Truck Platooning Early Deployment Assessment

Phase 2 Proposal Presentation

UC Berkeley PATH
December 4th, 2019

Outline

- Introduction
- Technical Approach for Phase 2
- Experimental Design
- IRB Approach
- Work Plan – Tasks and Deliverables
- Project Schedule
- Budget and Cost Share Summary
- Partnership and Outreach Plan
- Risk Management

Introduction: Background

- *Potential:* Truck Platooning has the potential to significantly improve efficiency of long-haul goods transportation
- Accomplishments in Phase 1
  - Built a partnership for Phase 2 field operational tests
  - Selected a multi-state corridor for Phase 2 from CA to TX
  - Developed an innovative and synergistic operational concept
  - Developed plan for CACC system/algorithm adoption
  - Developed data collection, storage and sharing strategy
  - Developed performance measures and an evaluation plan
  - Developed a comprehensive pilot deployment plan
  - Submitted a formal team proposal for Phase 2

Introduction: Project Goals for Phase 2

- Accelerate the deployment of CAV technologies for freight through an operational truck platooning pilot that includes in-service freight hauling
- Assess integration of truck platooning into truck fleet operations
- Better understand the impacts of truck platooning on:
  - Truck driver performance and attitudes
  - Operational logistics
  - Traffic operations
  - Public policy

Introduction - Project Team

- Core Team Members
  - University of California PATH (Project Lead)
  - Roly's Trucking, Inc. (Fleet Operator Located in LA)
  - Westat Inc. (Human Factors Experts)
  - Cambridge Systematics (Stakeholder Coordination)

- Unpaid Partners
  - Volvo Group North America
  - Caltrans and the California Highway Patrol (CHP)
  - I-10 Corridor Coalition through AZDOT
  - California Trucking Association

Introduction: Key PATH Staff

- Principal Investigator: Dr. Xiao-Yun Lu
  - Provides overall technical direction; system development; manages budget; manages technical staff; supervises field operational test
- Program/Project Manager: Ben McKeever
  - Manages scope, schedule; coordinates with project stakeholders; provides QA/QC
- Senior Advisor: Steven Shladover
  - Provides freight platooning expertise, strategic direction and QA/QC

Introduction: Key Staff

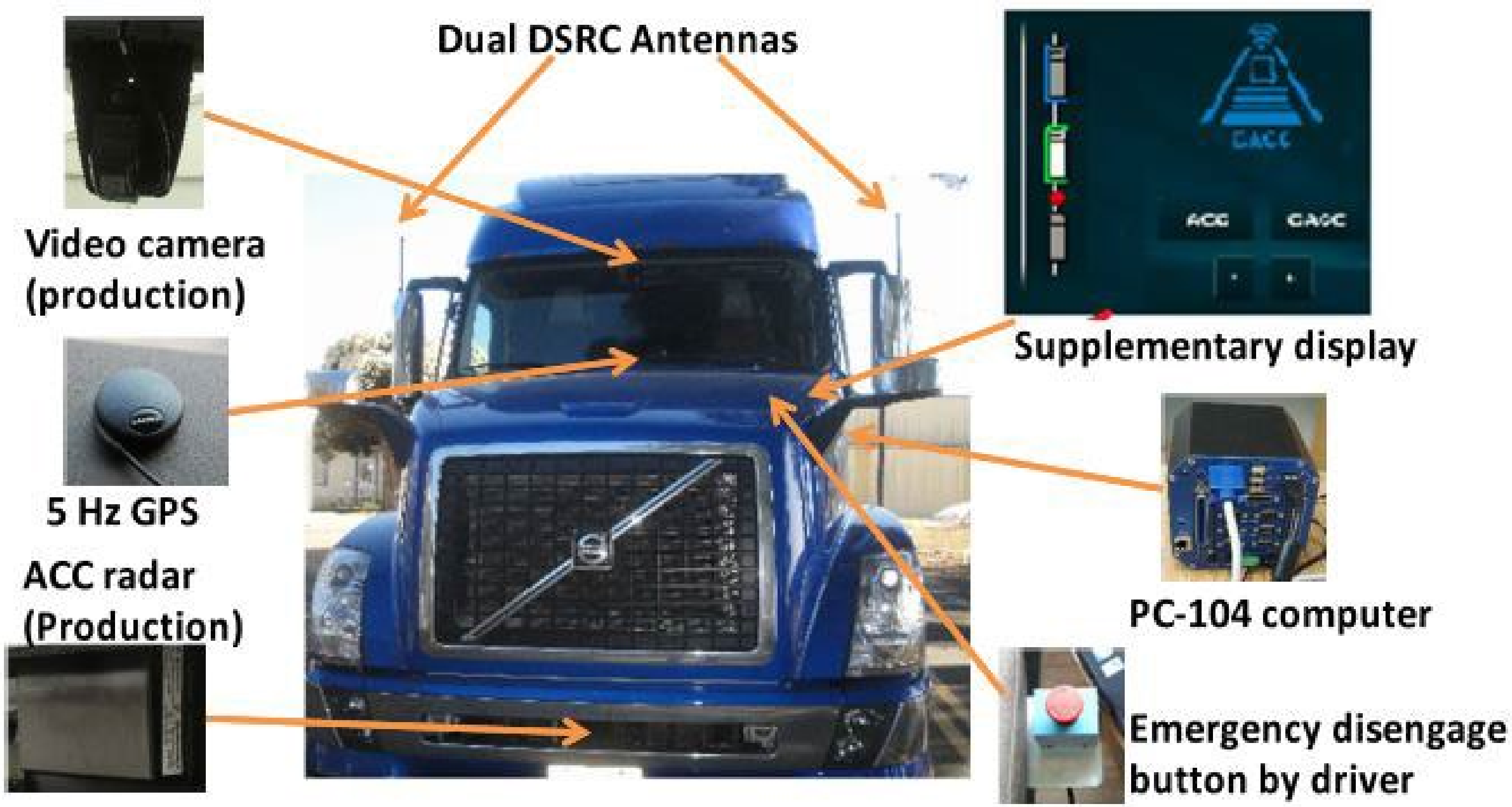
- Roly's Trucking Inc.: Michael J Johnson
- Westat: James Jenness, Rick Huey
- Cambridge Systematics: Mark Jensen
- Volvo Group North America: Carsten Lindgren, Aravind Kailas
- Caltrans DRISI: Matt Hanson

Technical Approach for Phase 2

- CACC System Implementation on New Trucks
- Safety Considerations
- Improvements over Previous PATH Truck CACC System
- Data Collection and Management Systems
- Data Collection List
- Driver Behavior Monitoring
- Estimating Fuel Consumption Savings
- Sharing Data with FHWA and IE
- Frequency of Data Sharing
- Readiness Test

CACC System Implementation on New Trucks

- **Implement CACC capability on 4 new trucks**
- **Field test for 3-truck CACC/platooning; the 4th truck will be used as the "Control Truck" as baseline for comparison, and a spare to swap in if needed**

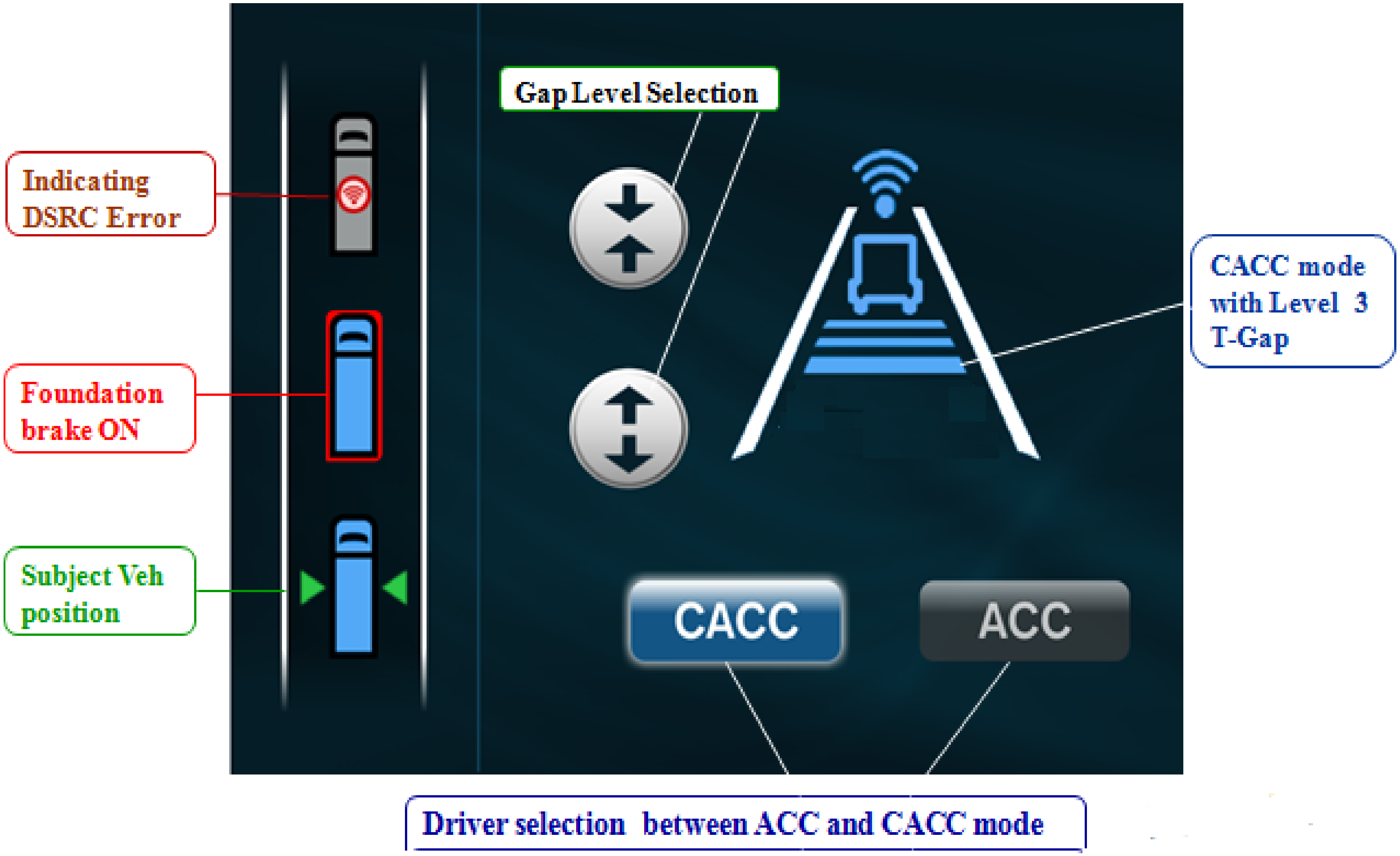


CACC System Implementation on New Trucks

- **Adopt previous PATH integrated ACC & CACC:**
  - **Overcome the cumulative delay of ACC, resulting in nearly synchronized behavior**
  - **First truck driven manually or in ACC mode for platooning**
  - **Followers in the platoon behave as if operated by *looking-ahead* and *synchronized-behavior* defensive drivers**
  - **The truck driver supervising is able to address the dynamic interactions with other vehicles in mixed traffic, which will exist for the foreseeable future**
  - **Allow smooth transitions between driving modes**
  - **Smoothly handle cut-in and cut-out by other vehicles**

CACC System Implementation on New Trucks

- **PATH developed DVI with Volvo: simple and intuitive, but information rich; convenient for driver operation; used for driver behavior tests in previous EAR project**



CACC System Implementation on New Trucks

- **CACC system activation: manual drive to above 15 mph ➔ switch on the ACC button**
- **Deactivation: ACC switch, touching brake pedal, or press emergency switch**

CACC System Implementation on New Trucks

- Feasible Concept of Operation (ConOps) for in-service assessment of truck platooning
  - PATH designed integrated CC/ACC/CACC system
  - Control almost as it is: using J-1939 Bus for internal data reading and control actuation
  - Add fixed beam lidars to enhance detection of cut-ins
  - DVI (Driver-Vehicle-Interface) and V2V (DSRC)
- Additional sensors will be installed for data collection:
  - Driver behavior monitoring
  - Interactions of CACC truck with nearby vehicles
  - Not for real-time control

Safety Considerations

- Safety from system and control point of view
- ACC – Progressive engagement /following strategy
- CACC – following strategy: more aggressive in splitting, less aggressive in gap-closing
- Interact with other traffic in cut-in and cut-out maneuvers:
  - Fast response to cut-in vehicles depends on several factors
  - Handling of multiple vehicle cut-ins
  - Handling aggressive cut-in scenarios
  - CACC → ACC → manual
  - CACC → Manual

Safety Considerations

- **Emergency Braking and Coordinated braking**
  - ***Emergency braking:*** **Driver of the lead truck manually applies service brake**
  - ***Coordinated braking:*** **using both service brake and engine retarder for all trucks automatically**
  - **Truck 2 & 3 using closed-loop automatic control to regulate the distance gap during the braking process**
  - **Quantitatively tested on Nov. 23 2019**
    - **Loaded 3 trucks with weight 21,000~*22,000 kg***
    - **Truck 2 & 3 respond based on DSRC information and sensor data**

Safety Considerations –Braking Responses

- Coordinated braking (automatically):
  - Service braking on truck 1 at: 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 m/s
  - Apply above service brake command + full engine retarder to truck 1
  - DSRC Info: Service brake switch signal, vehicle actual deceleration, engine retarder command
  - Truck 2 & 3 apply the maximum deceleration + maximum engine retarder commands of front truck(s)

Safety Considerations –Braking Responses

- Emergency braking (manually)
  - Brake switch signal, pedal deflection, vehicle actual deceleration
  - Truck 2 & 3 apply minimum initial deceleration $1.2\ [m/s^2]$ to avoid delay upon receiving braking switching signal of front truck(s)
  - Then apply the maximum of the deceleration of front truck(s) + 0.1 as the deceleration command

- Platoon gap increases

Safety Considerations

- Fault-detection & handling: DSRC, radar-camera perception, engine torque/brake control, service brake control, PC-104 control computer
- DVI and emergency button
- Avoid operation in questionable conditions
    - Set field operation speed range: e.g. 35~65 mph
    - Determine/list (and train drivers for) abnormal situations in which driver should take over manual control
    - Limit to freeways, not for onramps nor off-ramps
    - Limit weather & road surface conditions: e.g. avoiding slippery road, heavy snow & dust
    - Encouraging heavier vehicle in the front in platoon

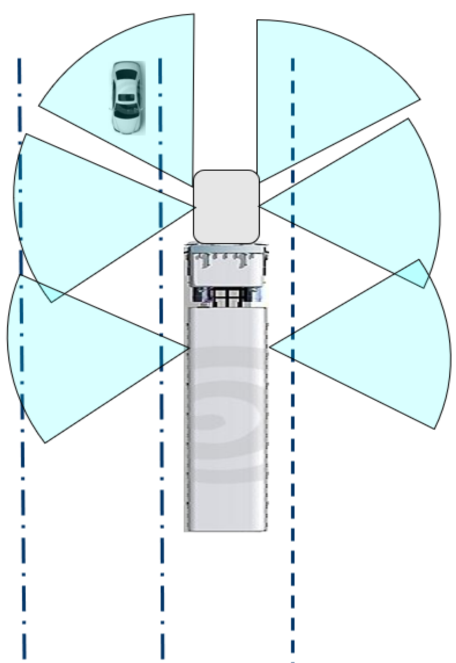
Improvements Over Our Previous Truck CACC System

- Fixed 16 beam lidar sensors mounted on the two corners of the front bumper to enhance perception of cut-ins
- Using hard-wired connection of components in the truck for better reliability (previously used WiFi)
- Improved coordinated braking and emergency braking
  - Allow driver to use service brake and engine retarder in emergency braking
  - Apply both service brake and engine retarder for coordinated braking
  - Using closed-loop control to regulate distance gap
  - Better response on negative grades

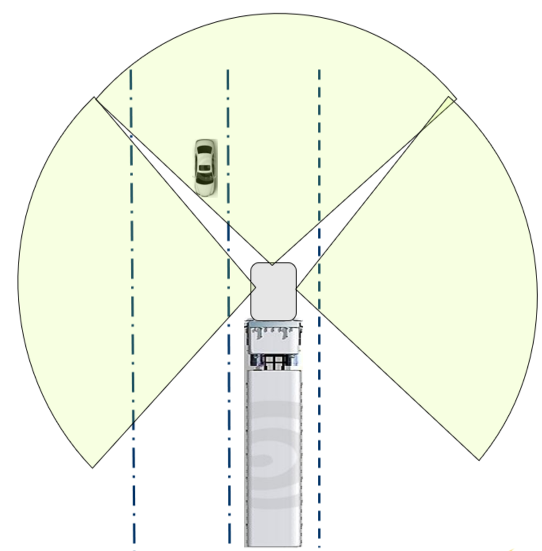
Data Collection and Management Systems

- Engineering data: onboard sensors, J-1939 Bus, control computer, and DSRC
- Extra sensors for surrounding traffic collection: fixed beam lidars and video cameras
- Wireless modem connection with trucks for monitoring: CACC system operation and data logging health

Six short distance fixed beam lidar units to cover the surrounding of the tractor; mount on the chassis only, not on the trailer

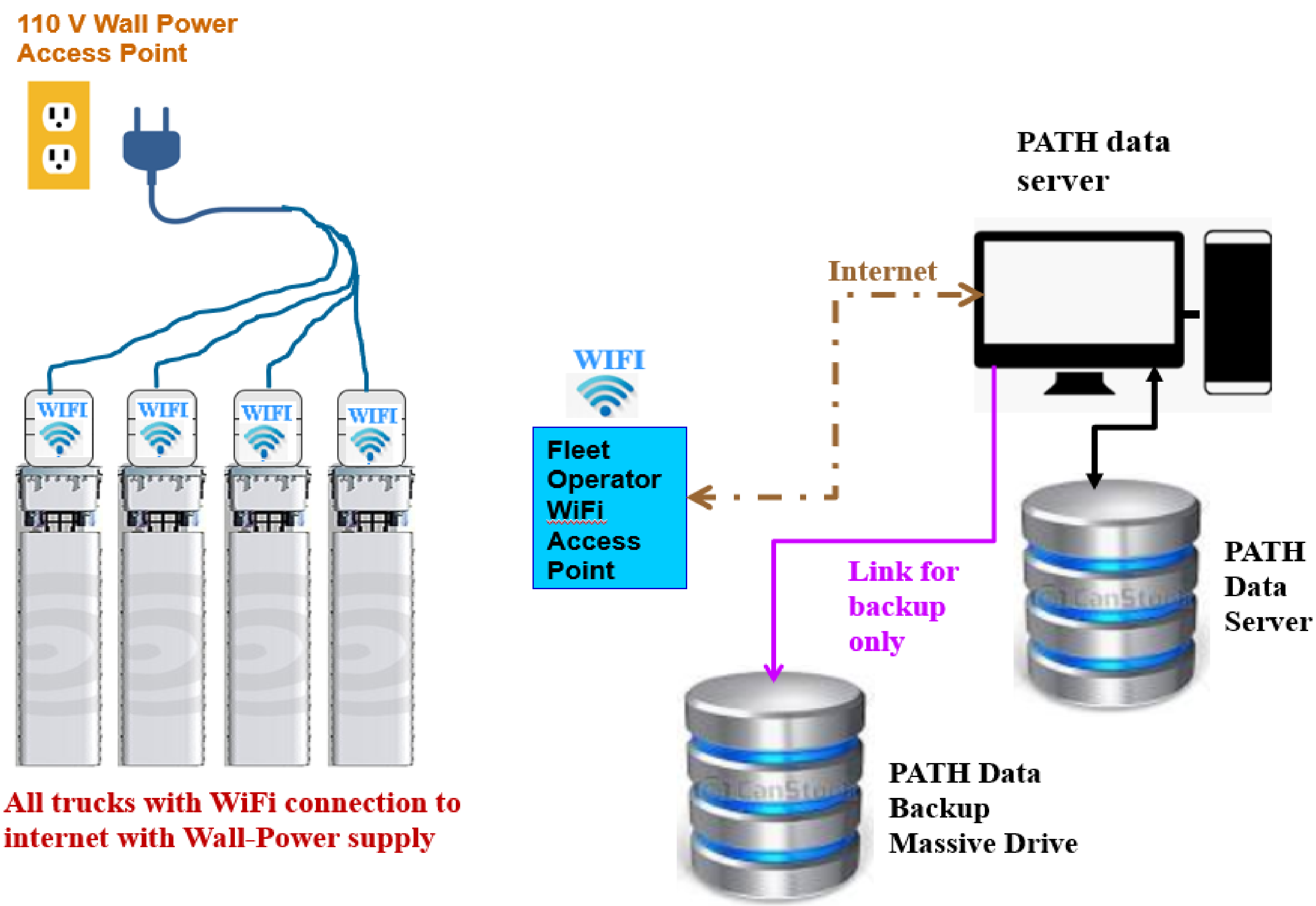


Three wide angle video camera coverage



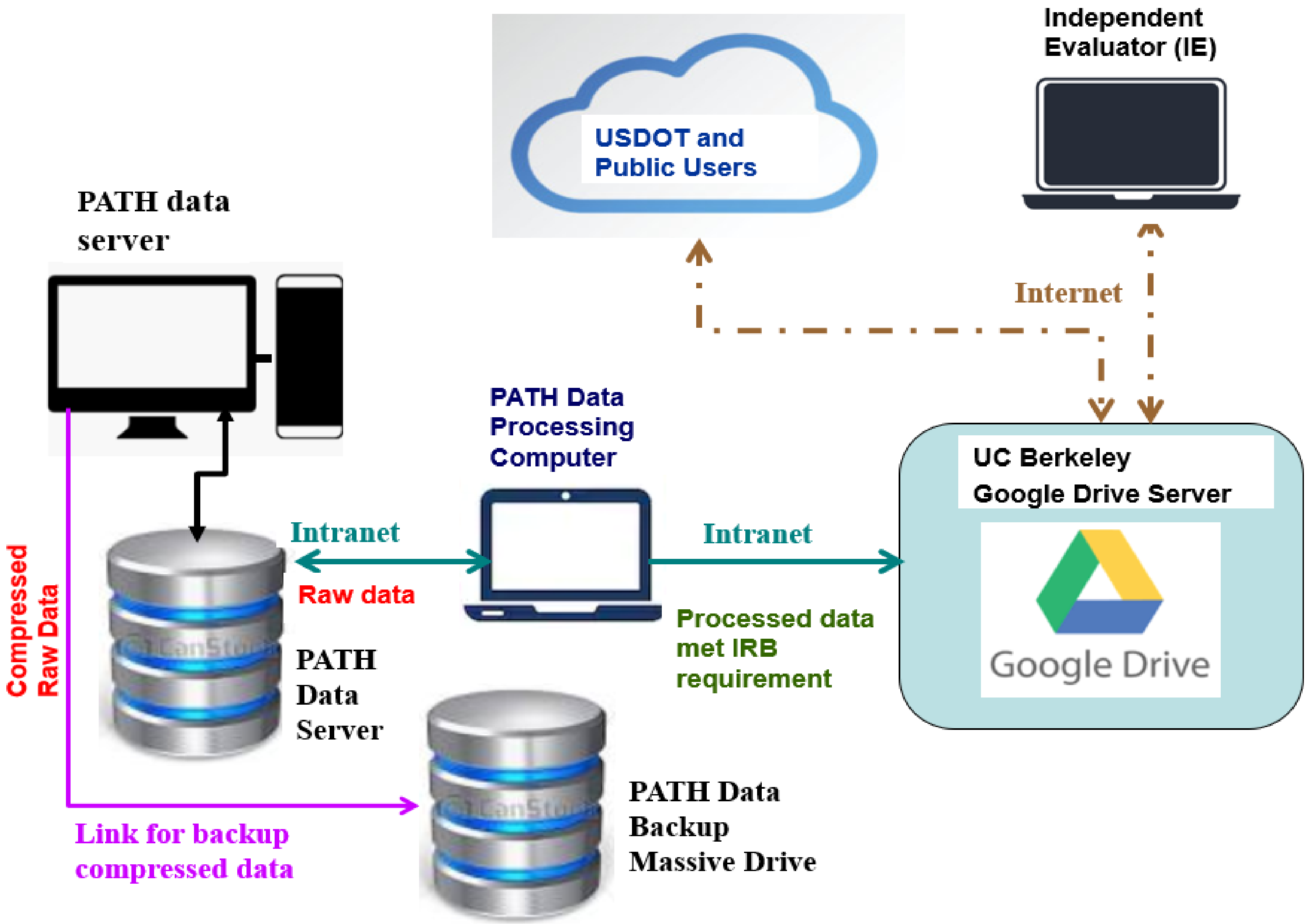
Data Collection and Management Systems

- **Data uploading strategy: through WiFi at fleet operator's access point after each trip, expected 1~3 days**



Data Collection and Management Systems

- **Data Storage, Processing and Sharing**



Data Collection List

Data Type and Name	Range	Data Type	Unit
J-1939 Bus Data and Control Data			
UTC Date: YYYY:MM:DD		int:int:int	
UTC Time: HH:MM:SS.sss		int:int:int:int	
Driver request of driving mode through Driver Vehicle Interface	{0,1,2,3,4}	int	
Actual Driving mode	{0,1,2,3,4}	int	
Fault index	0 ~ 100000	int	
ACC Time Gap Level	1~5	int	
CACC Time Gap Level	1~5	int	
Driver service brake pedal deflection [%] (measurement)	0.0~100.0	float	
Driver acceleration pedal deflection [%] (measurement)	0.0~100.0	float	
Veh position in platoon	1~3	int	
Platoon size	2~3	int	
ACC/CACC enable switch status	{0,1}	int	
Brake pedal status	{0, 1}	int	
Road Max Speed for truck	0 ~ 45	float	[m/s]
ACC/CACC Set Speed	0 ~ 45	float	[m/s]
Vehicle measured speed	0 ~ 45	float	[m/s]
Lateral acceleration	0 ~ 5.0	float	[m/s/s]
Longitudinal acceleration	0 ~ 5.0	float	[m/s/s]
Yaw rate	0 ~ 2.0	float	[rad/s]
Steering angle	0 ~ 2.0	float	[rad]
Road grade estimation	0 ~ 10	float	[%]

Data Collection List

Data Type and Name	Range	Data Type	Unit
J-1939 Bus Data and Control Data			
Truck mass estimation	0 ~ 50000	float	[Kg]
Service Brake command: deceleration	0 ~ 8.0	float	[m/s/s]
speed	0 ~ 45	float	[m/s]
acceleration	0 ~ 8.0	float	[m/s/s]
lateral acceleration	0 ~ 5.0	float	[m/s/s]
yaw rate	0 ~ 2.0	float	[rad/s]
steering angle	0 ~ 2.0	float	[rad]
mass estimation	0 ~ 50000	float	[Kg]
Running distance	0.0 ~ 999999.0	float	[m]
Desired following distance	0.0 ~ 150.0	float	[m]
Fuel consumption	0.0 ~ 100.0	float	[g/s]
Driver gap request from DVI	1~5	int	
Target acceleration (radar relative acceleration)	0 ~ 2.0	float	[m/ss]
Target speed (radar relative speed)	0 ~ 45.0	float	[m/s]
Target distance (radar/lidar measurement)	0.0 ~ 150.0	float	[m]
Target availability	{0, 1}	int	
Cut-in status	{0, 1}	int	
Windshield wiper status	{0, 1}	int	

Data Collection List

Data Type and Name	Range	Data Type	Unit
GPS Data			
All trucks: lat, long, altitude, heading	[-90.0 90.0]	double float	[deg]
Emission Data from OBD-II			
All trucks: Nox, CO, PMx (aggegated only)			
Additional Sensor Data			
16 beam lidar data			
Forward and sideward video camera			
Driver voice recordings			

Data Collection List – Driver Behavior

SmartCap LifeBand - Fatigue Output			
Data Name	**Range**	**Data Type**	**Units**
SC Fatigue Level	2 to 4	int	
SC Driver	1 to 40	int	
SC Truck	1 to 4	int	
SC Time	000000.00 to 235959.99	time	HHMMSS.ss
SC Date		date	YYYYMMDD

Jungo VuDrive - Attention Event List			
Data Name	**Range**	**Data Type**	**Units**
Jungo Time	000000.00 to 235959.99	time	HHMMSS.ss
Jungo Date		date	YYYYMMDD
Jungo Driver	1 to 40	int	
Jungo Truck	1 to 4	int	
FrameNumber	1 to 99999999	long int	frames
TimeFromStart	0 to 9999999999	long int	milliseconds
Date	YYYY-MM-DD HH:MM:SS.sss	date/time	
EventName	HELLO, START-RIDE, DISTRACTION, CPU-HIGH, END-RIDE	text	
EventDetails	Face	text	
EventUUID	freeform	text	
VideoFile	freeform	text	

Data Collection List – Driver Behavior

Jungo VuDrive - Individual Attention Events			
Data Name	**Range**	**Data Type**	**Units**
EventUUID	freeform	text	
EventName	HELLO, START-RIDE, DISTRACTION, CPU-HIGH, END-RIDE	text	
EventDetails	Face	text	
Date	YYYY-MM-DD HH:MM:SS.sss	date/time	
Duration	30s	text	seconds
Resolution	1280x480	text	pixels
Size	0 to 10	float	megabytes
Latitude	-90 to 90	float	degrees
Longitude	-180 to 180	float	degrees

Driver Behavior Monitoring

- **SmartCap LifeBand System**
  - **Assessing driver fatigue/ drowsiness**
  - **Uses AI-enabled dry EEG**
    - **Gold standard for fatigue**
  - **Truck-mounted phone/tablet**
  - **Automatic calibration and detection of each driver**
  - **Small, wireless, and lightweight**
  - **Fits various styles of hats or without a hat**
  - **Rechargeable battery with 60-100 hours of life**
  - **Measures levels of 1 (hyper alertness) to 5 (involuntary sleep), but reports levels 2 through 4**

LifeBand and App

2	TYPICAL LEVEL OF ALERTNESS	No immediate action required
3	ALERT WITH SOME EARLY INDICATORS	No immediate action required
3+	TRANSITIONING PHASE FROM 3-4 (EARLY WARNING)	Your risk of a microsleep is increasing, take action to help manage your fatigue.
4	HEIGHTENED RISK OF MICROSLEEP	You are at heightened risk of microsleep and need to take IMMEDIATE action.

Driver Behavior Monitoring

- **Jungo VuDrive System**
  - Assessing driver attention & distraction, (also useful backup for fatigue/drowsiness)
  - Automatic driver recognition
  - Uses AI-enabled face monitoring of head pose and gaze estimates
  - Flexible mounting for truck cabs
  - Local SD storage capable of 2 weeks of 24/7 dual cam recording
  - Location aware and cloud connected for review & archiving
  - Much smaller data footprint with fewer measures than eye tracking
  - Web portal for periodic review and issue assessment/adjustment

Driver Monitoring Camera

Road Scene Camera

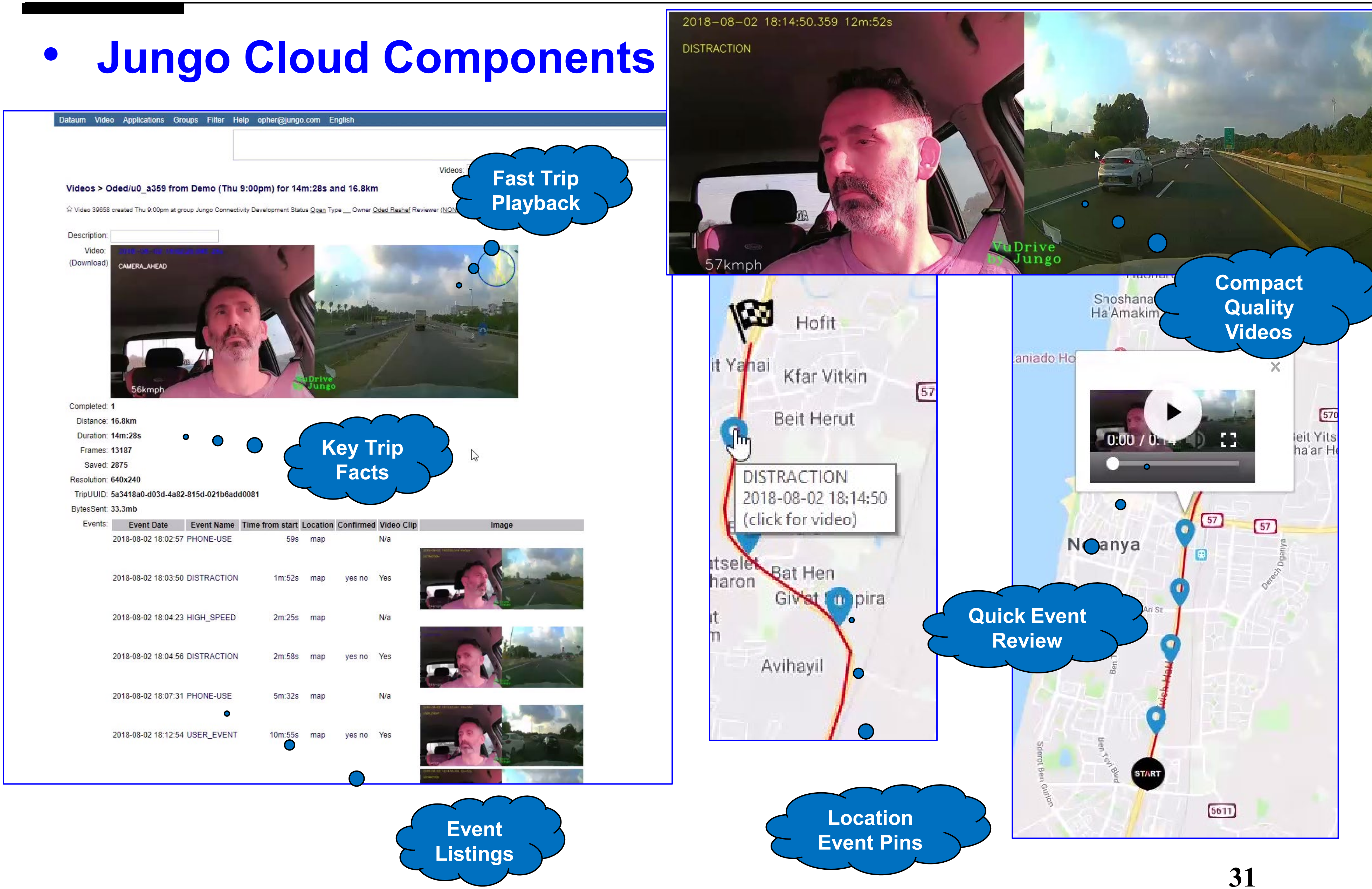
Manual Input Button

Driver Behavior Monitoring

- **Jungo & SmartCap Combination**
  - Gold standard fatigue monitoring from mature EEG technology
  - SmartCap is capable of detecting & alerting of microsleeps BEFORE the eyes close
  - Both systems provide driver recognition automatically
    - One through AI and the other through a dedicated LifeBand
  - Both are cloud enabled for easy and secure access to data
  - Jungo provides a dashcam-like record of drives and events for quick review and QC
  - Jungo provides mapping of trips and events for intuitive review
  - Jungo provides a level of roadway and surrounding traffic capture that may be valuable in assessments as well
  - Jungo may allow some additional, intelligent flags of phone use or head bobbing beyond the basic indications of distraction

Driver Behavior Monitoring

- **Jungo Cloud Components**

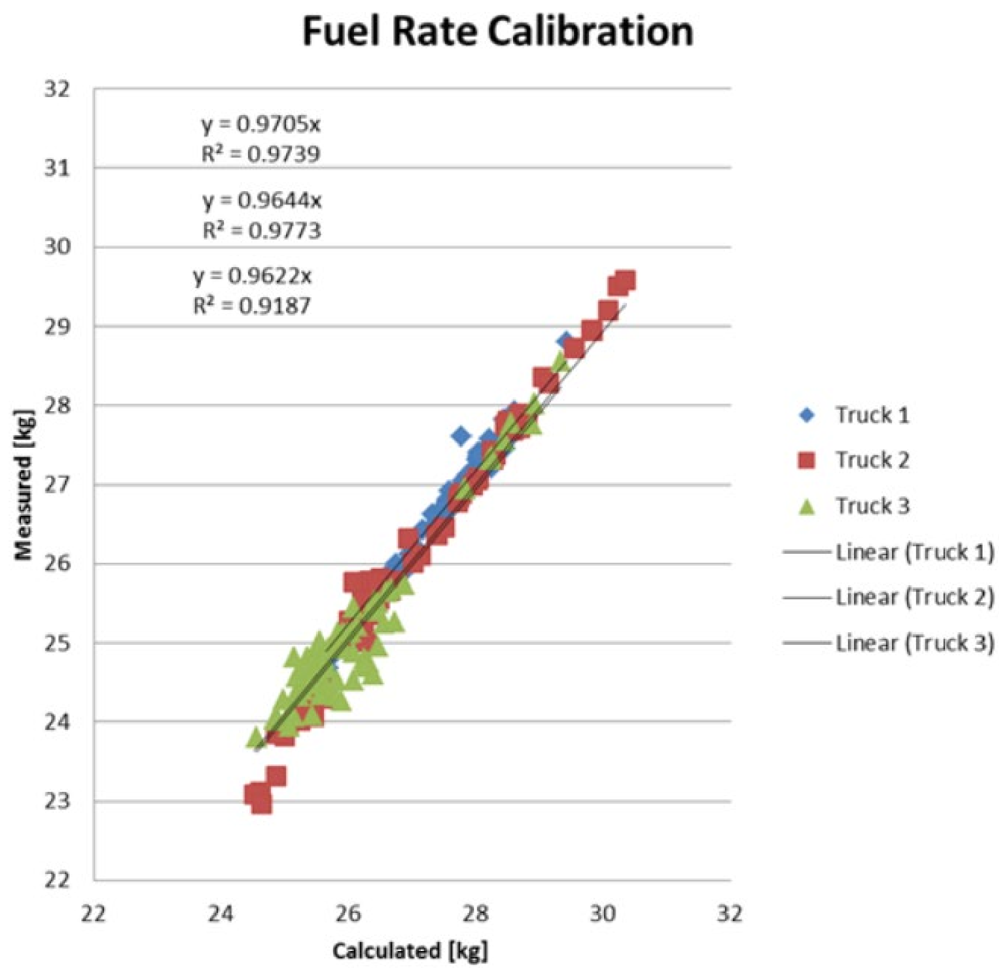


Estimating Fuel Consumption Savings

- Variability of real-world driving leads to less precise data than carefully controlled test track tests
- Fuel injector data recorded on all trucks as the primary data source – throughout each trip
  - Our tests with Transport Canada in 2017 included calibrating these data against the “gold standard” gravimetric fuel consumption measurements
- Compensate for differences in truck loading based on use of Volvo transmission (accurate) measurements of each truck’s mass
- Compare control truck against each truck in platoon to estimate savings from platoon driving on each trip

Estimating Fuel Consumption Savings

- Two data sources will be used for fuel consumption estimation:
  - CAN Bus fuel injector data, calibrated with actual fuel consumption
  - Additional Info: Fleet operator recorded actual fuel purchased along the way – including that not to be counted for test scenarios



Sharing Data with FHWA and IE

- **All engineering data**
- **Aggregated emission data (from OBD II)**
- **Processed driver behavior data within IRB requirement**
- **Processed video data within IRB requirement**
- **Operational Management Data**
  - **Trailer information**
  - **Trip distance and O-D**
  - **Combination weight (tractor + trailer)**
  - **Driver shifts**

Frequency of Data Sharing

Data category	Examples	Sharing Process
Non-regular event data		
At specific milestones	Surveys of drivers, dispatchers Driver training status	Report on completion of each milestone, within 2 weeks
Abnormal events	Crashes Significant failures Serious driver concerns	Notify within one day Summary report bi-weekly Full data upon resolution of issue
Regular event-based data		
Fleet off-board data	Dispatch schedules, loads Fueling, maintenance, inspection	Bi-weekly updates Google Drive server access
Truck onboard data	Driver concern logs Traffic incidents, low TTC events	Bi-weekly updates Google Drive server access
Continuously recorded data		
Truck eng'rg data	Sensor data from CAN bus Control performance, fuel use	Upload rate TBD – daily or weekly to Google Drive
Driver behavior data	Driver attention and fatigue Driver voice recordings, video	Bi-weekly or monthly, depending on effort involved – Google Drive

Readiness Test – Check List

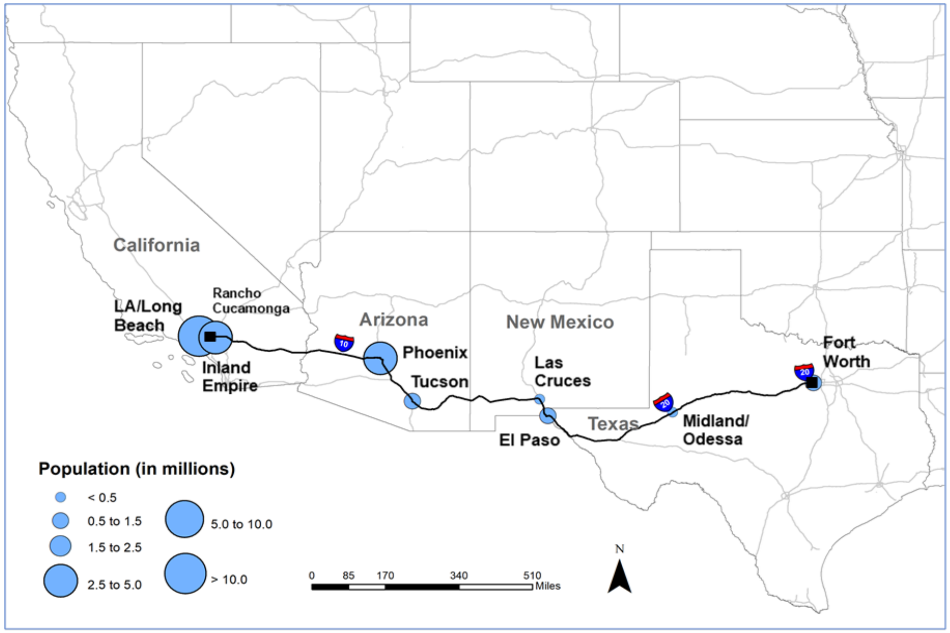
- Selected route – interstate operation and weather condition
- IRB approval
- Driver training and operation
- Freight demands and planned operational logistics
- CACC system functioning for all the planned scenarios
- Extra sensors for data collection, including driver monitoring
- Data logging of all data sources on the trucks
- Remote monitoring: CACC & data acquisition system health
- Data uploading to PATH Data Server
- Data management system and sharing with IE

Experimental Design

- **Based on balancing among priorities:**
  - **Produce a well-controlled experiment that generates authoritative data about platooning in the real world**
  - **Fit within Roly's Trucking's regular operations with a minimum of disturbance**
  - **Collect enough data for statistical significance**
  - **Fit within tight budget constraints**

Experimental Design – Test Route

- Rancho Cucamonga, CA to Fort Worth, TX – 1400 miles
- Mostly rural (I-10, I-20), with a few urban metro areas (Inland Empire, CA, Phoenix, Tucson, El Paso)
- Both daytime and nighttime driving
- California, Arizona, New Mexico, Texas (3 border crossings each way)
- Mostly flat, with a few mountain passes to cross



Experimental Design – "Control Truck" Concept

- One identical truck drives the same route as the platoon but separate from the platoon
- Dispatch close to the same time as the platoon to have similar traffic and weather conditions
- Compare data from solo truck with data from platooned trucks to identify differences in:
  - Fuel consumption
  - Driver behavior/alertness
  - Interactions with surrounding traffic
  - Travel time/delays
- Fourth truck is also a "spare" to replace a platoon truck with a possible CACC failure
- If demand does not support 4 trucks some days, could operate 2-truck platoon + control truck

Experimental Design – Truck Dispatching

- Eastbound trips well coordinated at Roly's headquarters in Rancho Cucamonga for platoon dispatch
- Westbound trips may not be as well coordinated based on demand patterns, so some may not be platooned
- Specific dispatching patterns will depend on fleet operational needs of Roly's at the time (18 months away)
  - Team driving of each truck to make fastest trip, without layovers (2 round trips per week) – about 200 one-way trips in a year of testing if all done this way
  - One driver per truck, with layovers at Love's Travel Stops (1 round trip per week) – about 100 one-way trips in a year of testing if all done this way
  - Data uploading at Roly's headquarters and at Love's Travel Stops

Experimental Design – Driver Assignments

- Train a cohort of 5 drivers to assign to the 4 test trucks (one extra to allow for possible unavailability of any driver)
  - Baseline manual driving data collection first
  - Individual ACC driving baseline data collection
  - Platoon driving – determine best patterns for rotating drivers among 3 platoon positions and control truck
- Each cohort goes 3 months, then repeat with next cohort to get a broader sample of drivers (~20 drivers)
  - Mix of different levels of driving experience
  - Long enough driving period for learning and adaptation by drivers – analyses will focus on changes in each driver's behavior over the 3 months, both in platoon and driving control truck solo

Experimental Design – Data Collection

- Extensive engineering data on technical performance of the CACC platooning system and fuel consumption
- Driver fatigue and attentiveness data
- Subjective data from questionnaires:
  - Drivers and dispatchers/managers at Roly's
  - Attitudes about truck platooning before, during and after completion of the test period
  - What they liked and did not like about the platoon driving
  - Any changes to their normal operations that were needed
  - Perceived costs and benefits (to combine with more objective measurements of these)

IRB Approach

- U. C. Berkeley Committee for the Protection of Human Subjects (CPHS) is Institutional Review Board (IRB)
- The human subjects research protocol requires:
  - Background about the project, including funding sources and research goals.
  - Details about subject recruitment processes
  - A detailed plan of what activities will be required of the subjects, who will interact with subjects, risks, benefits or costs the subject receives or incurs, and incentives offered to the subjects
  - What data are collected, how it will be collected, how it will be transmitted and stored, and who will have access to the data
  - Documented informed consent form(s)

IRB Approach

- Research protocols and CPHS approvals are public information, and can be shared with USDOT
- Data are considered identifiable when it can be traced back to an individual subject, such as video and some GPS data
- All driver identifiable data will be processed to meet IRB requirements before sharing
- SmartCap LifeBand EEG data and Jungo VuDrive video data will be processed by Westat

Work Plan: Task 1

- Task 1 – Program Management (PATH)
  - Prepare Project Management Plan (including a risk management plan and risk registry)
  - Hold project kickoff meeting: prepare presentation including PMP
  - Contract with sub-recipients
  - Finalize specifications for lease of four new trucks with Roly's Trucking's local Volvo Truck dealer
  - Quarterly project progress reports
  - Interim briefings at key milestones
- Deliverables
  - Project Management Plan (including a risk management plan and risk registry)

Work Plan: Task 2.

- Develop a Comprehensive Truck Platooning Deployment Plan Based on Phase 2 Proposal
  - Update the contents of the Phase 2 Proposal
  - Develop a Comprehensive Truck Platooning Deployment Plan for the Phase 2 field test, including the Operational Concept based on updated Phase 2 Proposal content

- Deliverables
  - Comprehensive Deployment Plan

Work Plan: Task 3

- Establish partnerships with organizations identified in Partnership Plan
  - Update Partnership Plan from Phase 1
  - Finalize detailed division of responsibilities with Roly’s Trucking
  - Finalize test route and scenarios
  - Twin with EU truck platooning field test project
  - Coordinate with the state partners along the test route
  - Set up test data uploading access points and procedures
  - Develop Partnership Establishment Result Report

Work Plan: Task 3

- **Deliverables**
  - **Updated Partnership Plan**
  - **Partnership Establishment Result Report**

Work Plan: Task 4

- CACC/platooning implementation on four Volvo Trucks
  - Lease Volvo trucks and purchase new hardware/software
  - Prepare System Refinement Plan
  - Purchase and implement driver status monitoring system
  - Implement PC- Control computer, install real-time operating system QNX and lower level software, and adapt and revise DVI (Driver Vehicle Interface)
  - Develop automatic data acquisition system (hardware and software)
  - Integrate truck control hardware and software, including DSRC interface

Work Plan: Task 4

- Adapt and refine CACC (Cooperative Adaptive Cruise Control) system on four new Volvo trucks
- Initially test trucks on test track
- Prepare System Refinement Result Report
- Prepare System Acceptance Testing Plan
- Extensively test and tune CACC/platooning system in public traffic
- Prepare System Acceptance Testing Result Report
- Prepare and conduct key-milestone briefing on CACC truck development

Work Plan: Task 4

- **Deliverables**
  - Key milestone briefing on CACC/platooning capability development
  - System Refinement Result Report
  - System Acceptance Testing Plan
  - System Acceptance Test Result Report

Work Plan: Task 5

- Obtain Human Use Approval
  - Update experimental protocol and data acquisition plan
  - Develop recruitment materials and questionnaires
  - Develop Human Use Approval Plan
  - Submit experimental protocol for UCB IRB review and respond to IRB questions until approval is achieved
  - Prepare Human Use Approval Result Report
- Deliverables
  - Human Use Approval Plan
  - Human Use Approval Result Report

Work Plan: Task 6

- **Recruit and train truck drivers with fleet operator (Roly's Trucking)**
  - Prepare Truck Driver Recruitment and Training Plan
  - Recruit drivers
  - Train first cohort of drivers and verify their readiness for public road testing
  - Repeat driver training and readiness verification for each new cohort of drivers

- **Deliverables**
  - Truck Driver Recruitment and Training Plan

Work Plan: Task 7

- Operational Readiness Test
  - Prepare Operational Readiness Test Plan
  - Refine and test CACC trucks with DVI on public roads with drivers of the fleet operator (Roly's Trucking) for verifying system performance and data collection system on the intended route
  - Test driver monitoring system functionality and reliability
  - Test data acquisition system functionality and reliability
  - Demonstrate to FHWA and IE and potentially other interested observers for system readiness
  - Analyze and compile interim test results based on test data

Work Plan: Task 7

- Prepare Operational Readiness Test Result Report
- Make "go/no go" recommendation for field test

- **Deliverables**
  - Operational Readiness Test Plan
  - Operational Readiness Test Result Report
  - Key milestone briefing on CACC/platooning system readiness
  - Demo of CACC/Platooning truck readiness to FHWA and IE and invited visitors

Work Plan: Task 8

- Conduct and complete field testing
  - Update Test and Performance Evaluation Plan, which includes Data Management Plan
  - Prepare Independent Evaluation (IE) Support Plan
  - Manage data throughout the field test according to the revised Test and Performance Evaluation Plan
  - Monitor performance of platooning and data acquisition systems continuously and repair as necessary to enable continued testing
  - Share data with FHWA and IE periodically
- Deliverables
  - Updated Test and Performance Evaluation Plan including Data Management
  - Independent Evaluation Support Plan

Work Plan: Task 9

- Evaluate the results based on Test and Performance Evaluation Plan of Phase 1
  - Prepare key data and update performance measures developed in Phase 1
  - Analyze driver behavior data
  - Analyze engineering performance data
  - Analyze energy consumption data
  - Share data with FHWA and IE periodically
  - Prepare Evaluation Report
- Deliverables
  - Evaluation Report
  - Data (key data and computed performance measures)

Work Plan: Task 10

- Conduct outreach on field test results
  - Prepare outreach plan
  - Prepare outreach documents and briefing materials
  - Conduct outreach on field test results through workshop, website and presentations at local and national meetings of relevant stakeholder groups

- Deliverables
  - Outreach Plan
  - Outreach documents and briefing materials

Work Plan: Task 11

- **Prepare final report**
  - **Prepare final project report to include summary of test results, methodology, lessons learned and other project close out information**

- **Deliverables**
  - **Final Report**

Project Schedule

Truck Platooning Early Deployment Assessment Phase 2 Schedule

Performance Period: 30 months

	Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Task #	Task Name	Milestones																														
1	Program management																															
2	Develop a Comprehensive Truck Platooning Deployment Plan																															
3	Establish partnerships with organizations identified																															
4	CACC/platooning capability development on four Trucks	CACC system develop																														
		test-track testing																														
		test in public highways																														
		Key milestonre breafing																														
5	Obtain Human Use Approval																															
6	Recruit and train truck drivers																															
7	Operational readiness test with professional truck drivers	Planning and extensive tests with truck driver																														
		Making "go/no go" decision																														
		Demo to FHWA and IE																														
8	Conduct and complete testing																															
9	Evaluate the results based on Test and Performance Evaluation Plan																															
10	Conduct outreach on field test results																															
11	Prepare final report																															

Budget and Cost Share Summary

PATH Cost Proposal Estimates by Task showing Matching Costs						
Project Title: TRUCK PLATOONING EARLY DEPLOYMENT ASSESSMENT,						
Project Period: 30 months						
			Matching Costs			**Total Project**
Task #	**Task/*cost element***	**FHWA Cost**	**Roly's**	**Caltrans**	**UC Berkeley**	**Cost**
1	Program Management	$ 300,000				$ 300,000
2	Comprehensive Truck Platooning Deployme	$ 15,000				$ 15,000
3	Establish partnerships	$ 70,000				$ 70,000
4	CACC/platooning capability development	$ 700,000		$ 200,000	$44,480	$ 944,480
5	Obtain Human Use Approval	$ 50,000				$ 50,000
6	Recruit and train truck drivers	$ 40,000				$ 40,000
7	Operational Readiness Test	$ 350,000				$ 350,000
8	Conduct and complete field testing	$ 950,000	$ 760,000	$ 175,000	$38,920	$ 1,923,920
	*- fuel for trucks during testing**		*$ 370,000*			*$ 370,000*
	*- driver labor during testing***		*$ 390,000*			*$ 390,000*
	- truck costs (lease, maint, insurance) fo	*$ 800,000*				*$ 800,000*
	- data collection and system monitoring l	*$ 150,000*		*$ 175,000*	*$38,920*	*$ 363,920*
9	Evaluation (driver behavior, fuel consumptio	$ 450,000				$ 450,000
10	Conduct Outreach	$ 50,000				$ 50,000
11	Prepare Final Report	$ 25,000				$ 25,000
	Total	**$ 3,000,000**	**$ 760,000**	**$ 375,000**	**$ 83,400**	**$ 4,218,400**
*	Roly's fuel cost share assumes 150,000 miles driven per truck, 4 trucks, 6.5 mpg per truck and $4 per gallon					
**	Roly's labor cost assumes 600,000 miles driven, $.50 per miles direct cost +30% for benefits (helath ins., etc.)					

Partnership and Outreach Plan

Site visit of Roly's Facilities
Rancho Cucamonga, CA, Nov. 4, 2019



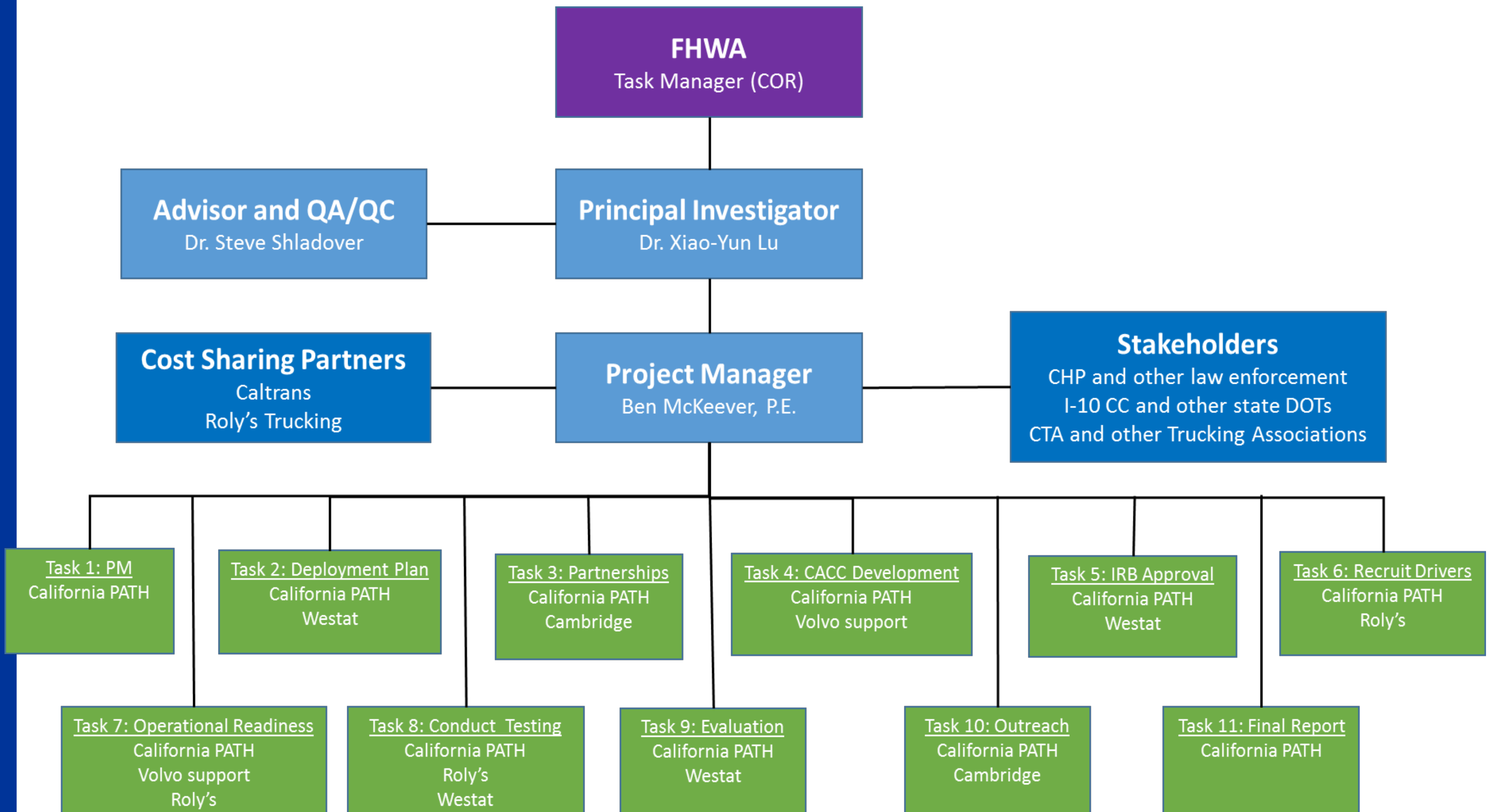

Core Team Members and their Roles

- University of California PATH
  - Prime Contractor/Project Manager: lead technical and scientific work, manage data, write reports
- Roly’s Trucking, Inc.
  - Fleet Operator: plan routes and dispatching, collect data, provide truck drivers and fuel
- Westat Inc.
  - Human Factors: design approach for monitoring drivers, collect and analyze driver monitoring data
- Cambridge Systematics
  - Partnerships: stakeholder coordination, facilitate relationship with Roly’s, plan public event

Unpaid Partners and their Roles

- Volvo Group North America
  - OEM support: assist with CACC installation on 4 new trucks, provide configuration details of 4 new trucks to be leased, ongoing tech support
- Caltrans and the California Highway Patrol (CHP)
  - Coordinate with infrastructure and enforcement operations on CA freeways, provide cost share through separate project
- I-10 Corridor Coalition
  - Facilitate necessary agreements and outreach efforts in CA, AZ, NM, and TX
- California Trucking Association
  - Engage with trucking industry and make them aware of platooning tests

Organization Chart



Partnership Agreement Schedule

Partner	*Phase 2 Business Relationship with UC Berkeley*	*Current Agreement*	*Detailed Agreement to Support Phase 2*	*Schedule for Detailed Phase 2 Agreement*	*Risks for Concluding Successful Phase 2 Agreement*
Roly's Trucking Inc.	Vendor	Letter of Support defining role and commitment; cost estimates	Vendor Purchase Agreement	NTP + 60 days	Low – Responsibilities and terms of agreement have been defined; also a contingency strategy has been developed
Volvo Group North America	Voluntary Support	Letter of Support defining role and commitment	No additional requirement - Letter Agreement signed	N/A	Very Low – terms of voluntary support from Volvo have been agreed to by Volvo as detailed in letter
Westat Inc.	Subcontractor	Phase 2 scope and cost estimate	Cost-Plus Subcontract	NTP +30 days	Very Low – draft scope defined
Cambridge Systematics	Subcontractor	Phase 2 scope and cost estimate	Cost-Plus Subcontract	NTP +30 days	Very Low – draft scope defined
Caltrans	Partnering Agency Staff Support	Letter of Support defining commitment including cost sharing	Contract with PATH	NTP +90 days	Very Low – Caltrans is a sponsor of CA PATH

Partnership Agreement Schedule (cont.)

CHP	Partnering Agency Staff Support	Past working relationship on truck platooning	Agreement to allow close following for truck platooning test	NTP +60 days	Low – CHP has been a partner on past PATH truck platooning projects
I-10 Corridor Coalition	Voluntarily Coordinating multi-state Coalition of DOT's	Letter of Support (for phase 1) defining coordination	No additional requirement – Partner Kickoff Webinar	Stakeholder meeting within 90 days of NTP	Very Low – Fits with Coalition goals and purpose
State Trucking Associations (CA, AZ, NM, TX	Voluntary Trucking Industry Coordination	Letter of Support defining coordination (currently CA)	No additional requirement -Partner Kickoff, webinars and meetings	Stakeholder meeting within 90 days of NTP (expand to NM and TX)	Very Low -- state trucking associations support operational testing
European Commission DG-RTG	Twinning project partner	Held initial discussions with EC	Leverage MOU on Twinning between USDOT and the EC	TBD - depends on the EC's selection of contractor for field test	Low – EC has expressed their interest in twinning

Risk Management

- A risk register will be included in the Phase 2 Project Management Plan
  - Includes potential safety, technical, partnership, schedule and cost risks and corresponding mitigation strategies
  - Includes risk levels to indicate likelihood and severity of risks
- A preliminary risk register is included in the following slides

Risk Register

Category/ID	Risk Identification	Risk Level Likelihood/ Severity	Risk Mitigation	Risk Status
Safety				
SA-1	In case of hazards or unusual situations, the driver must be able to take over vehicle control successfully to avoid any safety incidents.	Low/ High	PATH has developed a convenient mechanism for the driver to deactivate the CACC system and take over manual control; during PATH's driver behavior test process, this process did not raise risk in CACC operation compared to traditional manually driven trucks on freeways.	This is currently not an active risk but it will be reassessed during the operational readiness test.
SA-2	If the driver does not understand the system features and limitations, he or she may not use it correctly	Low/ Med	The system includes a simple and highly visible user interface to assist the driver, and all drivers will be trained in proper use of the system and will be monitored while they are using it.	This is currently not an active risk but it will be reassessed during the operational readiness test.

Risk Register (cont.)

Technical				
TE-1	The PATH system needs to perform well under various conditions with respect to load, road grade, traffic conditions, daytime/nighttime, weather, etc.	Low/ Med	In our Operational Concept document, we defined operational design domains where the system can perform safely and effectively and we tested it under a wide range of conditions to verify its successful operation. PATH will continue to improve the CACC system and make it ready for operational deployment.	This is currently not an active risk but it will be reassessed during the operational readiness test. If PATH reveals any locations where the system does not perform well, the drivers will be instructed to not use the system in those locations.
TE-2	The Secure Data Commons has not been used by PATH before and we are unsure how suitable it will be as a platform for data sharing with USDOT and the IE	Low/ Low	PATH has identified an option to develop its own data sharing platform instead of SDC due to its high cost. U. C. Berkeley Google drive can conveniently accommodate data with unlimited size, fully supporting the field operational test.	The use of SDC is considered a risk so we are currently planning to use Google Drive as described in our TEP.
TE-3	The field test might not generate a large enough or broad enough set of data to inform all of the desired performance measures.	Low/ Low	PATH has developed a broad set of performance measures that map to the key research questions so even if some performance measures need to be dropped there should be enough other performance measures to answer the research questions.	This is currently considered a low risk but it will be reassessed in phase 2 when we revise our experiment plan.

Risk Register (cont.)

TE-4	This field test needs a new high-capacity data acquisition system to record and save the large volume of data that will be generated on extended long-haul drives.	Low/Med	PATH has successfully implemented other data acquisition systems for vehicle field tests, and this system will be a natural extension building on that prior experience.	This is currently considered a low risk but it will be reassessed in phase 2 when we revise our TEP.
TE-5	Since a new model of Volvo truck is being used for Phase 2, there might be additional work needed to adapt the truck platooning system to the new host truck model.	Med /Med	Since the Volvo Group is supporting the project team, PATH expects this work to be manageable, based on suitable technical support from them for adapting the system. We have budgeted significant resources for making and verifying the needed adaptations of the system.	Ongoing, being monitored closely

Risk Register (cont.)

Partnerships				
PA-1	The ability of Volvo to deliver on commitments that support testing	Low/ Med	PATH has been working closely with Volvo to define the level of support needed from Volvo for Phase 2. PATH and Volvo met with USDOT in October to explain how Volvo will support PATH in Phase 2 and Volvo has signed a letter of support detailing the areas where they will support the PATH team.	Letter of support obtained; areas of Volvo commitment are explicit
PA-2	The ability of PATH to maintain the full engagement of the truck fleet operator during the field test	Med/ High	PATH has received a letter of support from Roly's Trucking and gotten them to agree to provide fuel and drivers as in-kind match to the project. PATH is also budgeting for additional Roly's staff time to support the project. Cambridge Systematics staff who are familiar with Roly's have been assigned to assist them in meeting test needs.	Letter of support obtained, contingency plan developed
PA-3	The ability of Caltrans, CHP and other public agency partners to deliver on their commitments that support testing	Low/ High	PATH, Caltrans and CHP have partnered together on the previous truck platooning project. PATH has received a letter of support from Caltrans and the CTA and previously from the I-10 Corridor Coalition and we will reach out to Arizona, New Mexico and Texas during Phase 2. Cambridge Systematics, who has supported the I-10 Corridor Coalition over the past three years, will be responsible for stakeholder engagement during Phase II.	Letters of support obtained from Caltrans, I-10 Corridor Coalition, and CTA

Risk Register (cont.)

Schedule				
SC-1	The project initiation gets delayed because of delays in getting all the subcontracts in place.	Med/ Med	PATH was successful in getting their phase 1 subs under contract in a timely manner by working closely with their subcontracting office to expedite the process. We will use the same approach in phase 2.	Ongoing, being monitored closely
SC-2	Operational readiness becomes delayed because of technological or staffing problems.	Low/ Med	PATH has developed a staffing plan for Phase 2 that includes sufficient resources and technical experts that have experience dealing with unexpected issues on projects such as this.	Ongoing, being monitored closely
SC-3	Operations becomes delayed because of issues with a project partner	Low/ Med	PATH has assembled a partnership plan that defines each partner's role and responsibility in phase 2 and has developed a schedule of partnership milestones. Cambridge Systematics will apply its special expertise in this area to assist PATH in implementing the Partnership Plan.	Ongoing, being monitored closely
SC-4	Operational readiness becomes delayed because of an issue recruiting or training enough drivers	Low/ Med	Fleet partner Roly's has agreed to help recruit some of their drivers for the Phase 2 field test and PATH has a proven training course that will prepare drivers for the field test.	This is currently not an active risk but it will be reassessed prior to the operational readiness test.

Risk Register (cont.)

Cost				
CO-1	Since a new model of Volvo truck is being used for Phase 2, there might be additional effort (costs) to adapt the truck platooning system to the new host truck model	Med/ Med	Since the Volvo Group is supporting the project team, PATH expects this cost to be manageable, based on suitable technical support from them for adapting the system, and has budgeted accordingly.	Ongoing, being monitored closely
CO-2	Truck leasing agreement includes additional costs for miles driven over 350K on each truck	Low/ Low	Under the current experiment plan, we only expect to drive each truck 150K miles during testing. Need to monitor if experiment plan changes and limit amount of miles driven outside of testing period.	TBD, will be reassessed after revision of our experiment plan

Questions & Comments