Requirements Development in the Automotive Industry: Challenges and Opportunities

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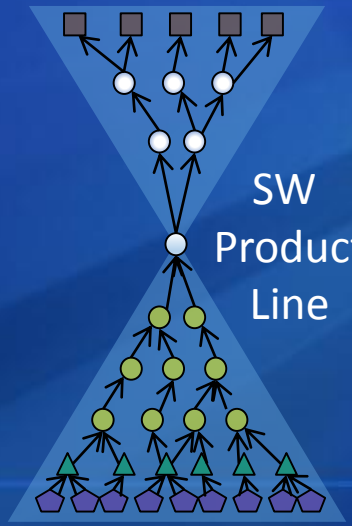
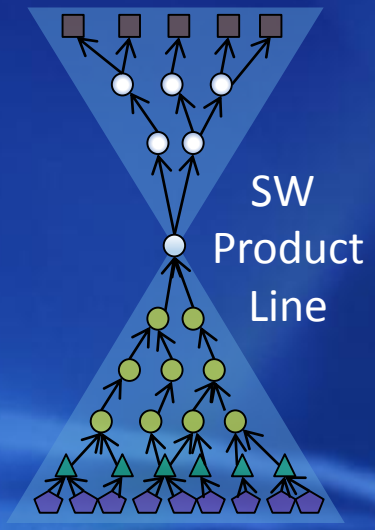


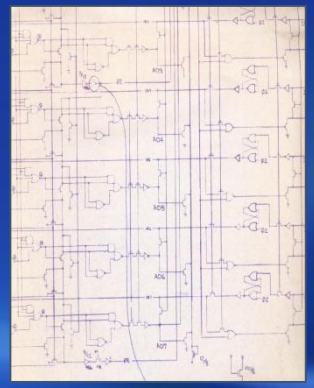
Outline

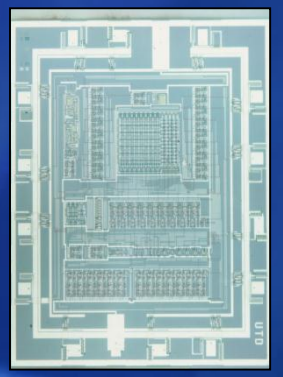
- Introduction
- Requirements Development for Automotive SW Product Lines
- GM R&D Experiences with Requirements Development for the SuperCruise Feature
- Summary



About Me – Dr. Joseph D'Ambrosio

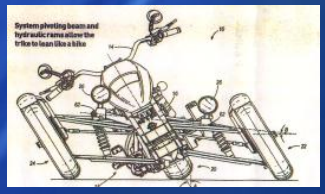
- Automotive Industry 25+ years
  - GM, Delphi
  - Research, Advance Development, Product Development
  - Model-Based Sys. & SW Development, Safety-Critical Systems, Cyber Security, By-Wire Systems, Vehicle Control Systems, VLSI Design & Tools, Testing
  - ISO Technical Expert – ISO 26262 Automotive Functional Safety Standard
- PhD University of Michigan – EE Design Methods / Optimization
- 50+ publications, 7 patents





QUADRASTEER
Four Wheel Steering

E-STEER
Electric Power Steering



GM RESEARCH & DEVELOPMENT

Warren, MI

SHANGHAI, CHINA

PALO ALTO, CA

HERZLIYA, ISRAEL

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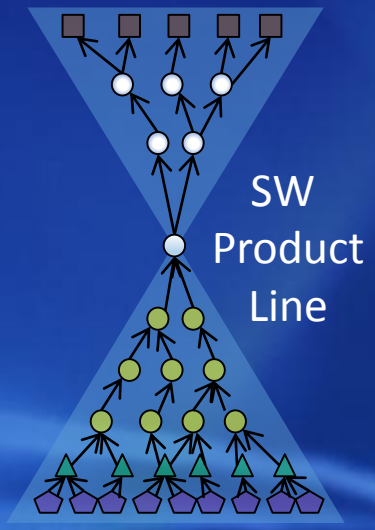


General Motors
Electrical, Controls and Software

- GM has one of the most complex systems and software product line engineering challenges in the world
  - 3000 contributing engineers
  - 300 hierarchical subsystems
  - Thousands of variant features
  - 100 Million lines of code
  - Millions of product instances per year
  - Tens-of-thousands of unique product variants
  - Dramatic increase in variation due to new propulsion systems and active safety
  - Global diversity in legislative regulations
  - Extreme economic and competitive pressures
  - Product line and feature set evolves annually
  - 15 concurrent development streams

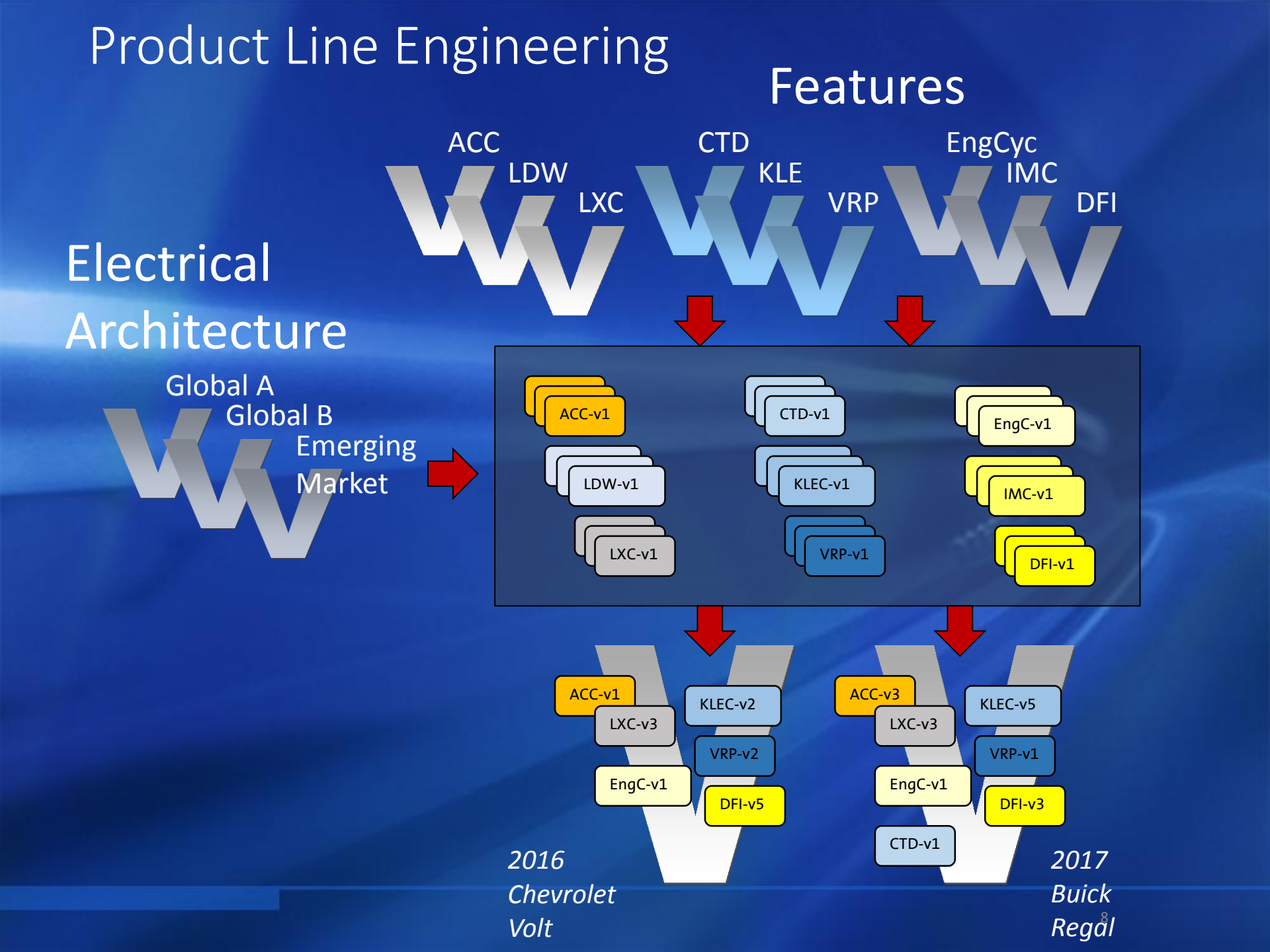
6

GM Enables massive Reuse through Software Product Lines

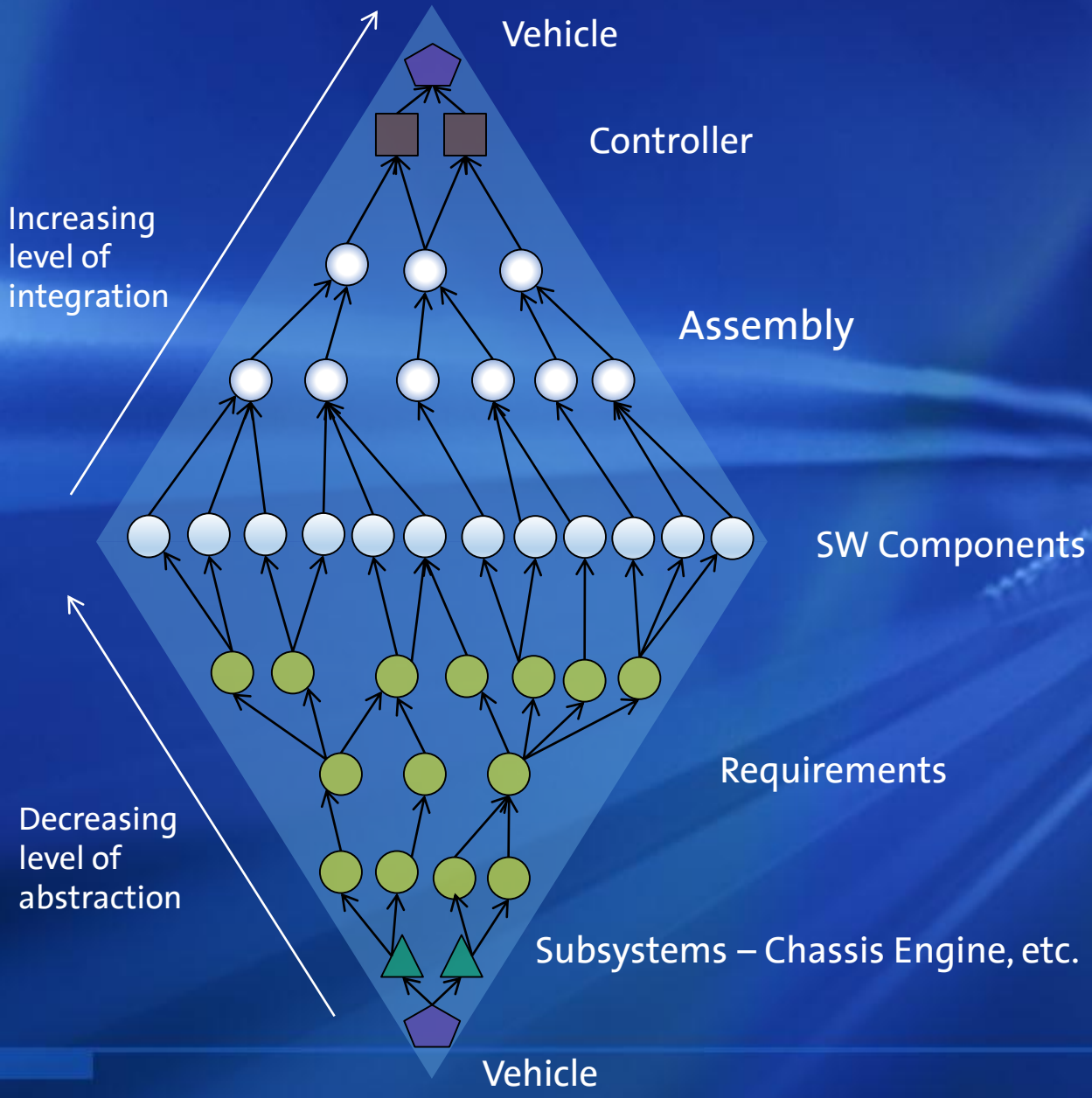
- A Product Line is a set of systems sharing a common, managed set of features that are developed from a common set of core assets in a prescribed way

- Why Product Line over Products for GM Embedded Software?
  - As much as an 85% reduction in effort for a second (third, fourth, etc.) application
  - As much as a 70% reduction in field claims overall

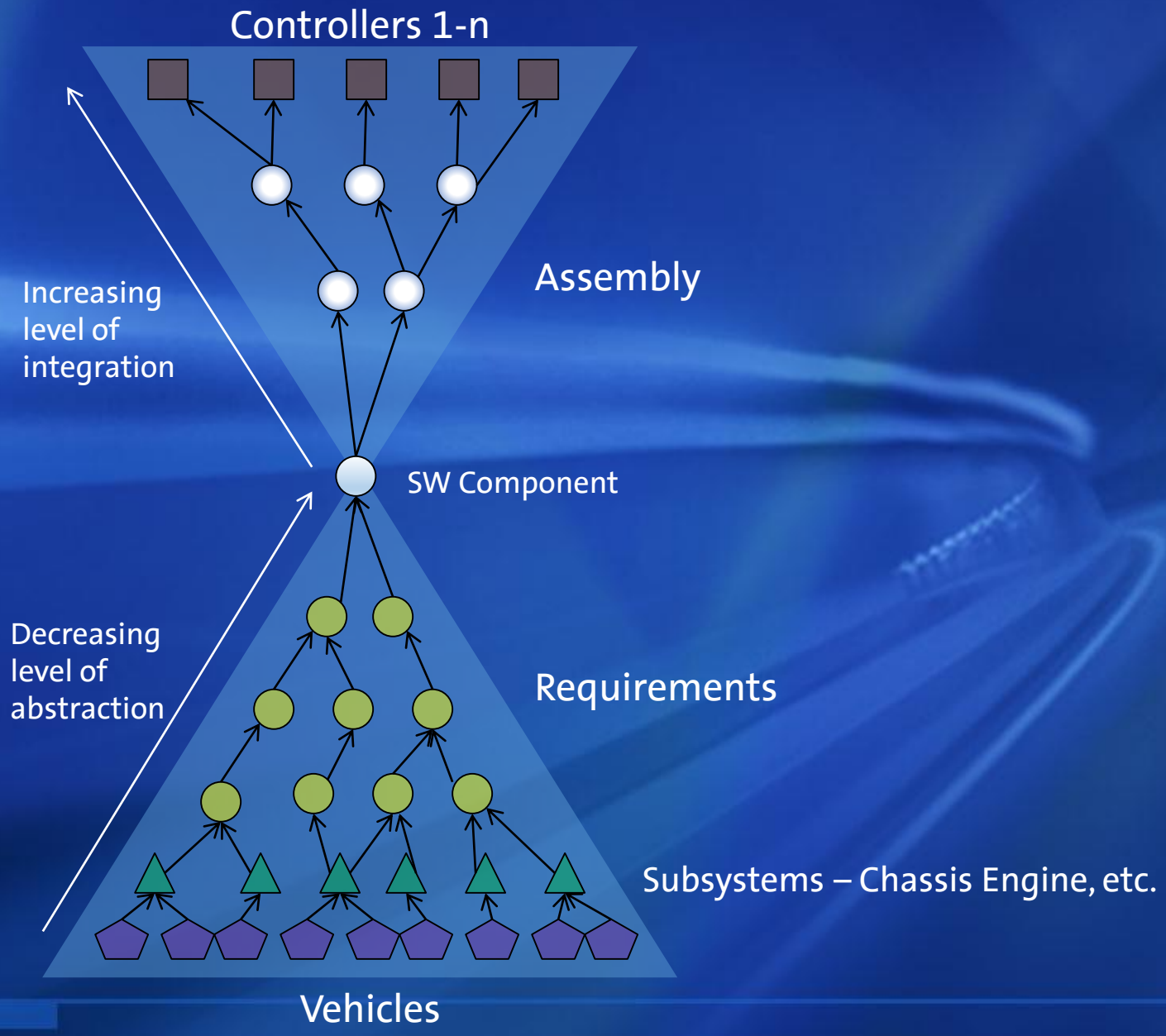
Product Line Engineering



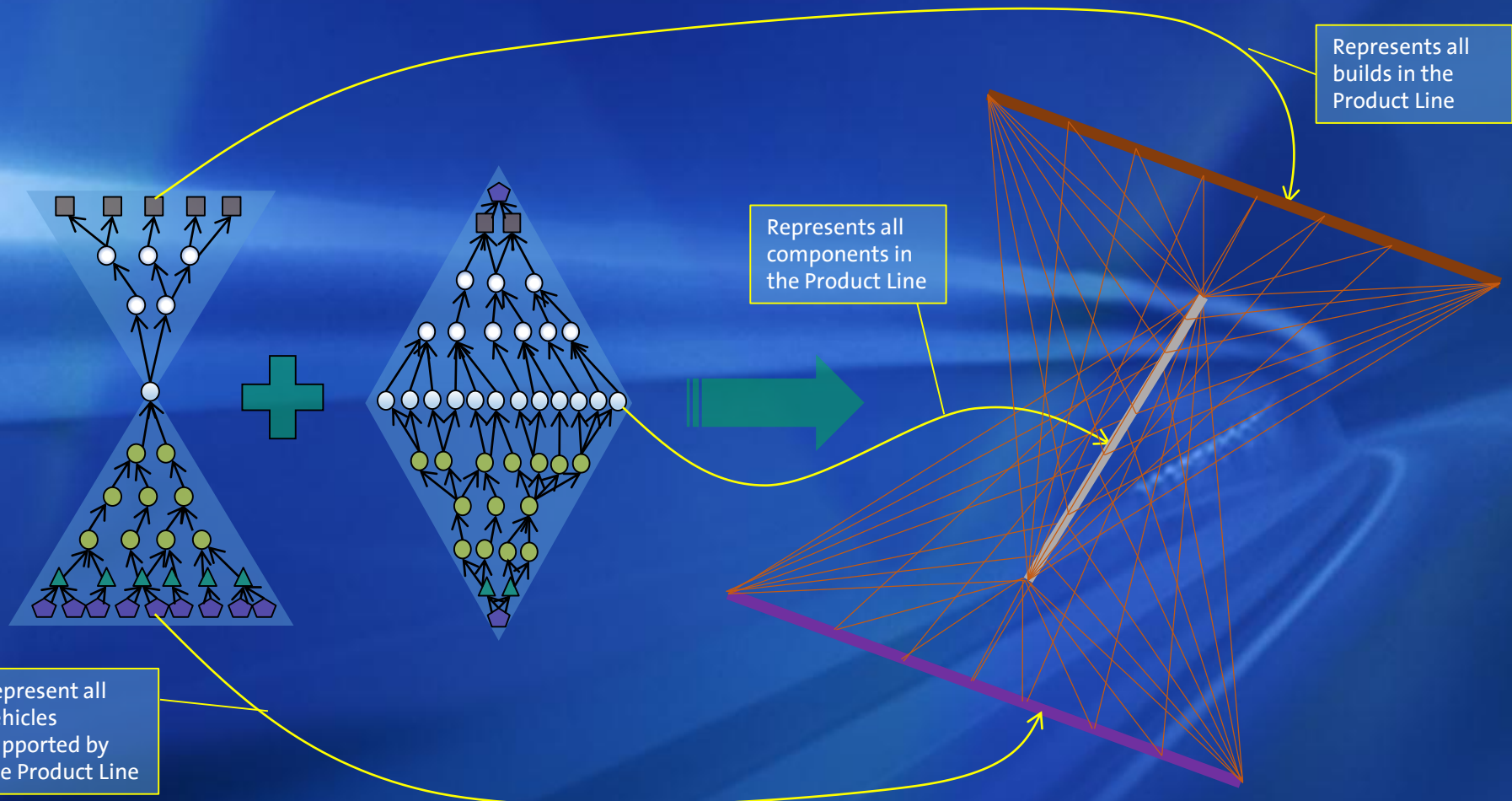
Software Product Line - Single Vehicle View



Software Product Line - Single Component View



Software Product Line - Components X Vehicles



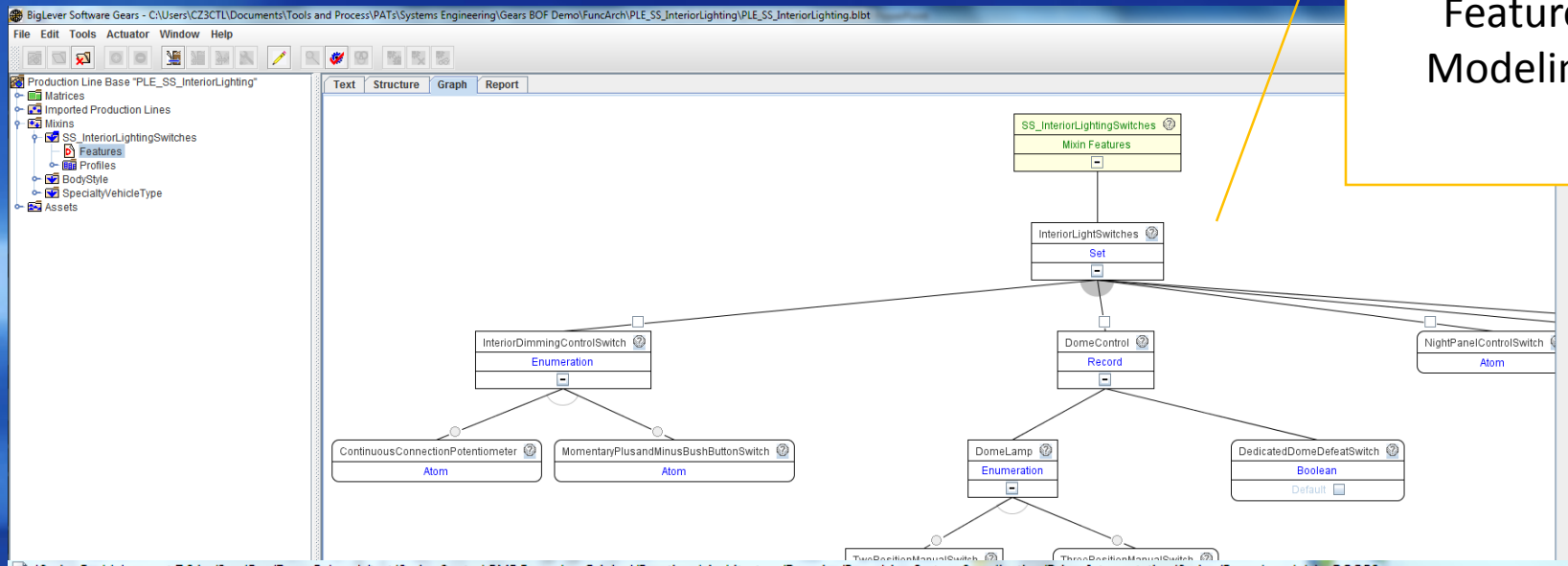
Example Product Line Requirements Challenges

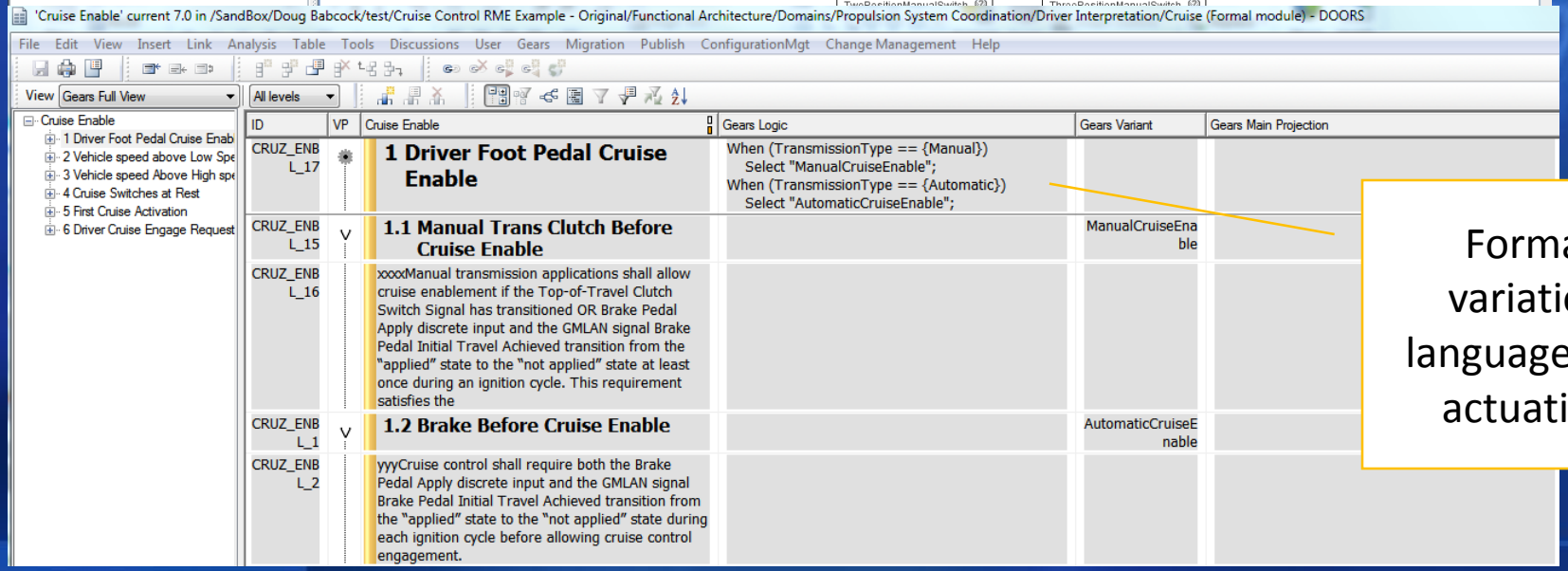
- Traceability of requirements to vehicles deployments
  - Which requirements apply to a specific vehicle?
    - What tests need to be run?
  - Why do we have this requirement?
- Product line development
  - Which deployments need to be supported?
  - Which combination of features need to be tested?
- Can a design element be modified?
  - Why does this design element exist?
  - What is the impact of changing the design element?

Feature Modeling Example

Rational Doors; Big Lever Gears in Combination

Feature Modeling





Formal variation language and actuation

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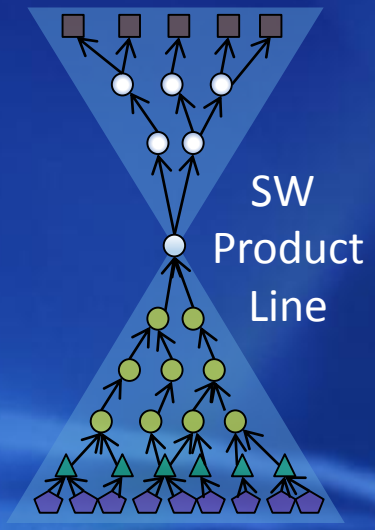
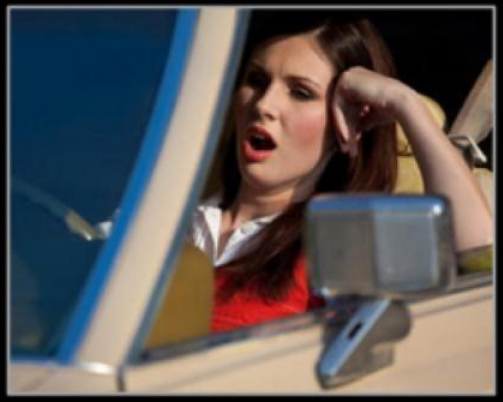


THE OPPORTUNITY

Crashes / Human Errors

Aging / Disabled

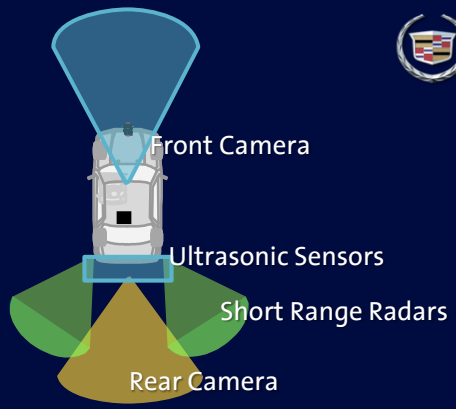
Congestion / Time



CADILLAC DRIVER ASSISTANCE / ACTIVE SAFETY

Package 1 – "Driver Awareness Package"

Cadillac ATS
Cadillac XTS
Cadillac SRX



Safety Alert Seat

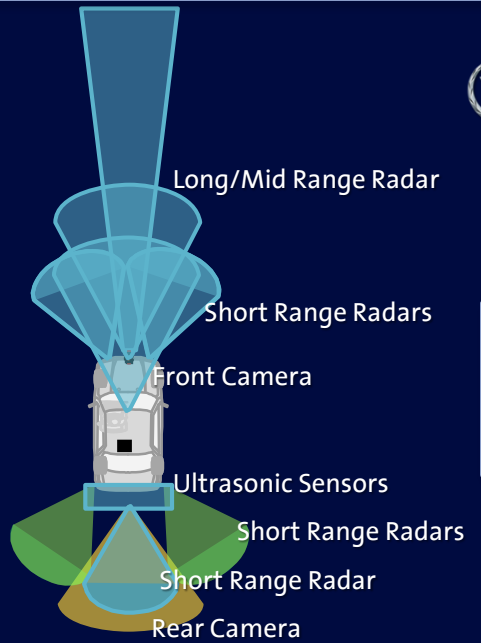
- Lane Departure Warning
- Forward Collision Alert
- Side Blind-Zone Alert
- Rear Cross-Traffic Alert
- Haptic Safety Alert Seat Feedback

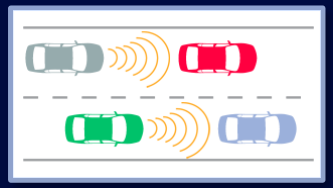
Also includes:

- Rear Vision Camera
- Front & Rear Park Assist

Package 2 – "Driver Assist Package"

Cadillac ATS
Cadillac XTS
Cadillac SRX





Package 1 plus:

- Full Speed-Range ACC (Stop w/Go Notifier)
- Auto Collision Preparation (includes Collision Imminent Braking)
- Low-Speed Front/Rear Automatic Braking (Emergency Braking to Avoid Contact)

DRIVING AUTOMATED
(IN NON-AUTOMATED VEHICLES!)

NEXT STEP: SUPERCRUISE

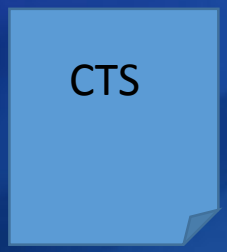
Requirements Development Challenges

Vehicle Technical Specification

- Not a focus, as vehicle integrates features from product line

Subsystem Technical Specification

- Requirements / Specifications for multiple features
- Very large documents, requirements for individual feature dispersed
- Difficult to comprehend
  - individual features
  - how features relate to one another
  - Intent of requirements



Component Technical Specification

- e.g., controller or sensor specifications
- Relevant during later phases of the project

SuperCruise Requirements Development Strategy

Use Cases

Describe how system should handle various key driving scenarios

Feature Technical Specification (FTS)

User Requirements
- High-level, capture key behavior aspects
- Implementation independent

Capture intent of functional requirements

Functional Requirements
- Detailed. all behavior described
- Comprehends interfaces with other features

Non functional Requirements

SSTS & CTS

Example User Requirements

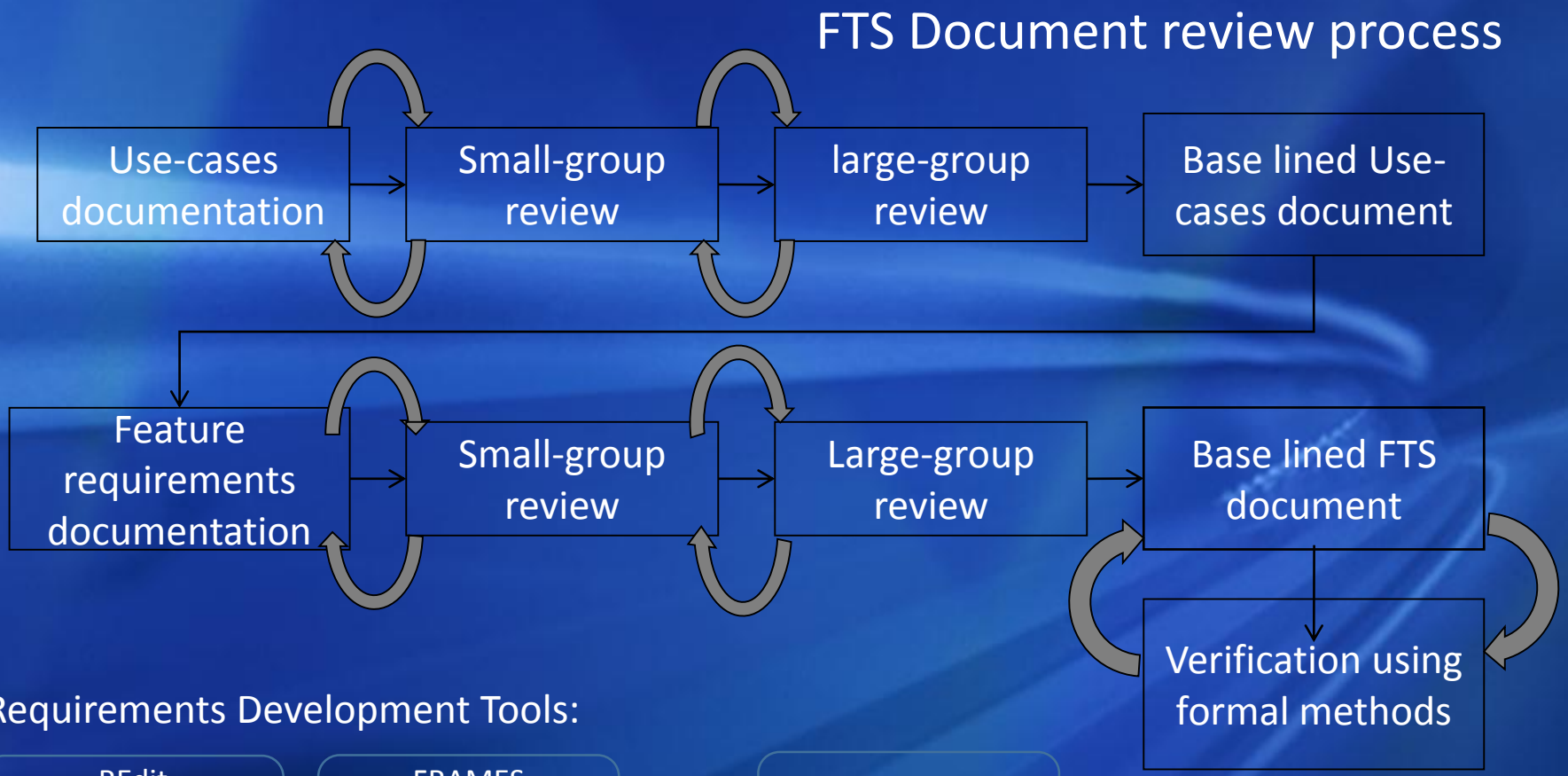
The Cruise Control (CC) feature shall assist the driver to maintain the vehicle at a constant speed, without the need for driver acceleration through the accelerator pedal.

- U -1 CC shall work for speeds between $V_{Low\ Speed\ Inhibit}$ and $V_{High\ speed\ inhibit}$ miles per hour.
- U -2 CC shall allow the driver to set the desired vehicle speed, when the vehicle current speed is between $V_{Low\ Speed\ Inhibit}$ and $V_{High\ speed\ inhibit}$ mph.
  - U -2.1 CC shall maintain the vehicle speed at the speed set by the driver.
- U - 3 CC shall allow the driver to increase and decrease the current CC speed,
  - U- 3.1 CC shall allow driver to increment or decrement the current CC speed by a fixed value of TBD mph.
  - U – 3.2 CC shall allow driver to accelerate or decelerate from the current CC speed until a maximum limit of TBD mph is reached.

Example Functional Requirements

- F-1.0 CC shall transition between the following states:
  - ***Control_Off*** (default state)
  - ***Disabled*** (not ready to control).
  - ***Performing_Diagnostics*** (Waiting for diagnostics results)
  - ***Standby_Disabled*** (feature chosen but the enable criteria is not fulfilled)
  - ***Standby_Enabled*** (feature is chosen and the enable criteria is also fulfilled)
  - ***Engaged*** (regulating the speed of the vehicle at the driver set speed)
- F-2.0 CC must receive the following information
  - VehicleSpeed
  - BrakePedalStatus (indicating when pressed)
  - AcceleratorPedalStatus (indicating when pressed)
  - ClutchPedalStatus (indicating when pressed)
- F- 3.0 CC shall transition from ***Control_off*** to ***Disabled*** state, when System_Power_Mode is in the ON mode.
- F- 4.0 CC shall first perform diagnostic tests when the driver requests for CC.
  - F-4.1 CC shall inform the driver when CC functionality has some problem.
  - F- 4.2 The diagnostic tests failed message shall be sent to the Driver Display Console when CC is not functional.
- F-5.0 CC shall transition from ***Disabled*** to ***StandBy_Disabled***, if CC passes diagnostic tests
  - F– 5.1 CC shall inform the driver when CC is ready to operate.
  - F–5.2 The CCOperatingIndicator shall light up when CC is operational (Which means that the diagnostic tests were passed).

SuperCruise Requirement Development Strategy (Cont.)



Requirements Development Tools:

REdit Requirements Authoring Tool

FRAMES Formal Methods Analysis

DOORS Requirements Management

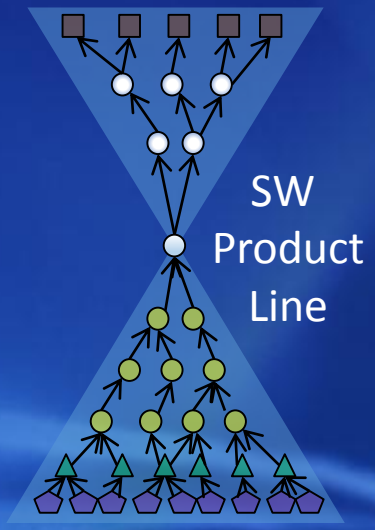
+

Virtual Validation

HIL Bench Validation

In-Vehicle Validation

Outline



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Summary

- Automotive product line challenges addressed by requirements & product line management
- Active safety and semi autonomous driving present new challenges
  - Complex interacting features
  - Highly depending on vehicle operating environment
  - To learn more
    - http://spectrum.ieee.org/transportation/safety/the-crashproof-car
- Challenges addressed by rigorous requirements development process
  - Implementation independent requirements vs. functional specification
  - Requirements management,
  - Design reviews and formal analysis
  - Validation activities: model-based, HIL bench, in-vehicle
- Next steps: System of Systems and feature interaction methods

Thank You!