New Approaches to Vehicle Emissions Inspections

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Outline

- 3DATX Company Overview
- PTI Overview
- parSYNC iPEMS
- PTI Pilot at Opus, Sweden
- PTI Pilot Data – Initial Findings
- OPUS Trial Overview
- PTI Pilot Status
- 3DATX Next Steps

Company Overview

3DATX's mission is to provide real world intelligence in a world seeking accurate data on personal and commercial vehicle engine emissions and performance

Tagline: *Real world vehicle emissions intelligence now!*

Year founded: 2014

Headquartered: Buffalo, NY

European Office: Belgium

3DATX Team:

- Nationally recognized Board with deep automotive and finance experience
- Multi-national and multi-competence team based worldwide
  - Wide and deep expertise in vehicle emissions measurement and transportation sustainability
- Many team members from Clean Air Technologies Inc. (founded by Dave Miller in 1999), the first company to manufacture a “Portable Emissions Measurement System” (PEMS).

PTI Today

- PTI for exhaust emissions are mostly regulated by Directive 2014/45/EU:
  - Correct performance of complex exhaust after-treatment systems are verified only by visual inspection (leaks, etc.)
  - Requires different requirements for vehicle engine type:
    1. Positive ignition engine emissions use a certified exhaust gas analyser to determine:
       a. Measured gaseous emissions (CO, CO_2, O_2, HC) do not exceed OEM specified thresholds
       b. If not specified, CO emissions do not exceed the thresholds defined by vehicle type
       c. Lambda coefficient not outside OEM specified range, or if not specified not outside 1±0.03
       d. OBD read-out does not indicate significant malfunction
    2. Compression ignition engine emissions use certified opacity meter and protocol to determine:
       a. Opacity does not exceed OEM specified thresholds
       b. If not specified, opacity does not exceed thresholds for defined vehicle types

- Directive 2014/45/EU is out of date:
  - Not referenced to regulatory thresholds and measurements defined for (RDE) type-testing, notably for NO_x and PN measurement/thresholds and CO or CO_2 thresholds
  - Existing PTI equipment cannot meet these requirements

PTI Tomorrow

- Post Dieselgate, European emission measurement is progressing:
  - VERT (DPF manufacturers association) advocates PN measurement at EU and member state levels
  - EU has implemented PMP and RDE protocol for vehicle type-approval testing, with measurement of CO, NO_x, HC+NO_x, PM and, from EURO-5, measurement of PN
  - Some member states are introducing new PTI regulations independently of EU regulation:
    - Netherlands, Germany and Belgium for PN for diesel vehicles post EURO5
    - France for NO_x for diesel vehicles
  - EU regulates OBM CO_2 monitoring for new vehicles from 2021, with PTI procedures to be defined
  - EU PTI emissions procedure is not homogeneous across the EU

- CITA has a role to play to implement emissions measurement at PTI:
  - Particulate protocol, measurement & threshold as per modified NPTI/Dutch procedure to be tested
  - NOx protocol, measurement & threshold as per CITA experience, to be developed and tested
  - CO and CO_2 protocol, measurement & threshold to be developed and tested
  - Advocating EU homogeneity and building future-proof systems

parSYNC® iPEMS Solution

- Next Generation: integrated PEMS
  - Easy to use and versatile
  - Rugged, light weight and mobile: <4 kg and >4 hours on battery
- Modular Sensor Cartridge Advantage: Particulates and Gases
  - GasMod cartridge measures NO (0-5000 ppm), NO_2 (0-300 ppm), CO (0-15%), and CO_2 (0-20%)
  - PM/PN cartridge measures Opacity Scattering and Ionisation and uses a matrix transform to calculate PM (ug/m^3) and PN ($\#/cm^3$)
  - Simplifies measurement and maintenance.

parSYNC® iPEMS will meet current (Opacity and Gas Analyser) & future (PN, NOx, …) PTI equipment standards

PTI Pilot – OPUS Sweden

Test Location

This presentation covers Phase-1 data collected at the Borås site.
We expect the Skellefteå site to join the pilot this week.

Vehicles Tested

Vehicle Summary

MAKE	Diesel	Petrol	2005	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
AUDI	4	1	1	1				1	1	1						5
BMW	5					1		1		1	2					5
CITROEN	1						1									1
DACIA		2						1			1					2
FORD	4	1			1		1	2	1							5
HONDA	1	1									1		1			2
HYUNDAI	1	1						1			1					2
JEEP		1							1							1
KIA	4								2	1			1			4
MAZDA	2	2								1	1	1			1	4
MERCEDES-BENZ	1									1						1
MITSUBISHI	2				1			1								2
NISSAN		1									1					1
OPEL		1										1				1
RENAULT	1	2		1						1			1			3
SAAB	1	1		1		1										2
SKODA		2	1					1								2
SUBARU	1							1								1
TOYOTA	1						1									1
VOLKSWAGEN	2	1	1					1						1		3
VOLVO	10	1				1		1	1	1	3	2	2			11
VW	1								1							1
Total	**42**	**18**	**3**	**3**	**2**	**3**	**3**	**11**	**7**	**7**	**10**	**4**	**5**	**1**	**1**	**60**

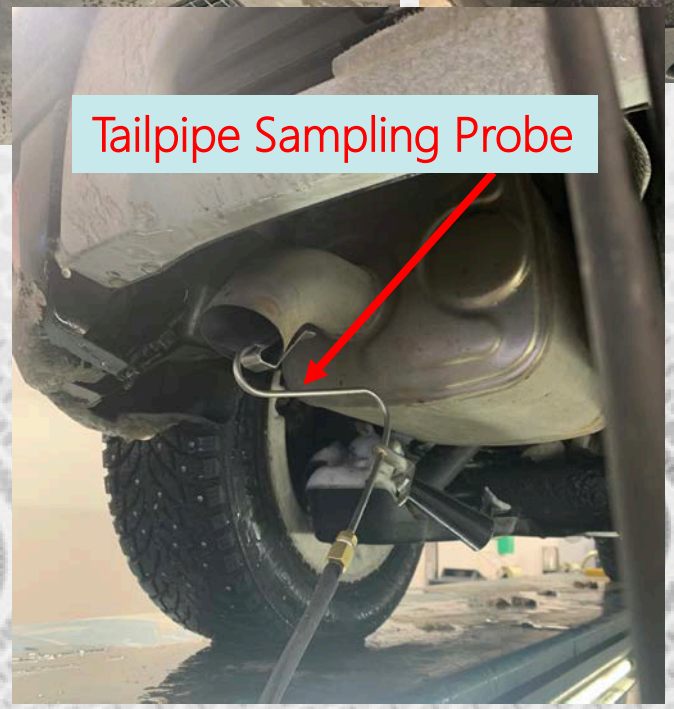
Jan 21
to
Feb 18, 2021

Test Protocol

Prep	• Warmup (or dry-out) the parSYNC using wall power while sampling clean ambient air (use HEPA filter if available)
0	• Start test data file | Sample clean ambient air for ~60 seconds
Zero	• Run the zeroing procedure while parSYNC is on the bench
0	• With parSYNC running on battery power move it to the vehicle | Connect to tailpipe probe | Connect OBD reader to ECU port | Start the vehicle | Drive to parking lot position | Idle vehicle for 60 seconds
1-3	• PN – 30 seconds of idle | Repeat 3 times
4-6	• NO_x High Idle – Idle → ~2500 RPM, hold for 5 seconds → return to Idle and hold for 10 seconds | Repeat 3 times
7	• Idle for 60 seconds to allow NO_x emissions to stabilise
8-10	• NO_x Acceleration – Stationary → 30 kph → Stationary | Repeat 3 times
11	• Return vehicle to workshop/garage to uninstall | Disconnect parSYNC and place on bench and connect to wall power | Sample clean ambient air for 60 seconds
Zero	• Run zeroing procedure with parSYNC on the bench

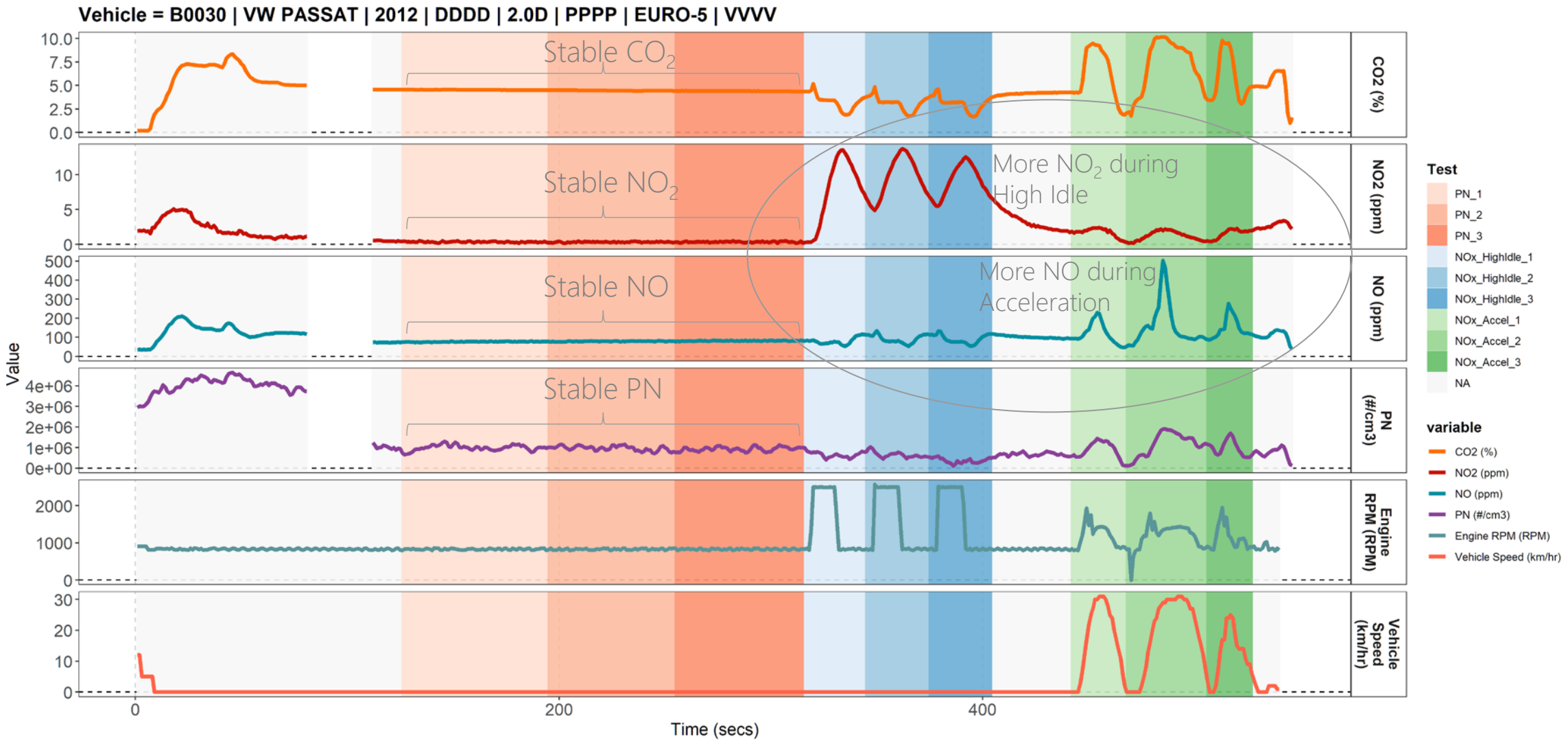
Test Setup and Conditions

parSYNC warmup and zeroing while vehicle is being prepared

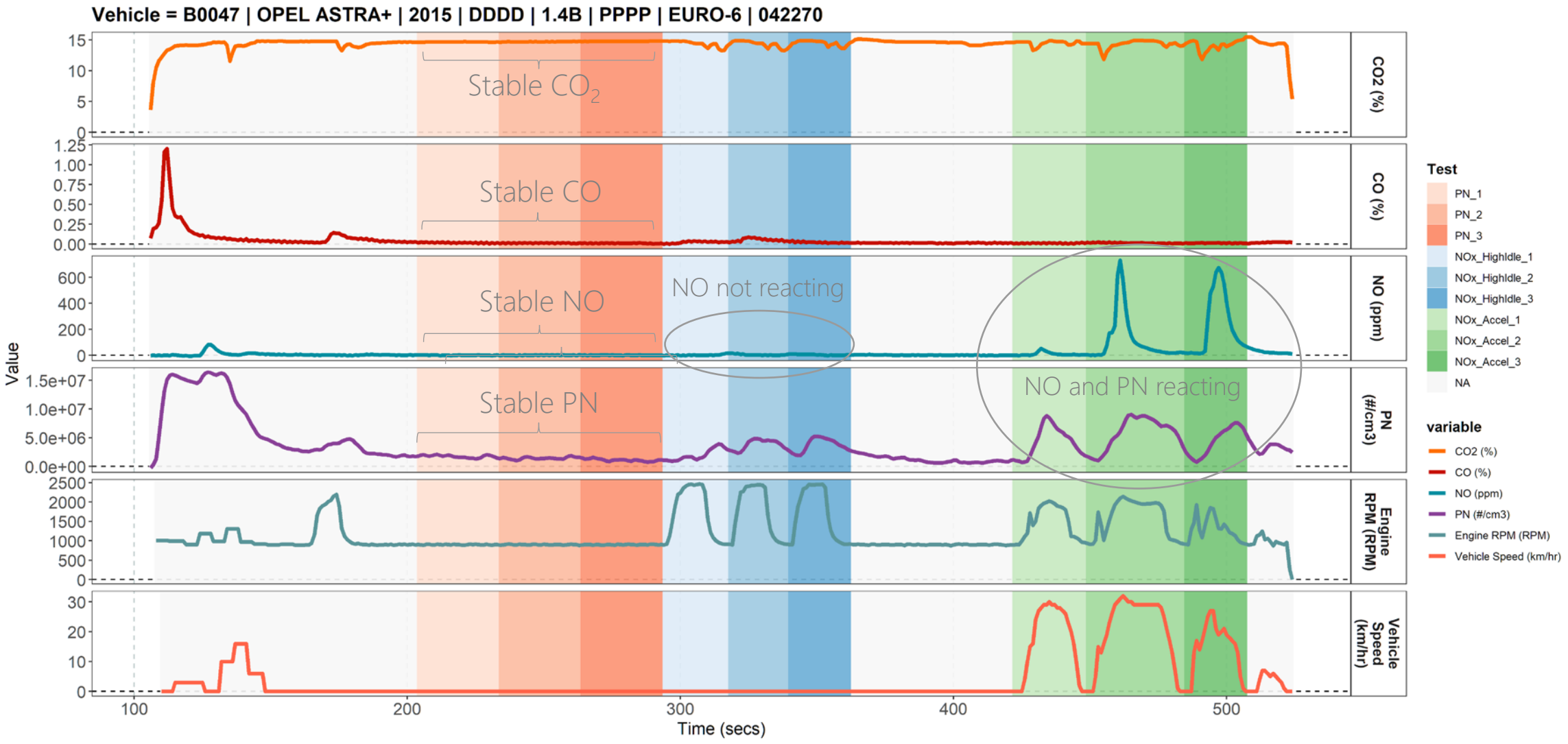


PTI Pilot Data – Initial Findings

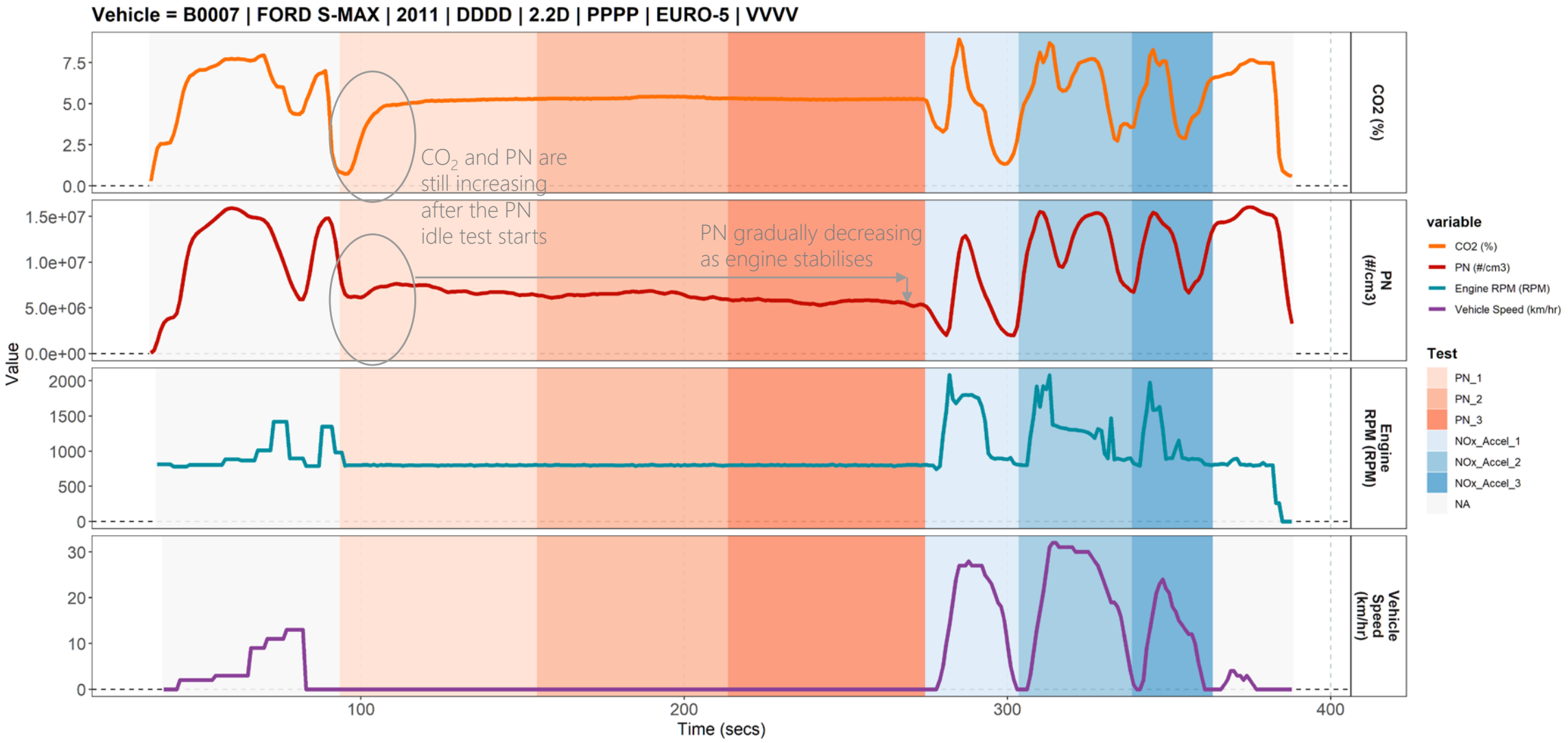
Example of a PTI Protocol Test – Diesel



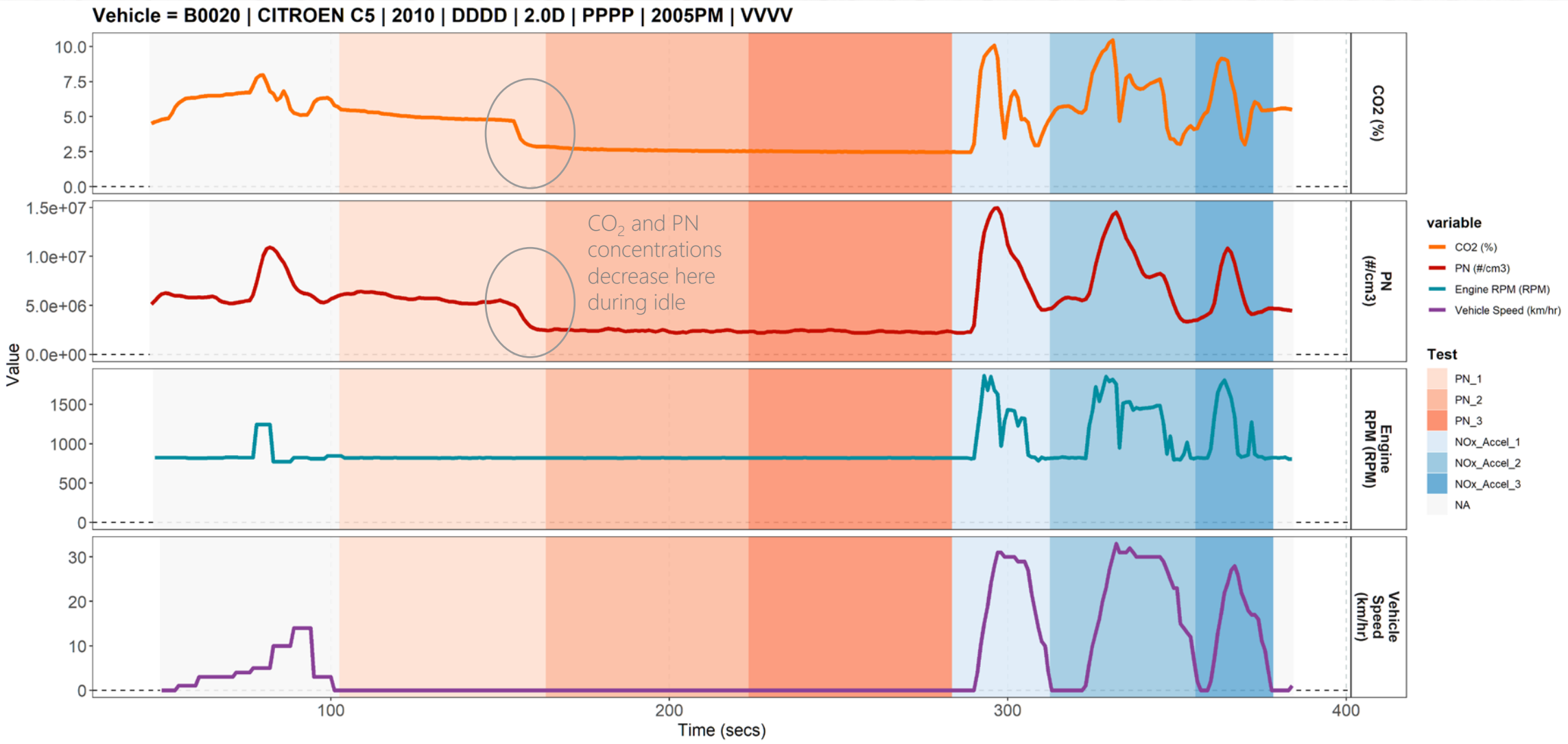
Example of a PTI Protocol Test – Petrol



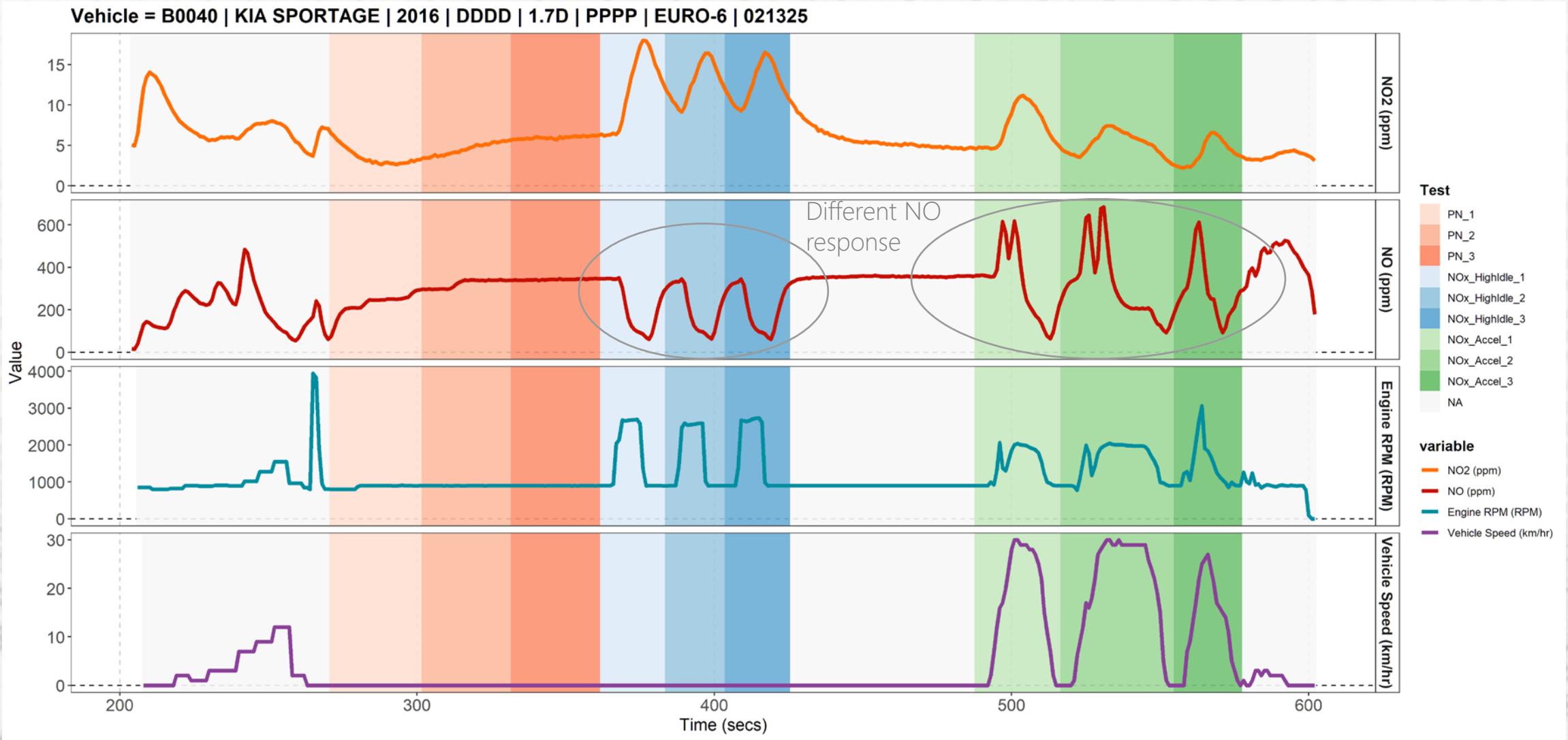
Example of Starting the PTI PN Idle too soon after Engine Ignition



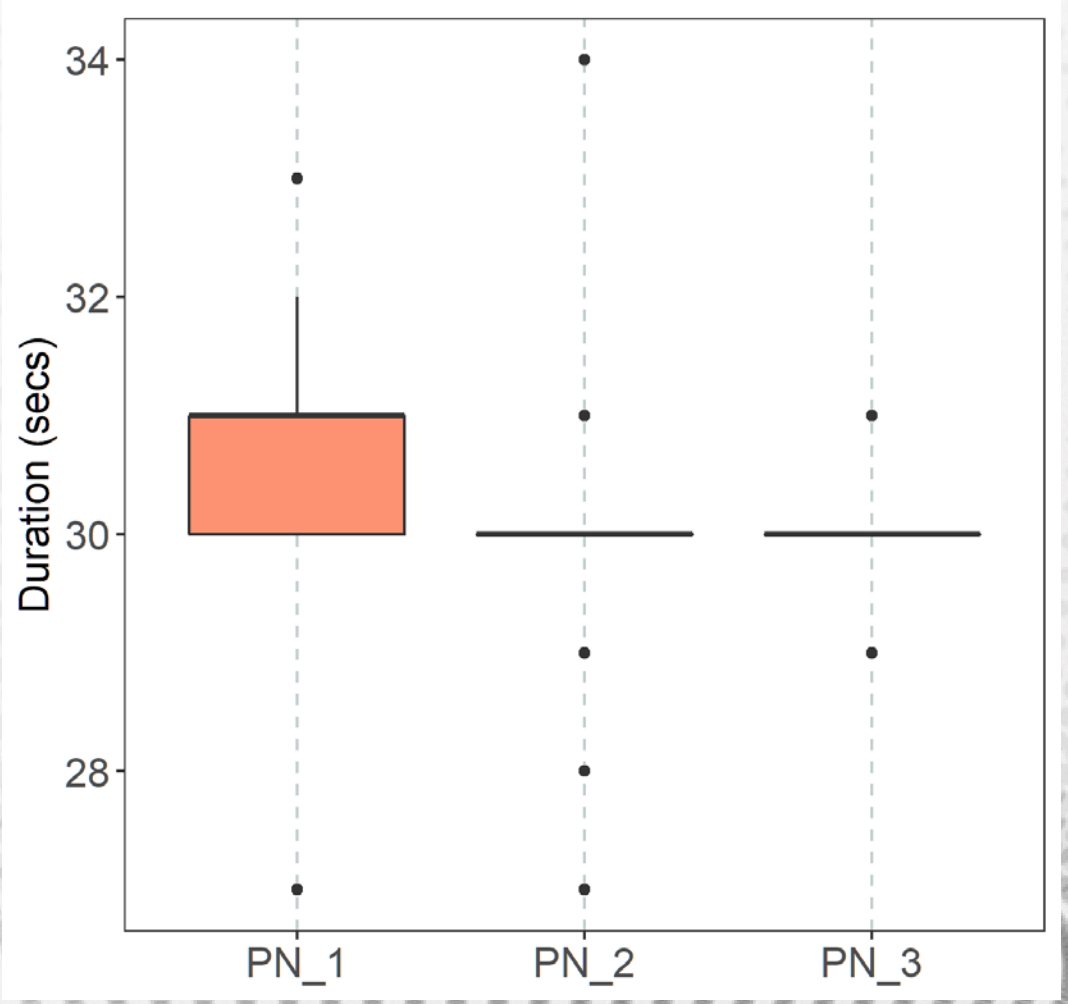
Example of Instability on the PTI PN Idle

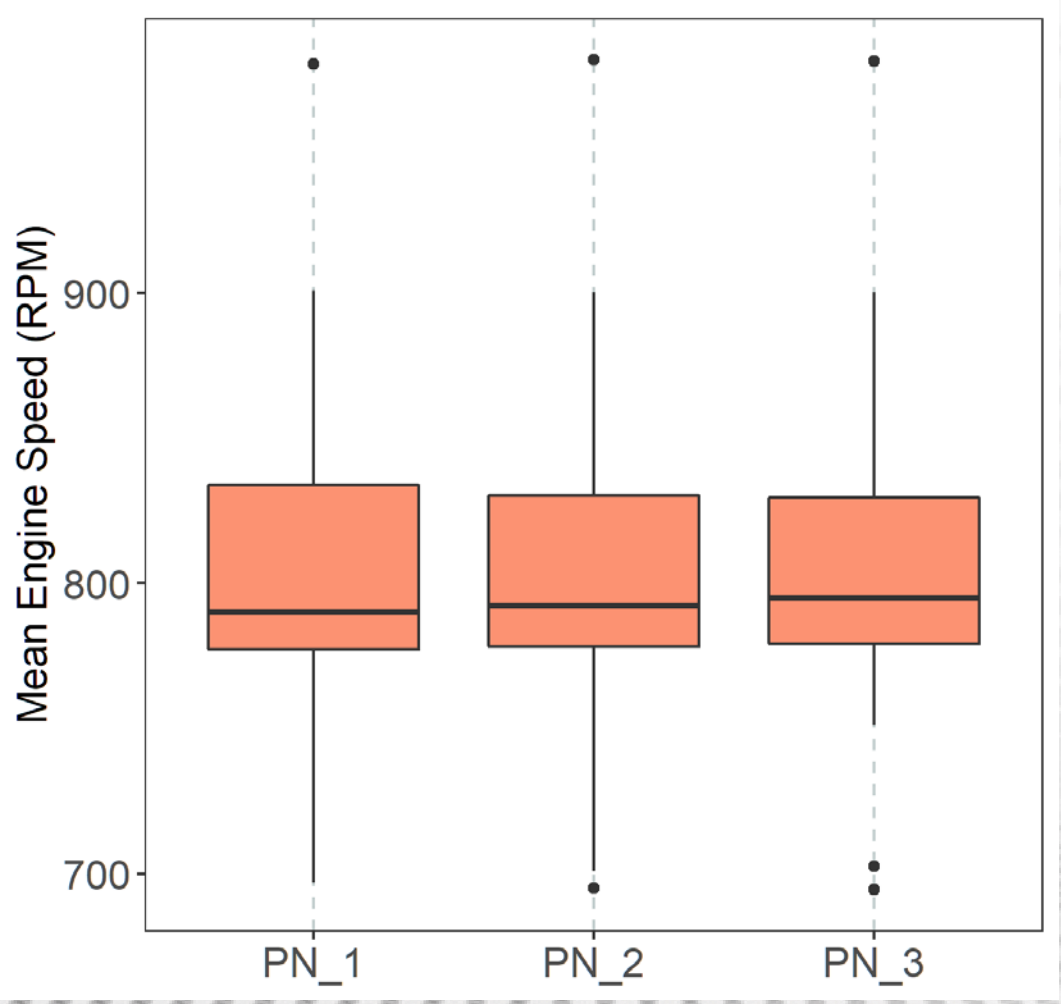


Example of Differences between PTI NOx Acceleration and High Idle Tests (Diesel)

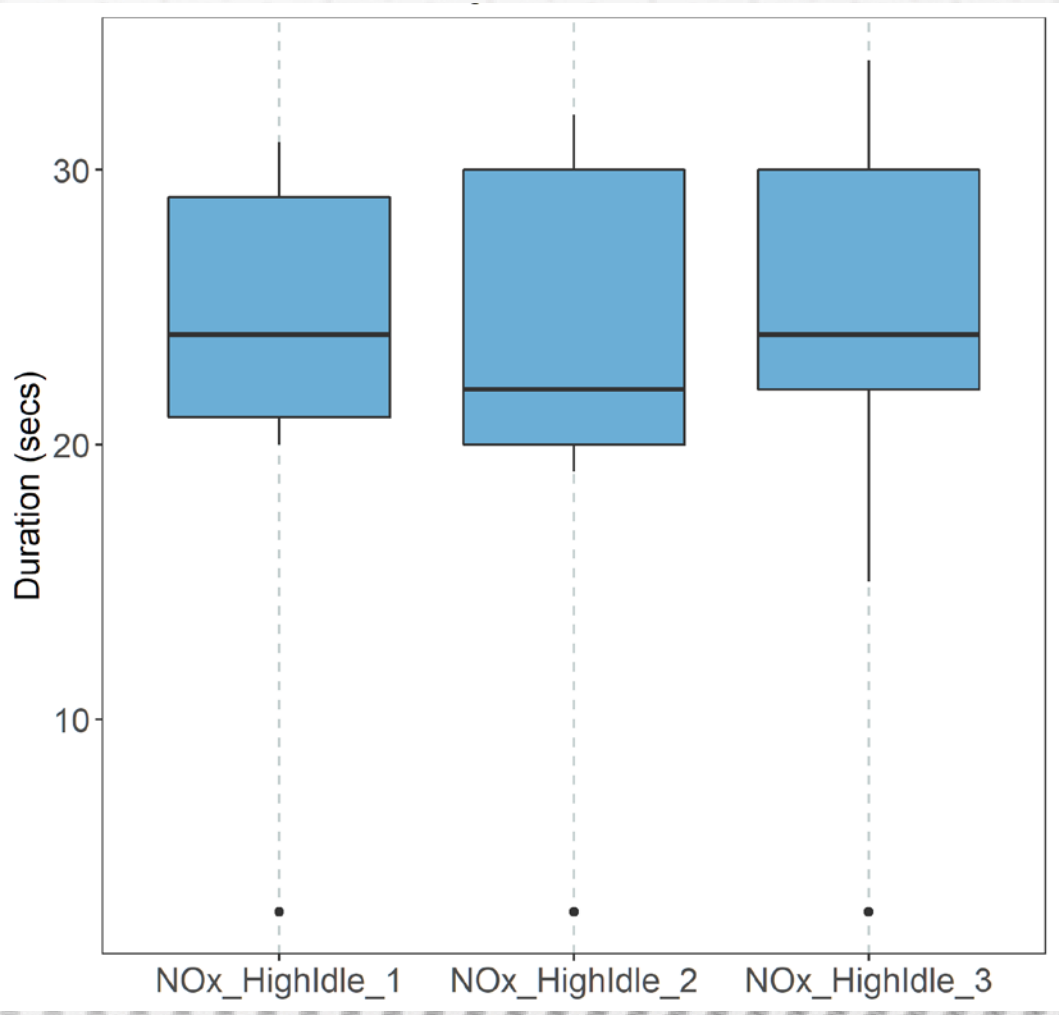


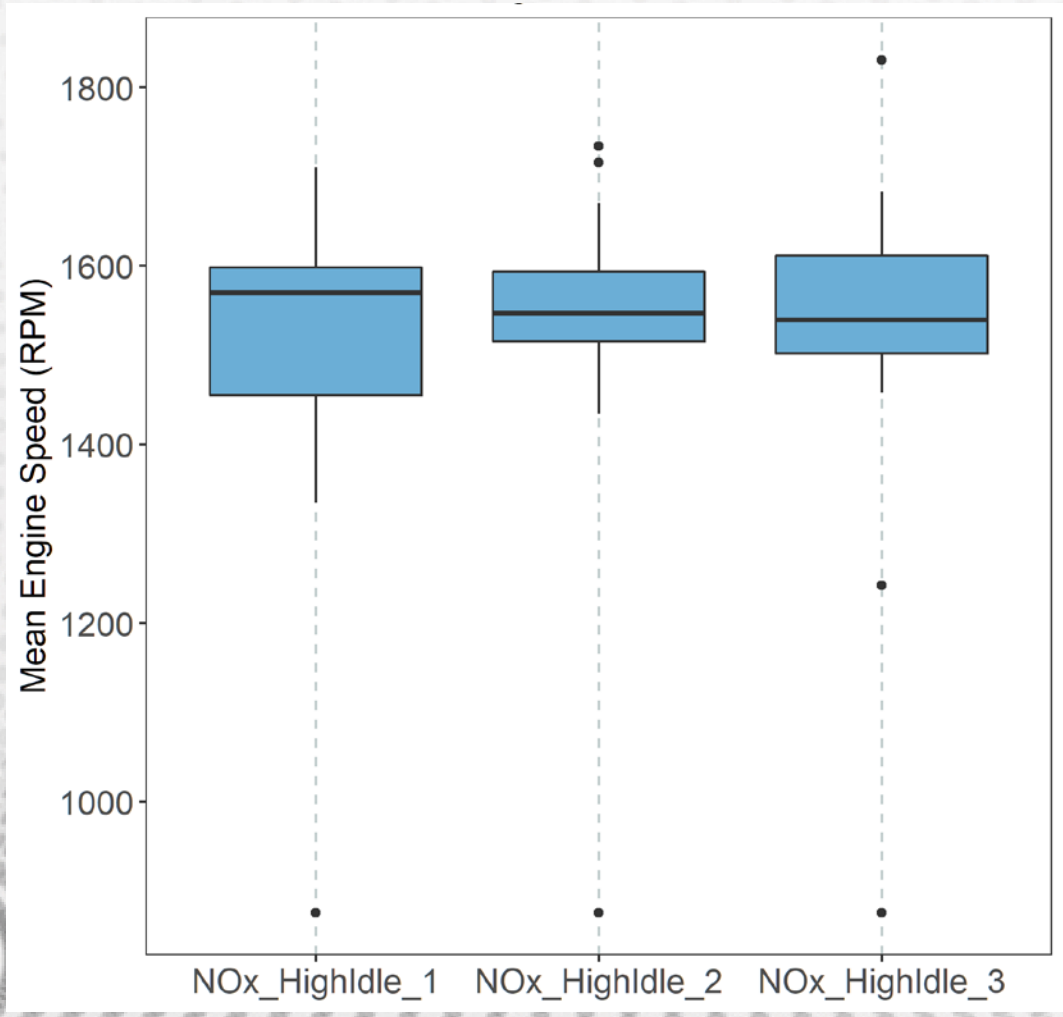
Repeatability of the PTI PN Protocol



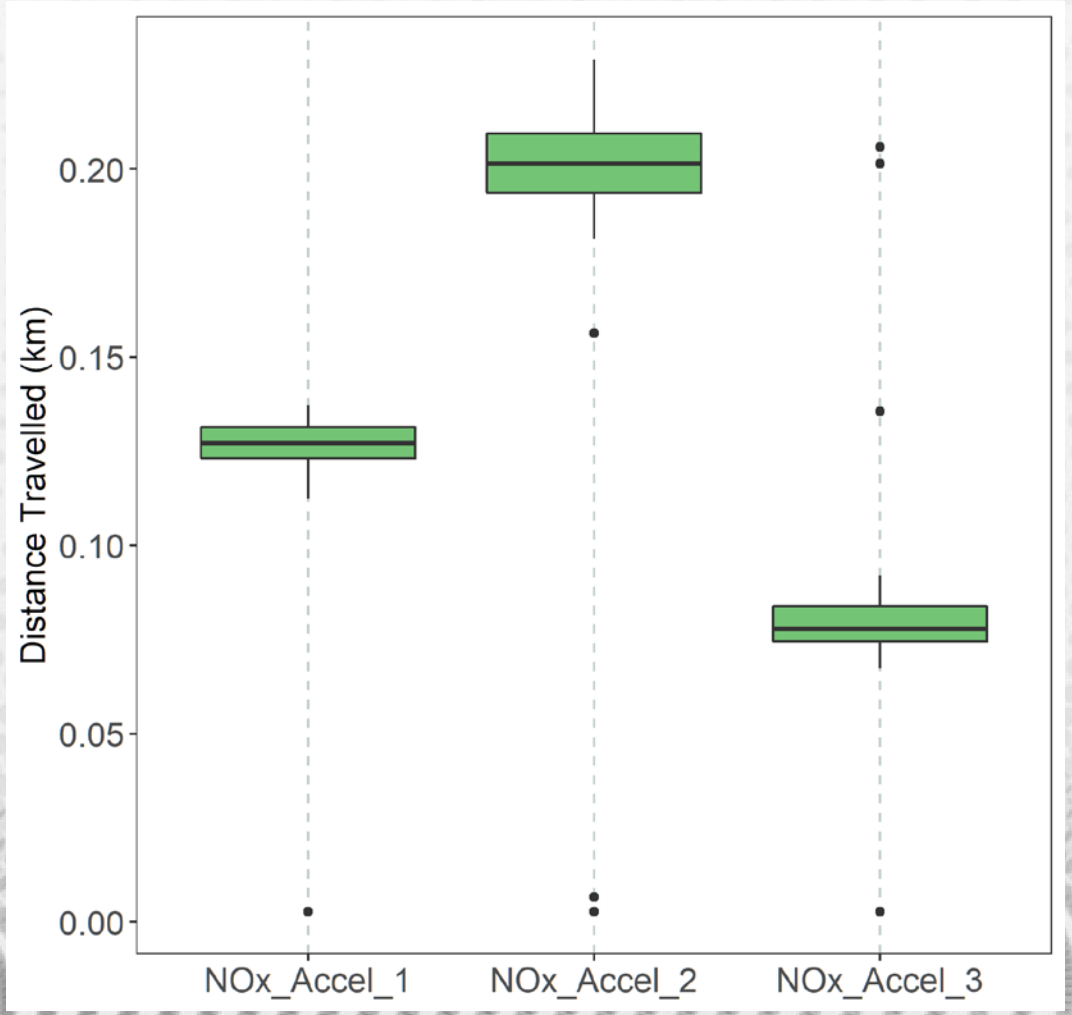


Repeatability of the PTI NOx High Idle Protocol





Repeatability of the PTI NOx Acceleration Protocol



Preliminary PN Results

Initial findings from 14 trial PTI tests. Average PN concentrations are calculated from the PN engine idle test periods (points 1-3 on slide 11).

Vehicle Make	Vehicle Model	Year	Engine	Euro Standard	PN_1 (#/cm³)	PN_2 (#/cm³)	PN_3 (#/cm³)	Average of lowest 2 PN (#/cm³)
FORD	S-MAX	2011	2.2D	EURO-5	6.9E+06	6.4E+06	5.7E+06	6.1E+06
MAZDA	6	2013	2.2D	EURO-6	4.6E+05	5.4E+05	4.7E+05	4.6E+05
AUDI	A6	2012	2.0D	EURO-5	7.1E+05	5.9E+05	6.0E+05	5.9E+05
BMW	520XDRIVE	2014	2.0D	EURO-6	1.2E+06	7.4E+05	4.0E+05	5.7E+05
AUDI	ALLROAD-Q	2006	3.0TDI	EURO-4	5.2E+05	2.1E+05	1.3E+05	1.7E+05
TOYOTA	AVENSIS	2010	2.0D	EURO-5	5.2E+05	3.9E+05	2.5E+05	3.2E+05
MITSUBISHI	OUTLANDER	2008	2.2D	EURO-4	1.6E+05	1.7E+05	2.5E+05	1.6E+05
CITROEN	C5	2010	2.0D	EURO-4	5.3E+06	2.4E+06	2.3E+06	2.4E+06
FORD	MONDEO	2011	2.0D	EURO-5	2.5E+06	1.7E+06	1.2E+06	1.4E+06
VW	PASSAT	2012	2.0D	EURO-5	1.0E+06	9.8E+05	9.4E+05	9.6E+05
JEEP	WRANGLER	2012	3.6B	EURO-5	1.4E+06	1.3E+06	1.3E+06	1.3E+06
VOLVO	V70	2009	2.4D	EURO-4	1.5E+06	7.3E+05	5.4E+05	6.4E+05
OPEL	ASTRA+	2015	1.4B	EURO-6	1.8E+06	1.4E+06	1.1E+06	1.3E+06
FORD	C-MAX	2008	1.8B	EURO-4	2.0E+06	1.8E+06	2.0E+06	1.9E+06

Proposed limits[1]
≤ 2014: $1x10^6$ #/cm³
≥ 2015: $2.5x10^5$ #/cm³

[1] Zuidgeest, Louis. 'Phased Introduction of a Particle Test for DPFs in the Netherlands'. Netherlands: Ministry of Infrastructure and Water Management, Netherlands, 14 March 2019. https://www.vert-dpf.eu/j3/images/pdf/VERT_Forum_2019/NL-Zuidgeest.pdf.

Preliminary NO_x Acceleration Test Results – Average Values

Initial findings from 14 trial PTI tests. Average NO_x concentrations are calculated from the NO_x acceleration test periods (points 8-10 on slide 11).

Vehicle Make	Vehicle Model	Year	Engine	Euro Standard	NOx_1 (ppm)	NOx_2 (ppm)	NOx_3 (ppm)	Average of lowest 2 NOx (ppm)
FORD	S-MAX	2011	2.2D	EURO-5	120	123	108	114
MAZDA	6	2013	2.2D	EURO-6	128	271	281	200
AUDI	A6	2012	2.0D	EURO-5	73	103	128	88
BMW	520XDRIVE	2014	2.0D	EURO-6	114	113	84	99
AUDI	ALLROAD-Q	2006	3.0TDI	EURO-4	151	133	226	142
TOYOTA	AVENSIS	2010	2.0D	EURO-5	70	132	166	101
MITSUBISHI	OUTLANDER	2008	2.2D	EURO-4	78	154	106	92
CITROEN	C5	2010	2.0D	EURO-4	170	157	252	163
FORD	MONDEO	2011	2.0D	EURO-5	199	253	239	219
VW	PASSAT	2012	2.0D	EURO-5	122	159	150	136
JEEP	WRANGLER	2012	3.6B	EURO-5	7	19	68	13
VOLVO	V70	2009	2.4D	EURO-4	445	556	537	491
OPEL	ASTRA+	2015	1.4B	EURO-6	11	115	232	63
FORD	C-MAX	2008	1.8B	EURO-4	36	20	31	25

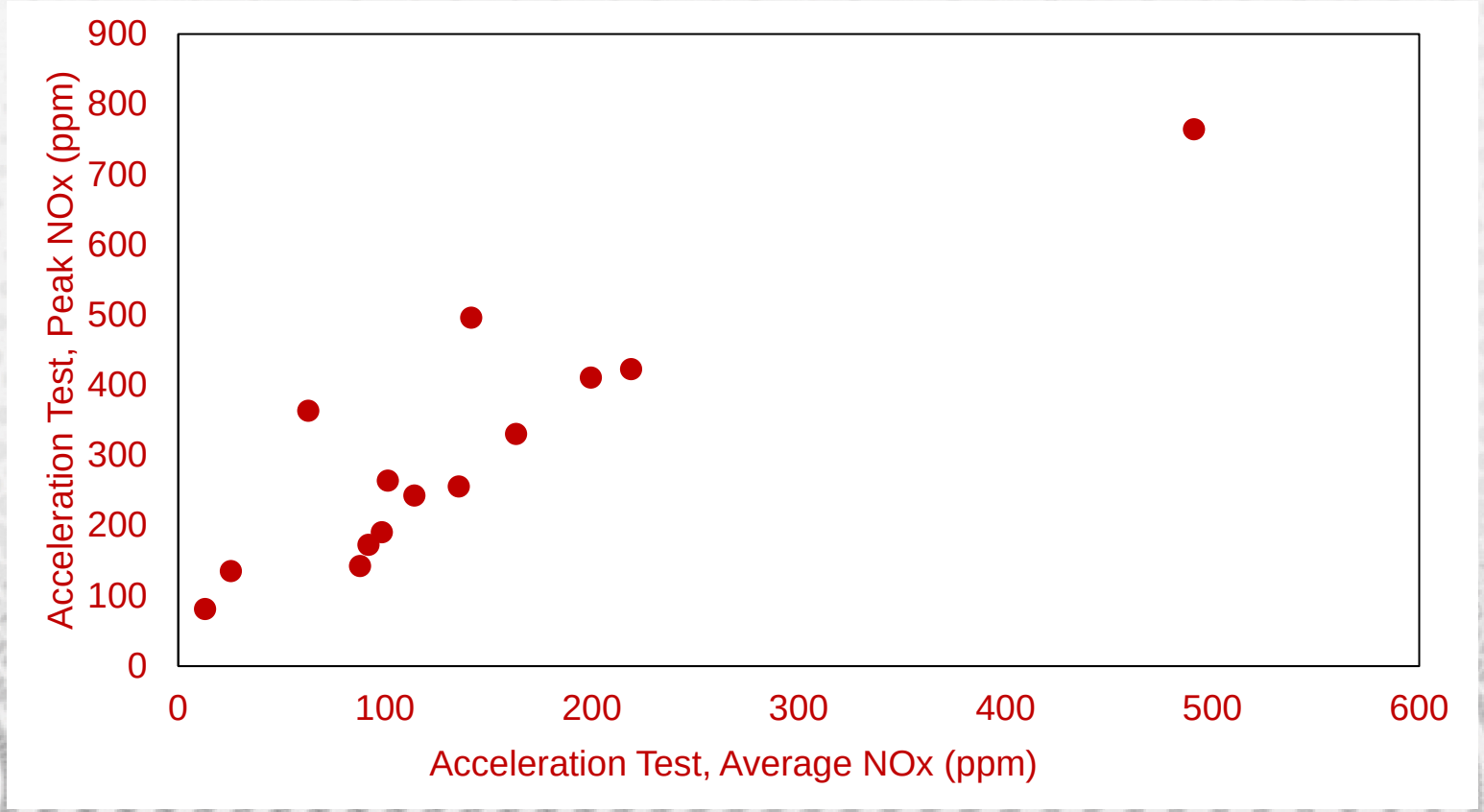
Preliminary NO_x Acceleration Test Results – Peak Values

Initial findings from 14 trial PTI tests. Peak NO_x concentrations are calculated from the NO_x acceleration test periods (points 8-10 on slide 11).

Vehicle Make	Vehicle Model	Year	Engine	Euro Standard	NOx_1 (ppm)	NOx_2 (ppm)	NOx_3 (ppm)	Average of lowest 2 NOx (ppm)
FORD	S-MAX	2011	2.2D	EURO-5	302	303	183	243
MAZDA	6	2013	2.2D	EURO-6	406	475	415	411
AUDI	A6	2012	2.0D	EURO-5	133	151	226	142
BMW	520XDRIVE	2014	2.0D	EURO-6	195	204	186	190
AUDI	ALLROAD-Q	2006	3.0TDI	EURO-4	409	582	742	496
TOYOTA	AVENSIS	2010	2.0D	EURO-5	135	452	392	264
MITSUBISHI	OUTLANDER	2008	2.2D	EURO-4	158	497	187	173
CITROEN	C5	2010	2.0D	EURO-4	304	356	427	330
FORD	MONDEO	2011	2.0D	EURO-5	410	435	470	423
VW	PASSAT	2012	2.0D	EURO-5	232	505	279	256
JEEP	WRANGLER	2012	3.6B	EURO-5	21	141	254	81
VOLVO	V70	2009	2.4D	EURO-4	708	934	821	764
OPEL	ASTRA+	2015	1.4B	EURO-6	53	731	674	363
FORD	C-MAX	2008	1.8B	EURO-4	182	88	212	135

Relationship between Average and Peak Values

Positive correlation seen between the NO_x acceleration test's average NO_x value and peak NO_x value for individual vehicles.



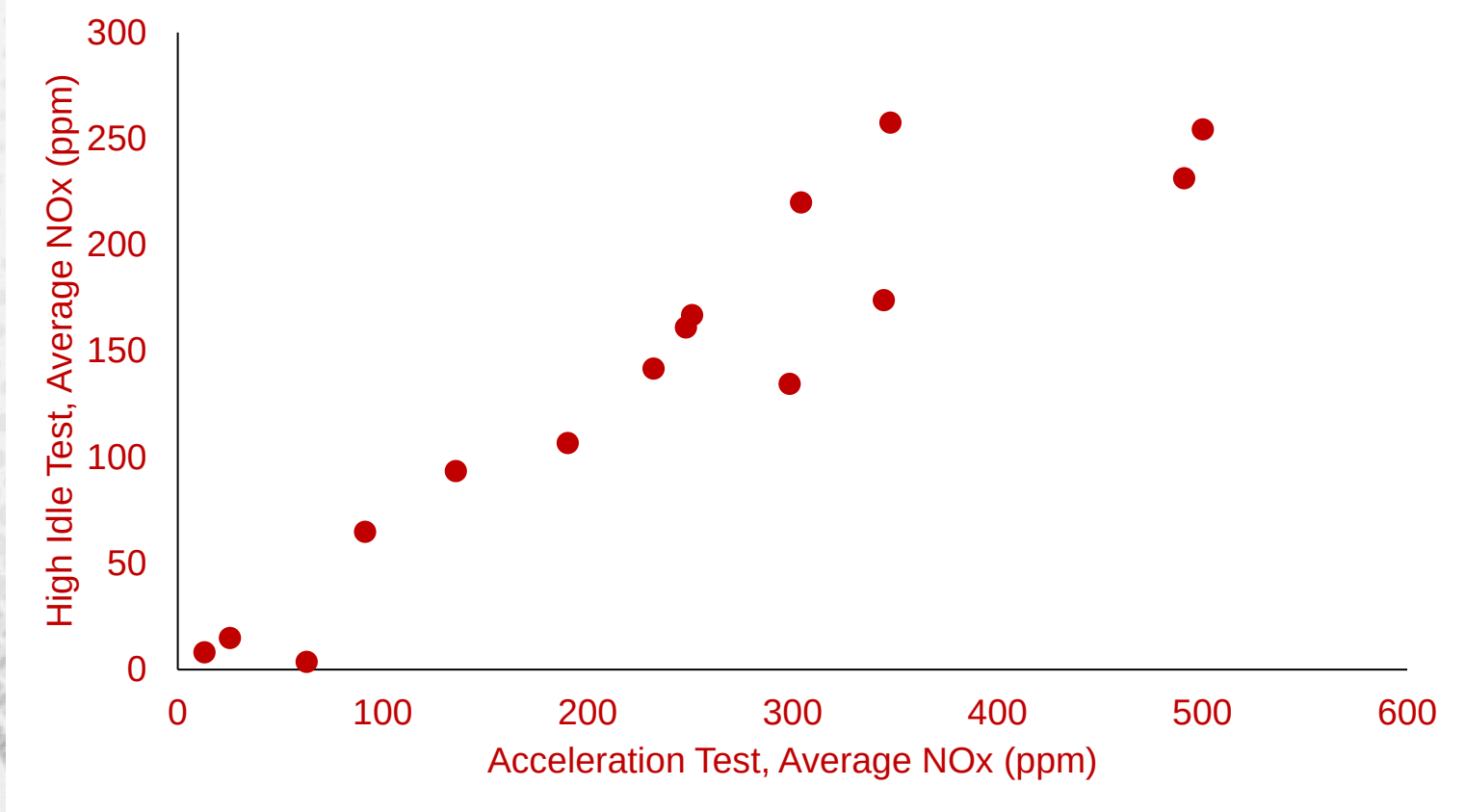
Preliminary NO_x High Idle Test Results – Average Values

Initial findings from 15 trial PTI tests. Average NO_x concentrations are calculated from the NO_x high idle tests (points 4-6 on slide 11).

Vehicle Make	Vehicle Model	Year	Engine	Euro Standard	NOx_1 (ppm)	NOx_2 (ppm)	NOx_3 (ppm)	Average of lowest 2 NOx (ppm)
SUBARU	LEGACY	2011	2.0D	EURO-5	167	159	163	161
VW	PASSAT	2012	2.0D	EURO-5	87	101	100	93
VOLVO	V70	2014	2.0D	EURO-6	135	134	136	134
VOLVO	XC70	2016	2.4D	EURO-6	165	182	187	174
JEEP	WRANGLER	2012	3.6B	EURO-5	7	9	12	8
HYUNDAI	I40	2011	1.7D	EURO-5	255	254	294	254
BMW	520D	2013	2.0D	EURO-5	180	163	171	167
KIA	SPORTAGE	2016	1.7D	EURO-6	228	216	224	220
FORD	KUGA	2012	2.0D	EURO-5	142	142	141	142
VOLVO	V70	2009	2.4D	EURO-4	227	235	243	231
HONDA	CRV	2014	1.6D	EURO-5	312	245	269	257
OPEL	ASTRA+	2015	1.4B	EURO-6	2	5	5	4
KIA	SPORTAGE	2012	1.7D	EURO-5-2	113	101	114	107
VOLKSWAGEN	PASSAT	2011	2.0TDI	EURO-5	65	64	71	65
FORD	C-MAX	2008	1.8B	EURO-4	13	25	16	15

Relationship between Average and Peak Values

Positive correlation seen between the average NO_x high idle test results and acceleration test results for individual vehicles.



Opus Trial Overview

- 3DATX persisted through COVID to begin the trial with Opus in Sweden:
  - Trial preparation for Borås and Skellefteå sites completed before Christmas 2020
  - Initial on-line training in Borås completed by 3DATX on January 17th
  - Protocol development testing in progress , including two separate NOx protocols
  - Training by Opus in Skellefteå by Opus personnel on February 17th
  - "Production" testing planned to begin on both Borås and Skellefteå sites
- Comments from Opus Inspectors:
  - parSYNC® iPEMS is "like a lab instrument" and is "pretty easy to use"
  - Time to complete extended test protocol, including install and uninstall –> 15-20 minutes
  - Can be installed and operated by one person
  - Bluetooth connection is robust – no disconnections yet
  - Improvements requested – tailpipe probe design to reduce install time, test protocol wizard GUI single rugged container for all components
  - Customer voluntary participation – 100% ☺

PTI Pilot Status

- PTI Trial progress in EU:
  - Germany: Simulated PTI Trial in progress with TRT Engineering in Munich,
    Training and testing planned in March with TüV-Nord in Essen and Dekra in Stuttgart
  - France: Training planned to begin with SGS France in Le Mans
  - Belgium: Training and testing foreseen to start in June/July
  - Spain: Awaiting feedback

3DATX Next Steps

- Phase 2 of testing in Sweden
  - Collect data from both sites - Borås and Skellefteå
  - Continue to refine the test protocol
  - Start publishing findings reports at regular intervals
- Phase 2 of PTI Pilot:
  - Expanded testing locations and strategic partners
  - Expanded scale of test vehicles
  - Continuing to consider additional strategic testing partners for target markets
- Database Development:
  - Coordinate with suitable partners such as JRC
  - Share vehicle emissions database with pilot partners
  - Provide a web-based interface to extract emissions trends and reports from the database

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  - Larry Mattison, Director of Engineering
  - Mike Dio, Lead – Customer Sales and Support
  - Sean Dineen, Head Engineer of Production
- Other
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