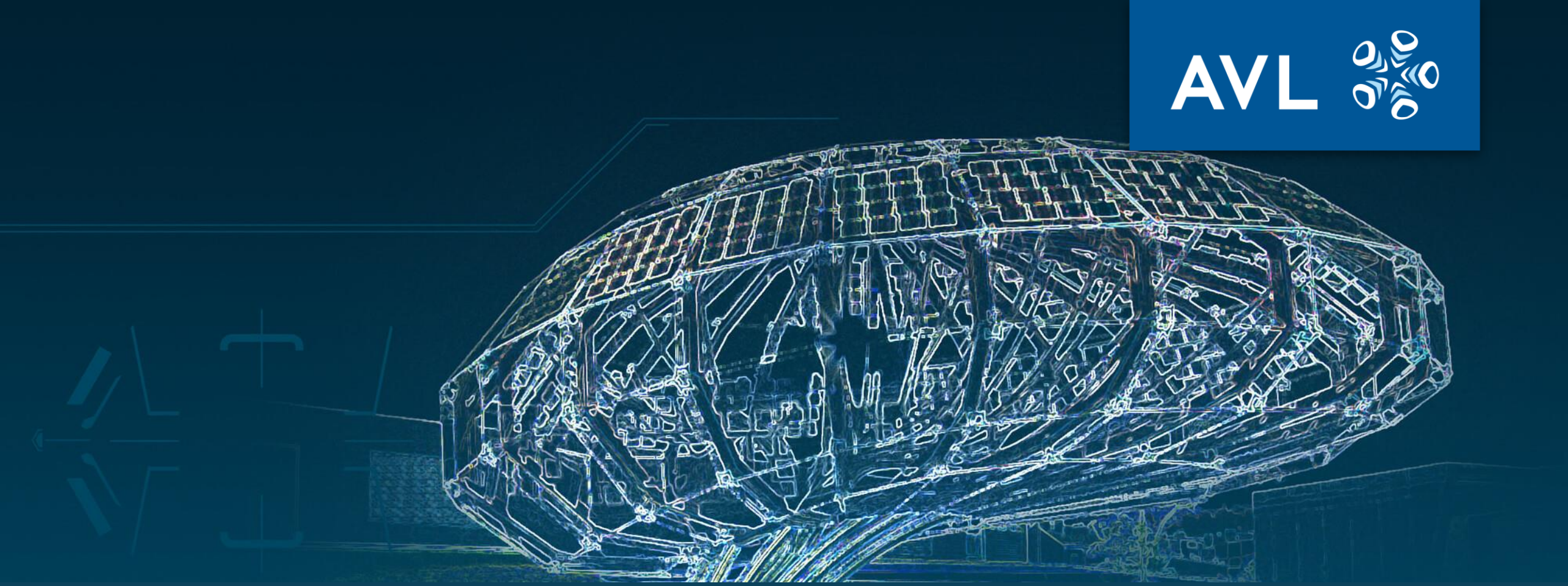


Testfield „OBD" and massive data analysis

A PTE success story ready to take off

Anomaly Detection in Test Fields

Anomaly Detection in Test Fields

Data science claims to **revolutionize** your test field efficiency.

Let‘s compare. This is your testfield **without** data science:

And this will be your testfield **with** data science:

…like if your doc diagnoses a slipped disk, but you still refuse your daily exercise

Anomaly Detection in Test Fields

Ok, that was a little provocative, but what does it really mean?

„Technology can be bought in – we need to develop people!“

Phil Lawson, JLR

So, you want to step into first league? Then you need….

Anomaly Detection in Test Fields

…an awesome race car!

…which means without self-adulation, an AVL testfield of course

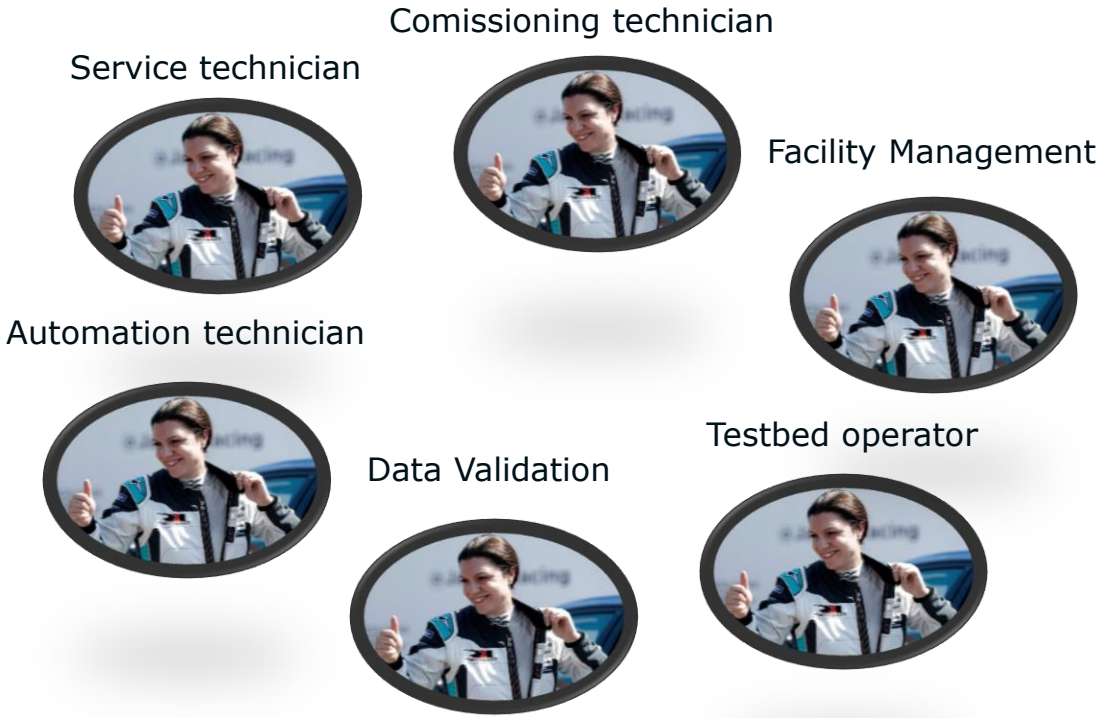
BUT!…

Anomaly Detection in Test Fields

BUT also…

…an awesome pilot!

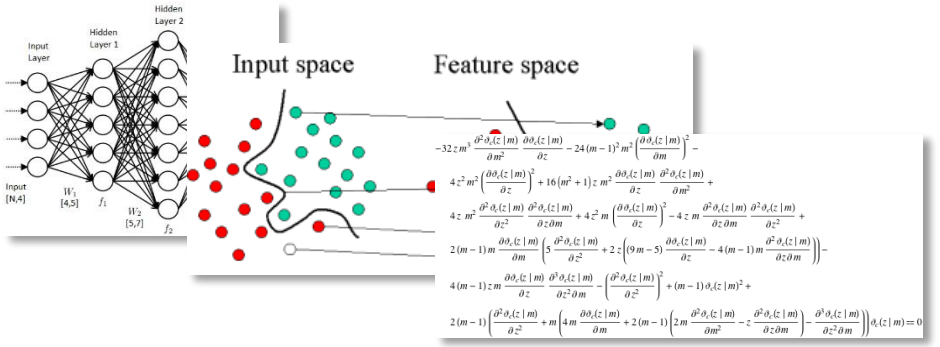
…which means a lot of pilots to be lead in your testfield contributing to maximize your test field output with meaningful data.

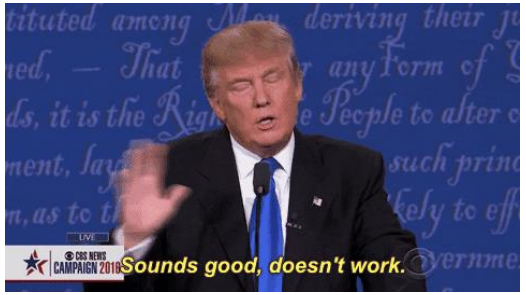


Anomaly Detection in Test Fields

So, what is the best approach to integrate data science to improve your testfield output?

Hire a mathematical genius!





...who communicates with

Automation technician

Service technician

Comissioning technician

Testbed operator

Facility Management

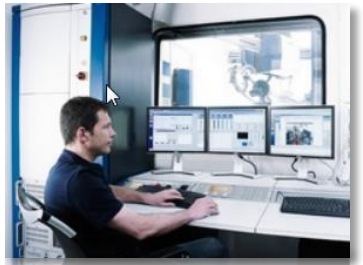
OMG, this person has no clue, what he is talking about....

The Evolution of a not planned PTE concept tool

The Evolution of a not planned PTE concept tool

Validation loop in 2011

Performing the test



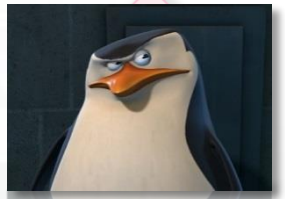
Generating Report and checking suspicious data manually

Released

Calibration Engineer

Released

Data Validation Engineer



suspicious

The Evolution of a not planned PTE concept tool

Validation loop in 2011

Performing the test

Calibration Engineer

Info if failed

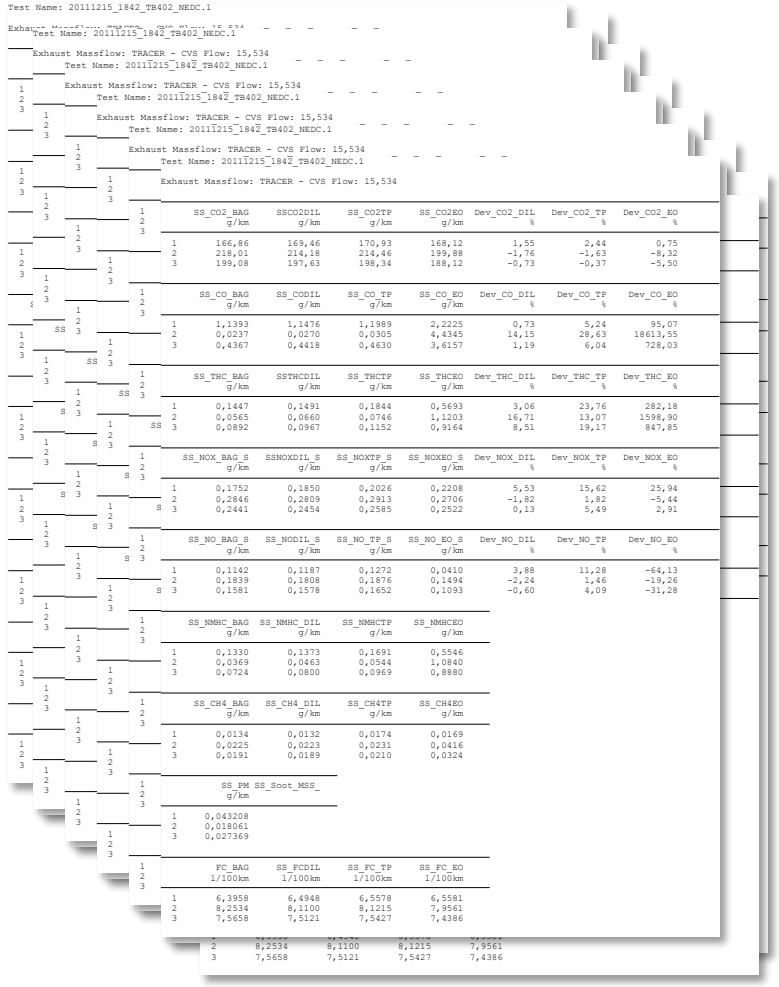
Data Validation Engineer

The Evolution of a not planned PTE concept tool

Validation loop in 2011 – first automation step – daily analysis

HOST

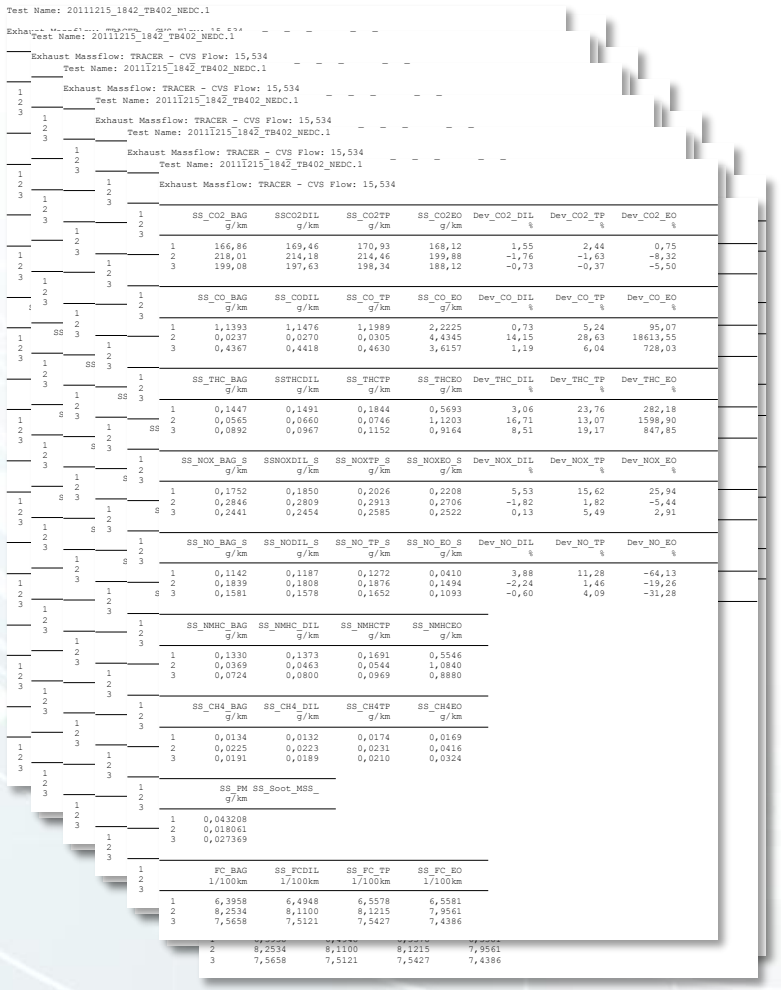
Concerto Script

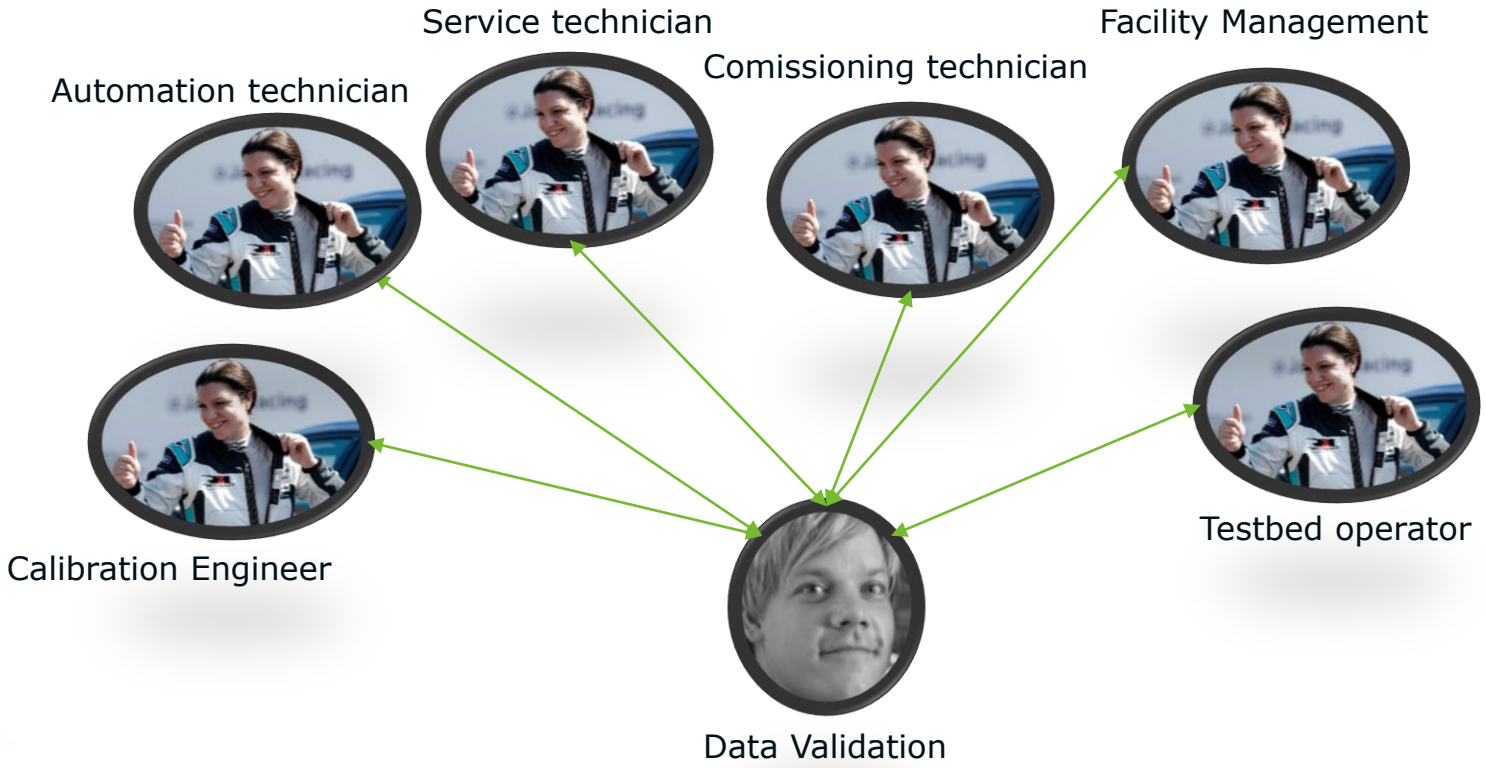


Manual check of all reports every morning… every day

The Evolution of a not planned PTE concept tool

Validation loop in 2011 – first automation step – daily analysis





Anomaly detection formula #1
Anomaly detection formula #2
Anomaly detection formula #3
Anomaly detection formula #4

Anomaly detection formula #5
Anomaly detection formula #6
Anomaly detection formula #...
Anomaly detection formula #...

Validation loop in 2011 – further automation steps

So, you managed to get through all data from the previous day and the ongoing shifts, heading home at 18:41…

Next day an applied anomaly detection detects an error at **18:42**. Which was an systematic error and all tests were broken until next morning.

…this is how i felt

Validation loop in 2011 – further automation steps

Furthermore, if an faulty measurement has been detected still a deep dive through the data via data analytics in concerto had to be done.

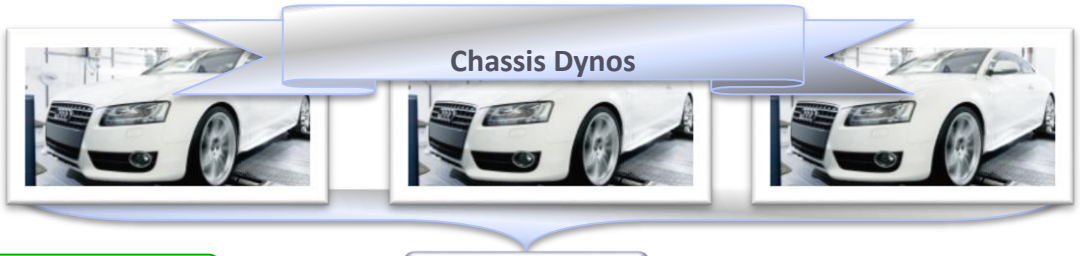
…but issues started being repetitive. It cristalized more and more a standard data analytics report.

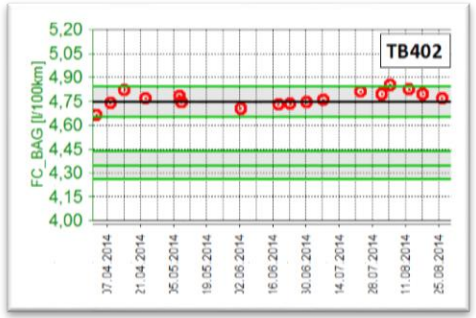
Next steps were obvious.

Mail notification of a standard data validation layout as PDF right after tests had been finished.

The Evolution of a not planned PTE concept tool

Review of Status 2014





Plausibility Task

All needed **signals** (flow, pressure, temperature, humidity, all gas species) for the modal analysis, the final **test results** and **chassis dyno parameter** are checked.

Signals:
- Validation check
- Limit monitoring
- Statistical analysis, Measuring range violation

Test results:
- Deviations BAG/DIL/TP
- Carbon balance BAG/DIL/TP/EO

Chassis dyno parameter:
- Parameter check (Removal rates, Coast down parameter etc.)

Concerto

Emission Calculation
Modalanalyis

Plausibilisation Rules
List of Errors
Standardized Report as PDF

Automated
Golden Vehicle Check

Automated
Validation

Blocked

Manual Release

Warning
Manual Check

PASSED

INVALID

Customer

Outlook *Excel*

- *Test Database*
- *Error Categories*
- *Fast and easy search*
- *Error Statistics*

...still only concerto scripts

The Evolution of a not planned PTE concept tool

Next Steps: Including INCA Files

Service/Maintenance/Comissioning processes have been improved. Total failure rate with 7% in 2011 only regarding emission measurement could be reduced to an **overall** failure rate of lower than 2%.

…but data validation job remained „hard“. Still complains like:“ECU Dataset has been changed, but change is not reflected in the measurement data.“

More and more single complains took several days of analysis to prove whether measurement equipment or UUT being the root cause.

ECU data started to play a significant role in anomaly detection. But INCA files were stored project specific.

Next Step: Including INCA Files

Santorin HOST

- Same storage hierarchy
- Automated, meaningfull nameing
- Algorithm for automated syncing PUMA and INCA data
- Linked→easily open them together

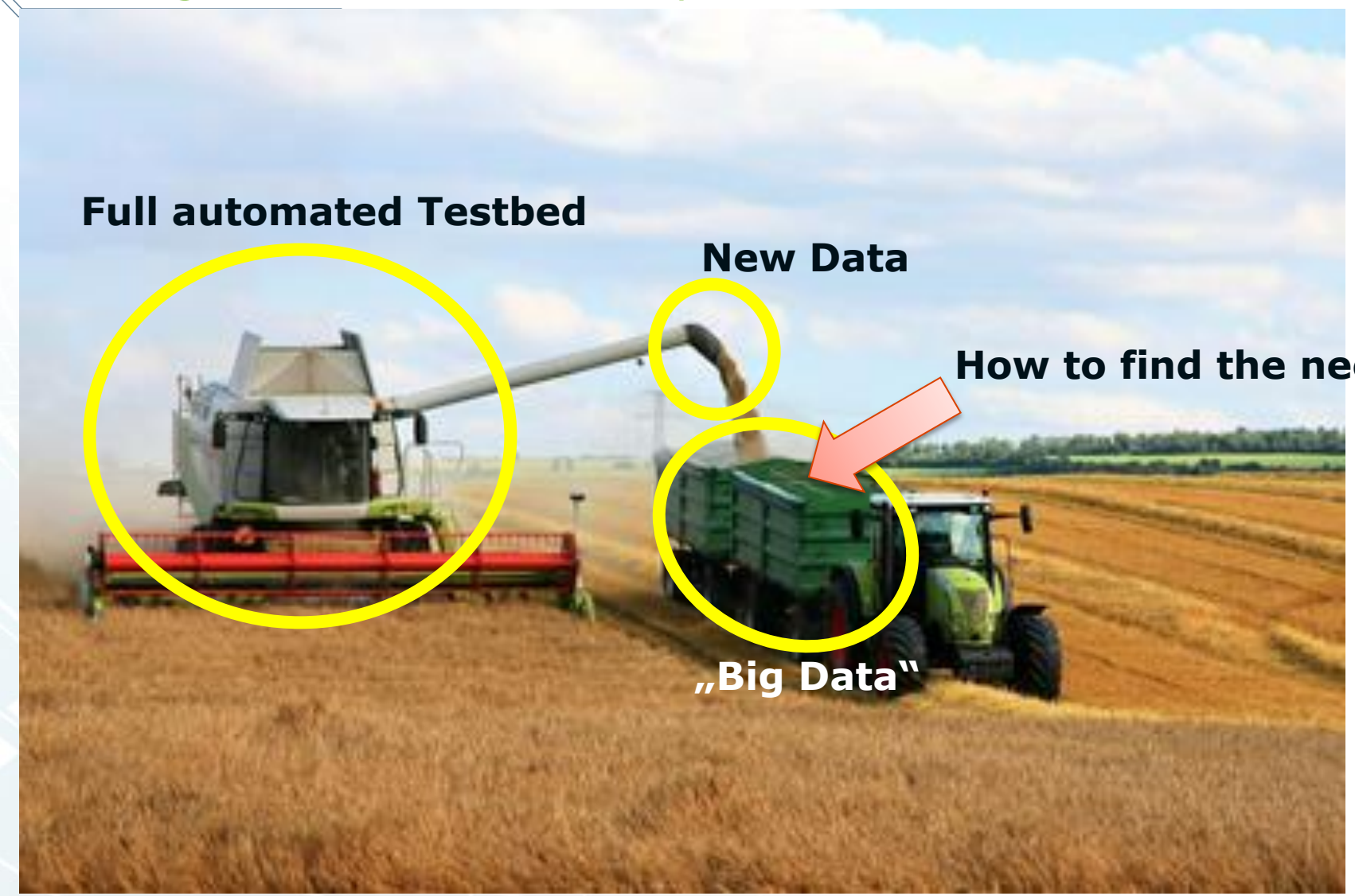
…Whats missing? A GUI

INCA HOST

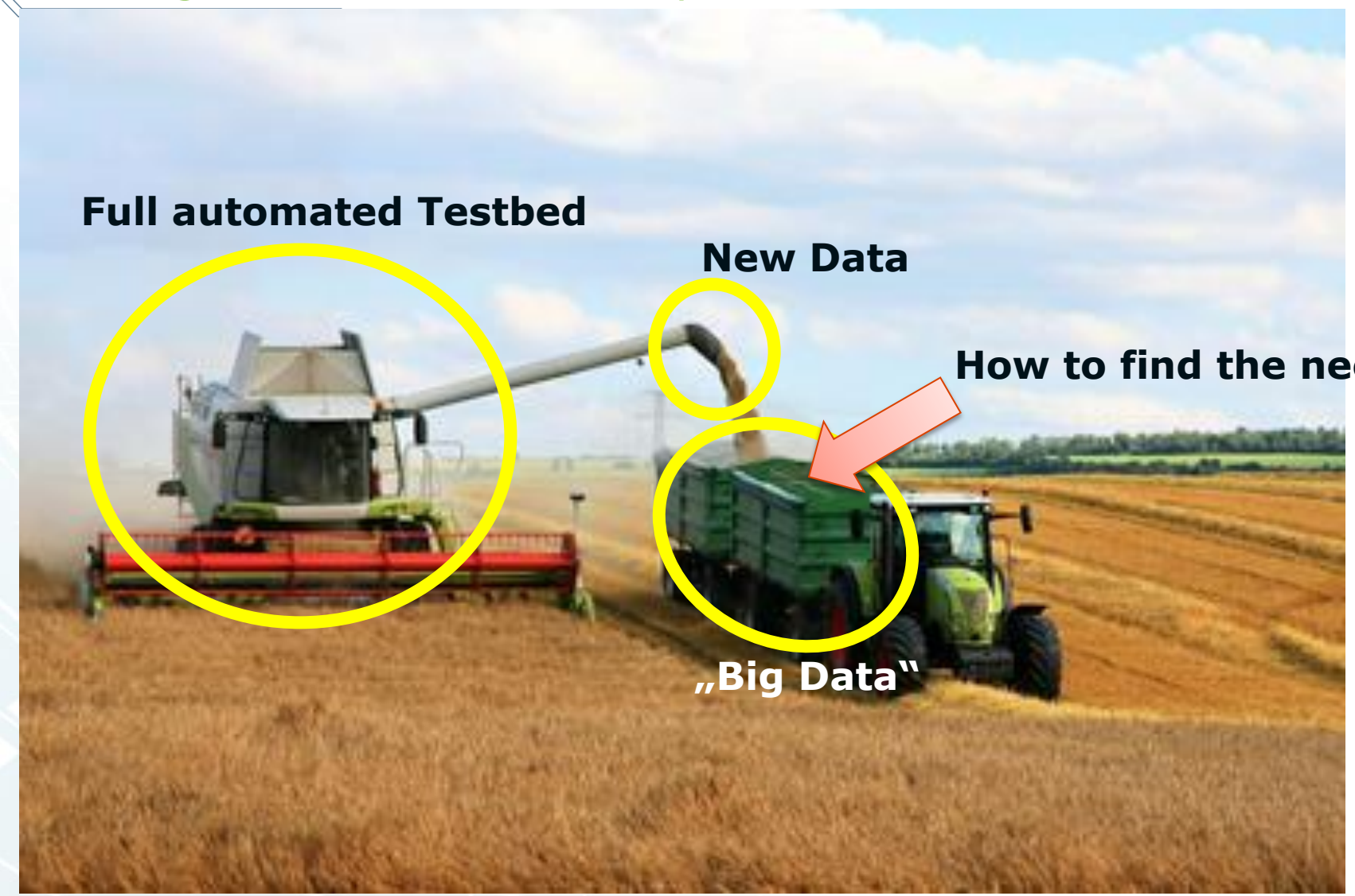
Testfield „OBD” and massive data analysis

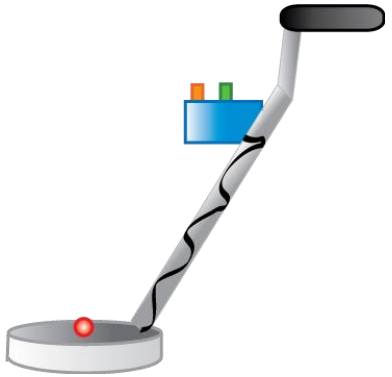
CalRep is born...

CalRep
Looking for the needle in a haystack



CalRep
Looking for the needle in a haystack

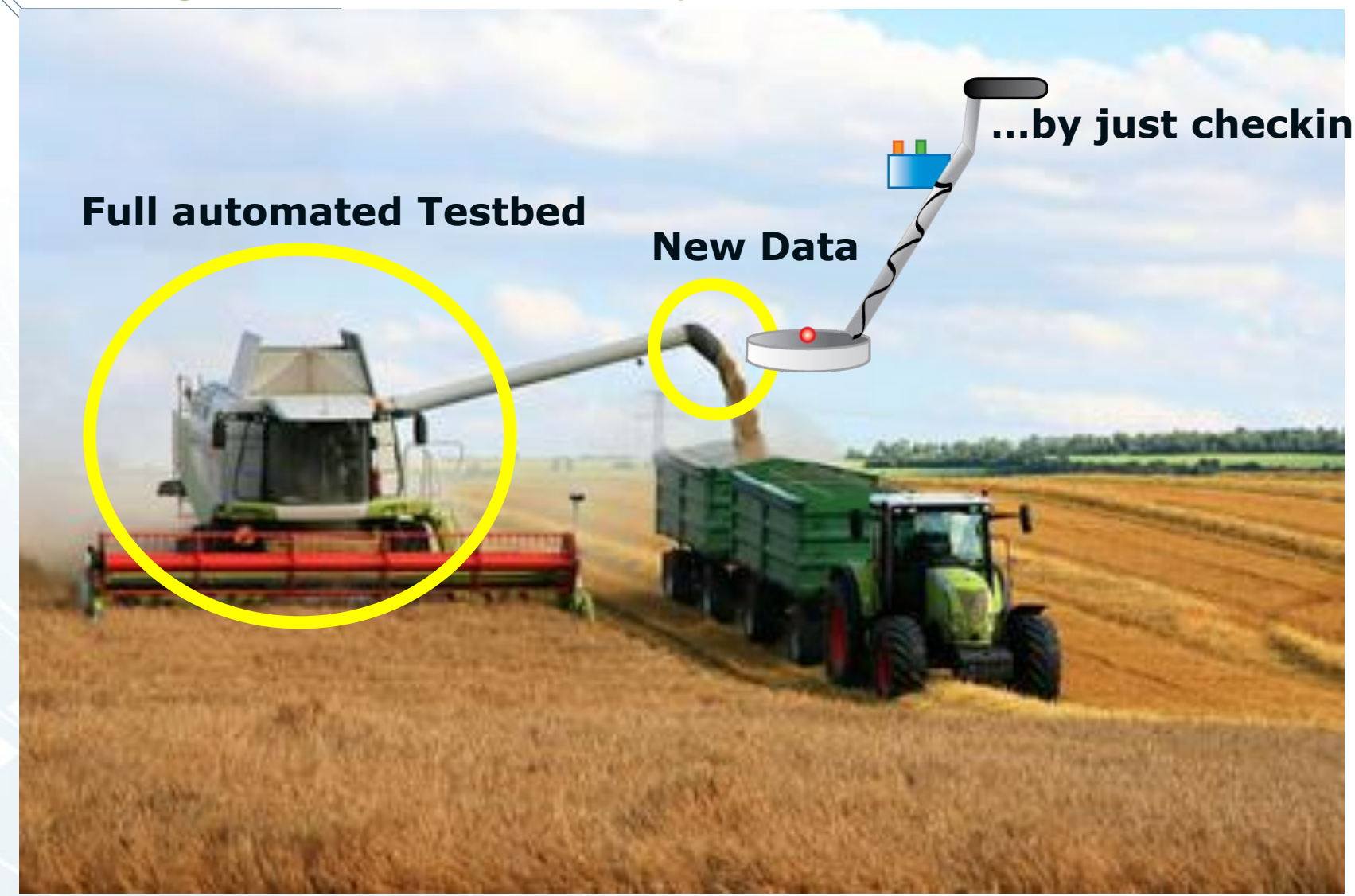




Not checking every straw (misunderstood Big Data Analysis), but with a metal detector.

But where?

CalRep
Looking for the needle in a haystack



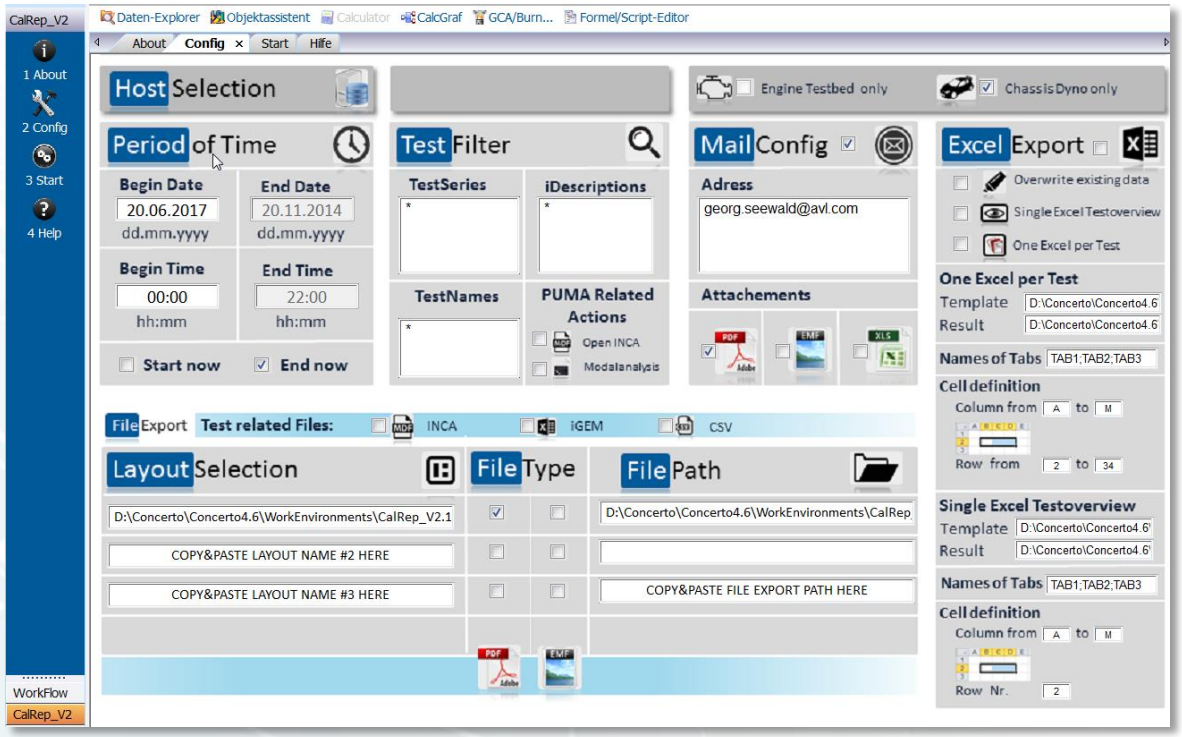
AVL PTE Concept Tool

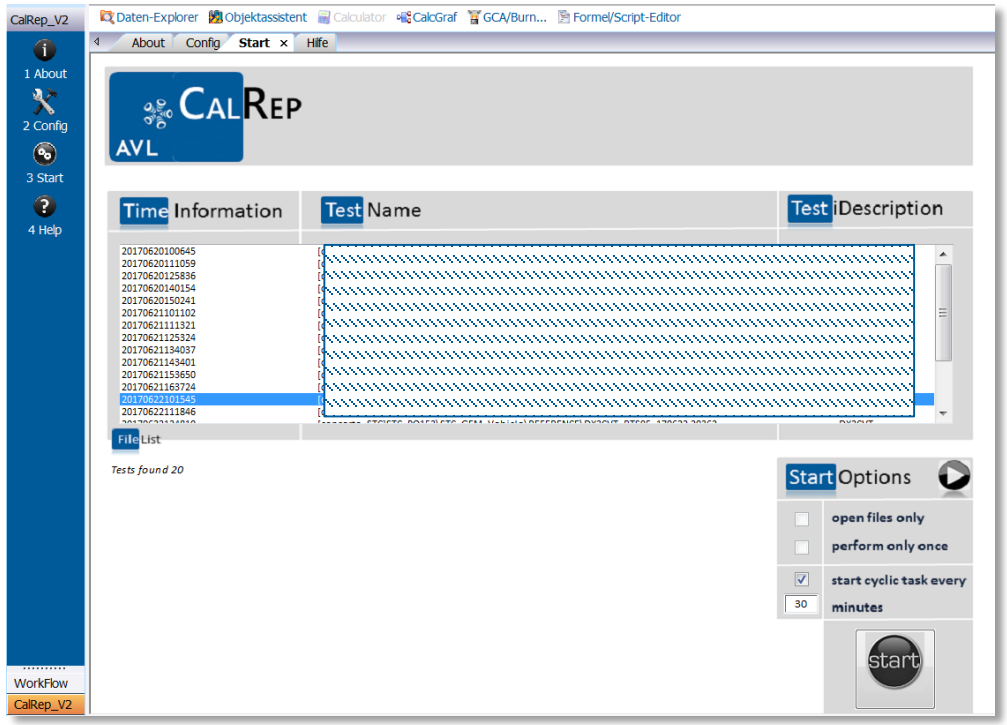
- Validation of all new test field data in a definable period e.g.: every 15min
- Applying plausibility checks = Testfield OBD
- Instant mail notification with definable analytics (layouts)
- And many more features

CalRep
Looking for the needle in a haystack

CalRep V2.0 – with graphical user interface

CalRep is an AVL Concerto based application for **Testfield „OBD“,** generating automated testing and validation reports for PUMA and linked INCA tests





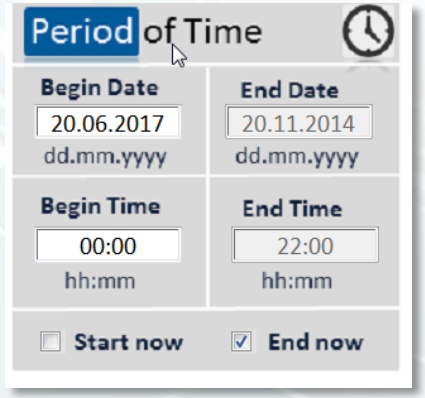
CalRep
Looking for the needle in a haystack

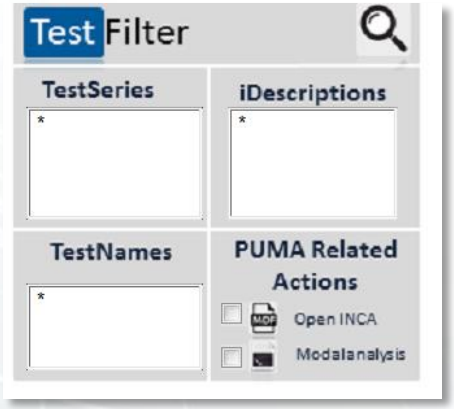
CalRep V2.0 – with graphical user interface

What can you do with CalRep?

- Choose your current Host (datasource) representing the Testing Environment, like Engine Testbed, PTTB or Chassis dyno, where you want your automated reports.

- Set Filters for the according datasource, like
  - Date and time, from – to (Massive Data Analysis or Continous Analysis)
  - Project names, Testseries names or even test names (NEDC, FTP75, WLTC, WHTC etc.)





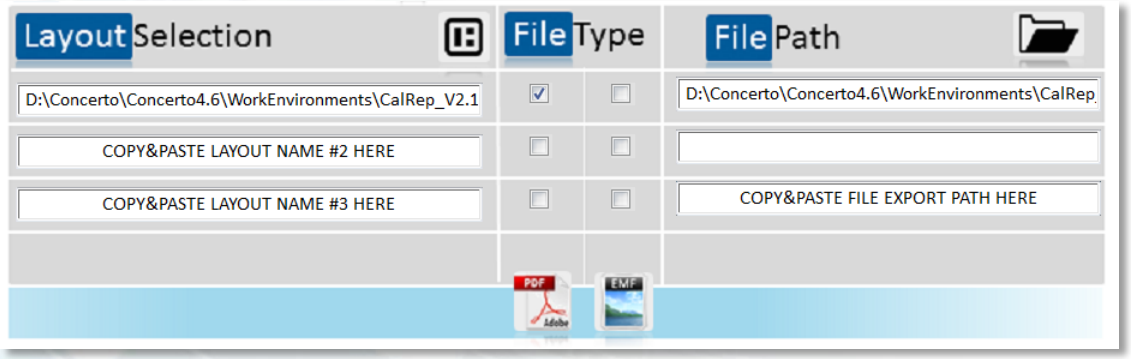
CalRep
Looking for the needle in a haystack

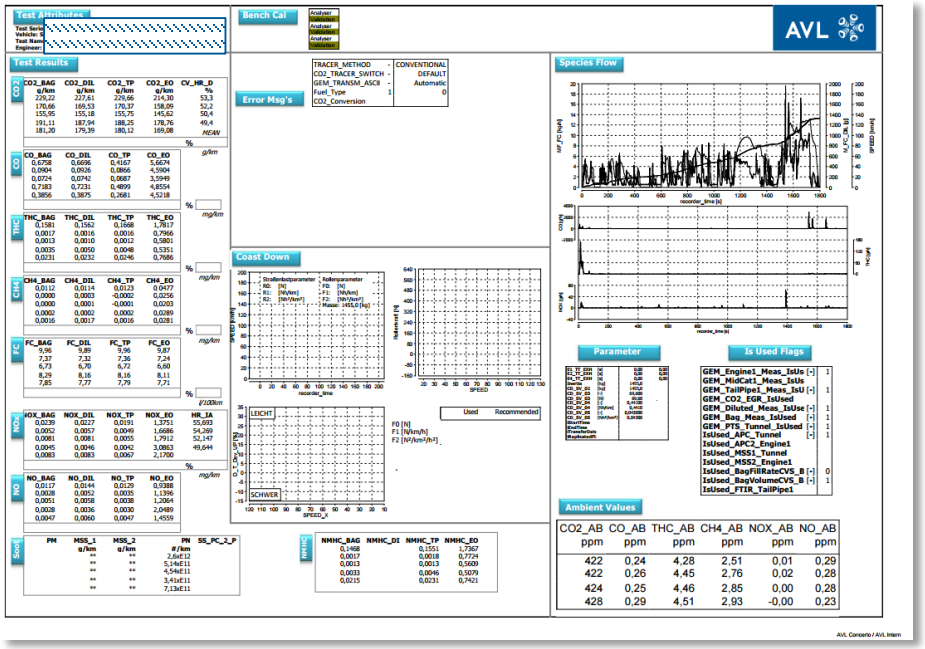
CalRep V2.0 – with graphical user interface

What can you do with CalRep?

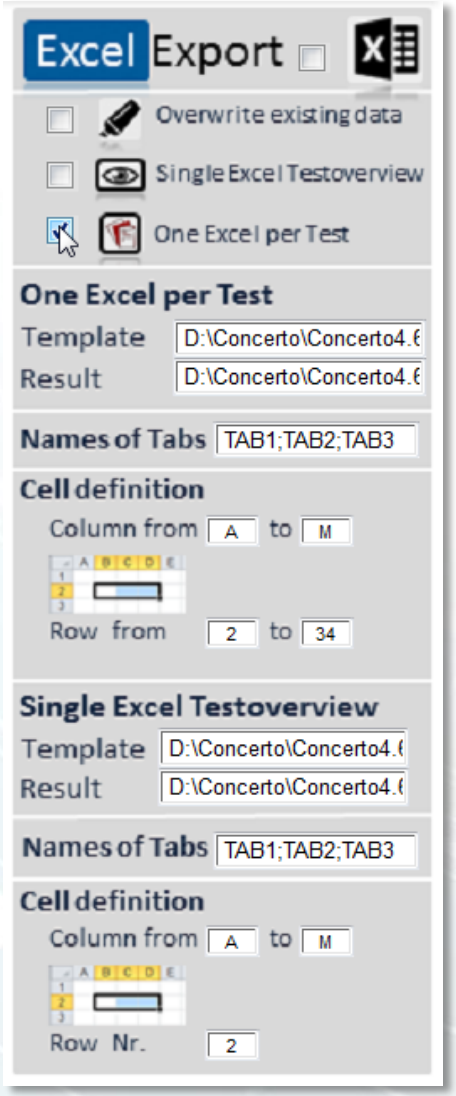
- Choose several customer specific Layout's, that will be applied on each test.
- Export those Layouts (or its pages seperately) to specific locations in choosable formats like
  - PDF
  - EMF

→*could furthermore be used for automated generating of PowerPoint reports!*





CalRep
Looking for the needle in a haystack

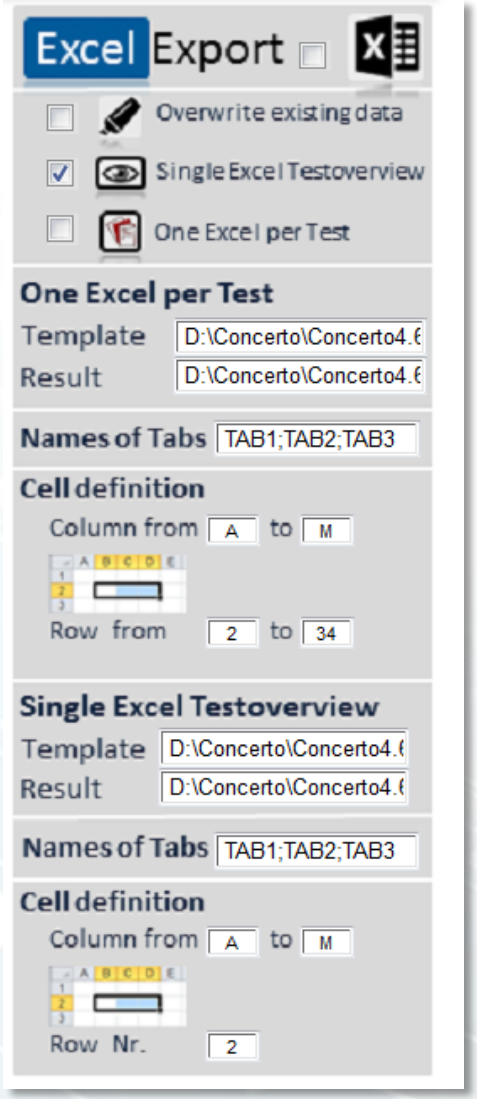


CalRep V2.0 – with graphical user interface

What can you do with CalRep?

- Useage of the internal **Excel Report Generator**
  - **Single Test Report**
    - Define an Excel Template. CalRep supports several tabs.
    - Choose as many channels of the test shown concerto as you like. It supports PUMA channels as well as channels from concerto forumula
    - Define single results or whole channels to report
    - With additional provided syntax information you can also report average, minimum, maximum or indicated (e.g. use always first, last or n-th entry of the channel) values of the defined channel
    - The Excel Template can also include diagramms to plot the results

CalRep
Looking for the needle in a haystack



CalRep V2.0 – with graphical user interface

What can you do with CalRep?

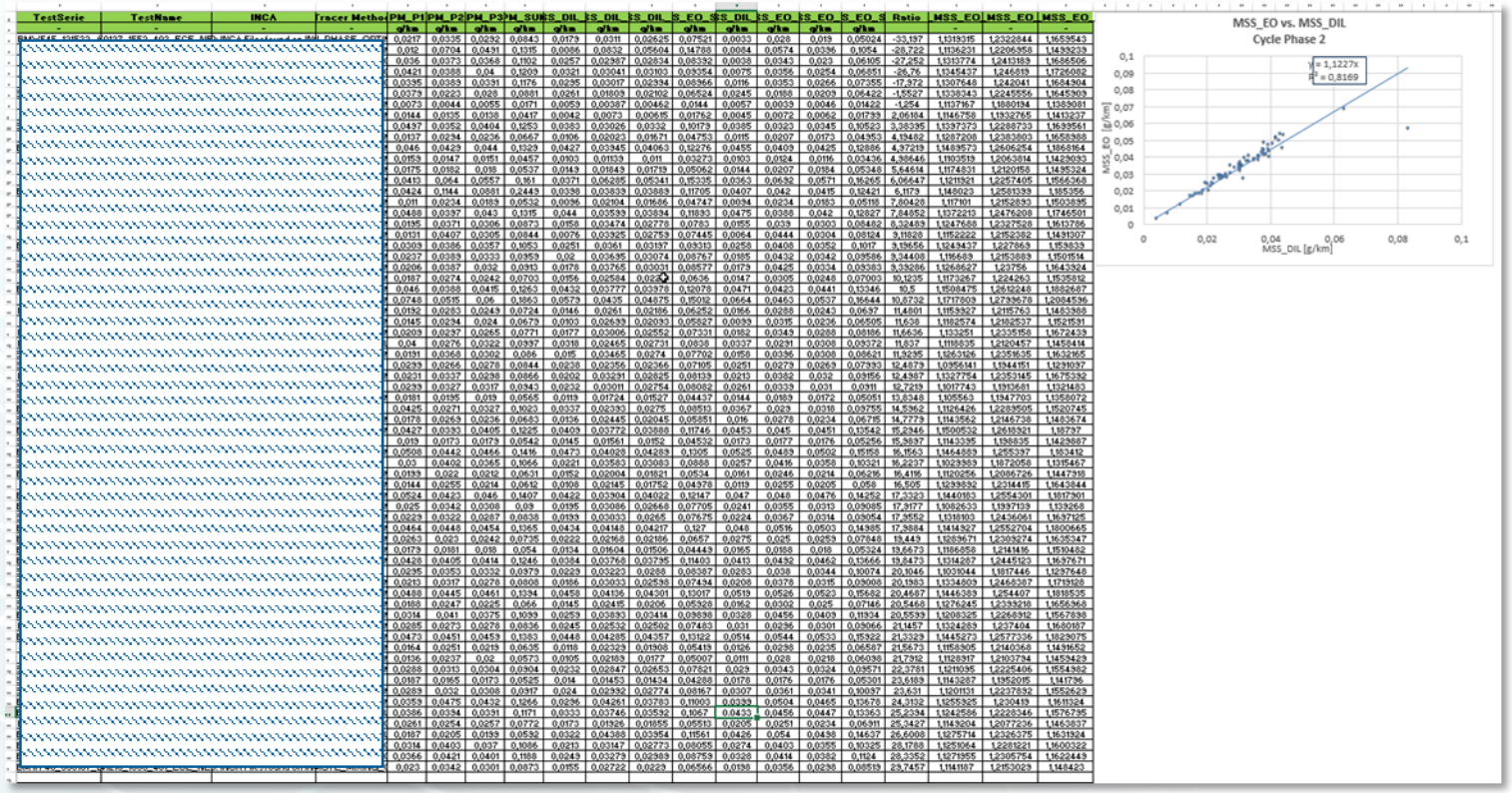
- Useage of the internal **Excel Report Generator**
  - **Overall TestSeries Report** (in addition to the Single Test Report)
    - Define an Excel Template. CalRep supports several tabs.
    - Each test is represented in one row, each column contains a free choosable value of PUMA or Concerto-formula value up to the maximum supported columns of Excel

CalRep
Looking for the needle in a haystack

CalRep V2.0 – with graphical user interface

What can you do with CalRep?

- Useage of the internal **Excel Report Generator - Example**



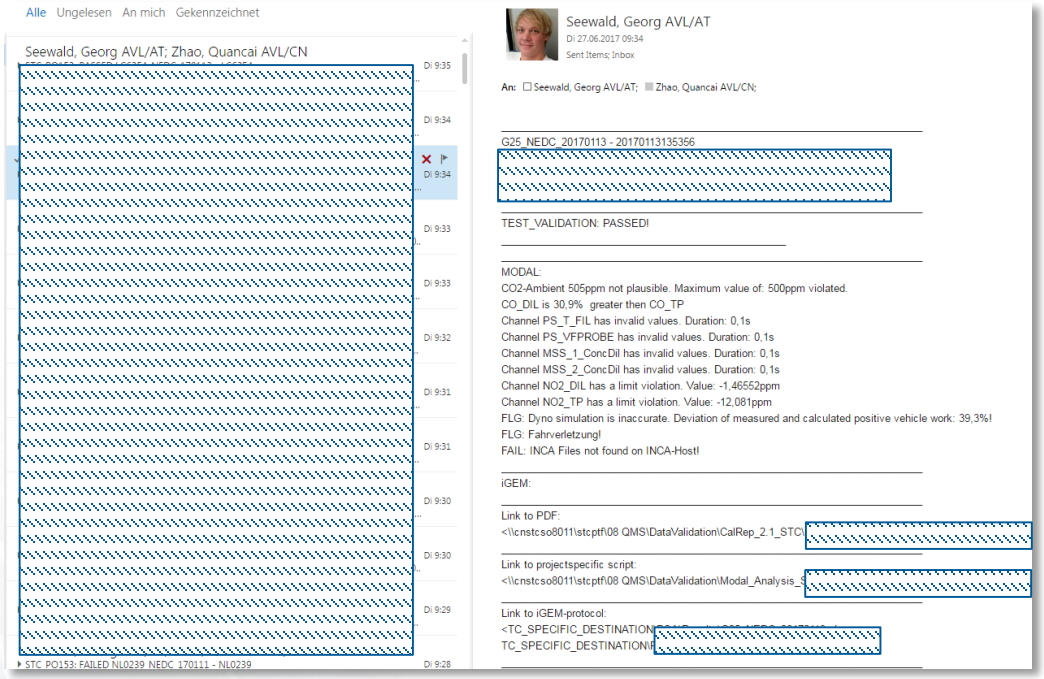
Correlation Analysis for new „Testfield OBD“ functions

CalRep
Looking for the needle in a haystack

CalRep V2.0 – with graphical user interface

What can you do with CalRep?

- Choose result for distribution via E-Mail@
  - Choose which results (Layouts, Excel Reports) you want to distribute
  - Define Mail distribution list with the colleagues you want to share the results

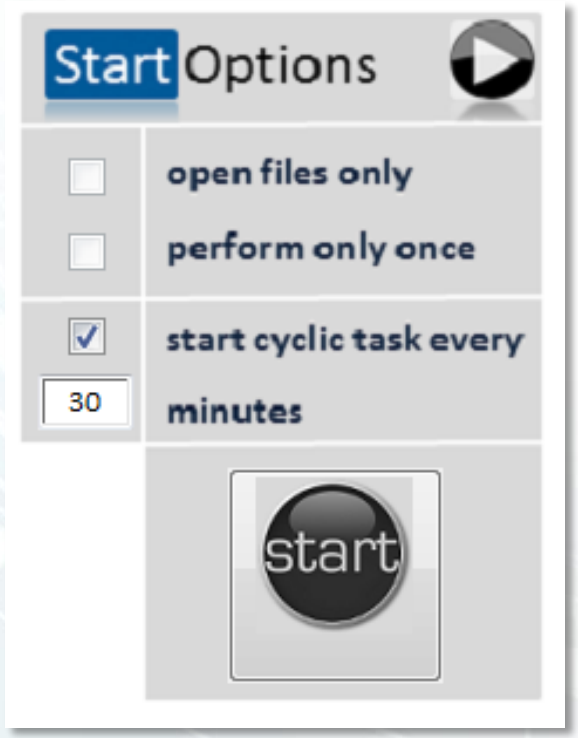


CalRep
Looking for the needle in a haystack

CalRep V2.0 – with graphical user interface

What can you do with CalRep?

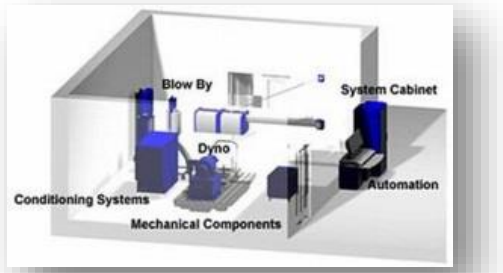
- Define Actions that shall be applied on the tests according to your filter setting



1. Just open the tests meeting the filter settings for other operations than supported by calrep
2. Perform CalRep only once for the selected tests for e.g. massive analysis of the past
3. **Start Cyclic Operation,** where every x minutes new tests on the selcted datasource will be searched according the filter settings and the selected layouts and excel reports can be stored on the specified location or sent by mail to the specified mail distribution list.

Of course, you can use the tool to analyse all historic data (Big Data Analysis)

CalRep
Looking for the needle in a haystack



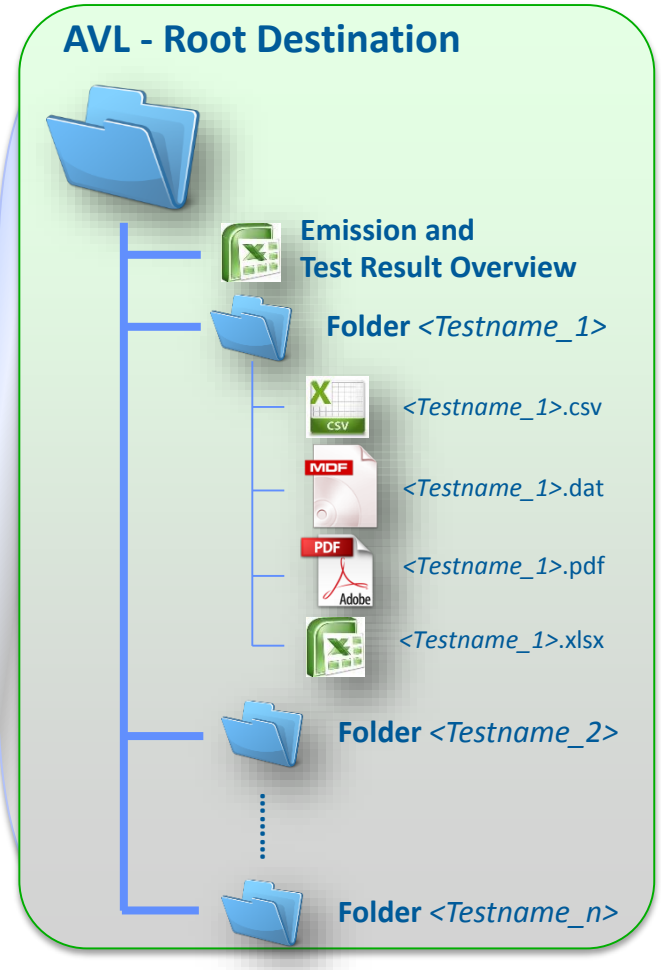
PUMA

INCA

Cyclic Test Searching Task

Concerto

- Emission calulcation acc. legislation
- Automated shifting,cutting and synchronisation PUMA-INCA
- testspecific time-based PDF export of a defined layout
- generating a CVS-file including time-based results of emission results and INCA-data
- automated filling of emission and test results overview



Testfield „OBD” and massive data analysis

Nice spin-off innovations along the road.

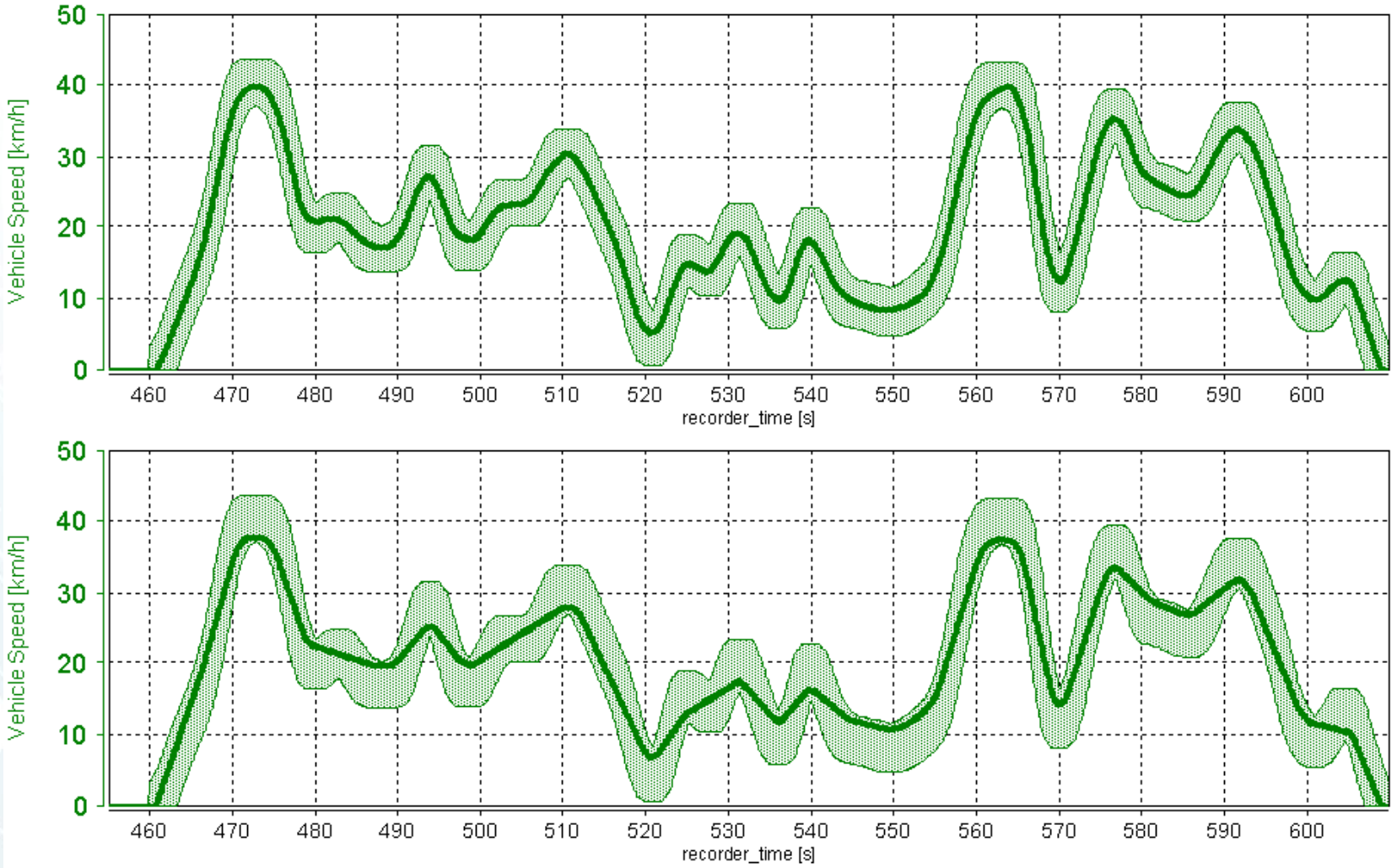
Artificial Human driver algorithm

Human driver algorithm

When complaining about ECU changes were not reflected in the measurement results, or worse: ECU data set has not changed, but results differ significantly in the most cases a different driving style could be identified, but only by means of visual comparison.

An artificial human driver algorithm has been devloped to derive an index about the real human drivers performance.

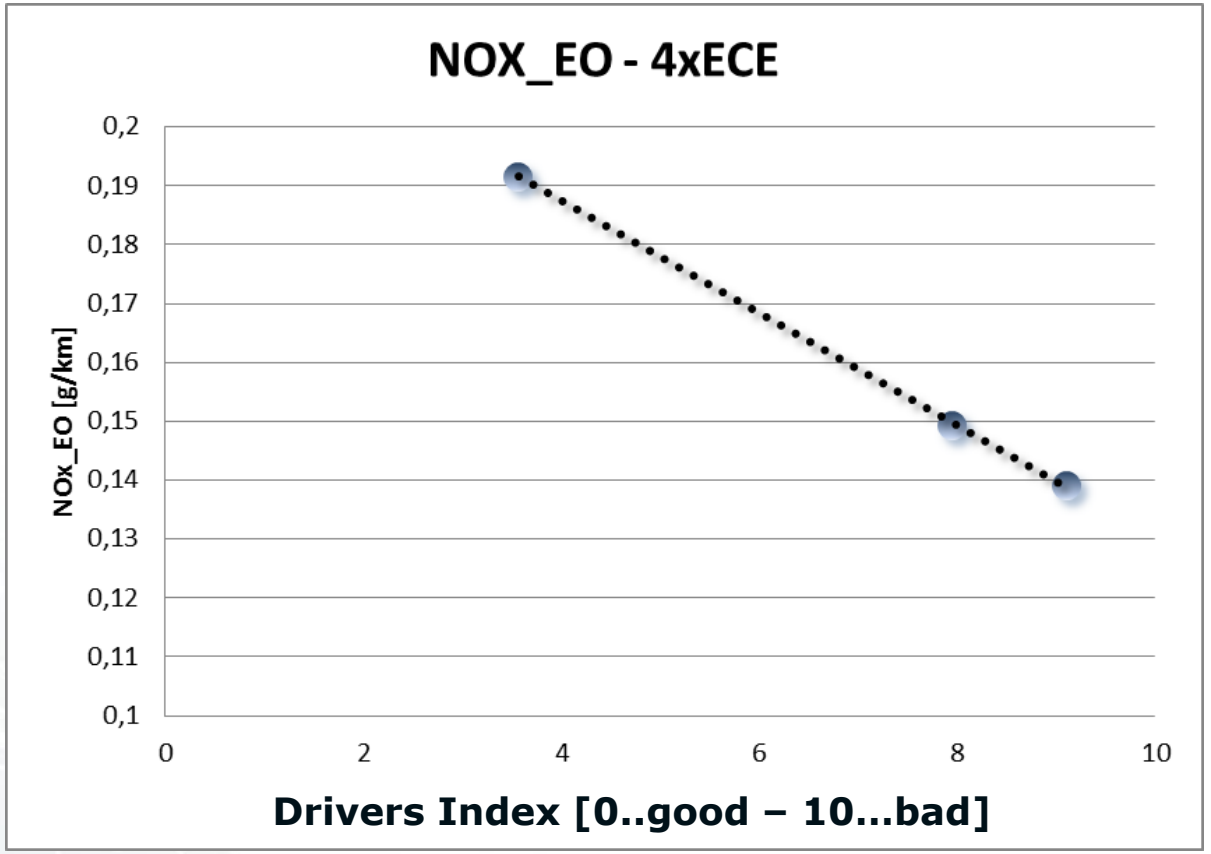
Human driver algorithm



Self developed „Optimum Path Algorithm" being quite near to a smooth human driver.

Utilizing curve characeristics for a drivers index.

Human driver algorithm



Correlation of drivers index with NOX engine out emissions.

Testfield „OBD” and massive data analysis

Massive Data Analysis with CalRep

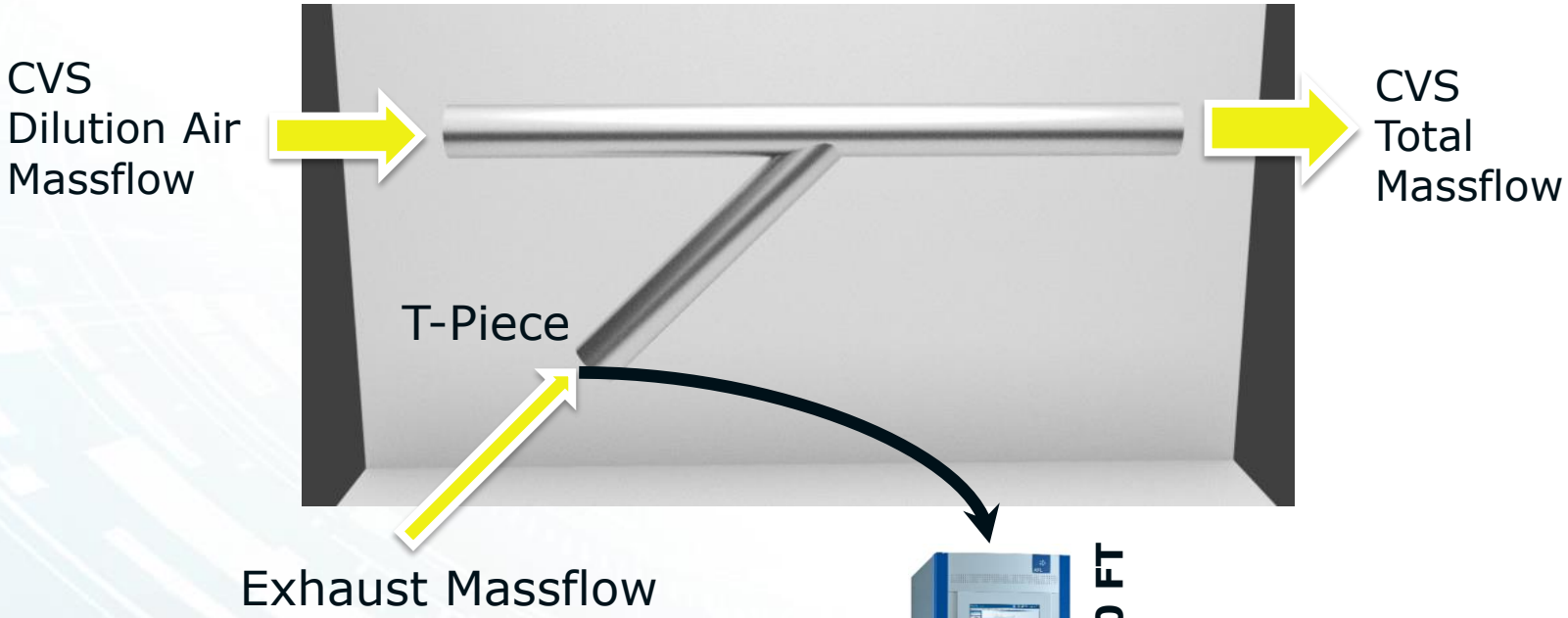
Bag to Modal with FTIR

Massive Data Analysis

Optimization Bag to Raw Modal Correlation

1. BAG AMA i60 vs. FTIR i60 at TailPipe

Setup



FTIR - Sesam i60 FT

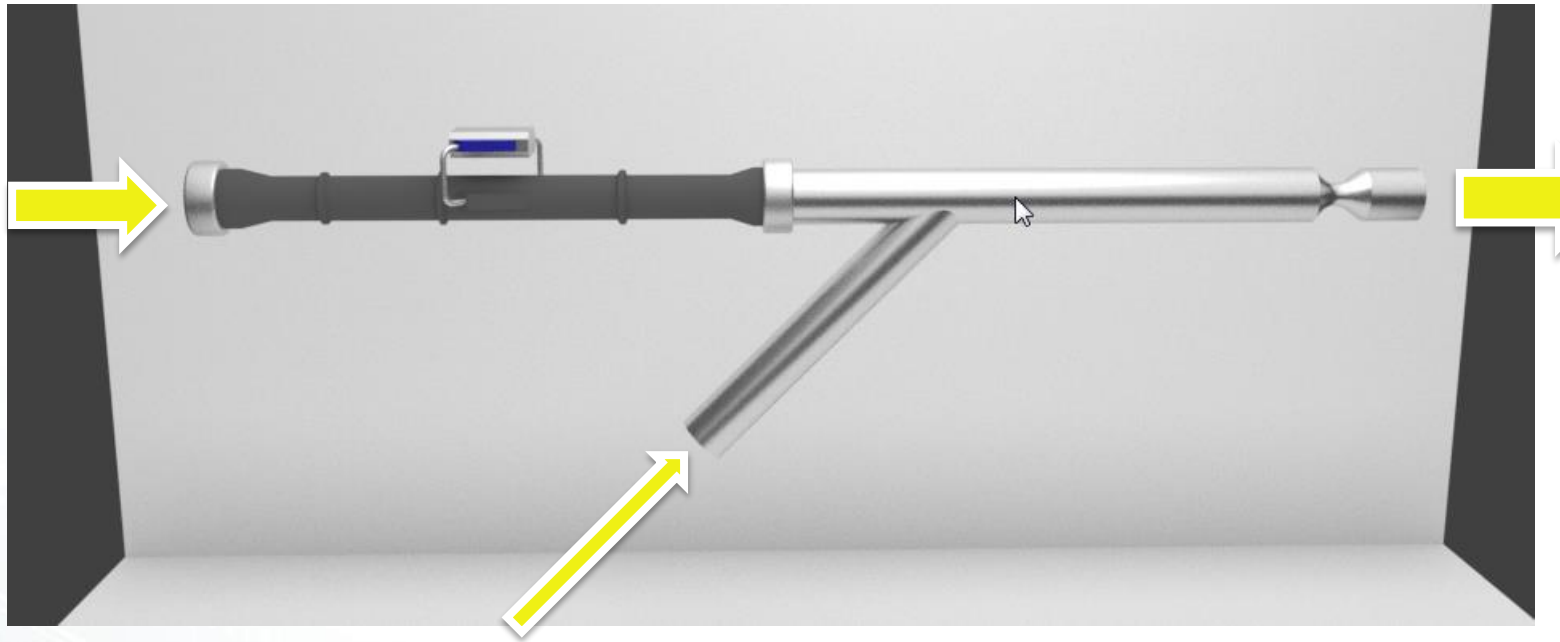
Testing

Chassis Dynos	3
Total Number of Tests	131
WLTC	77
NEDC	17
JC_08	11
OffCycle	11
FTP75	1
RDE	8
ADACEco	6

Massive Data Analysis

Optimization Bag to Raw Modal Correlation

2. Exhaust mass flow determination with CVS total flow and FlowSonix CVS dilution air measurement

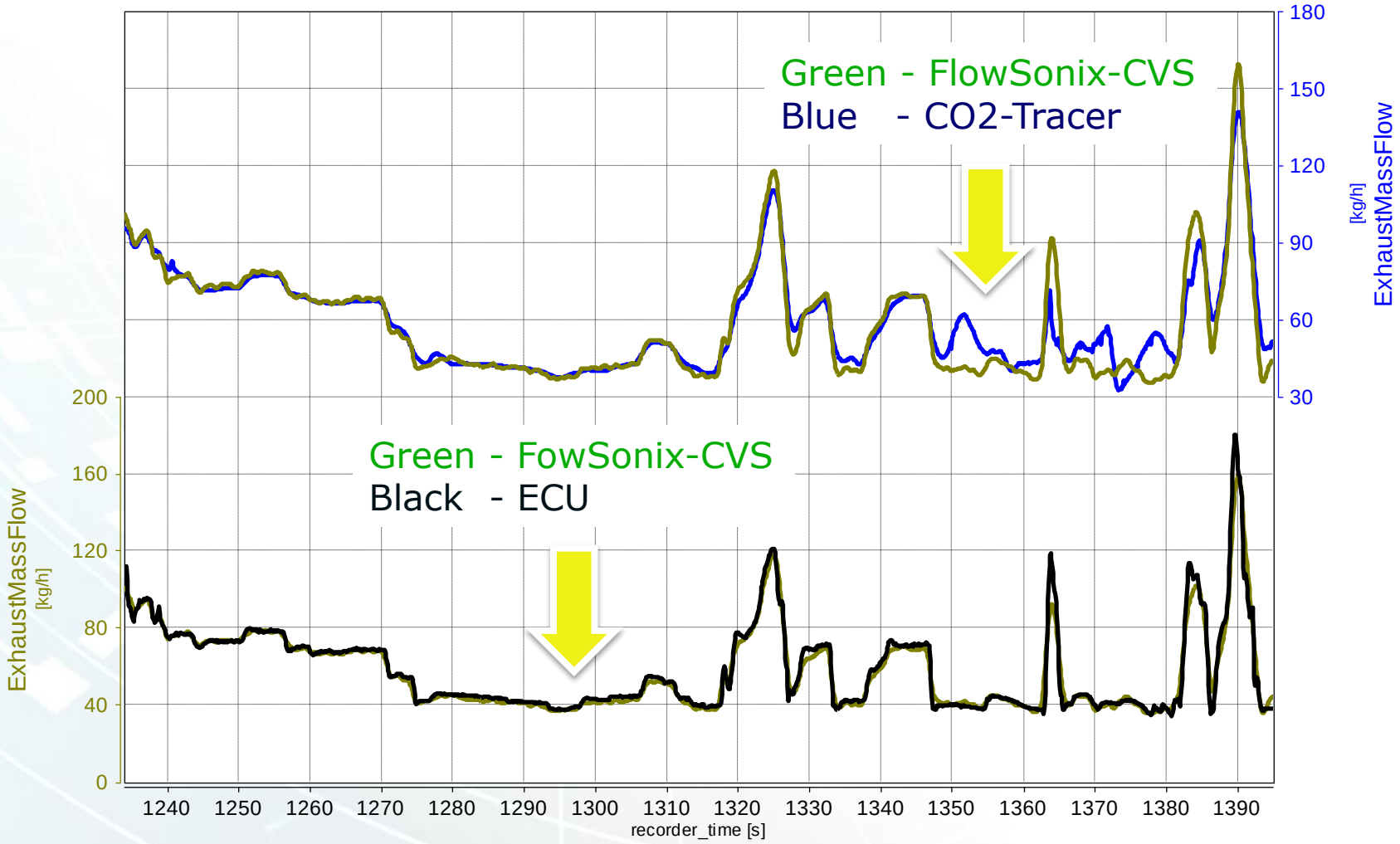


$$\dot{m}_{EXHAUST} = \left(\dot{m}_{CVS\_TOT} - \dot{m}_{CVS\_DIL}\right)$$ *...it is a bit more complex ;)*

Massive Data Analysis

Optimization Bag to Raw Modal Correlation

3. Potential Optimizations to Improve Bag to Raw Modal Correlation



Exhaust Mass Flow

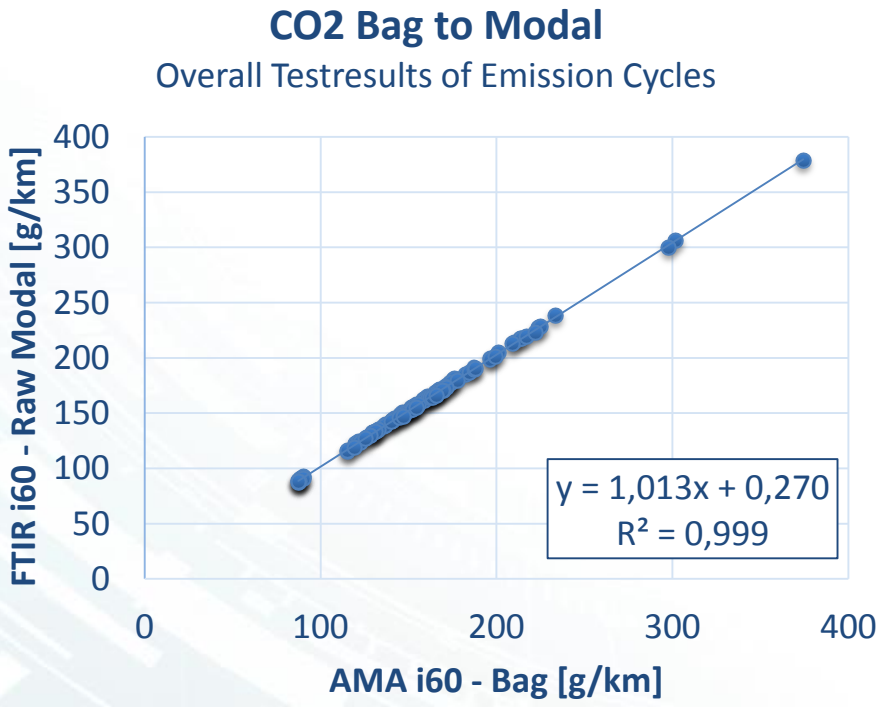
A further optimization can be achieved to switch from CO2-Tracer to CVS-Dilution Air (FlowSonix) based exhaust mass flow determination.

Like shown in the figure, the CO2 Tracer suffers from low analyzer dynamic aswell as from motoring phases, where no CO2 is emitted. Furthermore, CO2 Tracer only has no values during engine start.

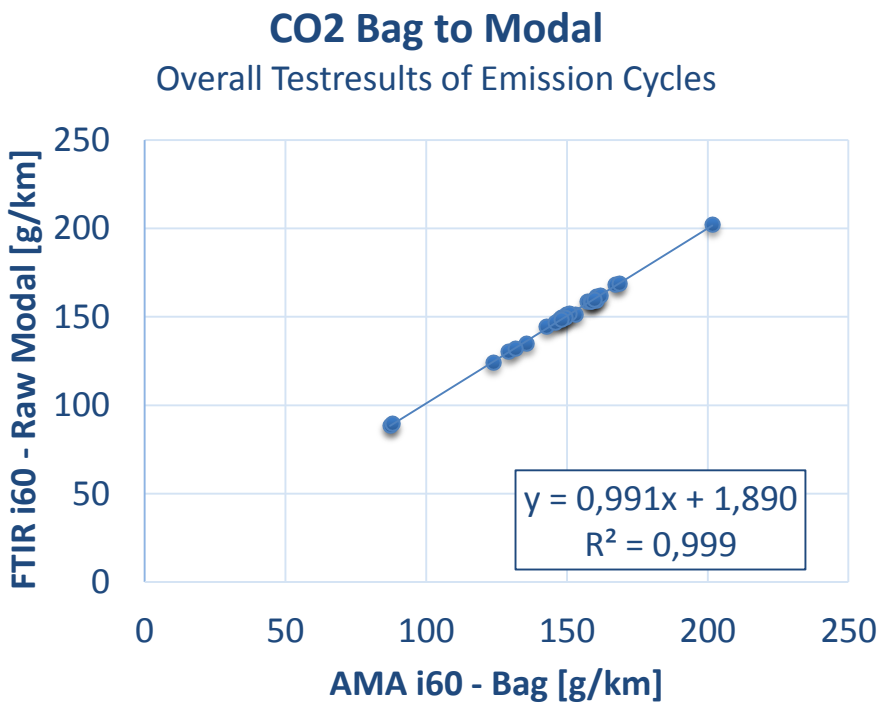
Despite some signal improvments can be done offline, the direct exhaust mass flow measurement via FlowSonix and CVS achieves much better time based signals.

Massive Data Analysis
Optimization Bag to Raw Modal Correlation

4. Impact of exhaust mass flow method on Bag to Raw Modal Correlation



CO2 - Tracer

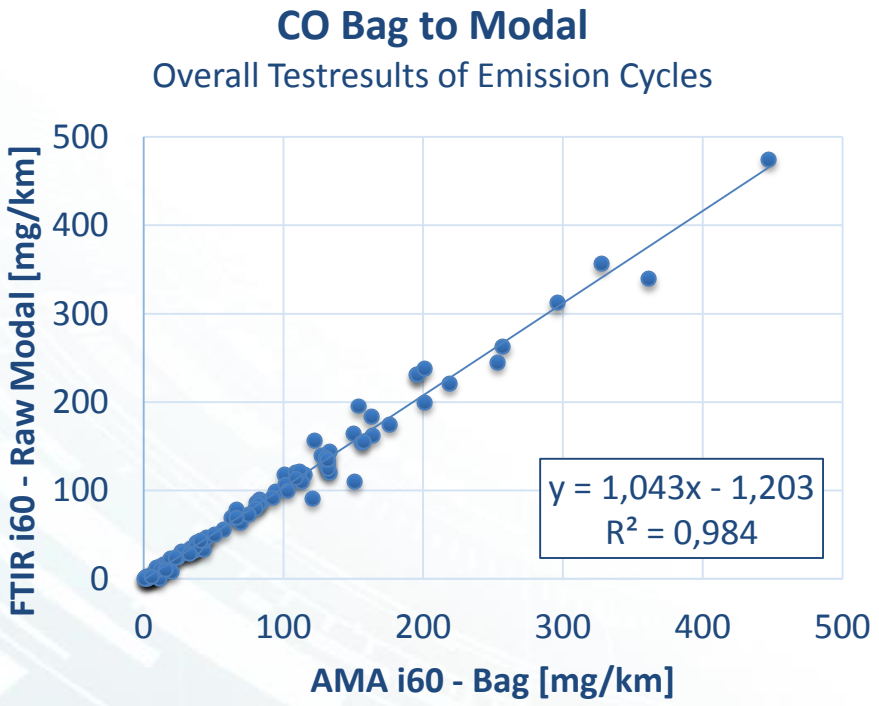


FlowSonix

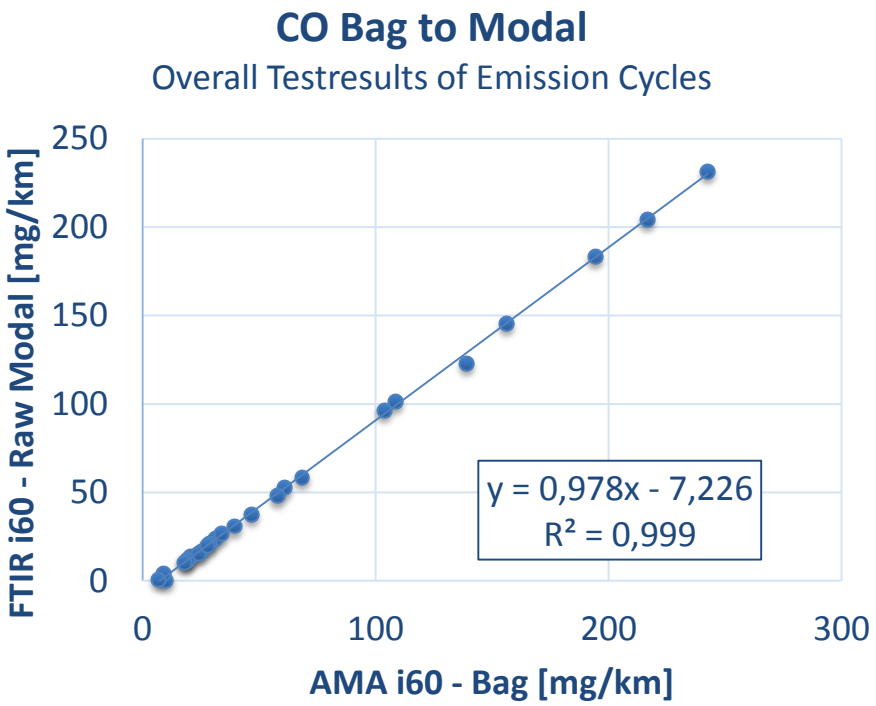
Massive Data Analysis

Optimization Bag to Raw Modal Correlation

4. Impact of exhaust mass flow method on Bag to Raw Modal Correlation



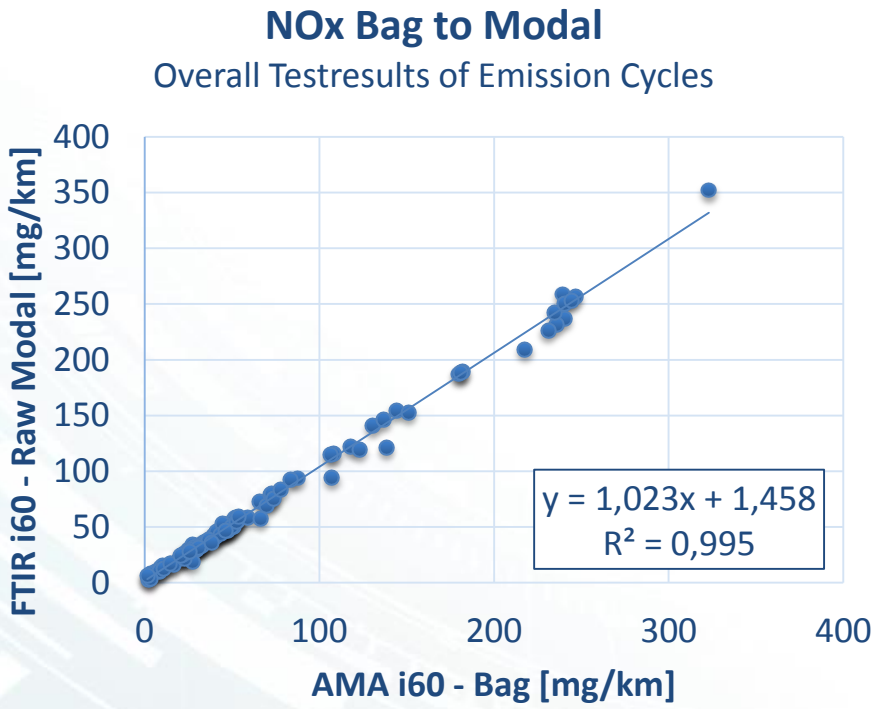
CO2 - Tracer



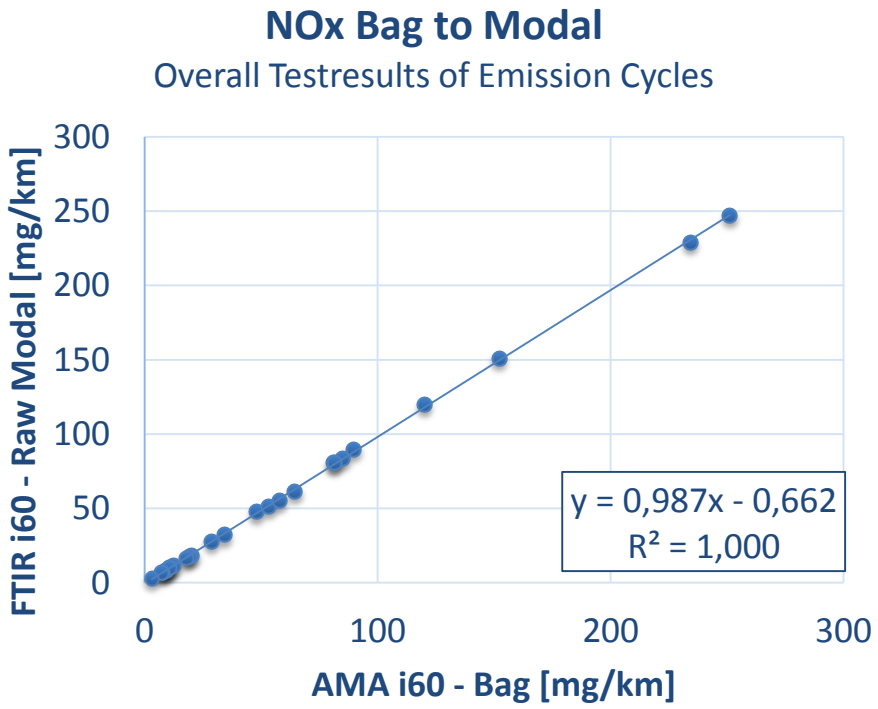
FlowSonix

Massive Data Analysis
Optimization Bag to Raw Modal Correlation

4. Impact of exhaust mass flow method on Bag to Raw Modal Correlation



CO2 - Tracer



FlowSonix

Testfield „OBD” and massive data analysis

How can you benefit from that?

Future business models.

What about digital services?