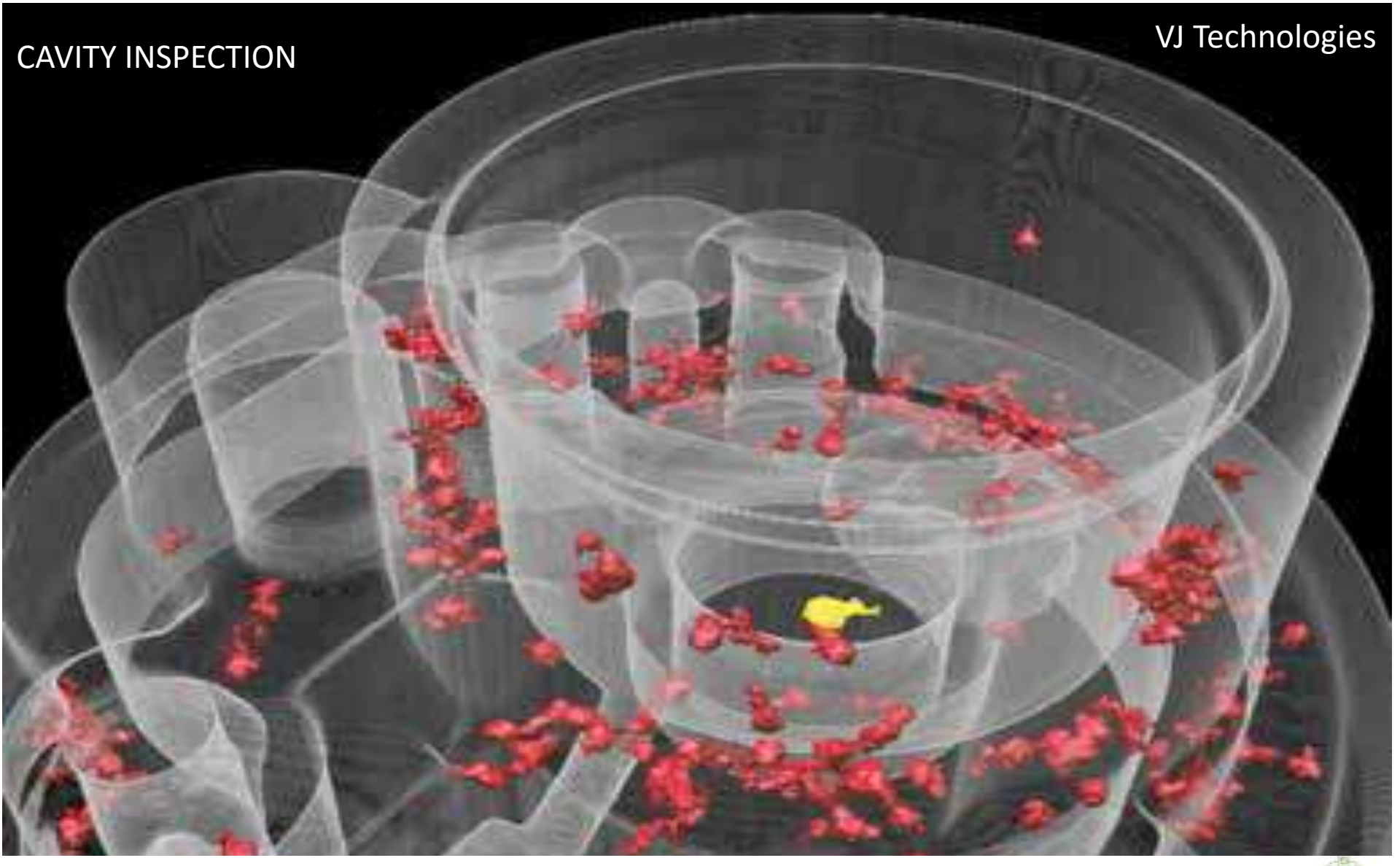
# NDT&E: Applications & Principles



# NDT&E: Applications & Principles

| | |
|---|---|
| **5.** | **NDT&E: Evolution of Reliability and Responsibility** |
| **5.1.** | NDT: its value and role for the evolution in industry |
| **5.2.** | Applications and Principles of Nondestructive Testing |
| **5.3.** | Codes and Standards |
| **5.4.** | Methods of NDT&E – an Overview |
| **5.5.** | The Human Impact |
| **5.6.** | Case Studies by Movies |

# NDT&E: Applications & Principles

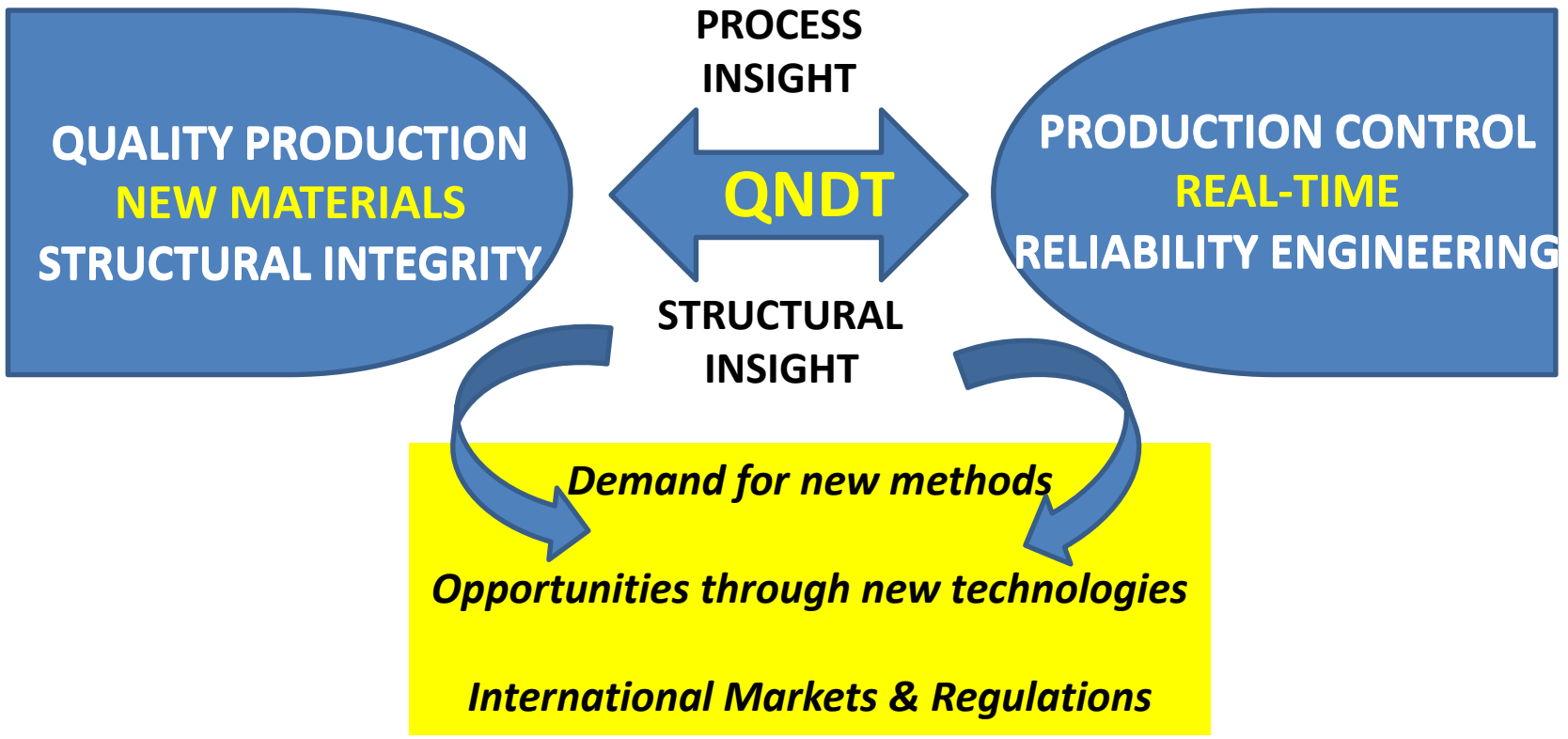
***Destructive tests are used to determine the physical properties of materials such as impact resistance, ductility, yield and ultimate tensile strength, fracture toughness and fatigue strength, but discontinuities and differences in material characteristics are more effectively found by NDT.***

***Today, modern nondestructive tests are used in***

- ***manufacturing,***
- ***fabrication and***
- ***in-service inspections***

***to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level. During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public.***

# NDT&E
# - in short -



# NDT&E: Applications in a Nut-Shell

**Destructive tests are used
to determine the physical properties of materials such as
impact resistance, ductility, yield and ultimate tensile strength,
fracture toughness and fatigue strength,
but discontinuities and differences in material characteristics
are more effectively found by NDT.**

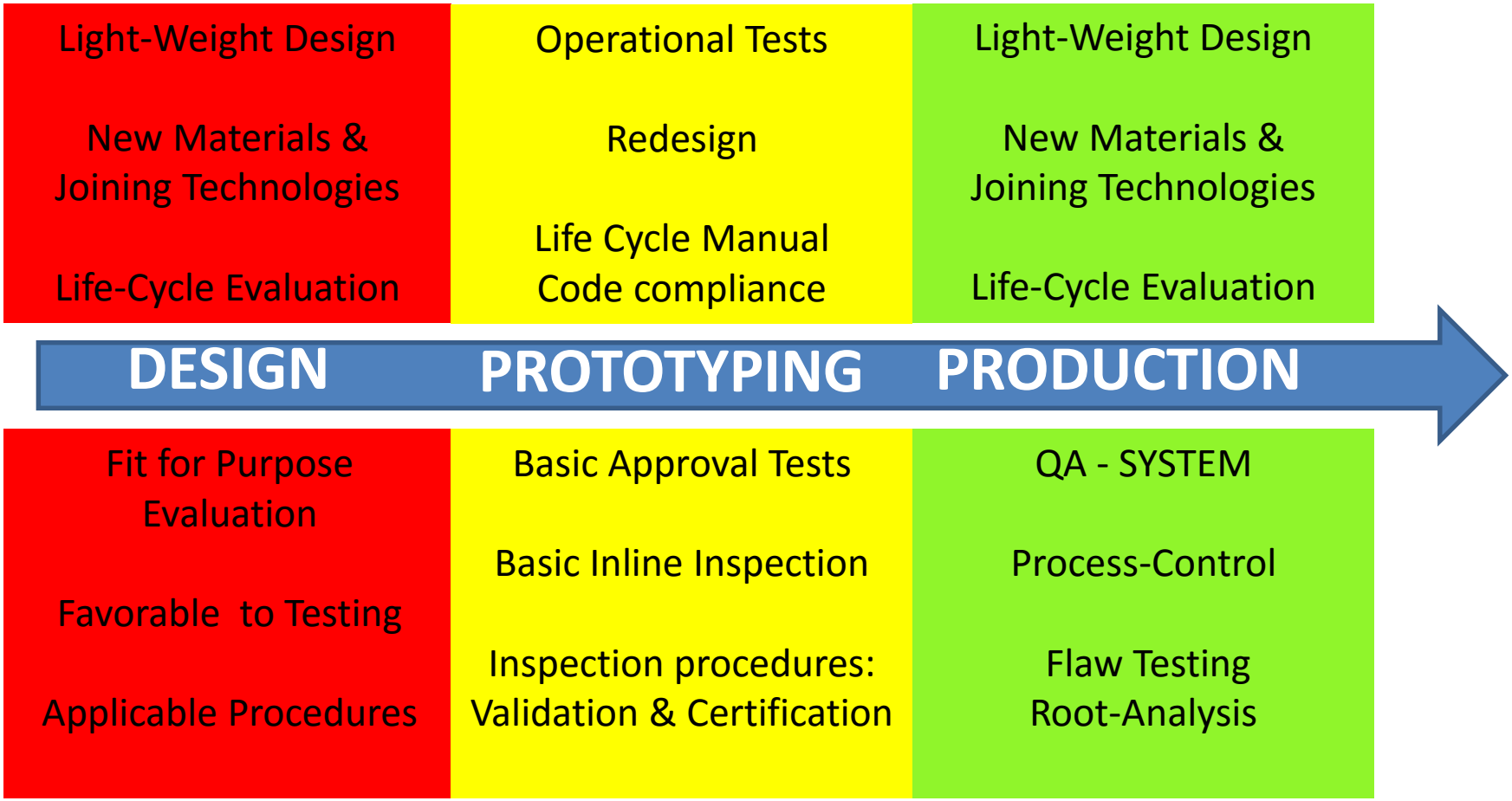
# NDT&E: Applications in a Nut-Shell

**NDT&E is used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level.**

**During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection , and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary for their usefulness and the safety of the public.**

# NDT&E: Applications & Principles

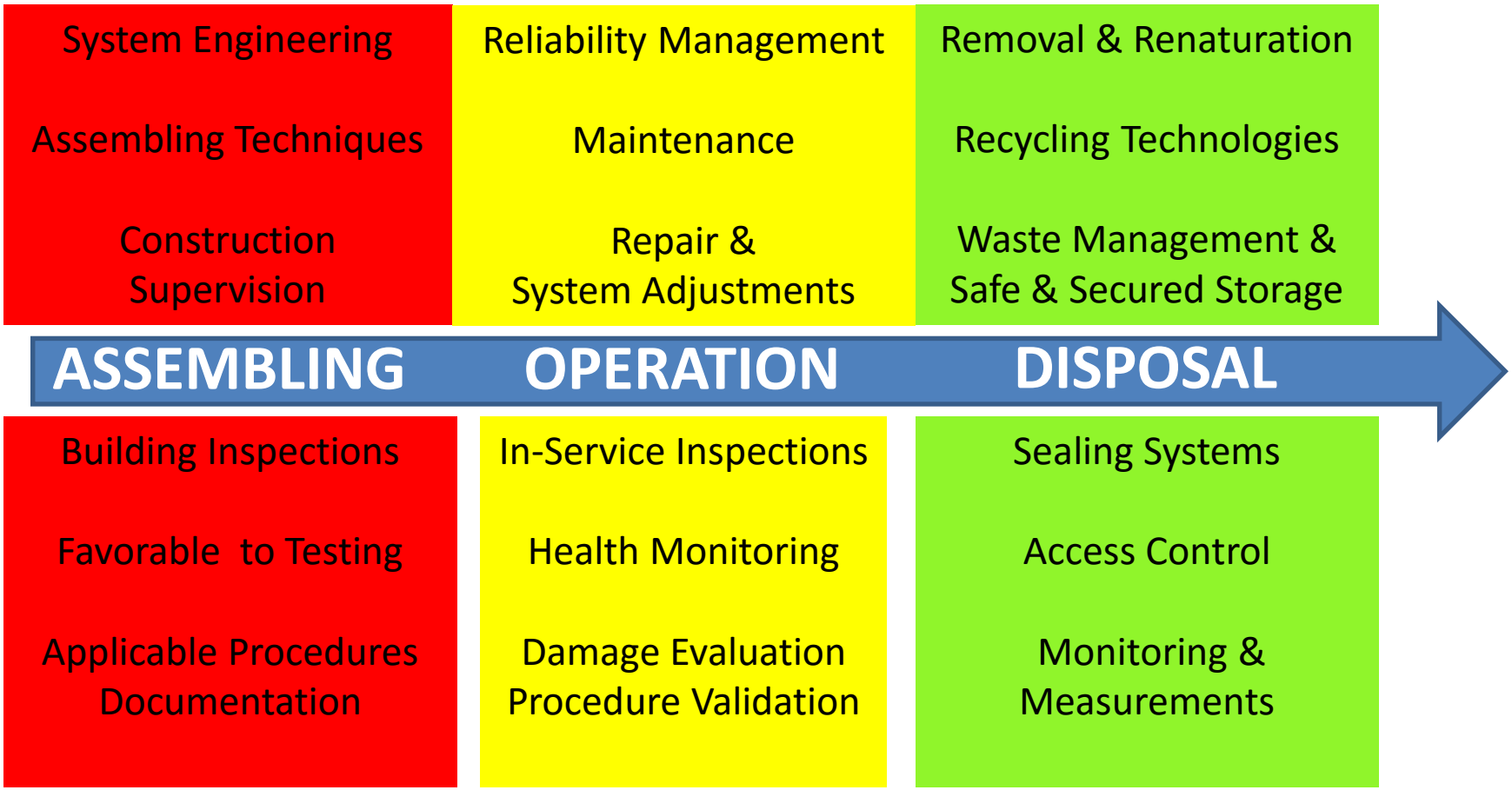
## R & D



# NDT&E: Design & Construction

**Concurrent Engineering applied in Product, System and Facility Development comprises NDT&E at various Stages of Integrated Design and Construction Engineering.**

# NDT&E: Applications & Principles



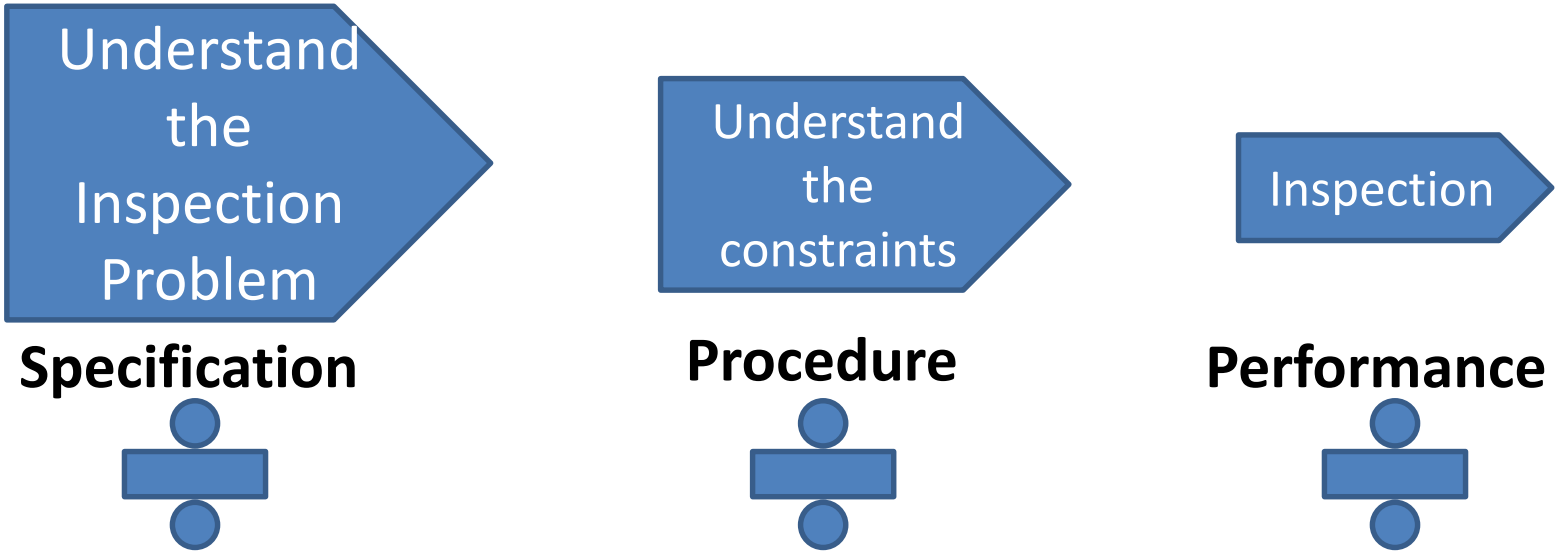
# NDT&E: Design & Construction

## ASSEMBLING:

***„fit together the separate component parts of a machine or other object. "my new machine is being assembled and my old one dismantled"***

***Synonyms:*** set up, join up, fit together, put together, piece together, connect, join, unite

# NDT&E: Applications



# NDT&E: Applications

**YOU HAVE TO PLAN AND PERFORM NDT&E!**

**WHAT HAVE YOU TO CONSIDER AND TO DO?**

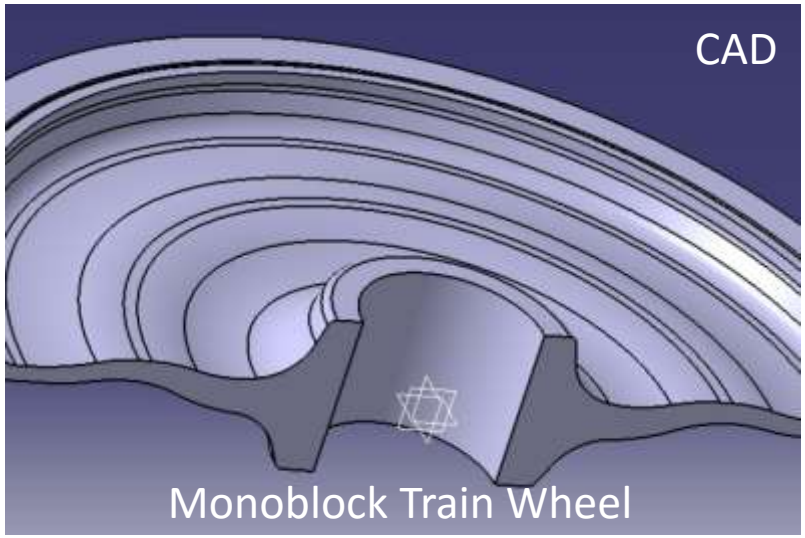
**LET US DISCUSS**

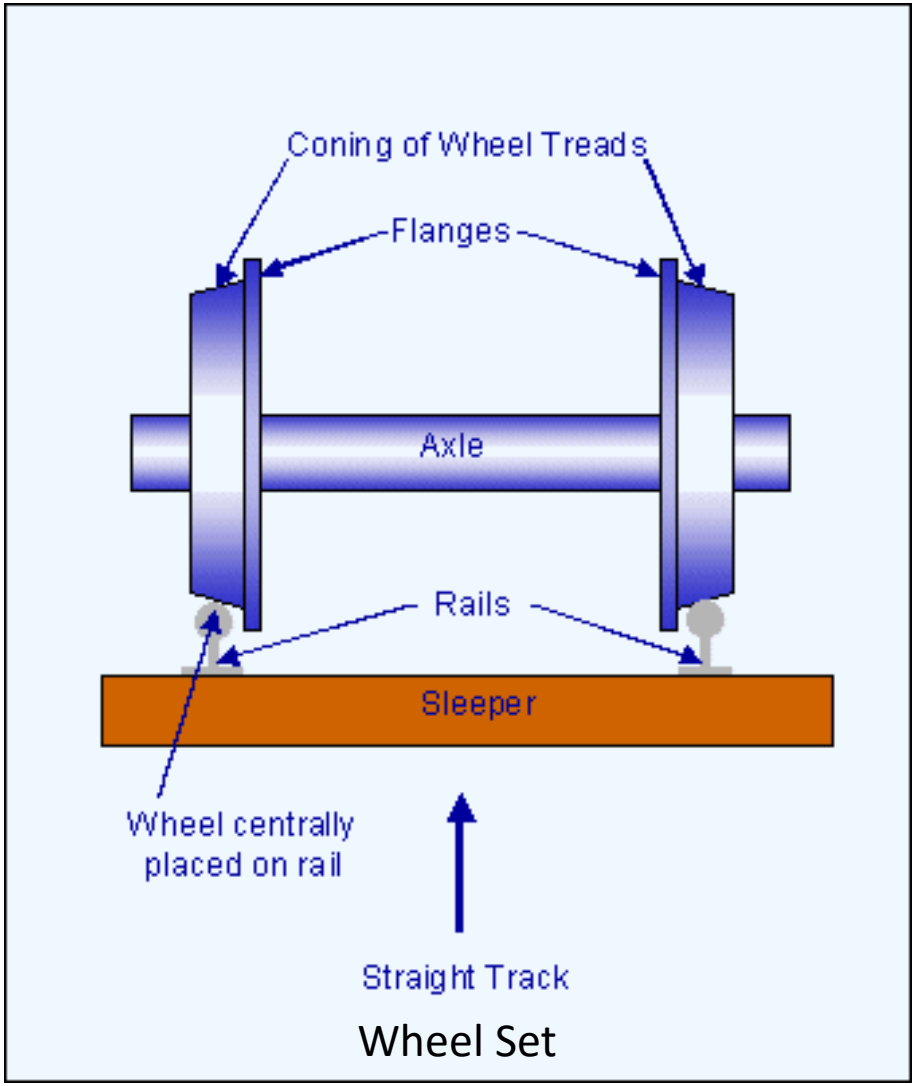
- **A RAILWAY WHEEL (Manufacturing)**
- **AN AIRPLANE STRUCTURE (Maintenance)**
- **A POWER PLANT PIPE INSPECTION (Maintenance)**
- **A WATER DAM INSPECTION (Maintenance)**
- **A RADIOACTIVE WASTE CONTAINER (Storage)**
- **A CRANKSHAFT (Manufacturing)**

**What is common with these inspections?**

# NDT&E: Applications

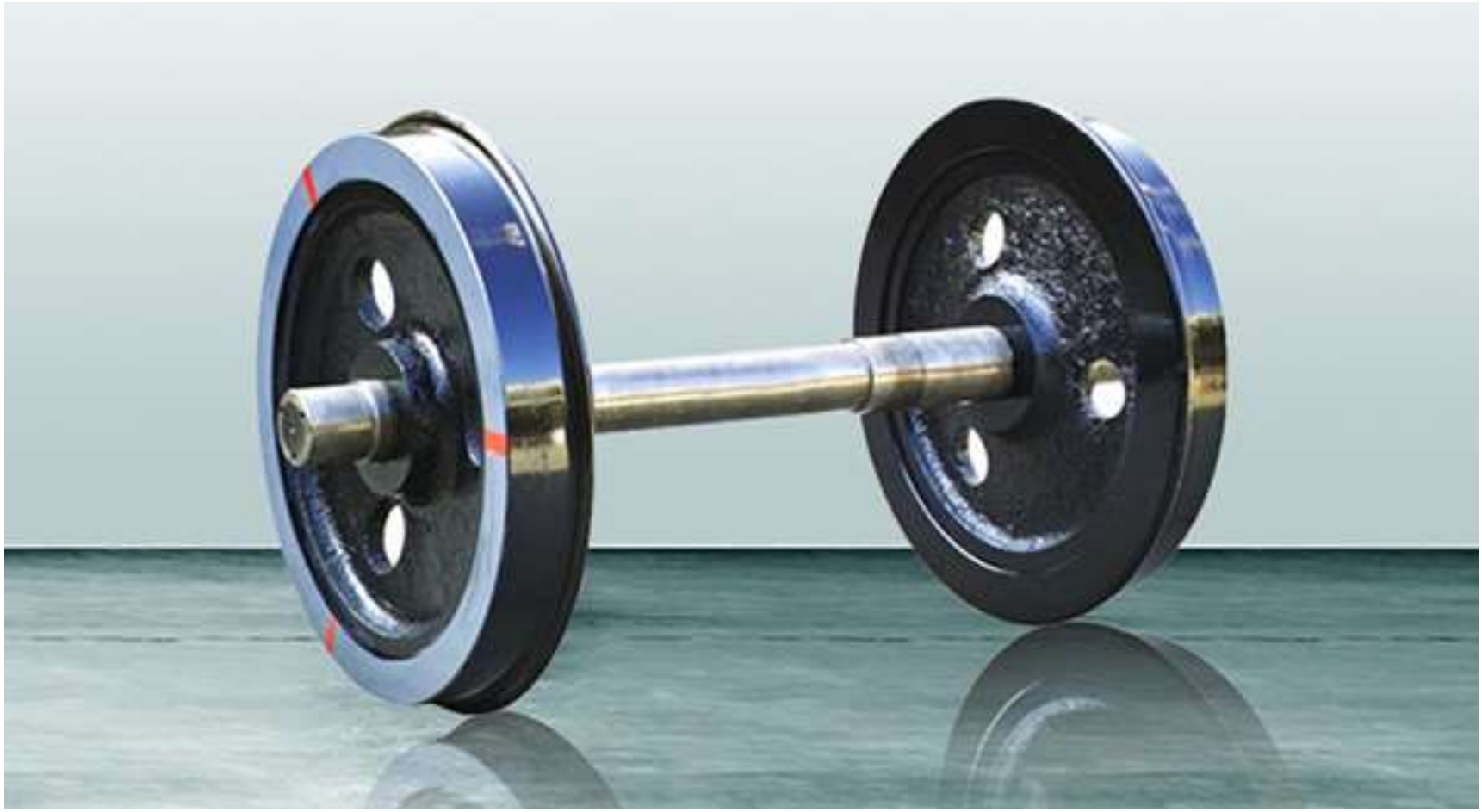
## WHEEL INSPECTION



# NDT&E: Applications

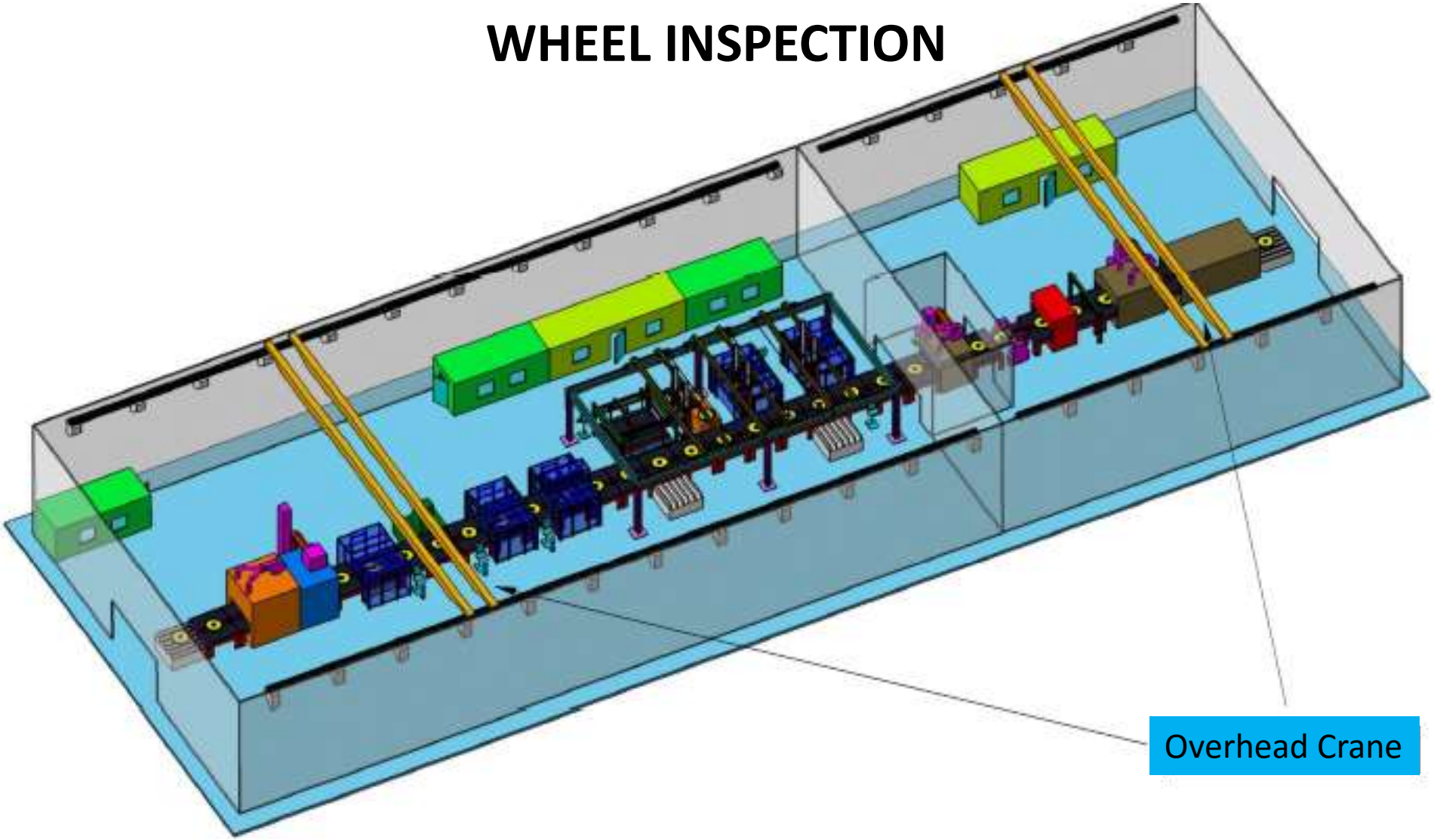
# WHEEL INSPECTION



## Freight Wagon Wheel Set

# NDT&E: Applications

## WHEEL INSPECTION




## INSPECTION LINE FOR HIGH SPEED WHEELS

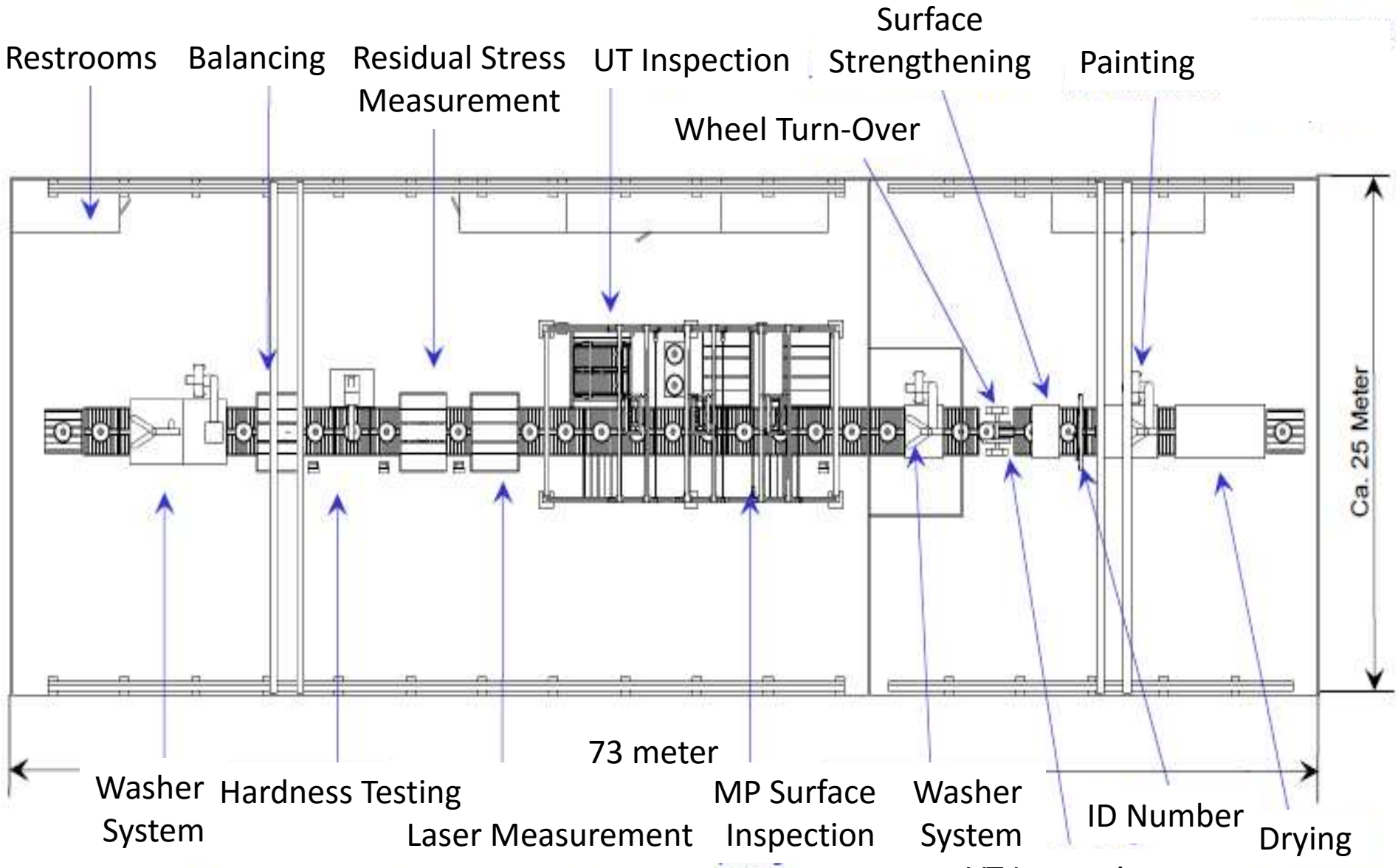
**Michael Kröning**

**Nondestructive Testing & Evaluation**

TPU Lecture Course 2015/16

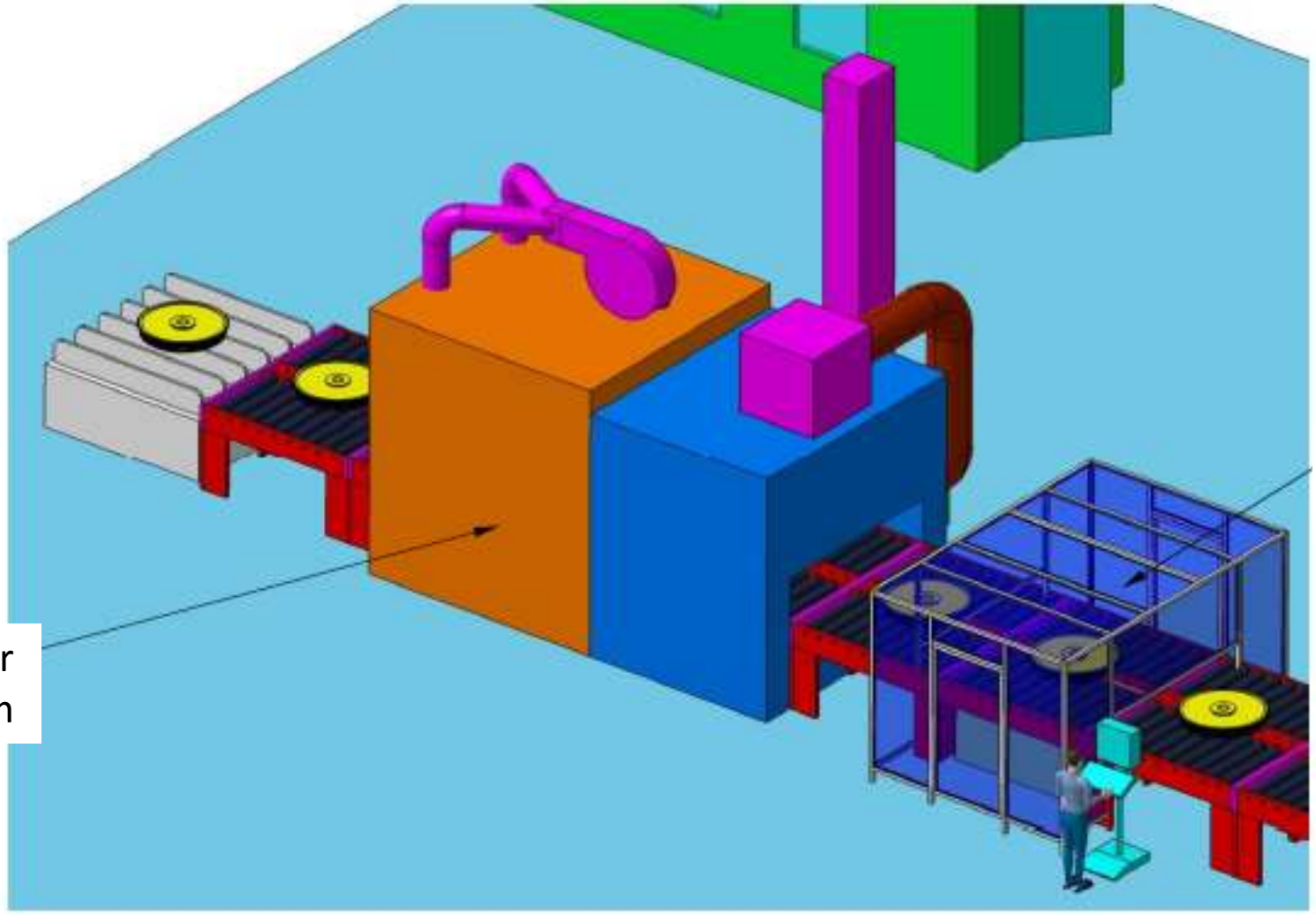
TOLMI

# NDT&E: Applications



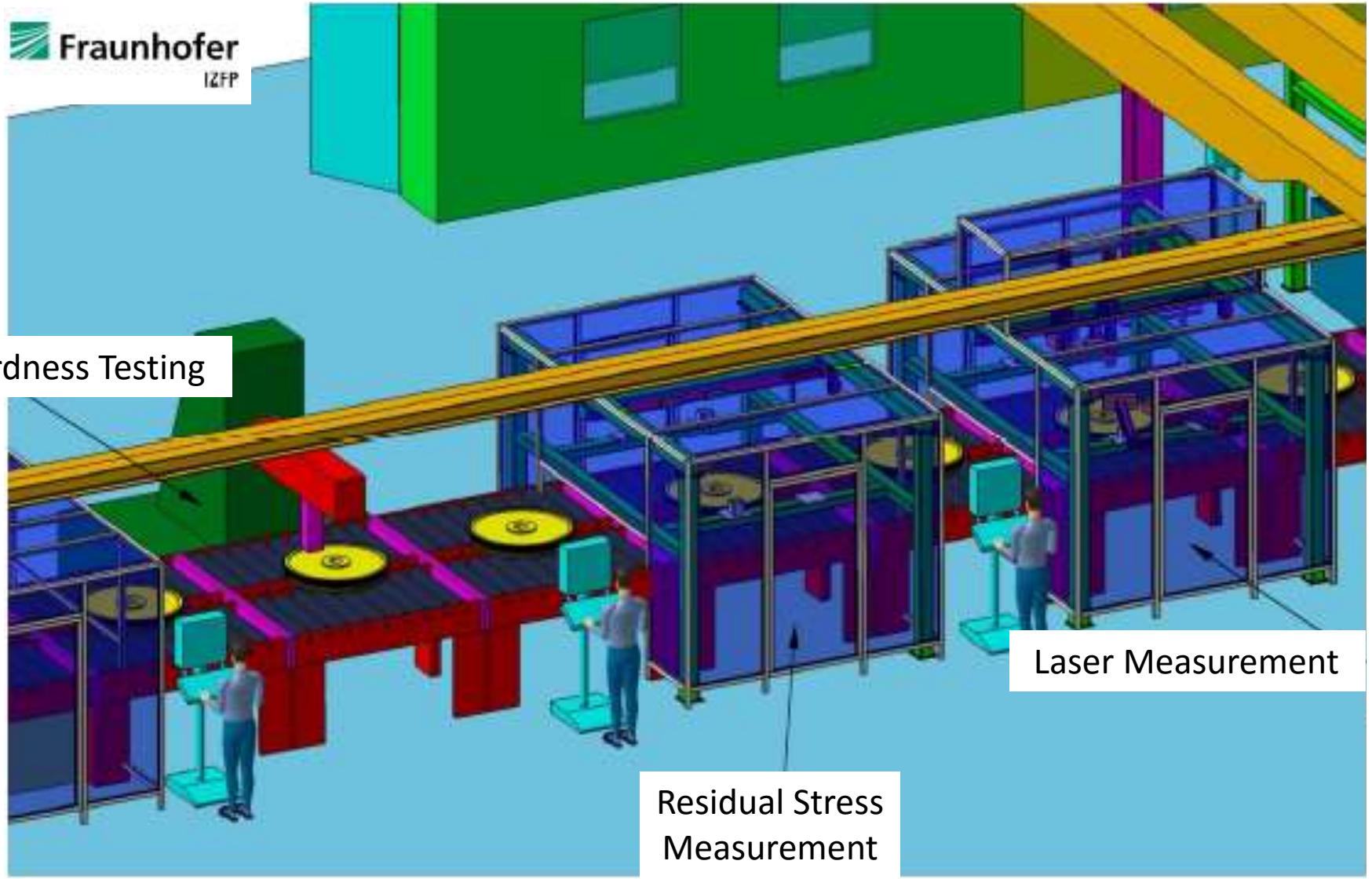
# NDT&E: Applications

# WHEEL INSPECTION



# NDT&E: Applications

# WHEEL INSPECTION



# NDT&E: Applications

# WHEEL INSPECTION

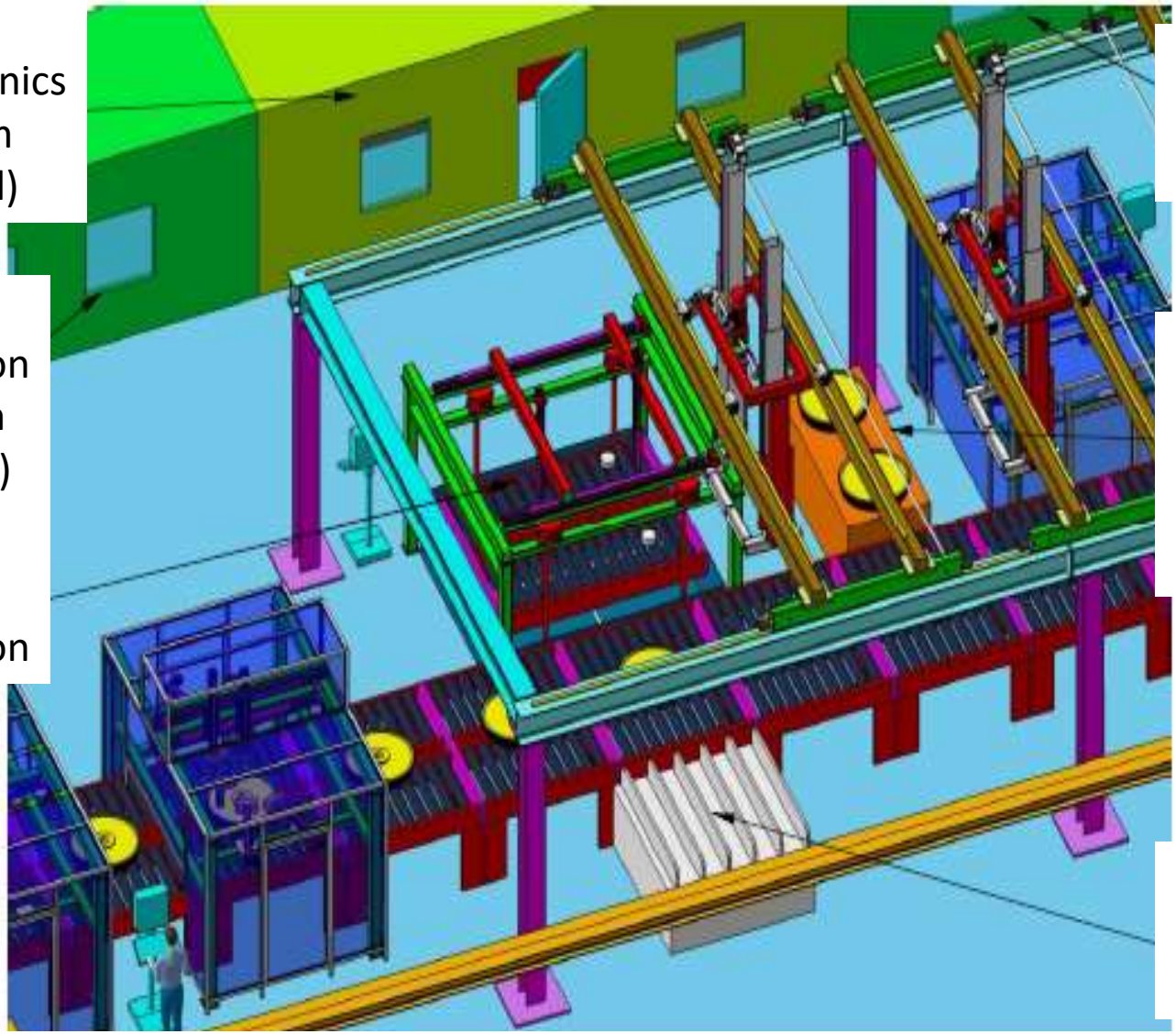
Control Electronics
Server Room
(conditioned)

UT – Inspection
Server Room
(conditioned)

UT – Inspection

GMH Prüftechnik

Fraunhofer IPA



MP – Inspection
Server Room
(conditioned)

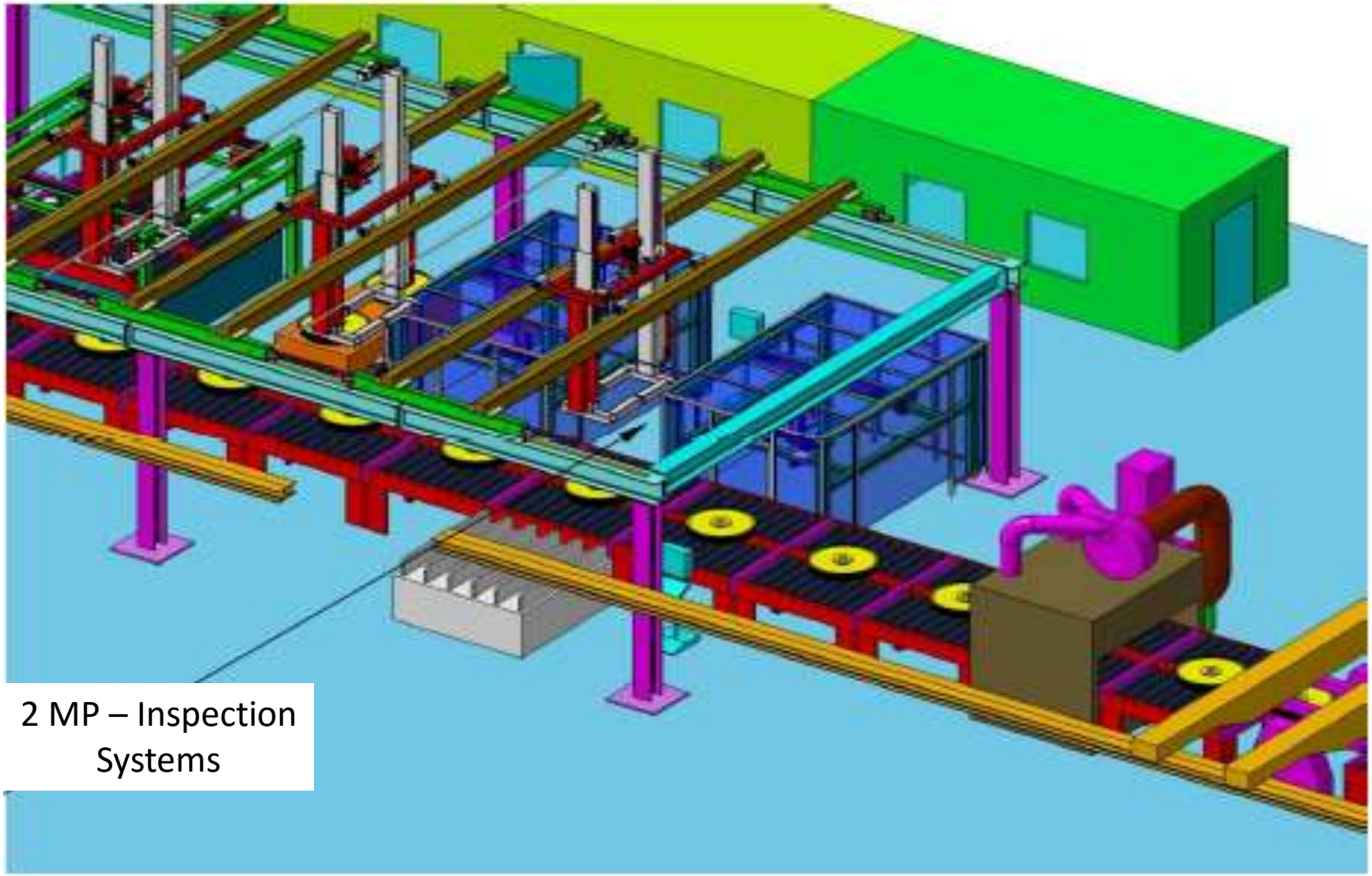
KARL DEUTSCH

Control Disks
UT – Inspection
MP – Inspection

Discharge Lock

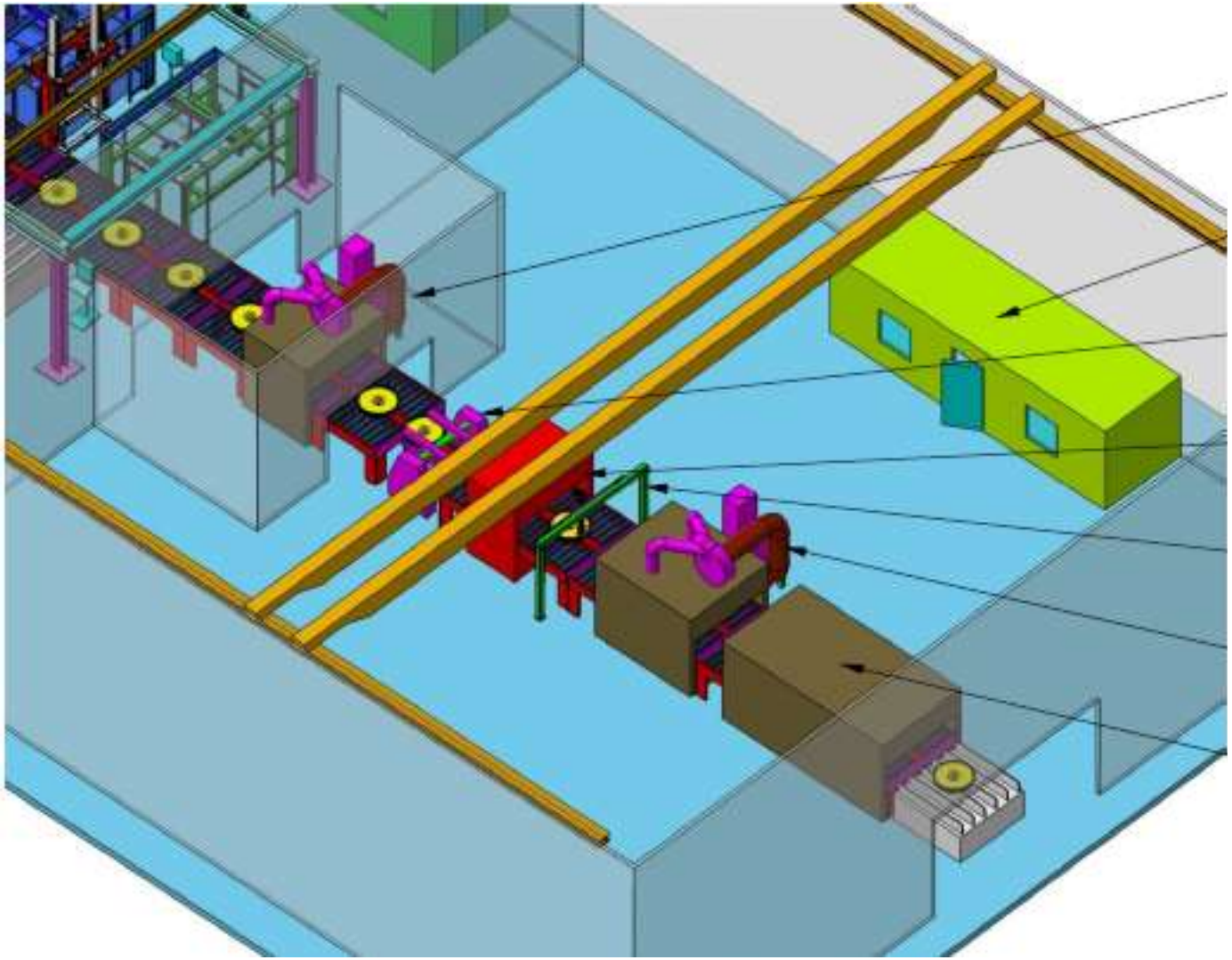
# NDT&E: Applications

# WHEEL INSPECTION



2 MP – Inspection Systems

# NDT&E: Applications
# WHEEL INSPECTION



Washer System

Control Electronic (conditioned)

Wheel Turn-Over Visual Testing

Surface Strengthening

ID Number

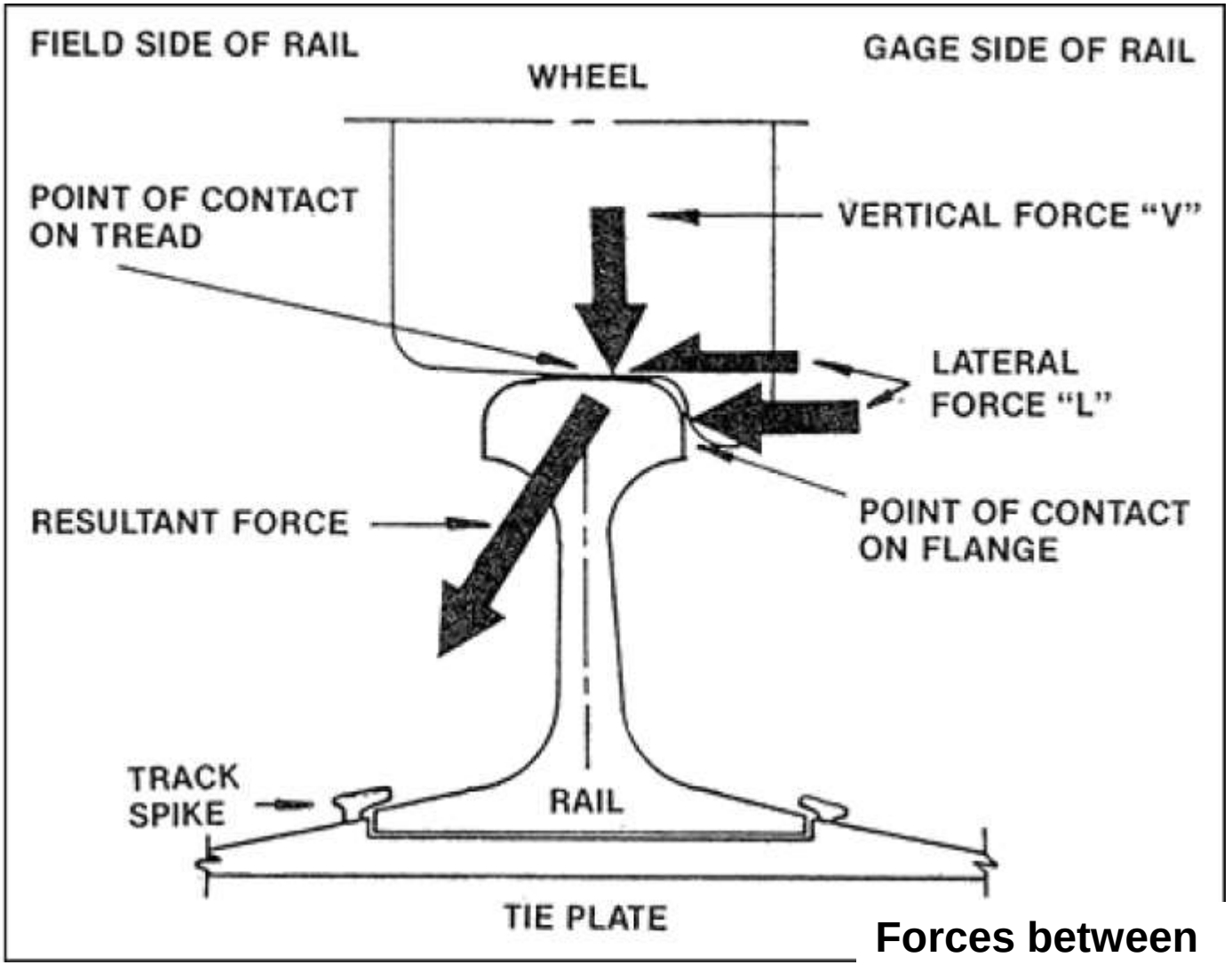
Painting

Drying

# NDT&E: Applications

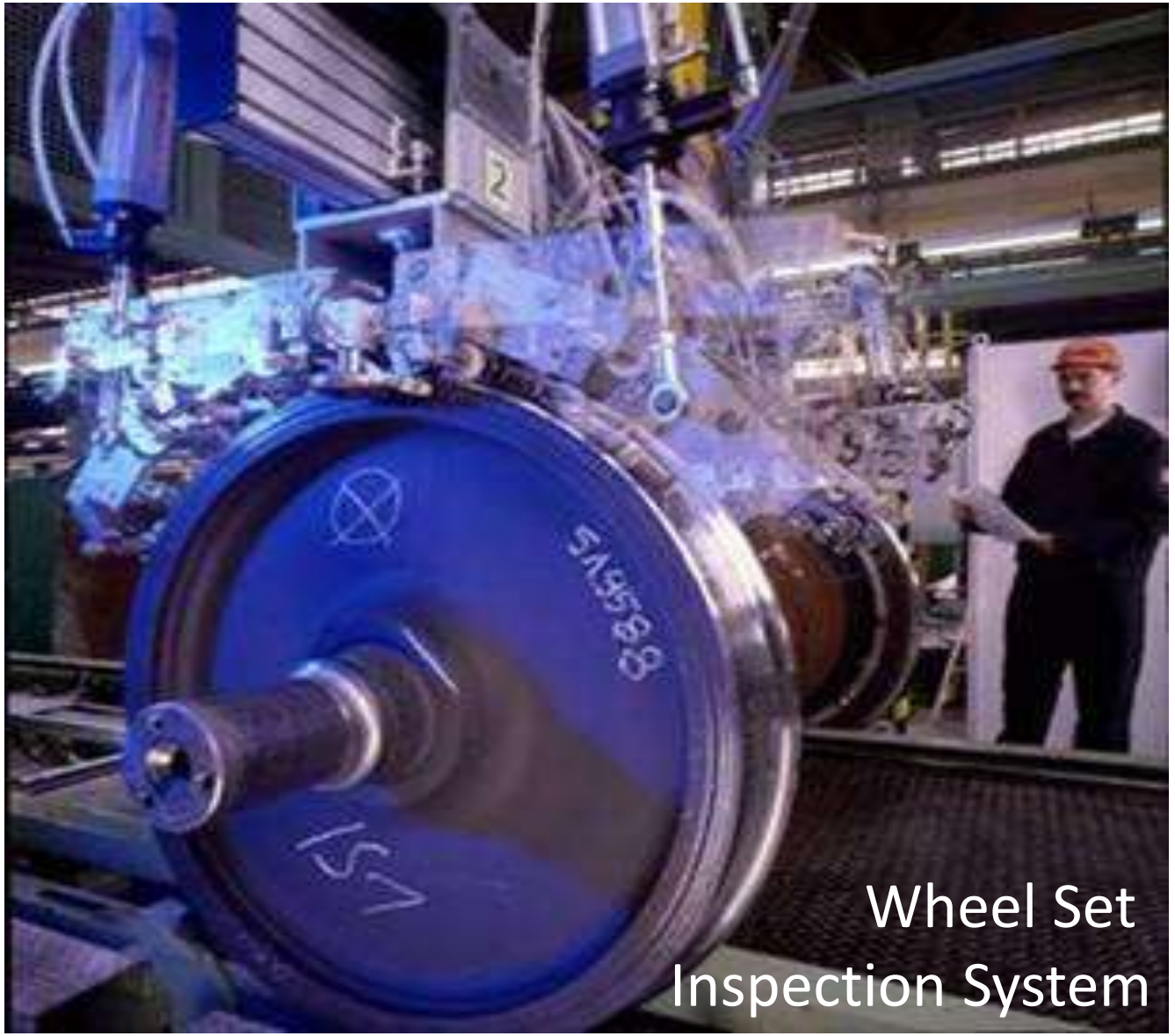
# NDT&E: Applications

# WHEEL INSPECTION




**Forces between Rail and Wheel**

# NDT&E: Applications



# NDT&E: Applications


**Wheel & Axle**
**UT System**
**Underneath the Train**

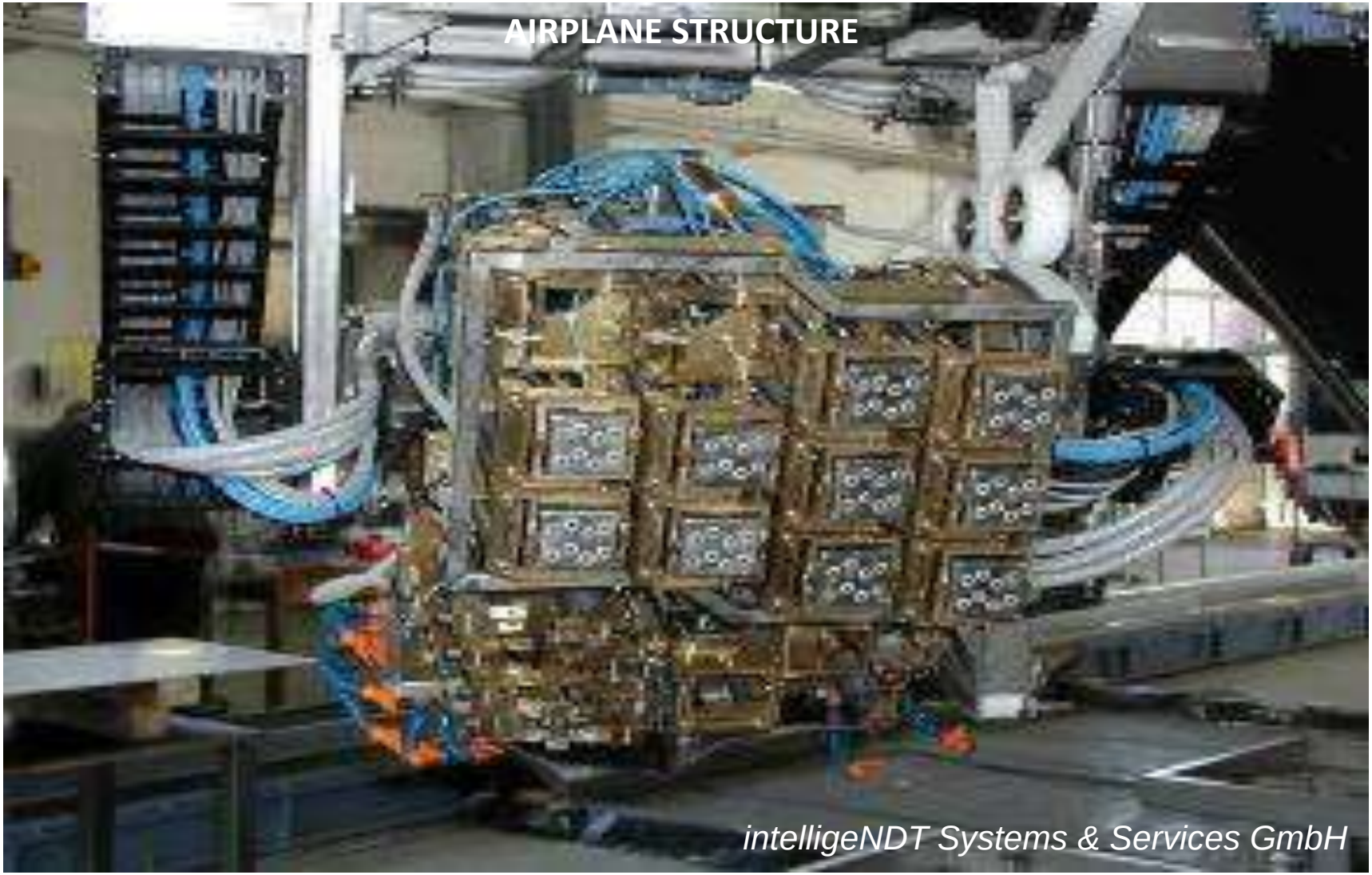
IntelligeNDT Systems & Services GmbH

# NDT&E: Applications

## AIRPLANE STRUCTURE


***Rear Pressure Bulkhead***

# NDT&E: Applications




***Multichannel inspection system for the rear pressure bulkhead***

# NDT&E: Applications

# Power Plant Pipe System – Weld Inspection

**DESIGN**
(Inspectable)

**LOAD**
(Monitoring,
Residual Stress)

**MATERIAL**
(Degradation,
Defect States)


Feed water pipe (WB36)

J. Jansky, 12. Int. Conf. structural mechanics In reactor technology,1993

**STRUCTURAL INTEGRITY**

# NDT&E: Applications

## Power Plant Pipe System – Weld Inspection

**STRUCTURAL INTEGRITY**

**Risk-based NDT**

| Probability of Failure | NDT |
| --- | --- |
| ➢ Load | ➢ Load Monitoring<br>➢ Stress Analysis |
| ➢ Material<br>➢ Degradation | ➢ Material Characterization |
| ➢ Cracking | ➢ Defect Detection and Assessment |

**Fracture Mechanics**

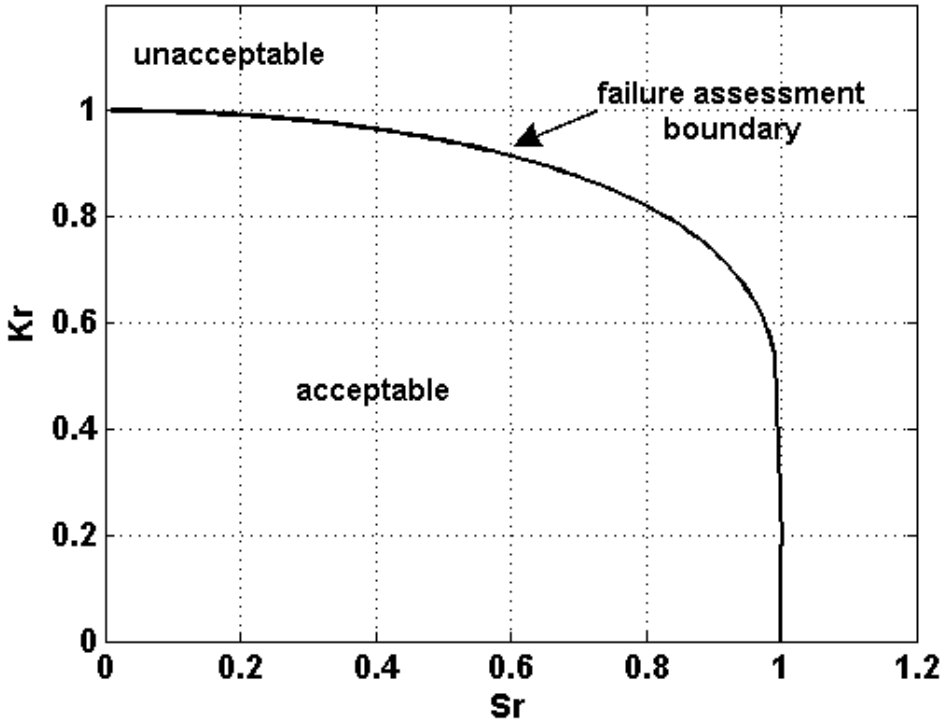
# NDT&E: Applications

# Power Plant Pipe System – Weld Inspection

## STRUCTURAL INTEGRITY

### Failure Assessment Diagram (FAD)

**Fracture mechanical assessment by fail/safe decision**




$$S_r = \frac{\sigma_{ref}}{\sigma_f}$$

**Measure of ductile response of material to loading**

$$K_r = \frac{K_1}{K_{1C}}$$

**Measure of brittle response of material to loading**

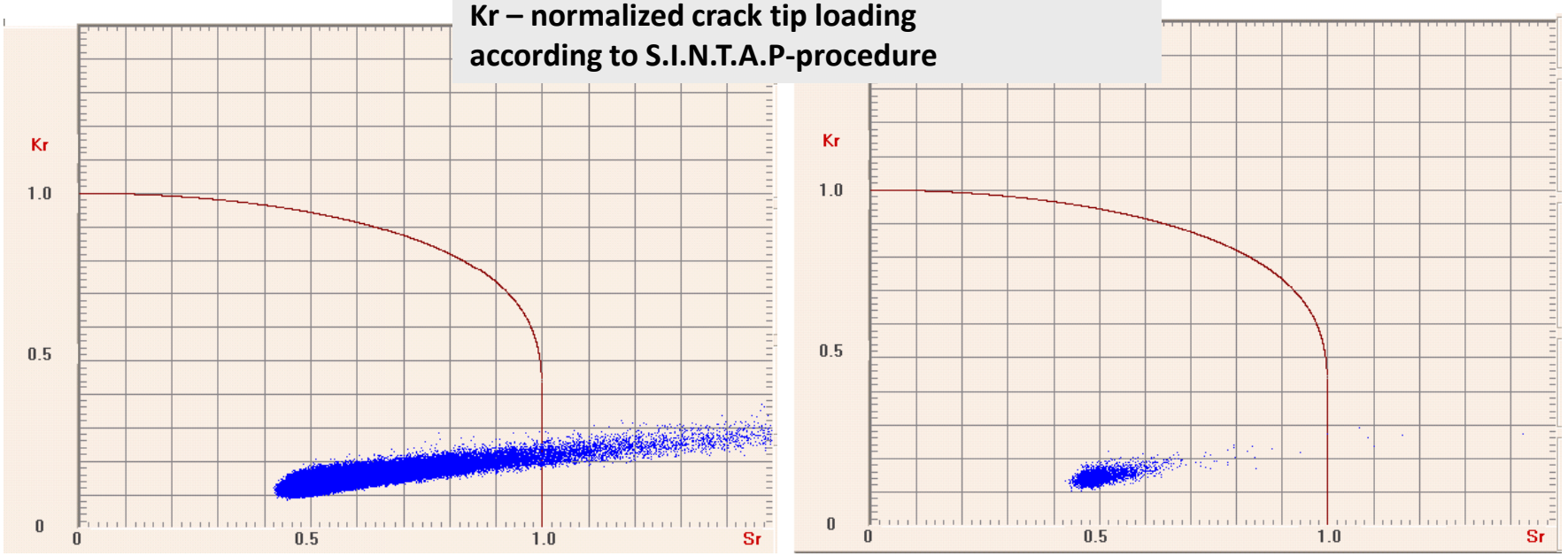
# NDT&E: Applications

# Power Plant Pipe System – Weld Inspection

## STRUCTURAL INTEGRITY

### The quantitative contribution of NDT to health monitoring

Sr – plastic deformation degree of ligament
Kr – normalized crack tip loading
according to S.I.N.T.A.P-procedure




FA-Diagram without (left) and with (right) consideration of NDT

**Quantitative NDT and Fracture Mechanics**


**Michael Kröning**

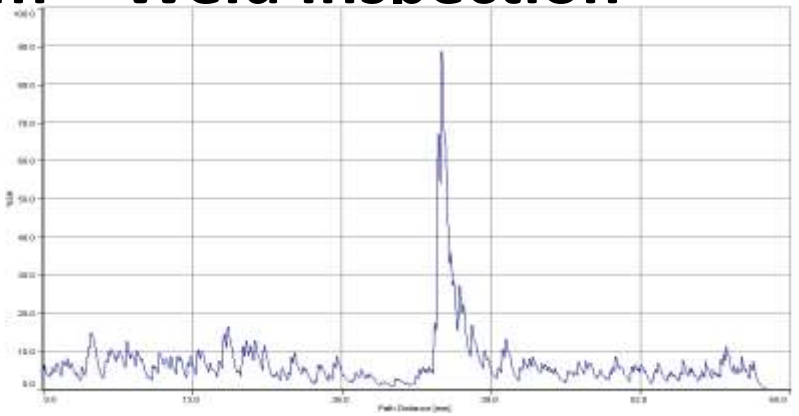
# NDT&E: Applications

# Power Plant Pipe System – Weld Inspection

## ULTRASONIC TESTING

Impulse – Echo Technique

A-Scan Image



45° Shear Wave Transducer

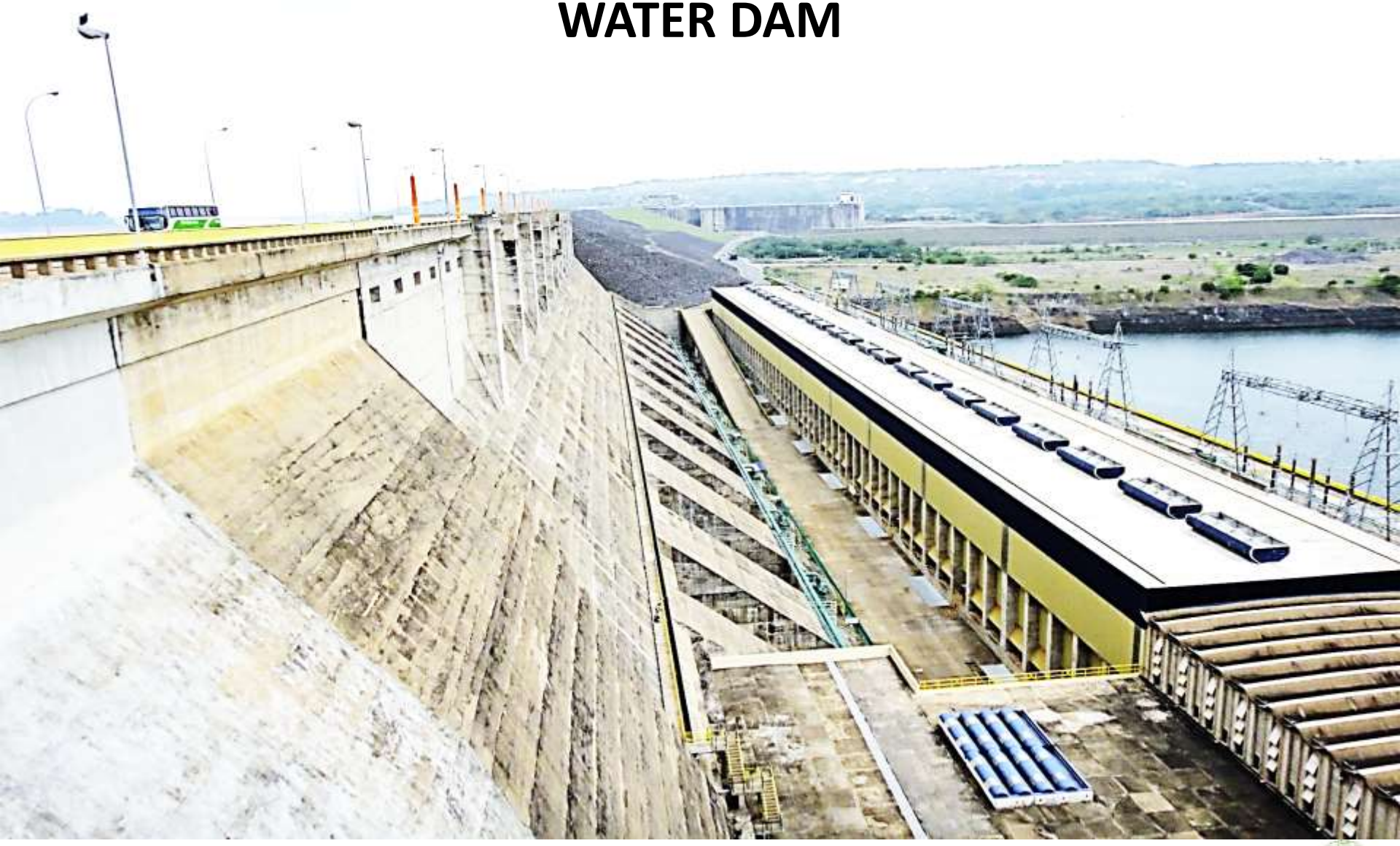
SIMULATION

# NDT&E: Applications

## Power Plant Pipe System – Weld Inspection

# NDT&E: Applications

## WATER DAM



# NDT&E Applications: WATER DAM

## *DIRECTED INSPECTION*

**What Can Cause a Dam to Fail?**

Dams can develop problems or fail for a number of reasons:
Deficiencies in the design, poor construction practices/materials, inadequate spillway capacity and poor foundation conditions are the most common structural failure.
During operation a dam can develop problems or fail for reasons related to poor operations and maintenance, or conditions beyond the control of the owner/operator

(*Dam Safety Guidelines, Version 2, 2011,* prepared by Dam Safety Section, Province of British Columbia, Canada, ISBN 0-7726-3520-X)

**Surveillance Inspections**

The purpose of safety inspections is to identify deficiencies that potentially affect the dam safety
Surveillance inspections should be carried out as appropriate for the item being inspected and the frequency based upon the dam's consequence classification

**Modes of Deterioration in Question (Concrete Dam)**

The principal items that are potentially hazardous at concrete dams are:
Structural cracking, foundation or abutment weakness, and concrete deterioration.
**At the steep up-stream dam face visual inspection below the water level is recommended**

# NDT&E: Applications

# WATER DAM

## Modes of Structural Problems

**CRACKING of CONCRETE STRUCTURE**

*Serious threats to concrete dams often involve cracks in the dam, abutments, or foundation. Cracks may develop slowly at first, making it difficult to determine if they are widening or otherwise changing over time…Cracking in concrete may be a visible indication of stress or movement, which the concrete cannot accommodate.*

(Indiana Department of Natural Resources: *Dam Safety Inspection Manual,* 2007)

**Classification of Cracks:**

(see also for example: ACI 201.1, *Guide to Making a Condition Survey of Concrete in Service*)

| INDIVIDUAL CRACKS | PERVASIVE CRACKS* | SURFACE CRACKS | STRUCTURAL CRACKS |
|---|---|---|---|
| Direction | Pattern Cracks | Individual Cracks | Typical: |
| Width | D-Cracks | Pervasive Cracks | Individual Cracks |
| Depth | Checking | | |

# NDT&E Applications: WATER DAM

## CRACKING of CONCRETE STRUCTURE

*The inspector should carefully examine all visible concrete surfaces for the presence of cracks.*
*If water is seeping from cracks on the downstream face,*
***an underwater inspection of the upstream face may be required,***
*depending on the severity of the problem and the amount of water seeping from the cracks.*
(Indiana Department of Natural Resources: *Dam Safety Inspection Manual,* 2007)

**Surface Cracks (Hairline Cracks):**

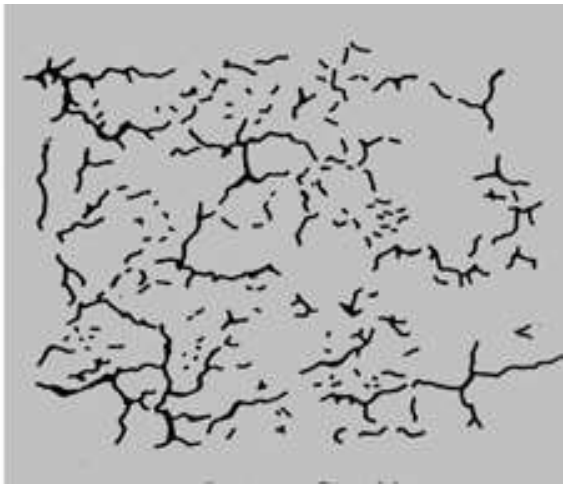
- Generally less than a tenth of an inch wide and deep.
- They may consist of single, thin cracks, or cracks in a craze/map-like pattern.
- A small number of surface or shrinkage cracks is common and does not usually cause any problems.

**Structural Cracks:**

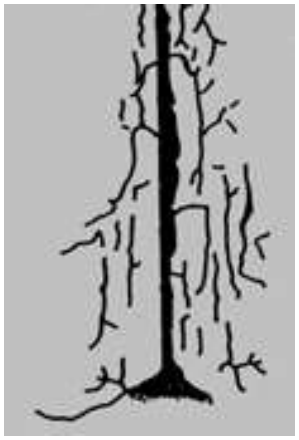
- Generally individual cracks
- They present the greatest potential for safety concerns
- They may develop as a result of structural problems or serious material deterioration

# NDT&E Applications: WATER DAM

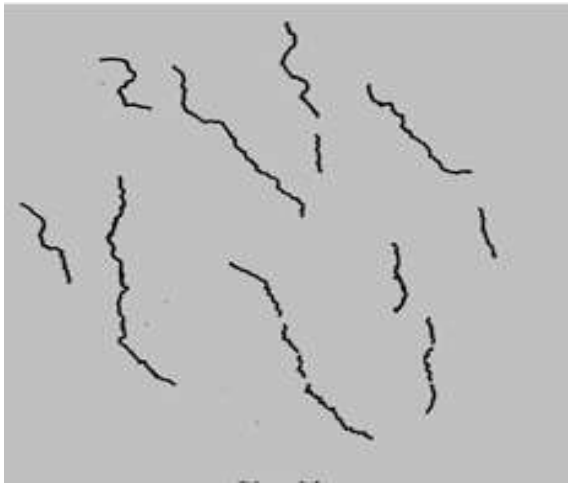
## CRACKING of CONCRETE STRUCTURE



Pattern Cracking




D-cracking



Checking

**Pervasive Cracking Classification (ASI)**

**Pattern Cracking:**
caused by shrinkage of concrete near the surface or a volumetric increase in concrete below the surface layer by **thermal stress**, alkali-aggregate reaction, for example

**D-cracking:**
fine parallel cracks at close intervals, usually along joints or edges.

**Checking:**
shallow cracks closely spaced at irregular intervals. The cracks may be several feet long.
Checking is usually caused by expansion and contraction or shrinkage of the concrete surface with alternating wet-dry periods.

# NDT&E Applications: WATER DAM

## DESIGN BASICS

**1** **DAMAGE DETECTION**

**CONTROLLED COMPLETENESS OF INSPECTION**
**EASY & FAST HANDLING**

***AUTONOMOUS ROBOTIC SYSTEM***

- ***Complete Surface Mapping***
- ***Precise Positioning***
- ***Advanced Optical Inspection***

**2** **DAMAGE EVALUATION**

**VISUAL CONTROL with SURFACE PROFILE**
**REPRODUCABLE RESULTS**

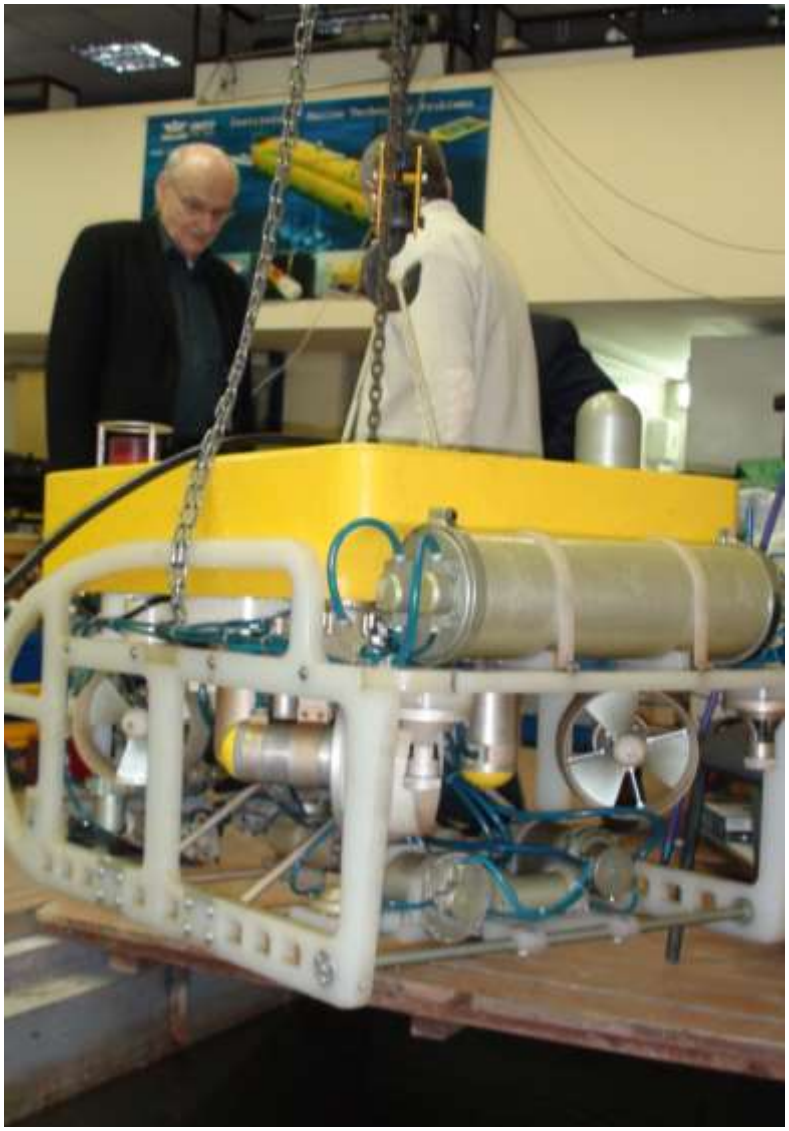
***DUAL INSPECTION METHOD***

- ***Precise Dimensioning***
- ***Visual Inspection for Mapping***
- ***Acoustic Inspection for Crack & Concrete Evaluation by Profile Measurement***

**NOTE: use of two acoustic frequencies:**
Lower frequency for surface mapping when water condition does not allow visual inspection
Higher frequency for the assessment of surface profile (scaling, spalling) and crack evaluation

# NDT&E Applications: WATER DAM

# NDT&E Applications: WATER DAM



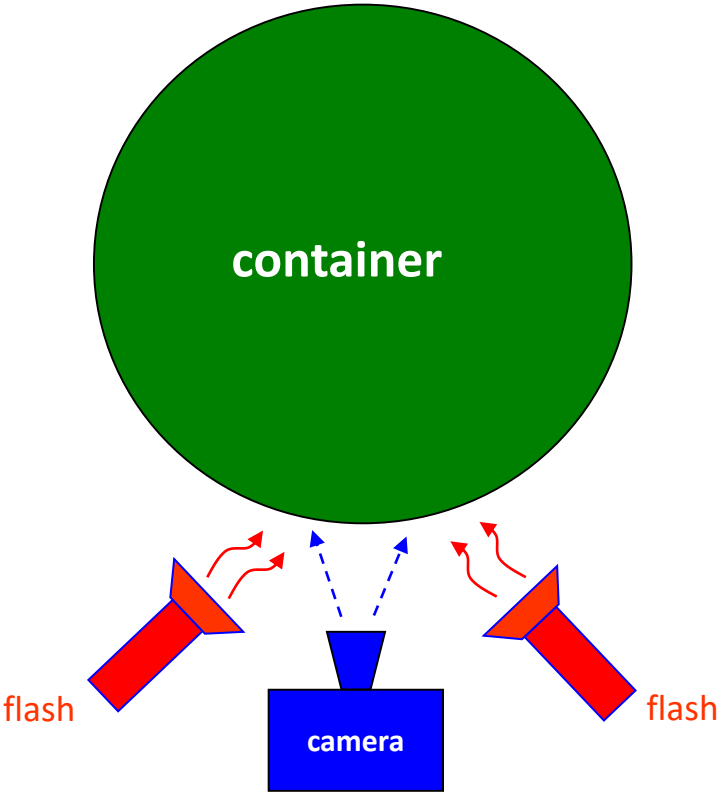
***Institute Problems of Sea Technology, Russian Academy of Science***

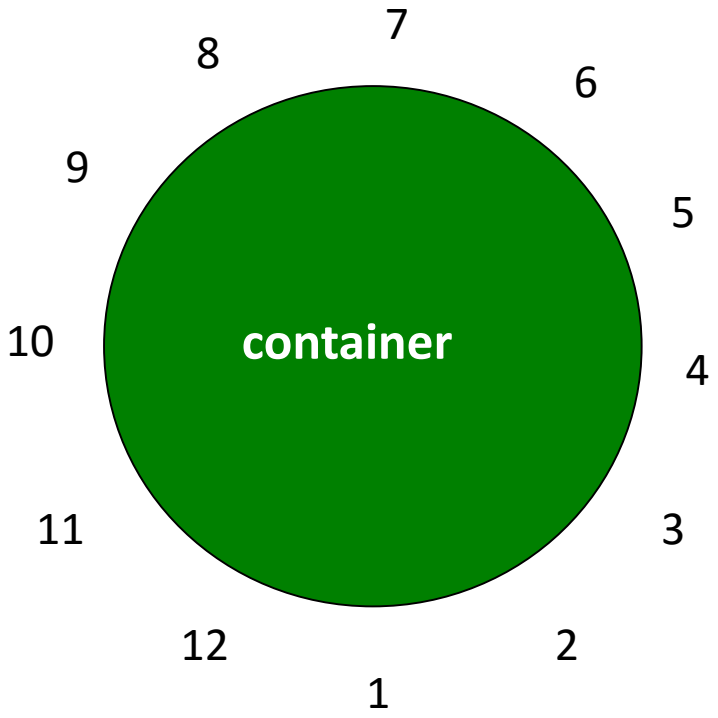
- Long-time experience
- Pioneering Research & Development
- Leading edge under-water technologies
- Excellent academic resources
- Awarded professional engineering

- Open for cooperation
- Appropriate autonomous robot for under-water inspections
- Latest system dated 2011 with updated digital technology
- International award for best engineering in robotics

# NDT&E Applications: WASTE CONTAINER

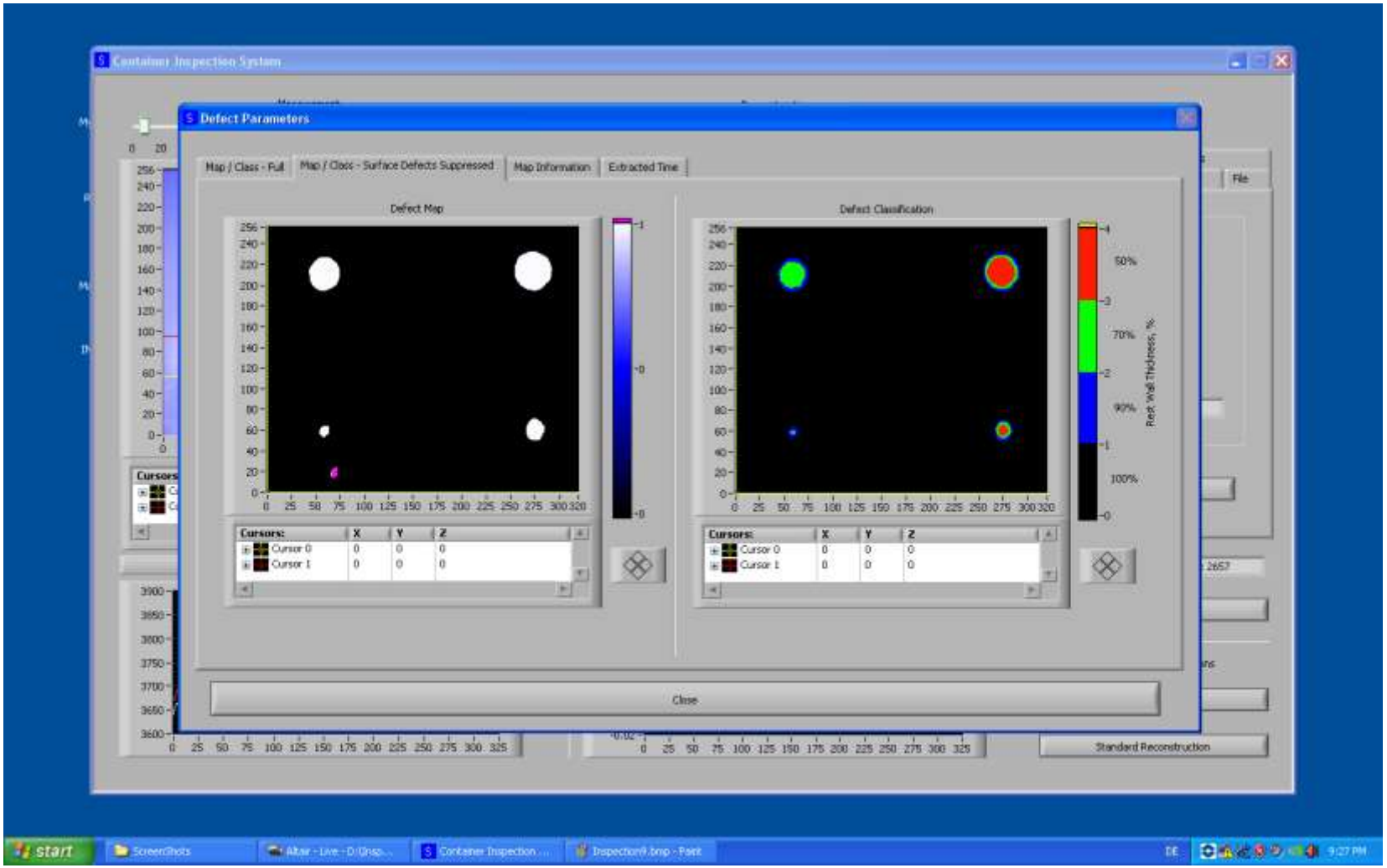
# NDT&E Applications: WASTE CONTAINER




## Inspection Method

# NDT&E Applications: WASTE CONTAINER



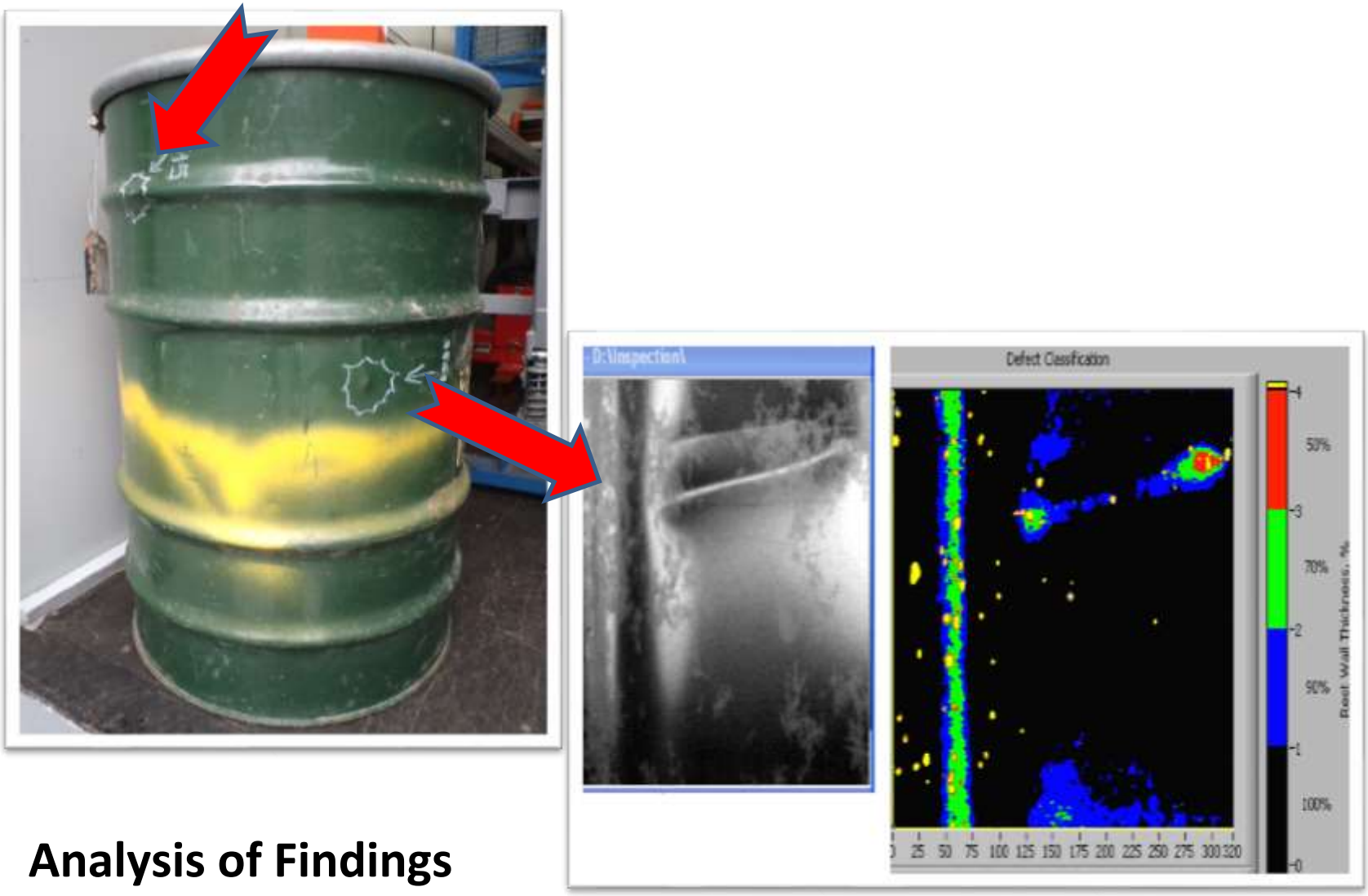

## Calibration Thermal Images of internal Wall Thinning

# NDT&E Applications: WASTE CONTAINER


## Verification of Metal Loss by UT Wall-Thickness Measurement

Michael Kröning

# NDT&E Applications: WASTE CONTAINER




## Analysis of Findings

# NDT&E Applications: WASTE CONTAINER

## Thermography System for Fast Inside Corrosion Control

# Literature

1. IAEA. *Application of non-destructive testing and in-service inspection to research reactors,* IAEA-TECDOC-1263, 2001