_AUTOCODE_DWork.is_active_c1_ActrTstBlowBy_AUTO = 1U; */

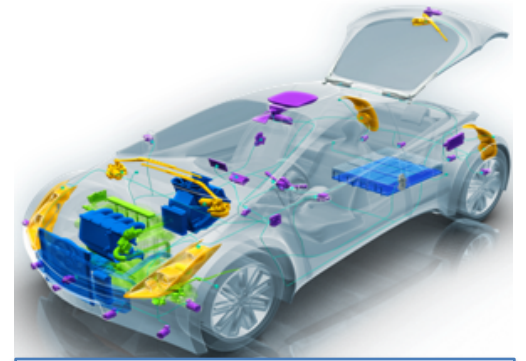
/* Entry Internal: ActrTstBlowBy/F02_BlowBy2Tst/F01_BlowBy2TstChart */
/* Transition: '<S8>:10' */
/* ValeoTool Comment: ActrTstBlowBy_AUTOCODE_DWork.is_c1_ActrTstBlowBy_AUTOCC
OIL_ACTRTEST_BB2_IDLE; */

/* Entry 'OIL_ACTRTEST_BB2_IDLE': '<S8>:1' */
Oil_stActrTstBB2 = OIL_ACTRTEST_BB2_IDLE;
```

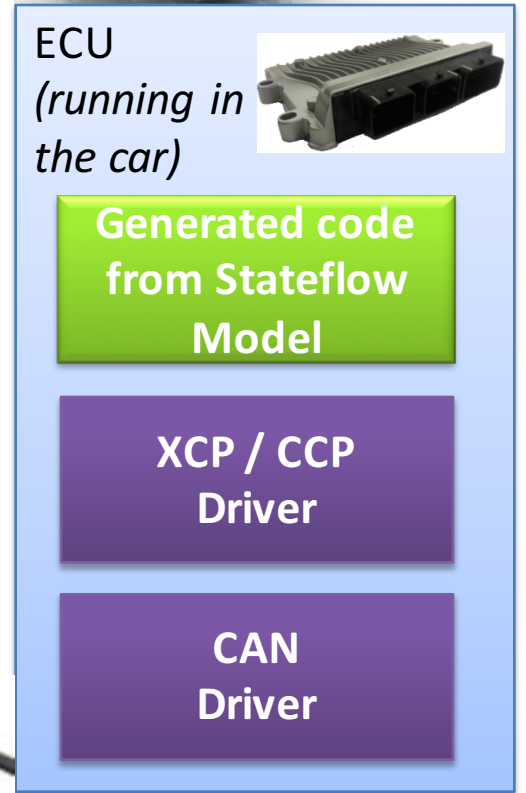
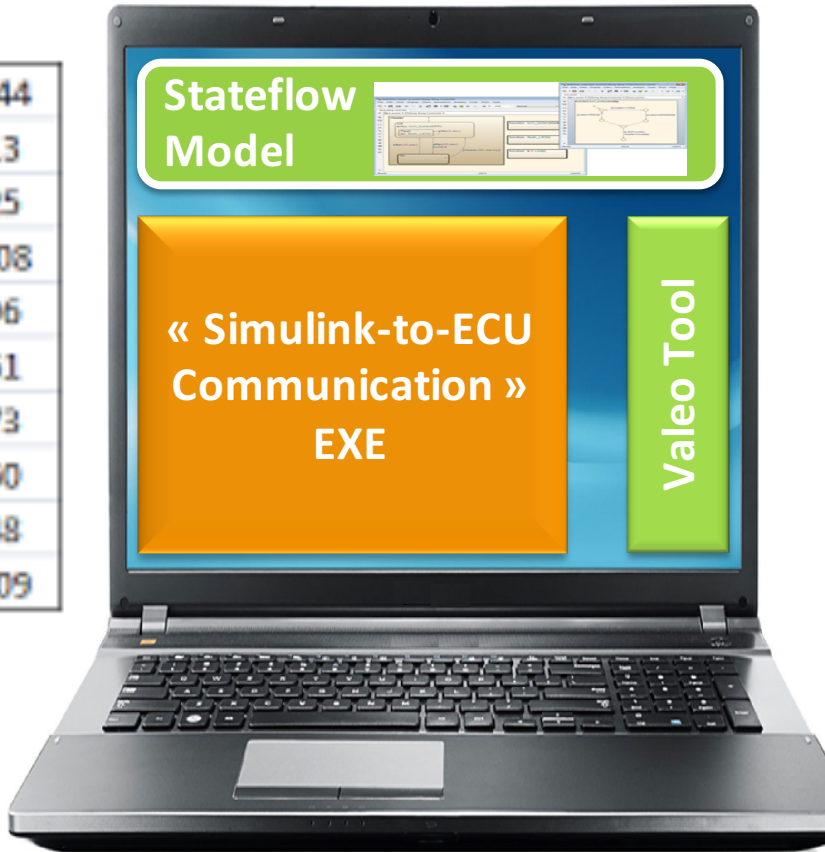


3rd Step: Final Setup

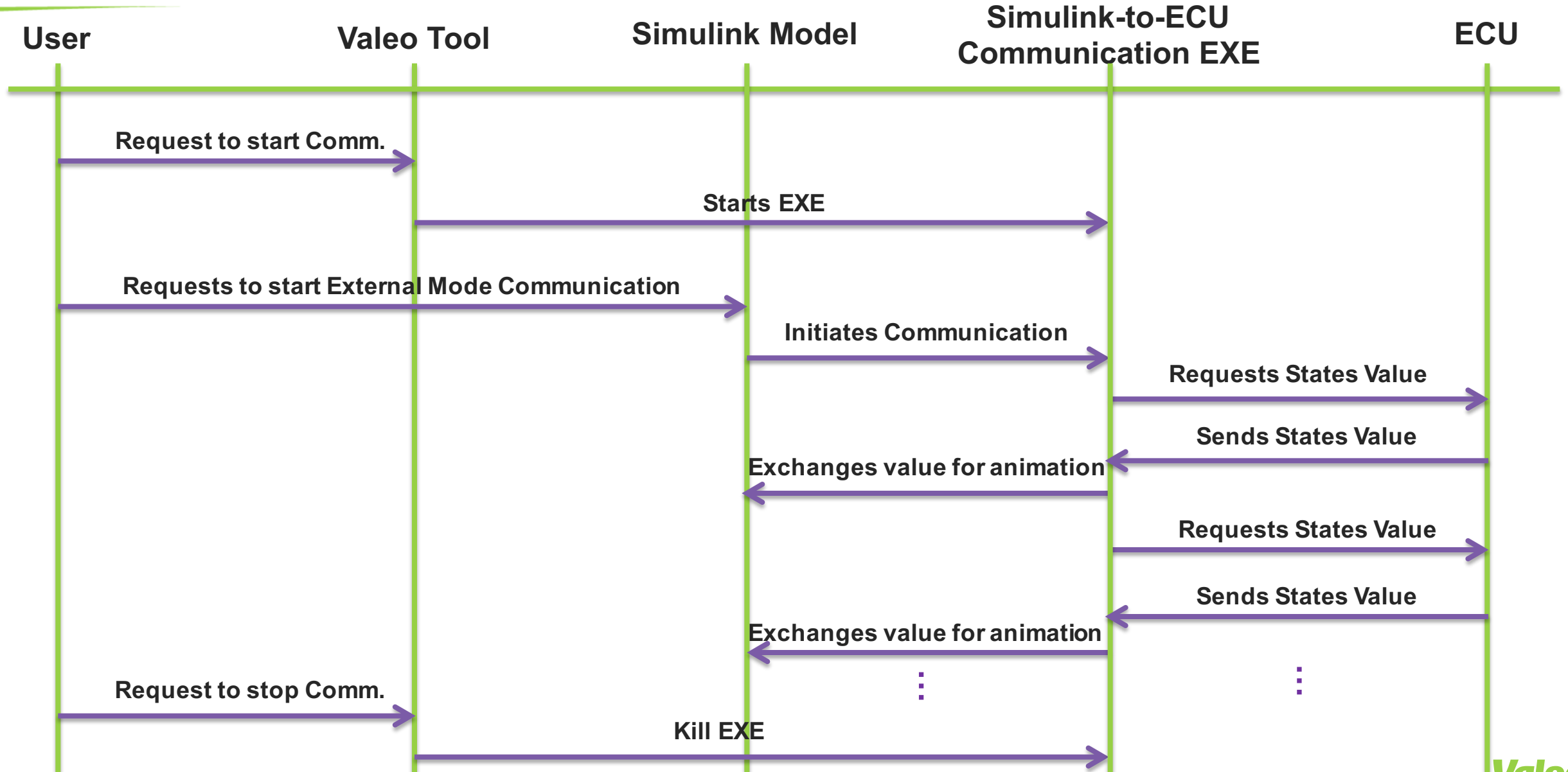
- Generate executable “Simulink-to-ECU Communication”:



144
13
25
108
96
61
73
60
48
109



Then, launch Stateflow Debugging Activity



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Conclusion

- Using “Simulink External Mode”, and with our in-house tool, we were able to read Statechart information in real-time from the ECU and accordingly animate Stateflow charts on PC.
- This technique facilitates a lot debugging of Statecharts for on-vehicle tests.
- Next step is to support FlexRay and LIN communication protocols.





Automotive technology, naturally

