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# Driving **Innovation**

## Hardware-in-the-Loop (HIL) of Connected and Automated Vehicle (CAV) Applications

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**SAXTON**  
LABORATORY

# Background and Existing Needs



- CAVs offer potentially transformative societal impacts including mobility, safety, energy, and environmental benefits.
- Agencies need a low-cost approach to quantify impacts of CAV deployments in order to make intelligent investment decisions.
- Traffic modeling and simulation tools provide an efficient approach to evaluate a new technology or strategy prior to implementation.
- Current modeling and simulation tools are not suited to evaluating CAV.



# HIL Testing of CAV Applications



- Background
  - Validity of results limited by model assumptions and lack of field-collected data for calibration.
  - Field tests are limited in scope because of expense.
- HIL
  - Ideal approach to evaluate CAV benefits with low cost.
  - Allows physical test vehicles to interact with virtual vehicles from simulation.
  - Can replicate actual conditions at early stages of CAV deployment.



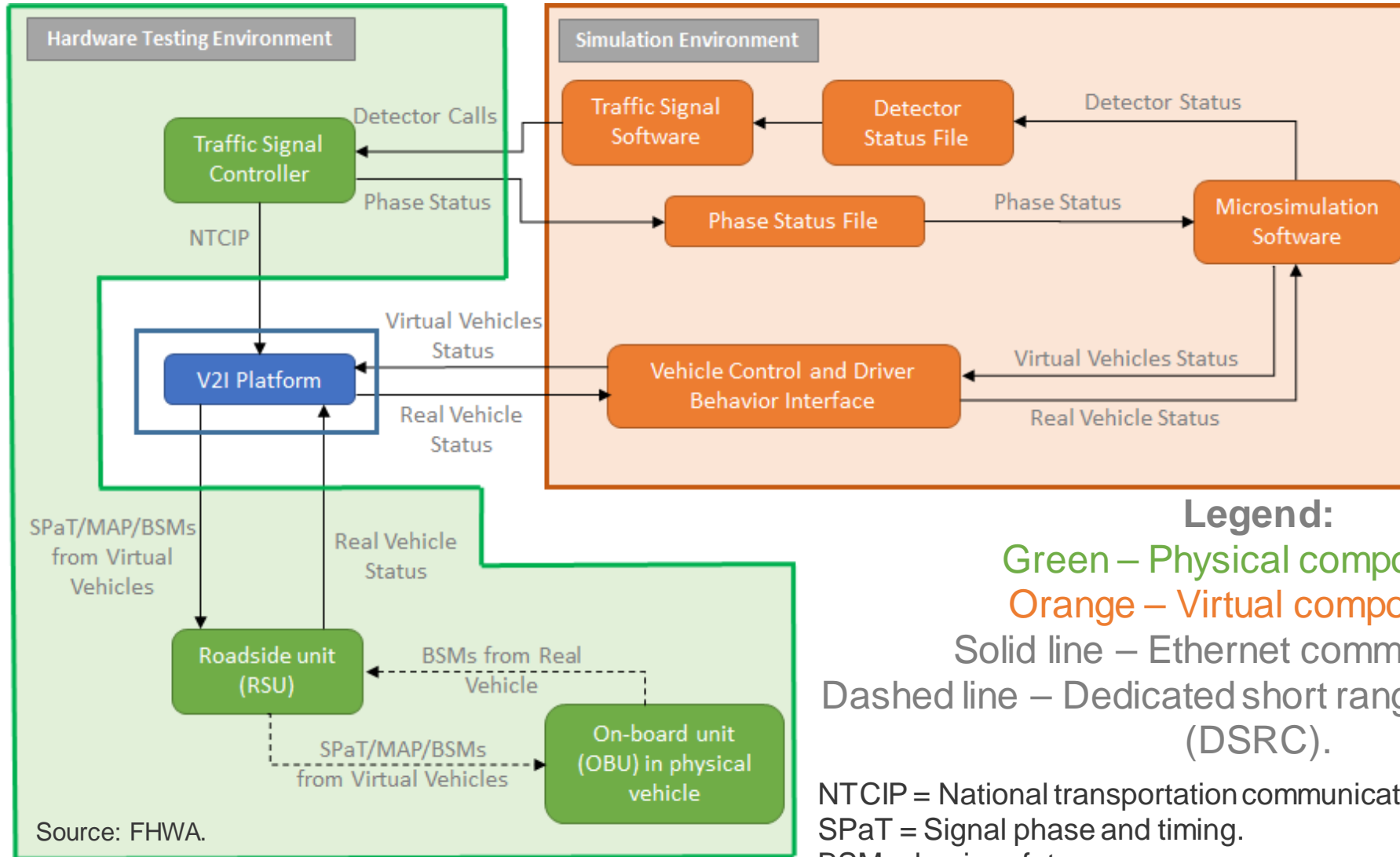
# Features of the Saxton Lab HIL System



- One of the first testing systems in the United States featuring level 1 automated vehicles.
- Developed vehicle-to-vehicle (V2V) testing capabilities:
  - Developed V2V HIL testing platform.
  - Application: cooperative adaptive cruise control (CACC).
- Developed vehicle-to-infrastructure (V2I) testing capabilities:
  - Developed V2I HIL testing platform.
  - Application: queue-aware signalized intersection approach and departure (Q-SIAD).



# V2I HIL Testing Architecture





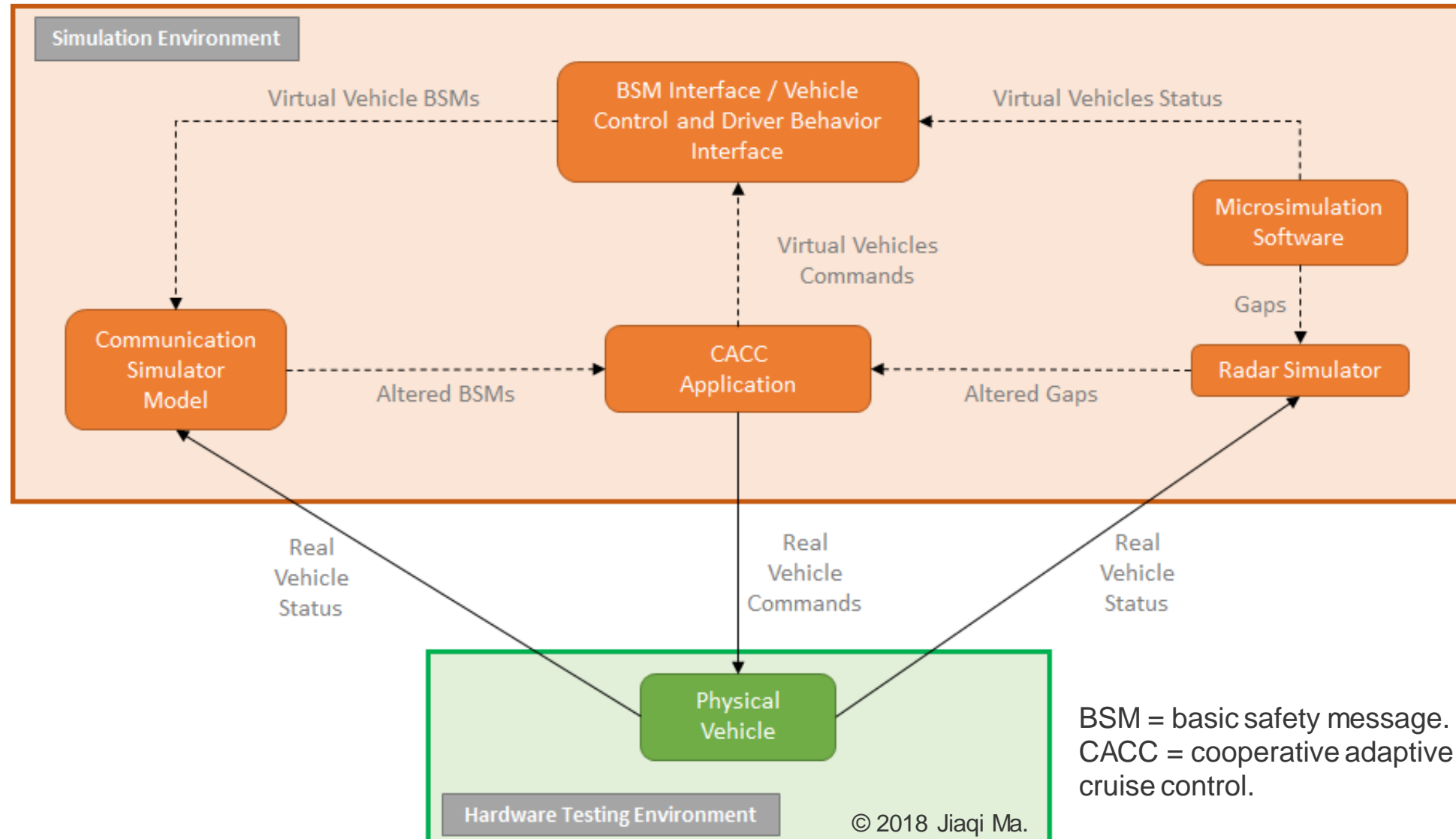
# HIL Testing of Q-SIAD



# V2V HIL Testing Architecture



**Legend:**  
Green – Physical components.  
Orange – Virtual components.  
Solid line – Communication via Ethernet.  
Dashed line – Communication between software components.



BSM = basic safety message.  
CACC = cooperative adaptive cruise control.





## Questions?

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## SAXTON LABORATORY

Saxton Laboratory is FHWA's emerging technologies research laboratory enabling industry development and adoption of next generation technologies. The lab works to improve transportation mobility, efficiency, access and safety through:

- Cooperative automation
- Analysis and modeling of new technologies
- Interoperability and performance testing
- Industry support and technology transfer