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EDAR

Emission Detection And Reporting

"Emissions Testing Doesn't have to be so Exhausting"

www.heatremotesensing.com

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The facts about worldwide air pollution

- **According to World Bank, 5.5 million lives lost each year are directly attributable to air pollution**
- **The financial cost of air pollution is $5.5 trillion**

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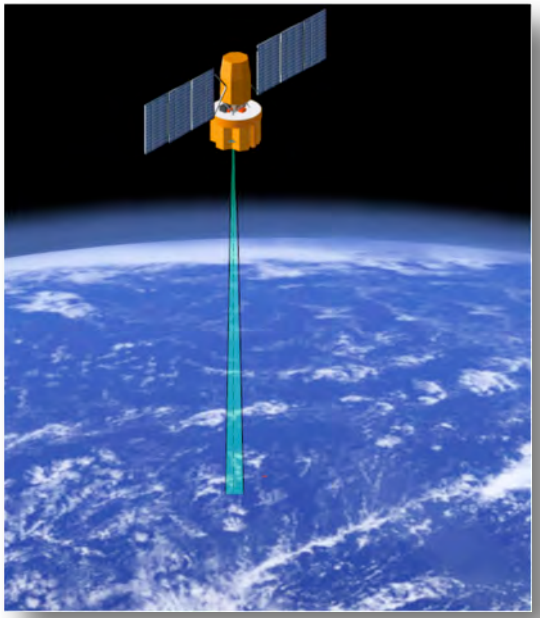
Mexico City's Commitment to Tackling Air Pollution Worldwide

- **Being a city committed to the C40 Climate Leadership Group, Mexico City is taking a lead in a plan to meet the goals set out by the Paris Agreement**

- **Advanced Technologies such as EDAR can positively contribute to reaching air quality targets**

Genesis of EDAR: Active Sensing of CO2 Emissions Nights, Days and Seasons (ASCENDS)

- NASA's Active Sensing of CO2 Emissions over Nights, Days and Season ("ASCENDS") satellite is a laser-based differential absorption LIDAR for CO2 remote sensing.
- Hager worked with NASA will continue to invest in to the development of this satellite platform.
- HEAT EDAR patents derived from modified/engineering maturation from NASA concept.



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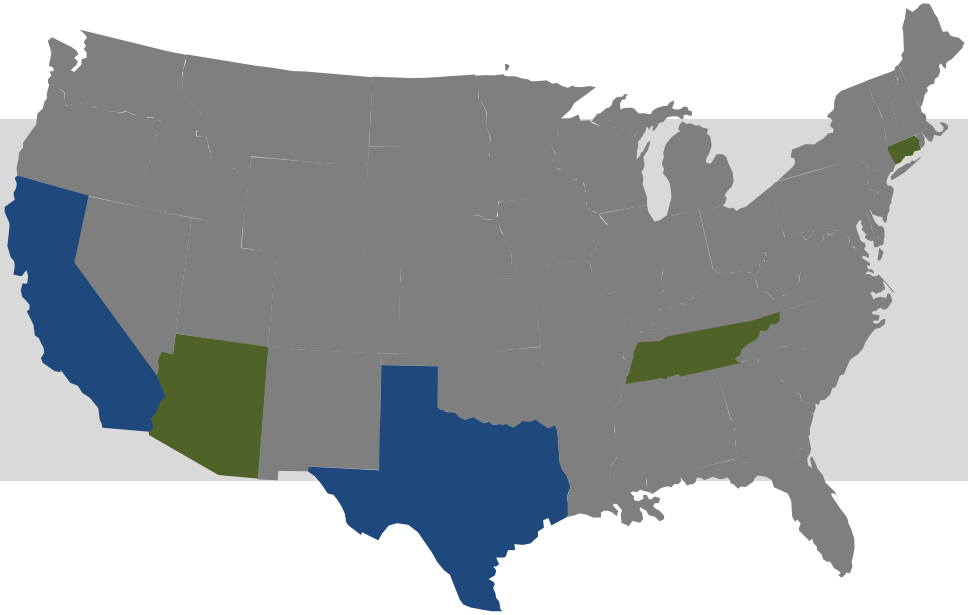
EDAR
"Emission Detection And Reporting"

- Remote Sensing IR Laser based technology, Class 1 eye-safe, FDA approved & IEC 60825 certified
- Geometry- Scans down onto any vehicle's exhaust plume and remotely measures gases coming out of such moving vehicles
- Creates a rolling, real time multi spectral 3-D image of entire exhaust plume
- Measures & Quantifies CO_2, CO, NOx, HC and $PM_{2.5}$
- One footprint for both heavy and light duty vehicles

Relevant Experience and Commendations



Commercially deployed:

- Connecticut
- Tennessee
- Arizona
- London
- Birmingham

Soon to be deployed:

1. California
2. Texas
3. Scotland

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Validation in the US and UK

EDAR has been validated and confirmed by:

Department for Transport

US EPA:

"EDAR is more much accurate than existing Remote Sensing technology"

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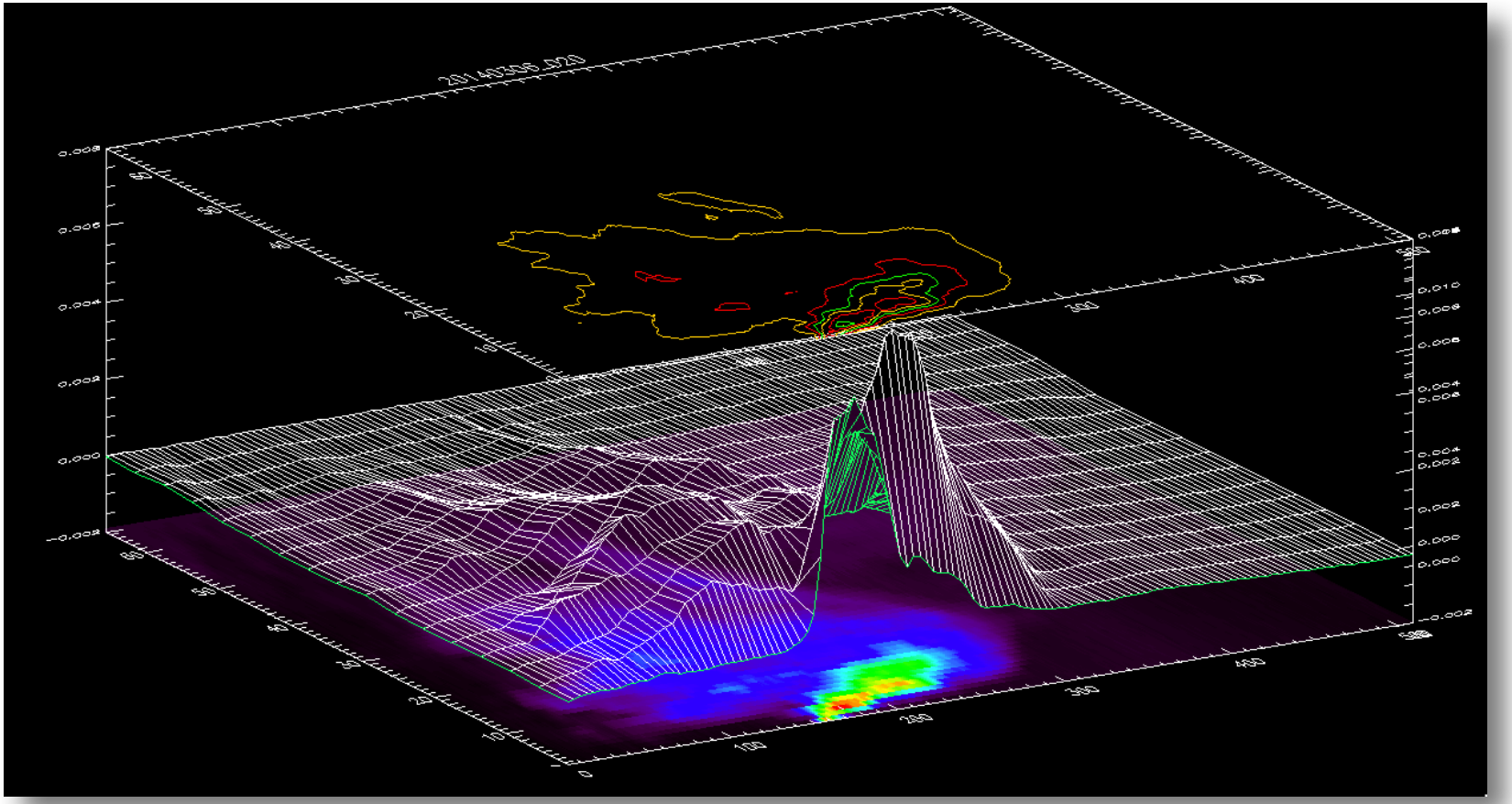
What We See with EDAR: A 3-D multi-spectral images of an entire exhaust plume



EDAR detects 512 Pixels per gas.

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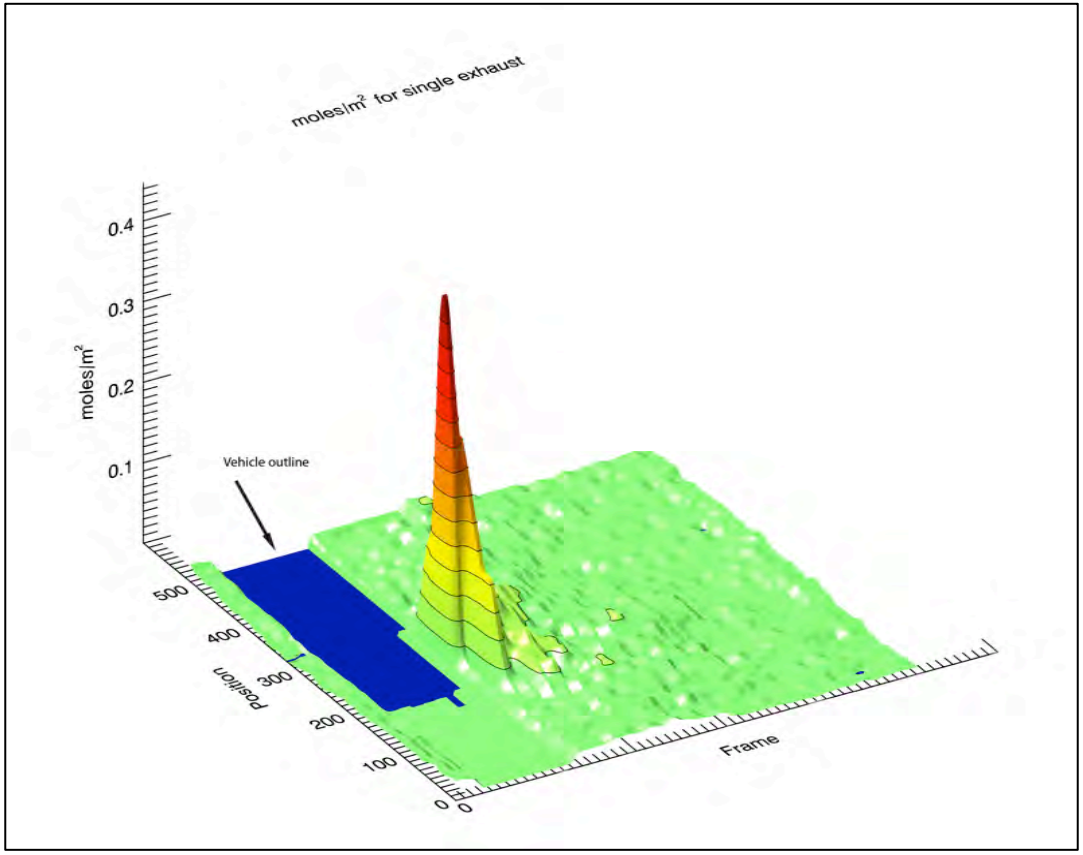
Grams per Mile



EDAR measures instantaneous grams/mile . EDAR sees the entire plume, therefore it can retrieve the amount of grams for each gas per scan. The 3D graph above illustrates how the vacuum behind the vehicle keeps the plume intact before the large eddies behind the vehicle disperses the exhaust plume. EDAR uses the scans with the intact plume to calculate the grams/mile.

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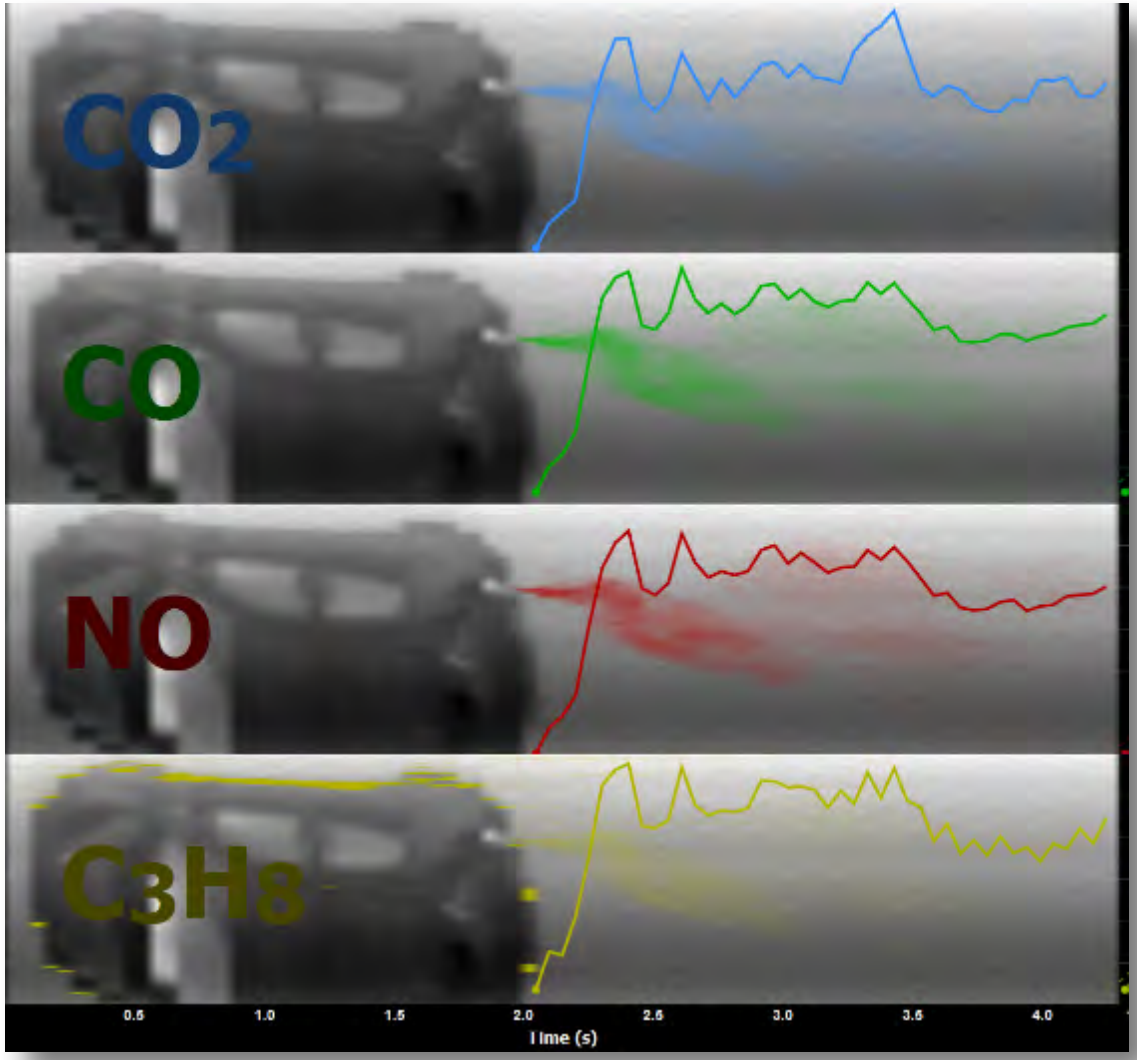
2-Dimensional Display View: Cars

- X-Axis is time
- Y-Axis is distance across road
- In satellite lingo, this is called "Whisk Broom Scanner"



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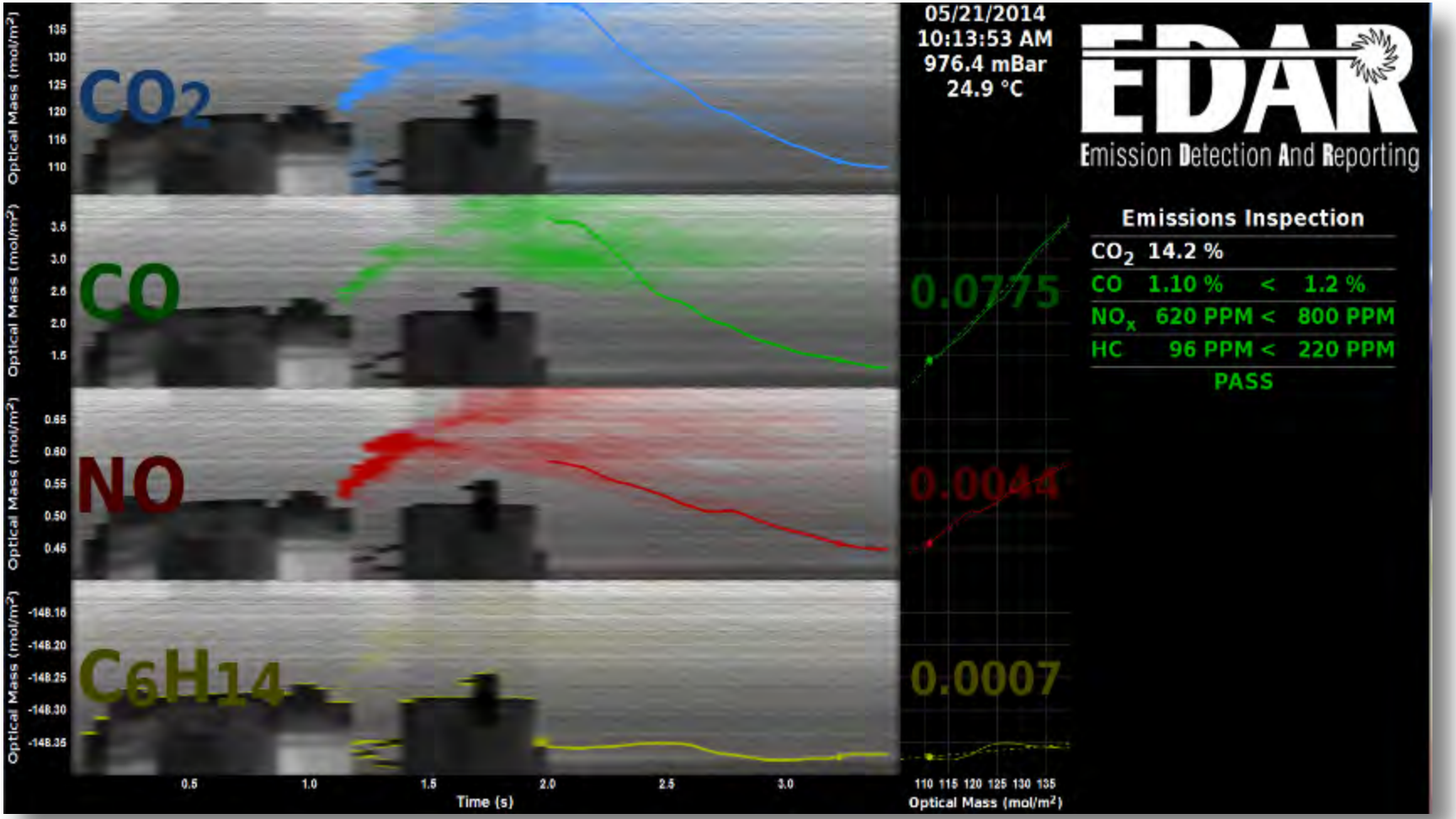
2-Dimensional Display View: Trucks



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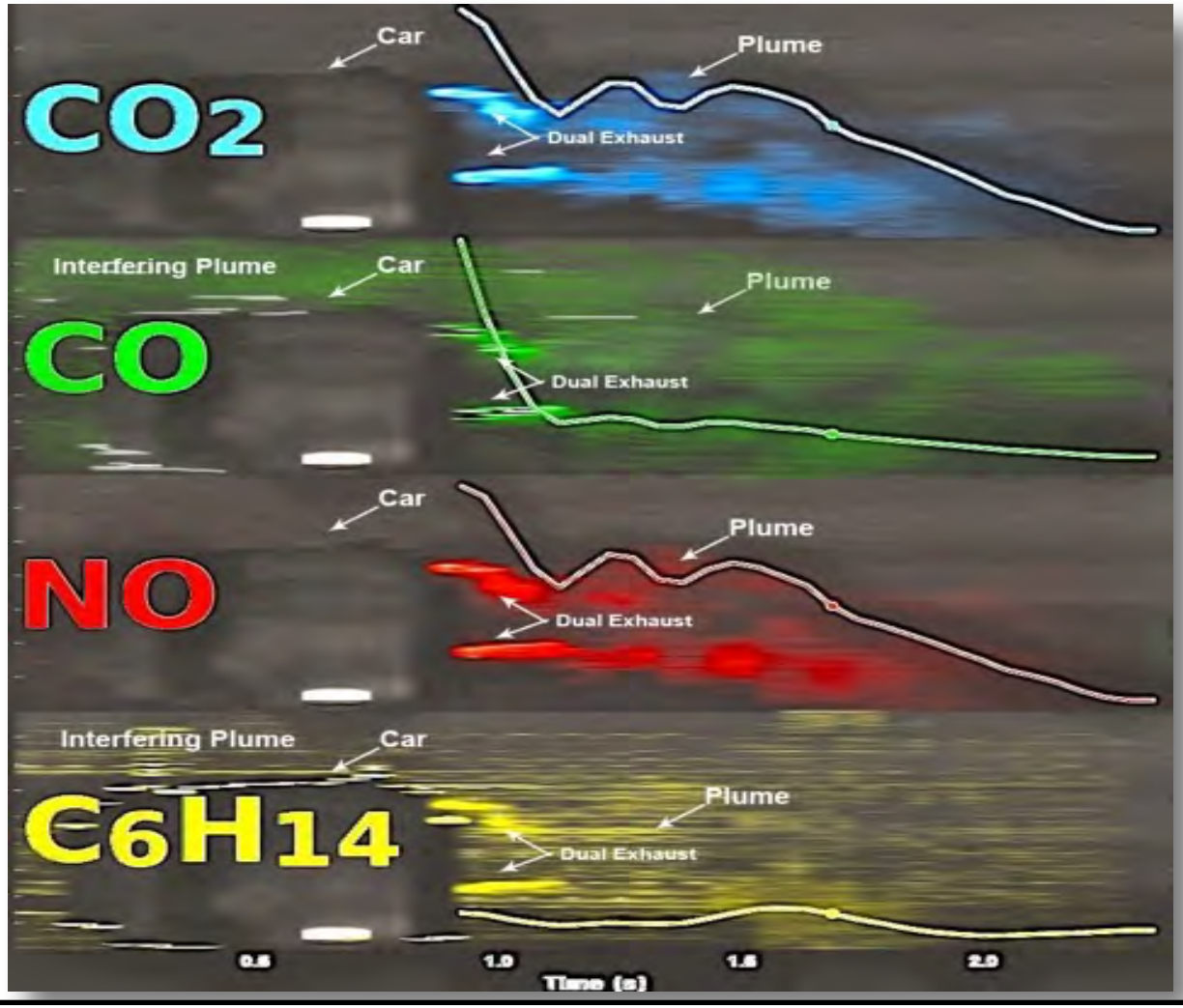
EDAR Images Dual Exhaust & Interfering Plumes



EDAR can detect and image the plume. In the case of a failing vehicle EDAR can be sure that the vehicle is not failing due to an interfering plume. The vehicle shown above did not fail it was drove thru a failing vehicle's plume.

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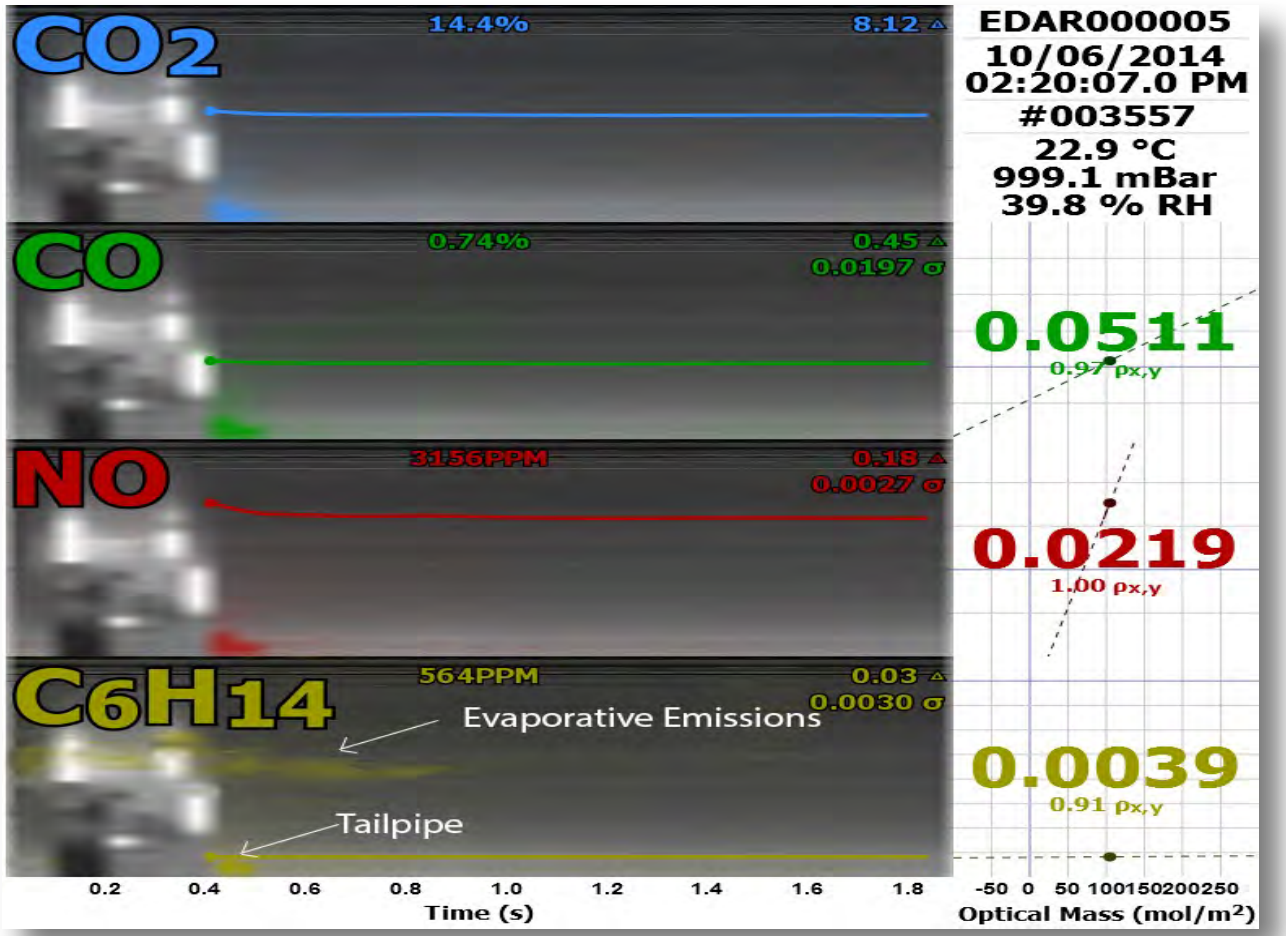
Evaporative Emissions



Evaporative emissions coming out of a moving vehicle captured by EDAR shown by the 2D image of the plume. The tailpipe location is clearly on the left side of the vehicle, yet hydrocarbons are seen towards the middle of the vehicle; therefore, these hydrocarbons must be coming from a source other than the exhaust pipe and are an evaporative emissions leak.

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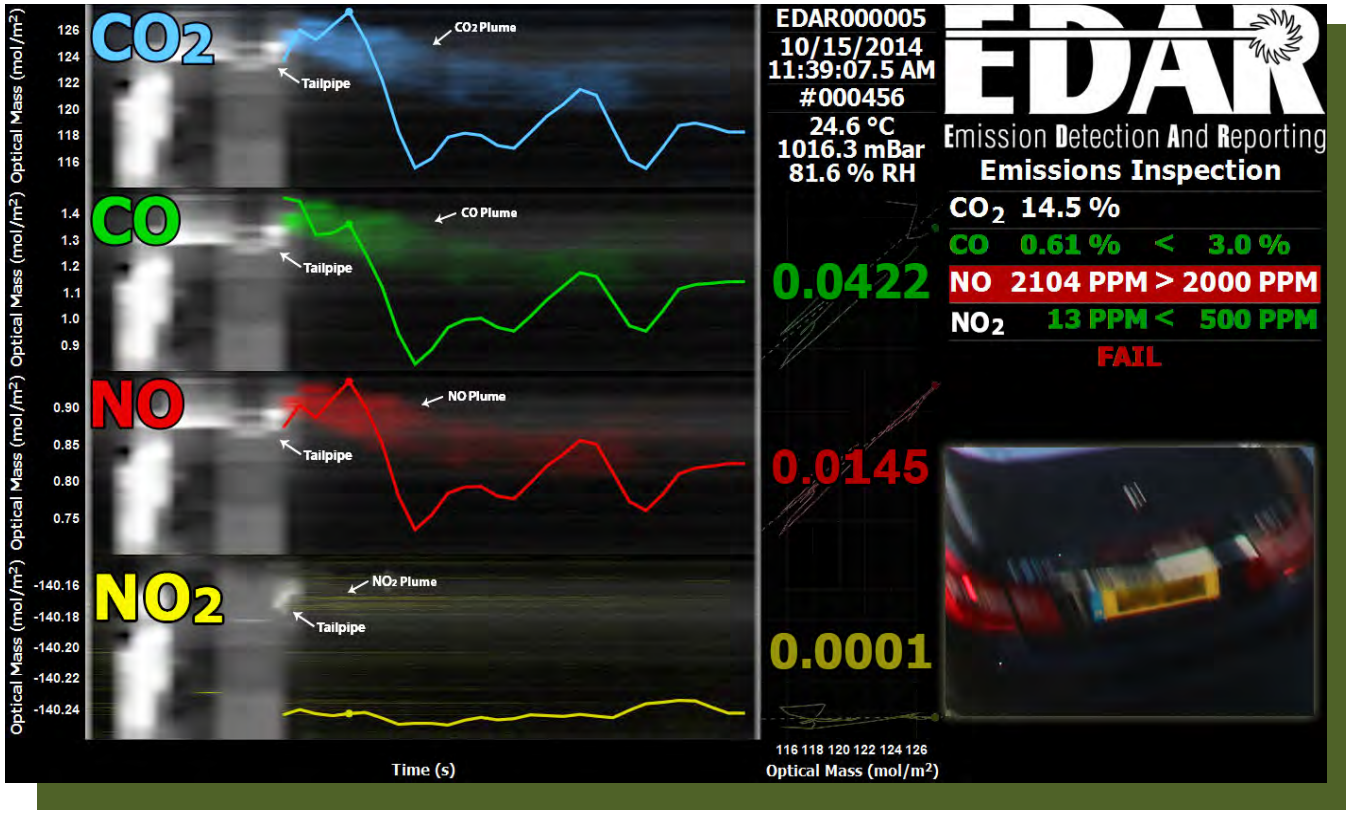
EDAR Output for Each Vehicle



- Entire Plume
- License Plate
- Speed
- Acceleration
- Temperature of Exhaust

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Detailed Comparison of EDAR vs. Existing RSD

EDAR	Existing Technology
Laser-based system	Filter-based system
Differential Absorption LiDAR spectroscopy **(DIAL)** method used: The most accurate way to quantify in remote sensing	**NDIR** Absorption
NO accurate within **± 10ppm**	**NO** Accurate within **± 250ppm**
CO accurate within **± 50ppm**	**CO** Accurate within **± 2500ppm**
HC accurate within **± 50ppm**	**HC** Accurate within **± 250ppm**
Able to see **entire plume no matter where the tailpipe is located** because EDAR sits above the roadway	Can **only read a slice of the plume** from tailpipes **at limited locations** on the vehicle because the device is set up at ground level
EDAR has a valid hit rate of **84% on multi-lane and over 95% on single lane**	Detection **rate much lower** due to the height of the beam and the less sensitivity of their system
EDAR can **detect the temperature of the exhaust** determining if the car is warmed up, therefore eliminating false failures from cold starts	Does **not measure** exhaust temperature on automobiles
EDAR's measurement is **NOT** affected by anything except rain (Remote sensing technologies, including satellite, do not work in rain because liquid absorbs the infrared signal)	RSD System is **affected** by rain, fog, humidity, temperature, dust, and splashing of dirt and water onto the optics after a rain event
EDAR **can detect** interfering plumes because it can measure background **before, during, after, and off to the side**	Cannot see interfering plumes after the beginning of the vehicle because they can only measure background before the car passes
EDAR is the only device that can be deployed on **multi-lane roads,** which can ensure capture of a variety of vehicles in their natural environment	Restricted to **single-lane** roads due to setup and mirrors across the road which requires safety cones and can hinder natural driving habits

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Actual On Road Footprint: EDAR V.S. the Competition

EDAR

Competitor

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Colorado Evaluation

CDPHE RSD audit truck has the needed gas bottles and gas release controls as shown in Figure 1. The audit truck is equipped with a simulated tailpipe and gas release controls to allow release of bottle gas to simulate an exhaust plume while the vehicle is in motion. The truck is also equipped with a flow meter that can be used to set the flow rate of gas releases. The audit truck engine's exhaust is re-routed 10 feet to the driver's side in Figure 2.

Figure 1. RSD Audit Truck Gas Bottle Stowage and Piping

Figure 2. RSD Audit Truck with Engine Exhaust 10-foot Side Extension

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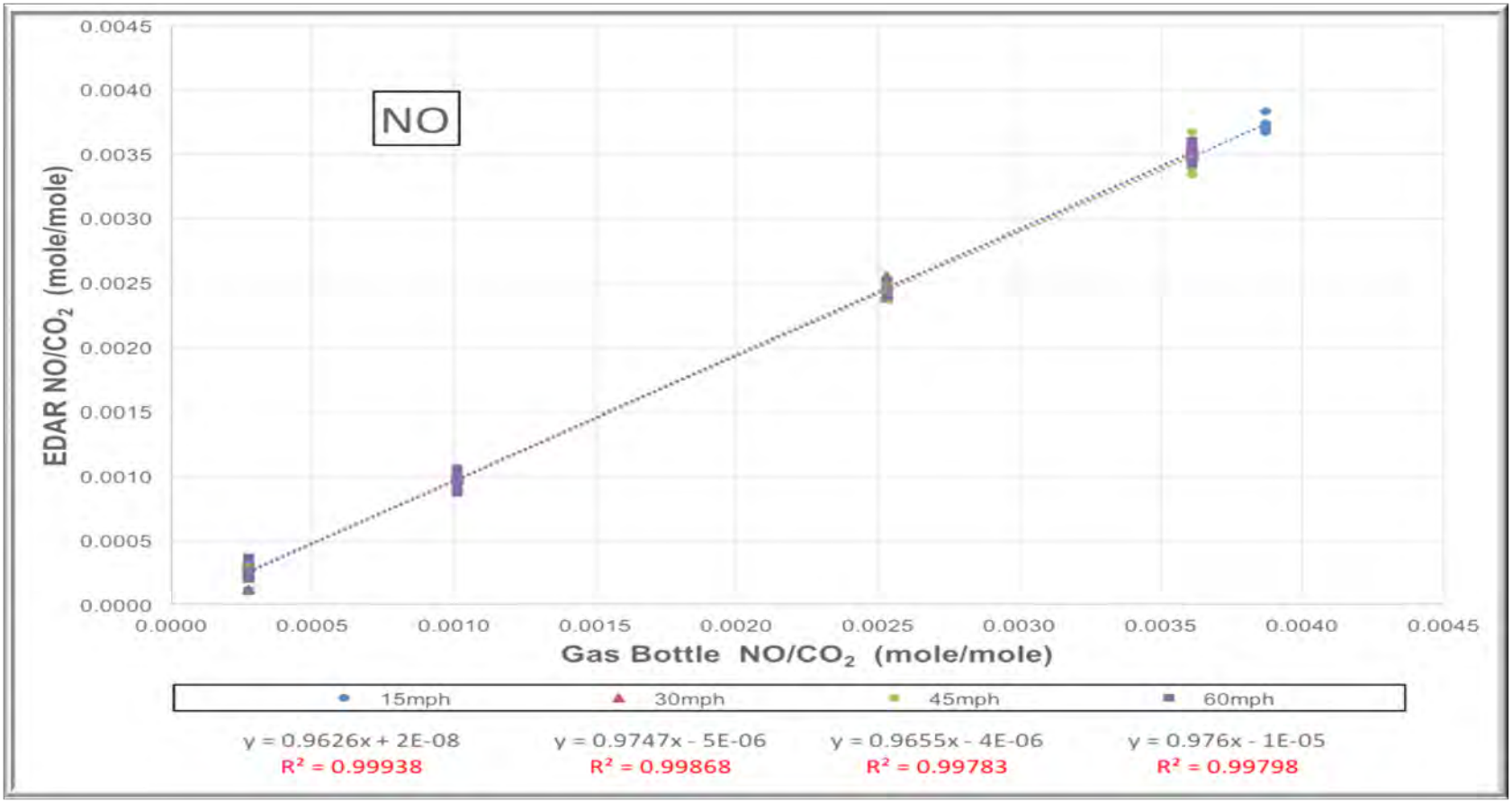
Colorado Evaluation

Comparison of EDAR-Measured and Bottle-Labeled NO at 4 Vehicle Speeds



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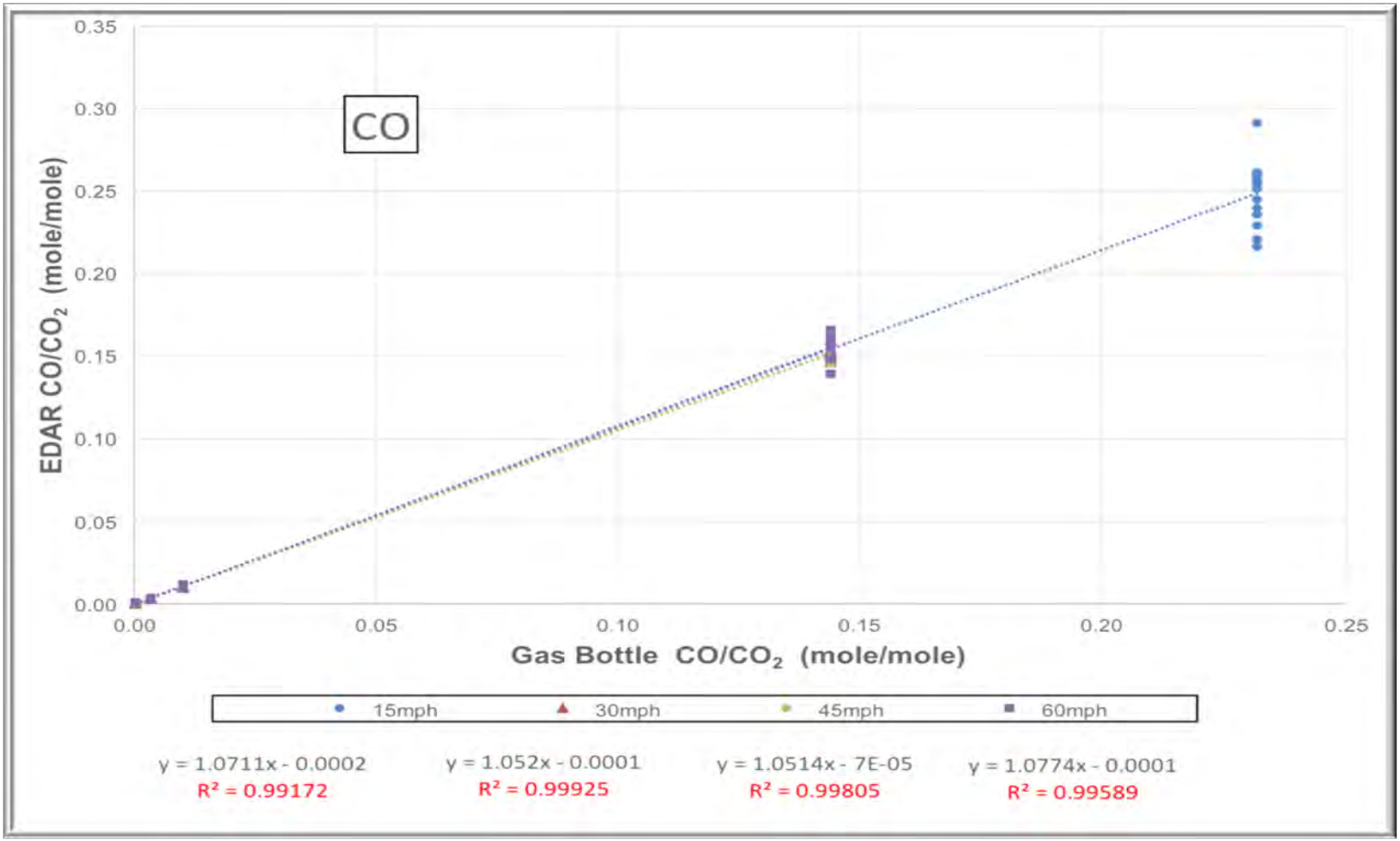
Colorado Evaluation

Comparison of EDAR-Measured and Bottle-Labeled CO at 4 Vehicle Speeds



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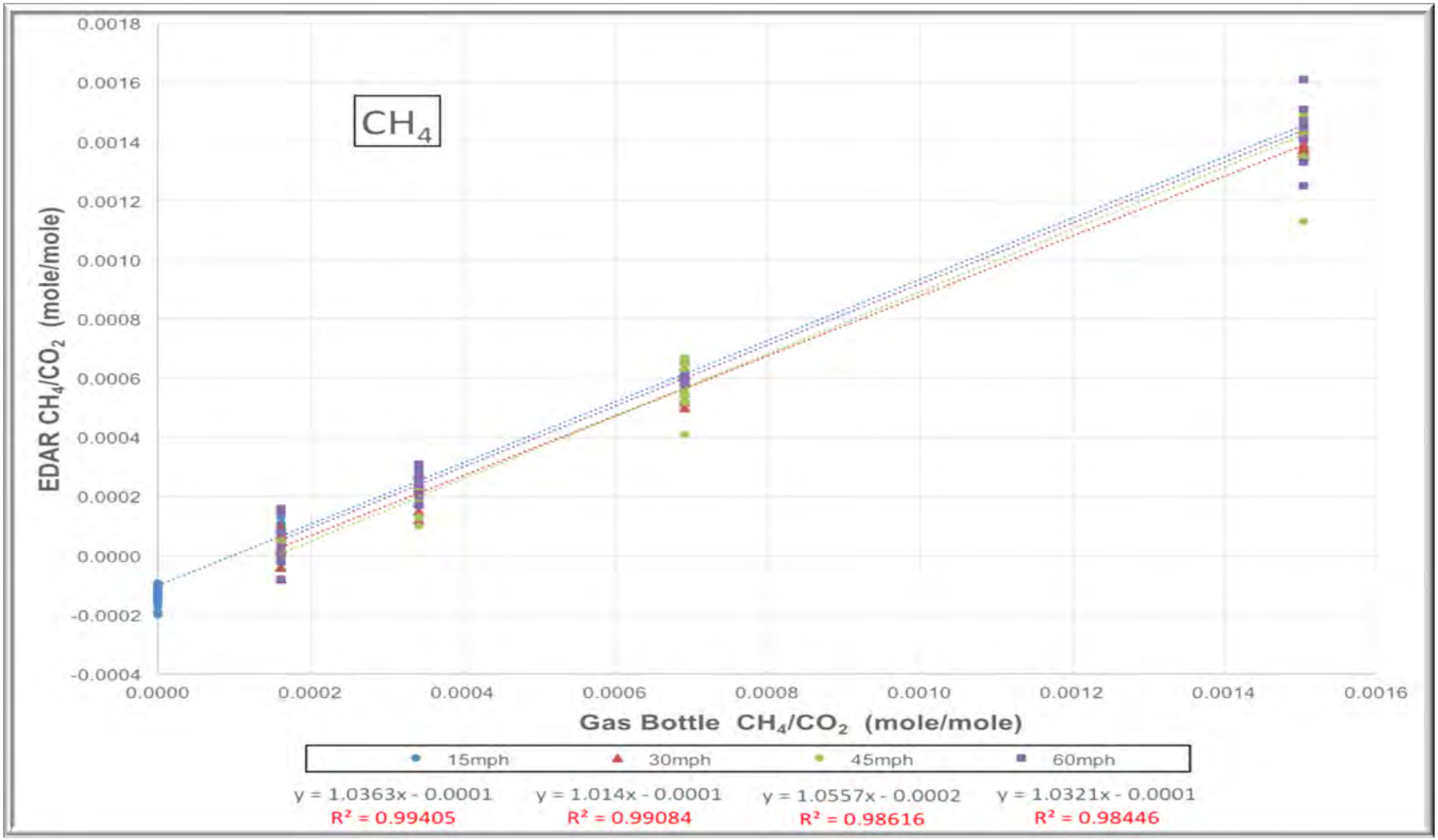
Colorado Evaluation

Comparison of EDAR-Measured and Bottle-Labeled CH4 at 4 Vehicle Speeds



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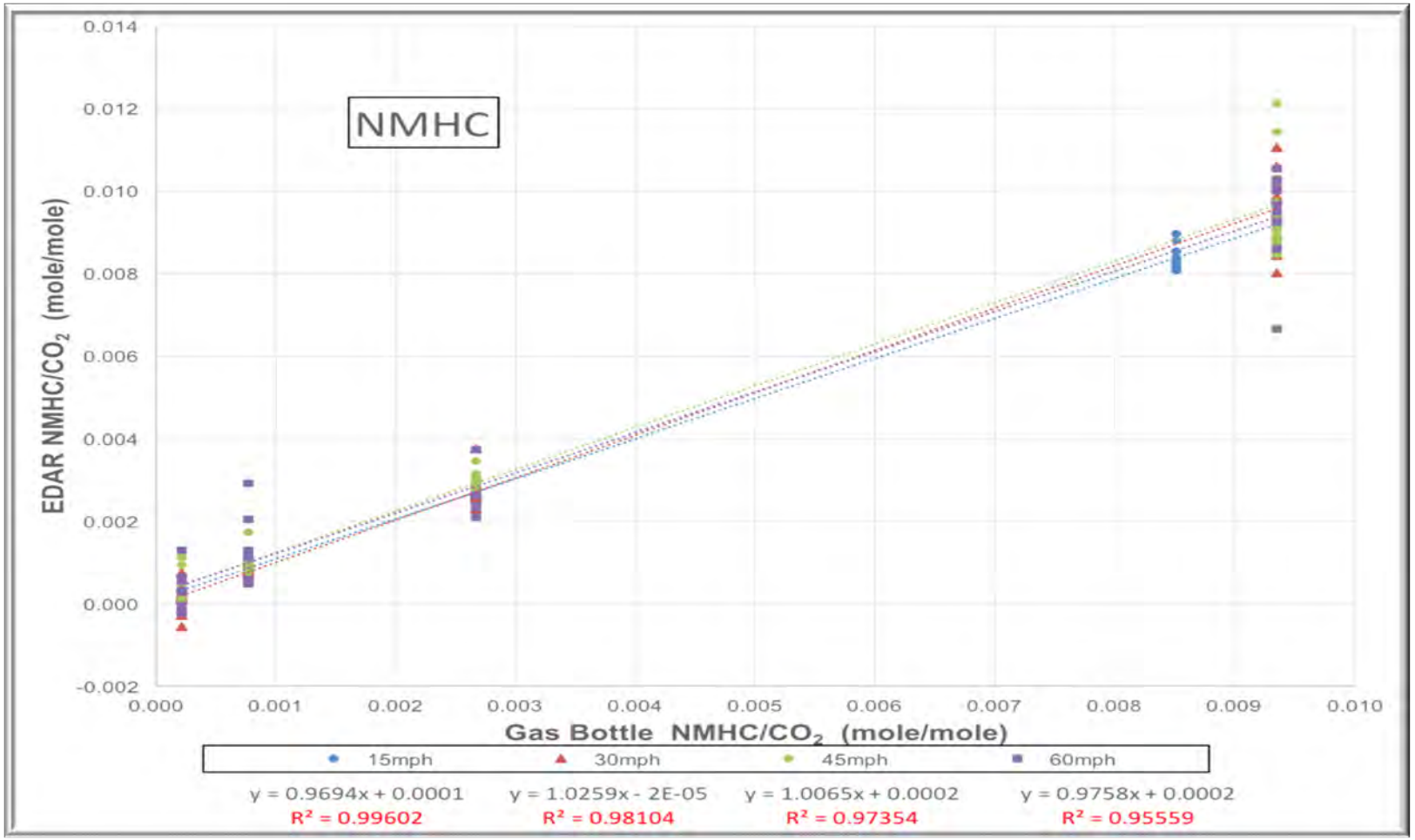
Colorado Evaluation

Comparison of EDAR-Measured and Bottle-Labeled NMHC at 4 Vehicle Speeds



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Colorado Evaluation

Mean ± 1 Standard Deviation
for Bottle CO2 * EDAR molePollutant/moleCO2
(At least 8 replicates at each condition except for Blend B at 60 mph which had 5 replicates)

Bottle Label	Bottle Value NO (ppm)	NO @ 15mph (ppm)	NO @ 30mph (ppm)	NO @ 45mph (ppm)	NO @ 60mph (ppm)
D	41	41 ± 3	39 ± 10	37 ± 4	38 ± 11
C	151	145 ± 4	146 ± 4	149 ± 6	146 ± 10
B	377	360 ± 2	365 ± 8	362 ± 7	365 ± 7
Q	500	480 ± 5			
A	502	488 ± 5	489 ± 5	484 ± 13	489 ± 8

Bottle Label	Bottle Value CO (ppm)	CO @ 15mph (ppm)	CO @ 30mph (ppm)	CO @ 45mph (ppm)	CO @ 60mph (ppm)
D	30	59 ± 57	52 ± 26	60 ± 28	63 ± 33
D*	30	32 ± 4	37 ± 8	36 ± 7	48 ± 6
B	494	509 ± 15	513 ± 16	497 ± 33	477 ± 64
C	1500	1532 ± 27	1507 ± 28	1536 ± 43	1554 ± 124
A	20000	21395 ± 575	21027 ± 507	21021 ± 747	21530 ± 1192
Q	30000	32116 ± 2517			

* After discarding suspected outliers: 2/10 @ 15mph, 3/11 @30mph, 5/10 @ 45mph, 2/9 @ 60mph.

Bottle Label	Bottle Value CH4 (ppm)	CH4 @ 15mph (ppmC)	CH4 @ 30mph (ppmC)	CH4 @ 45mph (ppmC)	CH4 @ 60mph (ppmC)
Q	0	-18 ± 4			
D	24	13 ± 5	2 ± 9	3 ± 3	8 ± 13
C	51	42 ± 4	32 ± 8	27 ± 7	36 ± 7
B	103	96 ± 5	87 ± 8	85 ± 11	89 ± 2
A	209	200 ± 6	192 ± 5	198 ± 14	200 ± 14

Bottle Label	Bottle Value Equivalent C6H14 (ppmC6)	NMHC @ 15mph (ppmC6)	NMHC @ 30mph (ppmC6)	NMHC @ 45mph (ppmC6)	NMHC @ 60mph (ppmC6)
D	16	14 ± 17	30 ± 44	75 ± 46	112 ± 65
C	58	67 ± 18	80 ± 34	132 ± 45	158 ± 52
B	199	214 ± 8	224 ± 61	265 ± 63	372 ± 75
Q	550	540 ± 17			
A	650	637 ± 18	653 ± 37	699 ± 50	712 ± 64

How can EDAR help governments?

EDAR can give governments the ability to:

- Characterize
- Monitor Real World Driving Emissions
- Police the Fleet
- Ensure Car Manufacturers are in Compliance with EU Standards
- Improve and Control Low Emission Zones

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How EDAR Can be Utilized in LEZ and Congestion Zones

Identify and Regulate high polluting vehicles

Entrance fee based on set parameters such as:

- Vehicle Classification
- Vehicle Model
- Pollution Levels

Create a **high-tech** and the world's most **advanced** LEZ that will **improve air quality** in Mexico City

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Conclusion

EDAR: A Continuous Emission Detection Solution
Less Cost, Less Hassle & Less Pollution

- EDAR has been validated in various environments in both on road and in laboratory settings, which translated in conclusive accuracy and validity results.
- EDAR is an **Active** Remote Sensing device
- EDAR is an unmanned system that does not require any calibration.
- EDAR can virtually read any molecule in a gaseous state.
- EDAR is easily deployable in either a permanent or temporary setting therefore preventing the hassle of an obtrusive device
- Operates 24/7 collecting real-time data for multiple applications.