

# Applying Digital Engineering Digital Twin to Support Ground Vehicle Virtual Experimentation

Robert J. Kanon  
Raveen Fernando  
Kevin W. Griffin  
Amir Shah  
Russ Kouba  
Mark Feury

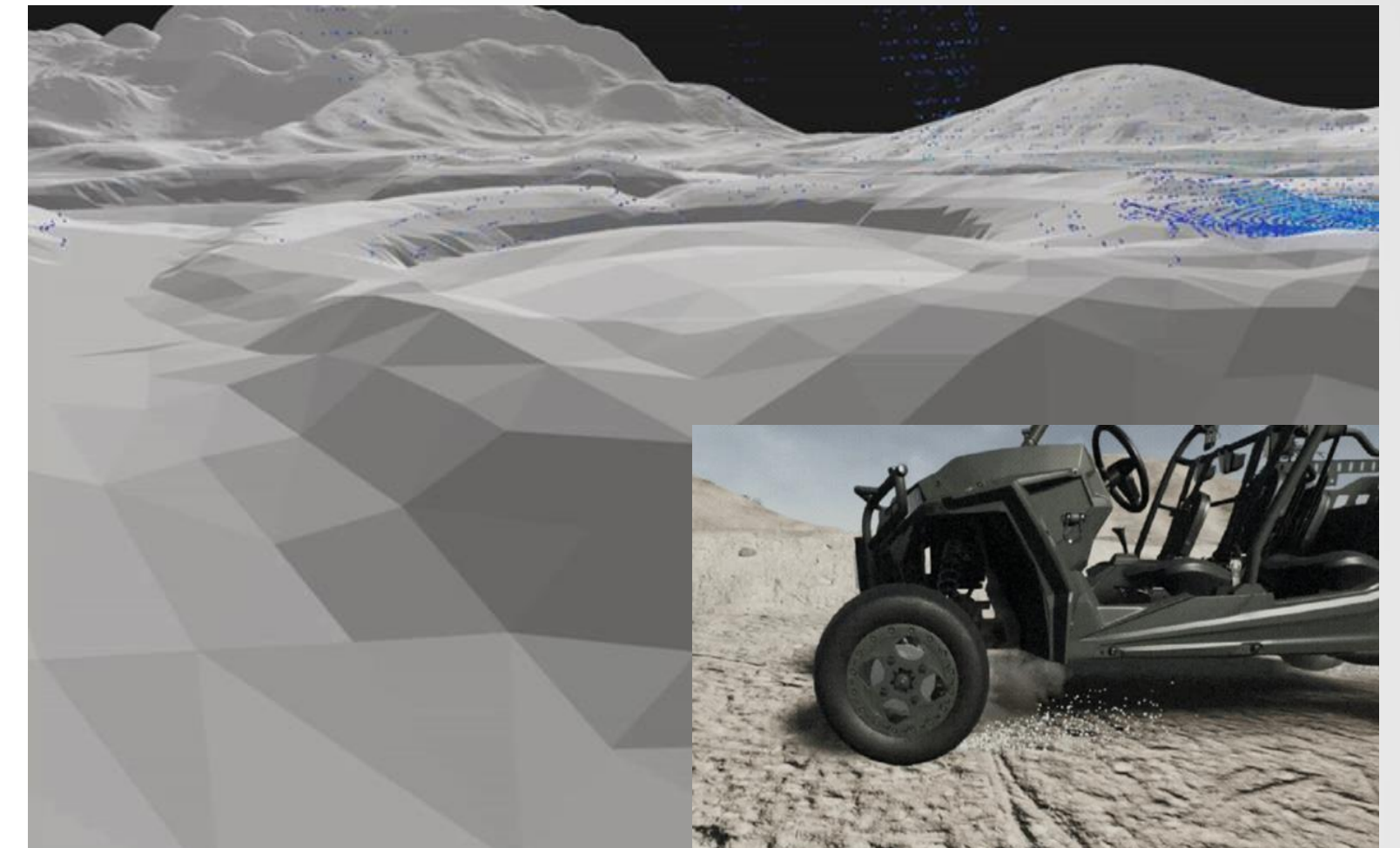




# Goals of Digital Engineering

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING

- Conduct trade studies to understand dependencies, cost drivers, risks, and impacts of design changes
- Reduce the need for physical prototyping to enable critical decision making
- Enable rapid software deployments, upgrades, training, and sustainment



# Digital Engineering Ecosystem

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING

Class 3 and 8 Ground Vehicle Requirements Capture / Analysis

Synchronized Digital Threads of Requirements, System Model artifacts, and other product lifecycle information

Trade Study Results, Simulations, and Analyses

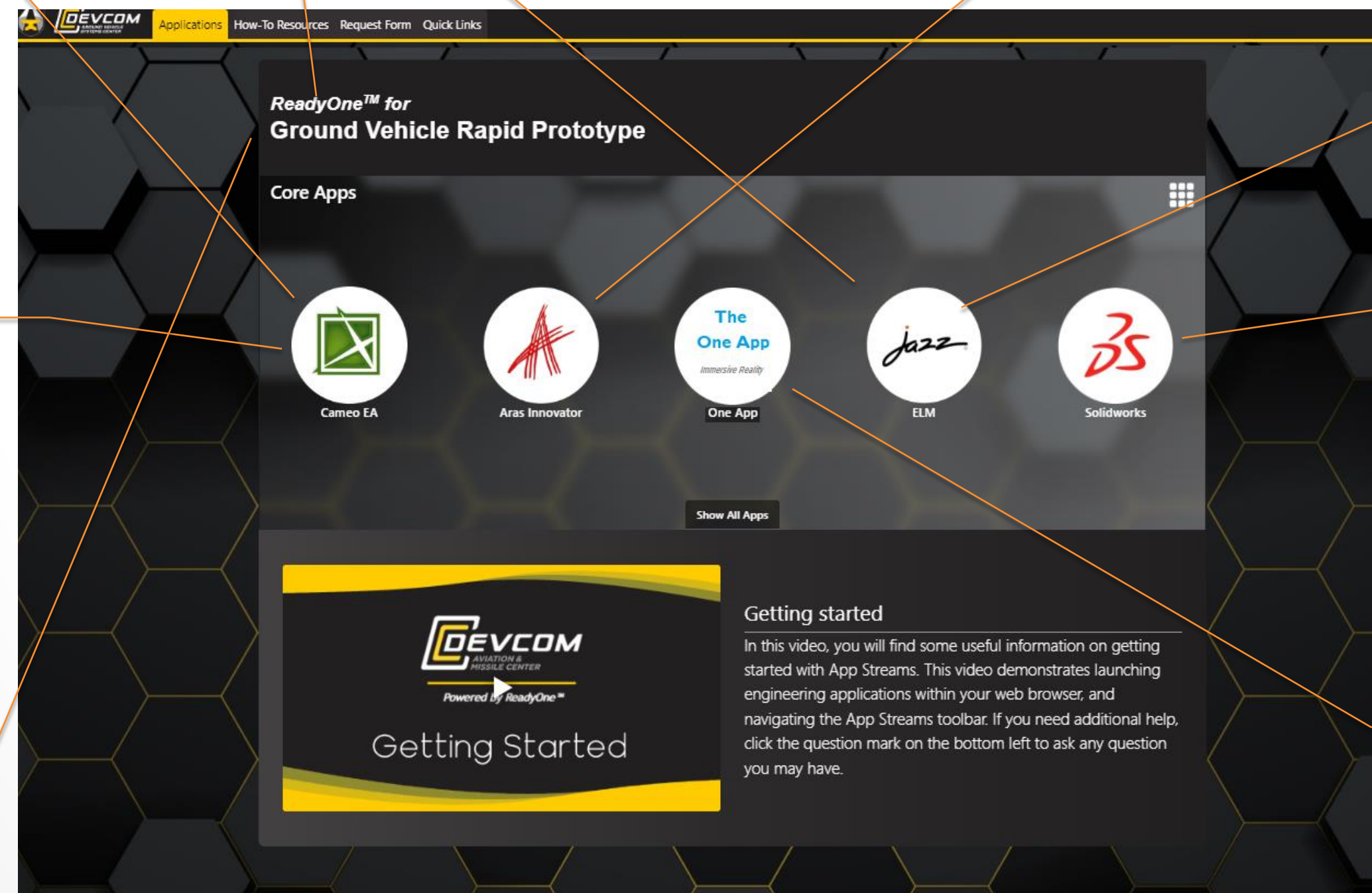
Class 3 and 8 System Models, Architecture, Low-level Feature Simulation, Traceability

Ground Vehicle Test Plans, Test Suites, and Test Cases

Project Reference Architecture, Process, Guidance, and Traceability to Industry Standards

Vehicle Concept and Preliminary Design Drawings and Information  
(Solidworks and PTC Creo)

Controlled, Secure, Role-based access



Immersive Reality

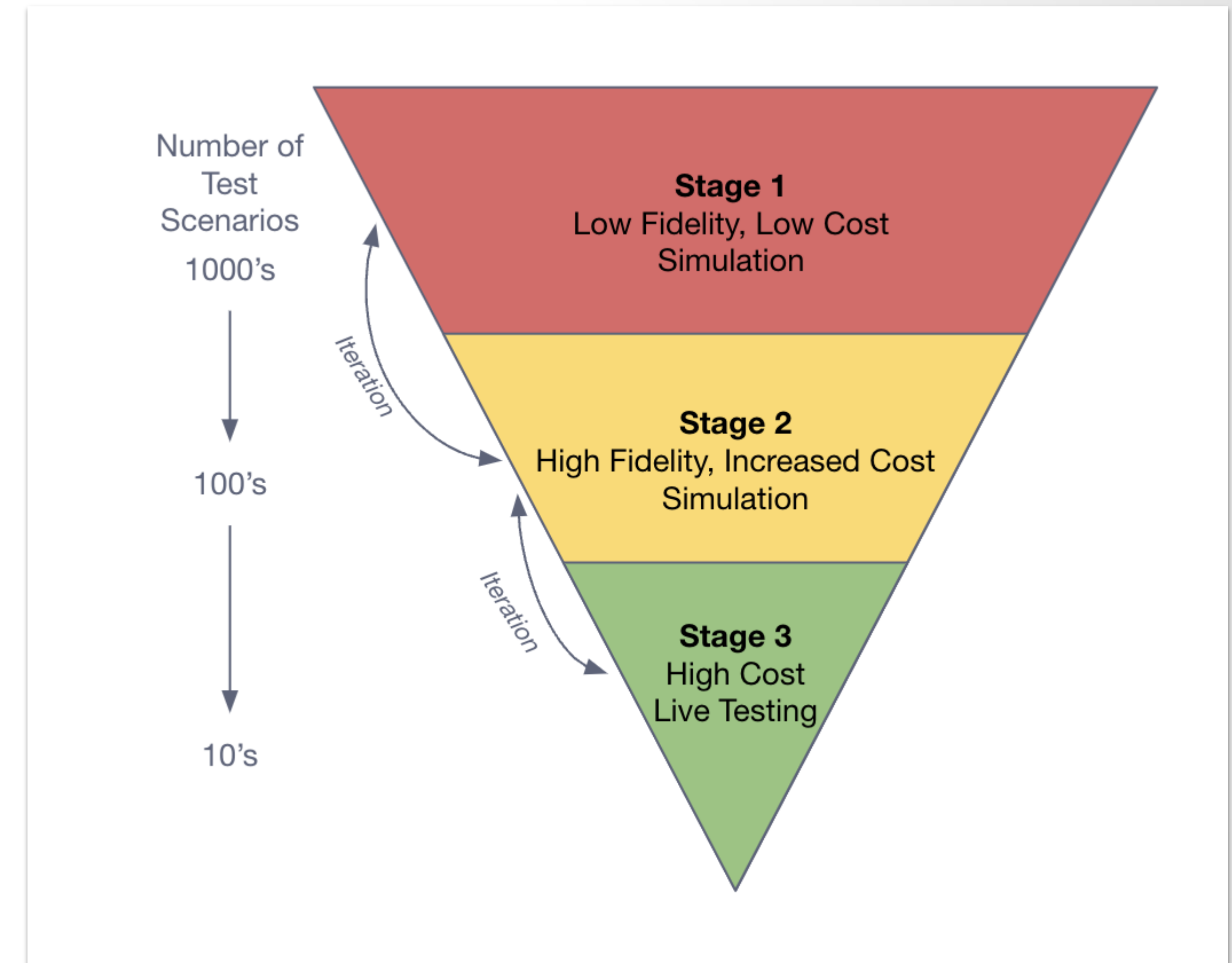




# Digital Twin Testing Framework

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**

- Execute high volume of tests in a low-cost digital environment
- Digital Twin data model created with artifacts of the full ground vehicle system
- Employ extensive, low-cost synthetic testing early on in development cycle
- Mature design and validate with strategic high-fidelity evaluations

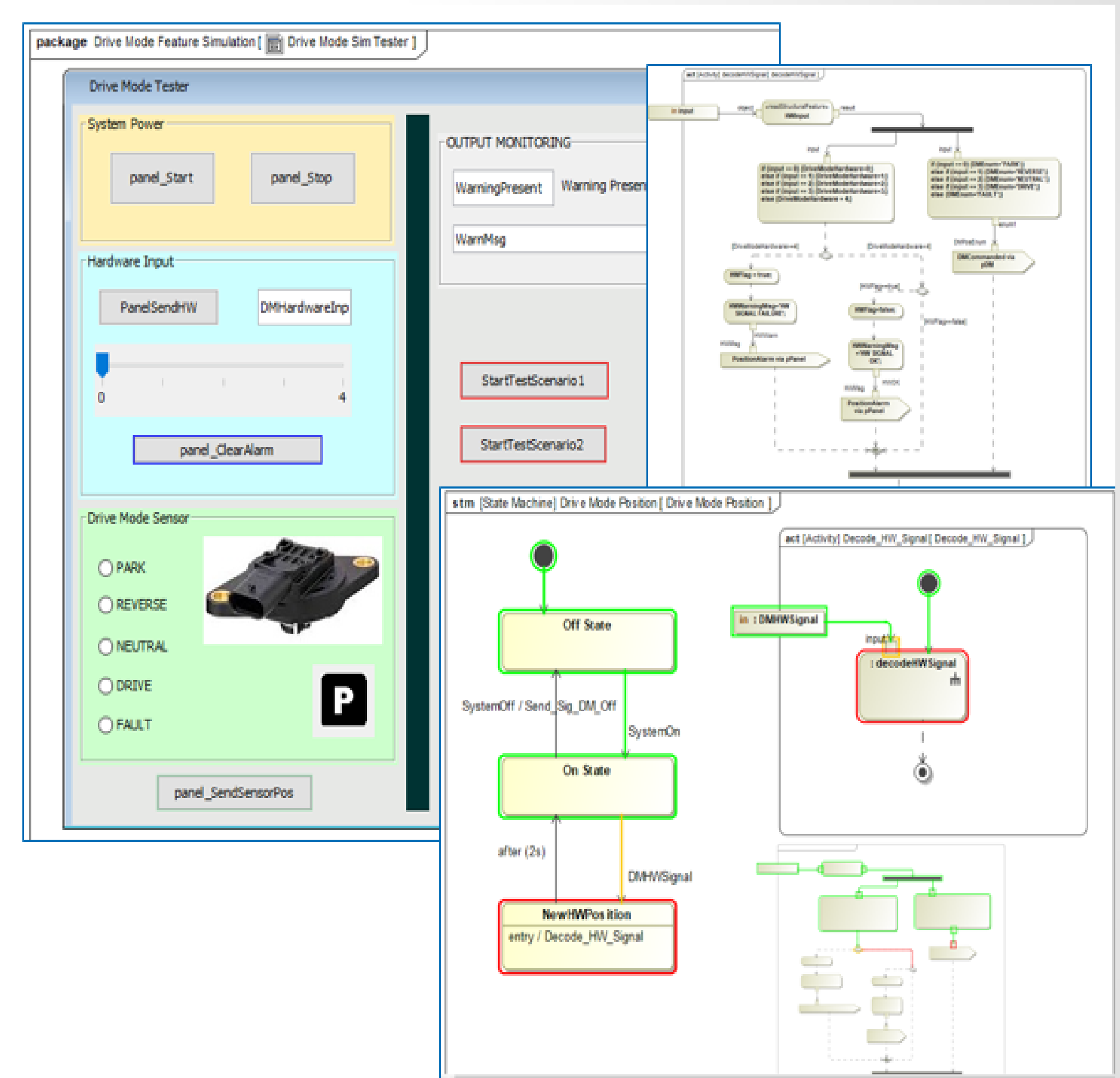


Digital Engineering Testing Framework



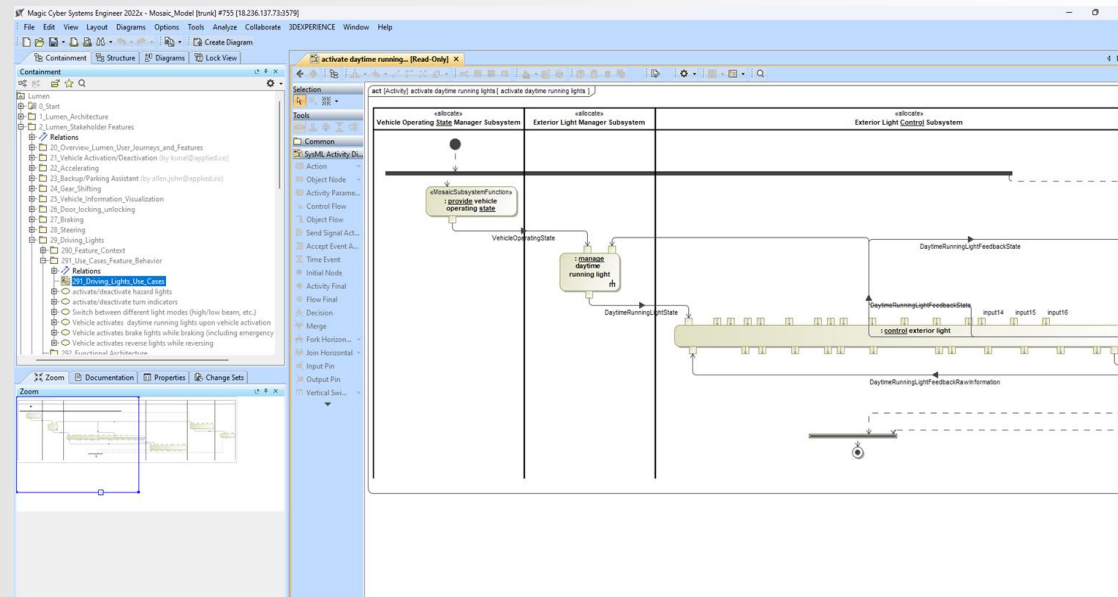
# Feature Simulation

- Low fidelity simulation within the system modeling environment ensures requirements are complete and well-understood early in the project timeline
- Issues and defects within the requirements are identified, leading to the creation of additional system level, performance, and timing requirements
- Creates a common understanding and shared vision to all stakeholders



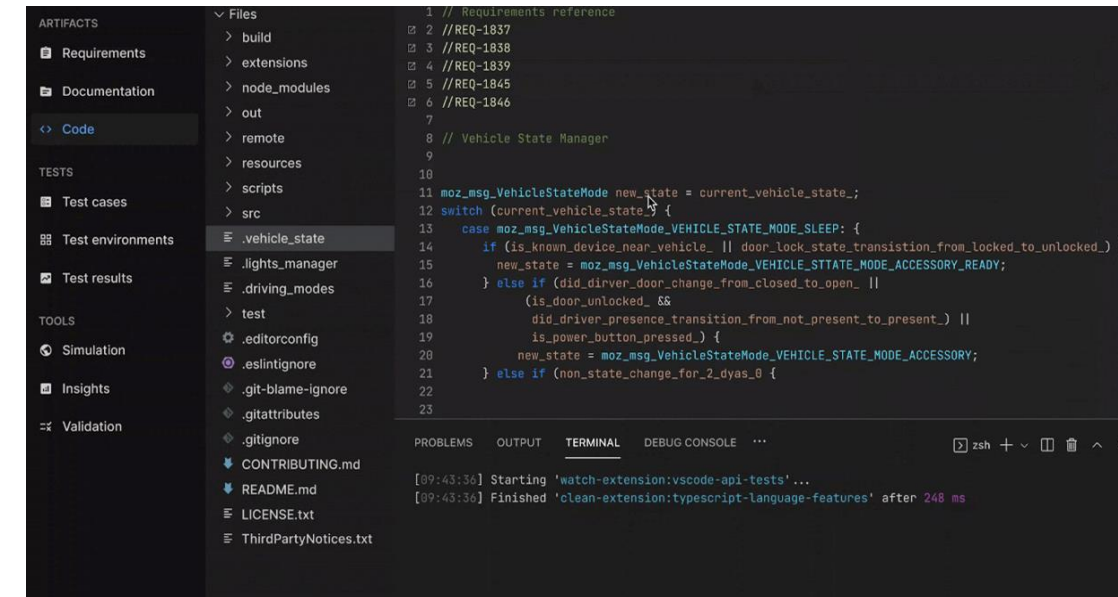
# Digital Thread

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING



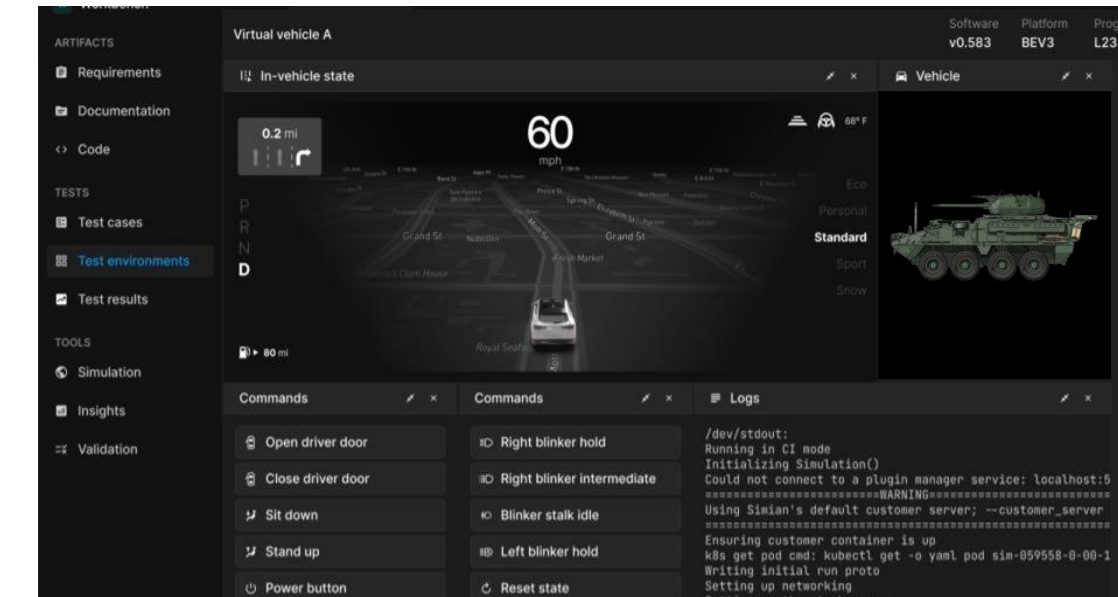
### System definition

Full traceability from definition to implementation



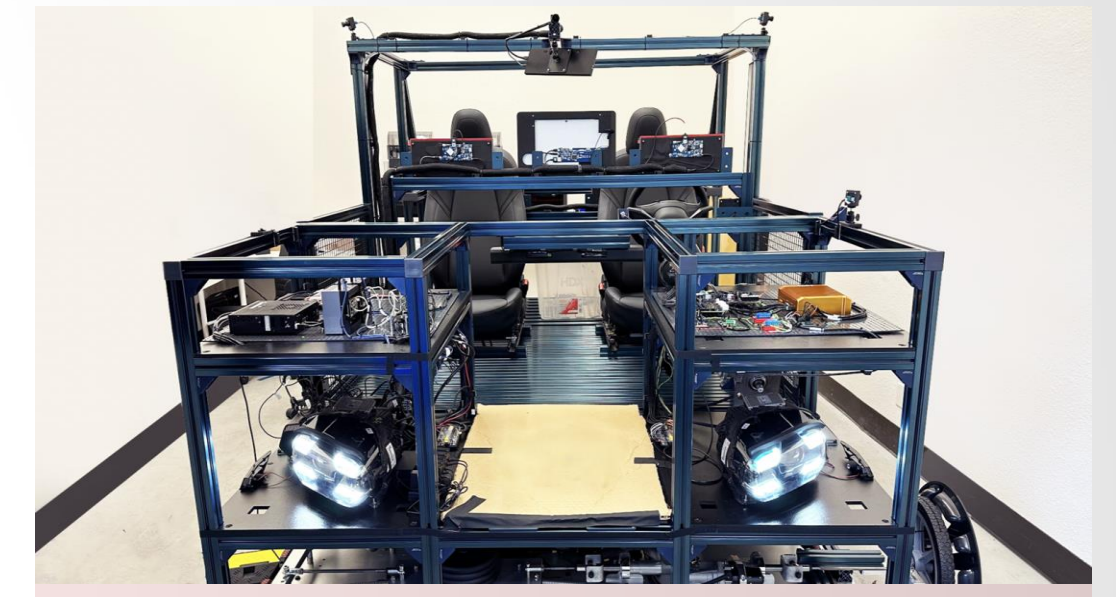
### Implement & iteratively develop

Write and deploy code, rapidly test and iterate



### Test in virtual SIL environment

Automate and scale feature testing; traceability to requirements for validation



### Deploy & test on HIL

Deploy code to physical hardware; interact & test remotely

Creates a common understanding and shared vision to all stakeholders





# Envisioning the Future of Battlefield Capabilities

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**

- 1** Current limitations of legacy defense systems underscore the need for adaptability and swift integration of advancements.
- 2** Recent global conflict zones reveals a pressing demand for increasing the speed between development and deployment of defense technologies.
- 3** The transition towards dynamic, software-driven solutions is not just necessary—it's inevitable.



# Current State

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING



A drone aloft at Skydio's facility in San Mateo, Calif.

### How American Drones Failed to Turn the Tide in Ukraine

Drones from American startups have been deemed glitchy and expensive, prompting Ukraine to turn to alternatives from China

By [Heather Somerville](#) and [Brett Forrest](#)  
Photographs by [Clara Mokri](#) for *The Wall Street Journal*

Updated April 10, 2024 4:56 pm ET

### Upgunned Stryker's software problems 'resolved,' says Army two-star

Soldiers will begin receiving the Strykers outfitted with 30mm cannons next fall, or roughly nine months to a year later than initially anticipated.

By [ASHLEY ROQUE](#) on December 08, 2023 at 2:29 PM



An F-35C Lightning II assigned to Strike Fighter Squadron (VFA) 125 launches off the flight deck of Nimitz-class aircraft carrier USS George Washington (CVN 73) Jan. 19, 2024. U.S. NAVY / MASS COMMUNICATION SPECIALIST 3RD CLASS AUGUST CLAWSON

**BUSINESS**

### Software delay will reduce F-35 deliveries for a second straight year

Lockheed says the TR-3 upgrade, due last year, has slipped to third quarter of 2024.

PATRICK TUCKER | JANUARY 23, 2024





# Industry Trends and a New Approach

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING



*“Our updated network architecture is expected to **reduce 60% of the ECUs and reduces the wire harness length by 25%**”<sup>1</sup>*

*“The ability to consolidate ECUs is not a few \$100, we’re talking **multi-thousand-dollar savings**,”<sup>2</sup>*

<sup>1</sup> [Rivian 2Q23 Shareholder Letter - Technology as a differentiator](#)

<sup>2</sup> [Rivian CEO’s plan to make EVs cheaper starts with their computers](#)



*“In Q1, we were able to navigate through global chip supply shortage issues in part by **pivoting extremely quickly to new microcontrollers**, while simultaneously developing firmware for new chips made by new suppliers.”<sup>3</sup>*

<sup>3</sup> [Tesla Q1 2021 Shareholder update - Vehicle Software](#)



*“Consisting of a data technology platform, a whole-car software platform and a hardware architecture platform, X-EEA [...] **optimizes overall vehicle R&D costs by 50%**”*

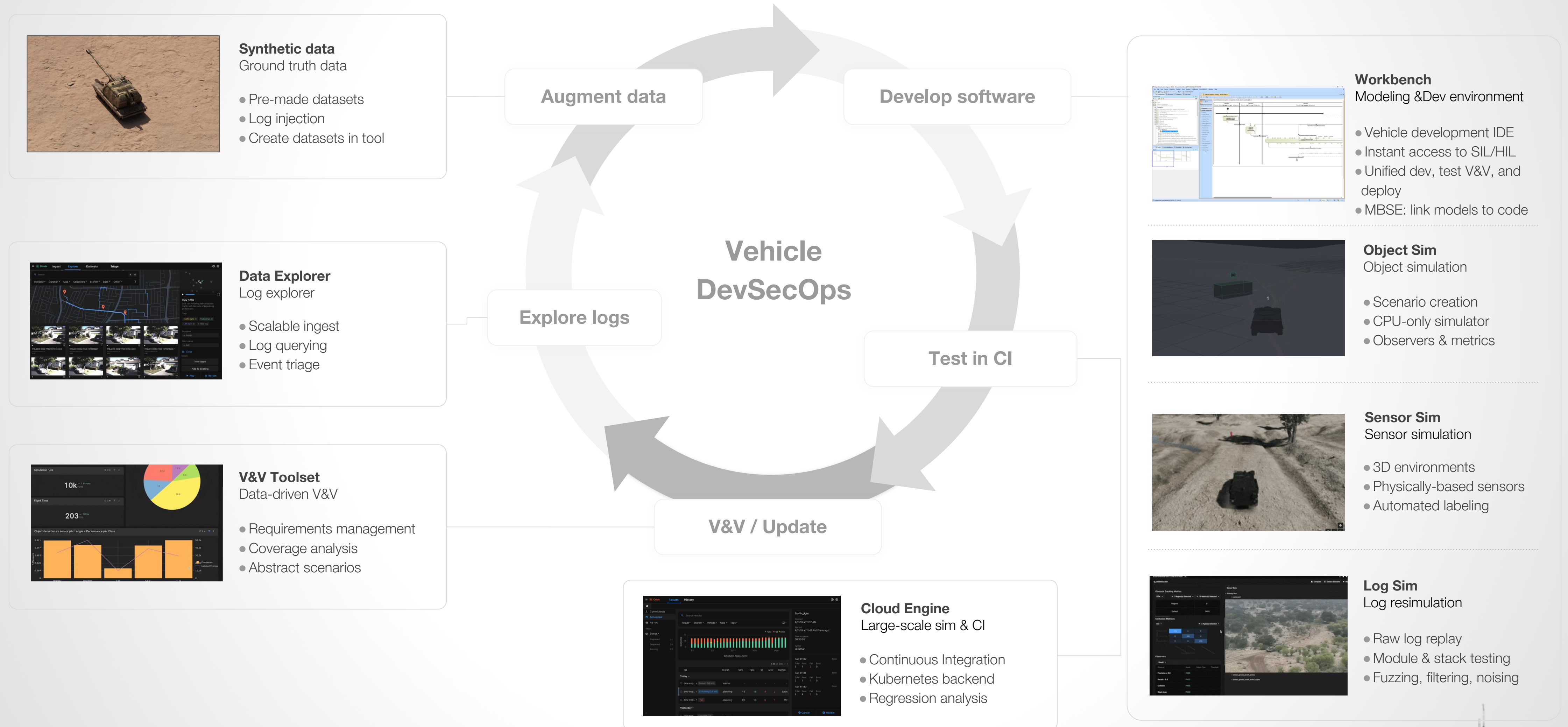
<sup>4</sup> [XPENG Presents Next-Gen Technology Architecture – SEPA2.0](#)





# DevSecOps Toolchain

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING





# Digital Twin Environment

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**



Holly Oaks Real vs Sim



Holly Oaks Simulated Environment





# Driver Crew Trainer

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**

- Testing volume reduced as an outcome of previous digital engineering simulation test environments
- Validation of human and autonomy teaming missions
- Incorporate target vehicle hardware in test cycles
- Validate full system requirements prior to deployment to real world vehicle prototype



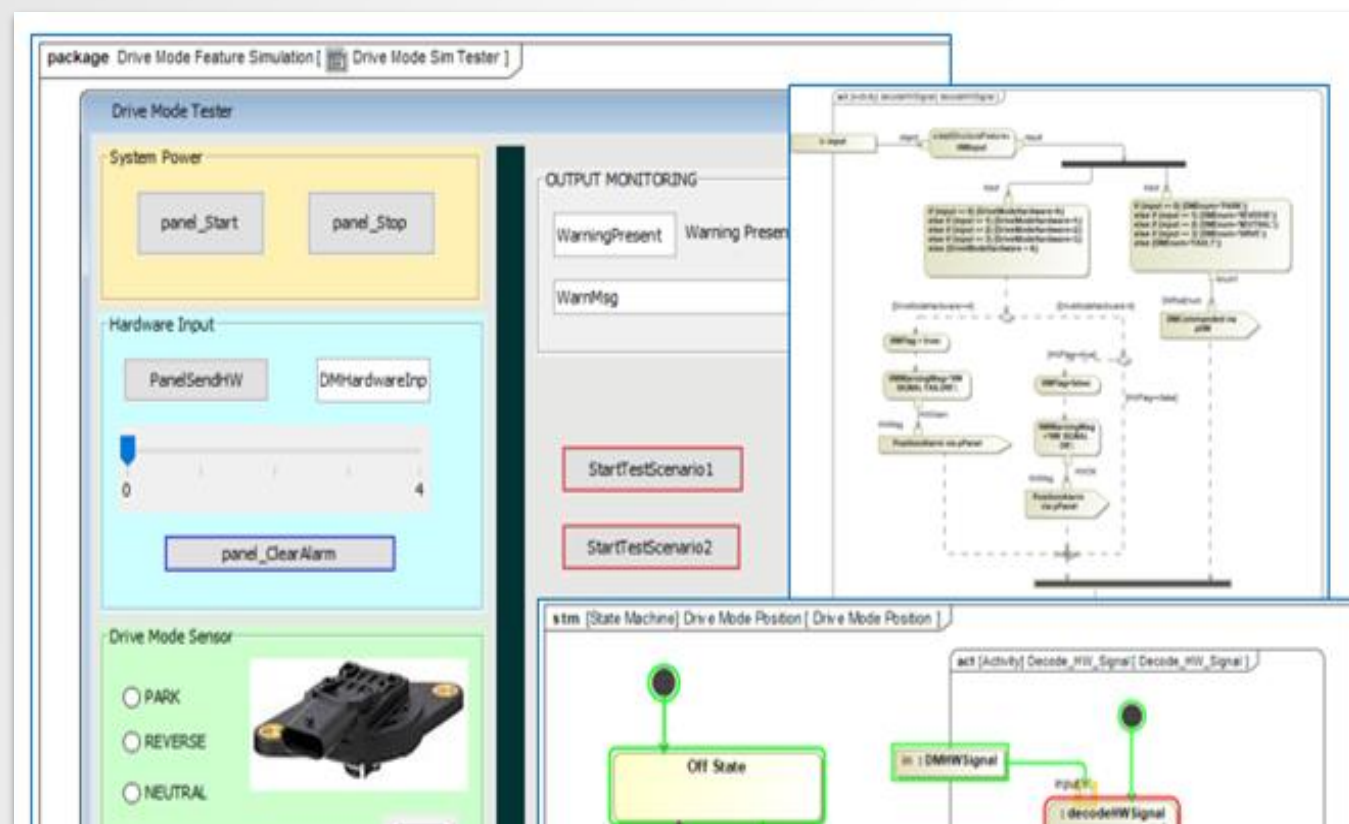
Applied Intuition Driver Sim Rig





# Continuous Integration and Continuous Deployment

## DIGITAL ENGINEERING / SYSTEMS ENGINEERING



Name	Contents	Verification Method
4.0 Vehicle Requirements	<b>4 Vehicle Requirements</b>	
4.0.1 HETV Variation	The HETV shall have four variants: (1) Standard Duty Ultralight (SDU), (2) Standard Duty Conventional (SDC), (3) Standard Duty Tracked (SDT), and (4) Medium Duty Conventional (MDC)	Analysis
4.0.2 Carbon Footprint	The HETV will reduce the carbon emission footprint by 60% when compared against similar vehicles today	Analysis
4.1 Physical Requirements	<b>4.1 Physical Requirements</b>	
4.1.1 Vehicle Curb Weight (VCW)	<b>4.1.1 Vehicle Curb Weight (VCW)</b>	
Definition of Vehicle Curb Weight	Vehicle Curb Weight is defined as the empty vehicle including ¼ tank of fuel, necessary operating fluids and lubricants. Curb weight does not include weight of passengers, optional equipment, or payload.	
4.1.1.1 Vehicle Curb Weight SDU	The SDU shall have a maximum curb weight of 9500 lbs	Analysis, Test
4.1.1.2 Vehicle Curb Weight SDC	The SDC shall have a maximum curb weight of 9500 lbs	Analysis, Test
4.1.1.3 Vehicle Curb Weight SDT	The SDT shall have a maximum curb weight of 9500 lbs	Analysis, Test
4.1.1.4 Vehicle Curb Weight MDC	The MDC shall have a maximum curb weight of 27,500 lbs	Analysis, Test
4.1.2 Gross Vehicle Weight (GVW)	<b>4.1.2 Gross Vehicle Weight (GVW)</b>	

Plan Item	UUID	Plan Item type	Edited	Status	Link
Vehicle Activation / Deactivation	REQ-1837	Feature	-	-	Open
Vehicle operating state machine	REQ-1838	Requirement	11/17/2023	Implemented	Open
Transition from "sleep" to "ready"	REQ-1839	Requirement	11/17/2023	To Implement	Open
Transition latency threshold	REQ-1839	Requirement	11/17/2023	Implemented	Open
Transition from "ready" to "accessory"	REQ-1839	Requirement	11/17/2023	Implemented	Open
Transition from "accessory" to "drive ready"	REQ-1839	Requirement	11/17/2023	Implemented	Open
Transition from "drive ready" to "driving"	REQ-1839	Requirement	11/17/2023	Implemented	Open
Gear state manager	REQ-760	Sub-system	-	-	Open
Transition from "R" to "P"	REQ-761	Requirement	11/17/2023	Implemented	Open
Transition from "D" to "P"	REQ-762	Requirement	11/17/2023	Draft ongoing	Open
Receive vehicle speed & status	REQ-763	Requirement	11/17/2023	Implemented	Open

### Update system model

- Testing identifies gaps in feature capabilities
- Modify MBSE system model to close the gap

### Update system requirements

- Changes in system model cascade to verification check of system requirements.
- Update requirements to align to new change

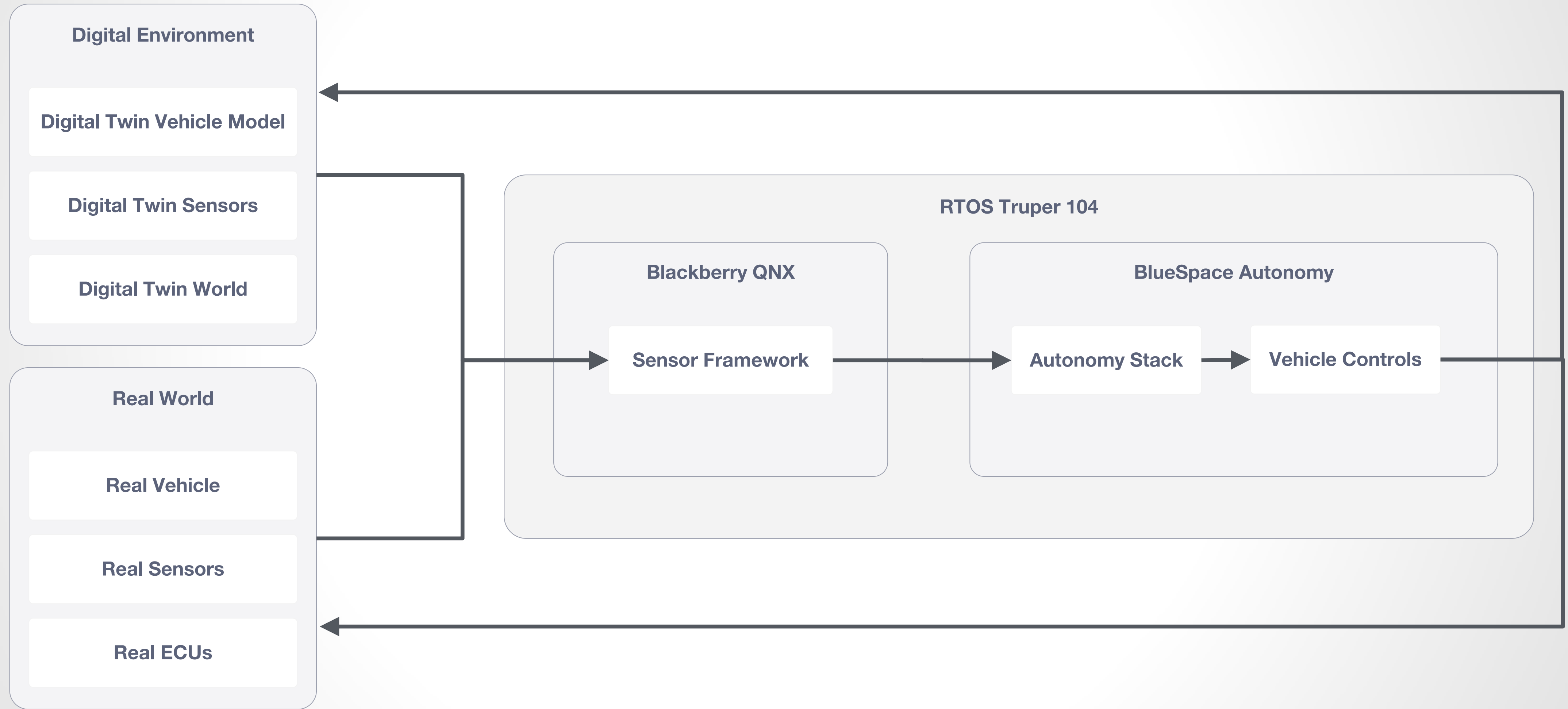
### Update implementation

- Quickly identify which source code elements need to change based on linked requirements
- Update or write new code in shared digital engineering environment; deploy & test updates instantly



# Ground Vehicle Rapid Prototyping

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**





# Thank You

**DIGITAL ENGINEERING  
/ SYSTEMS ENGINEERING**

- Future warfighting force needs to be modular and adaptable to changing needs
  - Software capabilities and fast deployments key to staying ahead
  - Shift majority of validation and verification left into digital engineering realm
  - Please stop by the SAIC booth for further demos, videos, and discussion
- 

