AUTOMOTIVE CPS: INTEGRATION CHALLENGES AND EXPERIMENTAL PLATFORM

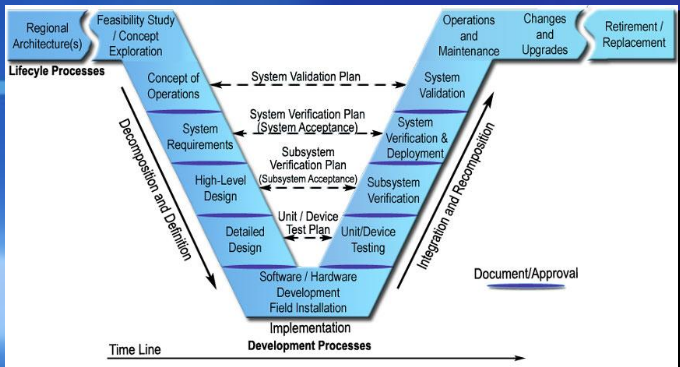
In Support of NSF CPS Science of Integration Project

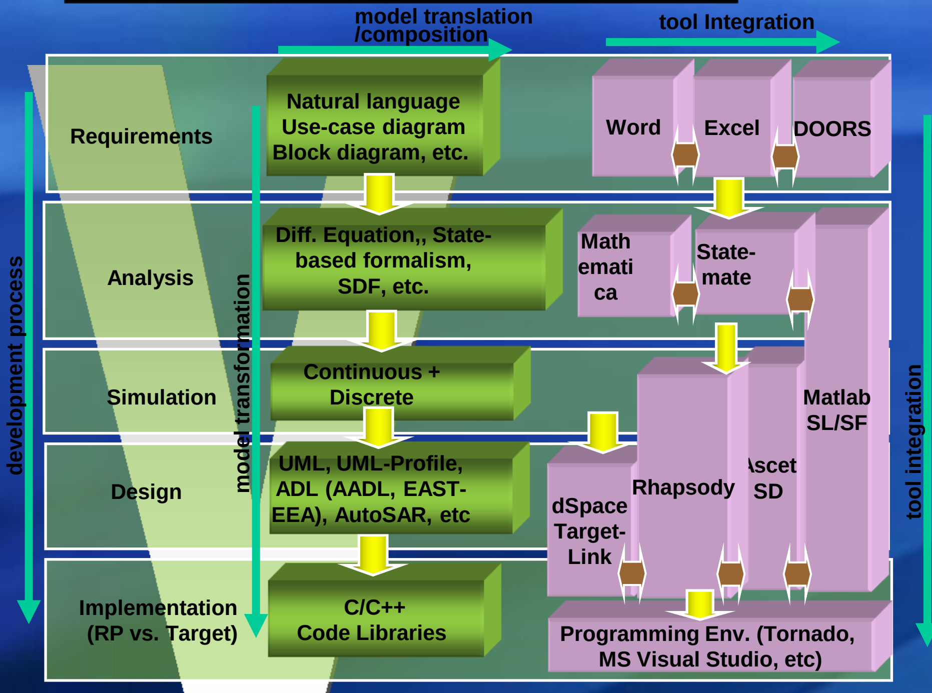
ECS Process, Methods and Tools Group
Electrical and Controls Systems Research Lab
General Motors Global R&D

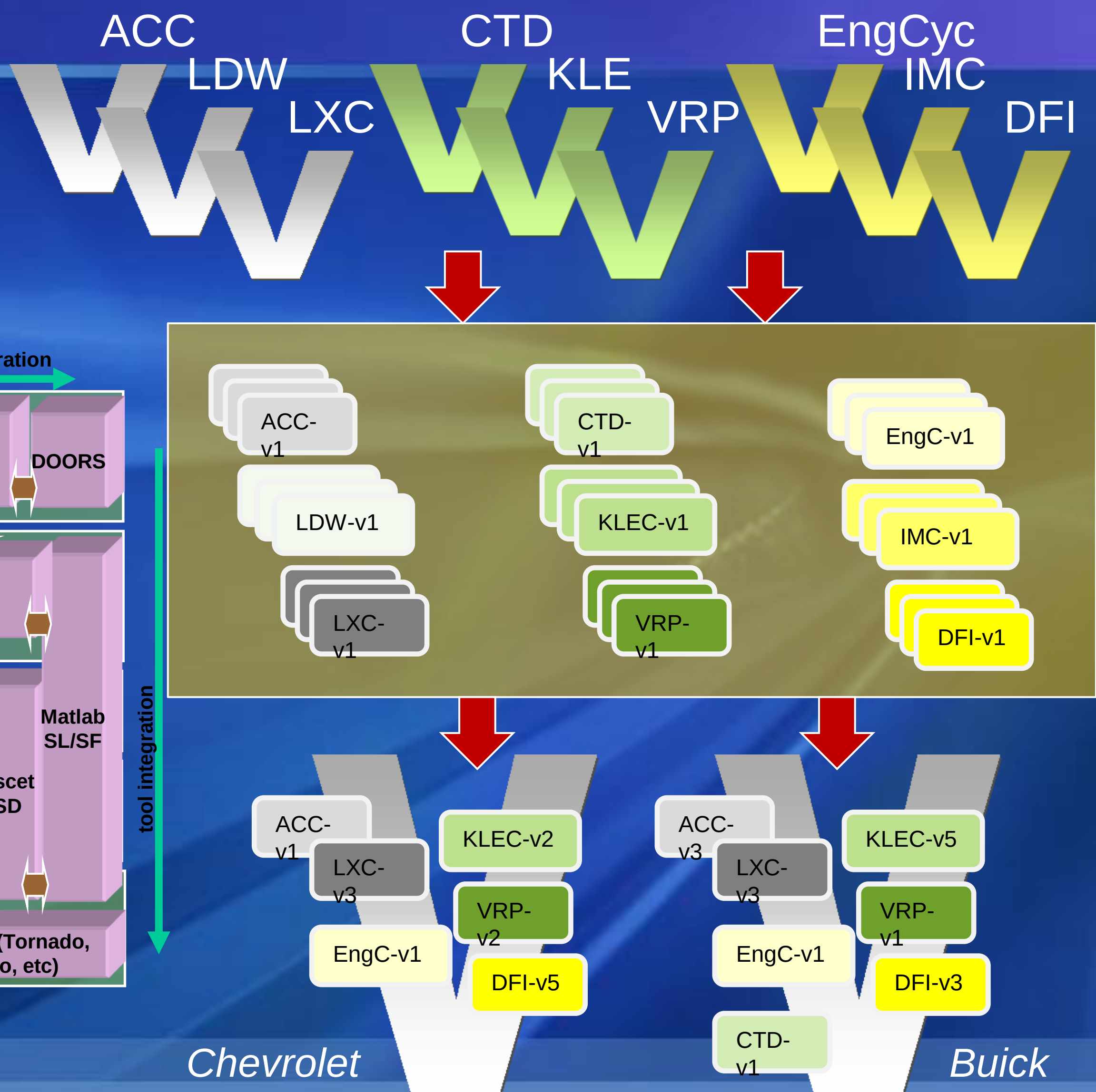
2012 GM Support & Interactions

- Site Visits
  - Prof. John Baras visited GM R&D (July/August 2012)
  - GM visits to ND (early 2012)
- GM provided 2 summer internships
  - Po Wu, Notre Dame University
  - Yuchen Zhou, Univ. of Maryland

Vehicle Control System Development







Automotive Evaluation Platform

- Integration Scenario 1
  - Product configuration – plug-play features
- Integration Scenario 2
  - Impact of new E/E technology – plug-play platform
- Integration Scenario 3
  - New property – plug-play property

Progress Summary

- Integration scenario 1: Passivity case study
  - Demonstrate the usefulness of the passivity property for integration of multiple features
  - ACC design improvement with passivity index
  - As a use case to exercise on experimental platform (at VU)
- Integration scenario 2: Simulation-based
  - Virtual platform using simulator
  - Integrated with control and vehicle simulator
  - Ongoing - GM experimental platform
    - Freescale Corba Dual-core controller
    - Debugging and runtime data logging equipment
- Integration scenario 3: System safety
  - Start from robust assessment – home-made tool

Progress Summary

- Integration scenario 1: Passivity case study
  - ACC design improvement with passivity index

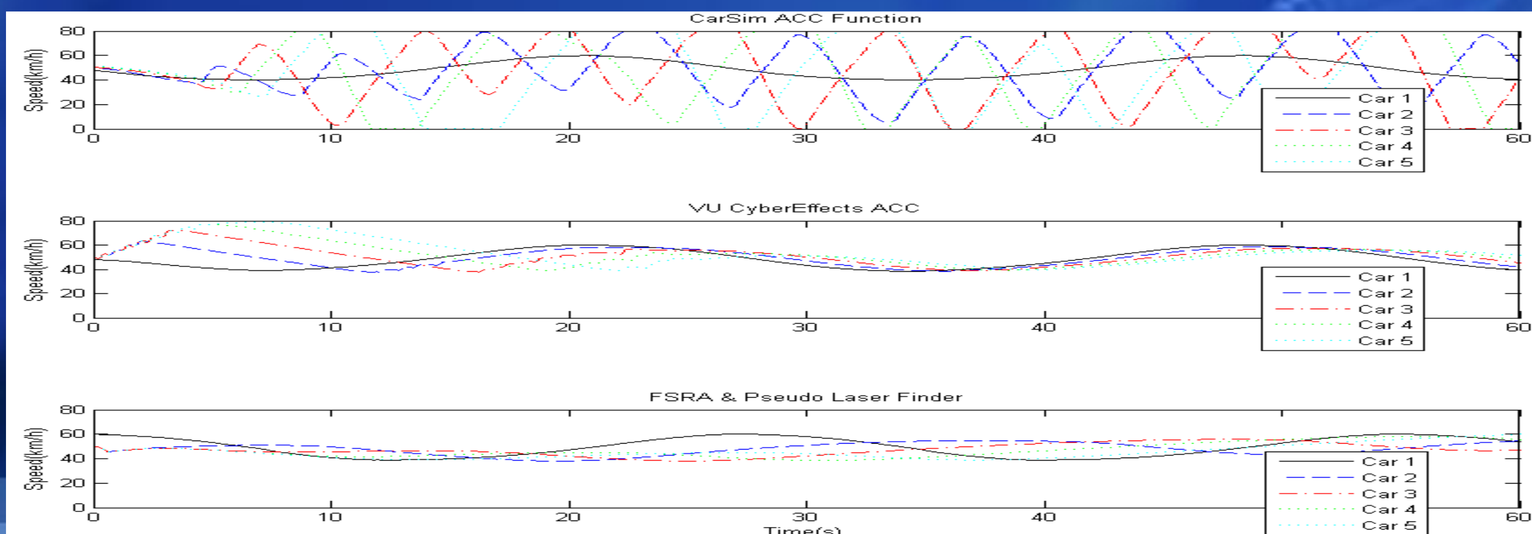
Vehicle i - 1 → Position / Speed → Vehicle i → Position / Speed → Vehicle i + 1 → Position / Speed

For example

$$\begin{bmatrix} X_h \\ V_h \end{bmatrix} = H \begin{bmatrix} X_l \\ V_l \end{bmatrix}$$

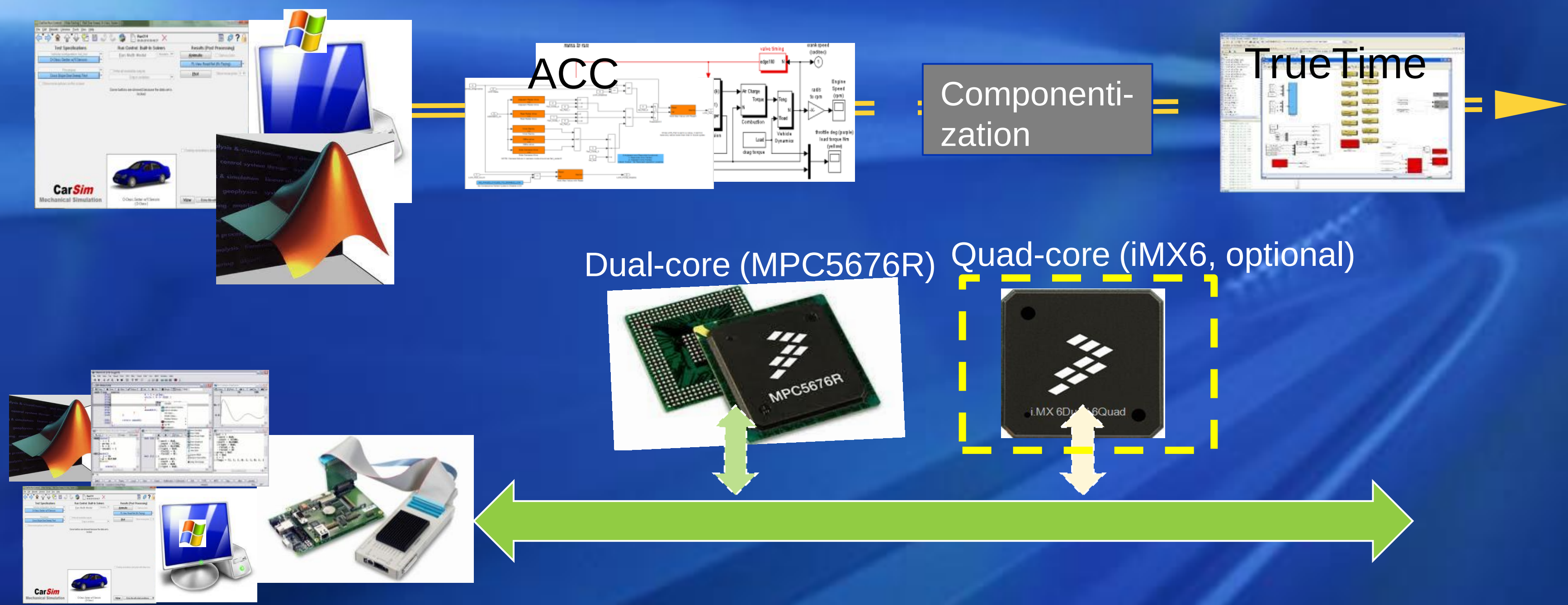
$$H = \begin{bmatrix} \dfrac{s^3 + 5.2s^2 + 15.51s + 1.5}{s^4 + 15.2s^3 + 25.51s^2 + 4.4s + 0.2} & \dfrac{-10s^3 - 36s^2 - 18.5\,s - 1.5}{s^5 + 15.2s^4 + 25.51s^3 + 4.4s^2 + 0.2\,s} \\ \dfrac{-5s^3 - 2.5s - 0.2}{s^5 + 15.2s^4 + 25.51s^3 + 4.4s^2 + 0.2\,s} & \dfrac{s^4 + 10.2s^3 + 10.01s^2 + 2.9\,s + 0.2}{s^5 + 15.2s^4 + 25.51s^3 + 4.4s^2 + 0.2\,s} \end{bmatrix}$$

$$\rho = \frac{1}{2}\min_{\omega \in \mathbb{R}}\left(eig(H + H^{-1})\right) = 40$$



Progress Summary

- Integration scenario 2: simulation-based
  - GM experimental platform extension

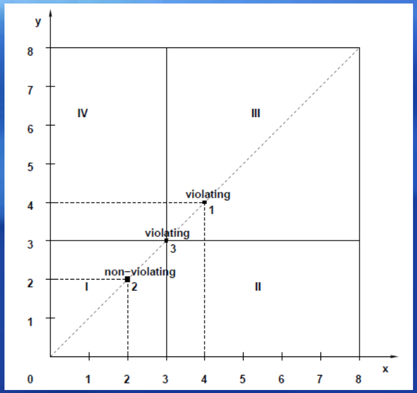


- Results compared with VU platform for validation and assessment

Progress Summary

- Integration scenario 3: System safety
  - Start from robust assessment – home-made tool

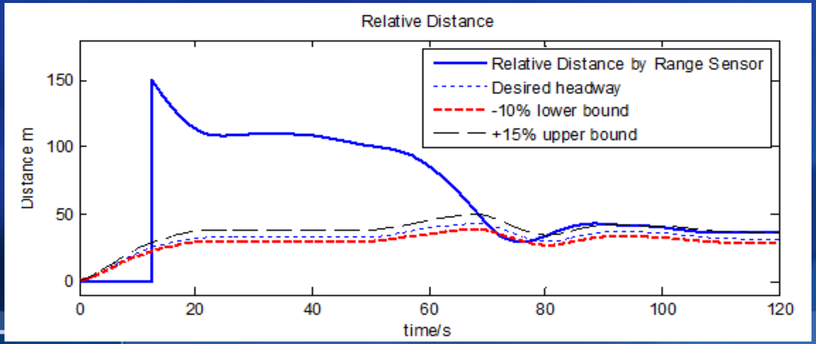
Method: divide-and-conquer



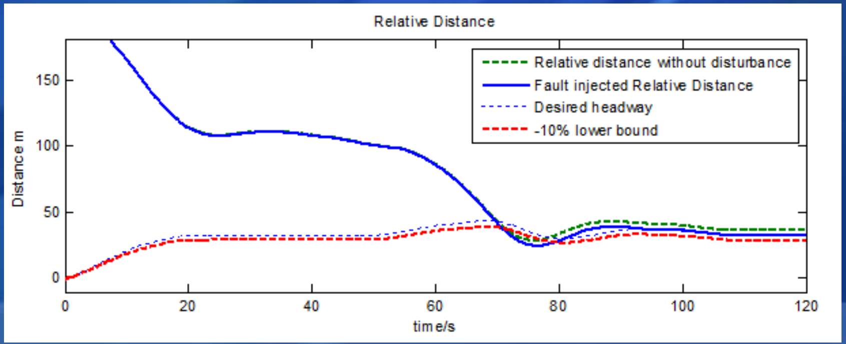
Counter-examples from RobustTool

Index	Part of Minimal Counter Example set
1	4 m shift on laser range
2	3 m noise on laser range and 1 km/h shift on laser range rate
3	2 km/h shift on laser range rate
4	1 m shift on laser range and 1 km/h shift on laser range rate
5	2 m shift on laser range and 5 km/h noise and 2 spikes on laser range rate
6	3 m shift and 1 m noise and 3 km/h noise and 2 spikes on laser range rate

Expected behavior



Behavior with fault in counter-example (4m shift)



THANK YOU