MTS GROUND VEHICLE SOLUTIONS

# Vibration testing using RPC-Software

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MTS Systems (Germany) GmbH
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be certain.

# Overview of presentation

- Single Axial Testing vs. Multi Axial Testing
- Multi-Axial-Testing using MTS RPC-software
- PSD-testing using MTS RPC-software
- Summary

# Single Axial Testing vs. Multi Axial Testing



- Most specimen see multi-axial loading in real life
- Sequential load application do not result in same failure modes as simultaneous load application
- Significant time saving, if simultaneous load application is applied

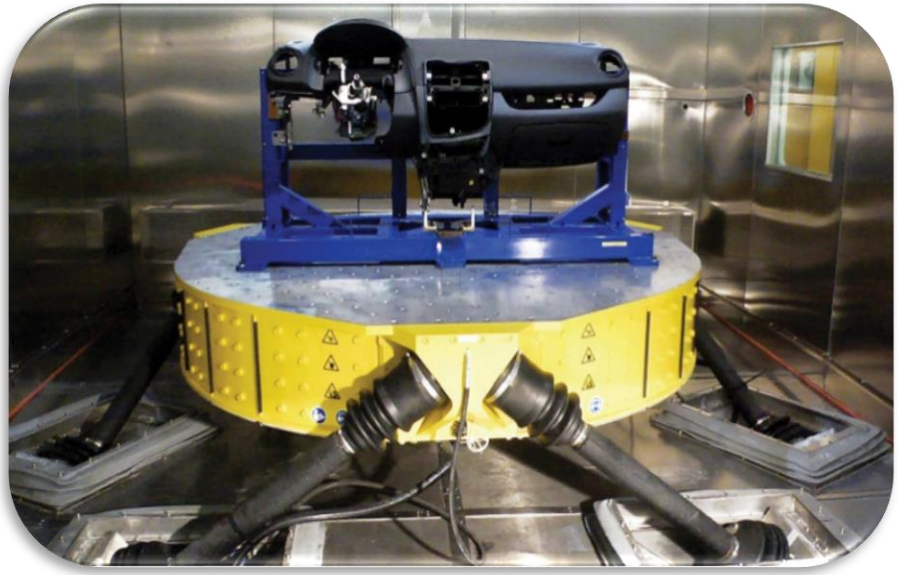
**Single-axial testing**

- Simple test setup
- Simple control algorithms sufficient
- Compensation techniques for single channel actuation can be applied

**Multi-axial testing**

- More complex test equipment (hardware) necessary
- More complex simulation software reguired to compensate cross coupling effects
- Limitations to software solutions to control such systems

# Virbation Testing using RPC software



**Durability/vibration testing of a variety of components or assemblies**

# Multi Axial Testing using RPC-Software

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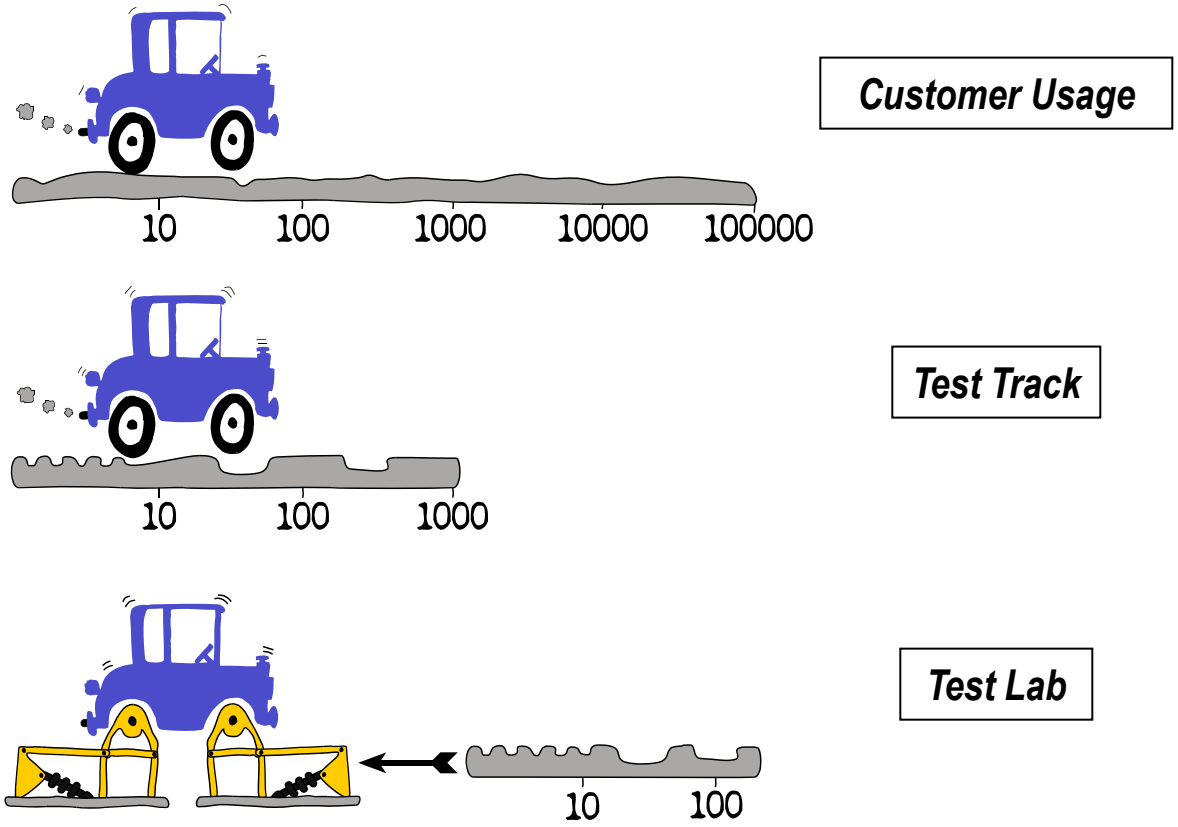
- What does RPC mean?
- Why is RPC-Software required?
- To achieve desired and recorded load data
  - Non-linear behaviour of specimen
  - Cross coupling effects must be respected
  - Compensate for amplitude and phase lag between actuation and specimen
  - Control to parameters, which is not the feedback of the control loop

# What is RPC needed for?

» The fundamental driving force of why we need RPC is to reproduce the *failure* caused by the road in a controlled lab environment




**Reproduce road damage in the lab with reduced test time**

# What is RPC needed for?

» To fulfill the required steps with the help of RPC, we divide the software into *five* parts:

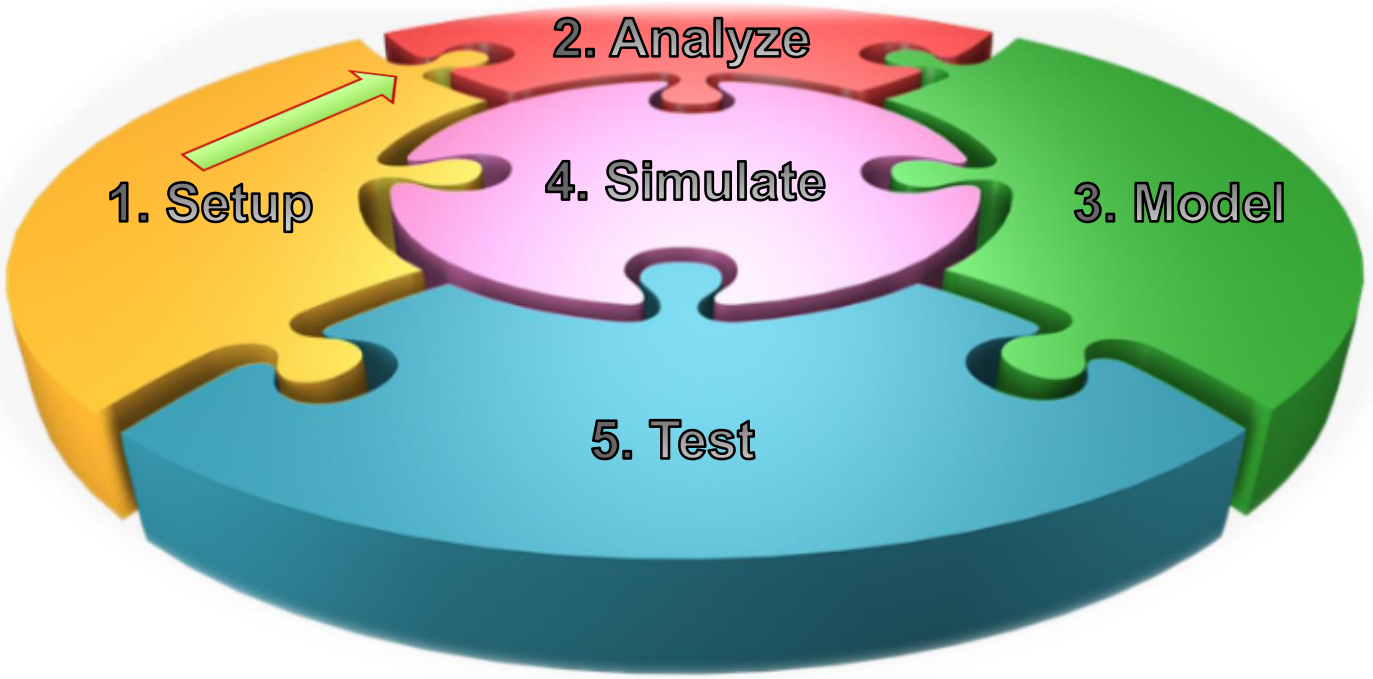
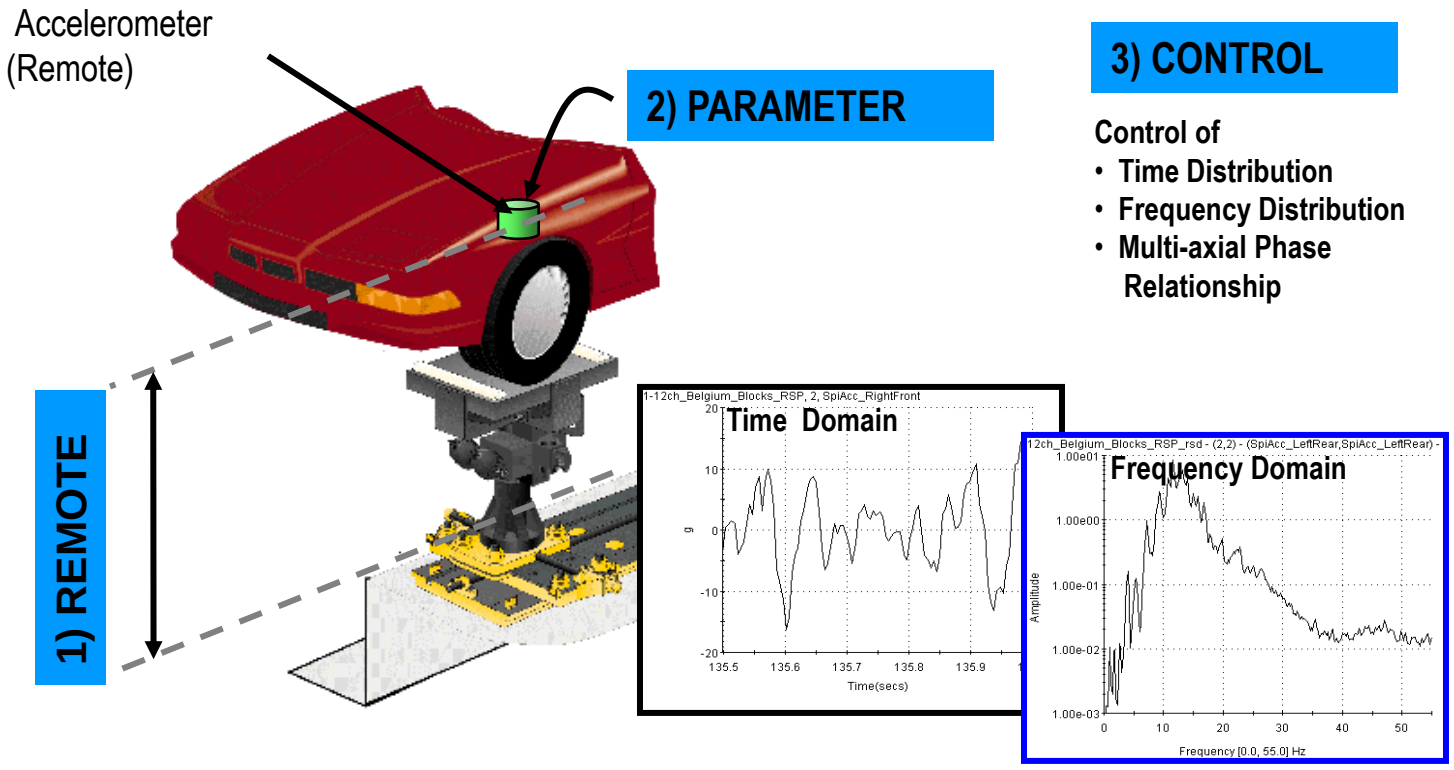


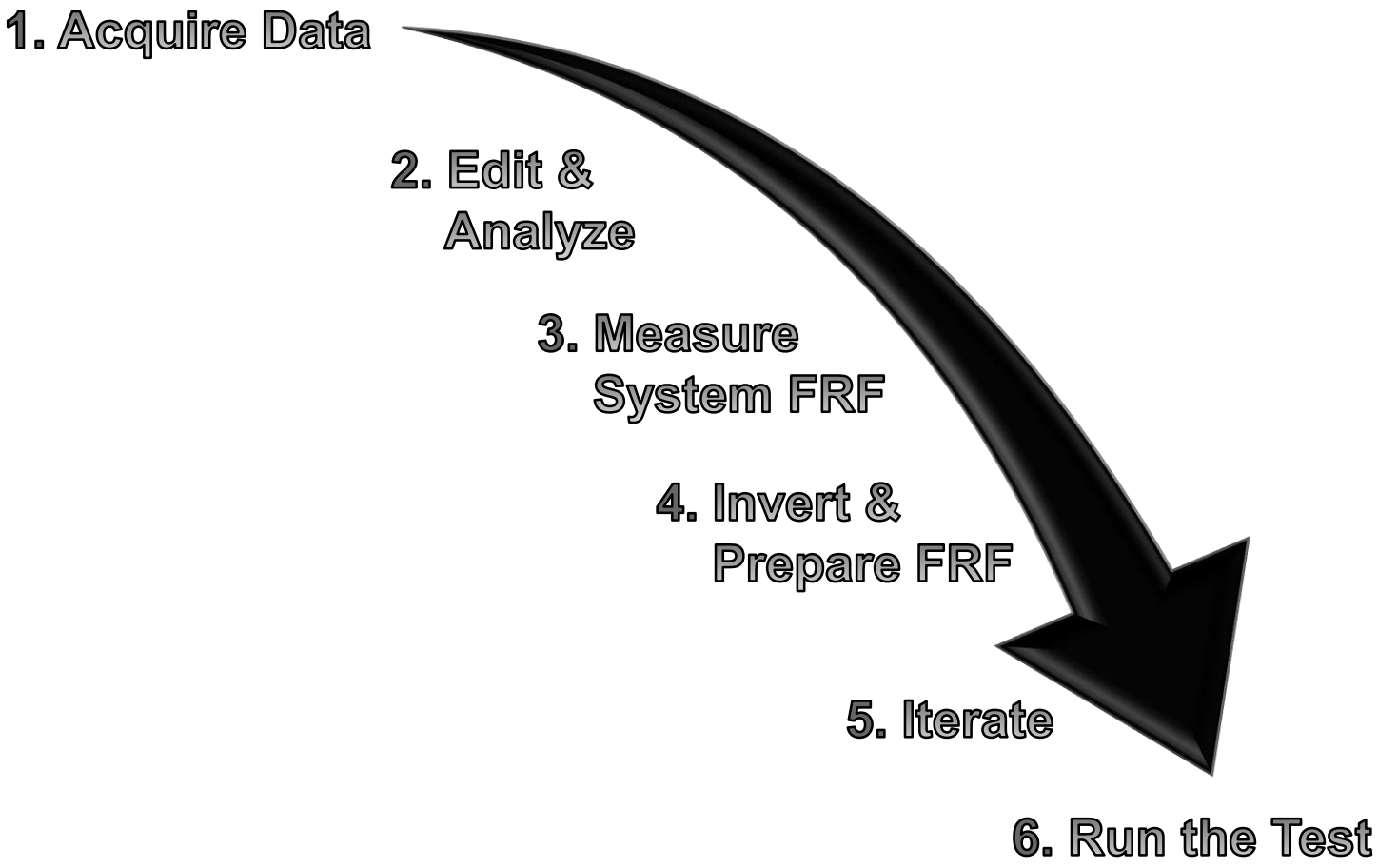

**Illustration of RPC Connect stages**

# What does RPC mean?

» RPC means **R**emote **P**arameter **C**ontrol



# Six Steps Of RPC Testing - Overview



# Six Steps Of RPC Testing



## Step 1: Acquire Data

Instrumented specimen

Data acquisition unit

- We need data to understand the loading a component experiences so that we can reproduce the failures in the lab

- Road data typically comes from the *proving ground* where events are specifically designed to induce high dynamic loads into the vehicle

# Six Steps Of RPC Testing

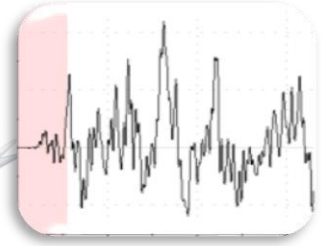


## Step 2: Edit & Analyze

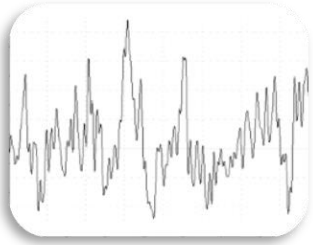
Import


Inspect

Edit



Target



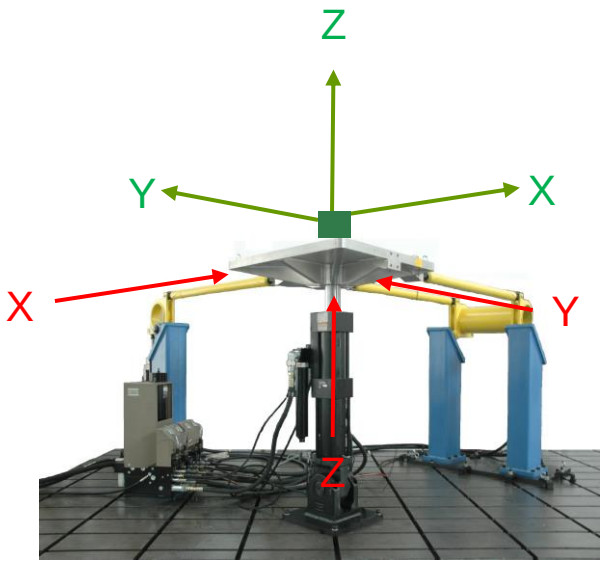
» Data preparation and editing

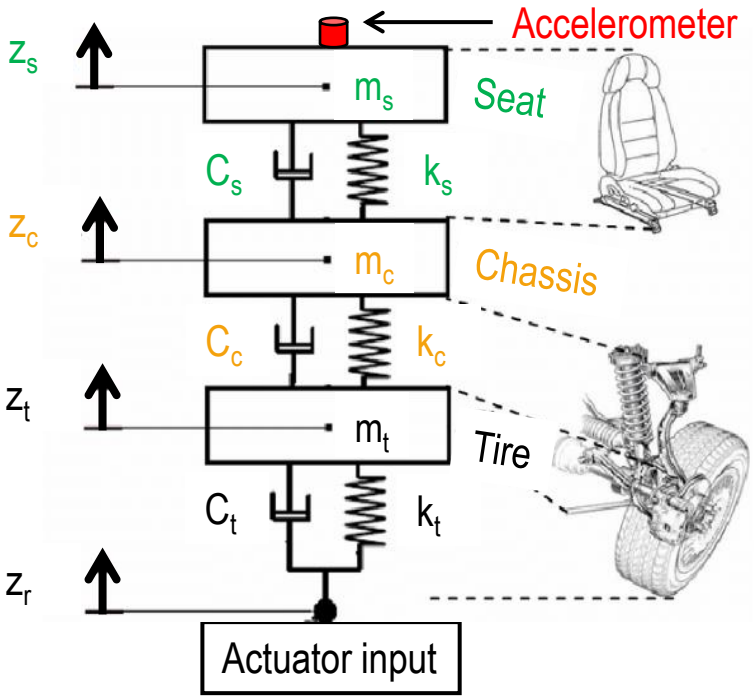
- Validate the “quality” of data
- *Analyze* the data and define your simulation events and frequency range
- *Edit* the acquired data to reduce test time while reproducing similar field damage

# Six Steps Of RPC Testing



## Step 3: Measure System FRF



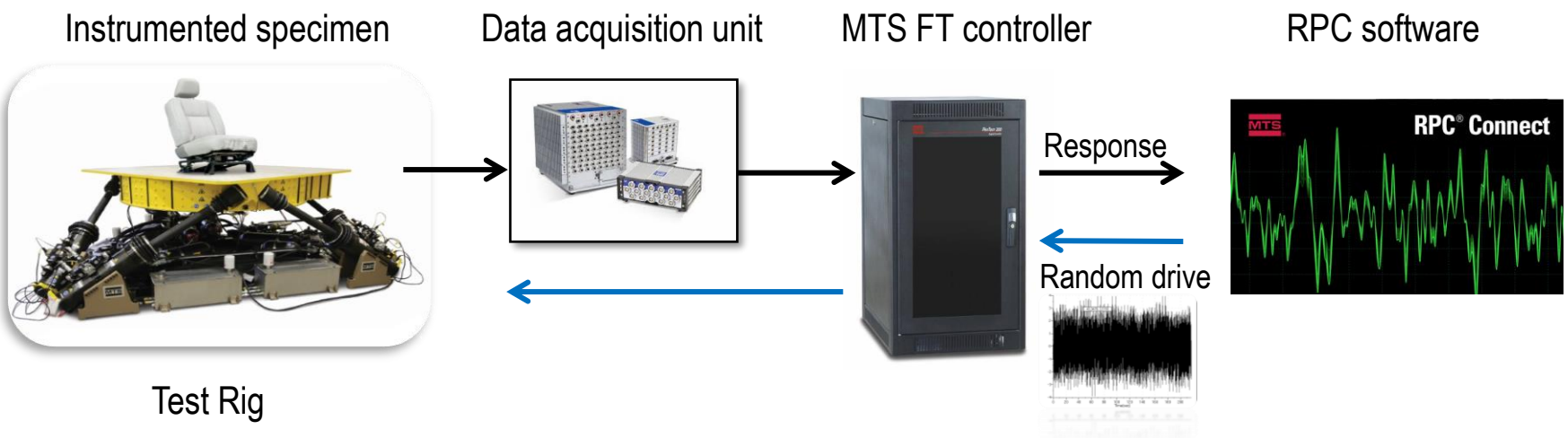




» System **F**requency **R**esponse **F**unction (**FRF**) is needed to find the relationship between system "*actuator*" input and specimen "*transducer*" output

» Modeling system FRF is the first time we will use the test specimen with the test equipment and will excite with a random input

# Six Steps Of RPC Testing

## Step 3: Measure System FRF

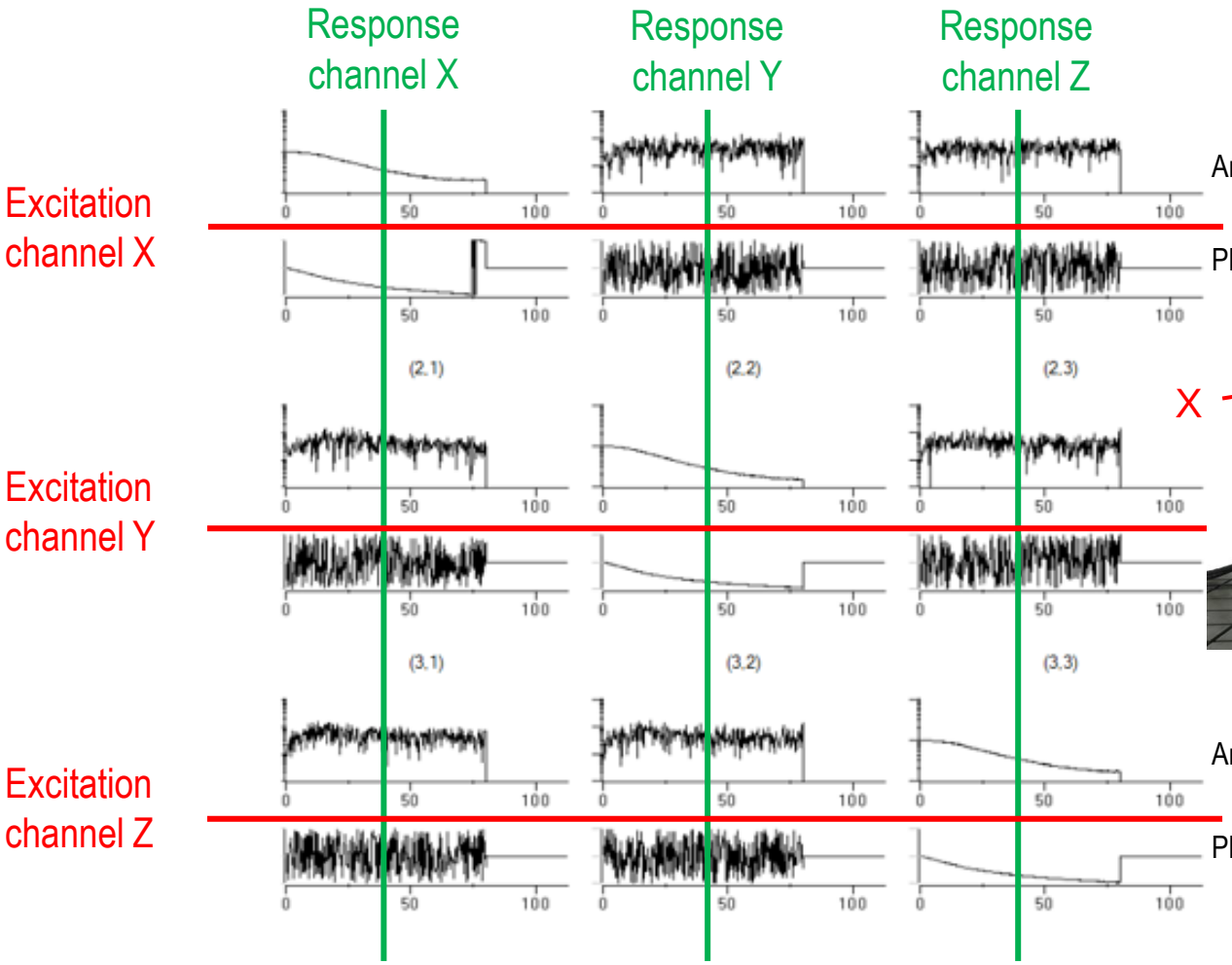


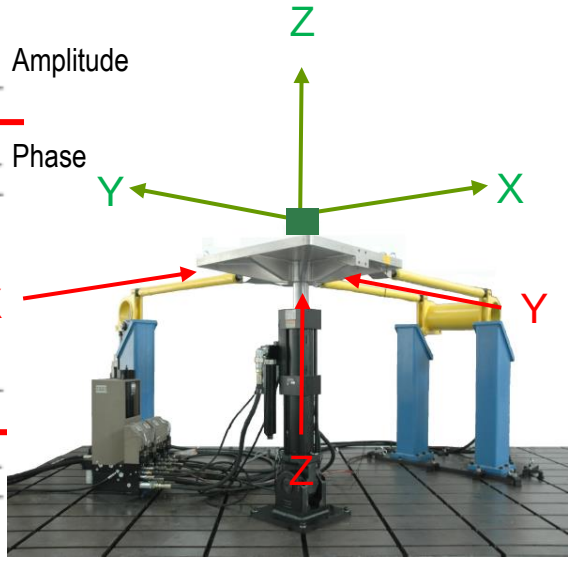

» Measure System Model

- Install instrumented specimen on the test rig and excite with random signal
- Define the relationship between system *input* and *output* across frequency bands
  - Calculate a linear model of the system for each frequency line
  - Determine the cross coupling effects between inputs and outputs

# Six Steps Of RPC Testing

## Step 3: Measure System FRF



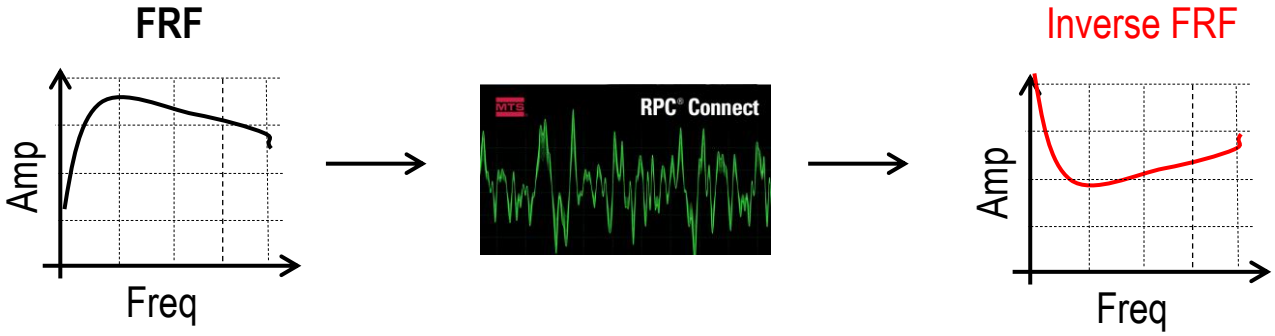



# Six Steps Of RPC Testing

## Step 4: Invert and Prepare FRF Inverse

System identification using „white noise“

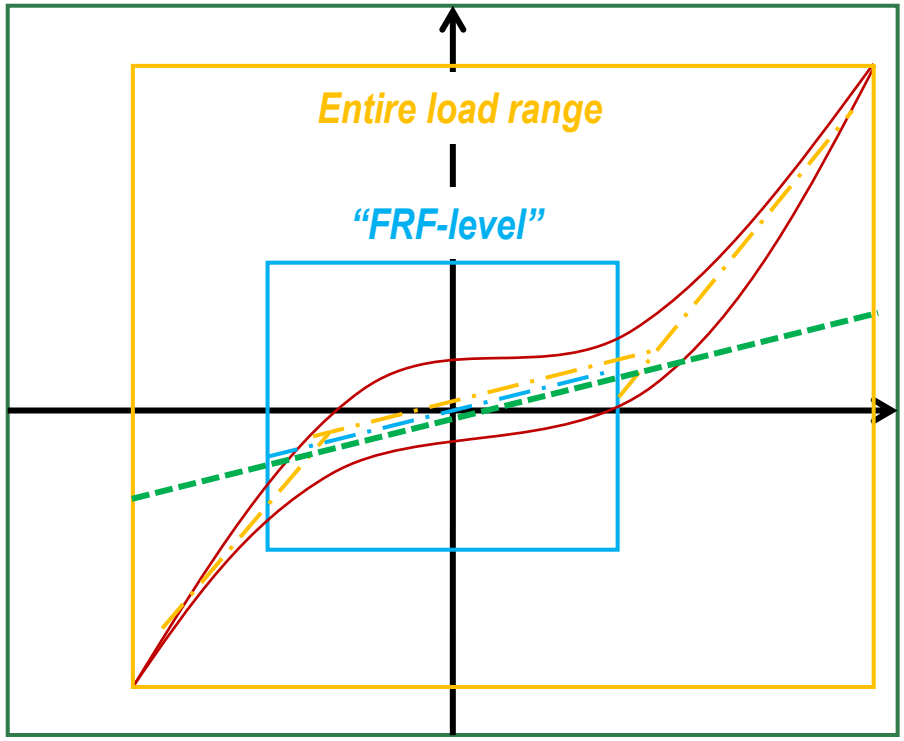

Invert FRF using RPC software



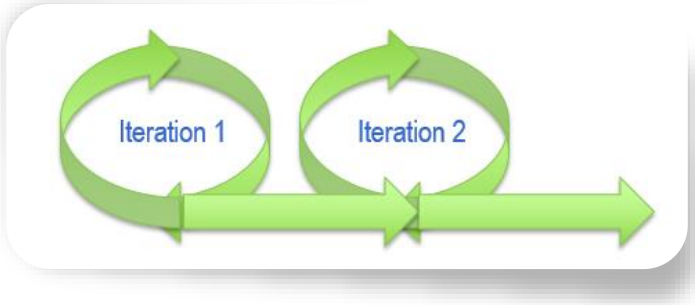

With inverted FRF, you can calculate the Input (drive) to a desired Output (response)

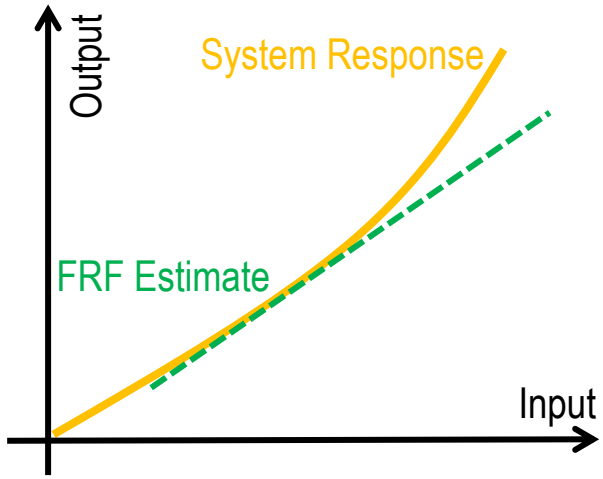
# Six Steps Of RPC Testing

## Step 5: Iterations




System Identification (FRF) executed
at reduced load level

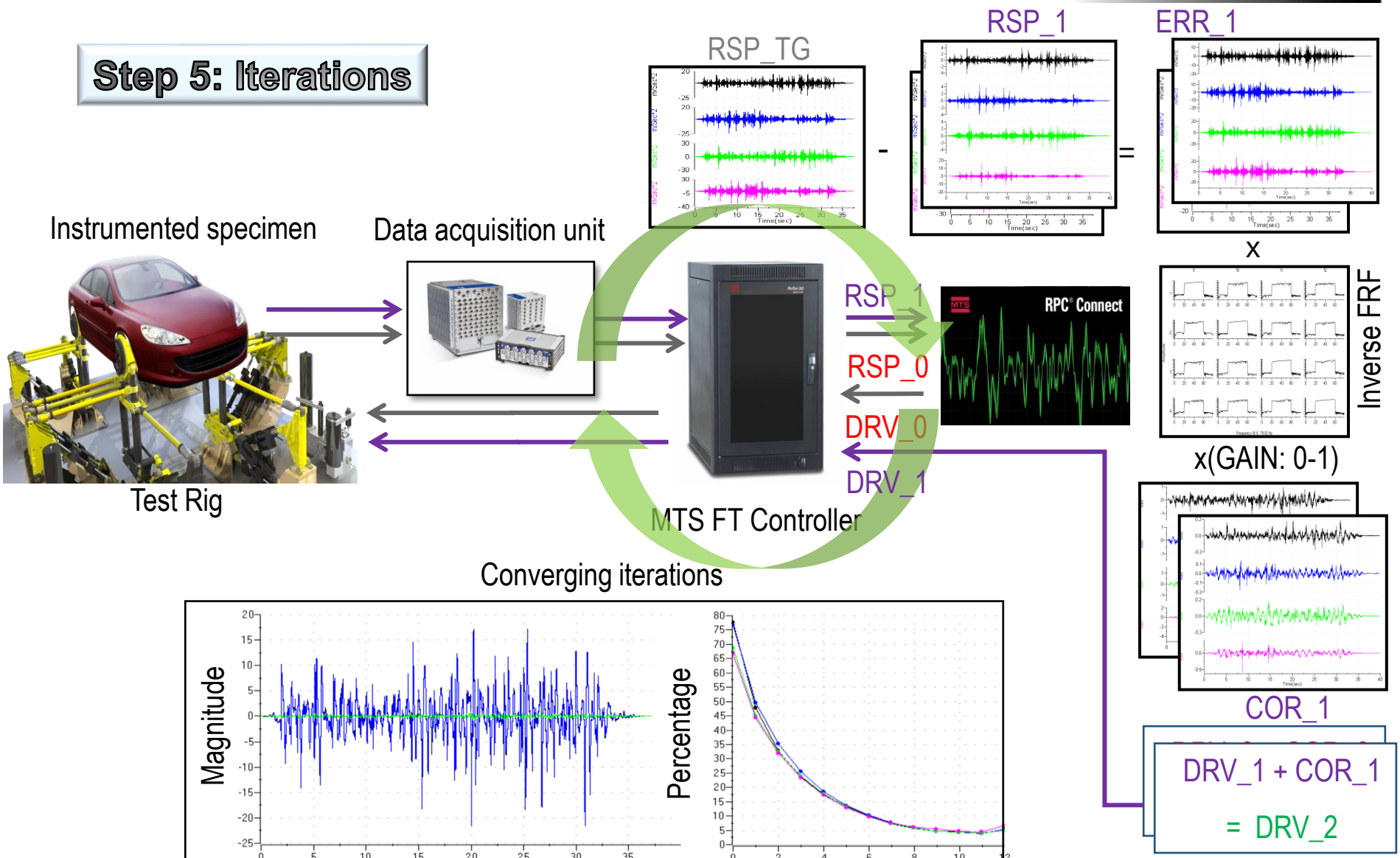



System FRF is an "*approximate*",
linearized model of the system

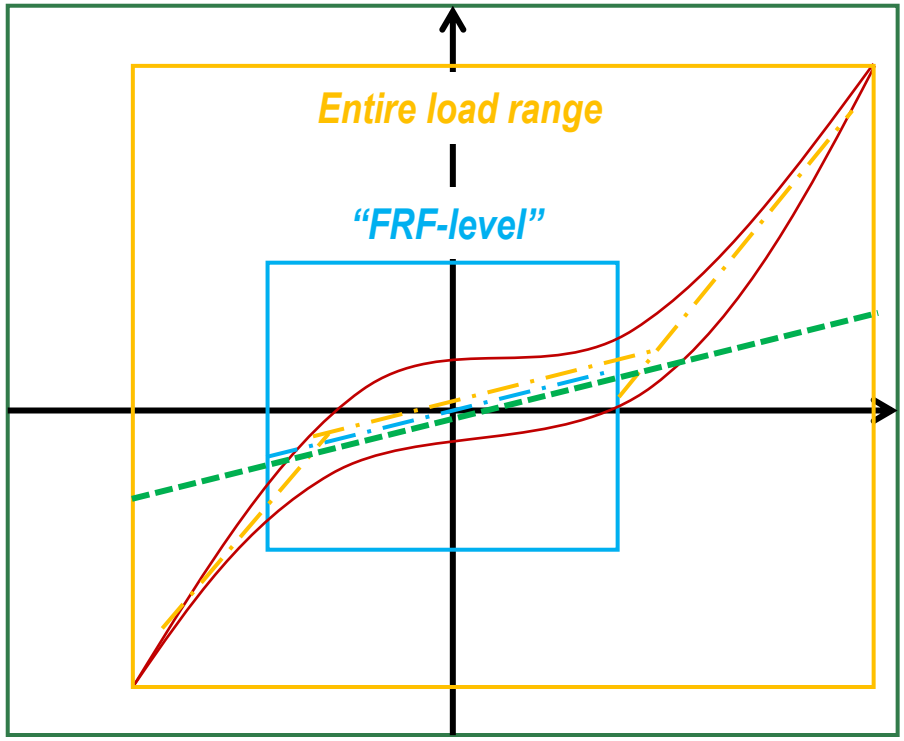
# Six Steps Of RPC Testing

## Step 5: Iterations



# Six Steps Of RPC Testing

## Step 5: Iterations

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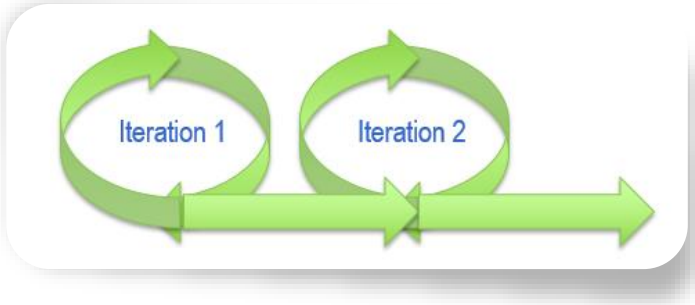


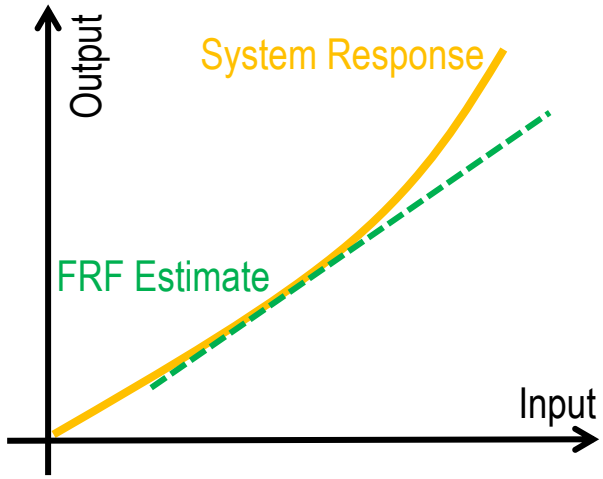


System FRF is an "*approximate*",
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# Six Steps Of RPC Testing

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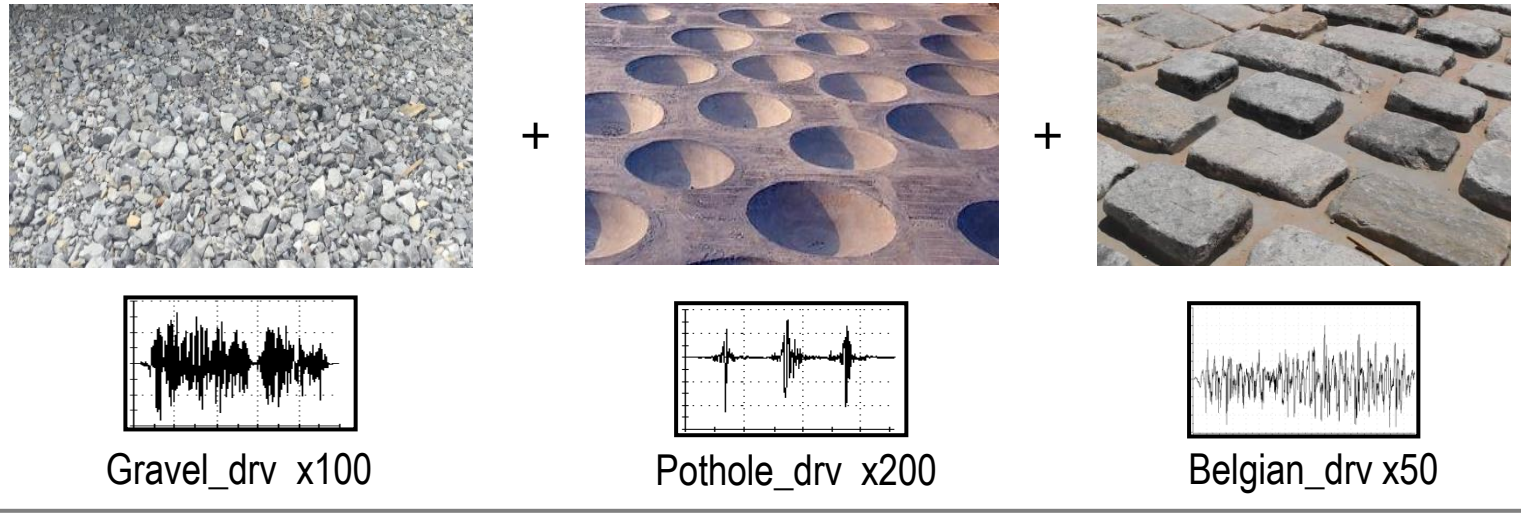
## Step 6: Durability Test




- After iterating each of the individual road profiles, a durability test can be constructed
- The durability test is created to replicate the durability schedule that would also be conducted at the track
- Run durability test to verify the product “life”

# Six Steps Of RPC Testing

## Step 6: Durability Test

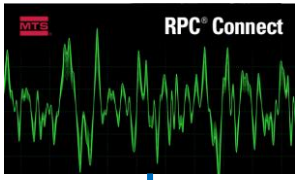
Instrumented specimen

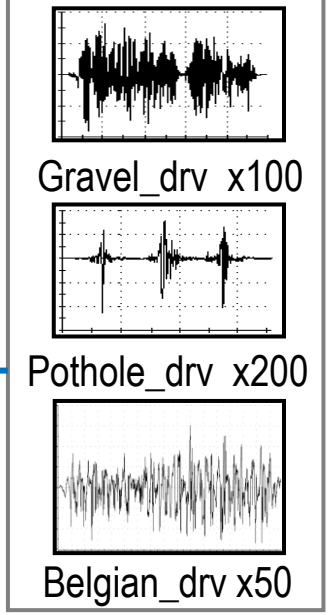
Test rig

Data Acquisition Unit

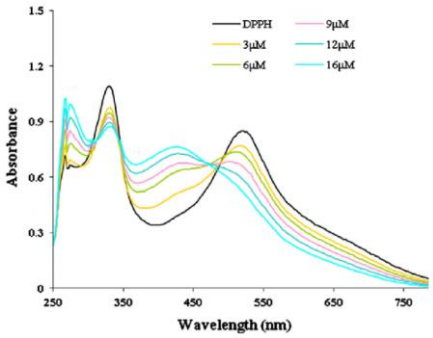
MTS FT controller

RPC software

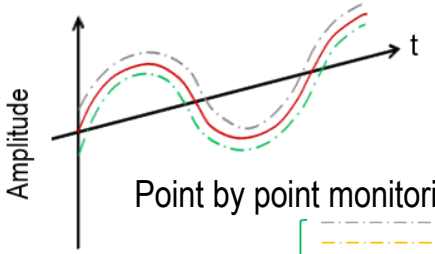


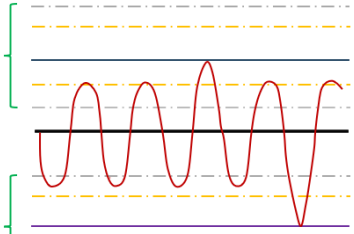

Durability sequence




Spectral monitoring




Point by point monitoring



Trend and fatigue monitoring

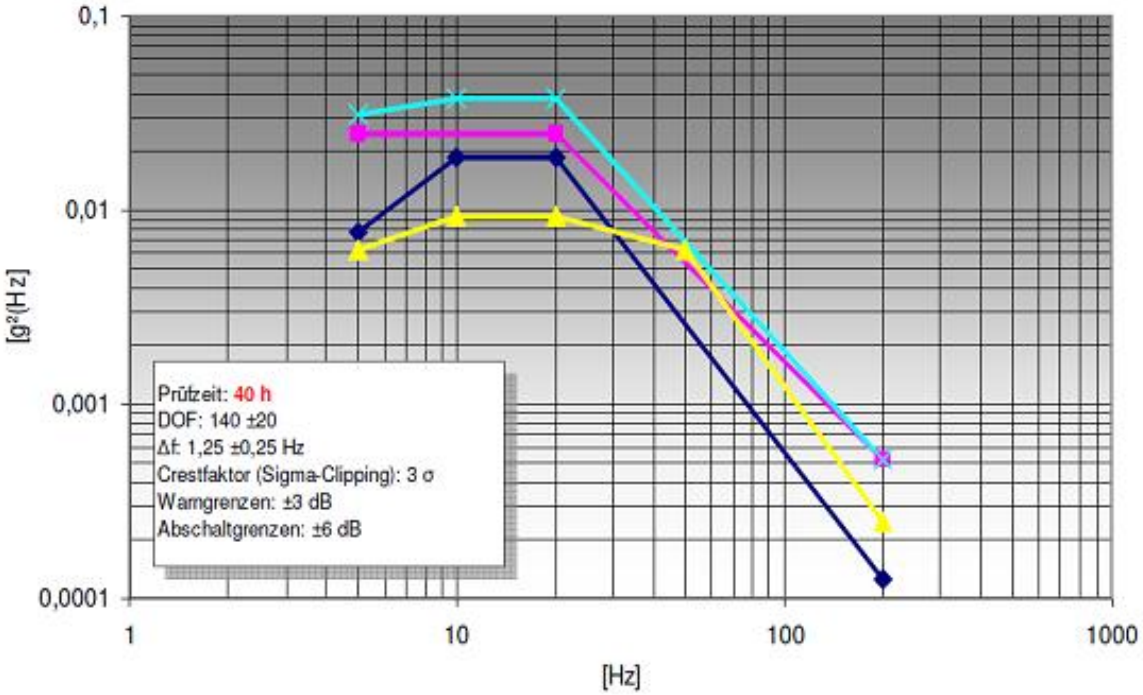
# Multi-Axial PSD-Testing using RPC

- Generate the Shape Matrix out of the PSD
- Generate the random TH-signal
- Iterate the desired TH-signal
- Playout the achieved drive signal

# Multi-Axial PSD-Testing using RPC



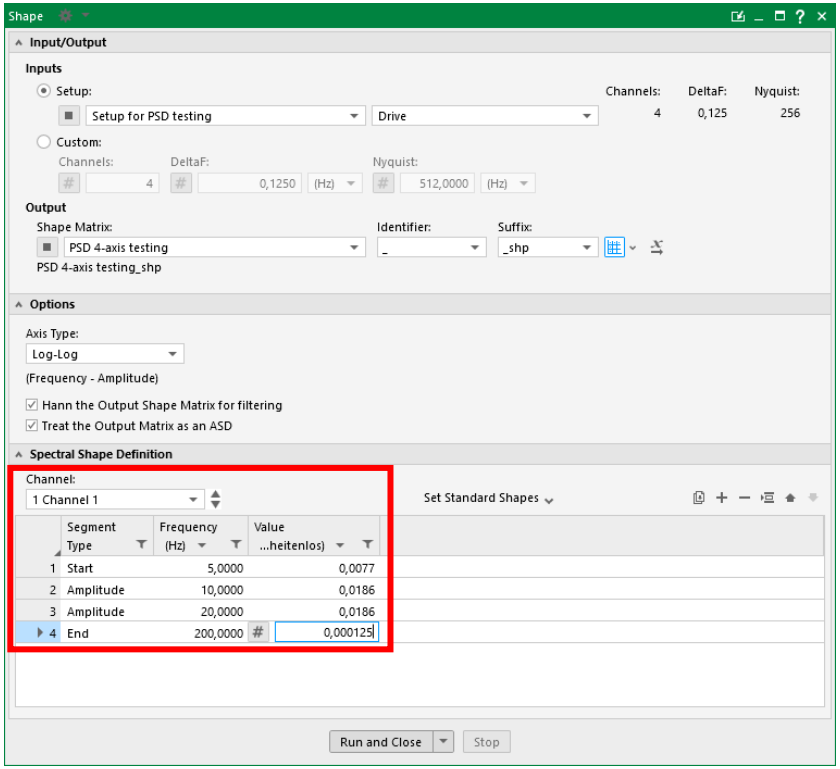
» Given PSD for 4 locations

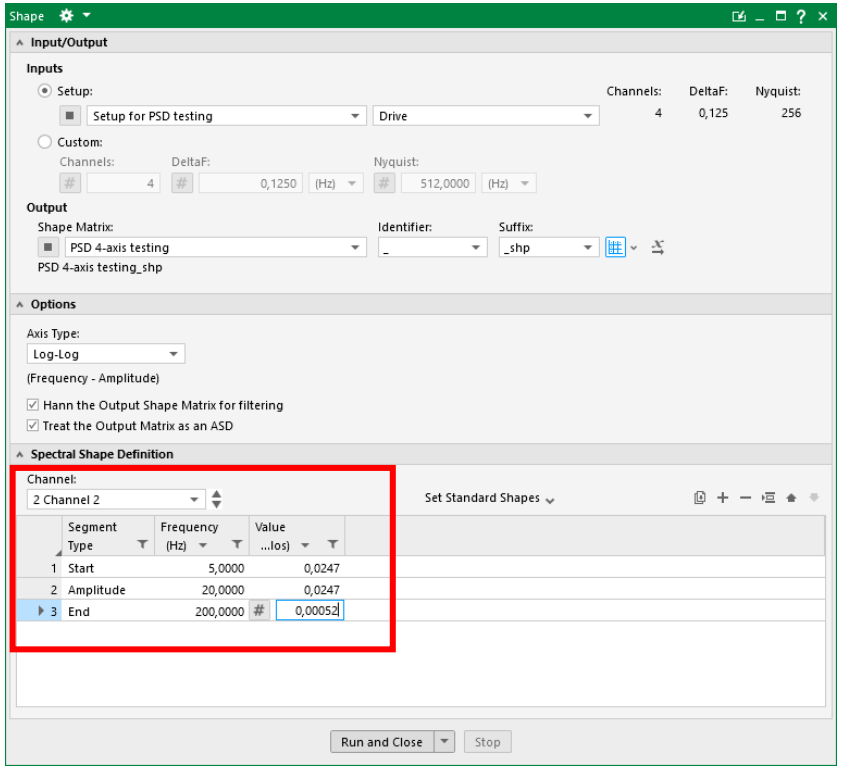



| X-Richtung | | |
|---|---|---|
| Hz | g²/Hz | (m/s²)²/Hz |
| 5 | 0,0077 | 0,74 |
| 10 | 0,0186 | 1,79 |
| 20 | 0,0186 | 1,79 |
| 200 | 0,000125 | 0,012 |
| RMS | 0,74 | |
| | | |
| Y-Richtung oben | | |
| Hz | g²/Hz | (m/s²)²/Hz |
| 5 | 0,0247 | 2,38 |
| 20 | 0,0247 | 2,38 |
| 200 | 0,00052 | 0,05 |
| RMS | 0,97 | |
| | | |
| Y-Richtung unten | | |
| Hz | g²/Hz | (m/s²)²/Hz |
| 5 | 0,0062 | 0,6 |
| 10 | 0,0093 | 0,895 |
| 20 | 0,0093 | 0,895 |
| 50 | 0,0062 | 0,6 |
| 200 | 0,000248 | 0,024 |
| RMS | 0,74 | |
| | | |
| Z-Richtung | | |
| Hz | g²/Hz | (m/s²)²/Hz |
| 5 | 0,031 | 2,98 |
| 10 | 0,0372 | 3,58 |
| 20 | 0,0372 | 3,58 |
| 200 | 0,00052 | 0,05 |
| RMS | 1,14 | |

# Multi-Axial PSD-Testing using RPC

» Generate the Shape Matrix out of the PSD



# Multi-Axial PSD-Testing using RPC

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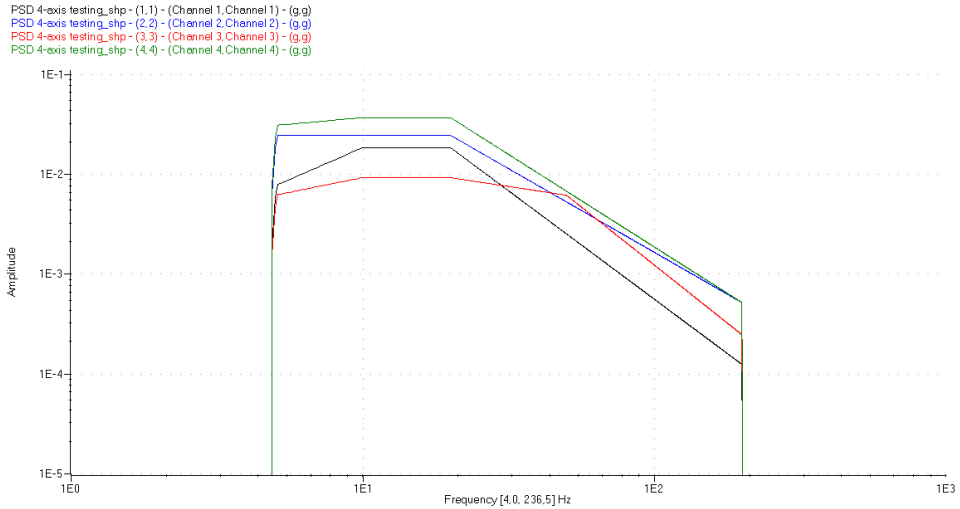


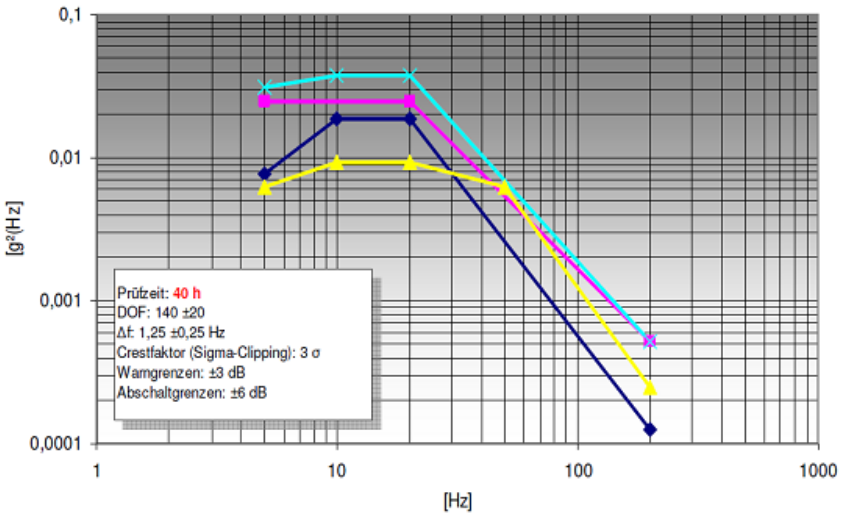

# Multi-Axial PSD-Testing using RPC

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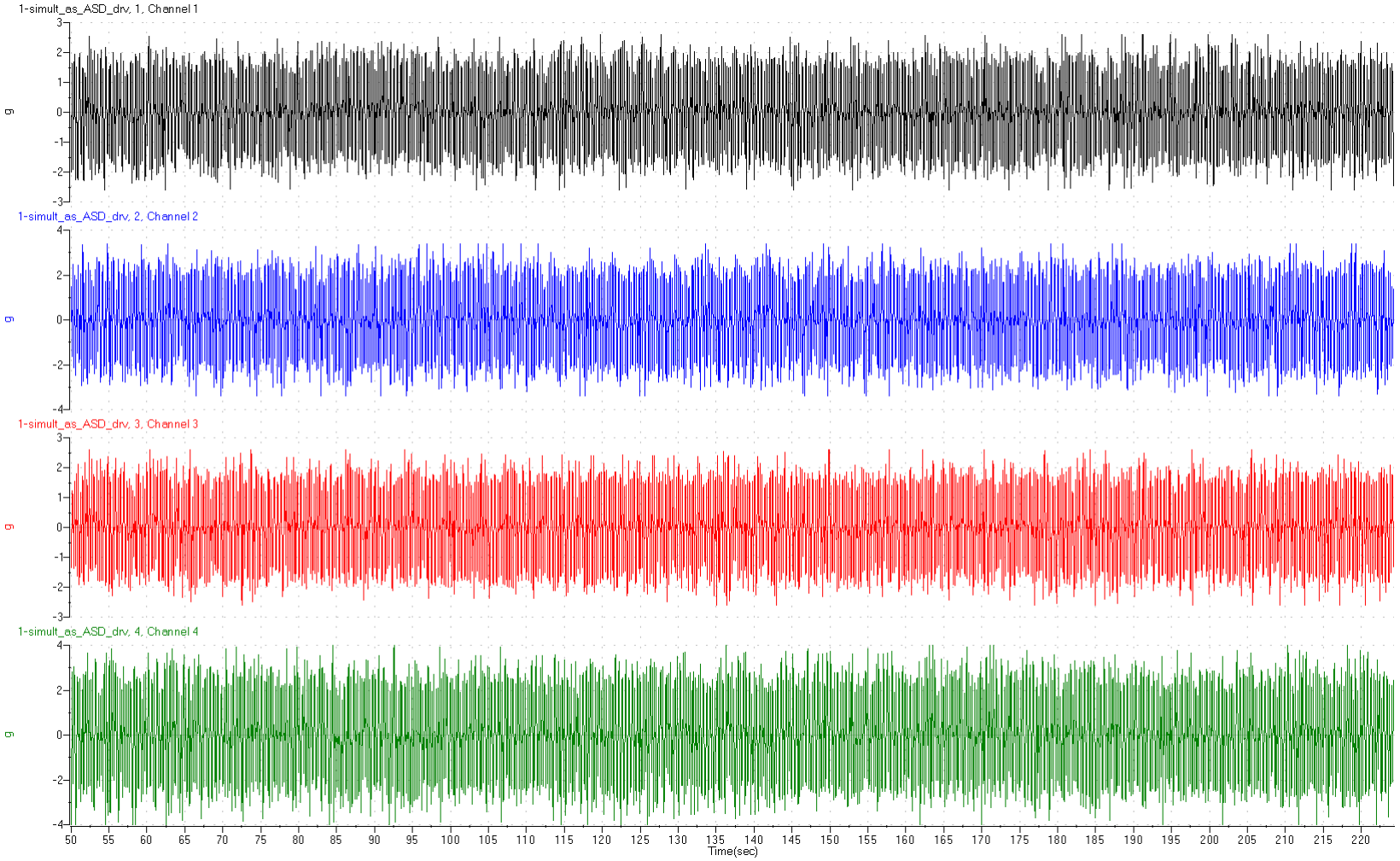
» Generate a Time History signal out of the given PSD (Shape Matrix)



# Multi-Axial PSD-Testing using RPC



- Iterate the generated time history signal representing the desired PSD
- Run the endurance test with the iterated drive signal to exactly represent the PSD-TH.

# What can RPC-software used for - summary

- Convert a desired Response signal into a Drive signal (Iterative process)
  - » Compensate for hydraulic performance roll-off
  - » Cross-coupling between channels
  - » Maintain correct amplitude and phase
  - » Control non-linear systems
- Analyze data in a number of different ways
  - » Time History domain
  - » Frequency domain
  - » Amplitude domain, statistics, ….
- Comprehense System Analysis and Simulation
  - » Fatigue analysis
  - » Playback drive signals, collect response signals
  - » Monitor specimen degradation
  - » Extract meaningful information from data (analyze data)
  - » Generate synthetic data
  - » Virtual simulation (e.g. in combination with ADAMS)
  - » Hybrid simulation (MTS HSRC approach)

*Thank you very much for your attention!*

*Questions?*

*Comments?*

*Suggestions?*