Development and Demonstration of the Truck Activity Monitoring System (TAMS)

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Sponsored by:
California Department of Transportation

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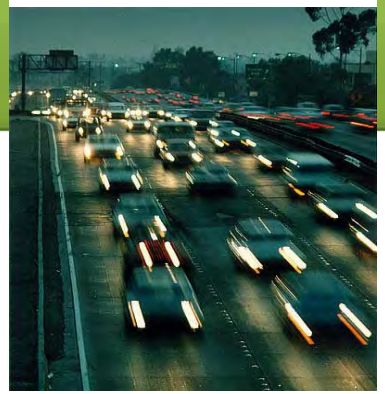
Irvine

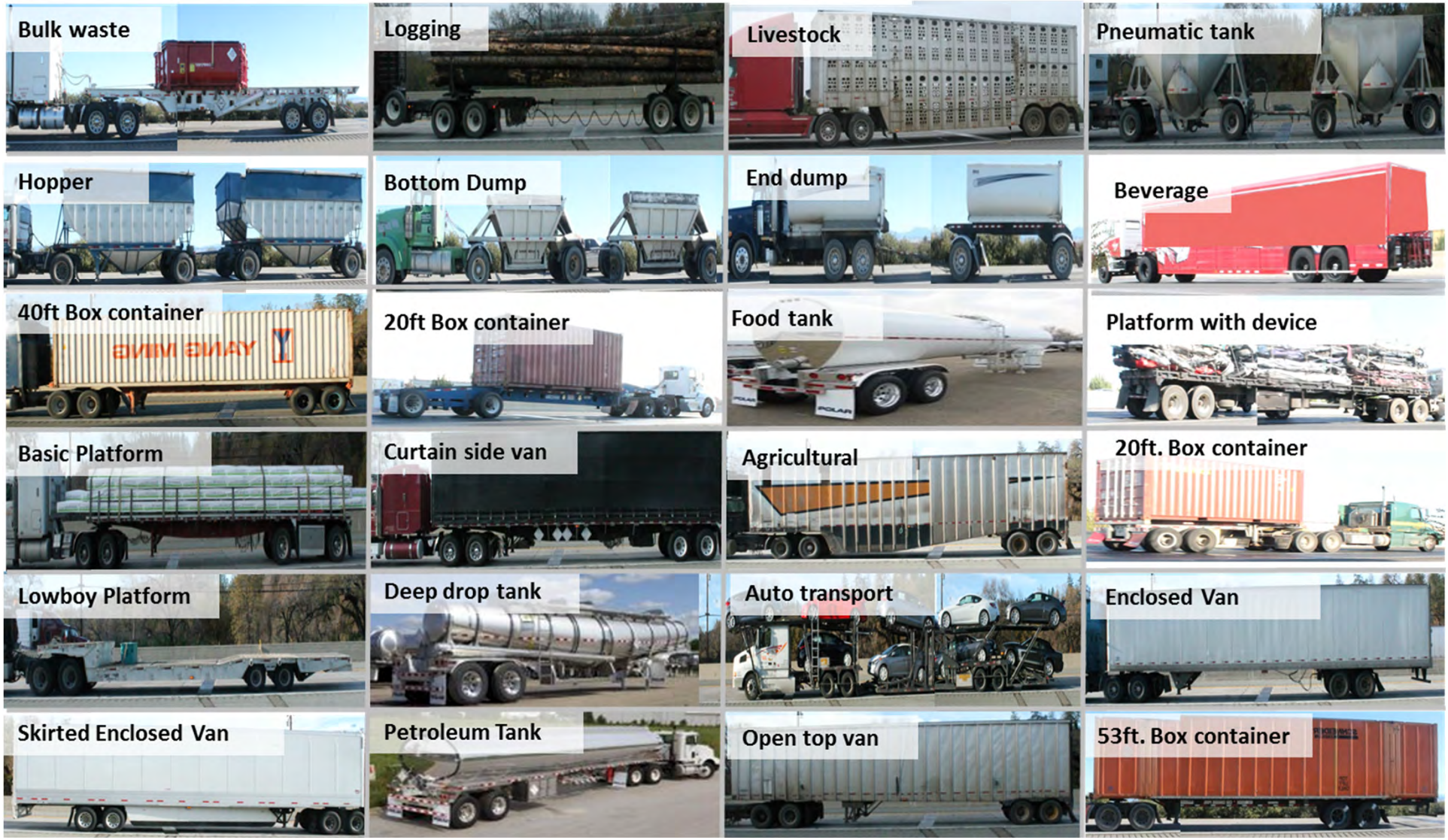


SCAG Modeling Task Force Meeting

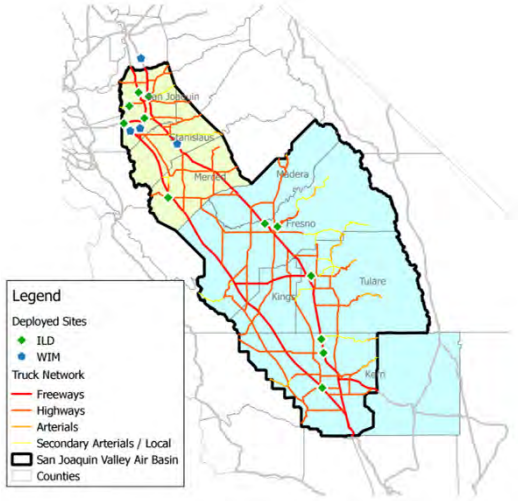
May 25th, 2016

Truck Configurations

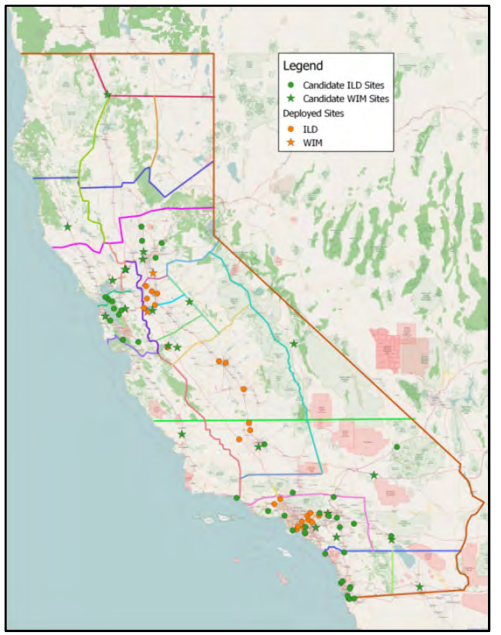
Trailer Configurations



Background



- Pilot study funded by California Air Resources Board in 2012
  - Initial development of inductive signature-based truck body classification models
  - Deployed at 16 weigh-in-motion (WIM) and inductive loop detector (ILD) sites in the California San Joaquin Valley



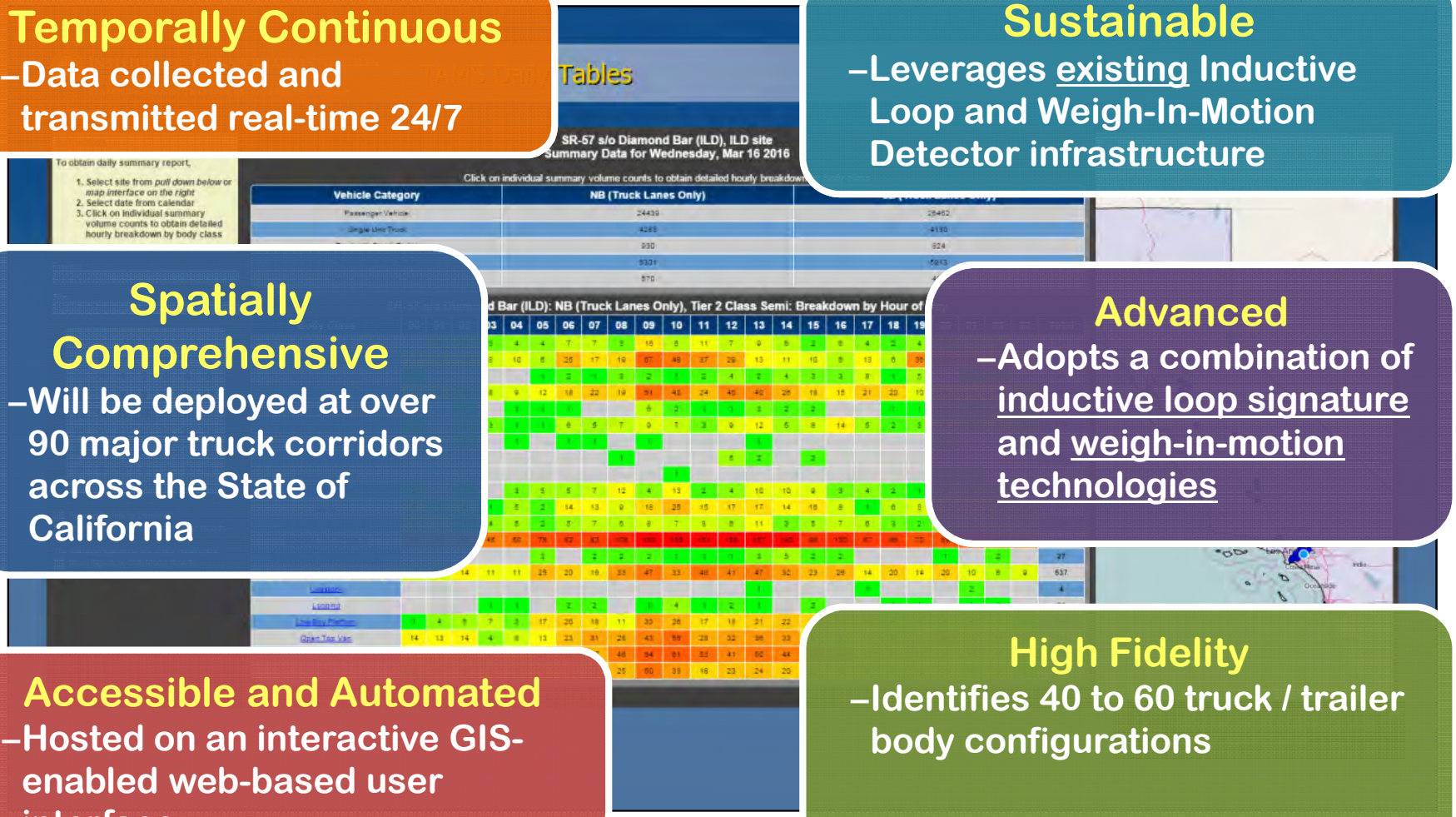
- Current study funded by Caltrans in 2015
  - Improved Validation and Calibration of the California Statewide Freight Forecasting Model (CSFFM)
  - Enhancement of truck classification models
  - Expand deployment to over 90 locations along major truck corridors in California, encompassing
    - state borders,
    - regional cordons, and
    - metropolitan areas

What is the *Truck Activity Monitoring System* (TAMS)?

A truck counting system that is…

Temporally Continuous
–Data collected and transmitted real-time 24/7

Sustainable
–Leverages existing Inductive Loop and Weigh-In-Motion Detector infrastructure



Spatially Comprehensive
–Will be deployed at over 90 major truck corridors across the State of California

Advanced
–Adopts a combination of inductive loop signature and weigh-in-motion technologies

Accessible and Automated
–Hosted on an interactive GIS-enabled web-based user interface

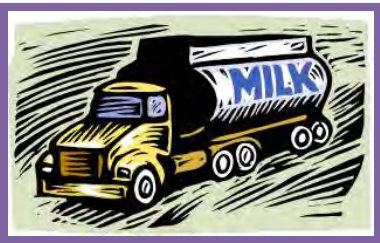
High Fidelity
–Identifies 40 to 60 truck / trailer body configurations

Potential Applications

Estimate proportions of freight and non-freight truck movements

Statistics relating to empty movements in freight trucks

Better understanding of truck travel patterns and behavior



Temporal and spatial travel behavior of trucks by industry

Estimate proportions of long and short haul trips along major and restricted truck corridors

Detector Technologies Behind TAMS

Two Types of Detector Solutions:

Combination of Weigh-In-Motion (WIM) and Inductive Loop Signature Technology

at existing WIM sites

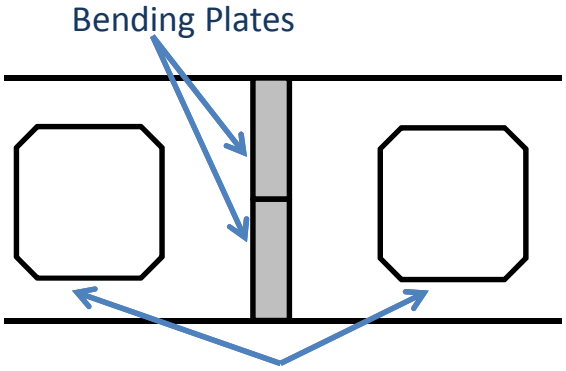
Standalone inductive signature technology

at existing Inductive Loop Detector sites

Weigh-In-Motion Technology

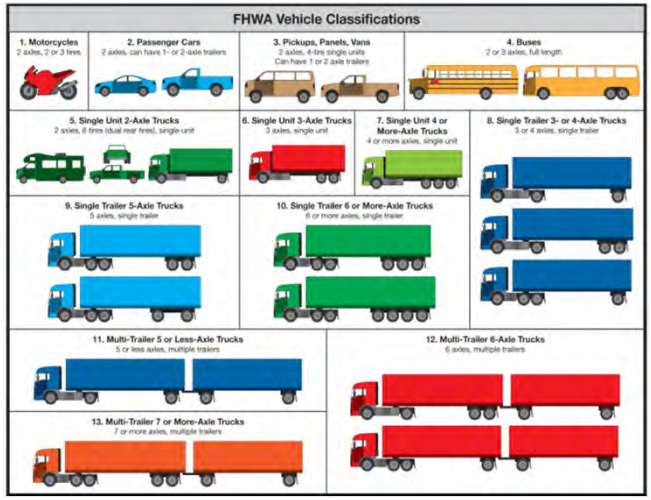
Components

- **Bending Plates**
  - Measure Wheel/Axle Weights



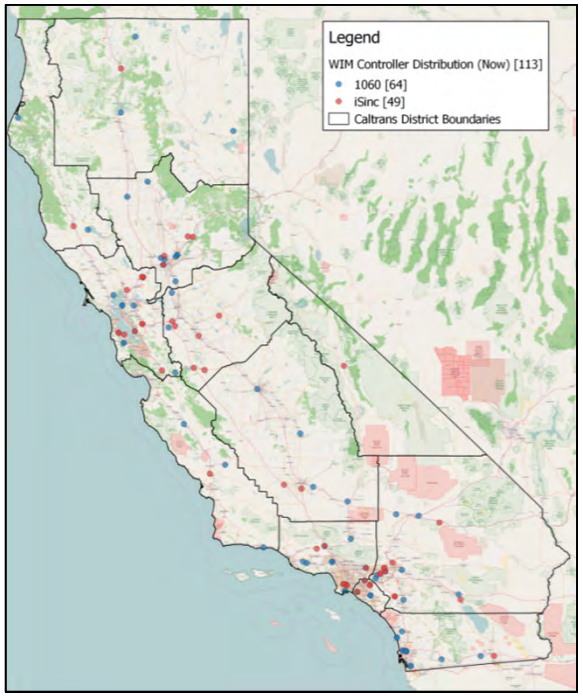
Traveled lane on freeway

- **Inductive Loop Sensors**
  - Presence detection
  - Speed measurement
  - Transform temporal gap in axle measurements into axle spacing



Provides 13 axle-based classifications (14 in California)

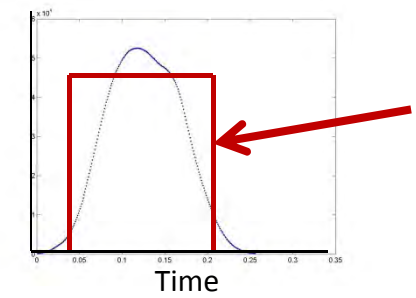
Weigh-In-Motion sensors located along a freeway

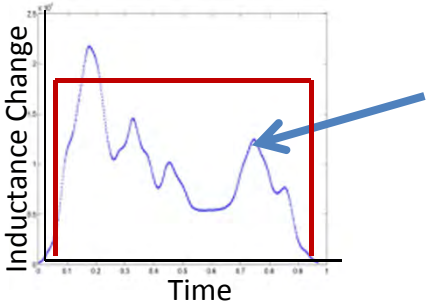


Over 100 Data WIM sites in California located along Major Truck Corridors

Inductive Signature Technology

- Conventional ILDs produce bivalent outputs
  - Generate traffic counts, not truck counts
- Advanced ILDs measure inductance changes → 'Inductive Signature'
  - Inductive signatures are indicative of body configuration

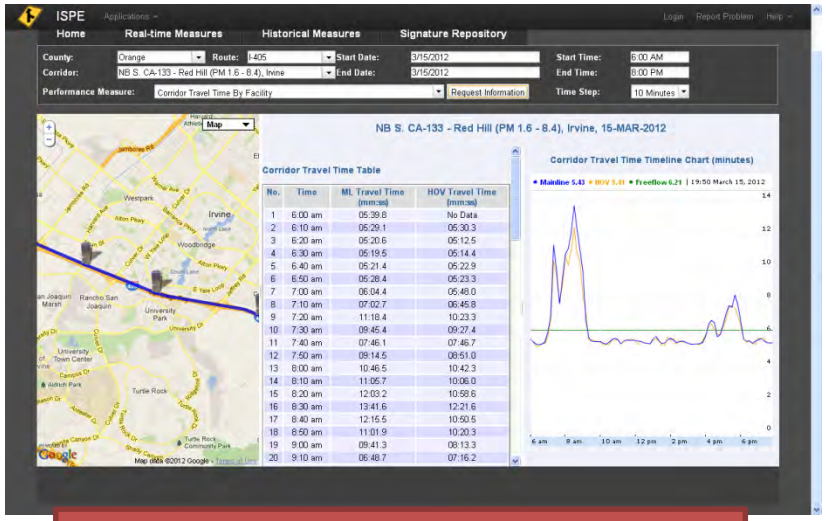




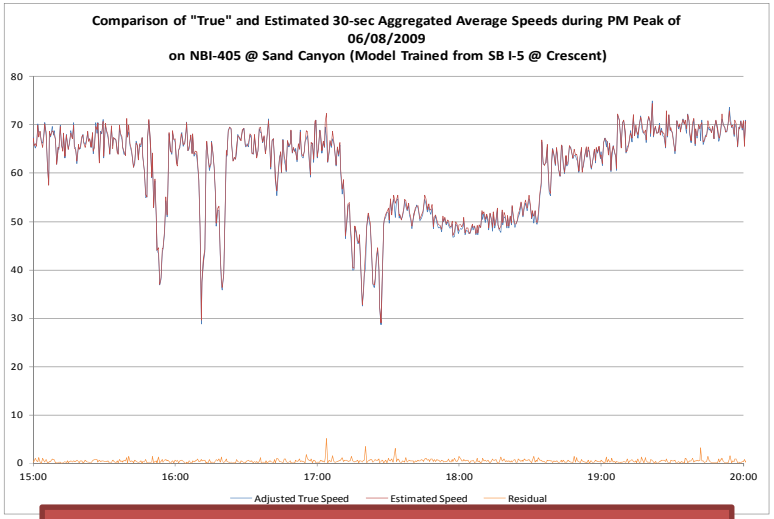
Conventional Measurement
[0,1] Binary output typically sampled at 30 samples/sec

Inductive Signature
High resolution inductive magnitude changes at up to 1000 samples/sec

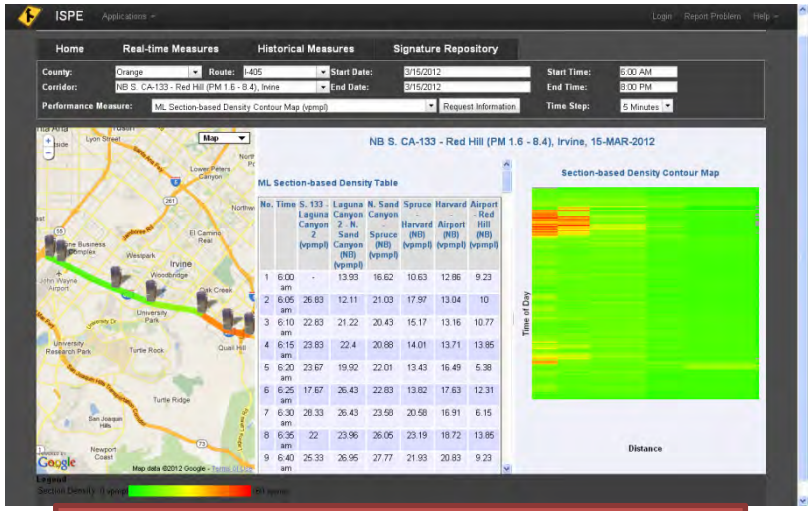
Inductive Vehicle Signature Applications



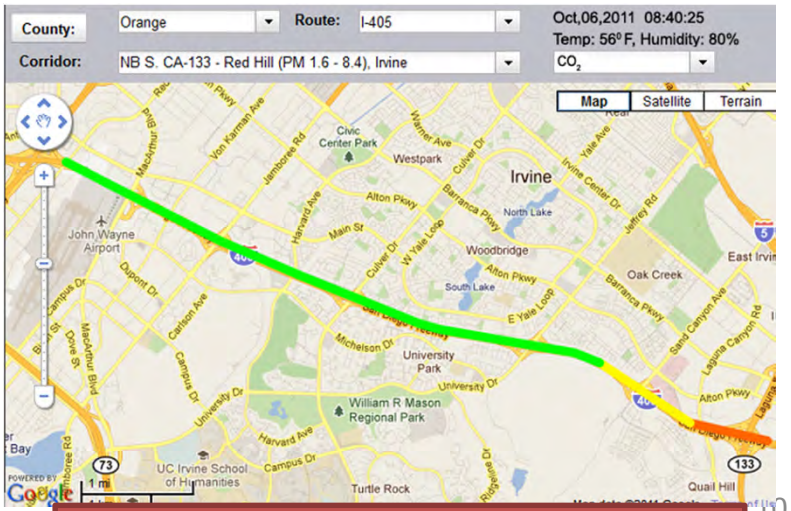
Real-time Section Travel Time and Speeds



Single Loop Point Speed Estimation



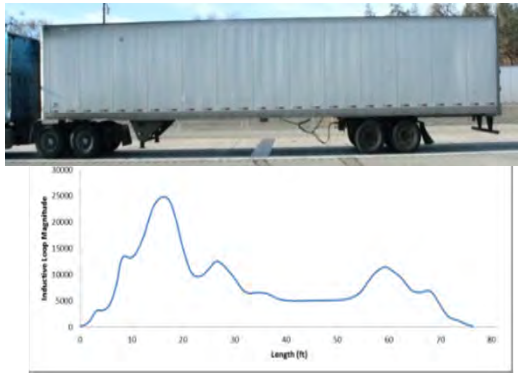
Section-level Density



Section-level Emissions Estimation

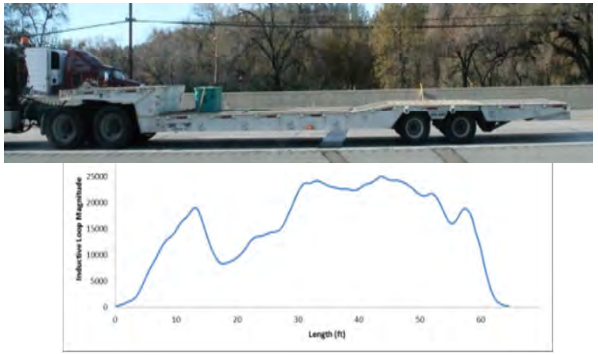
Sample FHWA Class 9 (5- Axle Semi-Trailer) signatures by trailer configuration

Enclosed Van

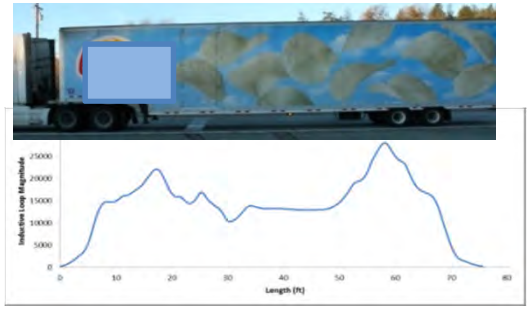


Livestock

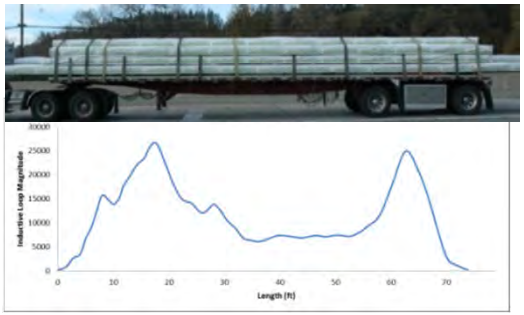
Low Boy Platform



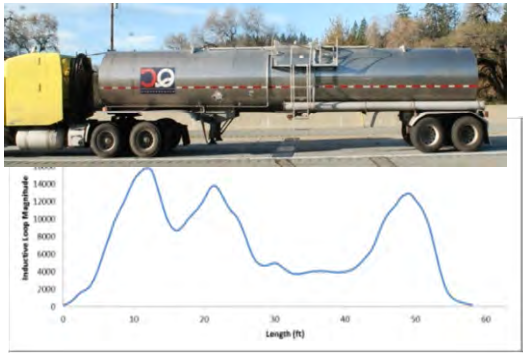
Drop Frame Van



Basic Platform

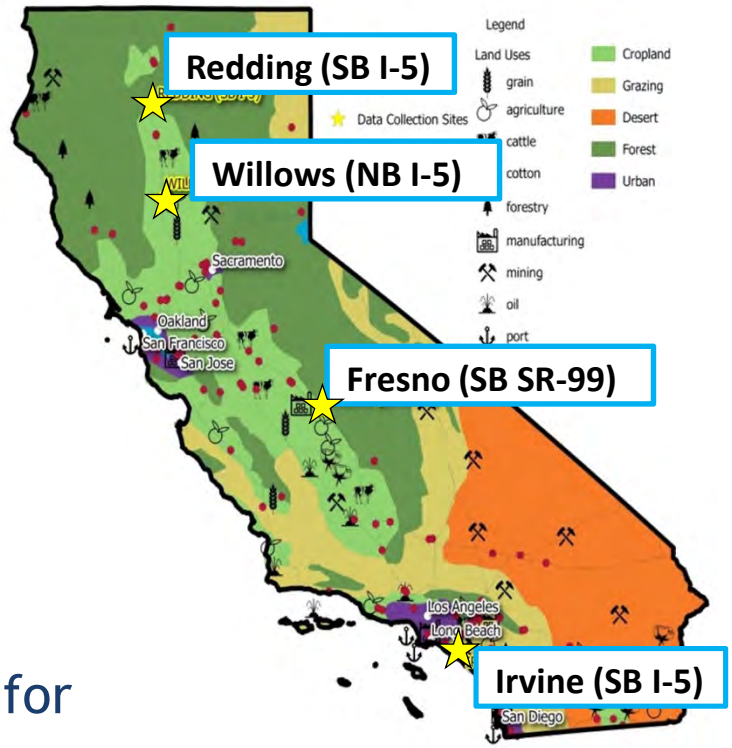


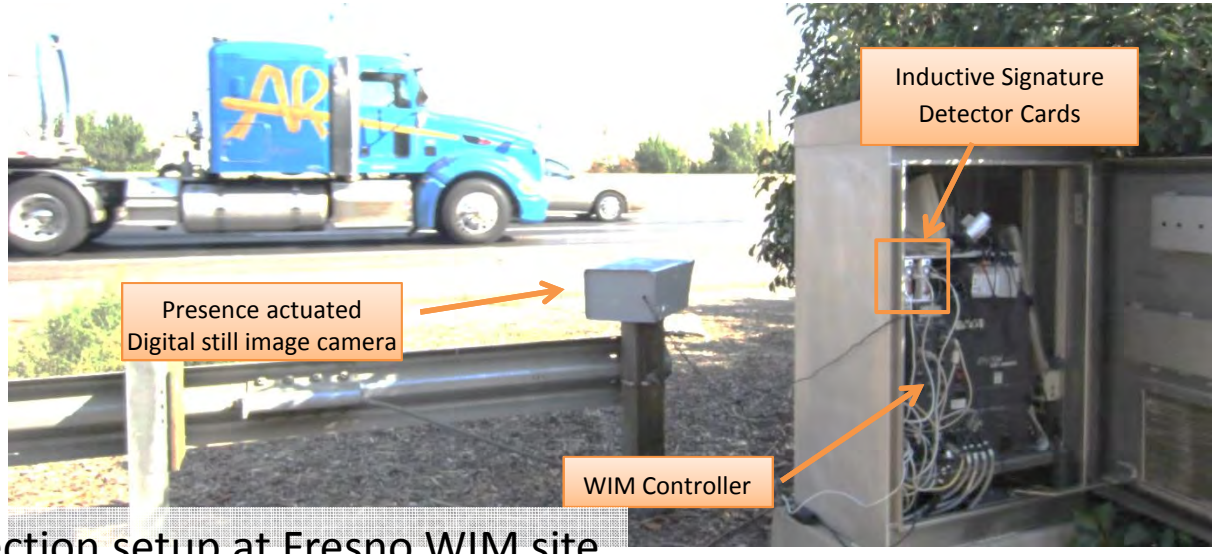
Tanks



Data Collection Sites

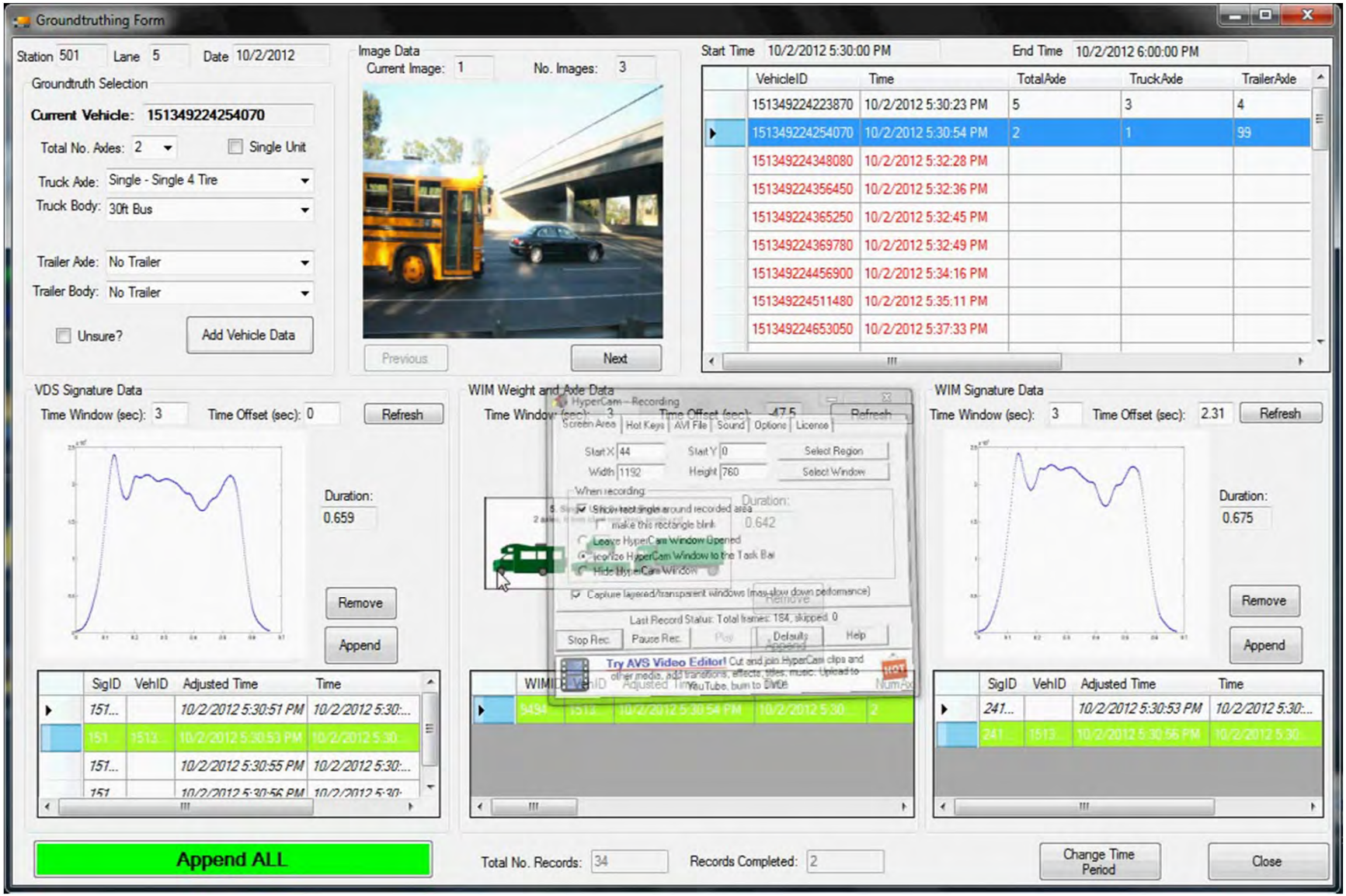
- **Land use variation:** four sites with differing land use characteristics
- **Comprehensive data:** still image photos, WIM data, and inductive signatures
- **Temporal variation:** multiple times of day, days of week, and seasons included
- 97 hours of data collected, with 35,000 vehicle records (mostly trucks) processed for model development and testing





Data collection setup at Fresno WIM site

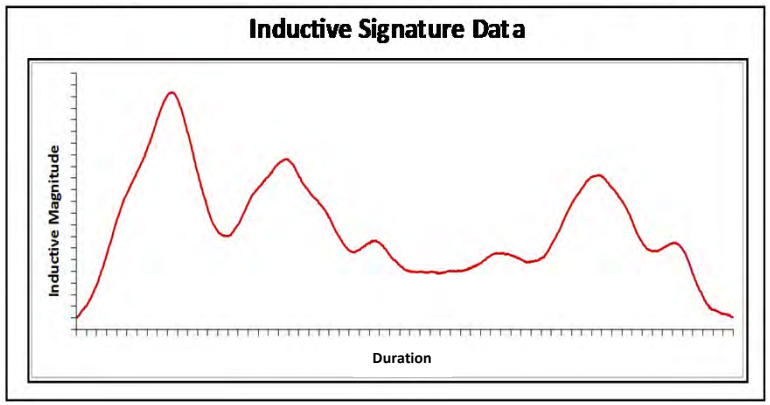
Data Groundtruth System



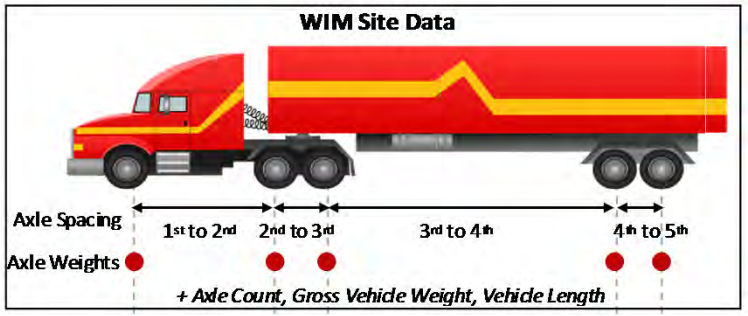
Model Design

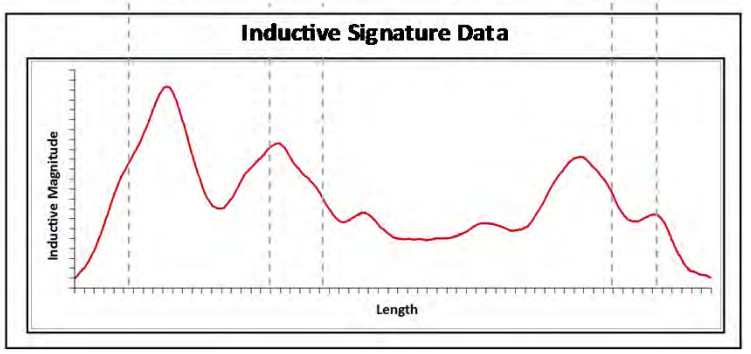
Two Types of Body Classification Models Developed:

Inductive Signature only Model (for existing ILD sites)

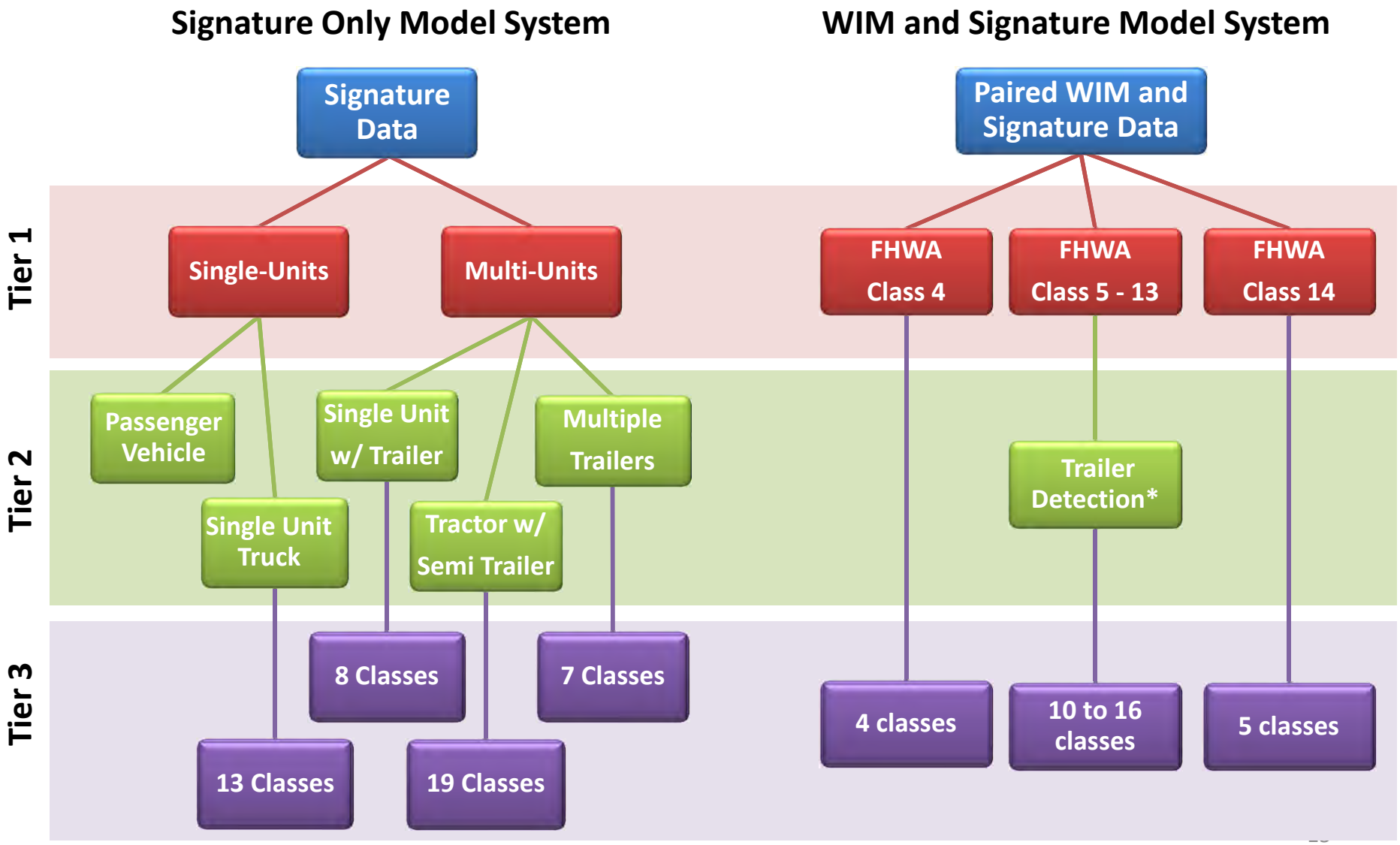


Integrated *WIM and Inductive Signature* Model (for existing WIM sites)





Body Classification Architecture: Two Systems of Models



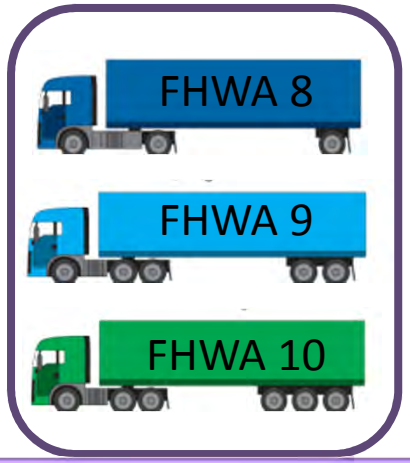
Signature Only Model Results

- Body class model results summary
  - 4 categories incorporating 47 truck body classes
  - 34 classes with classification accuracy > 70%
  - 27 classes with volume error < 10%

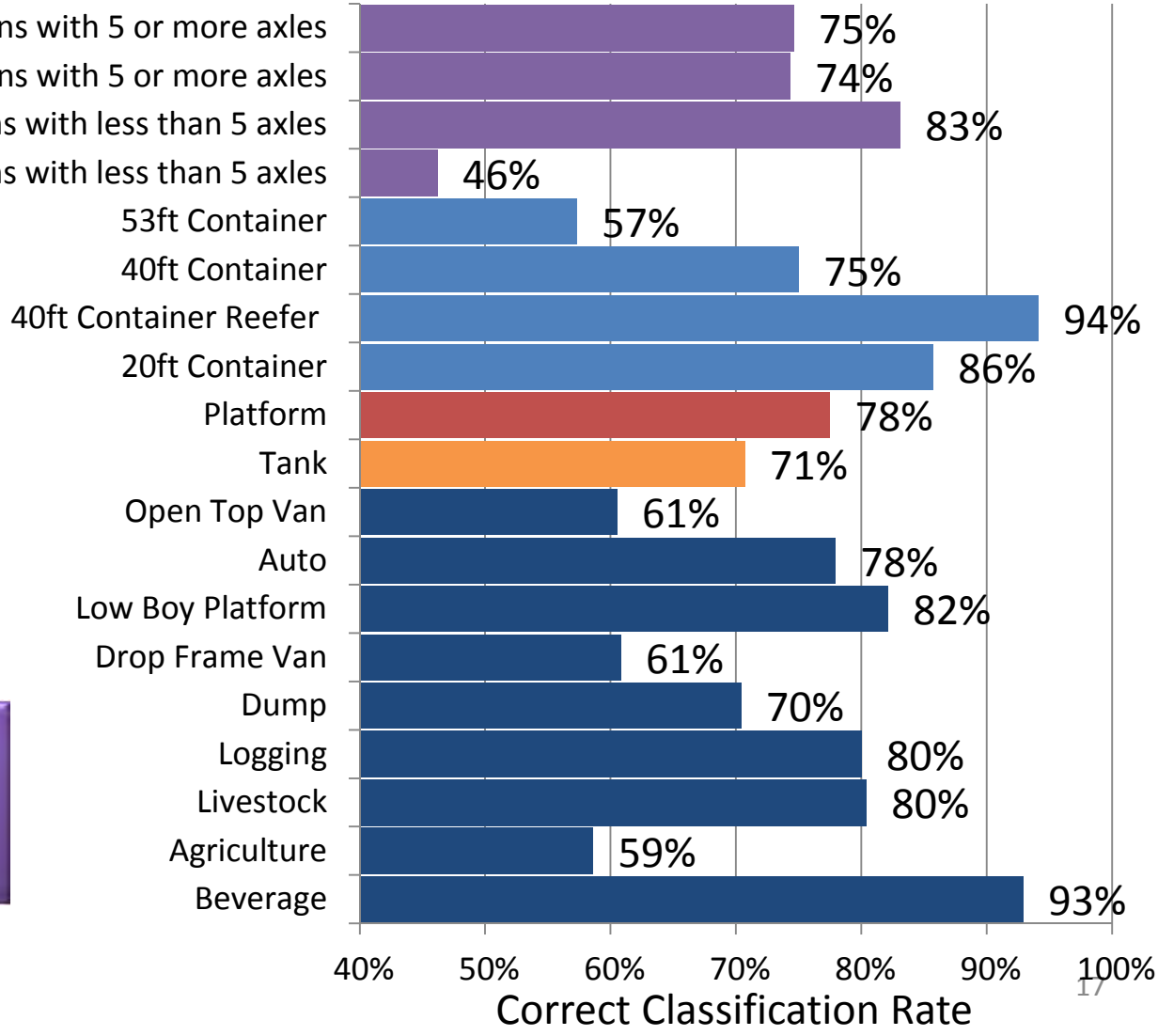
Sub-Model	Classes	Accuracy (%)	Volume Error (%)
Passenger Vehicles	1		
Single Unit Trucks	13	72.3	15.4
Single Unit w/ Trailers	8	94.2	8.2
Single Semi-Trailers	19	74.2	11.3
Multiple Semi-Trailers	7	90.4	7.0

Signature Only Model Results

Semi Tractor Trailers



Overall 74.3% Correct Classification Rate
19 body classes



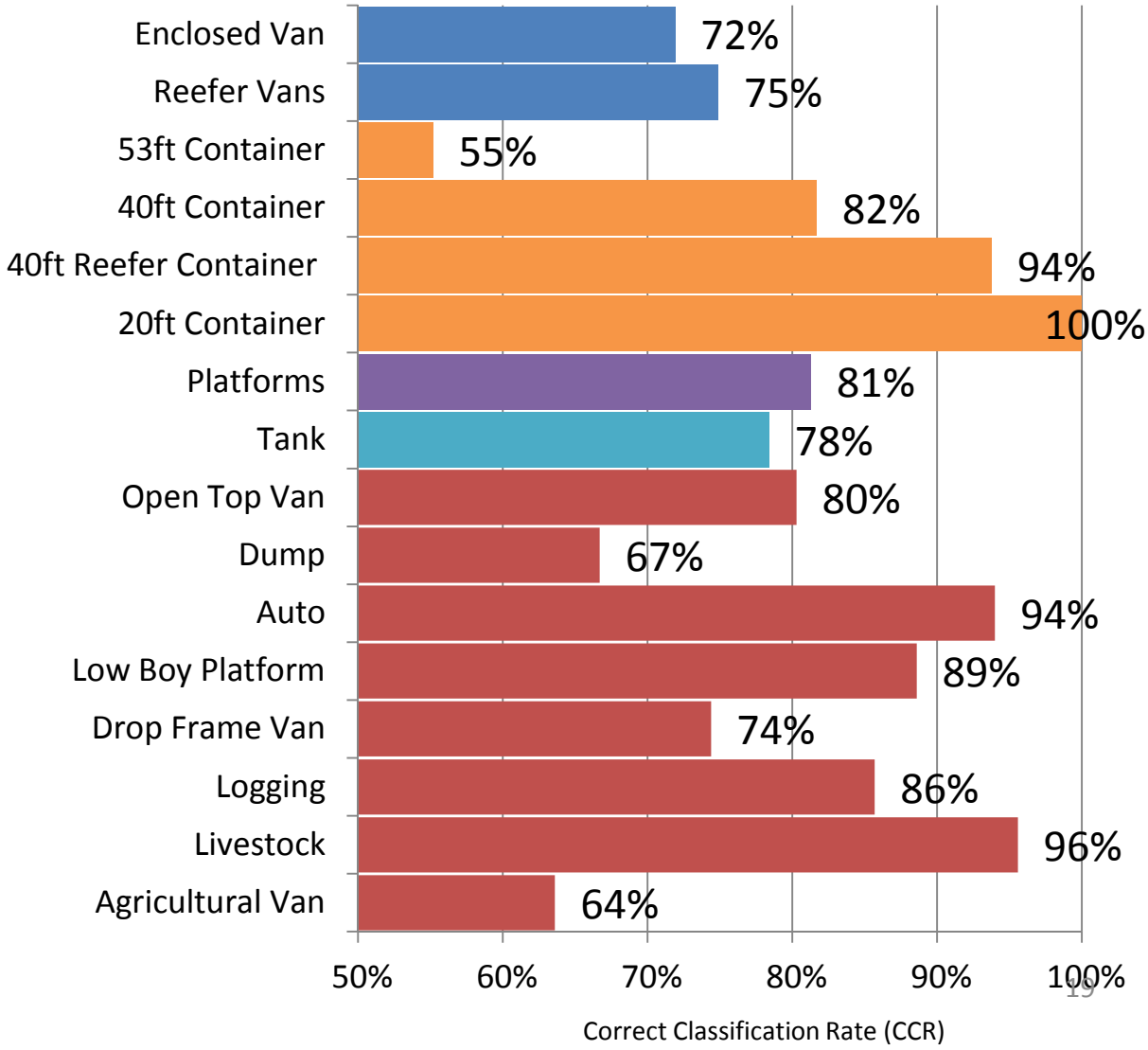
Integrated (WIM + Signature) Model Results

- System of 9 sub-models with 63 body classes
- 52 classes with classification accuracy > 70%
- 37 classes with volume error < 10%

	Model	Classes	Accuracy (%)	Volume Error (%)
	FHWA 4	4	95.2	9.7
	FHWA 5	10	75.3	6.8
	FHWA 6	8	80.5	9.2
	FHWA 7	4	100.0	0.0
	FHWA 8	5	90.9	4.2
	FHWA 9 Semi Tractors	16	75.4	12.2
	FHWA 9 Single Trailers	5	96.7	1.7
	FHWA 10	4	92.3	7.7
	FHWA 11 and 12	7	92.7	8.0

Integrated (WIM + Signature) Model Results

Overall 76% Correct Classification Rate
16 body classes



Hardware Components

Advanced Detector Cards

(Acquire Inductive Signature Data)

Fan-less Field Processing Unit

(Data Processing)

Wireless Modem (Communications to Server)

Types of Site Deployments

WIM-Signature Integration

WIM Site
on SR-99 between Stockton and Sacramento

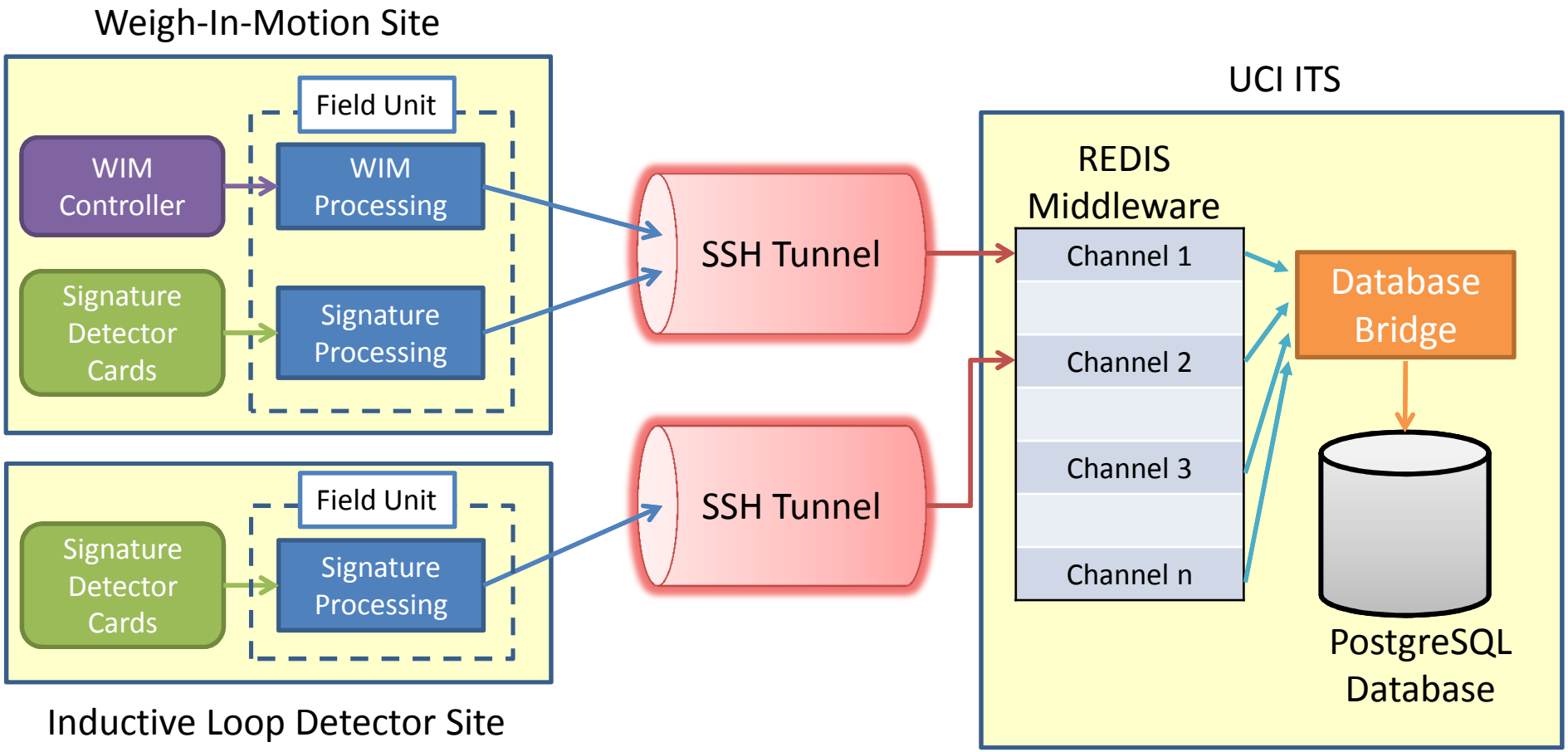
Inductive Signature Only

Ramp Metering ILD Site
on SR-91 in LA

Traffic Monitoring Site
on CA-4 near Stockton

Census AVC Site
on I-15 in Escondido

Data Flow Architecture Overview



LIVE DEMO

1. **Live Signature Transmission**
2. **Walk Through TAMS Web Interface**

Collateral Benefits

Policy Evaluation	• i.e. PierPass: Monitoring truck port activities
Enforcement	• Monitor truck lane violations • Monitor unauthorized travel along restricted routes
Impact Assessment of Non-recurrent Events	• Determine the impacts of port strikes, freeway closures, etc.
Understand Industry Impacts on Traffic, Infrastructure and Emissions	• Ability to analyze temporal and seasonal variations of truck activity by industry
Anonymous Truck Tracking	• Towards improved truck VMT estimates

QUESTIONS

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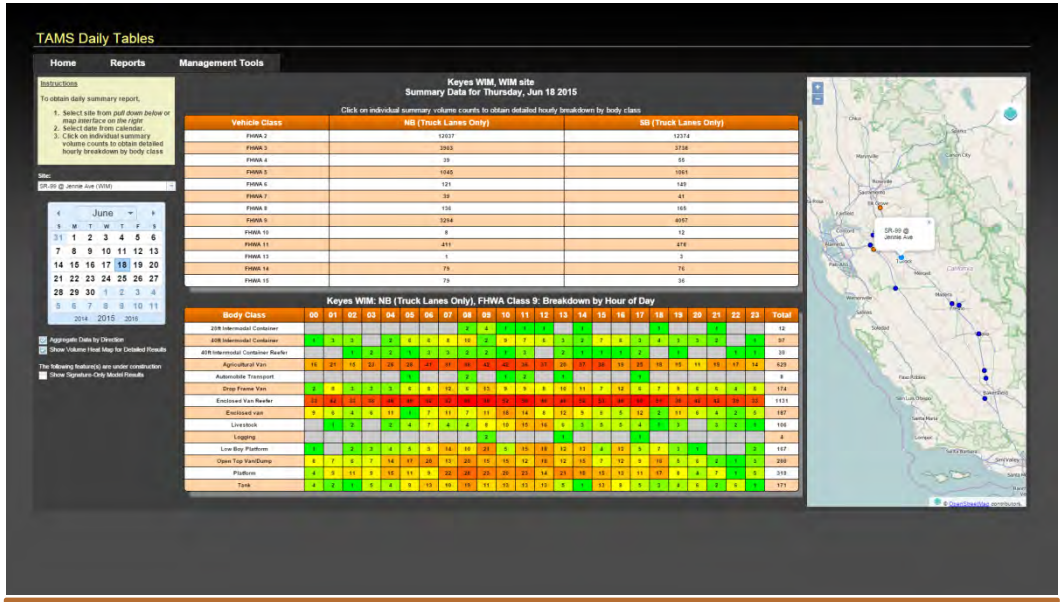


Truck Activity Monitoring System, http://freight.its.uci.edu/tams

Case Study I: SR-205 @ Tracy Corridor Analysis

SR-205 @ Mountain House Pkwy (ILD), ILD site
Summary Data for Thursday, Jun 11 2015

Click on individual summary volume counts to obtain detailed hourly breakdown by body class

Vehicle Category	EB (Truck Lanes Only)	WB (Truck Lanes Only)
Passenger Vehicle	34183	28872
Single Unit Truck	2170	1788
Truck with Single Trailer	519	331
Tractor with Semi-Trailer	2462	1843
Tractor with Multiple Trailers	153	107

Eastbound Direction

SR-205 @ Mountain House Pkwy (ILD): EB (Truck Lanes Only), Tier 2 Class Semi: Breakdown by Hour of Day

Body Class	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
20ft Container			1		2	2	3	7	3	3	7	6	8	7	6	16	12	7	11	7	2		1	2	113
40ft Container	1					3	12	21	7	8	19	11	28	9	8	24	17	23	29	22	3	1	2	1	249
40ft Container Reefer									2	1	1	3	1	2		4	1	1	1	1					18
53ft Container		2			2	1		4	6	2	5	3	9	8	7	5	3	4		3	3		2	1	70
Agriculture						1		5	2		1	1		2	1	1	1	2							17
Auto			1				1	2	2	1		1	3	2	3	2	2	2	1	3	1				27
Beverage						1			1		1	1	1		2			1			1				9
Bulk Waste										1	1	1	1				1						1		6
Container Chassis										1															1
Drop Frame Van				4			1	1	2		2	1	2	2	3	2	3	3	5	2	3	1	1	2	40
Dump						2	2	10	3	3	2	1	3	4	6	2	1		1	1	2	1			44
Enclosed Van (FHWA 8)	1					1	4	2		2	4	4	2	4	6	1	5	5	1	3	2		2		49
Enclosed Van (FHWA 9)	6	4	3	5	7	12	26	53	51	27	48	43	52	37	46	34	42	39	28	34	25	15	24	23	711
Enclosed Van Reefer (FHWA 8)				1				2	3	1		1		2	1	2	1	2	1				1		18
Enclosed Van Reefer (FHWA 9)	3	4	3	7	1	6	17	26	23	14	34	20	27	27	15	30	22	22	7	25	14	13	8	8	376
Livestock												1													1
Logging		1		1	2	1	2		1			2	3	8	4		2	12	4	1	4	4	4	2	58
Low Boy Platform			1	3	1		2	7	6	5	7	6	6	9	8	6	7	4	6	5	2	1	1	1	94
Open Top Van					2	3	9	7	9	7	11	3	6	11	3	9	4	1	10	5	3	1	1	6	111
Platform		2	2	2	4	3	11	21	37	21	29	12	29	34	21	19	16	17	13	5	2	2	1	3	306
Tank	3	3		1	1	2	7	11	15	6	13	6	7	10	8	4	2	7	12	7	9	2	4	4	144

Westbound Direction

SR-205 @ Mountain House Pkwy (ILD): WB (Truck Lanes Only), Tier 2 Class Semi: Breakdown by Hour of Day

Body Class	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
20ft Container	1		1	1		1	2	3	5	3	10	5	5	7	4	3	2	1	3	4	1	1	3		66
40ft Container	2		1	1		2	4	3	9	6	19	15	15	28	16	16	16	16	12	17	10	3	7	3	220
40ft Container Reefer								1	3	1	2	1		4	4	3		2		2	1	1	2	2	29
53ft Container			1	1				4	1	1	3	4	1	3	3	8	3	3	2	2	1	2		2	45
Agriculture						2		1		3	1	2	1			1		1		1			2	1	16
Auto							1	6			2	1					1								11
Beverage						1	1	3	1		1			2							1				10
Bulk Waste					1																				1
Container Chassis																						1			1
Drop Frame Van		1			2		2	4	1	1	1		2	2	1	2	1			3				1	24
Dump	1			1	2	2		1	4	3	3	4	1	6	5	2	3	2	1	3	2	1		1	48
Enclosed Van (FHWA 8)	2			1	1	1	2	1	6	2	7	3	2	3	3	3	2	7	2	1	2	1	4		56
Enclosed Van (FHWA 9)	18	5	3	4	4	1	18	29	30	17	45	21	33	34	39	30	30	24	18	24	26	15	20	23	511
Enclosed Van Reefer (FHWA 8)			1				1				1	1			1	3			3	1					12
Enclosed Van Reefer (FHWA 9)	8	3	3	6	3	2	7	7	11	13	16	5	24	18	16	18	19	27	10	18	13	6	13	9	275
Livestock									1											1					2
Logging				2			3	1	3				1	1	1	1							1		14
Low Boy Platform	2				1	1	3	17	2	6	5	7	11	6	5	6	3	1	1	1		3	2		83
Open Top Van	3		4	3	2	1	1		11	6	6	1	5	14	4	4	3	1	4	6	7	1	2	3	92
Platform	7		3	5	4	5	12	15	20	9	17	13	9	9	18	15	10	6	7	13	3		5	4	209
Tank		4		4	2	1	2	4	9	5	10	8	9	11	8	9	5	7	3	3	4	5	3	2	118

Time of day volumes of Semi-Trailers by Body Configuration
(color scale indicates hourly volume)

- Located between Port of Oakland and Lathrop rail facility
- Dominated by Enclosed Vans (Typical on most major truck routes)
  - Significant volume extends into the night
- Significant volume of 40-foot Intermodal Containers (~250/day)
  - Peak volume during the day
- Low volume of 53-foot domestic Intermodal Containers (~75/day)

Case Study I: I-5 @ Stockton Corridor Analysis

I-5 @ Valley Forge (ILD), ILD site
Summary Data for Wednesday, Jun 17 2015

Click on individual summary volume counts to obtain detailed hourly breakdown by body class

Vehicle Category	NB (Truck Lanes Only)	SB (Truck Lanes Only)
Passenger Vehicle	20030	19111
Single Unit Truck	2063	1567
Truck with Single Trailer	722	552
Tractor with Semi-Trailer	6259	5539
Tractor with Multiple Trailers	617	623

Northbound Direction

I-5 @ Valley Forge (ILD): NB (Truck Lanes Only), Tier 2 Class Semi: Breakdown by Hour of Day

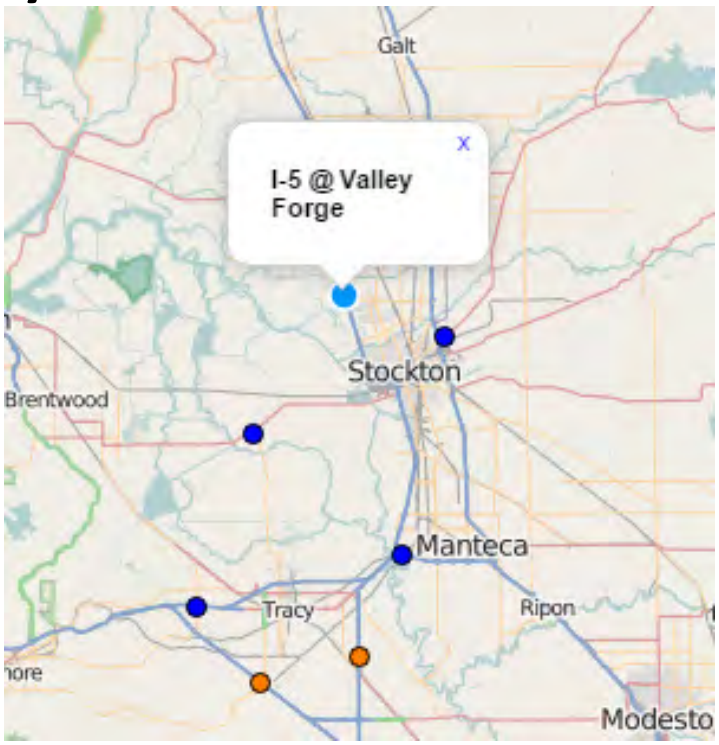
Body Class	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
20ft Container	1	1	2	3	2	4	5	5	5	1	2	3	1	2		3	1	2	4		1	4	1	1	54
40ft Container		1				2	6	2	3	5	1		3	4	3	3	1		3	4	3	2	1		47
40ft Container Reefer		1		1	1	2	2	1	1		1	1	1	3	1	2			2	3	1	1	1		26
53ft Container	3	4	6	6	13	34	20	30	27	11	17	18	22	27	15	15	8	14	12	13	12	9	6	3	345
Agriculture			1			3	3	2	3	1	1	2	1	2					1				1		21
Auto		1	2	1	1	5	4	9	6	3	7	4	5	6	3	2	4	6	3	6	3	2	2		85
Beverage					1	2	1	1	2	1		1		1	2			1	2		2		1		18
Bulk Waste						2	1	1	2	1	3	1			1		1								13
Container Chassis										1	1	1													3
Drop Frame Van	1	3	1	1	1	1	6	4	7	13	11	9	6	4	9	14	6	9	7	6	7	8	1		134
Dump	2	1		2	4	2	7	5	6	2	5	2	4	4	5	5	2	5	5	1	1		2	2	74
Enclosed Van (FHWA 8)	2		2	4	3	4	10	2	1	2	7	7	6	3	4	1	4	4	3	2	1	3	2	2	79
Enclosed Van (FHWA 9)	53	53	41	56	43	108	149	150	143	162	145	132	122	138	110	95	92	85	123	115	98	54	53	47	2386
Enclosed Van Reefer (FHWA 8)		1		1			1	1	1				1			1						2	1		10
Enclosed Van Reefer (FHWA 9)	35	36	42	37	32	47	61	63	67	57	87	98	78	74	64	64	50	50	68	63	60	60	61	38	1412
Livestock	1						1			1		3	6	2					3	1		1		2	23
Logging			1		1	2	1			1	1			2		4	1	3	2	1		3		2	25
Low Boy Platform	3	2	5	7	2	6	21	10	7	21	16	24	10	21	21	12	10	8	4	6	6	1	5	4	231
Open Top Van	2		2	3	9	13	14	20	8	16	13	8	10	11	12	13	7	9	5	5	2	3	3	2	190
Platform	11	8	8	13	22	36	42	37	45	50	40	48	37	44	49	32	29	28	41	15	26	23	20	15	717
Tank	4	6	11	12	12	20	27	24	31	29	31	23	14	13	18	15	17	11	14	5	11	7	7	4	366

Southbound Direction

I-5 @ Valley Forge (ILD): SB (Truck Lanes Only), Tier 2 Class Semi: Breakdown by Hour of Day

Body Class	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
20ft Container		2					4	3	3	4	2	1	5	1		3	4	1	6		2	1			42
40ft Container			1				1	5	2	2	3	2	3	4	2	2	2	4	2	1		1			37
40ft Container Reefer		2			1		2	2	1	1	3	3	1				5	1	2	2	1	1	1	1	30
53ft Container	3	4	4	5	9	3	11	13	16	22	23	27	26	27	35	27	24	23	25	20	11	10	9	5	382
Agriculture		1					2	1	1	1	1	2	3	2		1	1	1	2	1		2		1	23
Auto	3	1		1			2	7	3	2	2	3	6	2	6	5	7	7	4	2	2	2	1	1	69
Beverage										1	1		1				1	1	2	1					8
Bulk Waste					1		1	1	1	2	1			2	2	2	2		1	1	2				16
Container Chassis									1													1			2
Drop Frame Van		2	1			1	4	2	6	8	7	10	6	2	3	6	6	6	10	5	1	3	1	2	92
Dump		1	1	1	1	3	3	1	5	5	7	8	2	7	6	7	6	3	4	4	1	2		1	79
Enclosed Van (FHWA 8)	1	1	1	2	3	2	2	4	1	5	8	4	4	5	3	5	6	1	3	3	3	1	1		69
Enclosed Van (FHWA 9)	52	52	40	39	44	44	77	97	90	129	126	155	142	174	137	140	113	93	96	83	57	58	45	42	2131
Enclosed Van Reefer (FHWA 8)						1				2		1	1		2	1								1	9
Enclosed Van Reefer (FHWA 9)	26	23	16	27	14	30	42	52	52	77	65	89	71	66	65	75	57	54	51	46	36	33	40	35	1182
Livestock					1			1	3				1	2	2			1		1					12
Logging	1					1	1			5	4	2	2	3	4	2	2	1	2		1			1	32
Low Boy Platform	3	4	4	3	1	5	8	7	7	12	14	14	16	17	15	10	9	7	11	5	1	5	3	1	182
Open Top Van		1	3	3	2	2	7	4	9	15	12	8	9	5	16	9	7	5	7	4	7	1	1	2	139
Platform	6	12	13	5	3	21	23	28	31	40	46	38	49	50	48	29	27	35	31	36	15	18	12	11	627
Tank	5	1	1	5	5	11	24	16	16	24	23	22	20	36	22	31	12	20	18	22	17	9	9	5	373

Time of day volumes of Semi-Trailers by Body Configuration
(color scale indicates hourly volume)



- Located north of Stockton
- Dominated by Enclosed Vans (3,000 – 4,000 / day)
  - Significant volume extends into the night
- Insignificant volume of 40-foot Intermodal Containers (<100 / day)
  - Peak volume during the day
- Significant volume of domestic 53-foot Intermodal Containers (~ 350/day)