# Overview of California PATH's Cooperative Truck Platooning Systems

**Steven E. Shladover, Sc.D.**

**University of California PATH Program and Lawrence Berkeley National Laboratory**

**ARRB, September 2017**

BERKELEY LAB

CALIFORNIA PATH

# Outline

- What is truck platooning and why care about it?
- Background on prior truck platooning work
- PATH's earlier truck platoon tests
- The current implementation – cooperative adaptive cruise control and close-formation platooning

BERKELEY LAB

CALIFORNIA PATH

# What is truck platooning?

- Coordinated driving of clusters of heavy trucks using automatic control of their speed and separation (SAE Level 1 automation)
- Extension of adaptive cruise control (ACC), measuring truck separation using radar and controlling engine and brakes
- Addition of wireless vehicle-vehicle (V2V) communication to enable close coordination
- Loose coupling by cooperative ACC or tighter coupling with constant clearance gap
- Driver steers and watches for hazards

BERKELEY LAB

CALIFORNIA PATH

# Why care about truck platooning?

- **Significant energy savings from aerodynamic drafting**
- **More stable vehicle following dynamics, reducing traffic flow disturbances and saving additional energy and emissions**
- **Increased highway capacity and reduced congestion from improved traffic dynamics and shorter gaps**
- ***(Potential)* safety improvement**

BERKELEY LAB

CALIFORNIA PATH

# Truck Platoons are not new…

- **CHAUFFEUR Project in Europe 1996-2004**
- **First U.S. project – PATH research for Caltrans demo 2000-2003**
- **German KONVOI Project 2005-9**
- **Japanese Energy ITS Project 2008-2013**
- **European SARTRE Project 2009-2012**
- **European Truck Platooning Challenge 2015-16**
- **European multi-brand truck platoon project from 2018**

BERKELEY LAB

CALIFORNIA PATH

# PATH History with Truck Platooning

- **Demonstration project for California Department of Transportation 2000-2003**
  - **2-truck platoon at gaps from 3 m – 10 m, with energy saving measurements**
- **Development project for FHWA Exploratory Advanced Research Project (EARP) 2007-11**
  - **3-truck platoon at gaps from 4 m – 10m, with energy saving and maneuver tests**
- **Development project for FHWA EARP, 2014-17**
  - **3-truck cooperative ACC system at time gaps from 0.6 s – 1.5 s**
- **Fuel economy enhancements and testing for U.S. Department of Energy, 2017--**

BERKELEY LAB

CALIFORNIA PATH

# 2003 Tests of 2-Truck Platoon

BERKELEY LAB

PATH

# 2010 Tests of 3-Truck Platoon

BERKELEY LAB

CALIFORNIA PATH

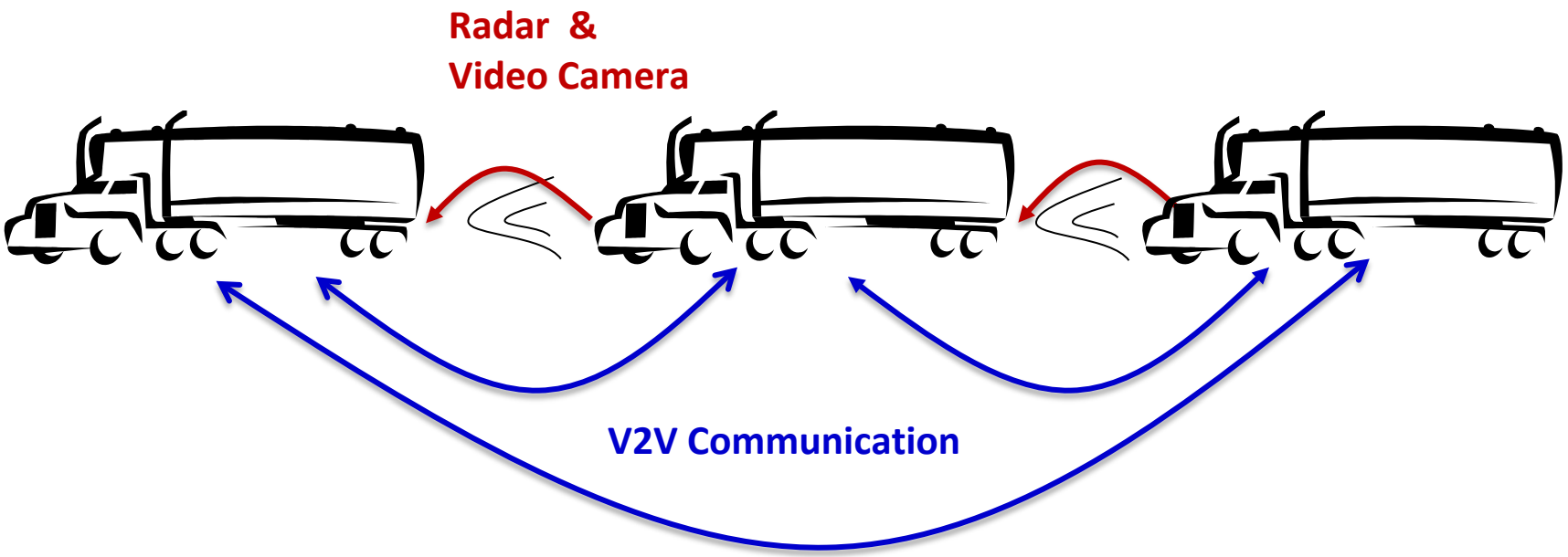
# The Current Truck Implementation

- **SAE Level 1 automation – longitudinal control only (driver steers and monitors for hazards)**
- **Building on Volvo VNL series truck ACC system (using same radar and video sensors)**
- **Added 5.9 GHz dedicated short range communication (DSRC) radio for V2V data**
- **Added touch-screen tablet display to show status of trucks and select gap settings**
- **Driver usage tested on California freeways at gaps of 0.6 s to 1.5 s (15 to 37 m at 90 km/h truck speed limit)**

BERKELEY LAB

CALIFORNIA PATH

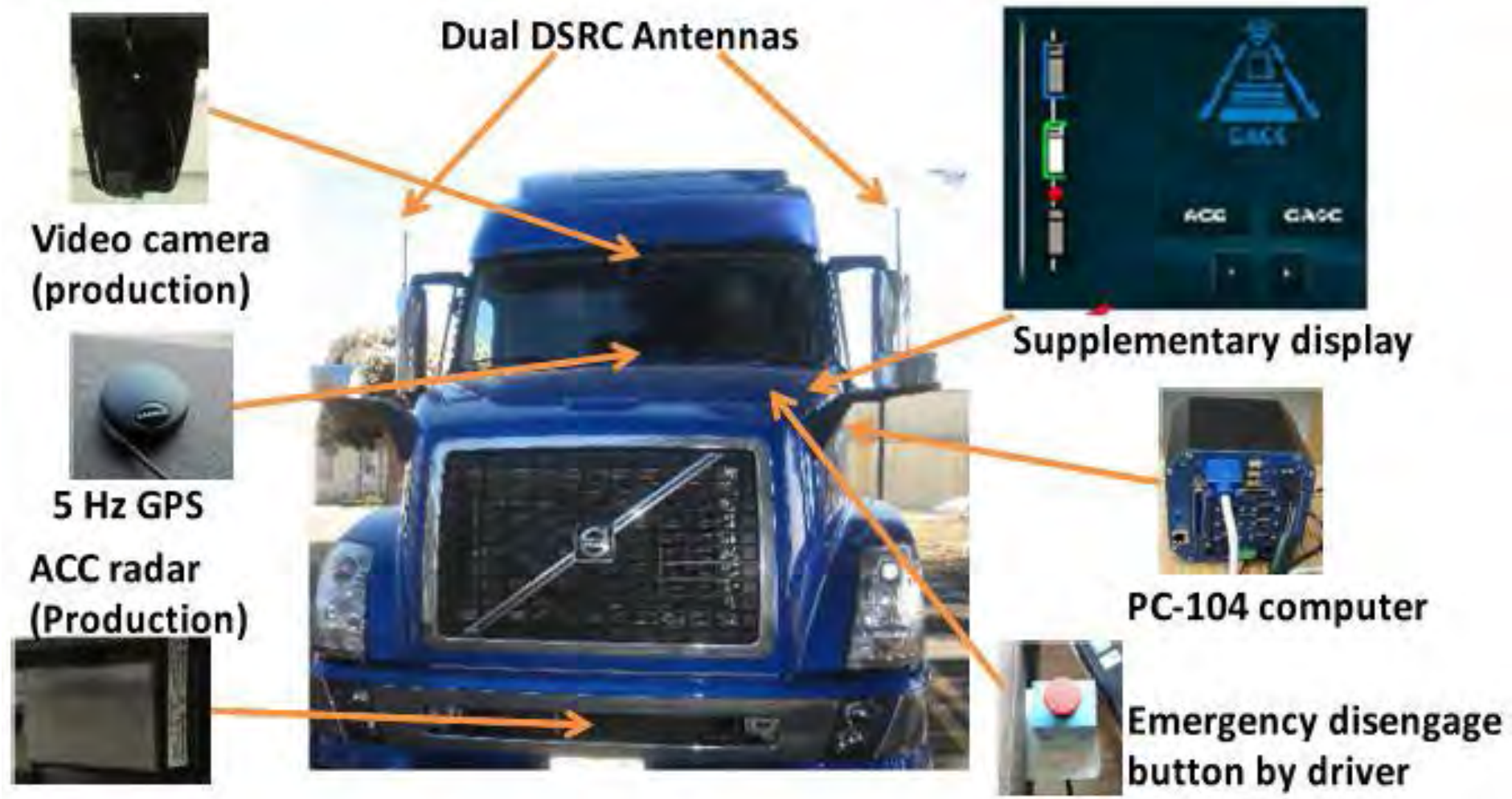
# V2V Communication/Cooperation




BERKELEY LAB

CALIFORNIA PATH

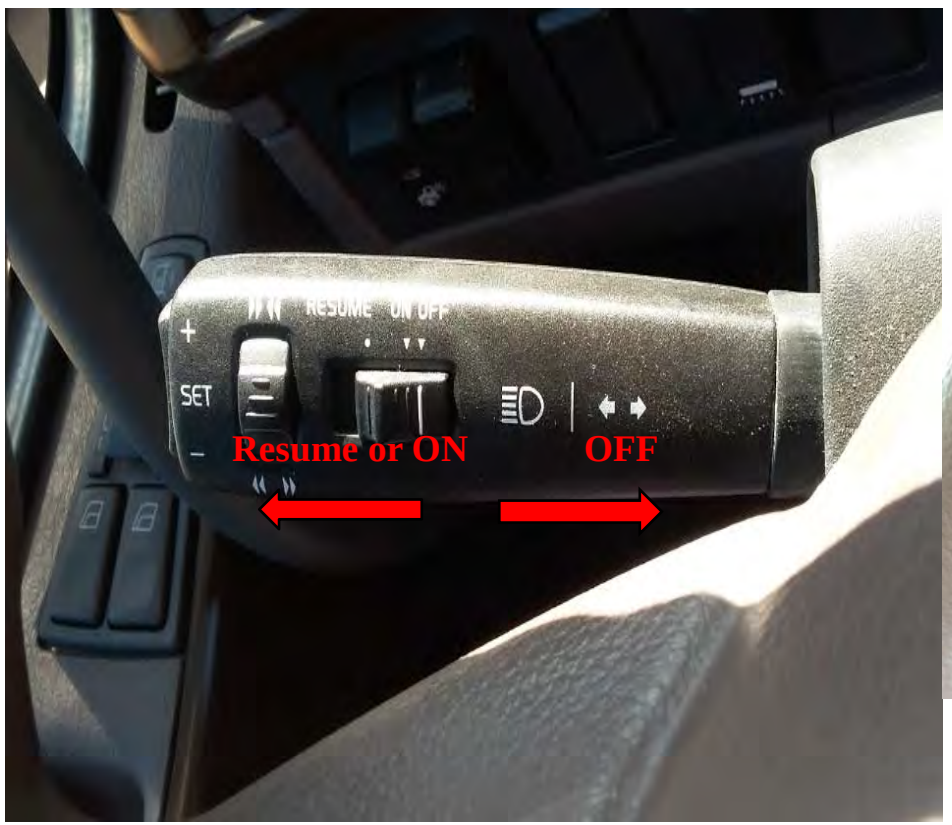
# System Elements




BERKELEY LAB

CALIFORNIA PATH

# Driver Interface



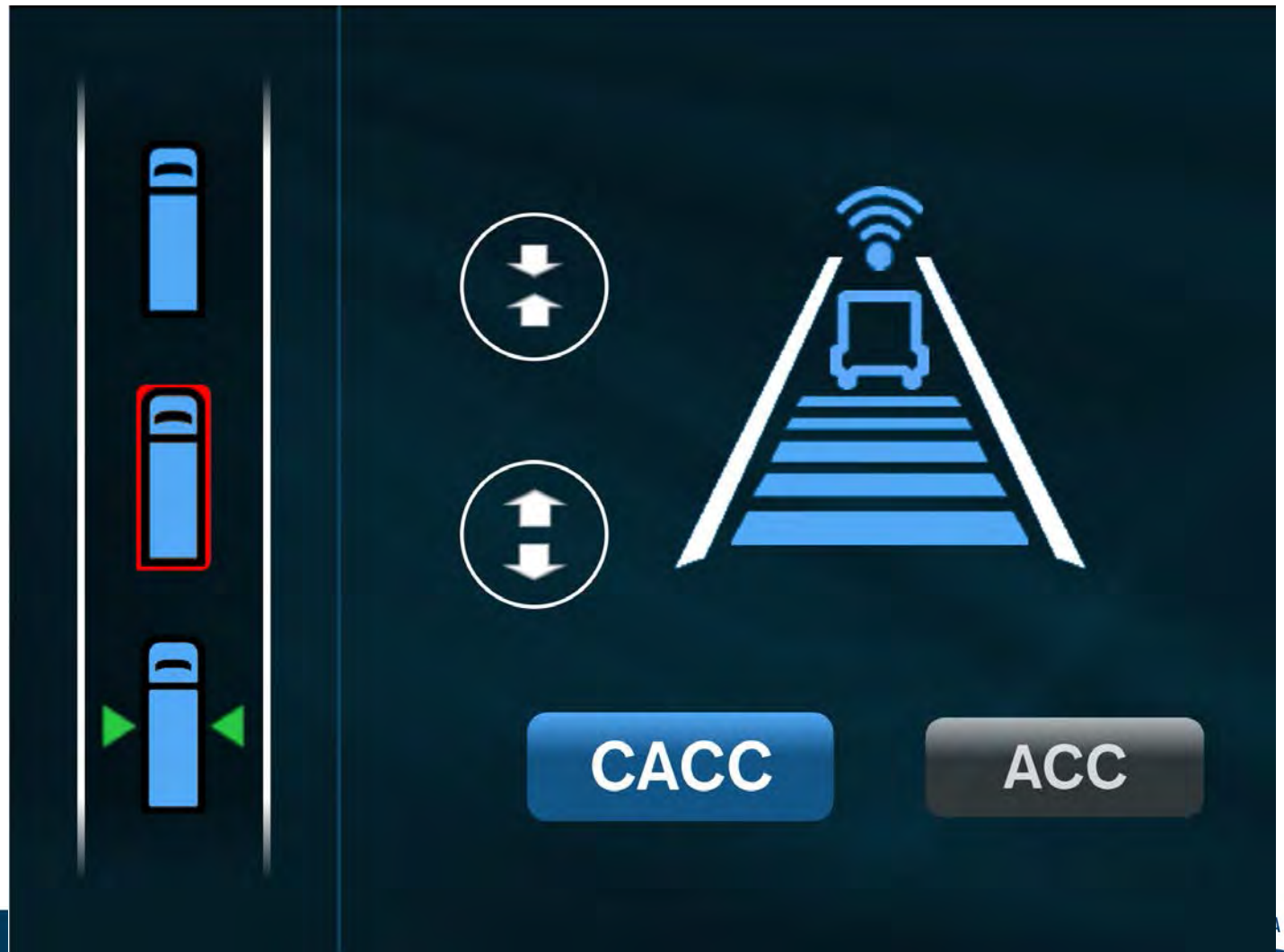

Steering wheel stalk control

# Display & Emergency Disengage Button


BERKELEY LAB

PATH

# Supplementary Display




BERKELEY LAB

CALIFORNIA PATH

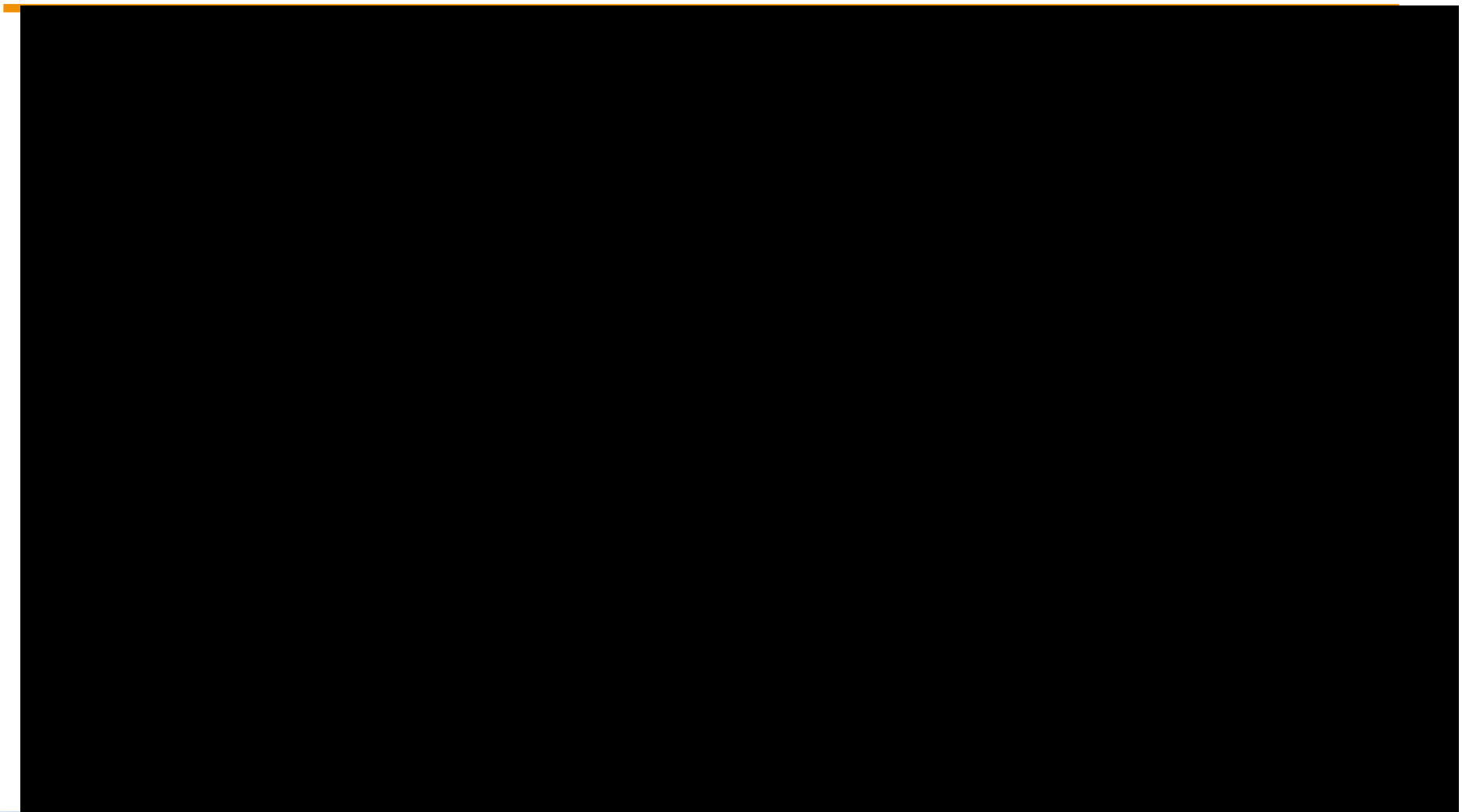
# System Enhancements

- **Wider range of gap settings implemented – from 4 m minimum fixed gap to 3 s maximum time gap (87 m at 65 mph)**
  - **Cooperative ACC at longer time gaps**
  - **Tightly-coupled platoon at shorter gaps**
- **Responses to cut-in vehicles between trucks**
  - **Performance trade-offs in rapidity of recovery vs. energy spent in more aggressive maneuvers**
  - **Need even earlier detection of cut-ins**

BERKELEY LAB

CALIFORNIA PATH

# Driving at 0.6 s Time Gap (2016)



# Driving at 4 m Gap (August 2017)

BERKELEY LAB

Transport Canada Transports Canada

CALIFORNIA PATH

# Fuel Savings per Truck at 110 km/h