Partial Automation for Truck Platooning (PATP) - Testing

Osman D ALTAN
Turner Fairbank Highway Research Center
osman.altan@dot.gov *202-493-3391*

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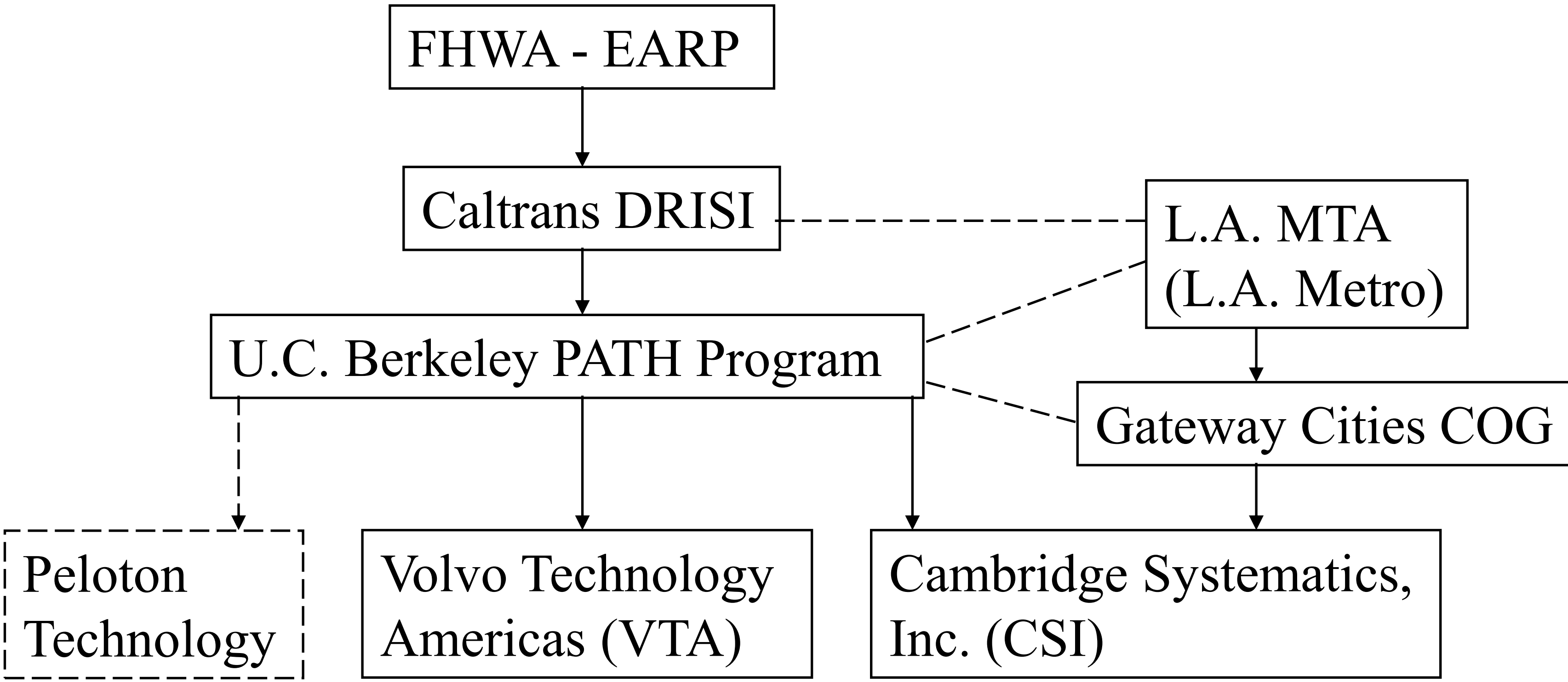
FEDERAL HIGHWAY ADMINISTRATION

PATP Project Goals

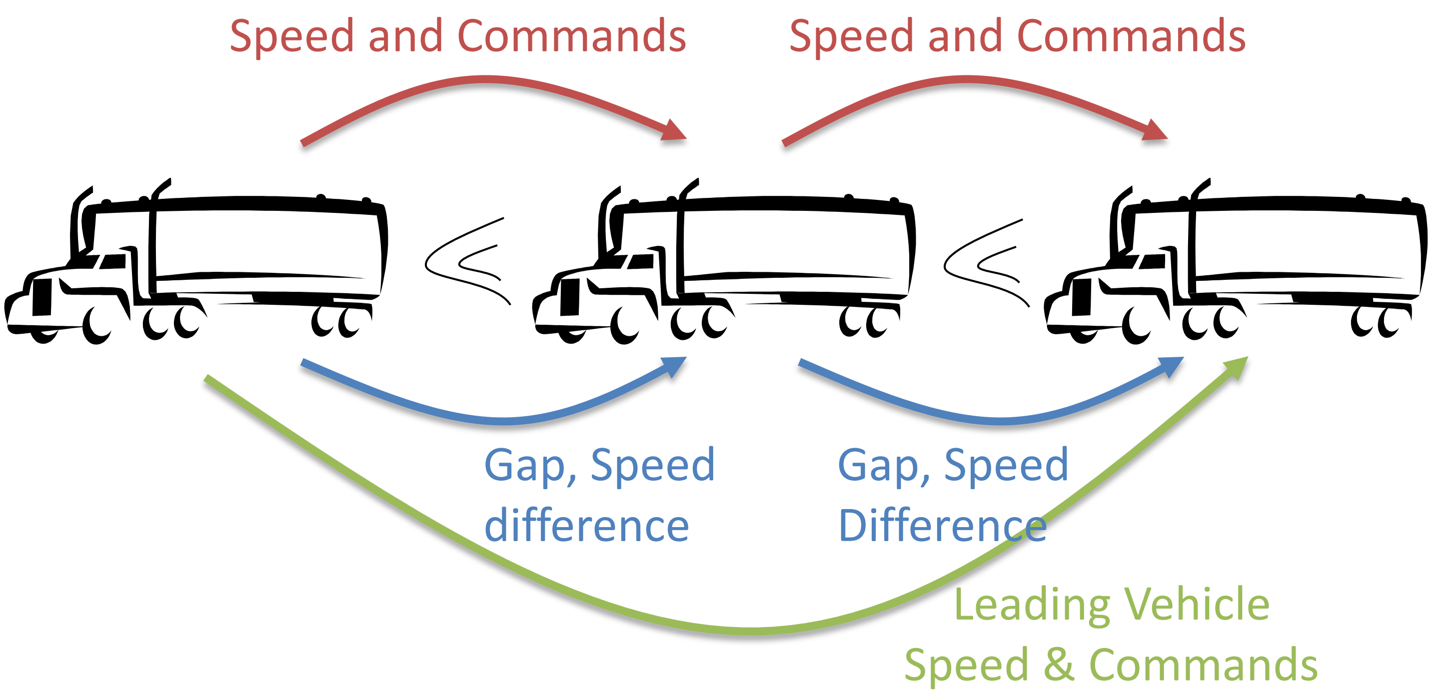
- Identify near-term opportunities for CACC to improve heavy truck operations
  - Energy savings from drag reductions
  - Traffic flow (stability and density increases)
  - Maintain safety
- Assess acceptance of moderately short CACC gaps by truck drivers
- Measure energy savings at gaps chosen by drivers
- Provide data and demos to show benefits to industry and public stakeholders

PATP Project Team



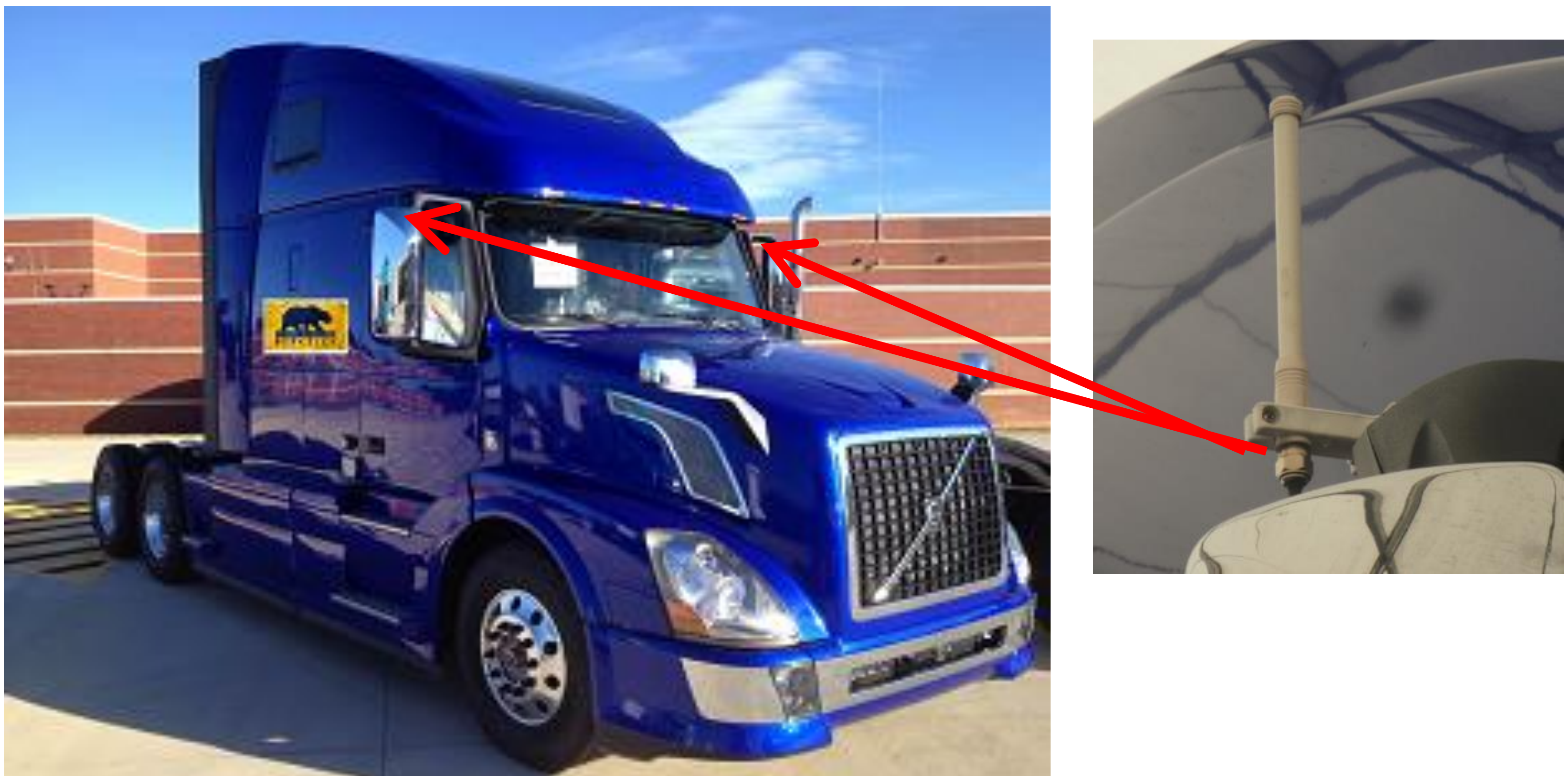
Experimental System Operating Concept

- Three truck platoon
- 5.9 GHz DSRC Communication
- Longitudinal control only (throttle and brakes) driver, steers the truck
- Vehicles already equipped with production ACC
- Lead truck either manually or automatically (ACC) driven
- Gap is based on time headway – consistent with driver preference



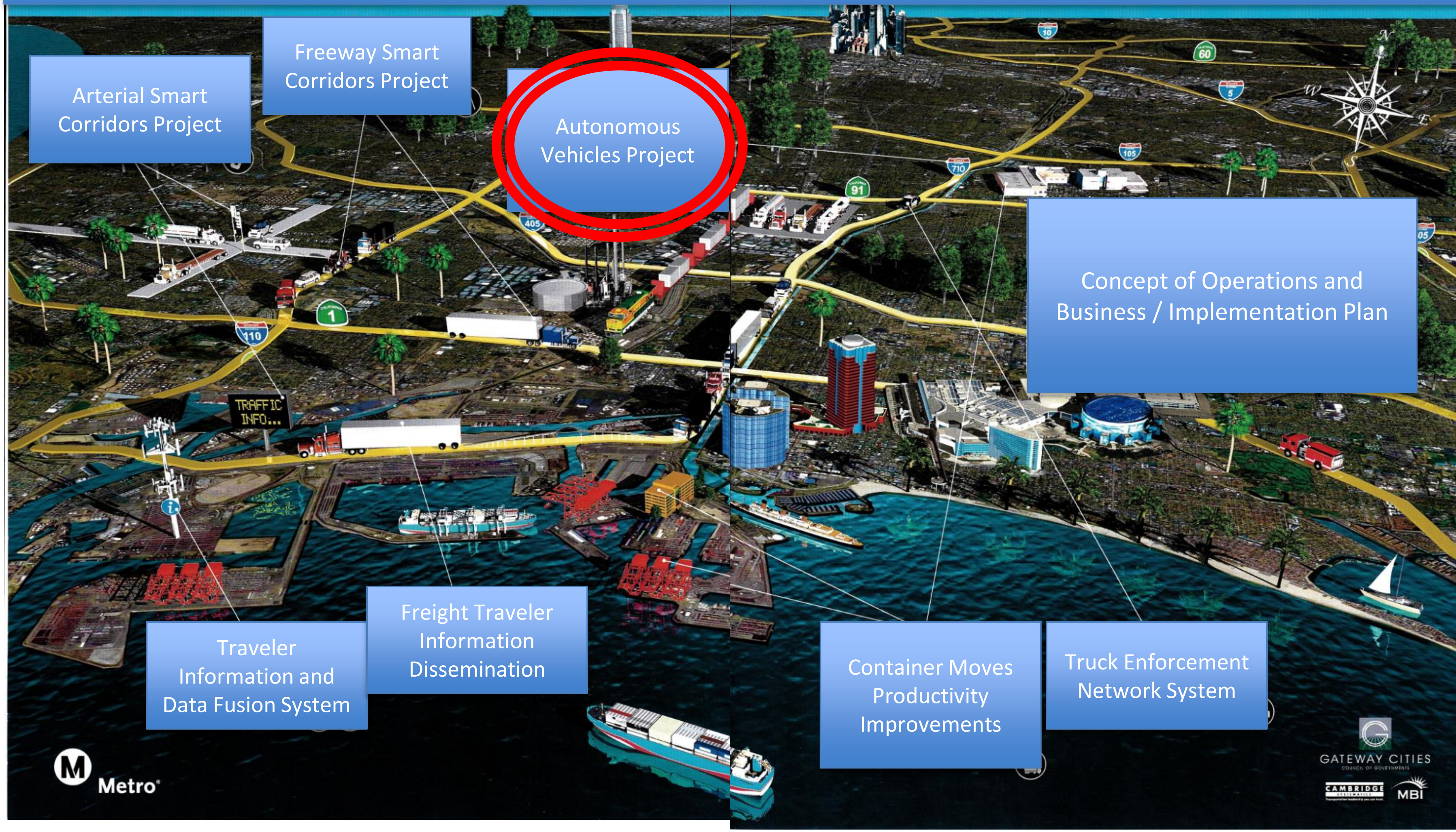
Three Trucks Equipped for CACC

- ACC + DSRC + modified vehicle following control
- Supplementary Information Display for driver



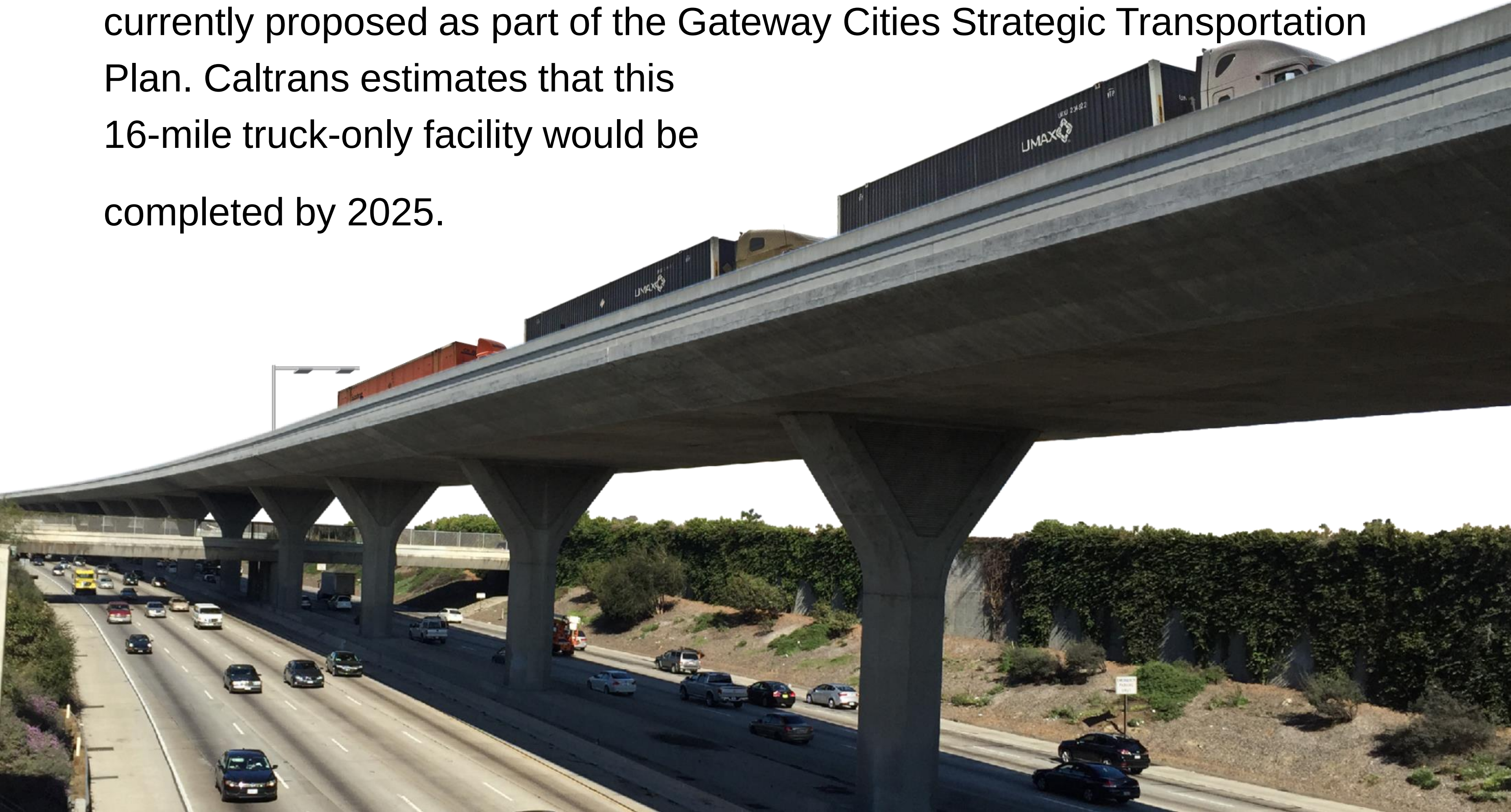
Gateway Cities Partnership and Role

Technology Projects for Gateway Cities Goods Movement



I-710 Freight Corridor Concept

A dedicated four-lane freight corridor parallel to the I-710 freeway is currently proposed as part of the Gateway Cities Strategic Transportation Plan. Caltrans estimates that this 16-mile truck-only facility would be completed by 2025.



Development/Testing Stages (1/2)

1. Modeling and simulating vehicle dynamic responses to acceleration and brake commands
2. Open-loop tests to measure truck responses to acceleration and braking commands
3. Calibrating vehicle dynamic models based on open-loop test data
4. Driving simulator tests to assess driver reactions to supplementary information display design and content
5. Closed-loop tests of CACC control at low speed on closed track, 2 trucks and then 3 trucks

Development/Testing Stages (2/2)

6. Closed-loop tests of CACC control on highway, 2 trucks and then 3 trucks
   - Large gaps, and then smaller gaps
   - Tuning to maximize string stability
   - Comparing performance with different V2V message content, for input to messaging standards
7. Human factors experiment with typical truck drivers on public roads to determine their preferences for CACC following time gap settings
8. Energy efficiency tests for range of time gaps chosen by drivers, on closed track with truck loading variations
   - Experimental controls for variations in grade and wind direction

Testing on Closed Track, Low Speed

- Initial testing of basic functionality after any modification to hardware or software
- Convenient to research team, no cost, no delay
- Minimize safety risks with low speeds and closed track
- Limitations: Short length of each run and very different truck performance compared to highway speeds

Driving Simulator Testing

- Applicable only for assessment of display design and content
  - Does it tell the driver what s/he wants to know, or is something missing?
  - Is it easy to understand?
  - Is it legible and sufficiently visible?
  - Is it too distracting (subjectively)?
- Insufficient fidelity for assessing control algorithms, following distances, safety, or steering performance

Testing on Closed Track, High Speed

- Closed track provides safety for potentially risky situations
  - Can exclude other traffic and debris
  - Any testing of fault or emergency conditions
- Closed track enables constant-speed driving for carefully-controlled energy consumption testing, with cancellation of grade and wind influences
- Need to minimize time on track for budgetary reasons
- Cannot test under real traffic conditions

Testing on Public Roads, High Speed

- Necessary to show performance under a wide range of road and traffic conditions
- Necessary for human factors experiments, to experience realistic traffic conditions
- Necessary for realistic demonstrations to stakeholders and media
- Need to be extra safety-conscious, especially with any new functionality
- Operating conditions may be constrained by state or local laws (e.g., minimum following distance)

Wind Tunnel Testing

Main Components of System

SENSORS:

Long range radar
Mid range radar
Near range radar
Scanning lidar
Fixed lidar
Mono camera
Stereo camera

OTHER:

V2X communications

GPS/Map

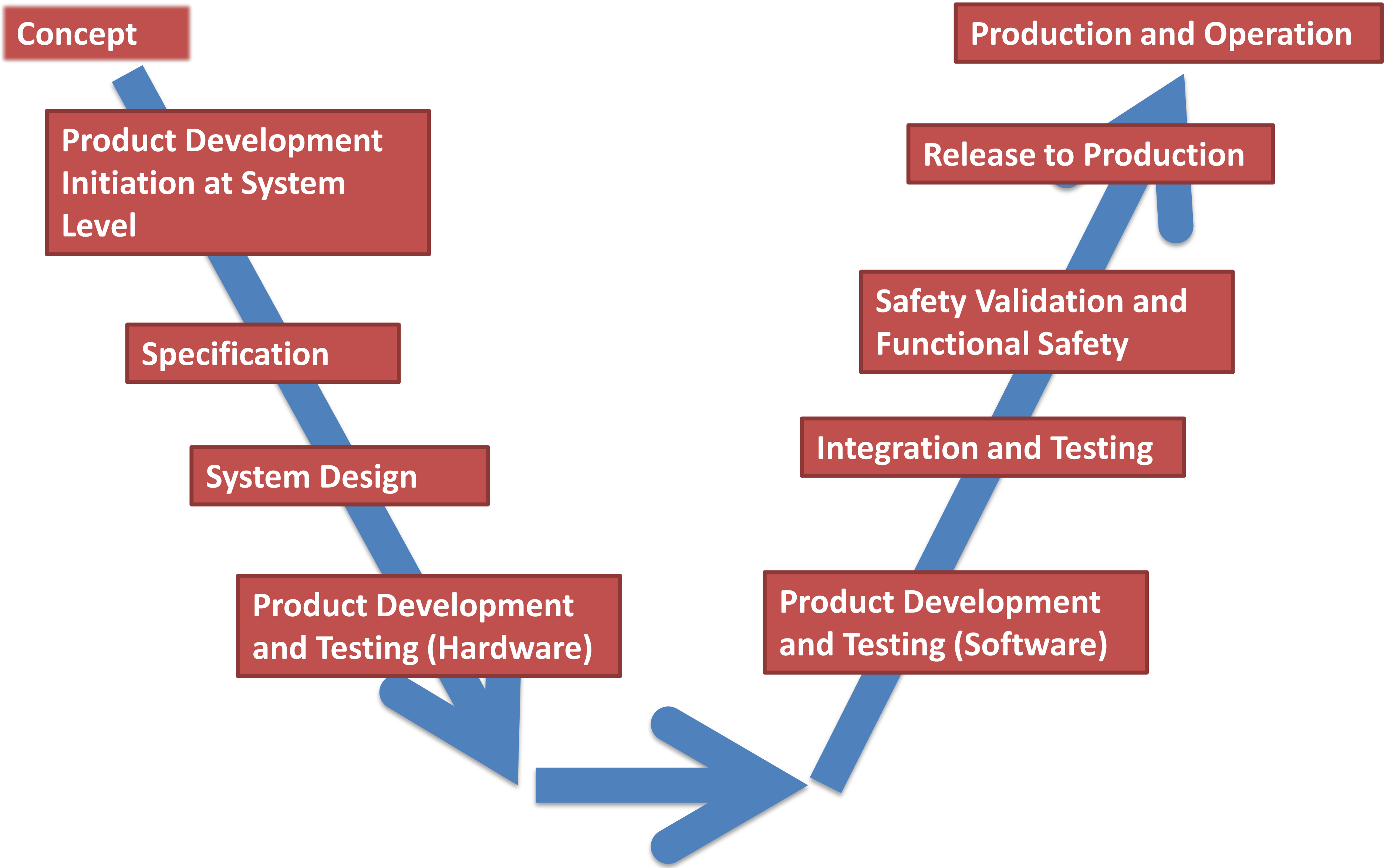
Algorithms (Software)

Control system (Hardware)

Actuators

Driver – Vehicle Interface

Concept to Production



ASIL

Automotive Safety Integrity Level (ASIL)

Classes of Severity:
S0 – No Injuries
S1 – Light and Moderate Injuries
S2 – Severe and Life Threatening Injuries
S3 – Life Threatening Injuries and Fatal Injuries

Classes of Controllability:
C0 – Controllable in General
C1 – Simply Controllable
C2 – Normally Controllable
C3 – Difficult to Control or Uncontrollable

Classes of Probability of Exposure:
E0 – Incredible
E1 – Very Low Probability
E2 – Low Probability
E3 – Medium Probability
E4 – High Probability

ASIL Level is determined for each hazardous event using the parameters;

- **Severity**
- **Controllability**
- **Probability of Exposure**

A – Lowest Safety Integrity Level
B –
C –
D – Highest Safety Integrity Level

SUMMARY

NHTSA AUTOMATION LEVELS:

Level 0 thru Level 4 – Each Level has its own attributes (hazards and consequences) and may require customized testing procedures.

NEED NEW PARADIGM FOR TESTING AUTOMATED SYSTEMS:

Virtual Testing;

Comprehends vehicle, driver, roadway, traffic, environment, etc.
Combination of Simulation, Hardware-in-the-Loop, Driver Simulation, etc.
Stress Testing
Interoperability Testing (Specifically for Connected Automation)
Vulnerability Testing

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