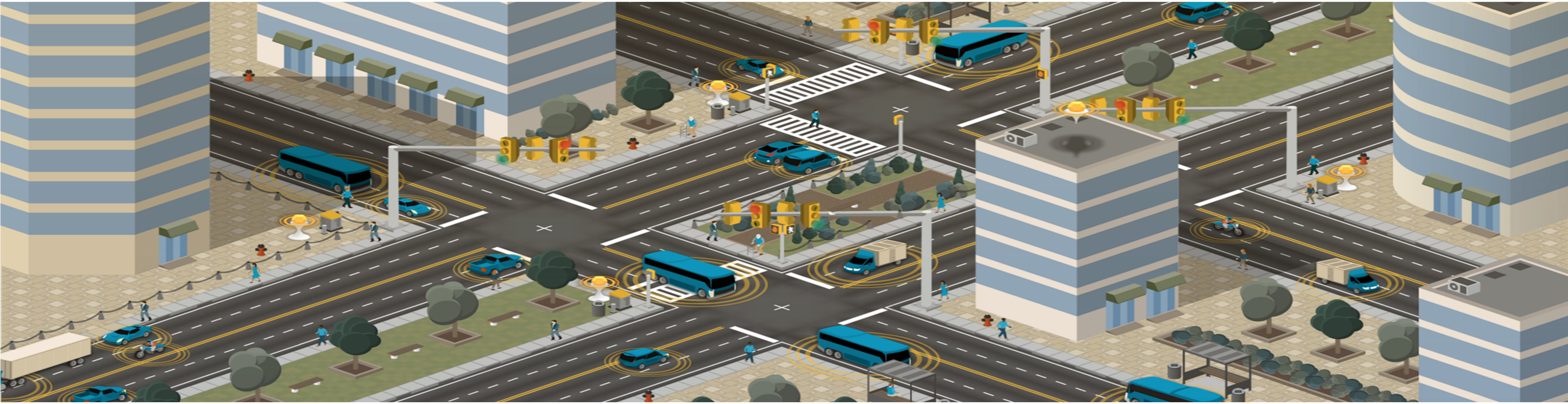
CONNECTED VEHICLE PILOT
Deployment Program

New York City CV Pilot Deployment Results and Transition Plan



Jonathan Walker, USDOT; Keir Opie, Cambridge Systematics; Jingqin Gao, NYU; Mohamad Talas, NYCDOT

ITS Joint Program Office

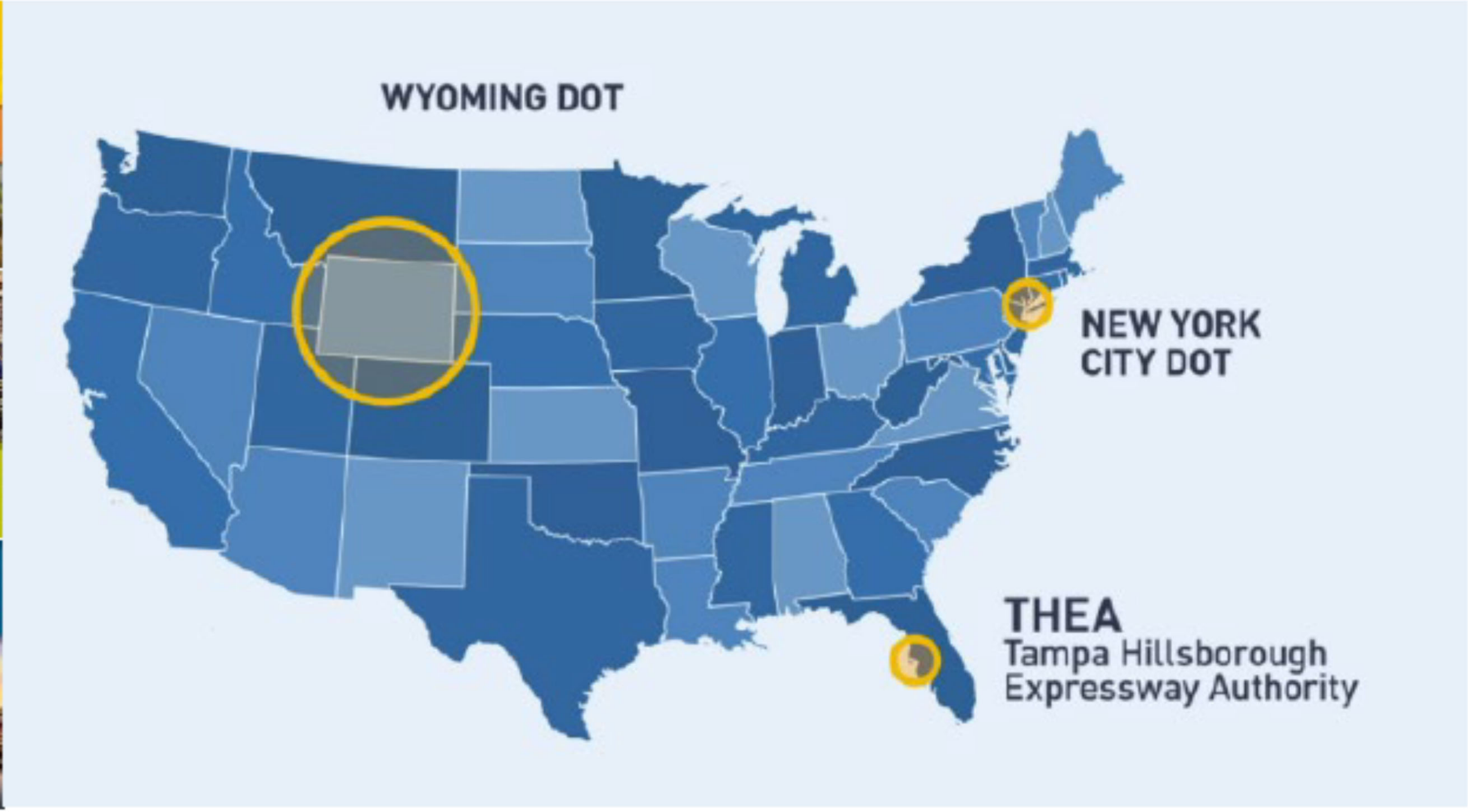
Webinar Agenda

- Purpose of this Webinar
  - Share the deployment performance results from NYC Connected Vehicle Pilot
  - Outline the plan after completion of Phase 3 Operations
- Webinar Content
  - Connected Vehicle Pilot Deployment Program Overview
  - NYC CV Pilot Deployment Performance Evaluation Results and Transition Plan
  - Stakeholder Q&A
- Webinar Protocol
  - Please mute your phone during the entire webinar.
  - You are welcome to ask questions via chatbox at the Q&A Section.
  - The webinar recording and the presentation material will be posted on the CV Pilots website.

Program documentation:
https://www.its.dot.gov/pilots/cv_pubs.htm

CV Pilot Deployment Program Goals

The Three Pilot Sites



Agenda

- Project Overview
- Data Collection and Processing
- Experimental Design & Analysis Plan
- Performance Results & Findings
- Transition Plan
- Perspective on CV Pilot Deployment
- Questions

Today's Presenters:

Keir Opie
NYC CVPD Performance Evaluation Lead
Cambridge Systematics

Jingqin Gao
NYC CVPD Safety Analysis Team
NYU

Mohamad Talas
NYC CVPD Project Manager
NYC DOT

Project Overview

NYC CV Pilot Deployment Goals

- Primary Goal:
  - **Improving safety** through the reduction of vehicle and pedestrian crashes, injuries, and fatalities

- Secondary Goal:
  - **Improving mobility** and reliability through crash prevention and lower crash severity

- Measure System Performance in meeting these goals
  - Data collection system was designed around project performance measures addressing privacy concerns and data collection costs

NYC CV Infrastructure

- Infrastructure:
    - 470 Roadside Units (RSU)
    - 3000 Vehicles
- Safety applications: 13
- Operations applications: 8
- This is a ***large scale*** deployment with challenges:
    - Location accuracy – urban canyons
    - RSU density
    - Application arbitration/interference
    - DSRC media only – channel management
    - First full-scale security deployment
    - Security boundary expanded to include all ITS communications
- Utilize edge computing concepts to minimize bandwidth

NYC CV Safety Applications

Vehicle-to-Infrastructure
(V2I) Pilot Area

- Red Light Violation Warning
- Speed Compliance
- Curve Speed Compliance
- Speed Compliance/Work Zone
- Oversize Vehicle Compliance
    - Over Height
- Emergency Communications and Evacuation Information (Traveler Information)

Vehicle-to-Vehicle
(V2V) Citywide

- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot Warning
- Lane Change Warning/Assist
- Intersection Movement Assist
- Vehicle Turning Right in Front of Bus Warning

Pedestrian Applications

- Pedestrian in Signalized Intersection Warning – *to vehicles*
- *Mobile Ped Signal System – Vision Disability Pedestrian Navigation Assistance*

NYC Agencies CVPD Fleets

Agency	Passenger Cars	Pickups and Trucks	Vans	Buses	Vehicle Installations
NYC Dept. of Transportation (DOT)	●	●	●		1238
NYC Dept. of Parks and Recreation (PARKS)	●	●	●		511
NYC Dept. of Correction (DOC)	●	●	●	●	293
NYC Dept. of Environmental Protection (DEP)	●	●	●		159
NYC Dept. of Homeless Services (DHS)	●		●		100
NYC Taxi and Limousine Commission (TLC-DCAS)	●	●	●		98
NYC Human Resources Administration (HRA)	●		●		86
NYC Dept. of Citywide Administrative Services Fleet (DCAS)	●				78
NYC Dept. of Education (DOE)	●	●	●		78
NYC Dept. of Buildings (DOB)	●				69
NYC Administration for Children's Services (ACS)	●	●	●		65
NYC Dept. of Housing, Preservation and Development (HPD)	●				48
NYC Dept. of Health and Mental Hygiene (DHMH)	●	●	●		45
NYC Dept. of Design and Construction (DDC)	●				38
NYC Office of Chief Medical Examiner (OCME)	●	●	●		29
MTA Bus & NYCT				●	14
NYC Emergency Management (OEM)	●				12
NYC Dept. of Consumer Affairs (DCA)	●	●			12
Anheuser-Busch InBev (ABI)			●		10
NYC Dept. of Information Technology and Telecommunications (DOITT)	●				9
NYC Dept. of Probation (DOP)	●				6
NYC CVPD Team Vehicle		●			1
Taxi Limousine Commission (Yellow Cabs)	●				1
Total	**1,662**	**967**	**269**	**102**	**3,000**

Fleet Agency Vehicles

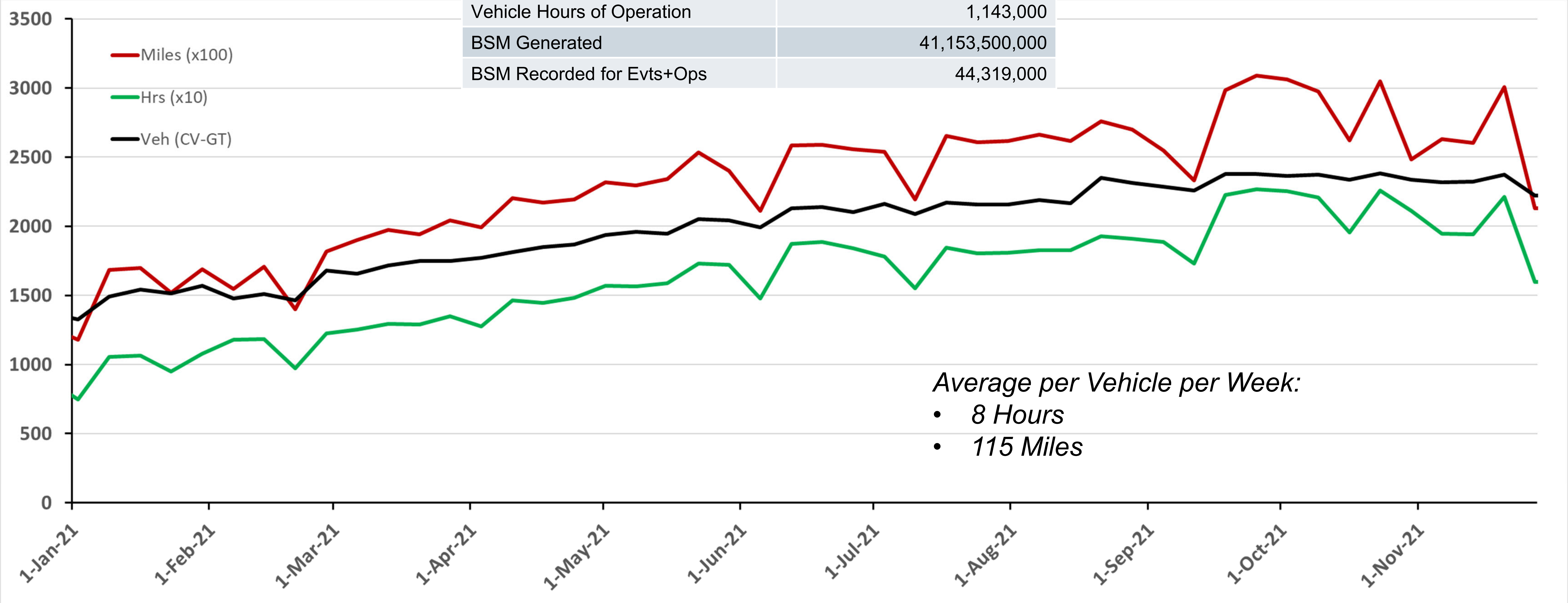
Photo Courtesy: MTA New York City Transit

Vehicle CAN bus interface provides speed data for Dead Reckoning to improve location accuracy

Vehicle Make	Passenger Cars	Pickups and Trucks	Vans	Buses	Vehicle Installations
Chevrolet	165	162	168		495
Chrysler			2		2
Dodge			16		16
Ford	331	714	83		1,128
Freightliner		1			1
IC Corporation				85	85
International				3	3
New Flyer				3	3
Nissan	130				130
Nova				7	7
Orion				4	4
Ram		90			90
Toyota	1,036				1,036
Total	**1,662**	**967**	**269**	**102**	**3,000**

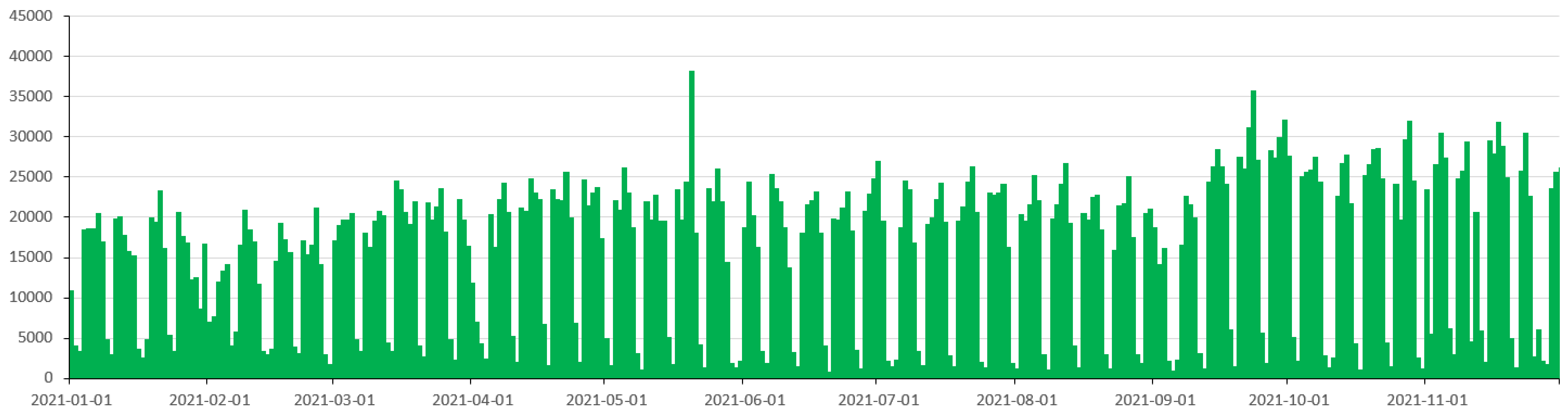
Fleet Weekly Operations

Estimates for our 3,000 Veh. Fleet	Jan 3 – Nov 27, 2021 (47 wks)
Vehicle Miles Traveled	16,294,000
Vehicle Hours of Operation	1,143,000
BSM Generated	41,153,500,000
BSM Recorded for Evts+Ops	44,319,000



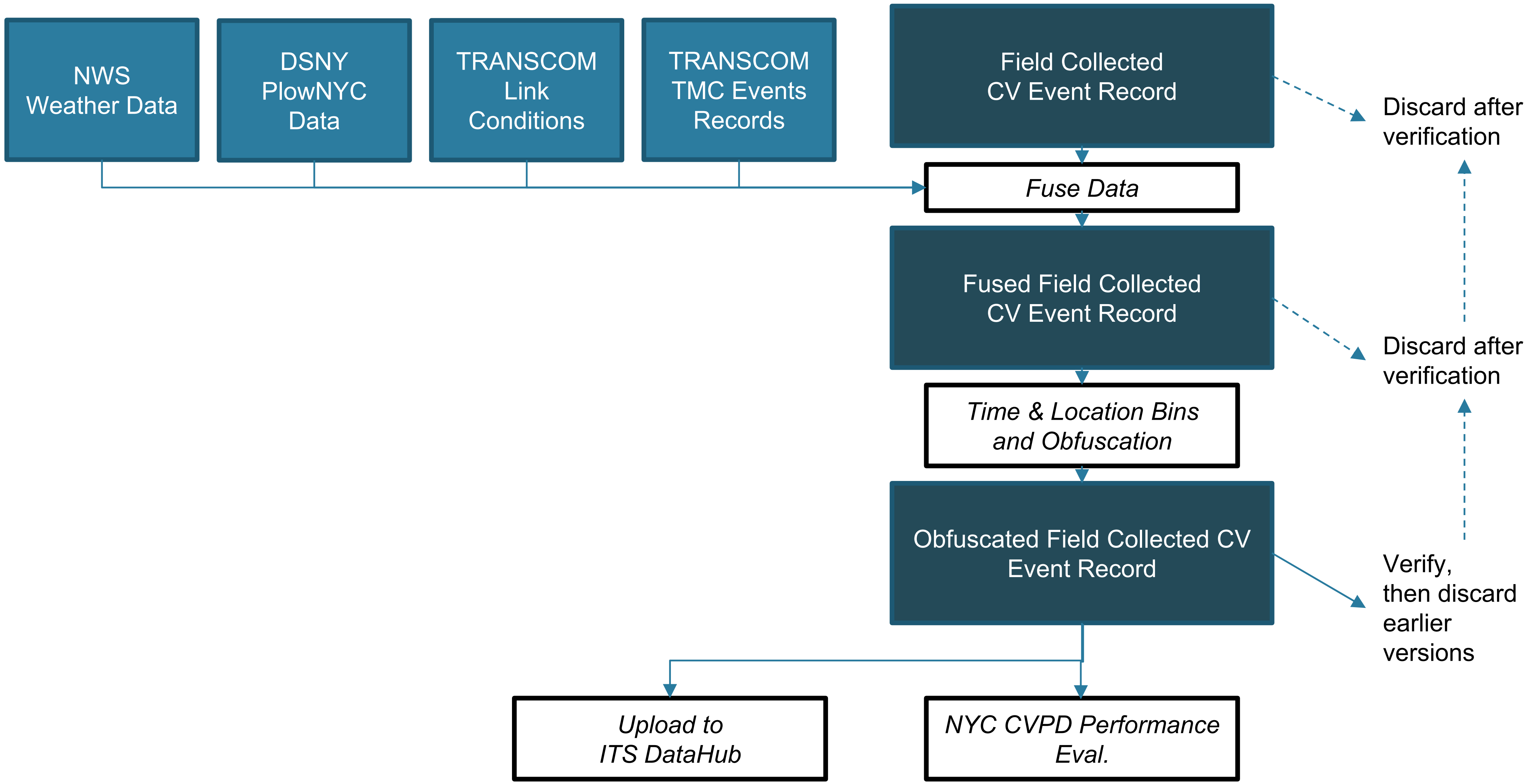
Average per Vehicle per Week:
- *8 Hours*
- *115 Miles*

OBU-OBU V2V Contacts (Daily)



Data Collection & Processing

CV Event Record Obfuscation Process

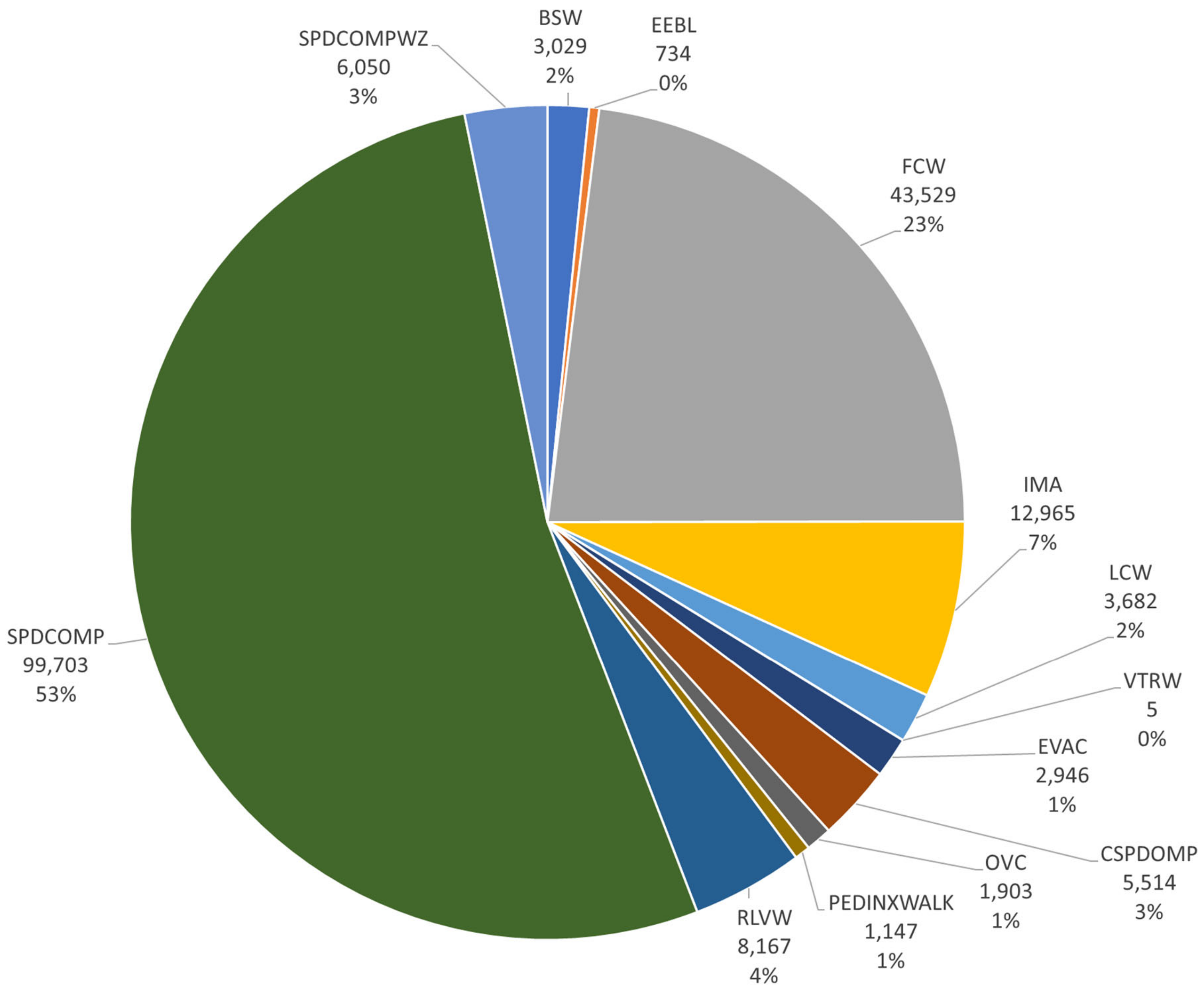


CV Events by Type (Ingested)

Jan - Nov 2021: Ingested

- 189,374 Total Events
- 34% V2V, 66% V2I

All events uploaded to the TMC, no scrubbing, checks, or cleaning



Error and Quality Checks

Month	Received	% Errors	% Old App	% Test	% Released	# Released
Jan-Nov	**189,374**	**12%**	**5%**	**3%**	**80%**	**151,146**
21-01	19,323	29%	19%	4%	47%	9,085
21-02	9,843	10%	10%	5%	75%	7,410
21-03	16,294	6%	7%	8%	79%	12,862
21-04	16,213	7%	4%	5%	84%	13,589
21-05	17,549	10%	4%	3%	83%	14,514
21-06	15,870	10%	3%	2%	84%	13,391
21-07	16,479	11%	3%	2%	84%	13,844
21-08	18,000	11%	3%	2%	85%	15,210
21-09	18,924	11%	3%	1%	85%	16,116
21-10	21,698	10%	3%	1%	86%	18,553
21-11**	19,181	9%	3%	1%	86%	16,572

*** November data is not yet finalized, December collection underway*

Errors:
- Timestamp errors
- Location Errors
- Data Logging Errors
- Early Firmware Versions

Old App:
- Older SW Firmware with known operational issues for only some CV Apps

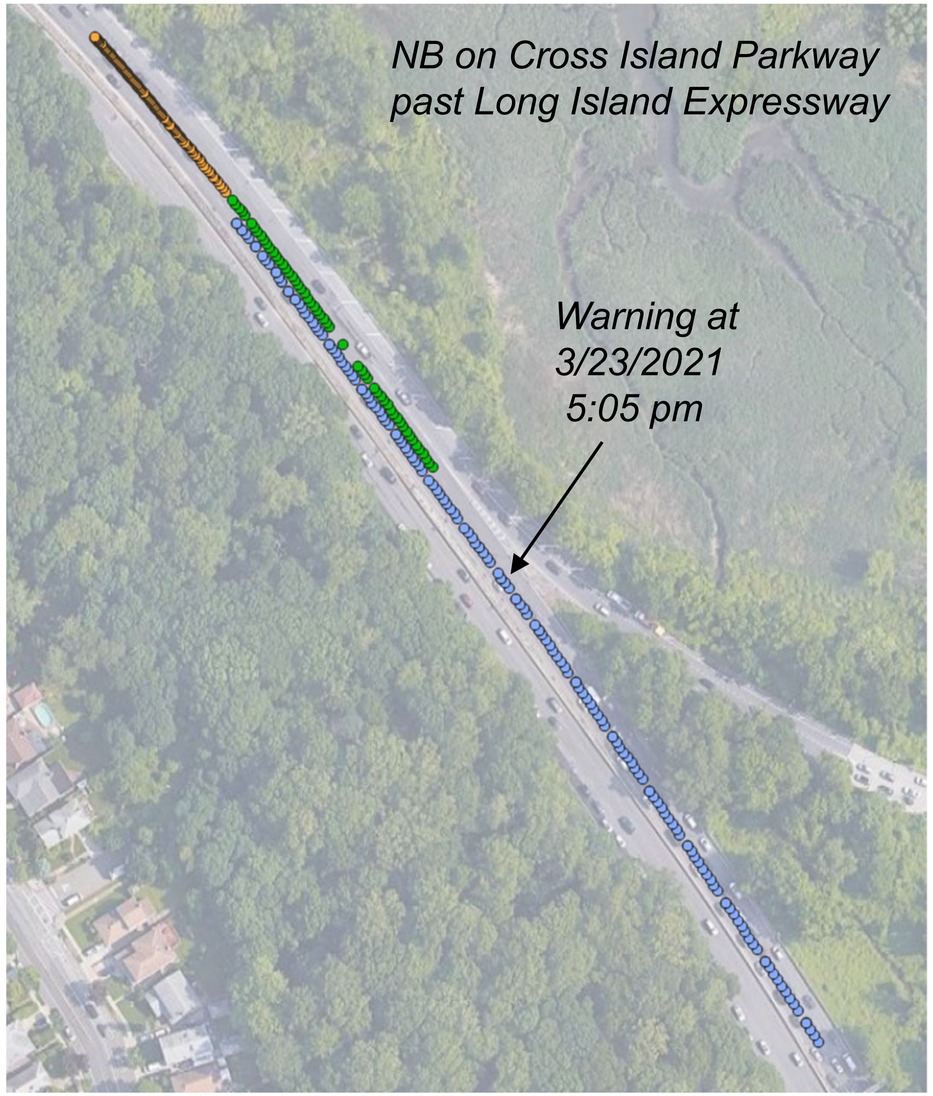
Test:
- Events from our CVPD test vehicles

Obfuscated Event Details

- All Detailed Lat/Long coordinates shifted to artificial cartesian coordinate system (meters)
- All unique IDs for vehicles, intersections (MAP or SPaT), or TIM messages removed;
  - Intersection IDs replaced with new letter codes; unique to one event only
- Time Bins:
  - Date becomes Month and Day of Week
  - Time of day:
    - Overnight period (12:00 am – 6:00 am): NT
    - Morning Peak (6:00 am – 10:00 am): AM
    - Midday Period (10:00 am – 3:00 pm): MD
    - Afternoon Peak (3:00 pm – 8:00 pm): PM
    - Evening Period (8:00 pm – 12:00 am): EV
- Location Bins:
  - NYC Borough (5: MN, QN, BK, BX, SI)
  - Roadway Type
    - RSU Equipped: Avenue or Street
    - Non-Equipped: Freeway, Avenue, or Other

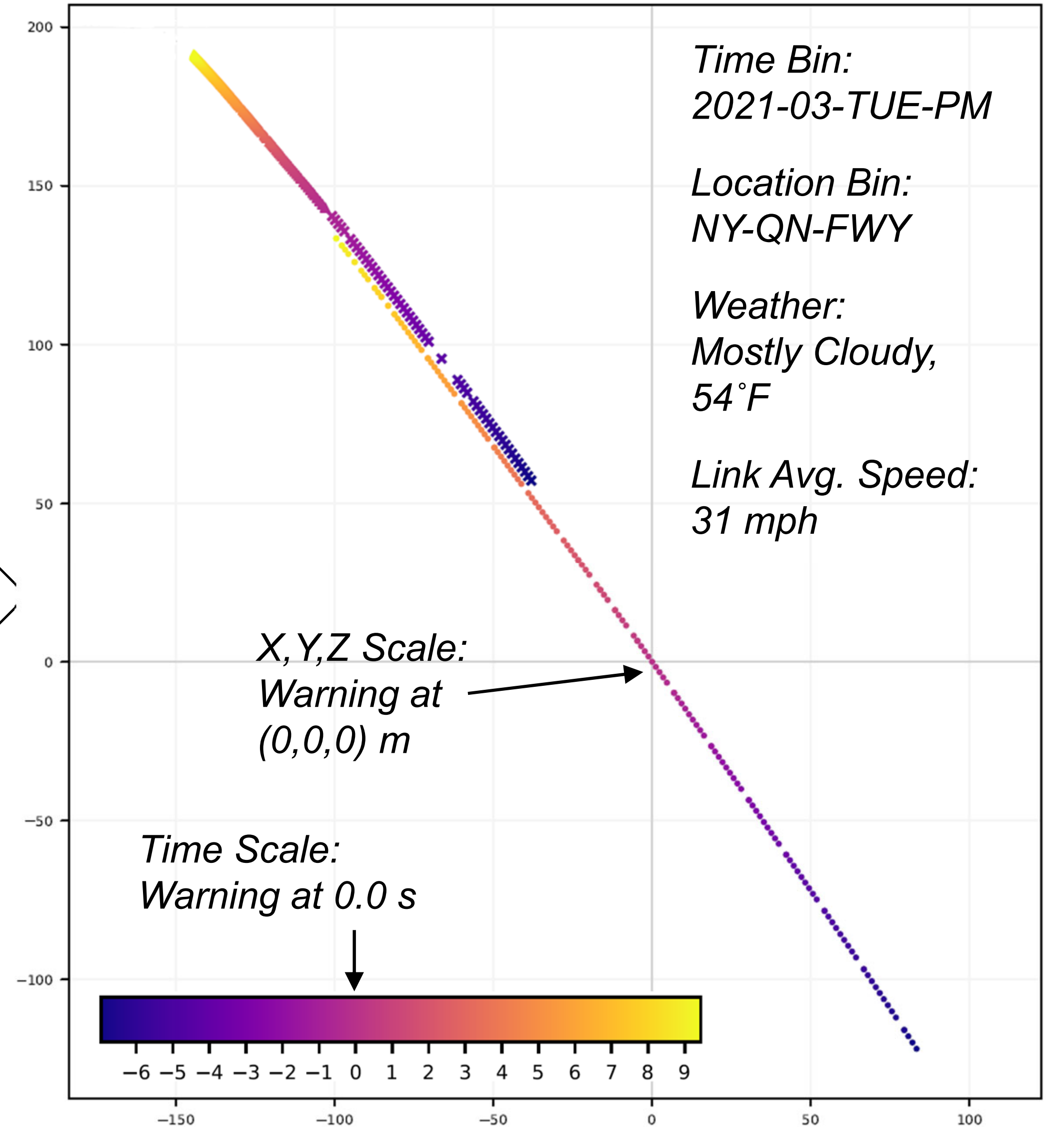
ASD Event Log Obfuscation: Example

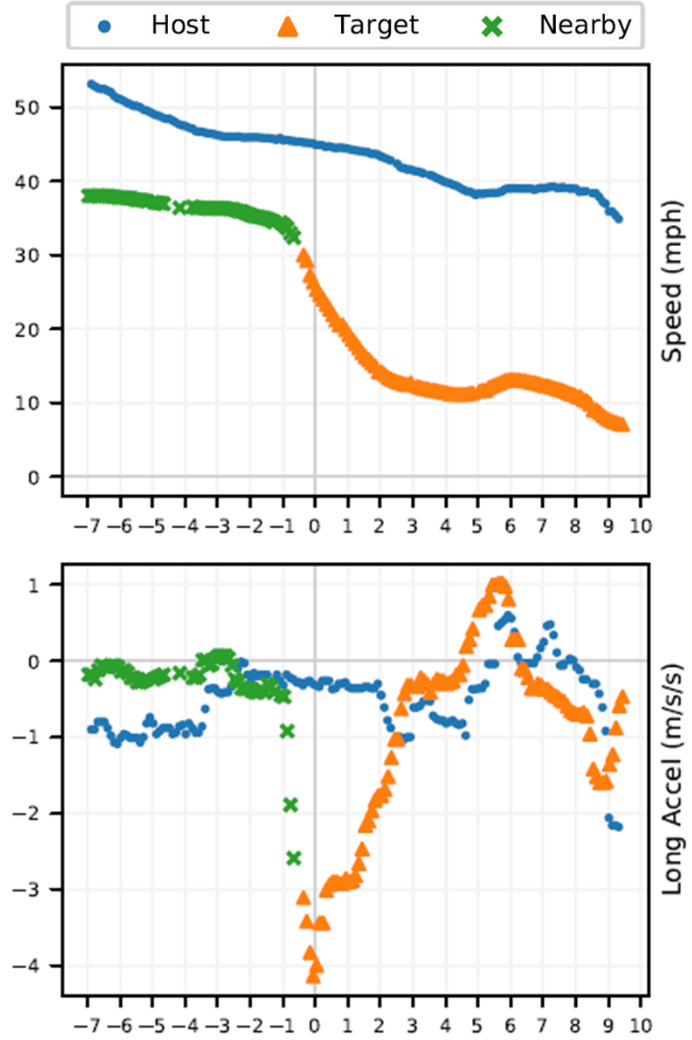
Recorded Event Data:



OBF.

Obfuscated Event BSM Data:



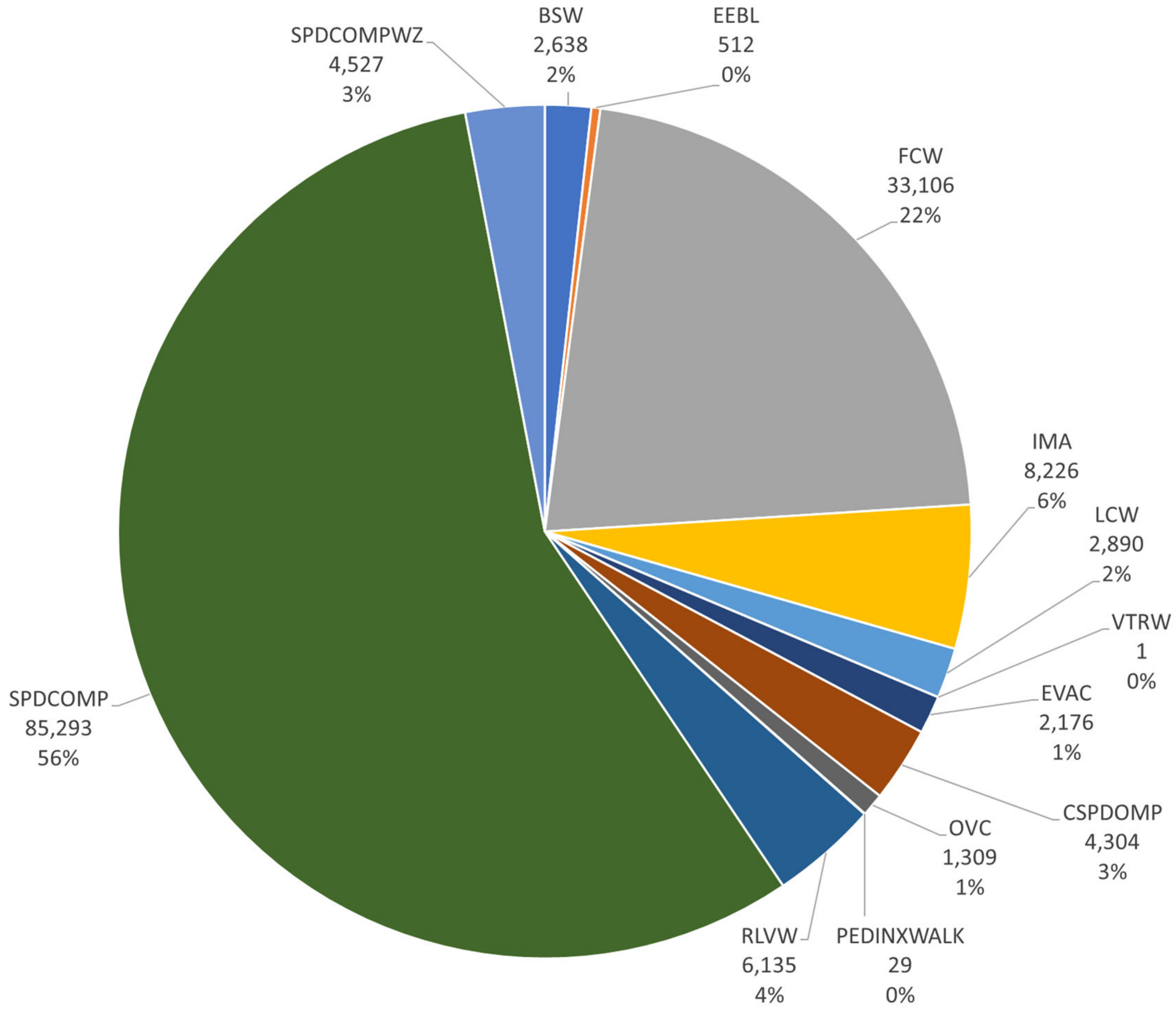


CV Events by Type (Released)

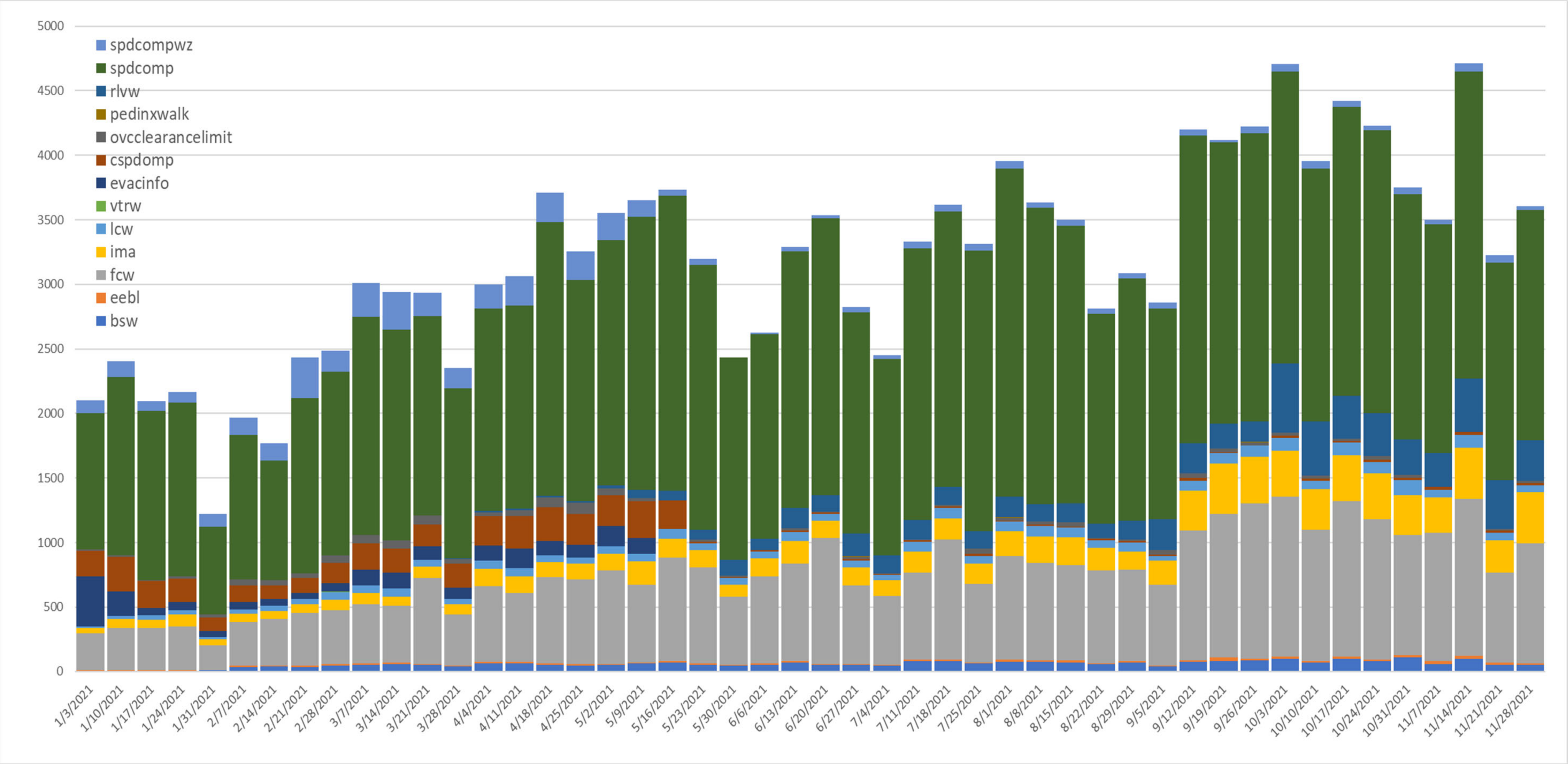
Jan - Nov 2021: Released

- 153,354 Total Events
- 31% V2V, 69% V2I

Obfuscated event files released to the ITS DataHub



Weekly Events Released

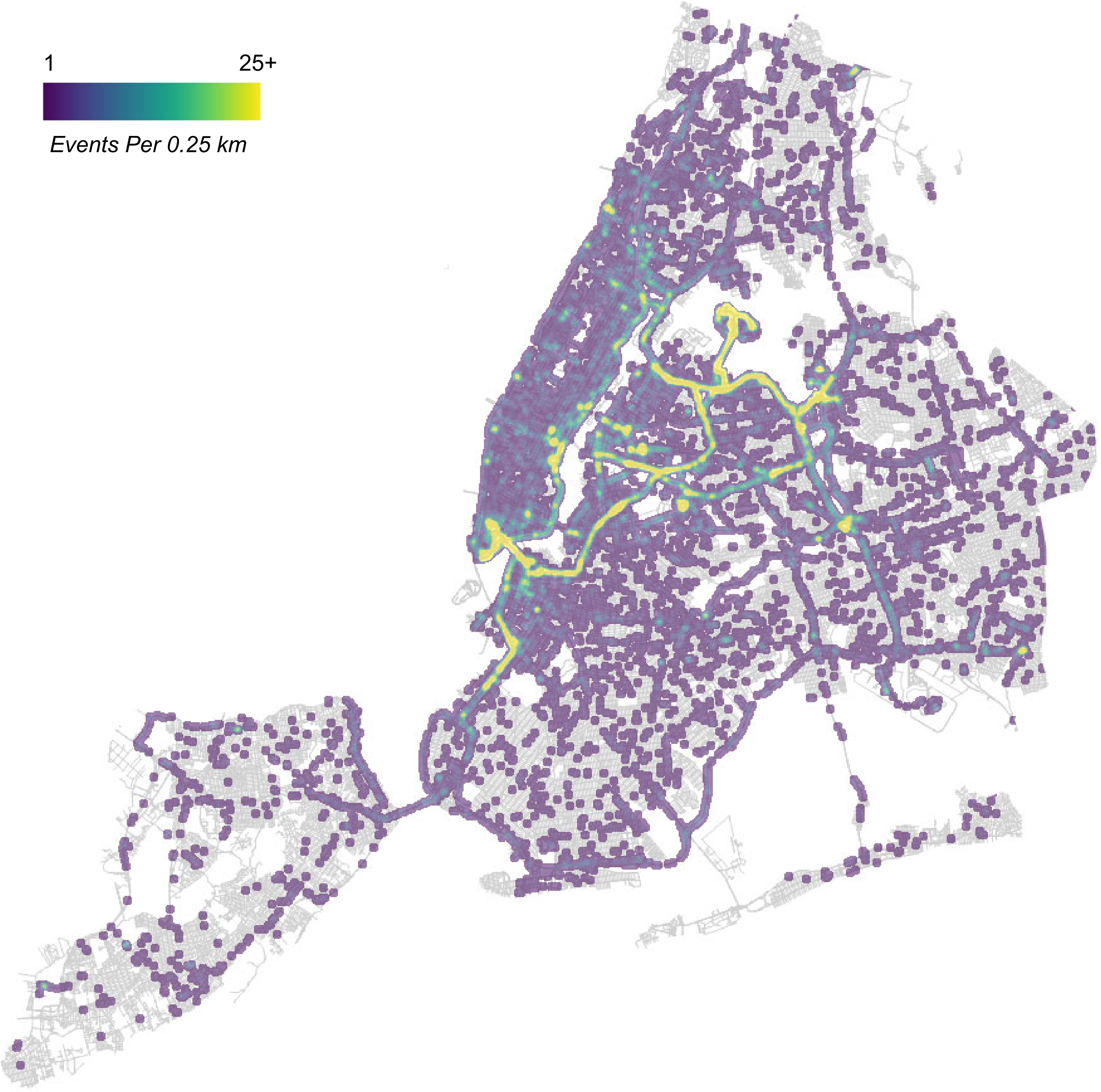


Forward Collision Warning (FCW) Events

Jan 1 – Nov 30, 2021:

33,106 events

V2V citywide



Speed Compliance (SPDCOMP) Events

Jan 1 – Nov 30, 2021:

85,293 events

V2I areas only

Experimental Design & Analysis Plan

Performance Measurement Program

Safety is Job #1.

- Once alerts are activated in a vehicle, they won’t be silenced.

User Needs related to Performance Measurement

- ***Maintain privacy of users throughout pilot and data collection***
- ***No enforcement***
- ***No driver evaluation***

Performance Measurement Program considers:

- Consider impacts of CV data combined with data from other sources.
- Approach to collecting the performance information.
- Approach to using data collection bins of performance information.
- Control Group vs Treatment Group

FHWA-JPO-16-302,
Performance Measurement and Evaluation Support Plan - NYCDOT

Vehicle Experimental Design

CV fleet vehicles operating "business as normal" citywide

Fleet Transistion: May 20 - May 31, 2021
Time for the Majority of Events to Transition to Active Alerts

Phase 3 Timeline:	January 1, 2021 to May 19, 2021	June 1, 2021 to December 31, 2021
	Pre-deployment (BEFORE)	**Post-deployment (AFTER)**
DOT - Control Group	No Treatment (Silent Warnings/Alerts) DOT_{CB-PC} DOT_{CB-TR} DOT_{CB-VN}	No Treatment (Silent Warnings/Alerts) DOT_{CA-PC} DOT_{CA-TR} DOT_{CA-VN}
DOT - Treatment Group	No Treatment (Silent Warnings/Alerts) DOT_{TB-PC} DOT_{TB-TR} DOT_{TB-VN}	Treatment (Active Warnings/Alerts) DOT_{TA-PC} DOT_{TA-TR} DOT_{TA-VN}
All Other Agencies - Treatment Group	No Treatment (Silent Warnings/Alerts) NYC_{TB-PC} NYC_{TB-TR} NYC_{TB-VN} NYC_{TB-BU}	Treatment (Active Warnings/Alerts) NYC_{TA-PC} NYC_{TA-TR} NYC_{TA-VN} NYC_{TA-BU}
MTA / NYCT Transit Buses - Treatment Group	No Treatment (Silent Warnings/Alerts) Bus_{TB-BU}	Treatment (Active Warnings/Alerts) Bus_{TA-BU}

Control Vehicles ~ 7% of Fleet

LEGEND

- CB: Control Group Before
- CA: Control Group After
- TB: Treatment Group Before
- TB: Treatment Group After
- PC: Passenger Cars & SUVs
- TR: Pickup and Work Trucks
- VN: Vans
- BU: Buses (Transit or non-Transit

Detailed Data Cleaning Prior to Analysis

- Additional steps taken to further clean and filter obfuscated records prior to analysis:
  - Illogical event warning time scales
  - Unreasonably high, zero, or constant speeds
  - Large elevation deltas between host and target vehicles
  - Stationary vehicles
  - Illogical trajectories: large gaps in BSMs, illogical relation to host and target vehicle
  - Detail vehicle trajectory speed cleaning (illogical speeds, speeds inconsistent with trajectory coordinates)
- Clean and repair when feasible
- Remove from consideration where not feasible

Safety Analysis - Methodology

ASD Data Based Analysis

- Gain score method
- Time to Collision calculation

Driver Reaction to Warnings

- Deceleration Difference
- Time Duration to Slow Down to Speed Limit After Warning
- Time Duration to First Deceleration After Warning

Crash-Based Analysis

- Survival Analysis Approach
- Use Crash modification factor (CMF)

Surrogate safety measure (SSM) Simulation Analysis

- Calibrate both safety and operational measures
- Incorporate driver behavior models
- Multi-objective stochastic optimization

Safety Analysis – Methodology (ASD Data)

Gain Score Method

A commonly used method to analyze before-after control-treatment group design, is adopted (Kim and Steiner 2021).

$$\text{Safety Effect} = \left(\frac{1}{n_{T,A}} \sum_{i=1}^{n_{T,A}} \text{PM}_i - \frac{1}{n_{T,B}} \sum_{j=1}^{n_{T,B}} \text{PM}_j \right) - \left(\frac{1}{n_{C,A}} \sum_{k=1}^{n_{C,A}} \text{PM}_k - \frac{1}{n_{C,B}} \sum_{l=1}^{n_{C,B}} \text{PM}_l \right)$$

Before-after ***Treatment*** *group difference*

Before-after ***Control*** *group difference*

$n_{T,A}$ and $n_{T,A}$ represent the total number of events in the treatment group in the after period and before period respectively.

$n_{C,A}$ and $n_{C,A}$ represent the total number of events in the control group in the after period and before period respectively.

PM is the safety performance measure used in the evaluation.

Account for potential unobserved confounding factors.

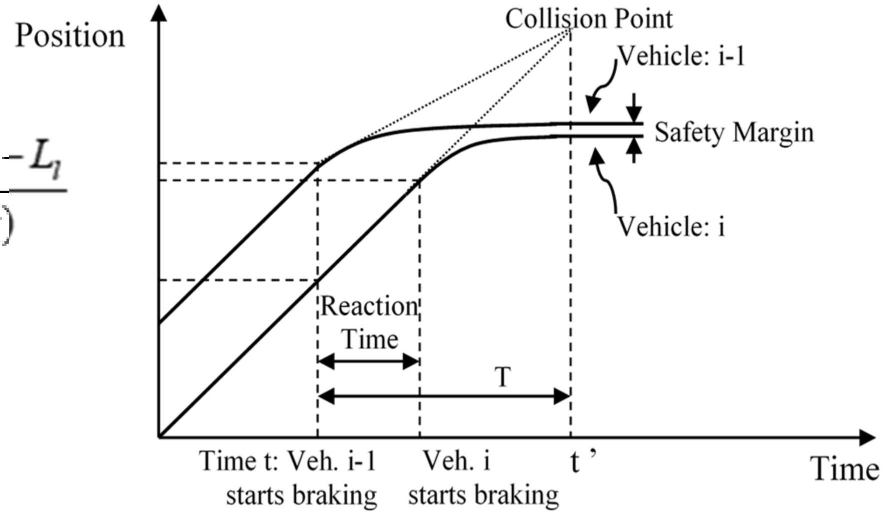
Kim, Y., Steiner, P.M., 2021. Gain scores revisited: A graphical models perspective. Sociological Methods & Research 50 (3), 1353-1375.
Hayward, J., 1972. Near miss determination through use of a scale of danger. 51st Annual Meeting of the Highway Research Board 384, 24-34.
Gettman, D., Pu, L., Sayed, T., Shelby, S., Siemens, I., 2008. Surrogate safety assessment model and validation. FHWA.

Time to Collision (TTC)

The time for two vehicles to collide if they continue at their present speeds and on the same path (Hayward 1972).

The calculation of TTC is largely adopted from the Surrogate Safety Assessment Model (SSAM) software (Gettman et al. 2008).

$$\text{TTC}(t) = \frac{X_l(t) - X_f(t) - L_l}{V_f(t) - V_l(t)}$$



$\text{TTC}(t)$: Time to collision at time t

$v_f(t)$: Speed of the following vehicle at time t

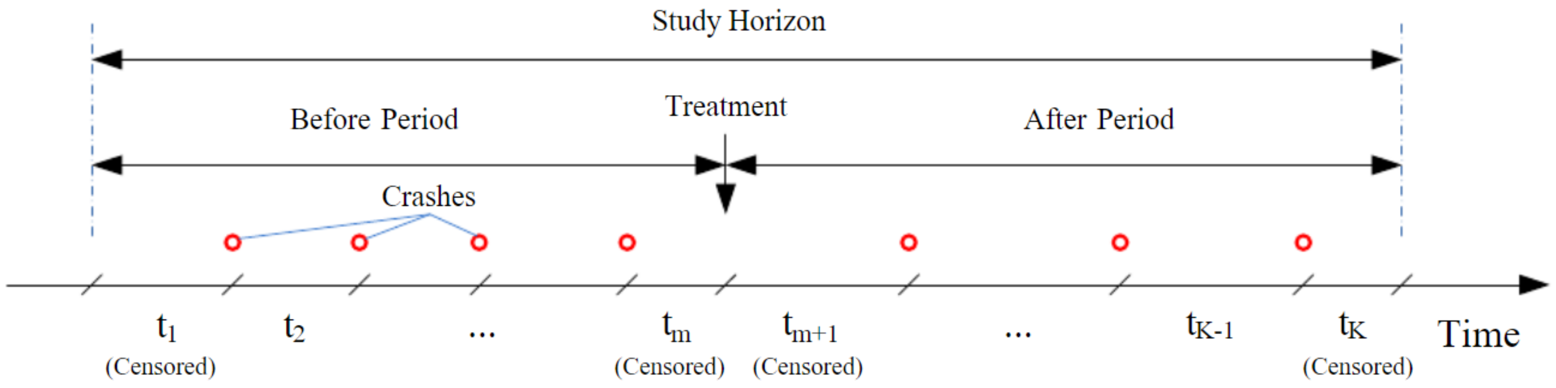
$v_l(t)$: Speed of the leading vehicle at time t

$X_l(t) - X_f(t)$: Relative distance between the leading and the following vehicle at time t

Safety Analysis – Methodology (Crash Analysis)

Survival Analysis Approach

- Model time intervals between two consecutive crashes instead of crash frequency
- Relax the assumption of the reference group
  - Allows the evaluation of NYC CVPD since V2V applications can be triggered at any locations



Xie, K., Ozbay, K., Yang, H., Yang, D., 2019. A new methodology for before–after safety assessment using survival analysis and longitudinal data. Risk analysis 39 (6), 1342-1357.

Crash modification factor (CMF), a multiplicative factor used to compute expected number of crashes after implementing a given countermeasure, can be calculate as CMF = $\exp(\beta_T)$.

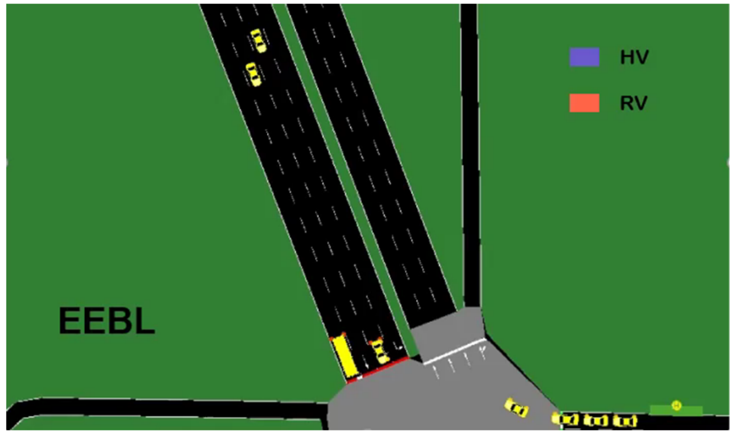
$$f\left(t_{ij} \mid \lambda_{ij}\right) = \lambda_{ij} \exp\left(-\lambda_{ij} t_{ij}\right)$$

$$\log(\lambda_{ij}) = \beta_0 + \sum_{p=1}^{P} \beta_p X_{pij} + \beta_T \text{Treatment}_{ij} + \varepsilon_j$$

λ_{ij} denotes the crash hazard parameter during the ith time interval at jth site. t_{ij} denotes the ith time interval at jth site. β_0, β_p, and β_T are model coefficients to be estimated.

Simulation-Based Surrogate Safety Measures (SSM) Analysis

- Base model is calibrated to both **operational** (volume, travel times, turning movements) and **safety measures** (traffic conflicts severity distributions).
- Open-source micro-simulator SUMO
- Integration of 7 CV App (5 V2V, 2 V2I) and driver behavior model
- Multi-objective stochastic optimization, about 400 simulation hours



Simulation Model Development → **CV Application Integration** → **Vehicle Trajectory Collection** → **Surrogate Safety Measure Calculation**

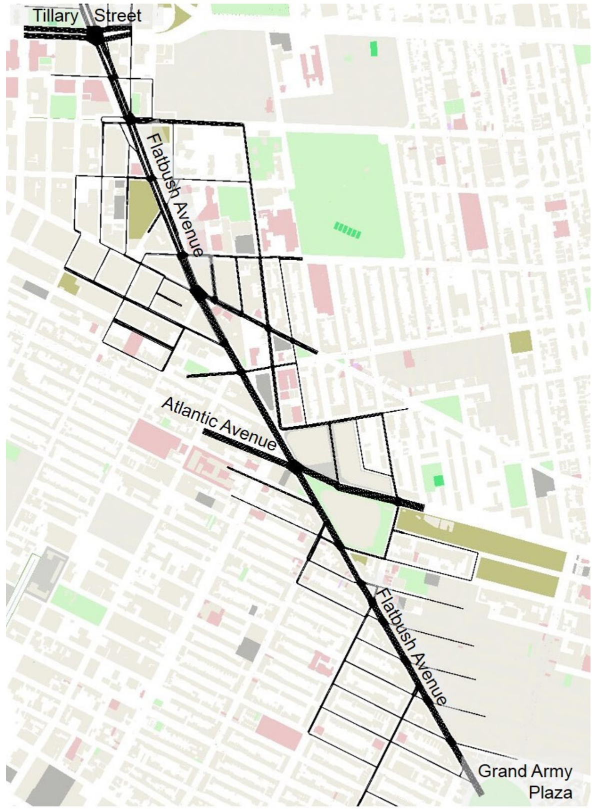
Simulation Model Development
- Develop and calibrate the microscopic simulation base model to match real-world safety and operational conditions
- Design CV Application algorithms for SUMO based on application specifications provided by the vendors
- Obtain driver behaviors from ASD data

CV Application Integration
- Combine SUMO simulation and V2I/V2V app programs via TraCI
- Convert real-world driver behaviors into driver parameters in the model
- Determine the number of runs required for the analysis
- Conduct multiple runs for each CV application

Vehicle Trajectory Collection
- Match host and remote vehicles for V2V applications
- Collect vehicle trajectories from simulation outputs for TTC calculation

Surrogate Safety Measure Calculation
- Generate Time to Collision values from the simulated vehicle trajectories
- Post-procession is conducted using parallel computing with 36 nodes in High Performance Computing (HPC)

Parallel / High Performance Computing

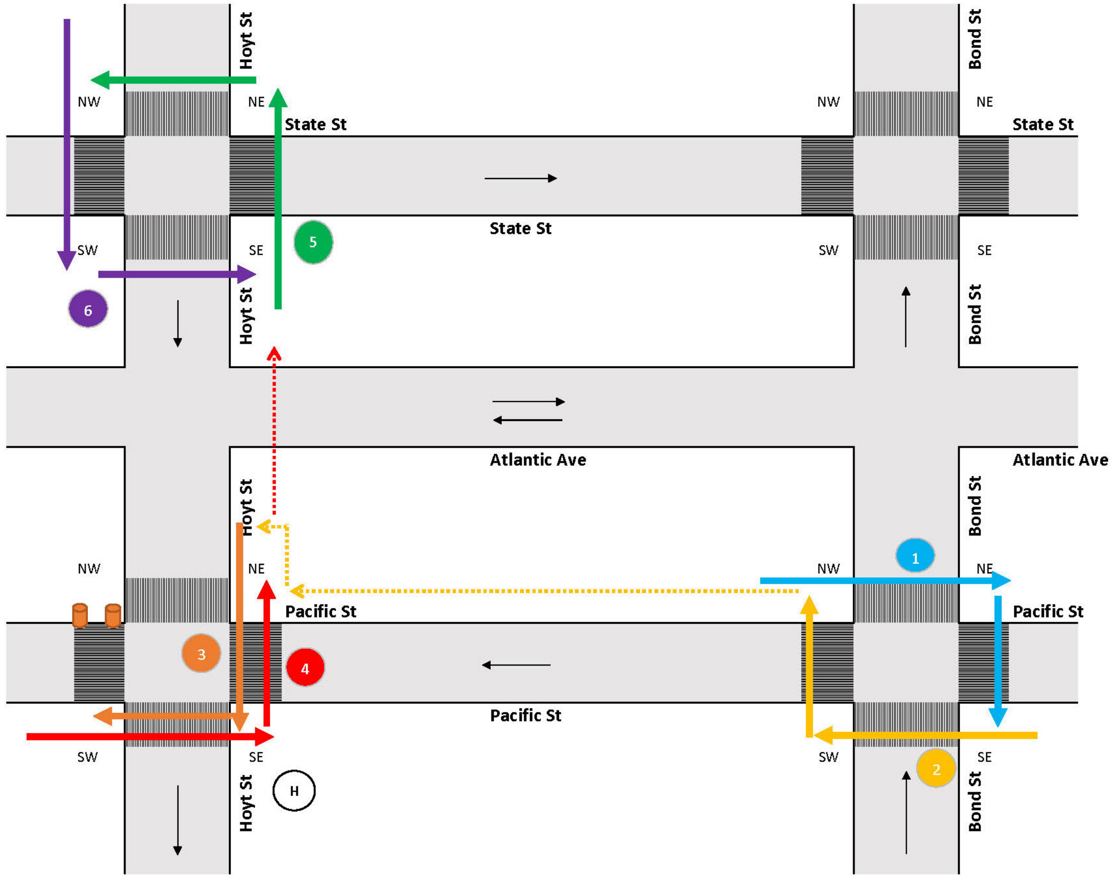


PED-SIG Experimental Design

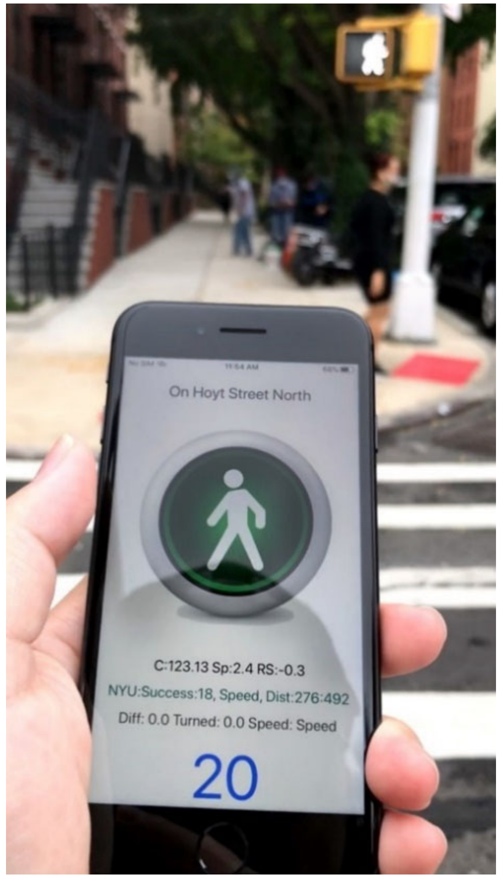
- Recruited 24 volunteer participants with vision disabilities via local and national organizations working with blind
- Participants navigated intersections using PID accompanied by NYU Institutional Review Board (IRB)-certified researchers.

Highlights:

- Four semi-protected intersections
- Six predefined routes, each made up of two crosswalk crossings
- Data collected from operational data logs, field observation and pre- and post-experiment surveys



User Interface for the PED-SIG Mobile Phone Application



Performance Results & Findings

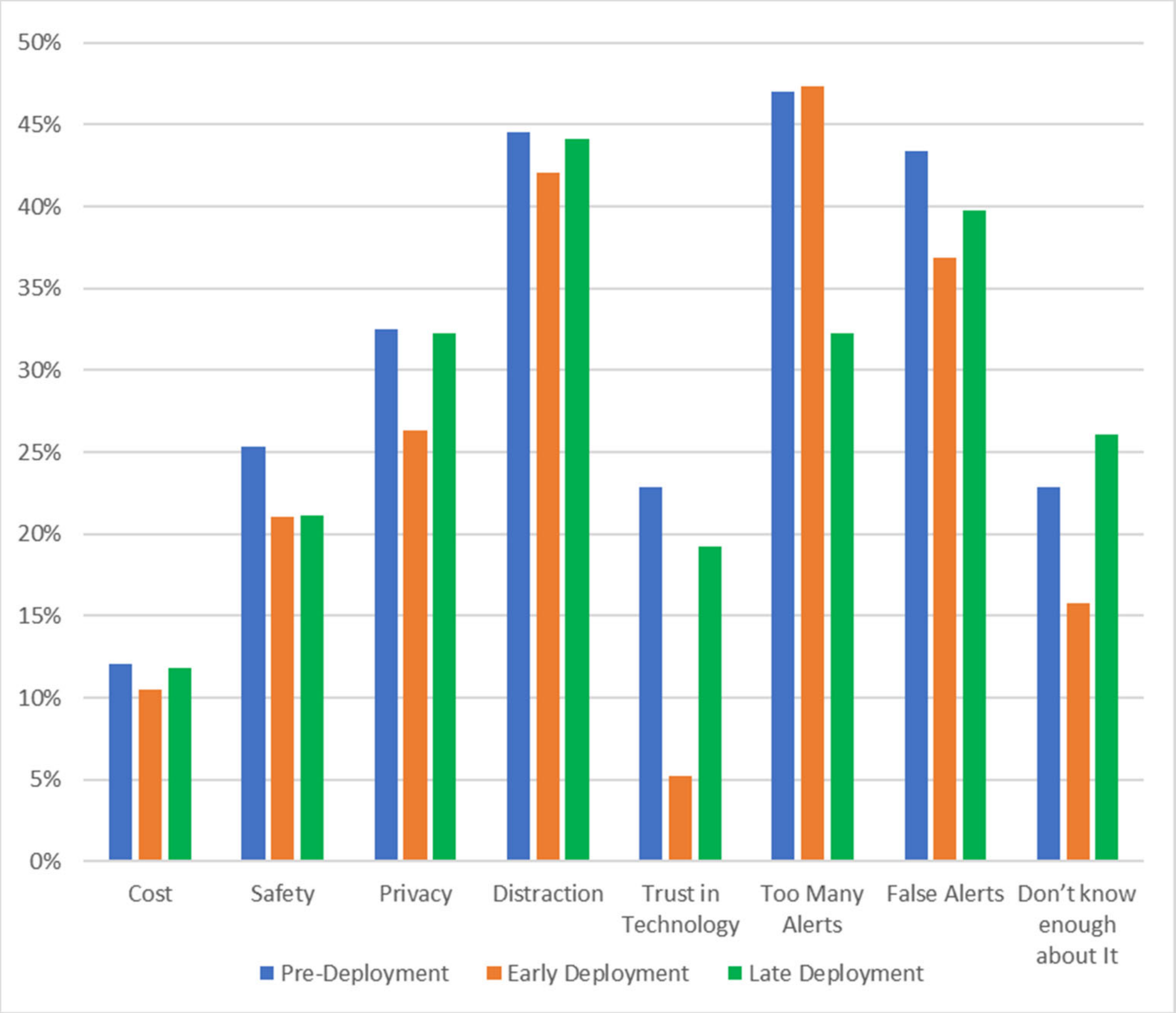
Qualitative Results – Driver Surveys

- Three surveys conducted:
  - Pre-deployment: Last month of before period
  - Early-Deployment: 1-2 Months into after period
  - Late-Deployment: 4-5 Months into after period
- Focus areas for questions:
  - Vehicle Usage on a typical day
  - Attitudes and perception of CV technology and Driving Safety in NYC
  - User experience with CV Apps (after period surveys only)
  - Basic demographics

Driver Survey Findings

- Typical respondent:
  - DOT employee
  - Drives in Manhattan and Queens
  - More than 10 years experience driving in NYC for work
  - Drives 20-50 miles* per day
    - **higher than typical vehicle use*
  - Likelihood of a crash or near crash with:
    - Another Vehicle: Slightly likely
    - A Pedestrian or Bicyclist: Slightly likely
    - Off-road or infrastructure: Not at all likely

- Concerns about CV Technology:



NYC Connected Vehicle Project
For Safer Transportation

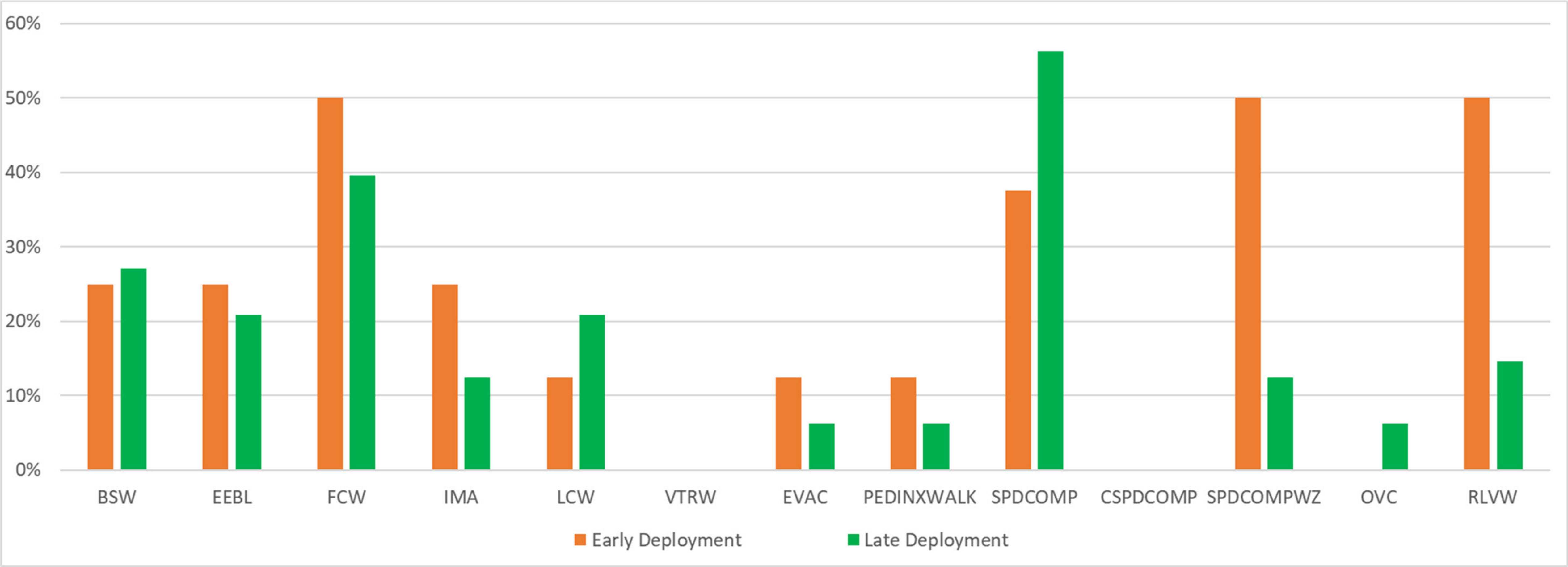
U.S. Department of Transportation

Driver Survey Findings – User Experience (1)

- Frequency of alerts heard varied evenly from never to many times per day
- Majority found alerts too loud
  - Somewhat loud 38%, Much too loud 22%
- *Majority found alerts distracting:*
  - *17% Slightly, 30% Moderately, 19% Very, 23% Extremely*
- *Majority found alerts helpful:*
  - *23% Slightly, 27% Moderately, 8% Very, 1% Extremely*
- Have the alerts affected how you drive?
  - No: 70%
  - Yes: 30% (split 20% very negative, 23% negative, 48% positive, 10% very positive)

Driver Survey Findings – User Experience (2)

- 38% reported alerts helped them drive more safely
  - Apps reported as helpful:



Analytic Results

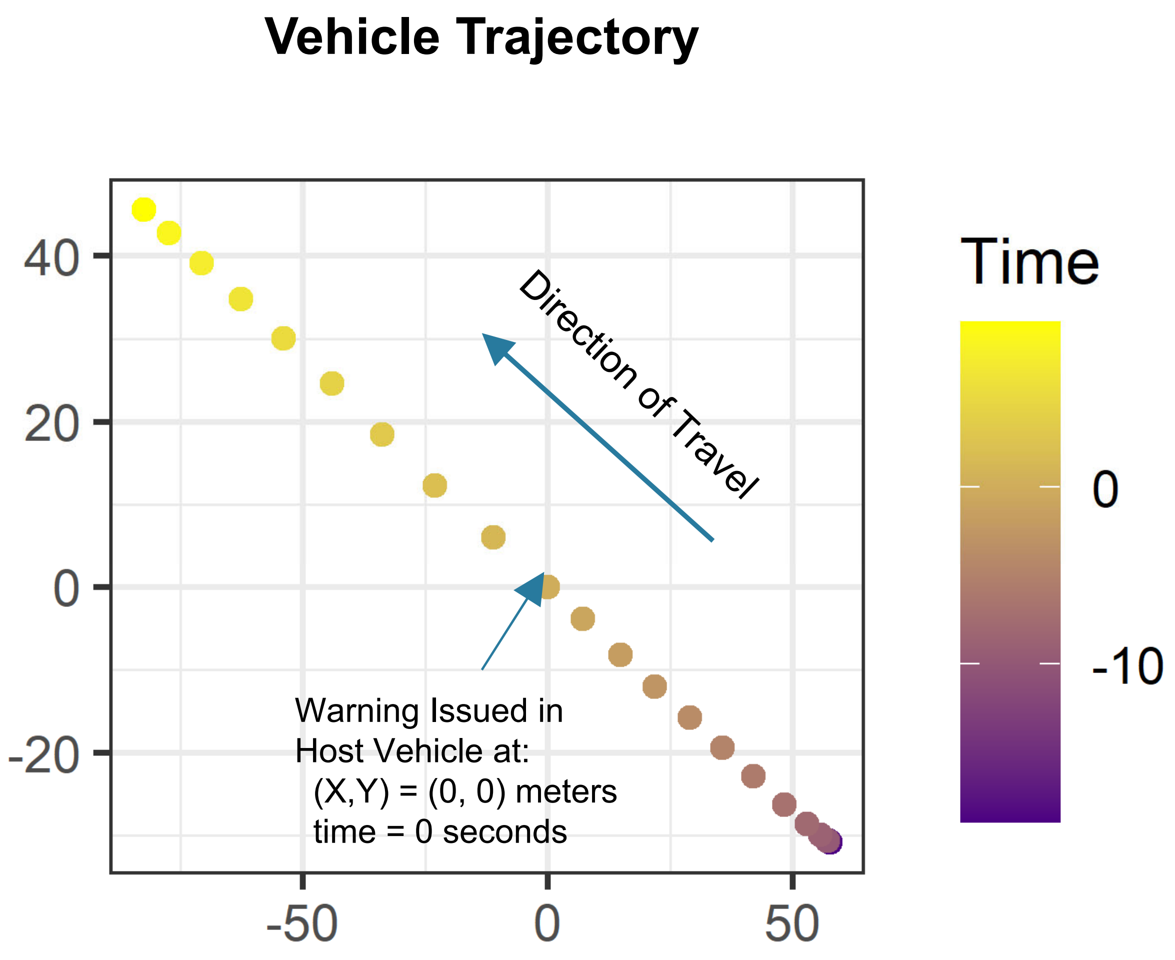
- App Specific Analysis that follows:
  - ASD-based Analysis:
    - Number of events refers:
      - CV event file warning logs included in the analysis
      - From January - April (before period) and June - September (after period).
      - Events remaining after all error checking, obfuscating, cleaning, and filtering is complete
  - SSM-based Analysis:
    - Simulation of CV apps based on driver behavior response analysis from event logs
    - Assumed a 5% CV market penetration rate

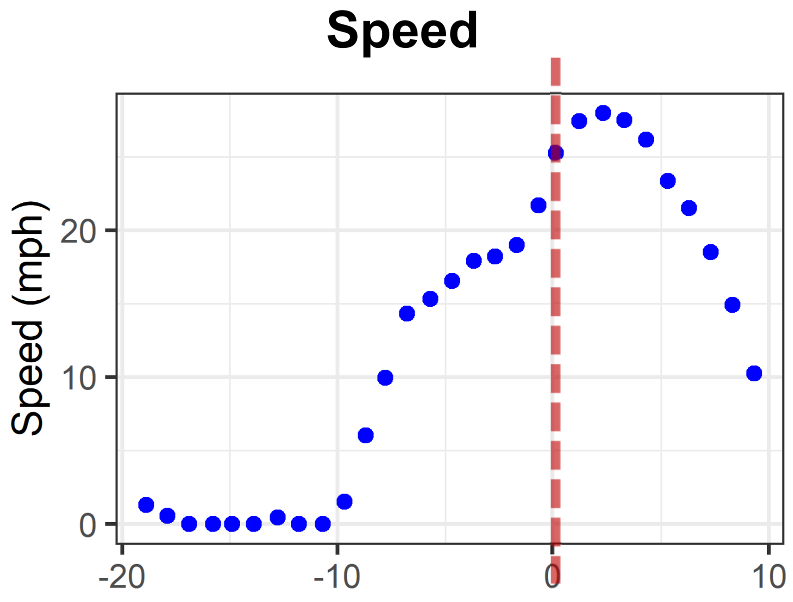
Safety Analysis Results
SPDCOMP: Speed Compliance

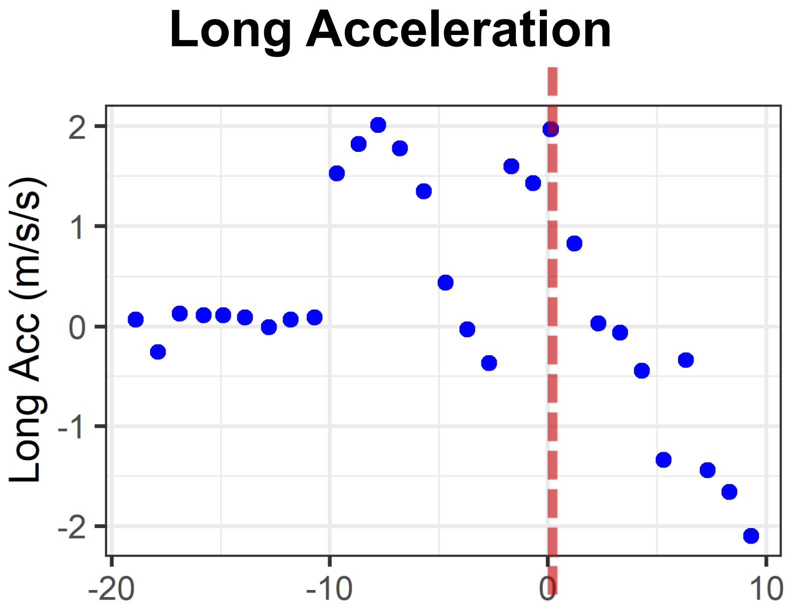
Statistically significant at 95%

- Number of events:
  - 40,635
- ASD-based Analysis:
  - Compared to silent warning scenarios, there are additional 47 events per 1,000 SPDCOMP events that driver slowed to the speed limit when treatment was enabled ✓
- Driver behavior response:
  - 0.148 m/s^2 extra deceleration on average after speed compliance warnings were issued ✓
  - 0.619 s reduction in time duration to slow down to speed limit ✓
    - Minor reduction (<1 s)

Safety Analysis Results
SPDCOMP: Driver Response Example







Safety Analysis Results
CSPDCOMP: Curve Speed Compliance

Statistically significant at 95%

- Number of events:
  - 27
- ASD-based Analysis:
  - 8.750 mph reduction in vehicle speeds at curve entry ✓
  - 0.691 m/s^2 reduction in lateral acceleration in the curve ✓
- Driver behavior response:
  - 0.908 m/s^2 decrease in deceleration difference ✓
  - In general, drivers did not decelerate after being given the curve speed compliance warning

Safety Analysis Results
SPDCOMPWZ: Speed Compliance in Work Zone

- Number of events:
  - 2,665
- Driver behavior response:
  - There is an extra 0.427 m/s^2 deceleration from the drivers on average after being issued the warnings ✓
  - 2.260 s reduction in time duration to slow down to speed limit ✓

✓ Statistically significant at 95%

Safety Analysis Results
V2V Applications

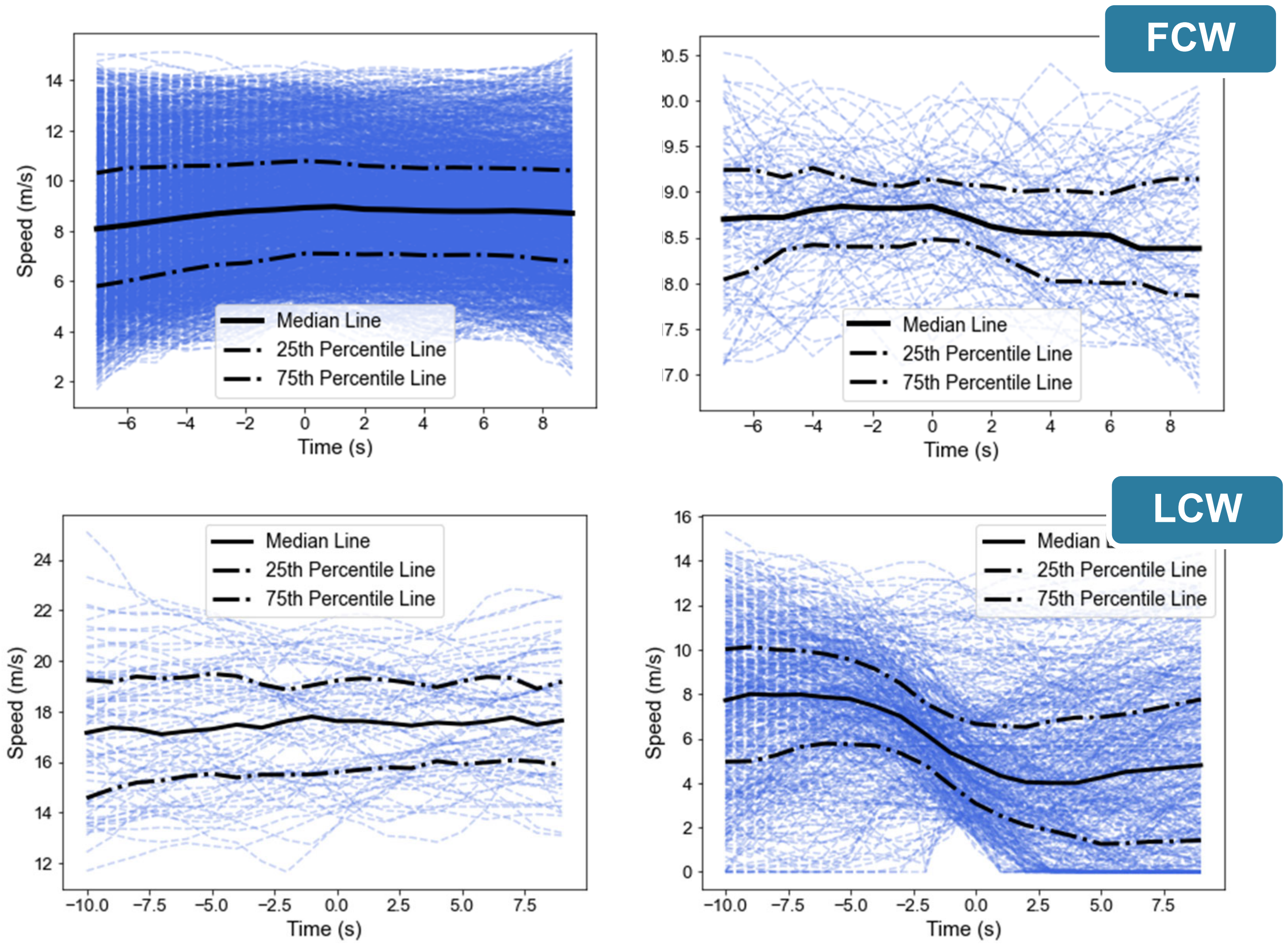
✔ Statistically significant at 95% ⊖ Marginally insignificant at 95%

CV App	# of Events	15th Percentile TTC - ASD		15th Percentile TTC – SIM (5% CV)	
FCW	12,255	0.198 s increase	⊖	1.60 s increase	⊖
EEBL	107	Insignificant according to 95%		1.58 s increase	⊖
BSW	738	Insignificant according to 95%		2.43 s increase	✔
LCW	873	0.265 s increase	⊖	2.03 s increase	✔
IMA	2,666	2.951 s increase	✔	-	

Safety Analysis Results
V2V Applications - Driver Responses

	# Events in Treatment Group	Reacted	No Reaction
FCW	2,263	18%	82%
EEBL	68	100%	0%
BSW	473	84%	16%
LCW	472	84%	16%
RLVW	1,114	100%	0%

Clustering of Driver Responses Based on Speed-Time Relationship



Safety Analysis Results
RLVW: Red Light Violation Warning

- Number of events: 2,073
- ASD-based Analysis:
  - Compared to silent warning scenarios, there are approximately152 fewer likely red-light violations* per 1,000 RLVW events when treatment was enabled ✓
- Driver behavior response:
  - Drivers tended to decelerate approximately 0.137 m/s^2 more after RLVWs were issued ✓
  - 0.083 s reduction in time duration to first deceleration after warning ⊖
- Simulation-based SSM Analysis:
  - 1.20 s increase in 15^{th} percentile TTC values ✓

*Drivers did not come to a full stop after receiving a red-light violation warning.

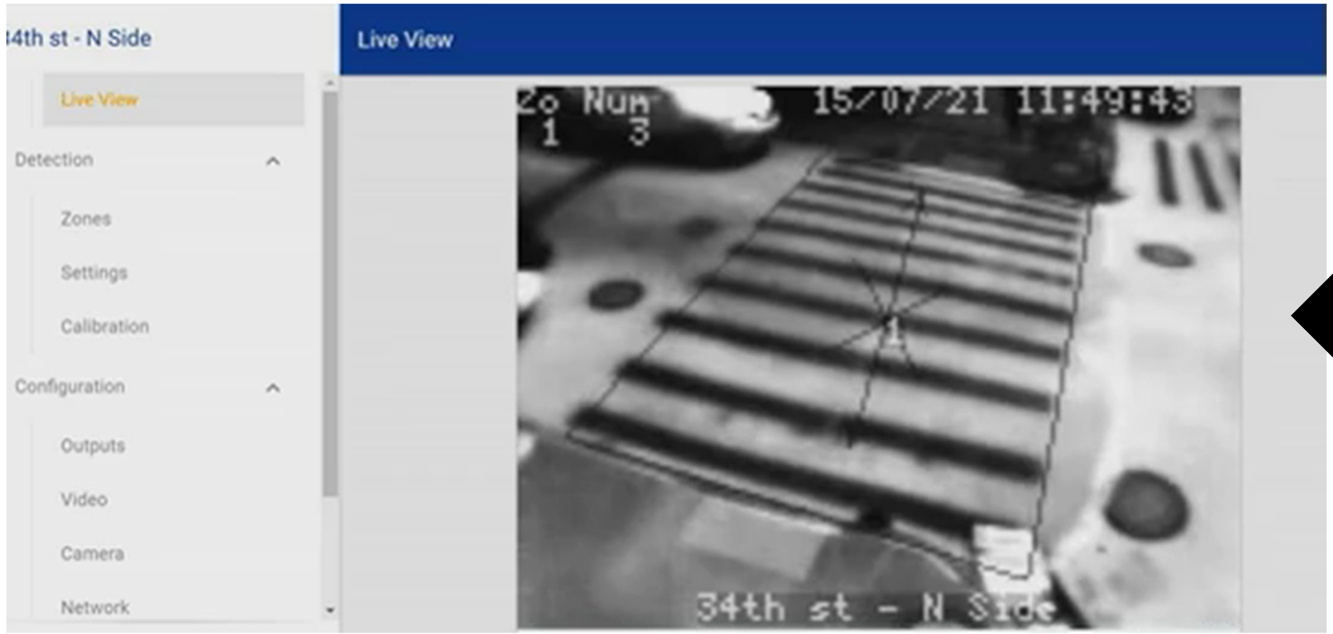
⊖ Marginally insignificant at 95%

✓ Statistically significant at 95%

Safety Analysis Results
PEDINXWALK: Pedestrian in Crosswalk

- Number of events: 20
- Simulation-based SSM analysis
  - 1.80 s increase in 15th percentile TTC values ✓ for vehicle to pedestrian conflicts

✓ Statistically significant at 95%



Thermal Sensor Pedestrian Detection

Safety Analysis Results
Crash-Based Analysis

Challenges:

- **Crash records cannot be linked to instrumented vehicles** due to the privacy/liability concerns.
- Thus, **crashes involving all vehicles** in NYC during the study horizon are used for crash analysis.
- Other safety-related **confounding factors that occurred simultaneously with the NYC CVPD**, including the COVID-19 pandemic, Vision Zero projects, planned special events, and so on.
- The crash analysis results should be interpreted as **a combined treatment effect for all the potential safety-related "treatments"** that occurred simultaneously around NYC during the NYC CVPD implementation period and may not be solely due to the CV applications.

Evaluation Results - Crash-Based Analysis

Rear-end Crashes (FCW & EEBL)

- Number of rear-end crashes (NYPD crash database): 4,581
- Crash modification factors (CMFs):
  - Injury crashes: 0.947 (Marginally insignificant)
    - – Reduction in injury rear-end crashes after account for crash exposure
  - Property damage only (PDO) crashes: 0.906 (Statistically significant)
    - – Reduction in PDO rear-end crashes after account for crash exposure

Side-swipe Crashes (BSW & LCW)

- Number of side-swipe crashes (NYPD crash database): 1,471
- CMFs:
  - Injury & Fatal crashes: 0.985 (Statistically insignificant)
  - PDO crashes: 0.850 (Statistically significant)
    - – Reduction in PDO side-swipe crashes after account for crash exposure

Statistically significant at 95%

Marginally insignificant at 95%

Statistically insignificant at 95%

Crash modification factor (CMF)

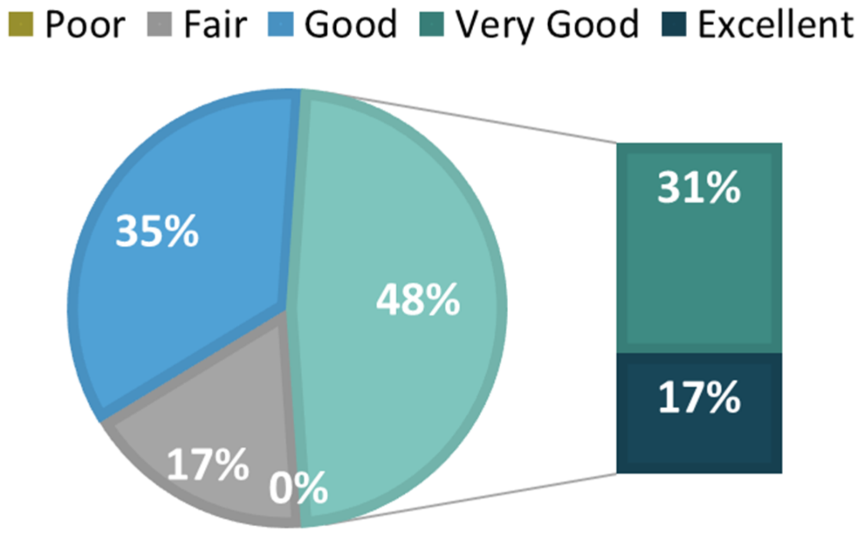
A multiplicative factor to compute expected # crashes after implementing a given countermeasure.

Crash Exposure

Traffic volume data are used as crash exposure to account for the COVID-19 recovery.

PED-SIG Evaluation Results

Overall PED-SIG Application Rating



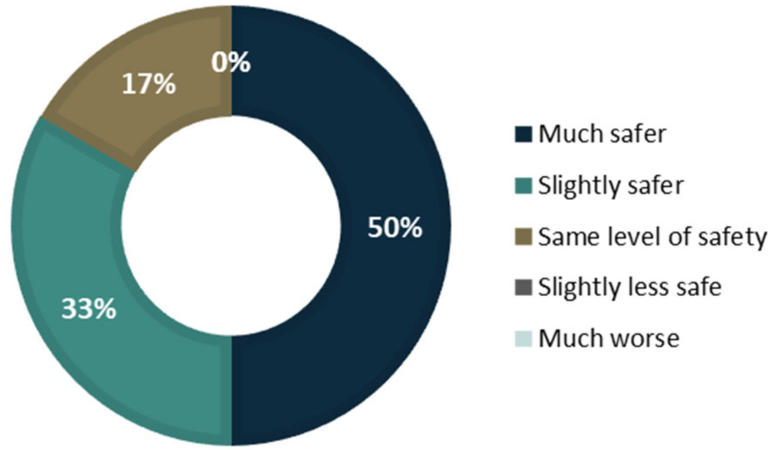
14 Participants were recruited from 14 local and national organizations working with blind communities.

100% Anticipated that pedestrians would benefit from the use of PED-SIG technologies.

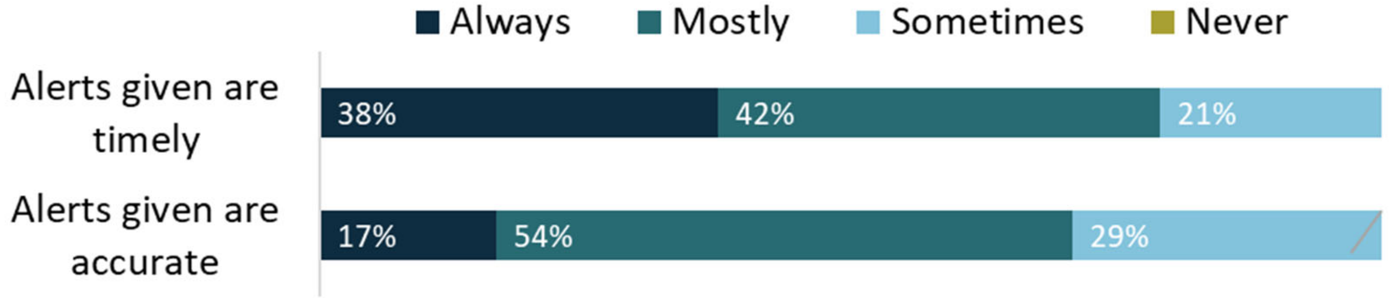
96% Felt they were given sufficient time to cross the intersection when using the PED-SIG application.

PED-SIG

PED-SIG Application Safety Perception



PED-SIG Application Alerts Were Accurate/Timely



The main problems experienced:

- Location information provided was not always accurate (75%)
- Slow responses (25%)
- Orientation was not accurate (21%).

PED-SIG Evaluation Results (1)

Operation data logs and field observations
Approximately **170 runs**, each made up of two crosswalk crossings, were completed.

Performance Measures:

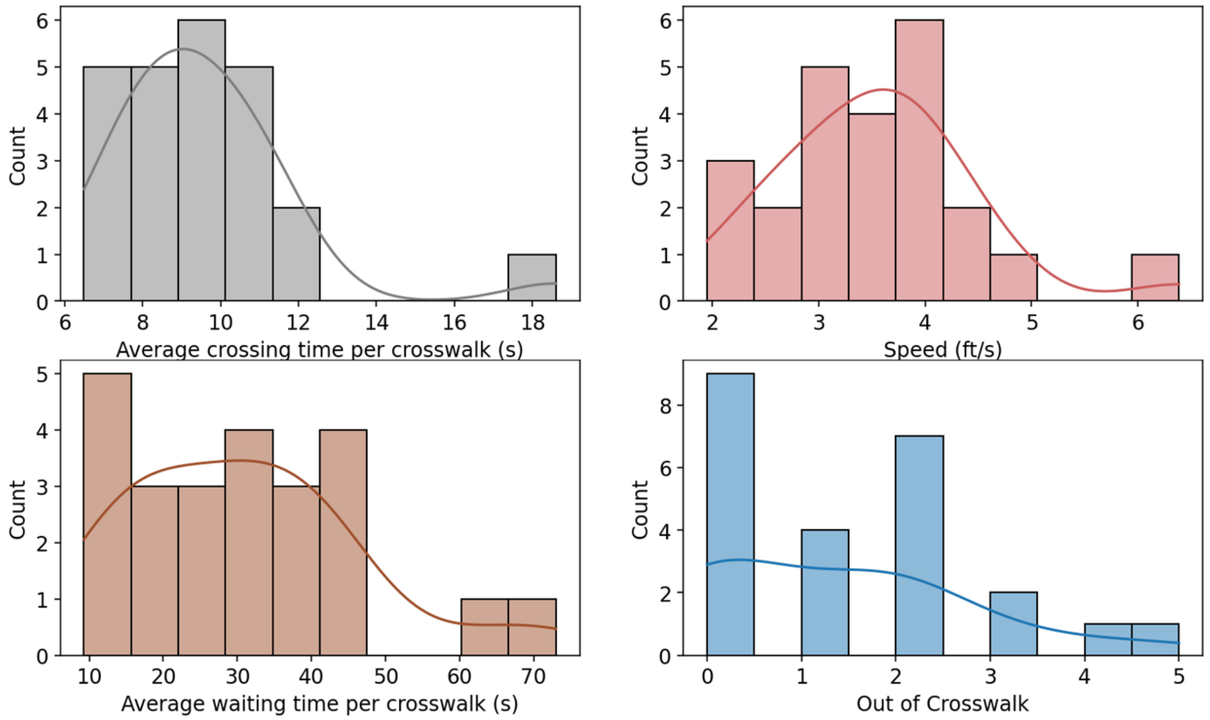
- Pedestrian crossing speed
- Pedestrian crossing travel time
- Waiting time at intersection for crossing
- Times out of crosswalk

PED-SIG Evaluation Results (2)

Main Findings:

- 63% of the participants veered off the crosswalk at least once.
- 54% of them crossed the streets faster than the 3.5 ft/s assumption used for signal timing design.
- The waiting time per crosswalk varies among different participants.

	Crossing speed (ft/s)	Avg crossing time per crosswalk (s)	Avg waiting time per crosswalk (s)	Out of Crosswalk (Avg #times)
Mean	3.6	9.6	31.0	1.4
Std	0.9	2.4	15.9	1.4
15th /85th Percentile	[2.6, 4.2]	[7.7, 11.0]	[14.9, 43.0]	[0.0, 2.3]



CV Transition Plan

Next Steps

- **Original plan** anticipated a sustainable investment for future connected vehicles
- **Driven by FCC First Report and Order** to clear the lower 45 MHz by July 2022
- **Additional complications** create substantial complexity with respect future temporary configurations
- **Suspend DSRC transmissions** after completing the project's Phase 3 Operation
- New York City is not abandoning CV concepts

NYCDOT Perspective on CV Pilot Deployment

NYC Perspective

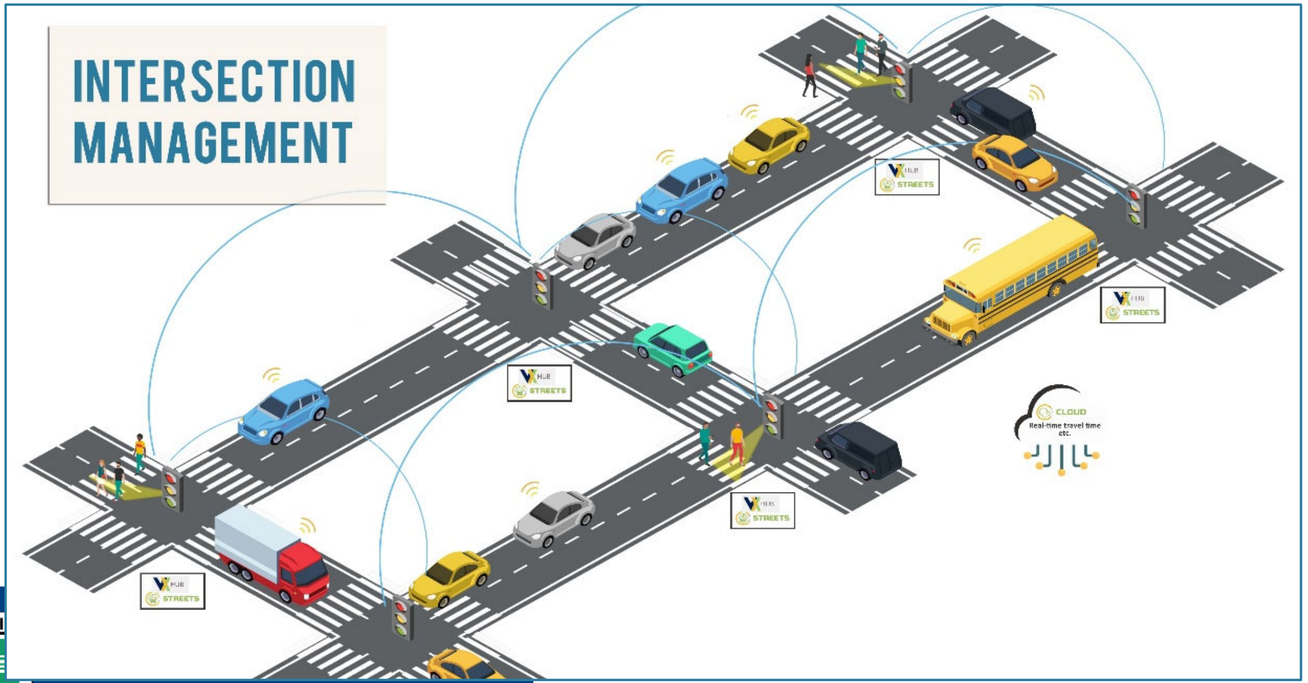
- **Successful project!** Produced large data set for future research
- **Equipping and managing a fleet is challenging** with many “black box” components
- Many **Lessons Learned** and **Contributions to CV Community**
  - Urban Deployment and Performance Reliability
  - Maturity of CV Deployment, Operations, and Maintenance **at scale**
  - Managing Security Aspects for CV Deployment

NYC Cooperative Driving Use Cases

CD for ACV Use Cases Mapping to NYC:

1) Pedestrian and bicyclist safety through cooperation
2) Cooperative work zones
3) Cooperative intersection management.

See full use cases here (https://c2smart.engineering.nyu.edu/wp-content/uploads/2021/12/CD_for_ACV_NYU_UseCase_DataAnalysis.pdf)



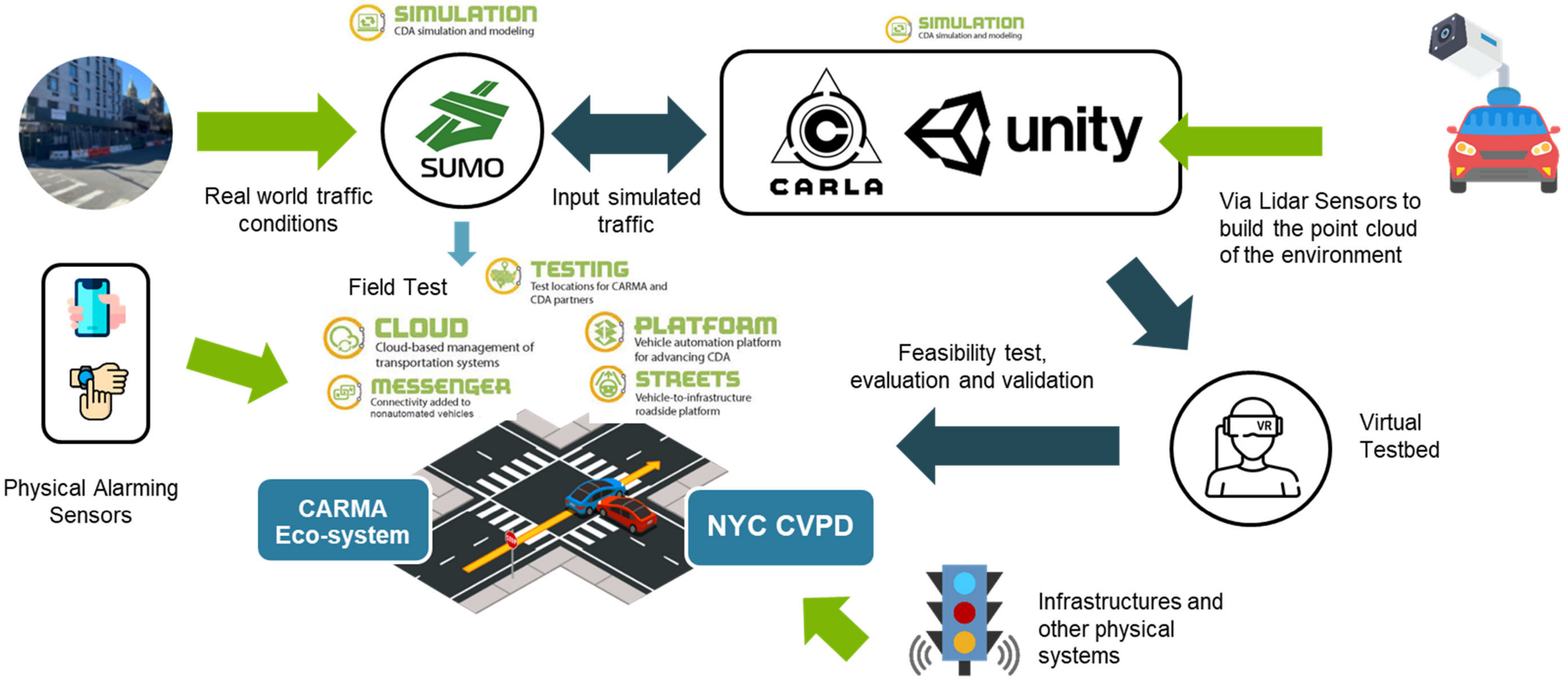
Future of CVs in NYC

With deployed CV infrastructure and experience in NYC, we could:

- Enable "Cooperative Perception"
  - **Cooperative Driving for Advanced Connected Vehicles** (CD for ACVs) at urban intersections in NYC
- Develop co-simulation environments for safe and realistic testing of CD for ACV
  - Cyber-physical testbed for prototype testing, learning, evaluation and integration of FHWA's CARMA.

Potential Cyber-Physical Testbed

NYC could integrate its facilities for an expanded CARMA cyber-physical testbed.



Questions?

M60 SELECT BUS SERVICE
5985
Photo Courtesy: MTA New York City Transit

Stay Connected

Contact for CV Pilots Program/Site AORs:

- Kate Hartman, Program Manager, Wyoming DOT Site AOR; Kate.Hartman@dot.gov
- Jonathan Walker, NYCDOT Site and Tampa (THEA) Phases 4 AOR; Jonathan.b.Walker@dot.gov
- Govind Vadakpat, Tampa (THEA) Phases 1-3 AOR; G.Vadakpat@dot.gov
- Walter During, Evaluation COR, Walter.During@dot.gov

Visit CV Pilot and Pilot Site Websites for more Information:

- CV Pilots Program: http://www.its.dot.gov/pilots
- NYCDOT Pilot: https://www.cvp.nyc/
- Tampa (THEA): https://www.tampacvpilot.com/
- Wyoming DOT: https://wydotcvp.wyoroad.info/