

Three Decades of Real World Driving Emissions (Remote Sensing)

Scottish Air Quality Database and Website Annual Seminar

February 12, 2019

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Opus Group

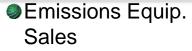
(https://www.opus.global/about/)

Vehicle Inspection

Emissions & Safety Inspection; Sales and Services

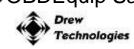
Intelligent Vehicle Support

Advanced Vehicle
 Diagnostics and
 Reprogramming Sales &
 Services











Integrated Emissions & Safety Inspection Services







Remote Sensing Sales & Services





Advanced Vehicle Reprogramming



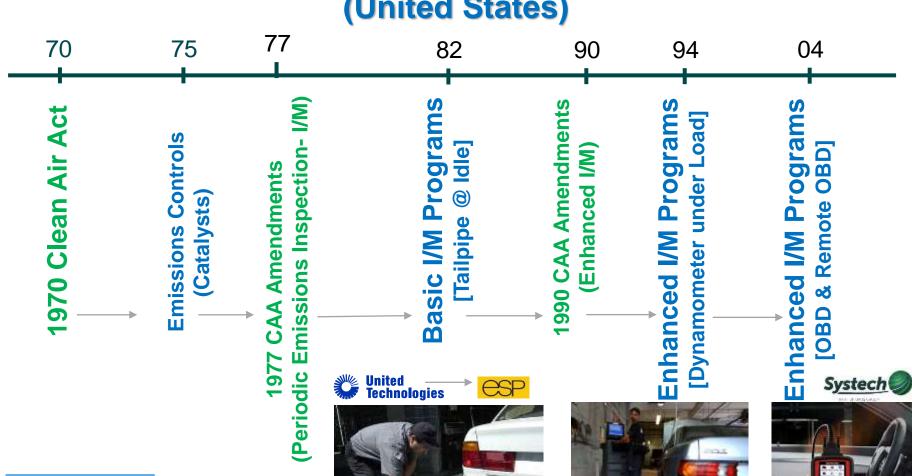
Advanced VehicleDiagnostics





Inspection / Maintenance Legislation

(United States)



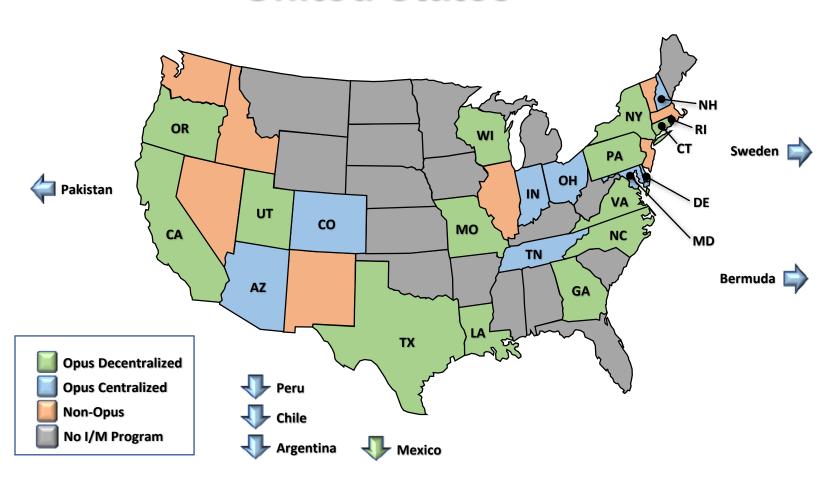
Legislation **Outcome**



Envir@test



Largest Inspection Company in the United States





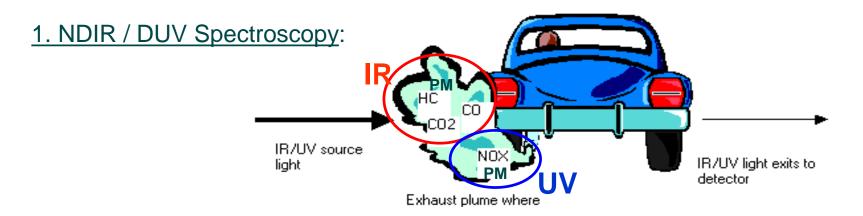
Remote Sensing of Real World Driving Emissions

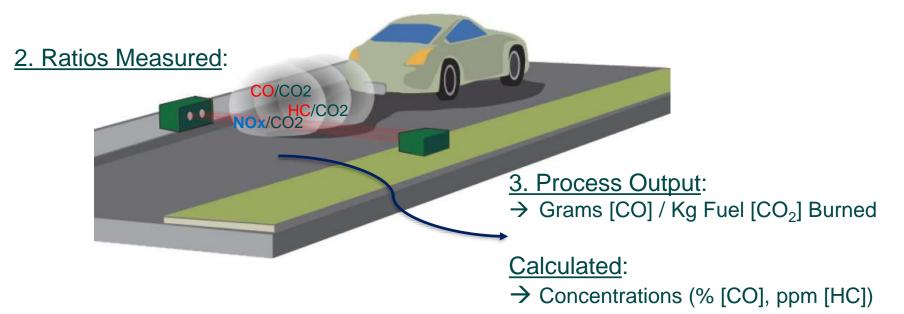
Presentation Outline

- 1. Introduction to Opus Remote Sensing Device (RSD) Technology
- 2. Opus RSD Product and Application Development ('88 Early '00s)
 - What we learned that shaped our technology and applications.
- 3. Opus Remote Sensing Program US (Since Early '00s)
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- 5. Three Decades of USA Remote Sensing Data
 - How far have we come reducing motor vehicle emissions?

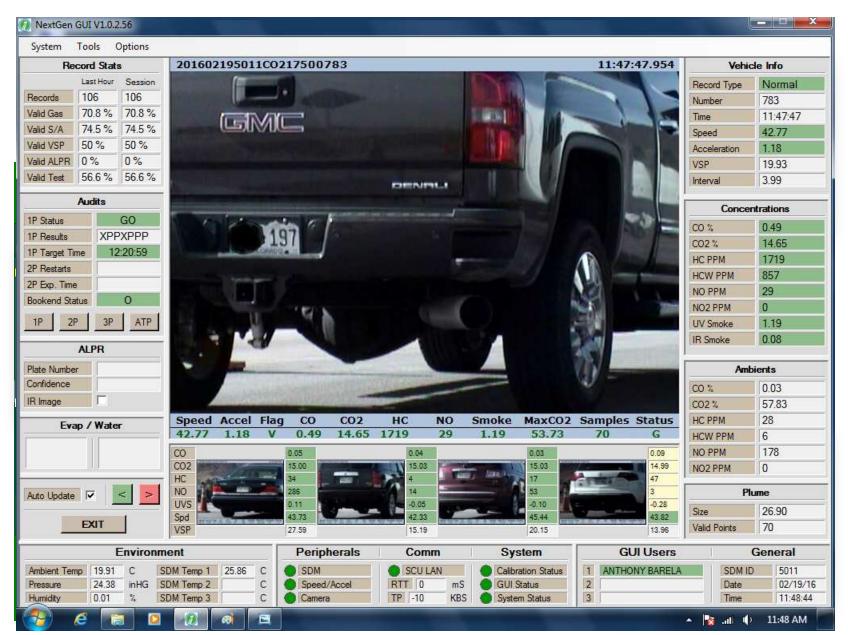


Measurement Principle Spectroscopy (Light Absorption)











Mobile Attended Operation

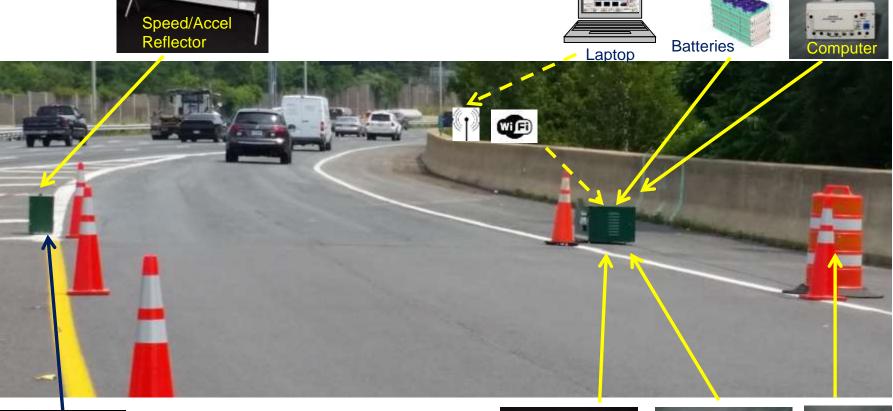
Opus RSD1000 thru RSD4000





Mobile Semi-Unattended Operation

Opus RSD5000













Typical RSD5000 Deployment

(Virginia & Colorado Screening Program)









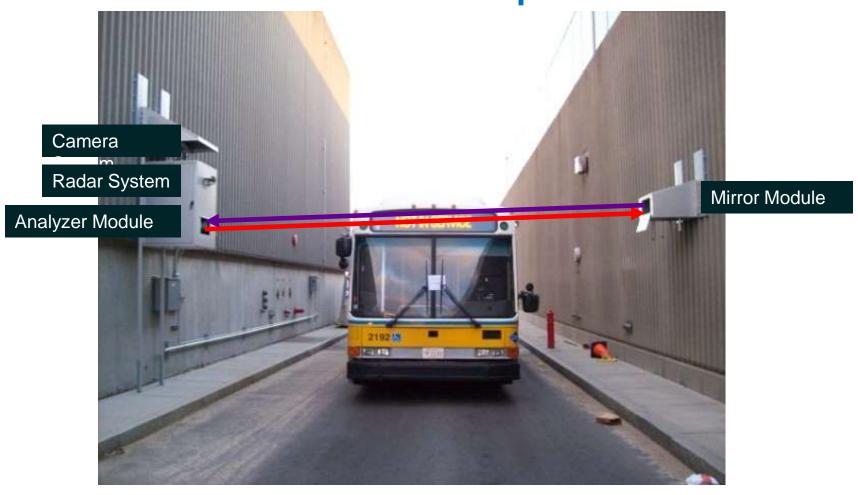
- Three systems per Van & Operator in Virginia and Colorado.
- Simple deployment (20 minutes); Quickly moved to "sweet-spot."
- Stand-alone components (no infrastructure required) off traffic lane.





Fixed Unattended Operation

Boston Bus Depot

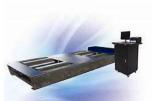




Remote Sensing of Real World Driving Emissions

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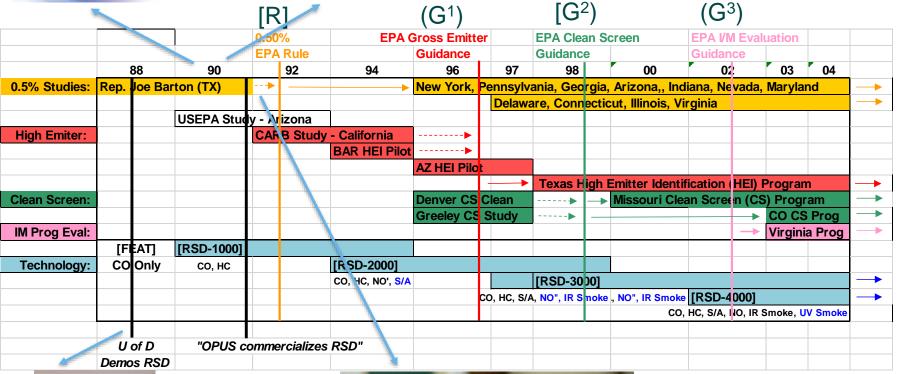
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ent ('88 – Early '00s)



act/Concept Der RS Applications and Guidances



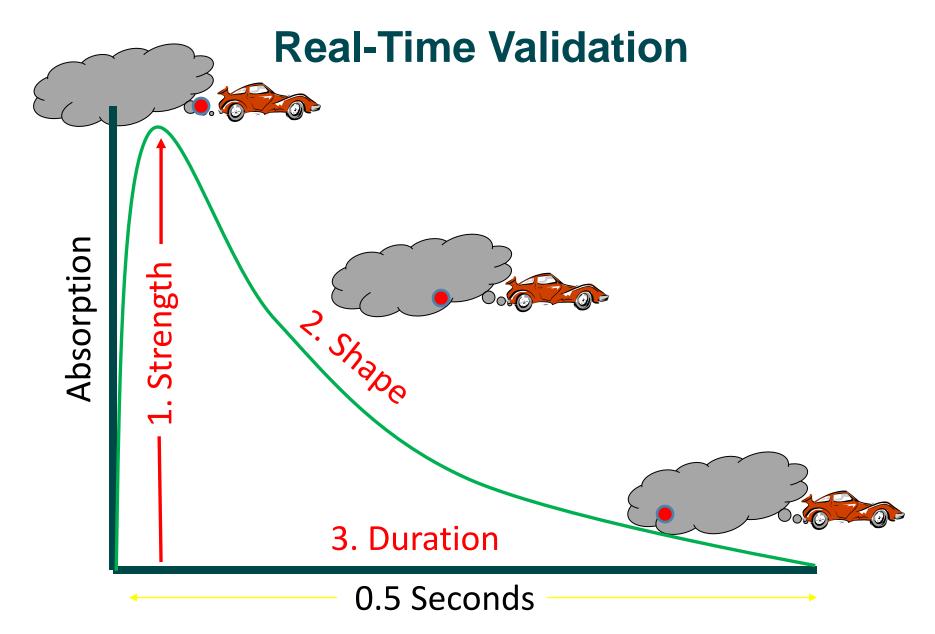
al Rule [R] Documents (G)



What Did We Learn?

- Not to accept every measurement (only high quality)
 - It's a dynamic environment (not a test lane)
 - Temp, pressure, wind, turbulence, interference
 - Validate measurement in real-time
 - Measurement strength, shape, duration
 - Audit RSDs regularly
 - To assess and defend performance
- Not to apply every measurement (only representative)
 - Screen measurements for each application
 - VSP, Cold Start, Vehicle History (LEI, HEI), Sanity Check
- Stay mobile, stay flexible
 - Change sites frequently (max coverage)
 - Change deployment at site (max validity)





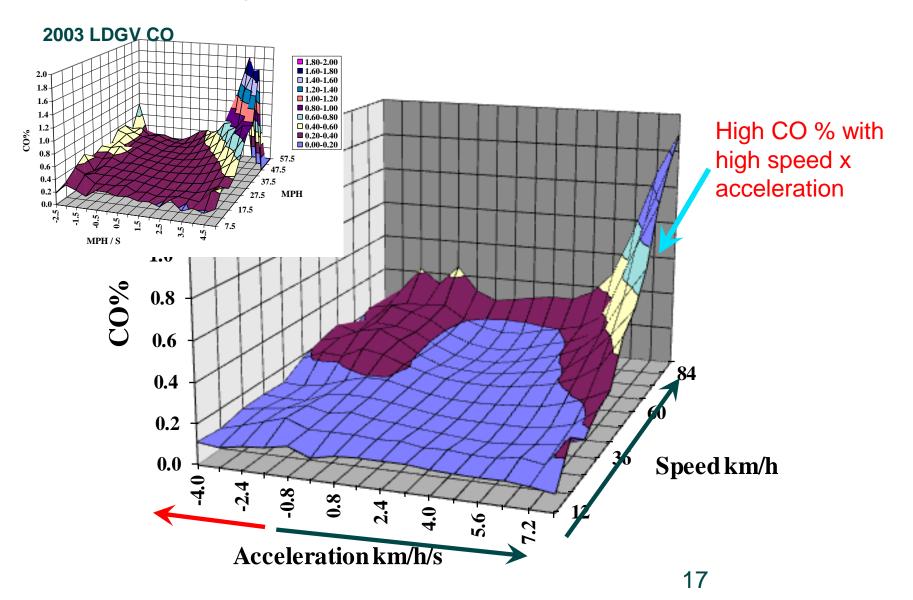


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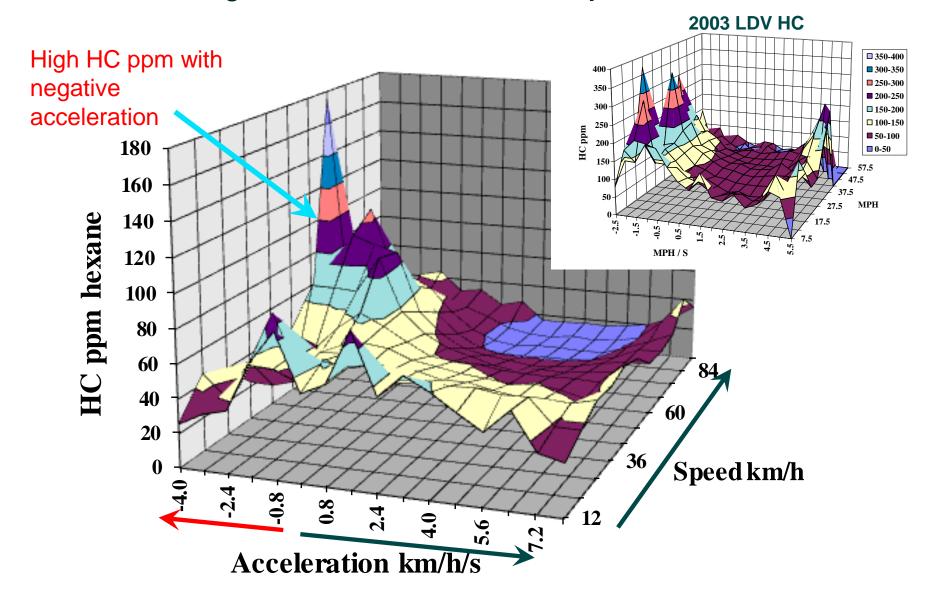


USA 2013 Light Gasoline Vehicle CO vs Speed and Acceleration



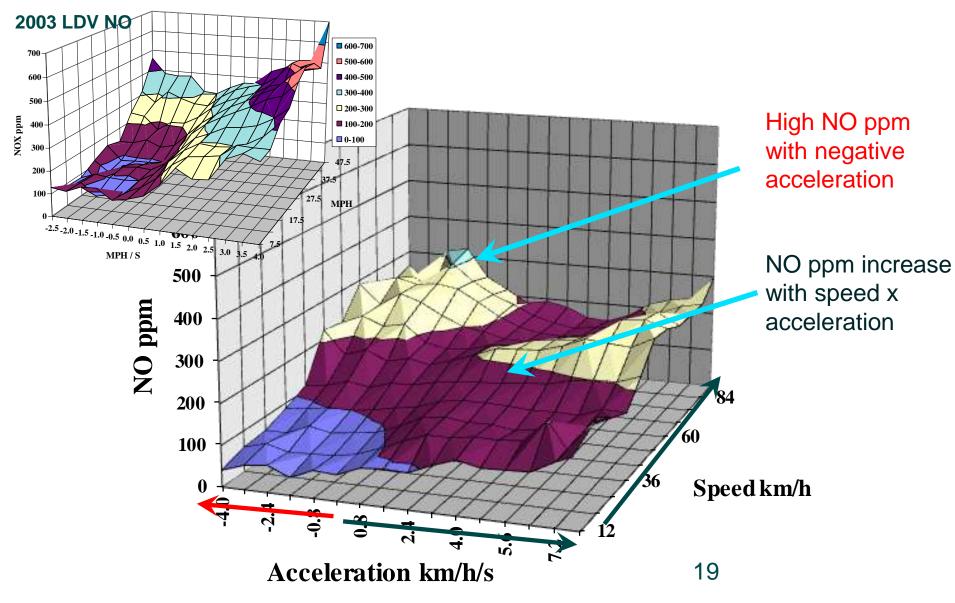


USA 2013 Light Gasoline Vehicle HC vs Speed and Acceleration





USA 2013 Light Gasoline Vehicle NO vs Speed and Acceleration



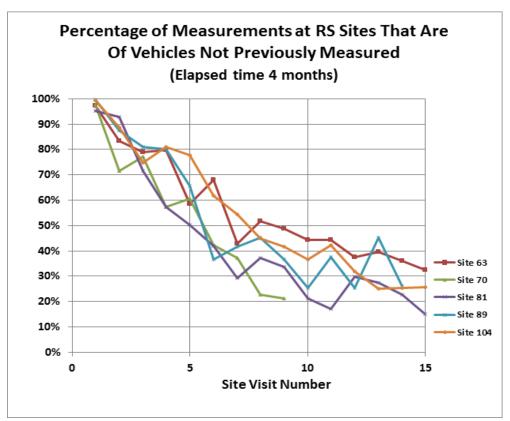


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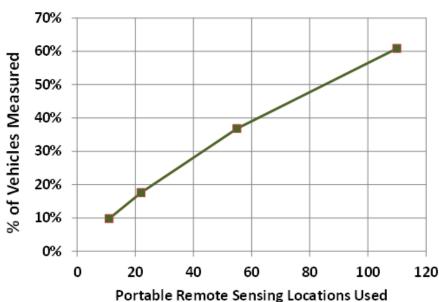


Rotating Sites Essential to Coverage



New vehicle capture falls to 20-45% by 10th day; 15-35% by 15th. We rotate across 120+ sites in our large US to programs to achieve broad coverage.

> % of Unique Vehicles Measured in 2.4M Vehicle Metro Area





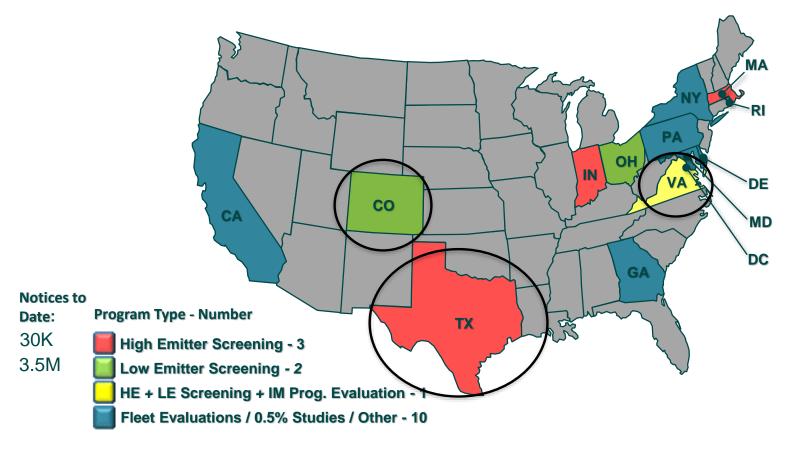
Remote Sensing of Real World Driving Emissions

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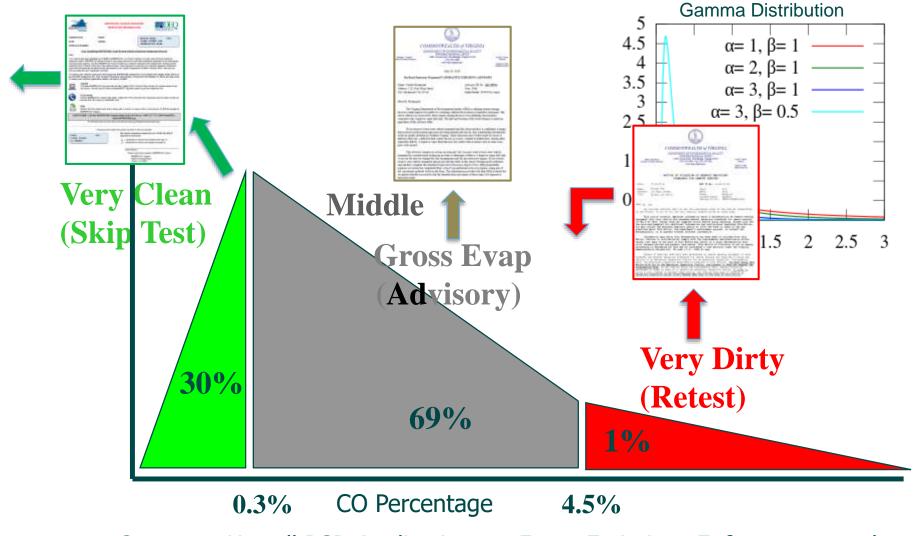


Opus Remote Sensing Programs - US





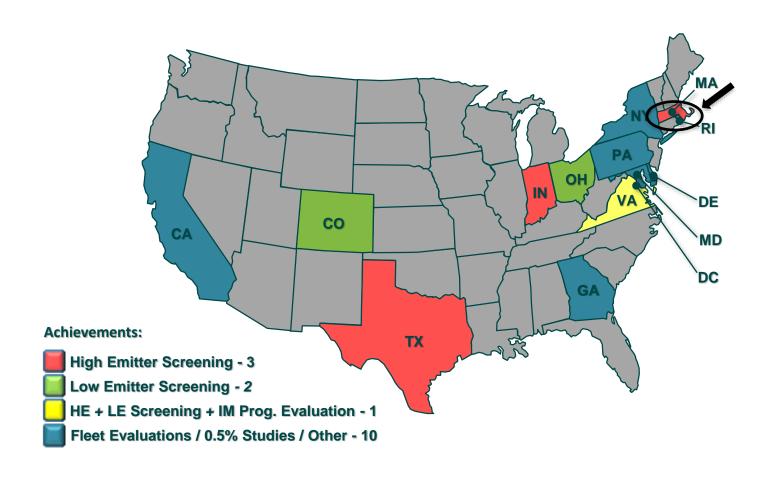
Virginia "Total Screening" Program



Concept: Use all RSD Applications to Focus Emissions Enforcement and Consumer Assistance on High Emitters, Improve Program Efficiency & Environmental Benefit, & Evaluate Fleet & I/M Program.



Opus Remote Sensing Programs - US





Bus Emissions Testing Program: since 2007

Massachusetts Bay Transit Authority (Boston)





Mobile Deployments

Fixed Deployments

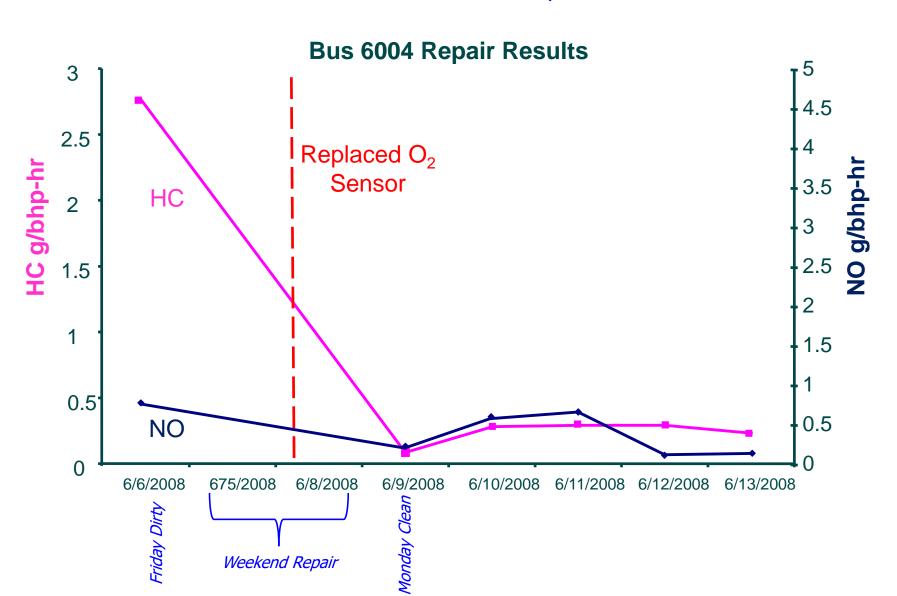
Outcome:

- Proven Effective as an In-Use Screening Protocol for Buses:
 - 1. Operators learned to use RSD → Consistent & Reliable RSD data.
- 2. Benefits of Early Maintenance Demonstrated:
 - Weekly Bus Emissions Summary Reports → Depot Mechanics.



Effect of Maintenance

CNG Bus Example





Bus Emissions Testing Report Published on MBTA Website



MBTA Trimester Report Bus Emissions

Testing conducted from 8-26-2008 to 1-22-2009

All buses flagged as high emitters were removed from service, repaired, and retested prior to returning to revenue service.

Trimester Summary

Depots Tested Charlestown, Arborway, Fellsway, Lynn, Albany St, Cabot, Southampton, Quincy

Buses Tested 870 # Individual Tests 2259 # Screened for Retest 10

Repair Summary

Bus#	Fuel Type	Reason	Repair
2076	CNG	Hydrocarbons	catalytic converter replaced
2044	CNG	Oxides of Nitrogen	replaced spark plugs and engine tuned up
2069	CNG	Hydrocarbons	valves adjusted
2281	CNG	Hydrocarbons	exhaust manifold leak repaired
2125	CNG	Oxides of Nitrogen	oxygen sensor changed and Air Fuel Ratio tables cleared
2135	CNG	Oxides of Nitrogen	oxygen sensor changed and Air Fuel Ratio tables cleared
2171	CNG	Oxides of Nitrogen	turbocharger and exhaust flex pipe replaced
293	Diesel	Oxides of Nitrogen	replaced diesel particulate filter
1028	CNG	Hydrocarbons	replaced spark plugs, boots, coils and valves adjusted
1031	CNG	Hydrocarbons	replaced spark plugs, boots, coils and pulse width modulated motor stepper valve



Remote Sensing of Real World Driving Emissions

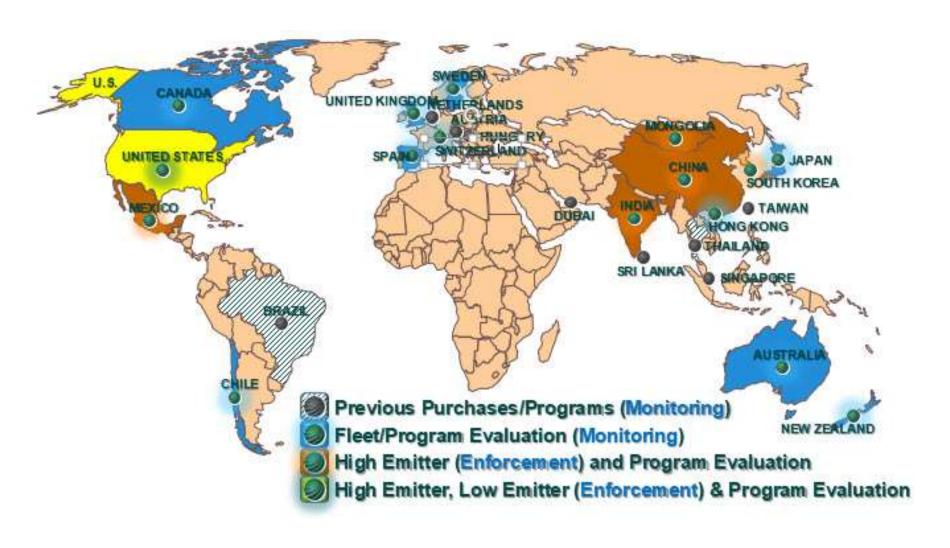
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Opus Remote Sensing Activity - International

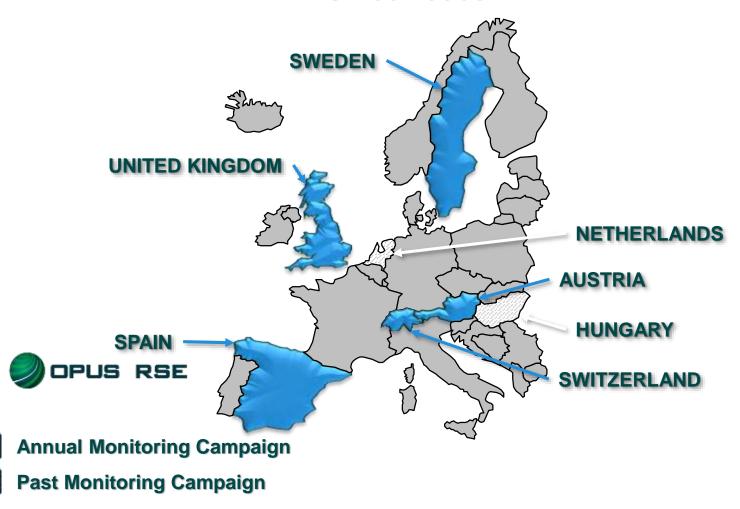
17 of 25 Countries Still Use Opus RS





European Remote Sensing Monitoring

Since 1990s





Getting the Emissions Picture

N = 1,000,000 (1 Year)





Getting the Emissions Picture

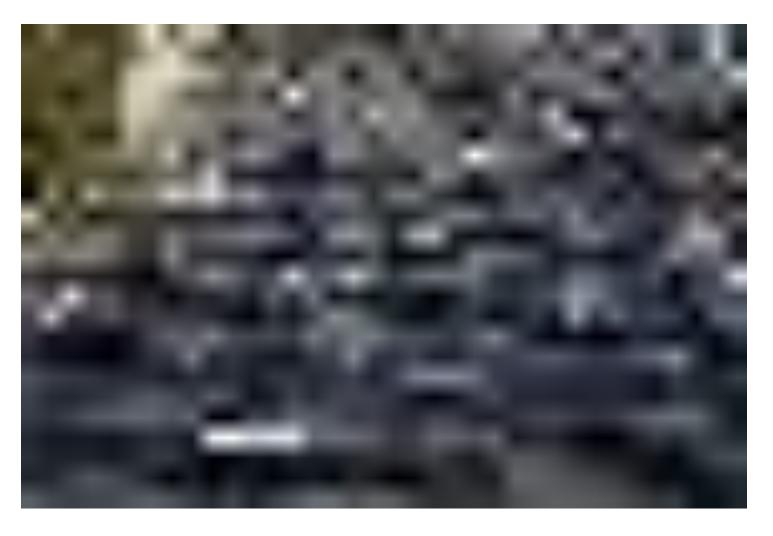
N = 100,000 (2 Months)





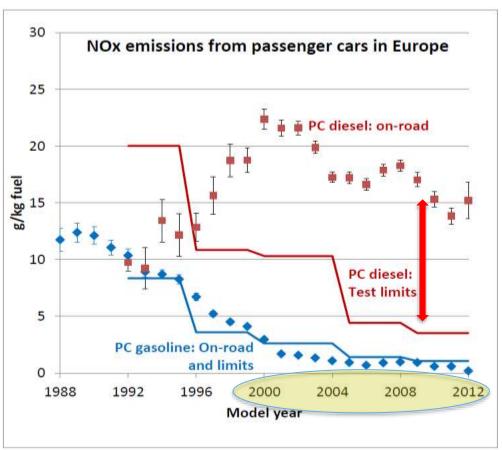
Getting the Emissions Picture

N = 10,000 (Week)





High On-road Diesel NOx Emissions in EU



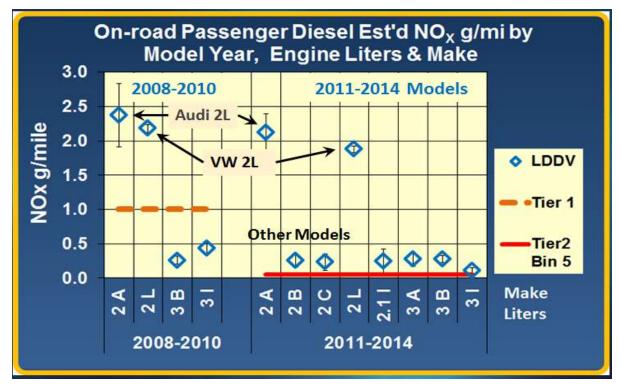
Source: Borken-Kleefeld, Atm. Env. 88 (2014)

Researchers using Remote Sensing in Europe and UK have reported high on-road NOx from modern light diesels for several years:

- "Real-driving emissions from cars and light commercial vehicles –
- Results from 13 years remote sensing at Zurich/CH"; Y. Chen, J. Borken-Kleefeld, Atmospheric Environment 88 (2014), p.157-164.
 - "Trends in NOx and NO2 emissions and ambient measurements in the UK"; Carslaw, D., et. al.; prepared for Defra, version 3rd March 2011.
 - "On the increasing levels of NOx in some cities"; Haeger-Eugensson et. al.; prepared for Swedish Environmental Protection Agency by IVL, June 2010.



High On-road Diesel NOx Emissions in USA



March 2015

Source: P. McClintock, "High NOx Emissions from Light Diesels also Observed on US Roads"; 25th CRC Real World Emissions Workshop, Long Beach,

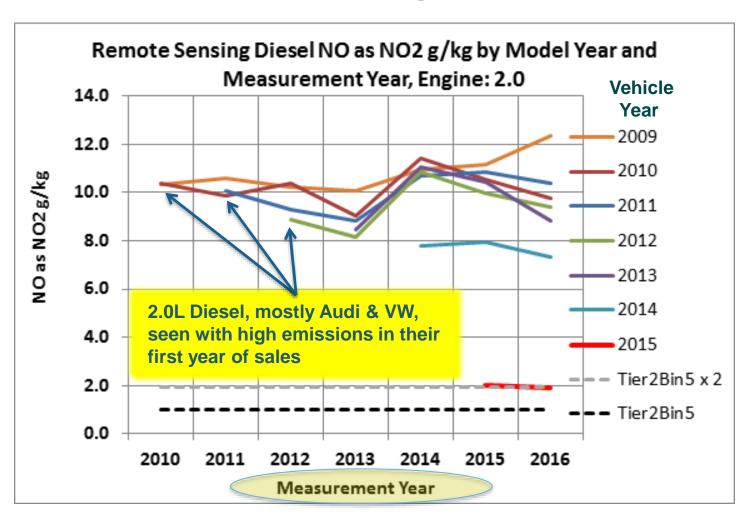
CA; March 2015

Opus researchers examined and confirmed the high on-road NOx emissions of light VW and Audi diesels compared to 2 liter diesel peers in US remote sensing data.



Could VW have been Alerted Early?

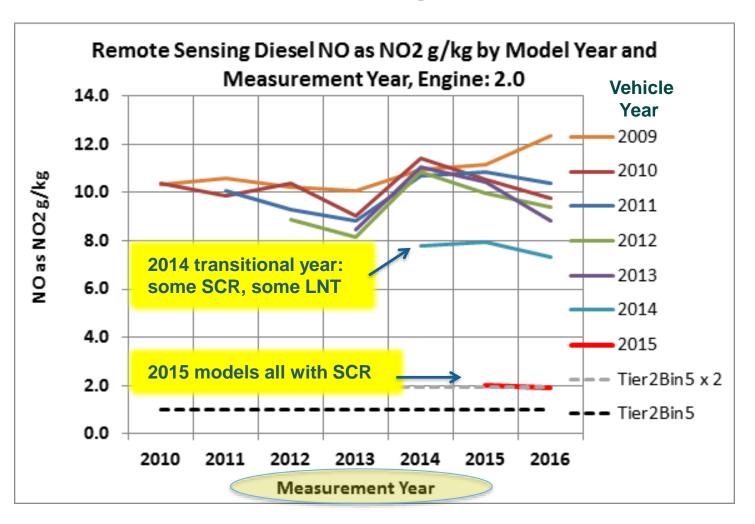
USA Remote Sensing Data: 2010-2016





Could VW have been Alerted Early?

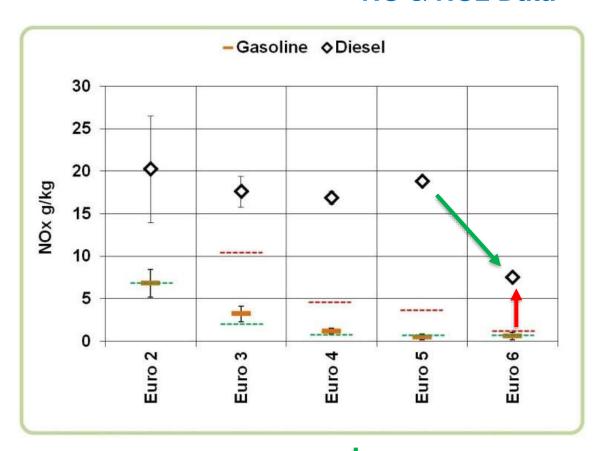
USA Remote Sensing Data: 2010-2016

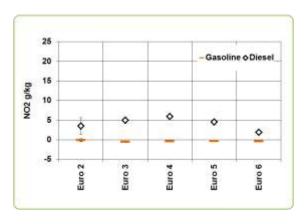


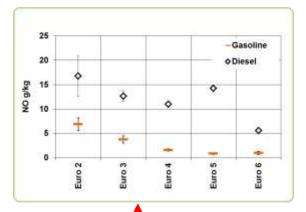


Recent EU Data on Euro 6 Diesels

NO & NO2 Data





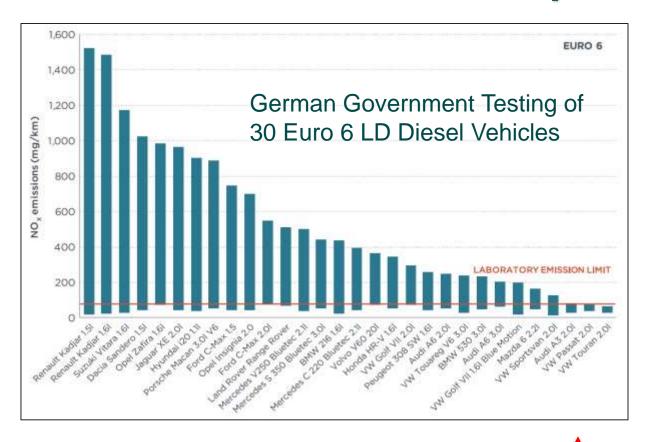


Euro 6: At 8 g/kg, 60% less; but still 6-7 times above Standards.

Data Source: Sjodin (IVL, Sweden), Carslaw (Ricardo, UK), Alt (AWEL, Switzerland)



Euro 6 Real World NOx Compliance



ICCT: Real-world NO_X emissions are 6 to 7 times the 80 mg/km Euro 6 standard (http://www.theicct.org/nox-europe-hdv-ldv-comparison-jan2017)



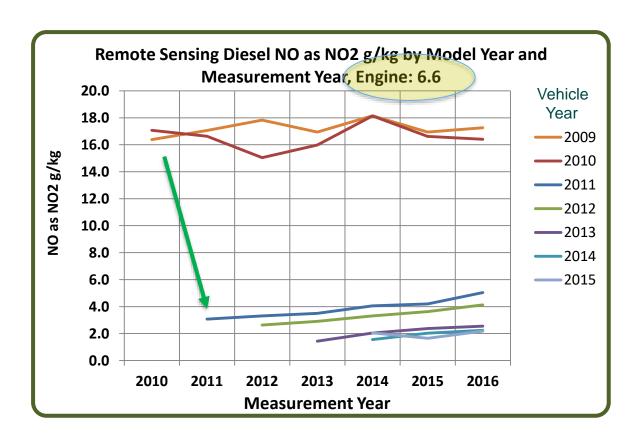
Light-Heavy (Medium) Diesel Vehicles



Picture intended to indicate type of truck; not to identify brand.



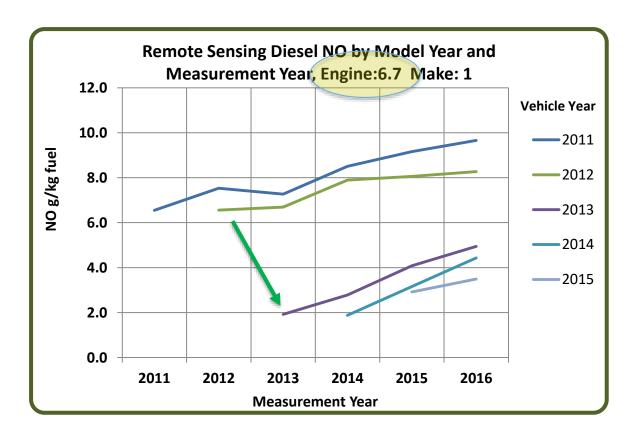
USA Light-Heavy Diesel NOx Deterioration?



- Huge improvement between 2010 and 2011 with SCR
- Deterioration: 2011 model from ~3 to ~5 g/kg (66%) over 3-5 years



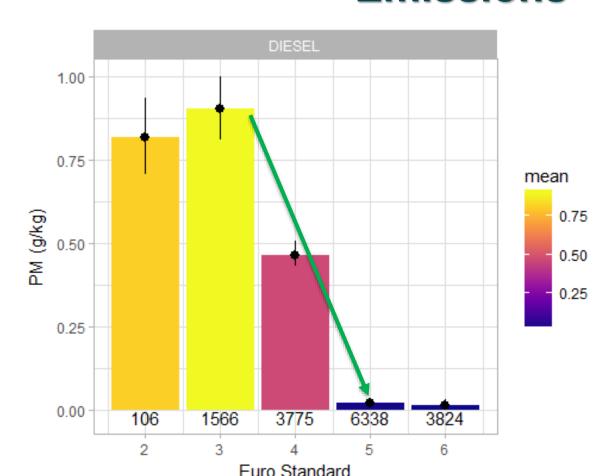
USA Light-Heavy Diesel NOx Deterioration?



- Less improvement between 2012 and 2013 models
- Deterioration: 2013 model from ~2 to ~5 g/kg (150%) over 3 yrs



Effect of Diesel Particulate Filters on PM Emissions



- Early DFP adoption in Euro IV reduce PM by 50% from Euro III.
- DPF became mandatory for Euro 5 Diesels.
- The 90%+ PM reduction cited in literature between Euro III and V is clear in the data.

[DieselNet:

https://www.dieselnet.com/tech/dpf.php]

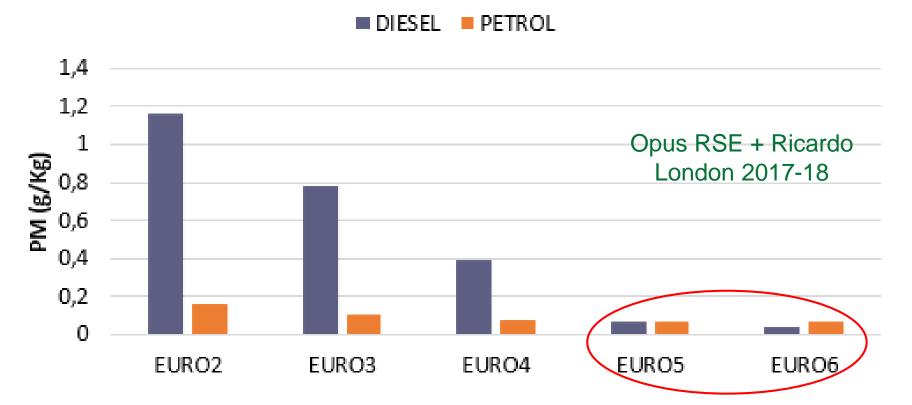
[Source: https://ee.ricardo.com/news/remote-sensing-demonstrating-diesel-particulate-f]







Importance of Good PM Measurements



- Euro 6 Petrol and Diesel PM standards are roughly the same.

 [source: https://engage.aiche.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=d4fae029-91c5-4189-ac75-d8d404d81f41&ssopc=1]
- Researchers find Petrol and Diesel PM emissions to be same.

[source: https://www.nature.com/articles/s41598-017-03714-9]



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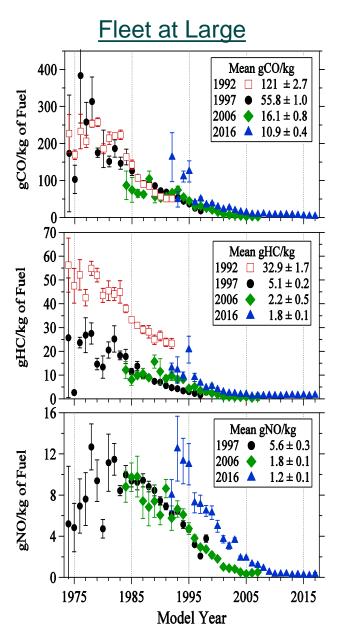
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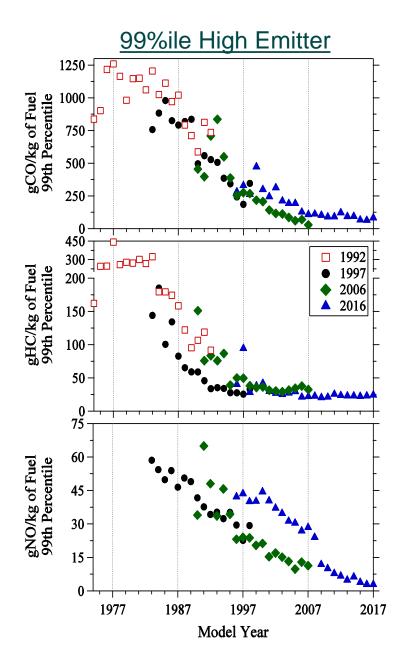
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UNIVERSITY 3 Decades of RSD Data - USA





Remote Sensing of Real World Driving Emissions

Where do we go from here?

Remote Sensing in the United States

- Developed as On-road Screening (Enforcement) for Enhanced I/M
- Two Decades Proven History Screening High and Low-emitters.
 - 3.5 million Low-emitters & 30 thousands High emitters Notified.
- \circ 120 million still live in (2015 8-hr O₃ = 70 ppb) non-attainment areas
- Continue as I/M On-road Screen until Remote OBD Supplants
 - Remote Sensing will adopt a Monitoring / Surveillance Focus

Remote Sensing in Scotland

- 4 LEZs by 2020, starting with Glasgow.
- LEZs can be operated like Enhanced I/M areas (i.e., AQMAs).
- Like Boston, include a focus on Inspecting and Maintaining the Investment in Bus Modernization.
- Include High Emitter Screening (Enforcement) for the Private Fleet.