A Holistic View on NDT Reliability: Multi-Parameter-POD and Human Factor Influences within the Modular Reliability Approach

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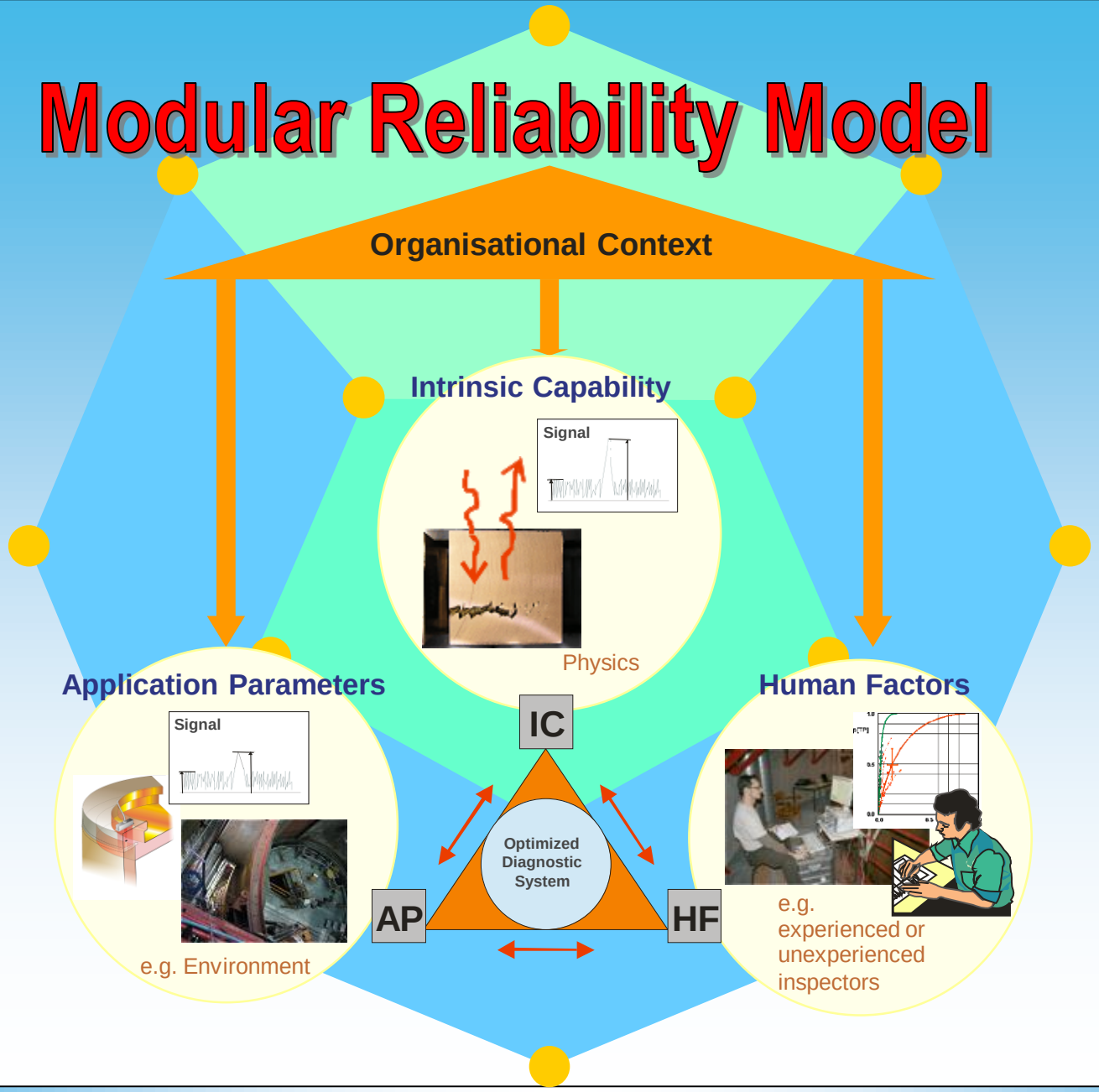
Modular Reliability Model



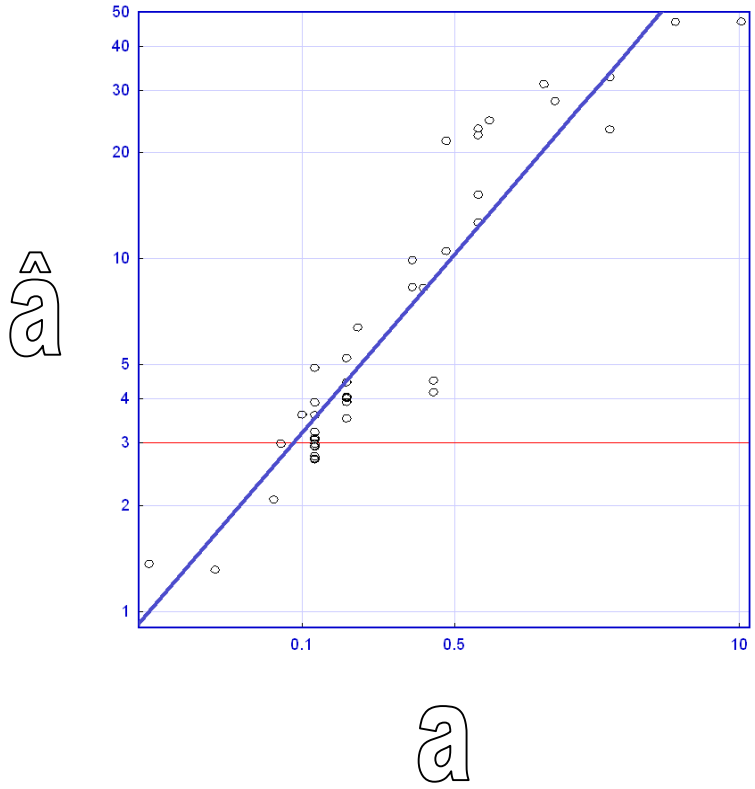
Progress in Methods for

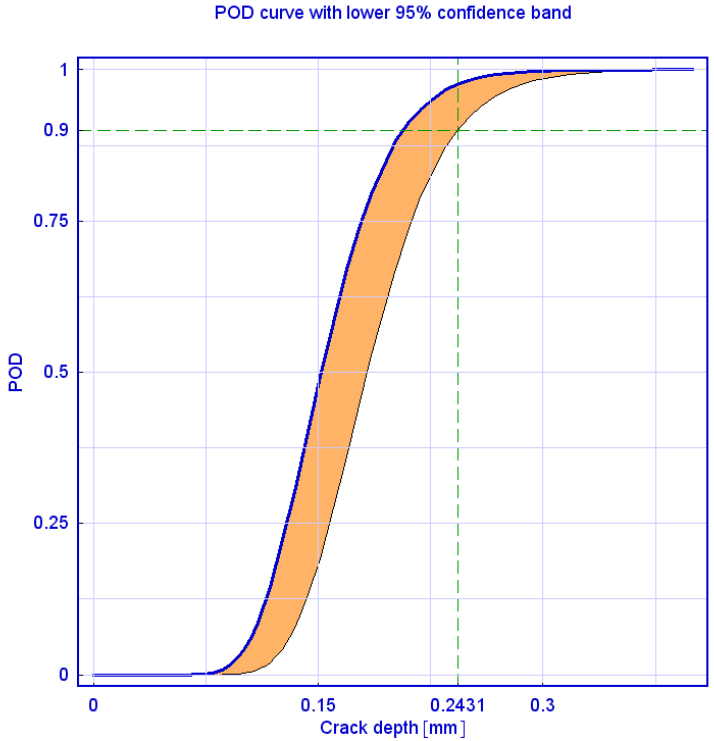
- 1. Intrinsic Capability: Physics and technical influences
- 2. Application Parameters: Environment of the experiment
- 3. Human Factors: In calibration, set up and evaluation and decision making as well as in the organizational context
- 4. Organizational Context: Business-, Technical-, Information Process

Contents

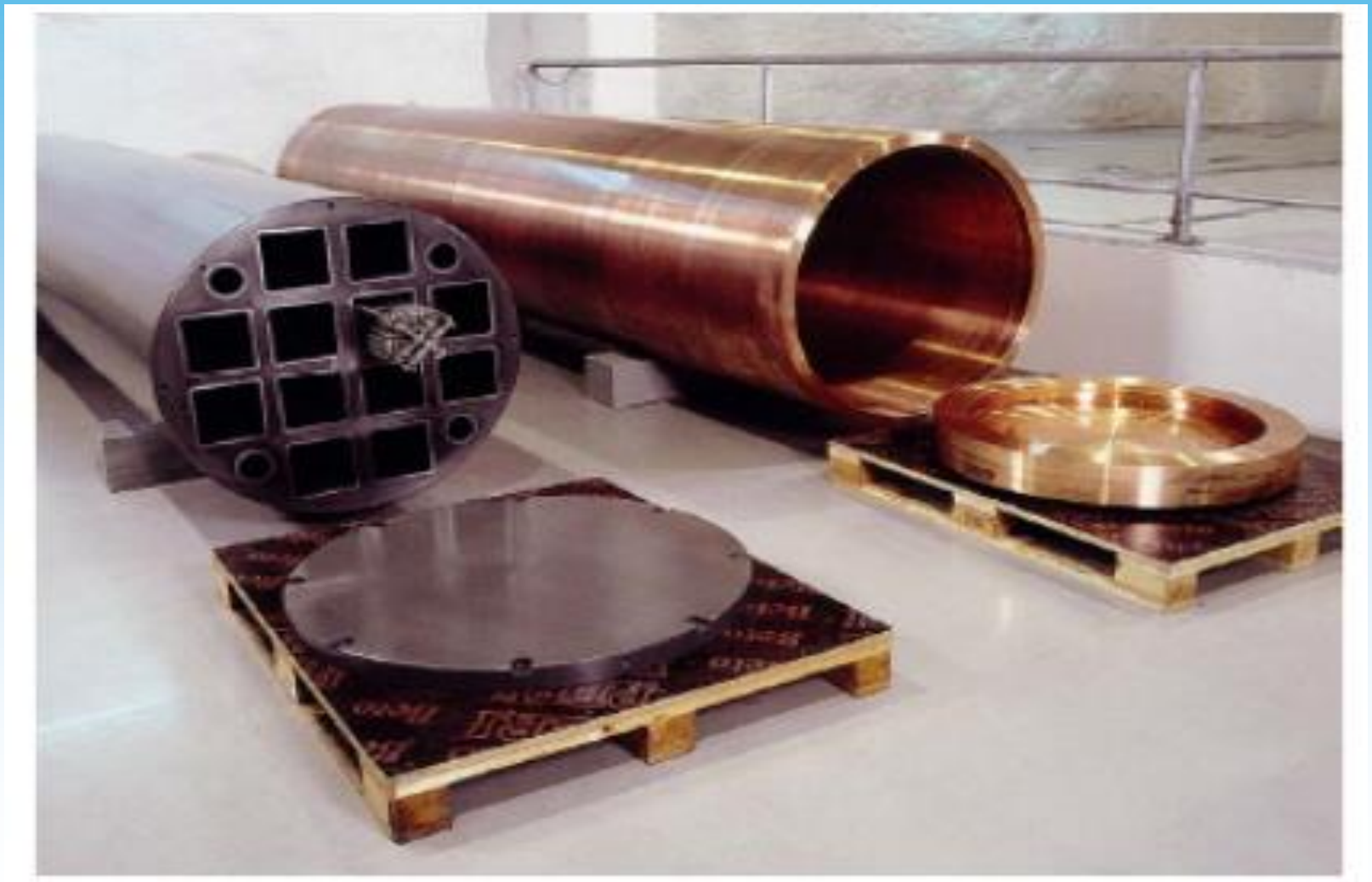
Probability of Detection (POD)
– â vs. *a* approach – for realistic testing conditions

We need multi-parameter „a“ (depth, size, orientation, roughness …)
And data-field „â“ (more than a maximum) for real industrial appl.

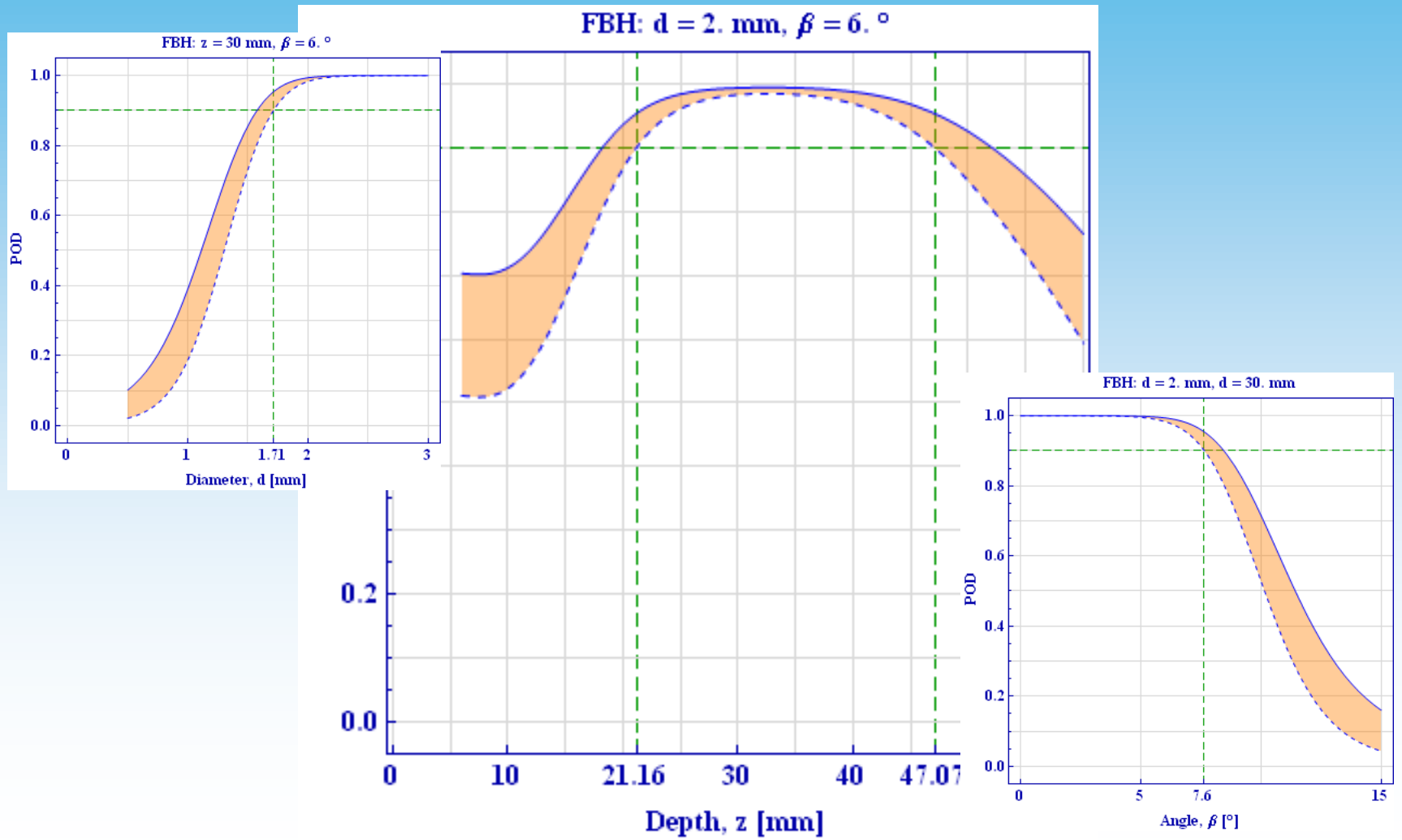




Copper Canisters for Spent Nuclear Fuel SKB



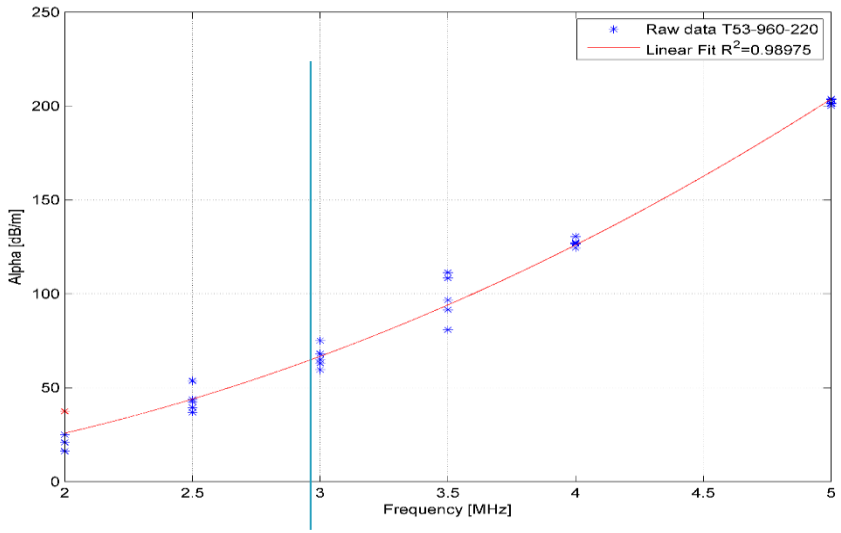
MP-POD as function of diameter, depth, angle
Mato Pavlovic (UT testing of copper canisters)

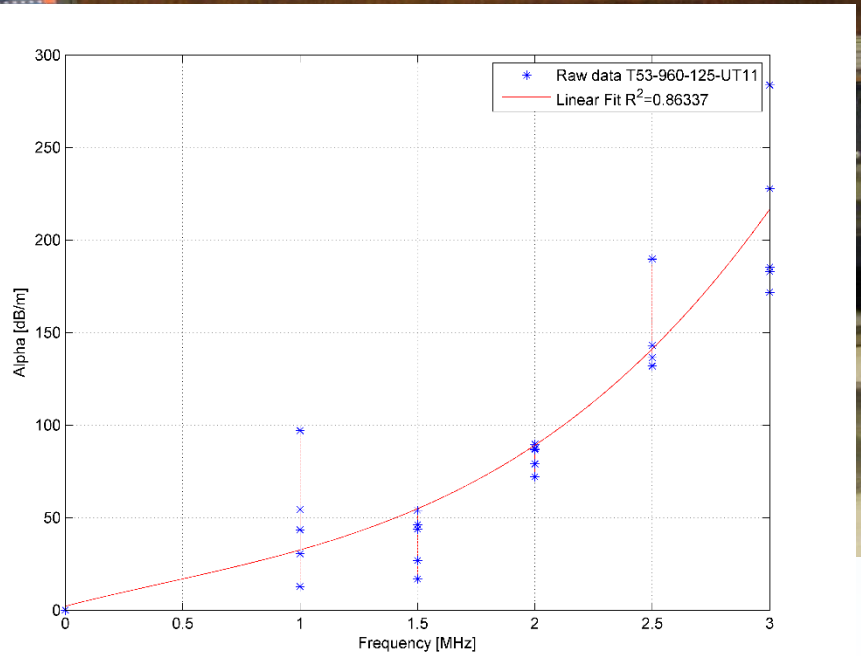


PA UT Testing SKB

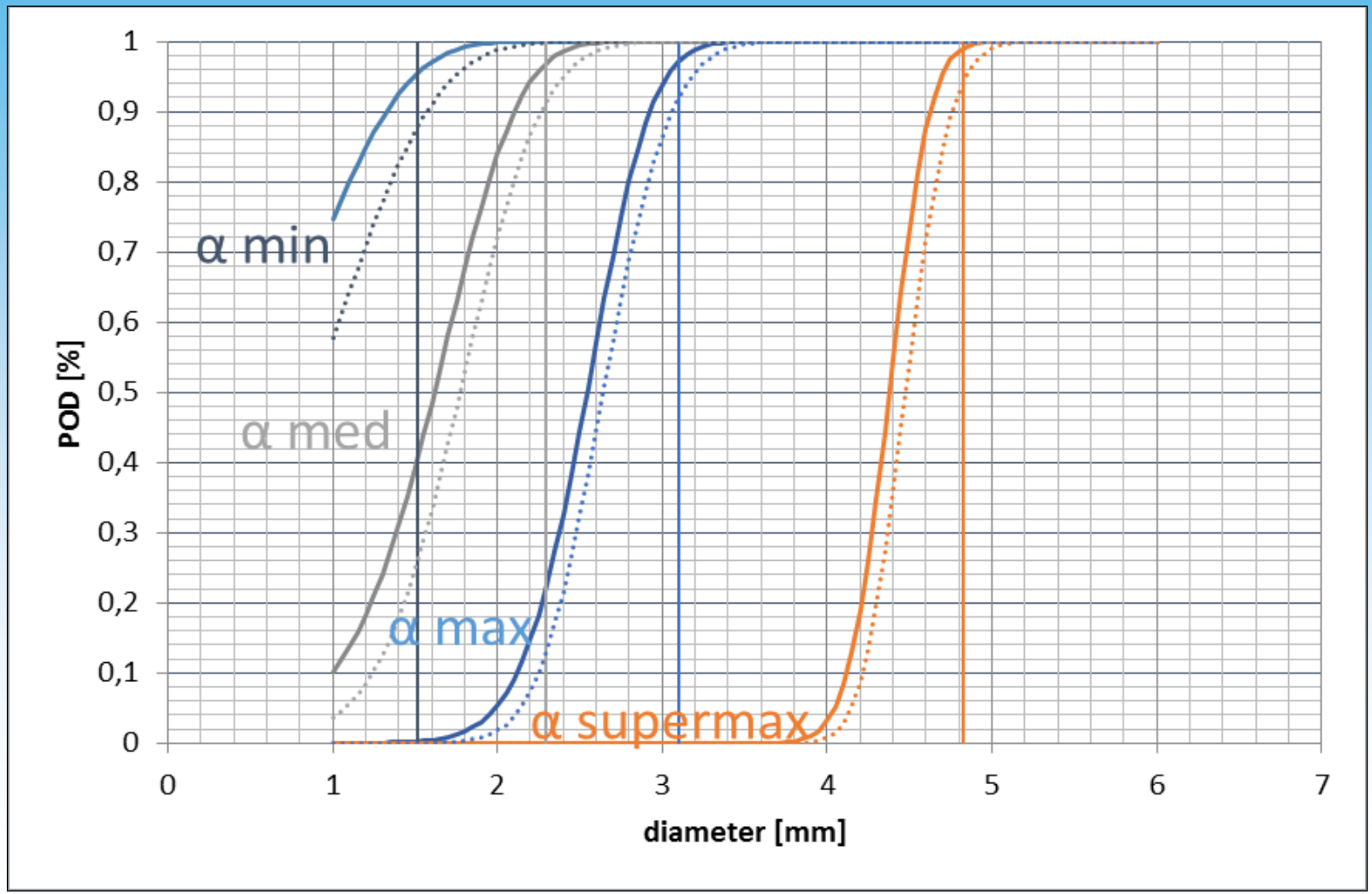
Andrea Gianneo

Regions of different attenuation





MP-POD for Copper with different UT attenuation

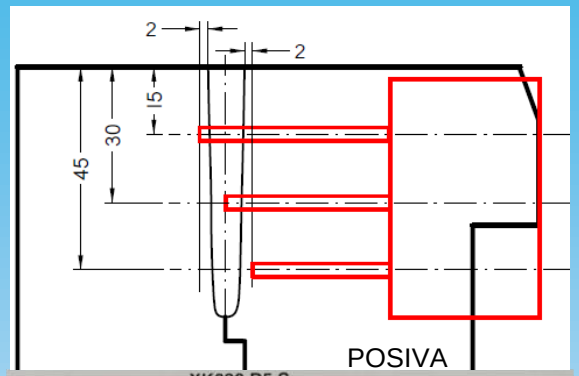


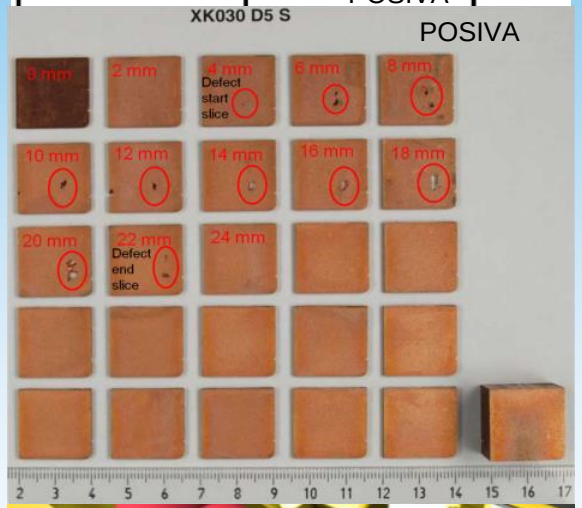
From artificial to real flaws: Three-Step Testing

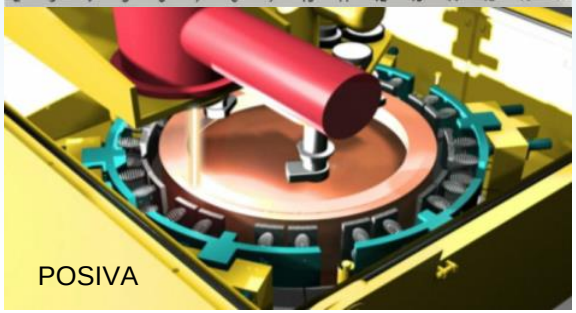
Artificial defects – According to the EN & ASTM Standards

Realistic welding defects (in this work: = real defects)

Production of the disposal canisters for the use in the final disposal (after 2020)







The POD of artificial defects:
-evaluate the measurement process / the application factor
=> POD describes the limits with an ideal defect behavior.

The POD of real defects:
-evaluate of the interaction with complex defects
=> necessary for an “Overall POD”.

Bayesian Approach

D. Kanzler

Contents

Statistical Evaluation of Manual UT of Railway Hollow Wheel Axles

- Artificial and real defects at different positions (shaft, seat, transition region (unknown size and angle, ~ 2 mm notch)
- Defined Technique UT 5 MHz 45°, 70° inwards, outwards
- UT inspectors during education examination (first and refresher and 1 extra round robin)

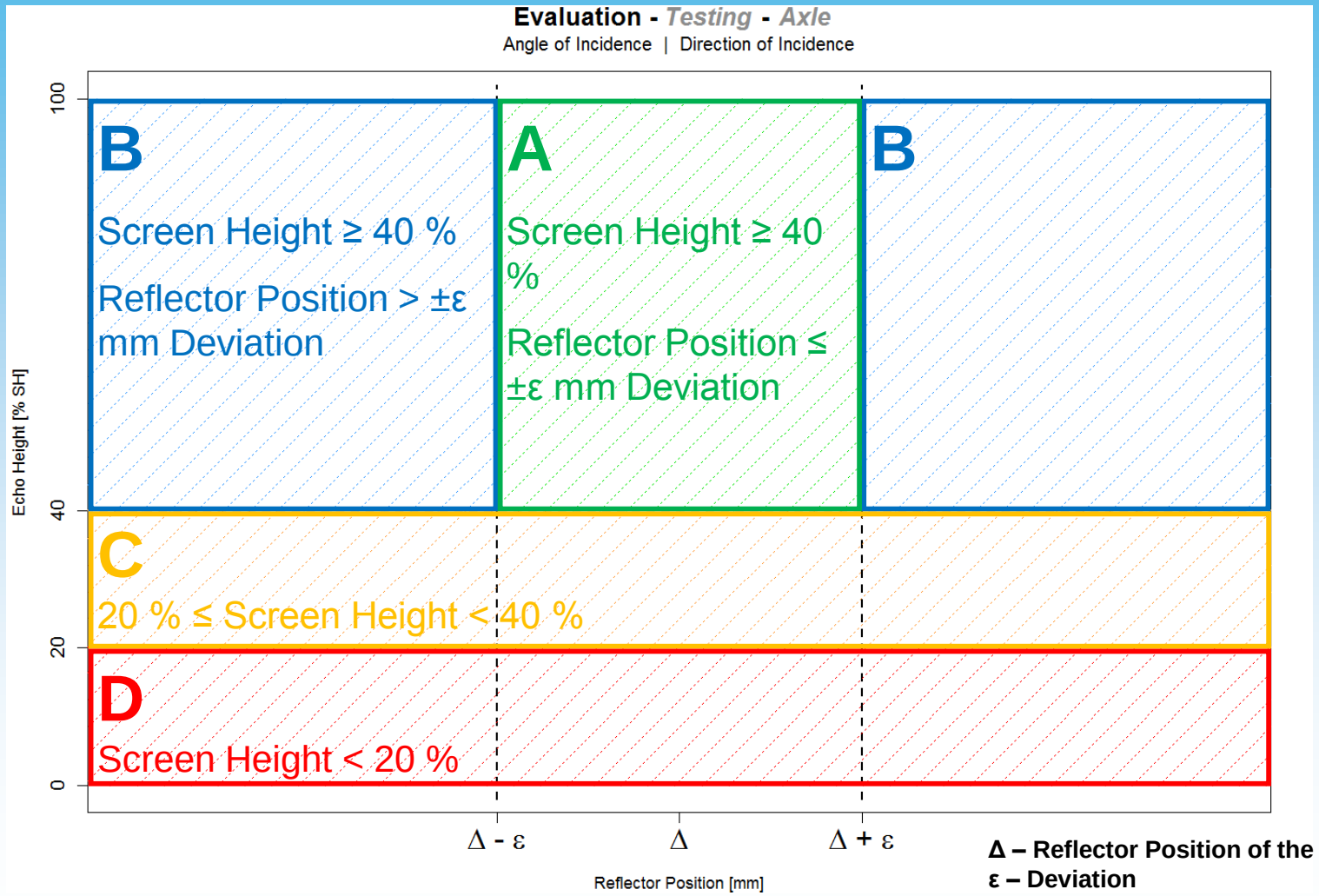
Overview of the data

Number		Round Robin Test	Refresher Examination	part. Mechanized Testing	First Examination
Axles		1	23	1	13
UT-Probes	45°	10	24	2	9
	70°	7	10	-	1
Protocols		26	599	236	18
Measurement Values	total	272	3477	(2088)	105
	Calibration Reflector / Geometrical Contour Echo	97	1786	-	38
	not usable*	63/6	620/292	39/39	44/1
	relevant*	**112/169**	**1071/1399**	**197/197**	**23/66**

** first value: Evaluation Echo Height / DeltaPhi; second value: Evaluation Echo Height / Reflector position*

Stand: 22.05.2014

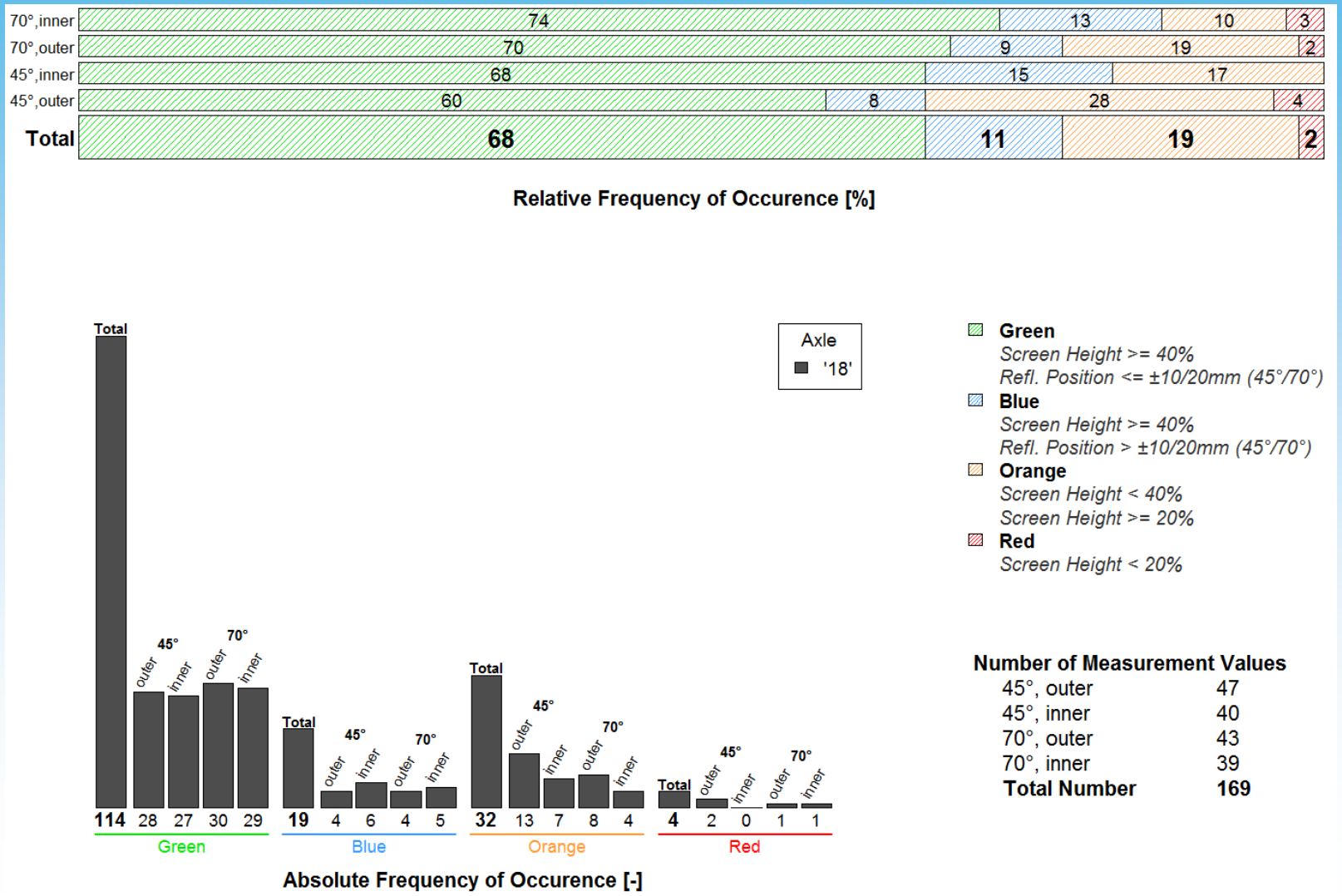
Graphical Illustrations –
Echo Height [%SH] / Reflector Position [mm]



Δ – Reflector Position of the best result
ε – Deviation
10 mm (45° Angle of Incidence)
20 mm (70° Angle of Incidence)

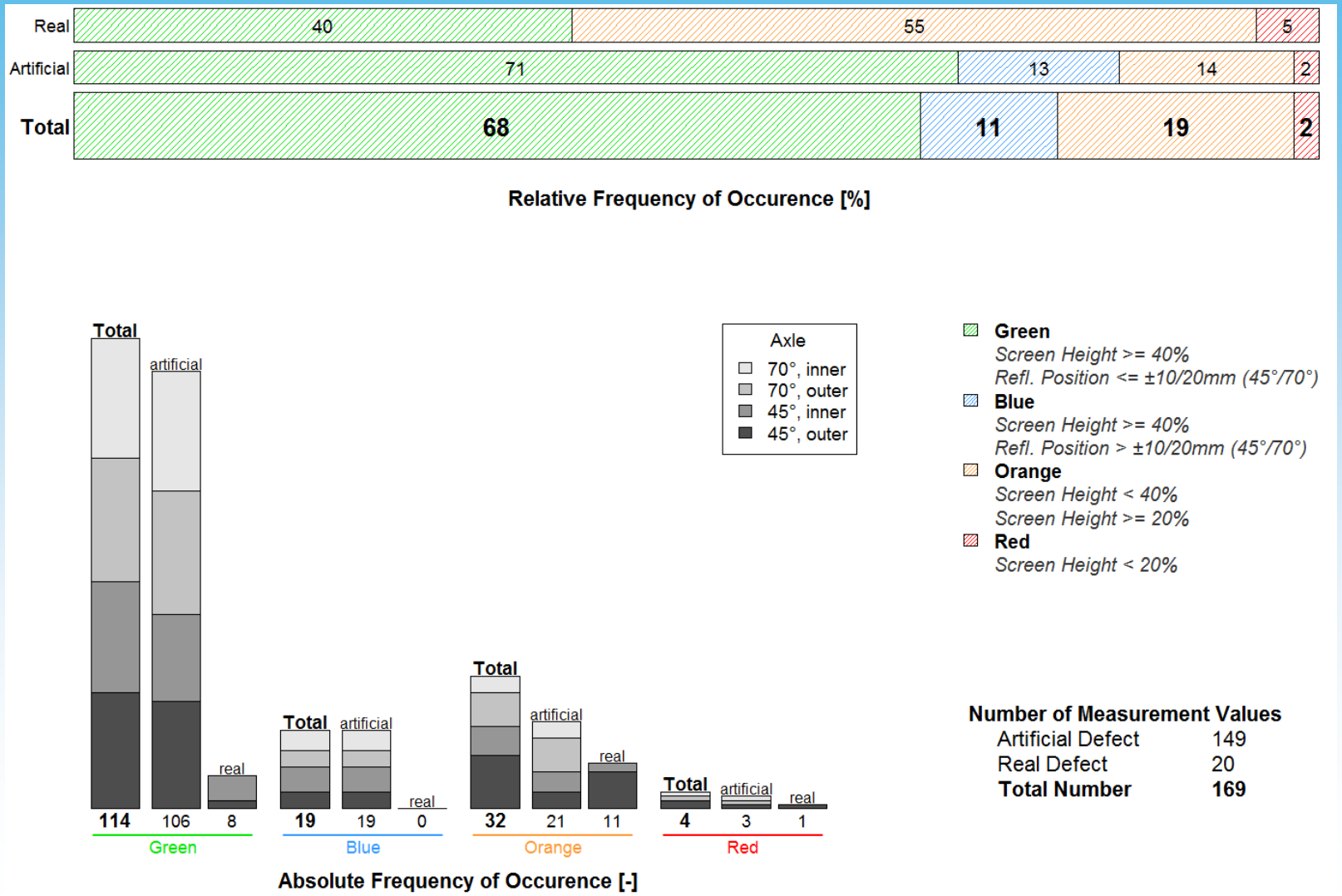
Overview – Round Robin Test

Reflector Position ≤ ±10/20 mm Deviation



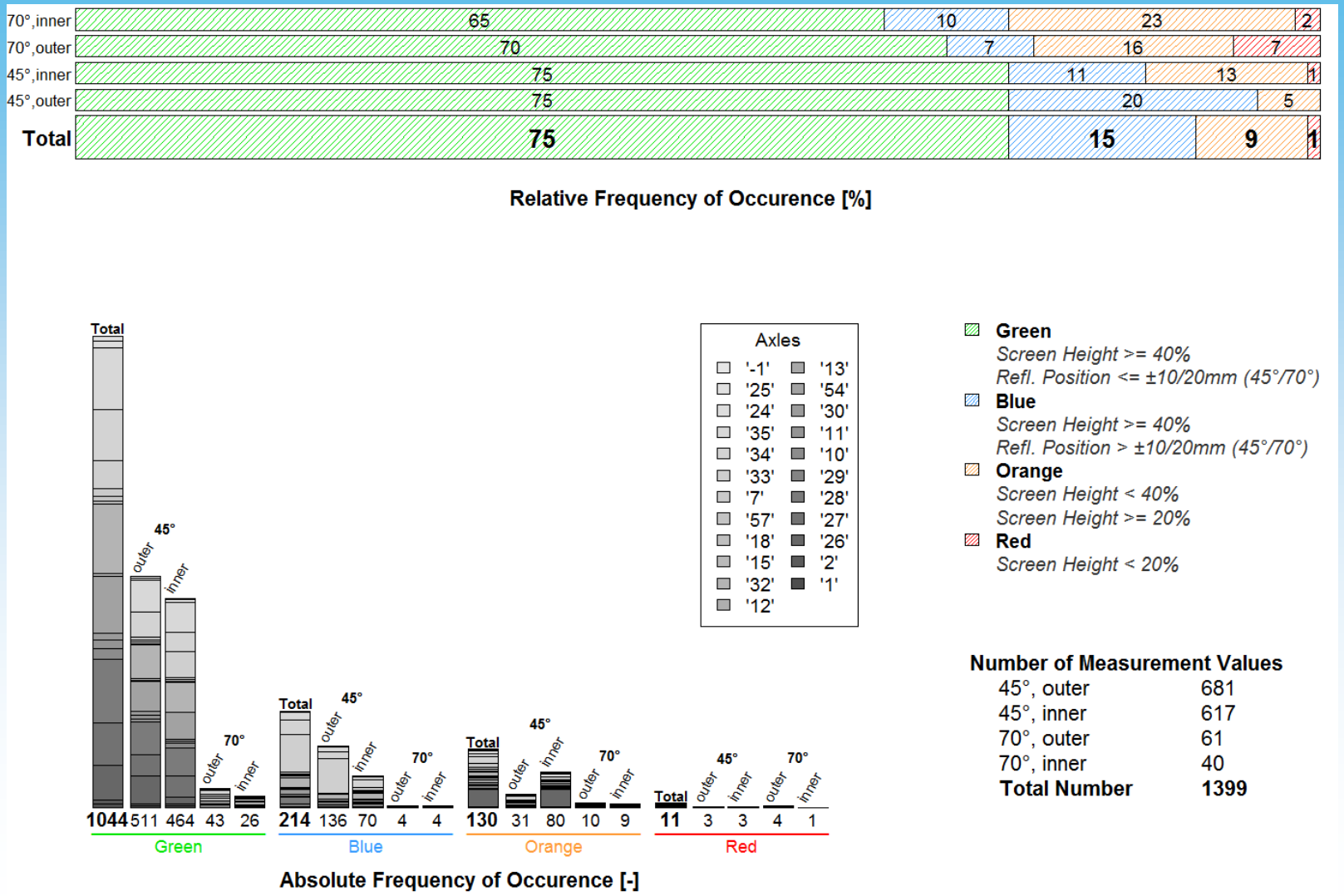
Comparison Artificial/real Defects – Round Robin Test

Reflector Position ≤ ±10/20 mm Deviation



Overview – Refresher Course Examination

Reflector Position ≤ ±10/20 mm Deviation



Number of Measurement Values

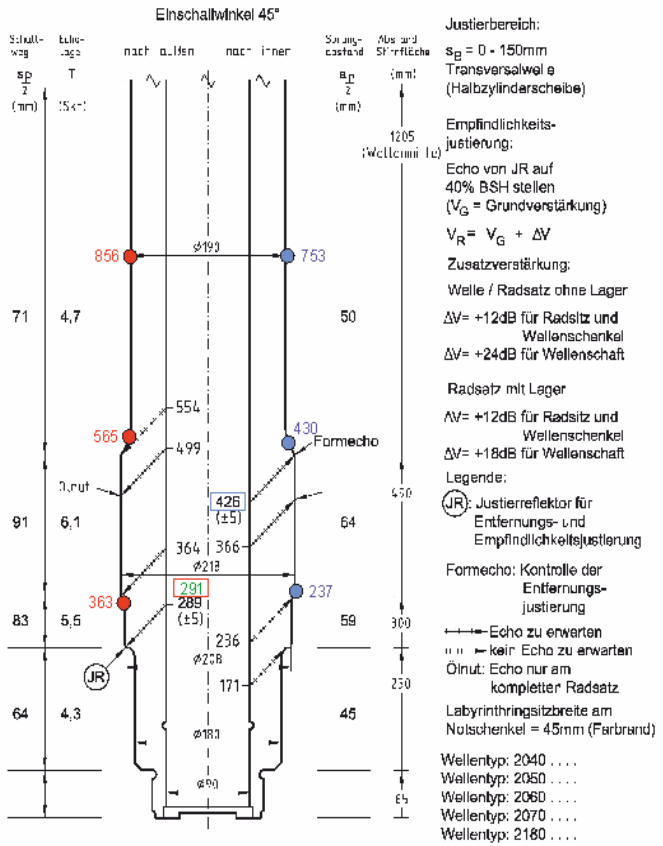
45°, outer	681
45°, inner	617
70°, outer	61
70°, inner	40
Total Number	**1399**

Axles for Round Robin Test with defects

Radsatzwelle ‚18'

Ultraschallprüfung von Radsatzwellen
Tfz-BR 110, 111, 113, 115, 120, 139, 140, 151

Einschallwinkel 45°



Justierbereich:
s_B = 0 - 150mm
Transversalwelle
(Halbzylinderscheibe)

Empfindlichkeits-justierung:
Echo von JR auf 40% BSH stellen
(V_G = Grundverstärkung)

$V_R = V_G + \Delta V$

Zusatzverstärkung:

Welle / Radsatz ohne Lager

ΔV= +12dB für Radsitz und Wellenschenkel
ΔV= +24dB für Wellenschaft

Radsatz mit Lager

ΔV= +12dB für Radsitz und Wellenschenkel
ΔV= +18dB für Wellenschaft

Legende:

JR: Justierreflektor für Entfernungs- und Empfindlichkeitsjustierung

Formecho: Kontrolle der Entfernungs-justierung

Echo zu erwarten
kein Echo zu erwarten
Ölnut: Echo nur am kompletten Radsatz

Labyrinthringsitzbreite am Notschenkel = 45mm (Farbrand)

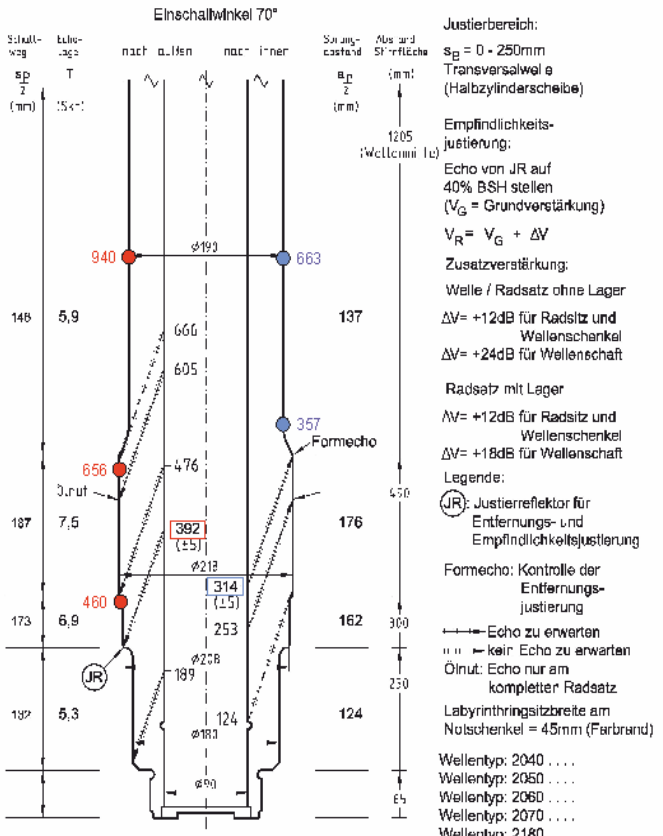
Wellentyp: 2040 ....
Wellentyp: 2050 ....
Wellentyp: 2060 ....
Wellentyp: 2070 ....
Wellentyp: 2180 ....
Wellentyp: 2220 ....

907.9010 Ultraschallprüfung von Radsatzwellen Seite 1/7
Tfz-BR 110, 111, 113, 115, 120, 139, 140, 151 (Fotokopier(Ehiges Muster) A1 4.2-80

Radsatzwelle ‚18'

Ultraschallprüfung von Radsatzwellen
Tfz-BR 110, 111, 113, 115, 120, 139, 140, 151

Einschallwinkel 70°



Justierbereich:
s_B = 0 - 250mm
Transversalwelle
(Halbzylinderscheibe)

Empfindlichkeits-justierung:
Echo von JR auf 40% BSH stellen
(V_G = Grundverstärkung)

$V_R = V_G + \Delta V$

Zusatzverstärkung:

Welle / Radsatz ohne Lager

ΔV= +12dB für Radsitz und Wellenschenkel
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Wellentyp: 2040 ....
Wellentyp: 2050 ....
Wellentyp: 2060 ....
Wellentyp: 2070 ....
Wellentyp: 2180 ....
Wellentyp: 2220 ....

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Round Robin Test – Total-*POD* – 3 Defects in 1 axle – 267 measurements

$$POD_{HIT}^{Total} = \left(1-\left(1-POD_{HIT}^{45°,outer}\right)\times\left(1-POD_{HIT}^{45°,inner}\right)\times\left(1-POD_{HIT}^{70°,outer}\right)\times\left(1-POD_{HIT}^{70°,inner}\right)\right)$$

Bold → Transition region
Italic → Seat
Normal → Shaft

Axle	Number of Protocols	Defect Position [mm]	$POD_{HIT}^{45°,outer}$	$POD_{HIT}^{45°,inner}$	$POD_{HIT}^{70°,outer}$	$POD_{HIT}^{70°,inner}$	POD_{HIT}^{Total}
'18'	73	**299**	0,42	0,21	0,28	-	**0,67**
	97	**500***	0,50	0,33	0,92	0,79	**0,99**
	97	803	0,92	1,00	0,36	0,79	**1,00**

** Real crack*

Position bold means „transition" between shaft and seat

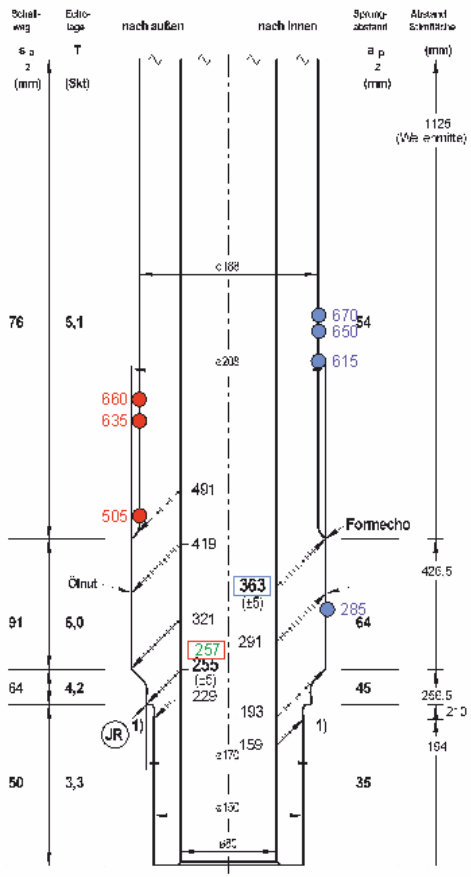
The artificial defect in the shaft at 803 mm is found with 100 % POD while the real defect at 500 mm is found with 99 % POD and the artificial defect at 299 mm with 67 % The latter are beta situated in the transition region but right have different sizes.

Axles with defects in the transition region, seat and shaft – more than 1000 refresher measurements (22 axles, 65 defects)

Radsatzwelle ‚12'

Ultraschallprüfung von Treibradsatzwellen
ET-BR 401, 402 (ICE 1 u. 2)

Einschallwinkel 45°



Justierbereich:
s_B = 0 - 150mm
Transversalwelle
(Halbzylinderscheibe)

Empfindlichkeitsjustierung:
Echo von JR auf
40% BSH stellen;
(V_G = Grundverstärkung)

$V_R = V_G + \Delta V$

Zusatzverstärkung:
Welle/Radsatz ohne Lager
ΔV= +12dB für Radsitz und Wellenschenkel
ΔV= +24dB für Wellenschaft ab 426,5 mm Länge

gefügter / eingebauter Radsatz
Radsatz mit Lager
ΔV= +12dB für Radsitz und Wellenschenkel
ΔV= +18dB für Wellenschaft ab 426,5 mm Länge

Legende:
(JR): Justierreflektor für Entfernungs- und Empfindlichkeitseinstellung
Formecho: Kontrolle der Entfernung
Echo zu erwarten
kein Echo zu erwarten
Ölnut: Echo nur am kompletten Radsatz
Labyrinthringsitzbreite am Notschenkel = 10 mm (Farbrand)
1) Anzeige aus Ende neuer Spritzschicht (± 2mm)

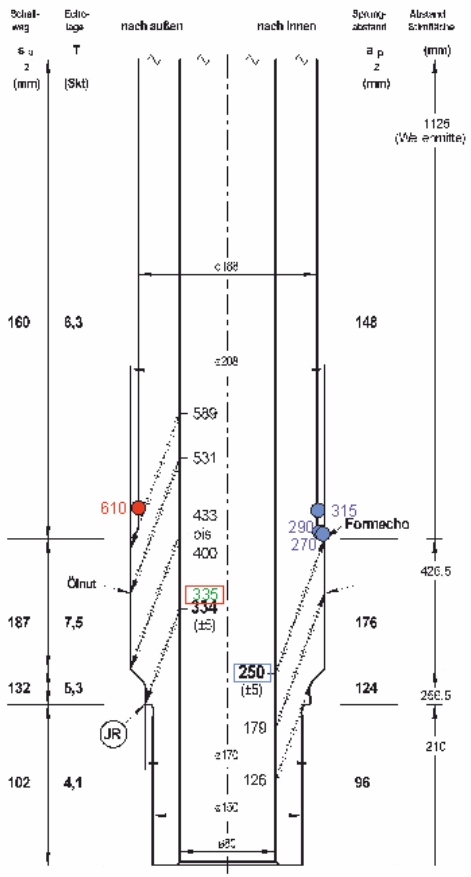
Wellentyp: 2510 . . . .

907.9041 Ultraschallprüfung von Radsatzwellen ET-BR 401, 402 (fotokopierfähiges Muster) A4 Seite 1/5 01.2010

Radsatzwelle ‚12'

Ultraschallprüfung von Treibradsatzwellen
ET-BR 401, 402 (ICE 1 u.2)

Einschallwinkel 70°



Justierbereich:
s_B = 0 - 250mm
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Wellentyp: 2510 . . . .

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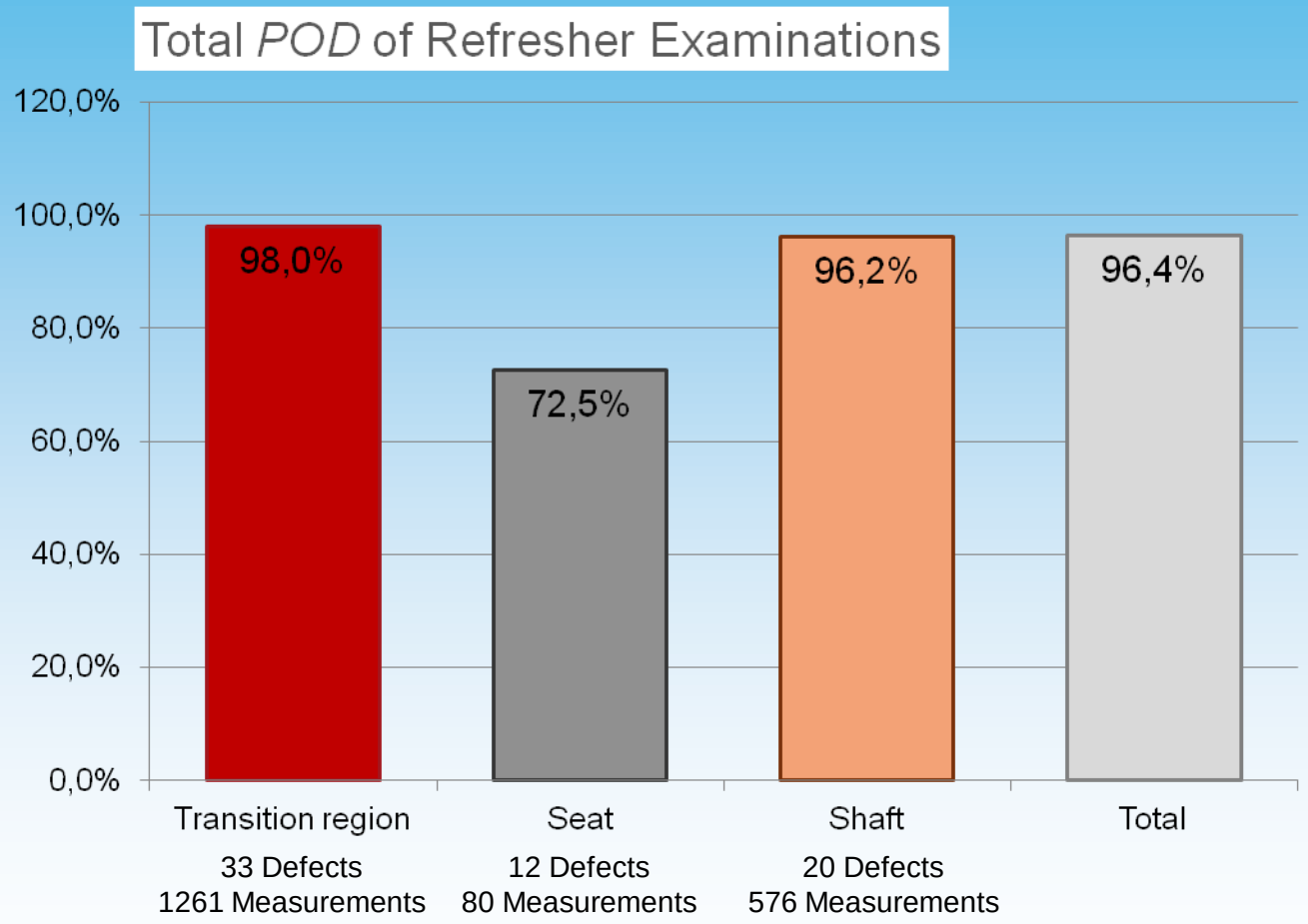
Refresher Examination – Total-*POD*



Total number of defects: **65**
Total number of measurements: 1917

Human factors

- Investigations by our working psychologist Marija Bertovic

Bundesanstalt für Materialforschung und -prüfung

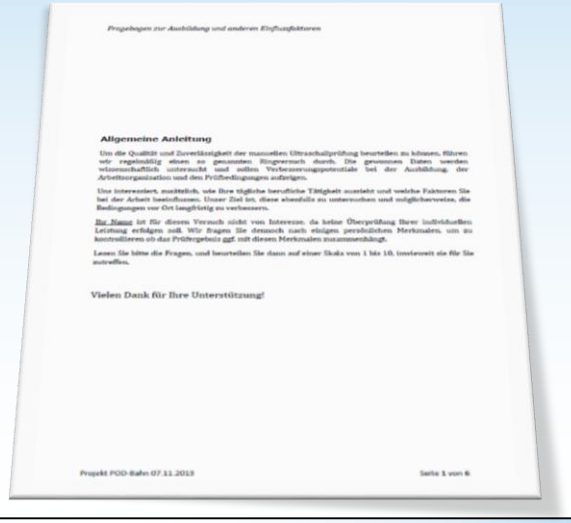
8.3 Radiologische Verfahren
Zuverlässigkeit zerstörungsfreier Prüfsysteme

DGZfP
Deutsche Gesellschaft für Zerstörungsfreie Prüfung e.V.

Research questions

- There is a variability in the inspection results!
  - Which factors lead to variability?
  - How can these factors be controlled?
  - How can the reliability be increased?

- 1. step – questionnaire:



Fragebogen zur Ausbildung und anderen Einflussfaktoren

Allgemeine Anleitung

Um die Qualität und Zuverlässigkeit der manuellen Ultraschallprüfung beurteilen zu können, führen wir regelmäßig einen so genannten Ringversuch durch. Die gewonnen Daten werden wissenschaftlich untersucht und sollen Verbesserungspotentiale bei der Ausbildung, der Arbeitsorganisation und den Prüfbedingungen aufzeigen.

Uns interessiert, ausschließlich, wie Ihre tägliche berufliche Tätigkeit aussieht und welche Faktoren Sie bei der Arbeit beeinflussen. Unser Ziel ist, diese ebenfalls zu untersuchen und möglicherweise, die Bedingungen vor Ort langfristig zu verbessern.

Ihr Name ist für diesen Versuch nicht von Interesse, da keine Überprüfung Ihrer individuellen Leistung erfolgen soll. Wir fragen Sie dennoch nach einigen persönlichen Merkmalen, um zu kontrollieren ob das Prüfergebnis auf mit diesen Merkmalen zusammenhängt.

Lesen Sie bitte die Fragen, und beurteilen Sie dann auf einer Skala von 1 bis 10, inwieweit sie für Sie zutreffen.

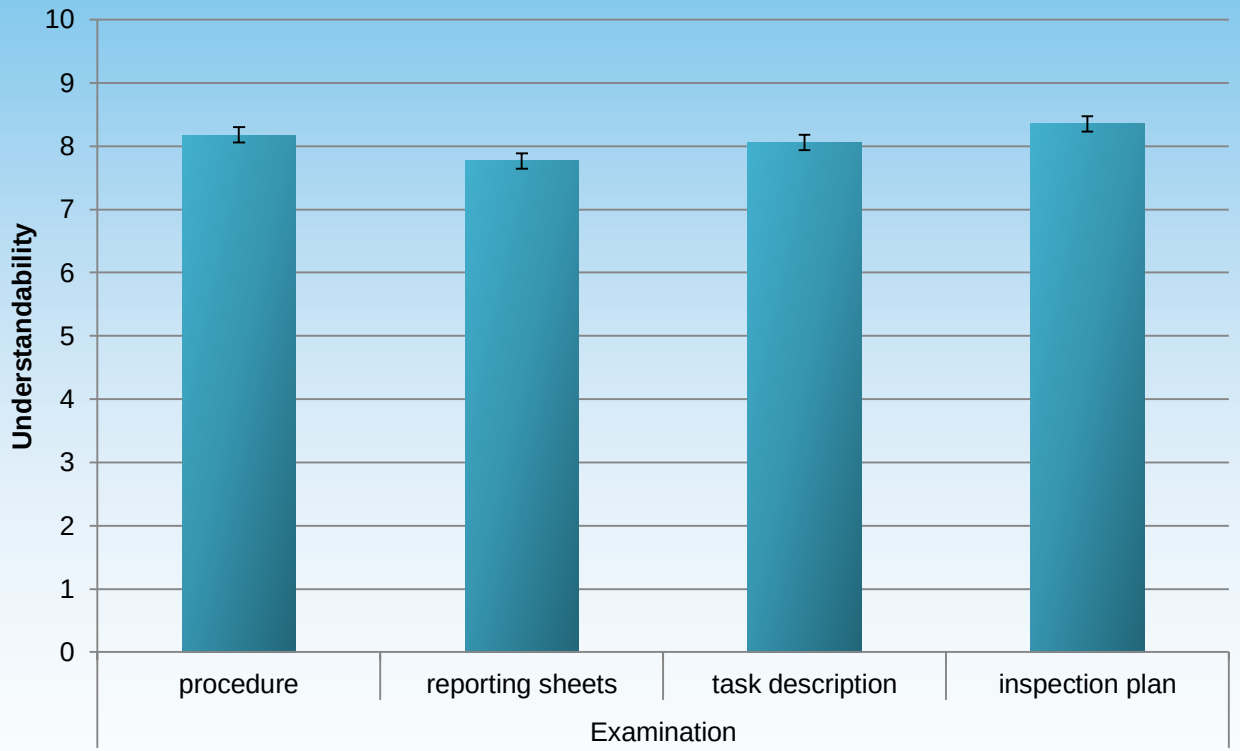
Vielen Dank für Ihre Unterstützung!

Projekt POD-Bahn 07.11.2013 Seite 1 von 6

M. Bertovic

Preliminary results (N=18)

- During examination



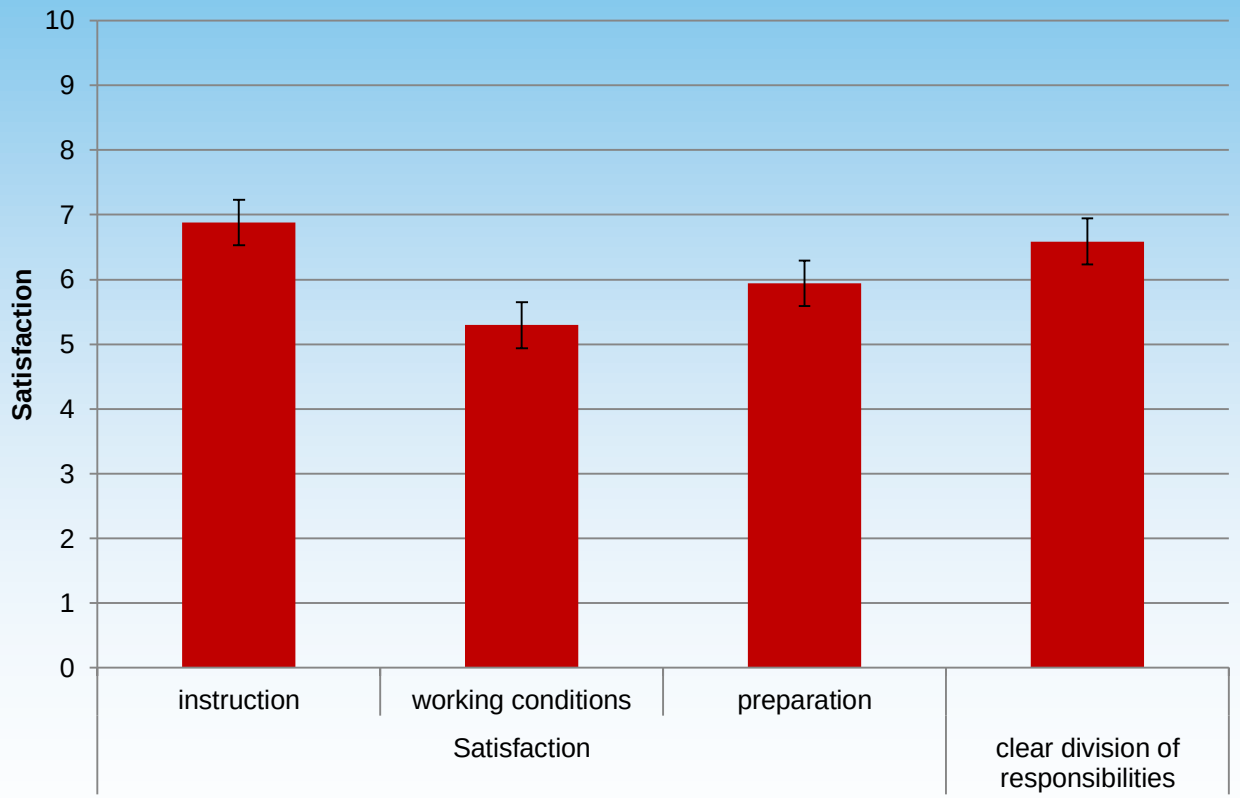
How understandable is the documentation?

a) Inspection procedure
b) Reporting sheets
c) Task description
d) Inspection plan

M. Bertovic

Preliminary results (N=18)

- In the field



How satisfied are you with :

a) The quality of the **instruction** through the supervisors (e.g. explanations, task description)

b) Working conditions in the field (e.g. cleanliness, temperature, noise, access)

c) Inspection preparation (e.g. preparation of the components, documentation, time, coordination)

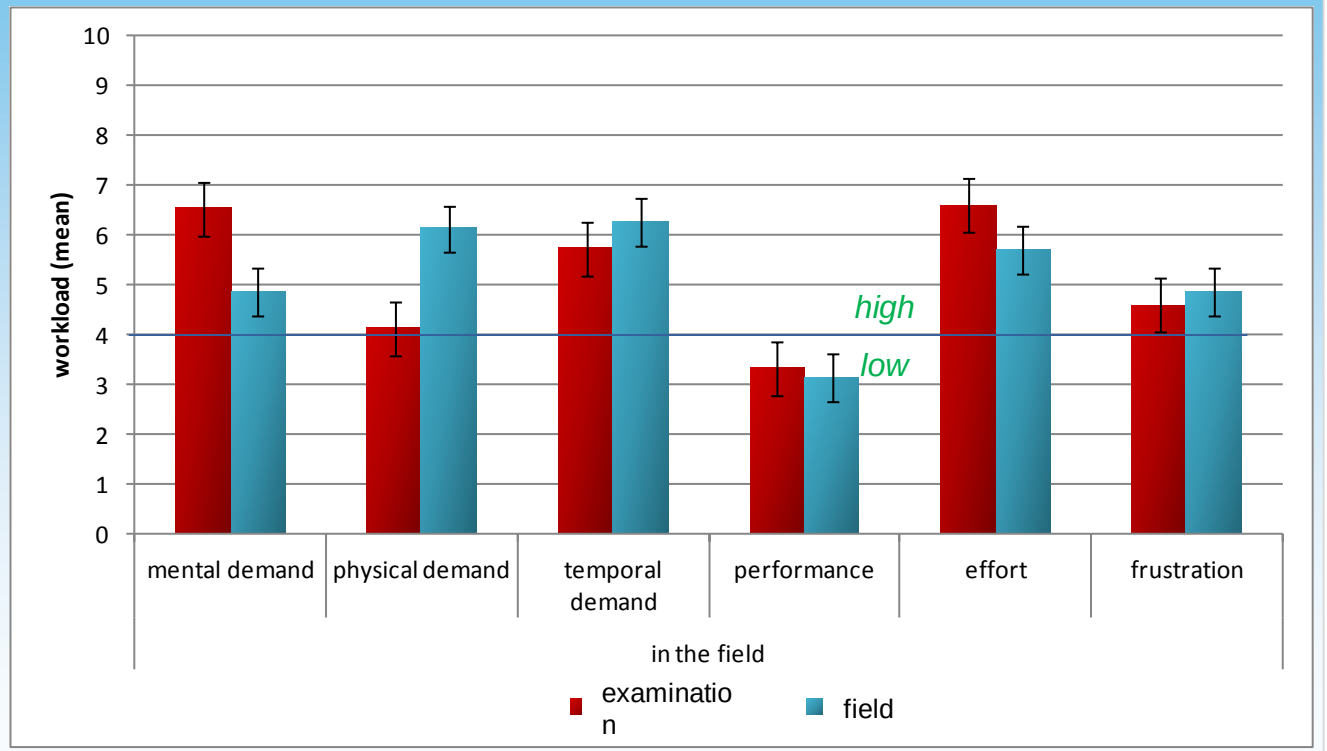
How clear is

a) The division of **responsibilities** (e.g. inspector, supervisor, management)

M. Bertovic

Preliminary results (N=18)

- During the examination and in the field



MENTAL WORKLOAD

Mental Demand

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)?

Physical Demand

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)?

Temporal demand

How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?

Performance

How satisfied were you with your performance in accomplishing these goals?

Effort

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration

How insecure, discouraged, irritated, stressed and annoyed did you feel during the task?

M. Bertovic

General Problems of HF in NDT

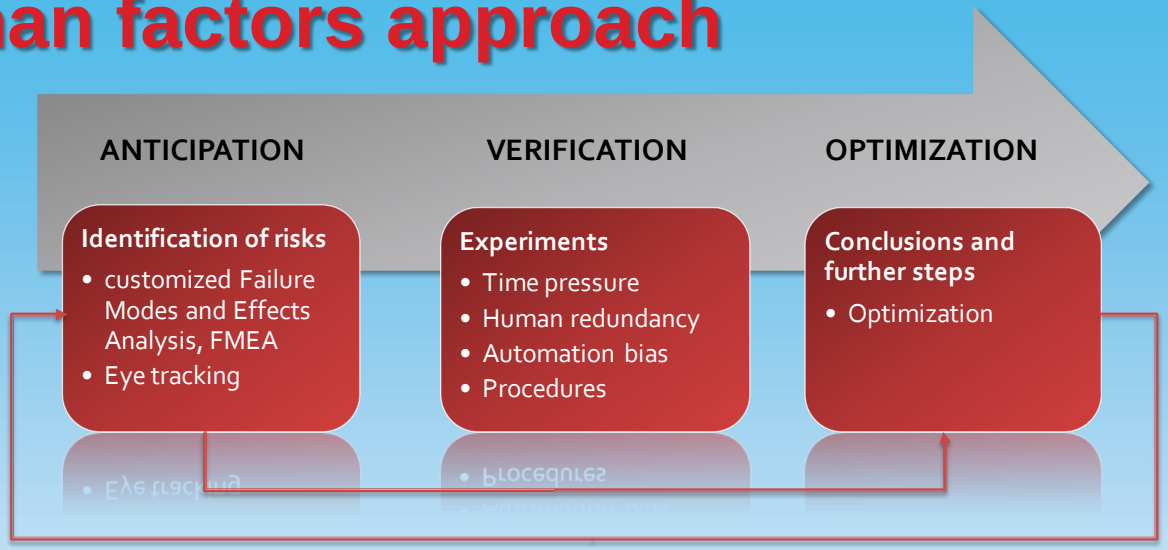
- Observation: variability in the inspection results
  - Source: human factor

- Problem: gap in knowledge
  - Variability attributed only to the inspector
    - other influences neglected or unknown (technology, team, organization, extra-organizational environment)
  - Manual vs. mechanized NDT
    - Mechanized NDT is seen as the solution for the „human factors problem“
  - Research in the field of NDT is missing!
  - Knowledge not reaching the end user
    - Bridge between engineering and psychology needed
  - Methodology how to address human factors in NDT unknown
  - Optimization methods
    - Missing or not implemented

M. Bertovic

Human factors approach

Method



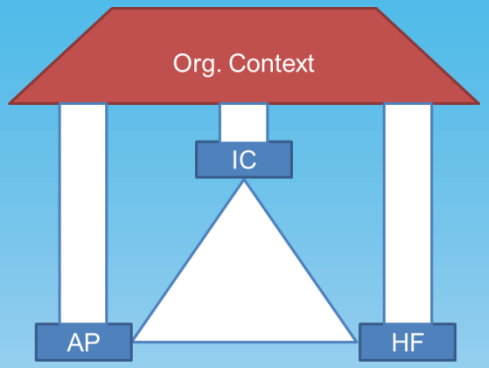
Main conclusions

- **FMEA:** There is a risk of failure in mechanised NDT
  - The risk arises not only from the inspector, but mainly from the technological shortcomings, organisation, characteristics of the task and the environment, human-human and human-automation interaction.
- **Overtrust** in the reliability of the mechanised equipment or an automated software can lead to errors (compliance with the errors of the automation).
- **Time pressure** has an effect on the inspection quality. **Organisation** even a more important one!
- Only when inspectors work completely independently of each other can we profit from **human redundancy** (4-eye principle).
- **Inspection procedures and instructions** need to be developed with the user using human factors principles to:
  - ensure ***understanding*** of the content, and
  - increase ***usability*** of the procedure.

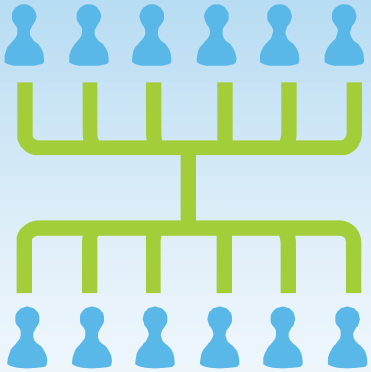
Progress in Methods for

- 1. Intrinsic Capability: Physics and technical influences
- 2. Application Parameters: Environment of the experiment
- 3. Human Factors: In calibration, set up and evaluation and decision making as well as in the organizational context
- 4. Organizational Context: Business, technical and information process

Organizational Context?



- **Internal Organizational Factors**



- **External Organizational Factors**

Ralf Holstein DGZfP

Human Factor and Organization

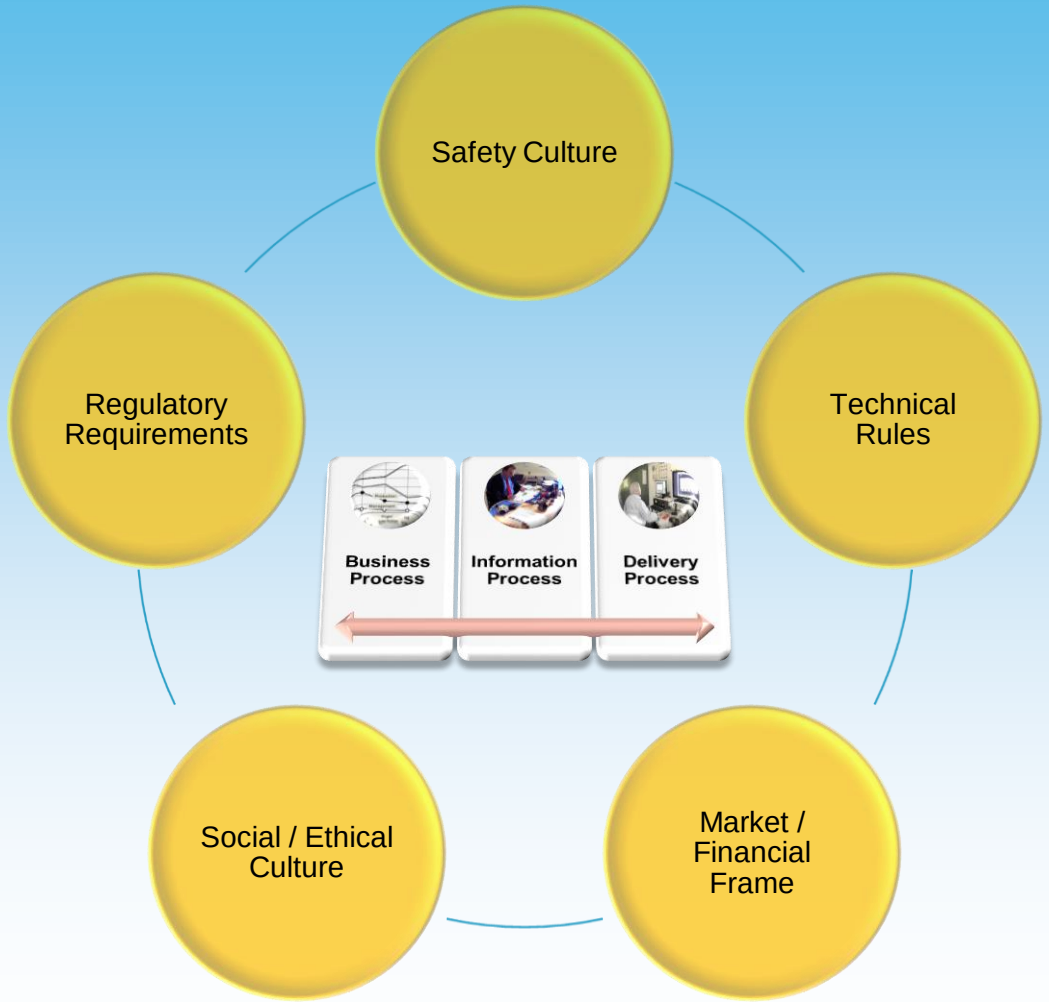
- All three processes influence operator performance
- Amount of information requires *"Information Management"*
- Communication Chain between

Customer - Contractor - Level III - Operator

should be carefully designed

Ralf Holstein DGZfP

Process Environment



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Conclusions

- **ROC and POD** methods are adequate means measuring the reliability of NDE-systems for **high safety demands**
  - **But all influencing factors** needs to be known and controlled
  - POD of a component should be used as an **optimization tool (rather than final judgement)**

- Human Factors in NDE → Complex Interactions
  - Organizational context determines the way inspections are performed and therefore highly influences on the inspection quality in addition to individual capabilities.
- NDE-reliability incl. HF-investigation → assist optimization

DEUTSCHE GESELLSCHAFT FÜR ZERSTÖRUNGSFREIE PRÜFUNG E.V.

BAM

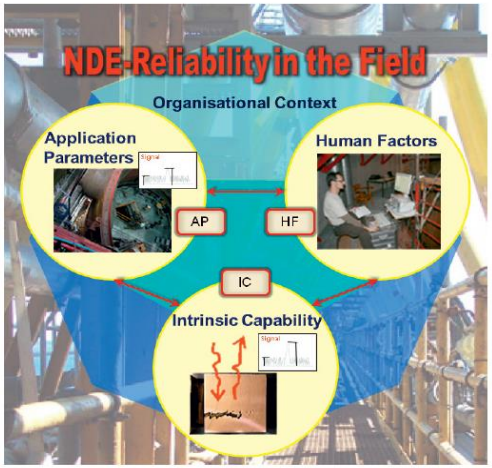
ASNT

SMRT

EF NDT European Federation for Non-Destructive Testing

FIRST ANNOUNCEMENT AND CALL FOR PAPERS

5th European-American Workshop on Reliability of NDE



6th European American Workshop on Reliability of NDE

In connection with
QNDE 2015 - Minneapolis, USA
July 27-31st

Tutorial for POD basics
Lectures and posters:
Avanced Metods (MP-POD, MAPOD, BAYES)
Application in Industry
Reliability of SHM
Integrated Solutions
Human Factors

„Open space workshop“
on challenging topics

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