NDT integrity engineering

P Trampus, V Krstelj
Academia NDT International

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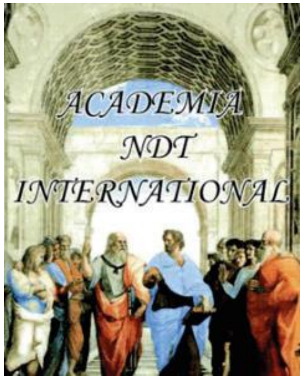


Layout

- Introduction
- About NDT / NDE
  - Evolutionary process
  - Main areas
- Need for NDT integrity engineering
- Overall structural integrity scheme
- NDT integrity engineer competences
- Outlook

Context

- **Gothenburg Social Summit, 2017**
  - informal discussion on education / training (European leaders)
- **EC vision: European Education Area, by 2025**
  - 1st European Education Summit, Brussels, 2018
  - 2nd one will follow, later this year
- These events clearly demonstrate the role and importance for the **need to increase the level of competency in engineering disciplines**

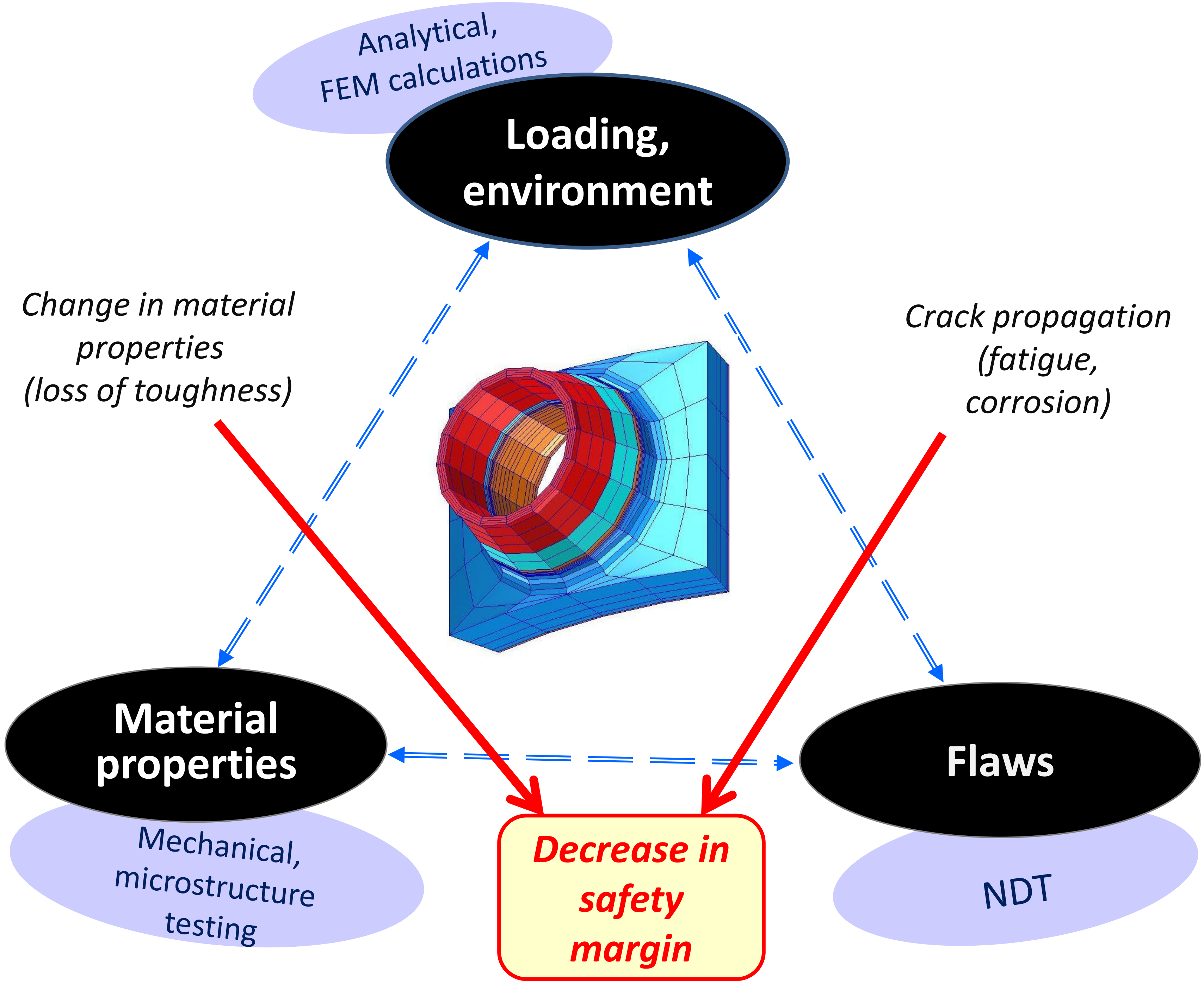
NDT belongs to STEM

- **S**cience, **T**echnology, **E**ngineering, **M**athematics
  - a family collecting most important areas of emerging technologies
  - NDT requires to join other professions also aiming to adjust their educational programs
- **History**
  - NDT engineering profession – a „new profile” (Fall Conference of ASNT, 1967 – *RB Socky*)
  - NDE engineer – the „missing subject matter expert” (ASNT Research Conference, 2016 – *JC Duke*)

NDT integrity engineering

NDT integrity engineering combines

- **materials science with fracture mechanics**
- **to engineer a non-destructive evaluation process**
- **that would guarantee and enhance the safety and reliability, or integrity, of structures in everyday life**


Analytical,
FEM calculations
Loading,
environment
Change in material
properties
(loss of toughness)
Crack propagation
(fatigue,
corrosion)
Material
properties
Mechanical,
microstructure
testing
Decrease in
safety
margin
Flaws
NDT

NDT objectives

- Save general public, also natural and built environment in case a structure / component fails dut to non-detection of a flaw („social" objective)
- Optimize the productivity of assets, i.e. component or structure of a facility being inspected („commercial" objective)

Casper Wassink: PhD Theses, TU Delft, 2012

Evolution

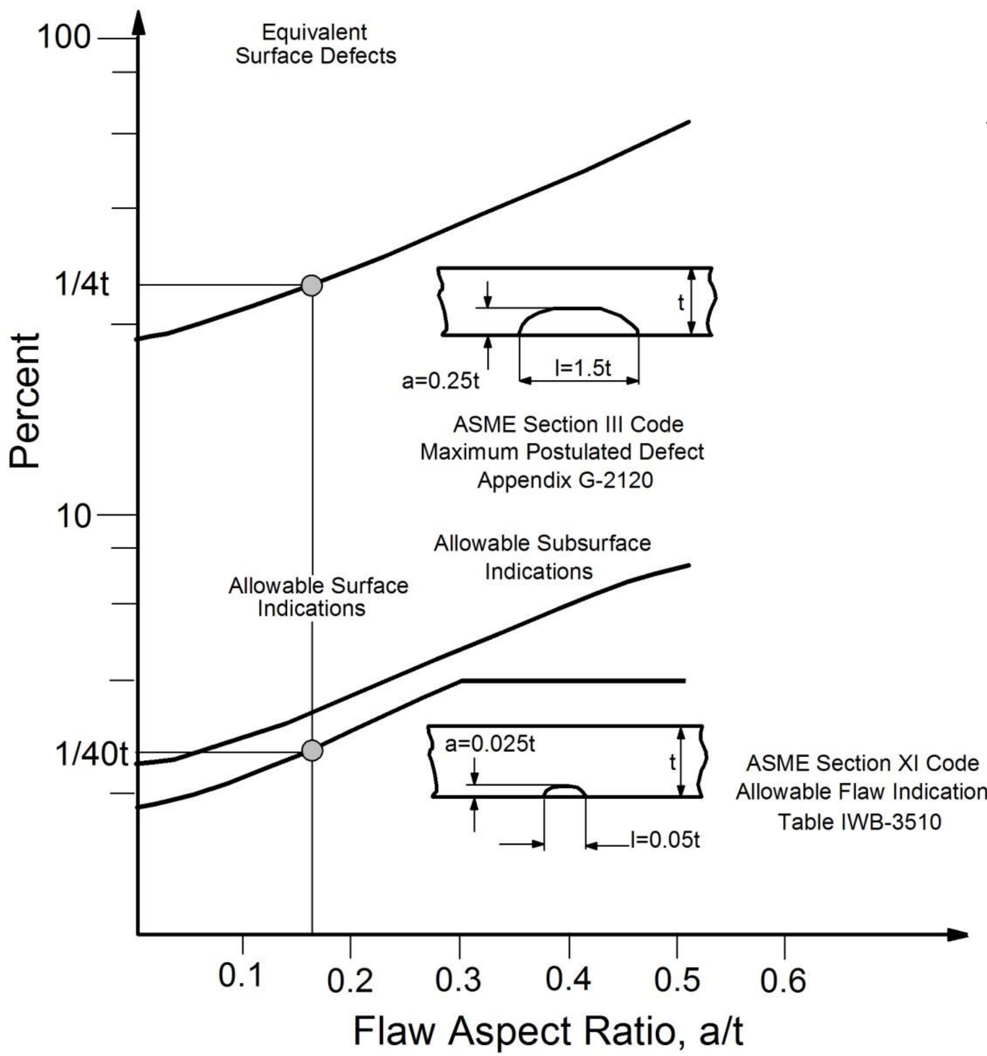
Pioneer period: Non-Destructive Testing (NDT)

- Tool for quality control (QC-NDT)
- Overriding role of standards
- Result (usually): allowable / non allowable
- Strong dependence on human factor
- Accepted despite unknown NDT capability (substantial design margins)

Recent past and present: Non-Destructive Evaluation (NDE)

- Quantitative requirements (Q-NDE)
- Changes in design concept (***safe life*** $\rightarrow$ ***damage tolerance***)
- Development in fatigue and fracture theory
- Risk analysis, condition monitoring, life management,…

Example: damage tolerance concept



ASME BPVC III & XI

Griesbach: in Companion Guide to ASME BPVC, 2009

Main areas of NDT / NDE

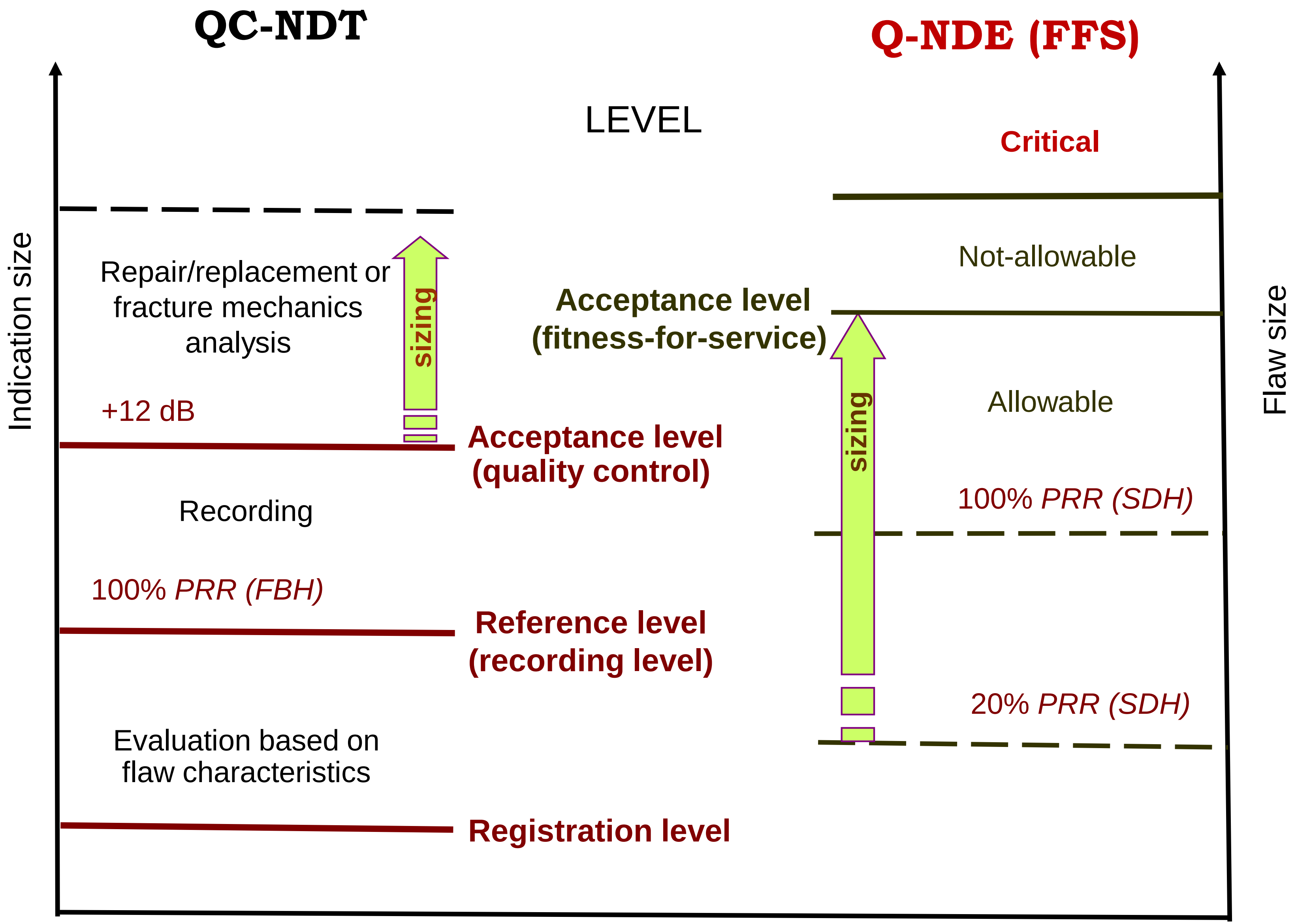
Quality control type NDT (QC-NDT)

- Deviations: analog (reference) signals
- Artificial (reference) reflectors
- Comparison of flaw indication and reference reflector indication
- Closeness of comparison depends on many factors
- Registration /acceptance level depends on the testing method

Fitness for service (FFS) type NDT, i.e. Q-NDE

- Deviation: bounding rectangle or square (i.e. size) of flaw
- Analog signals: close to registration level
- Sizing: from 20-50% of primary reference response (SDH or FBH)

Comparison of QC-NDT and Q-NDE



Need for NDT integrity engineering

Economic drivers

- Increase of productivity
- Management of ageing assets

Safety aspects

- Change in relation / attitude to safety

Serving fracture mechanics

Gap in decision-making process

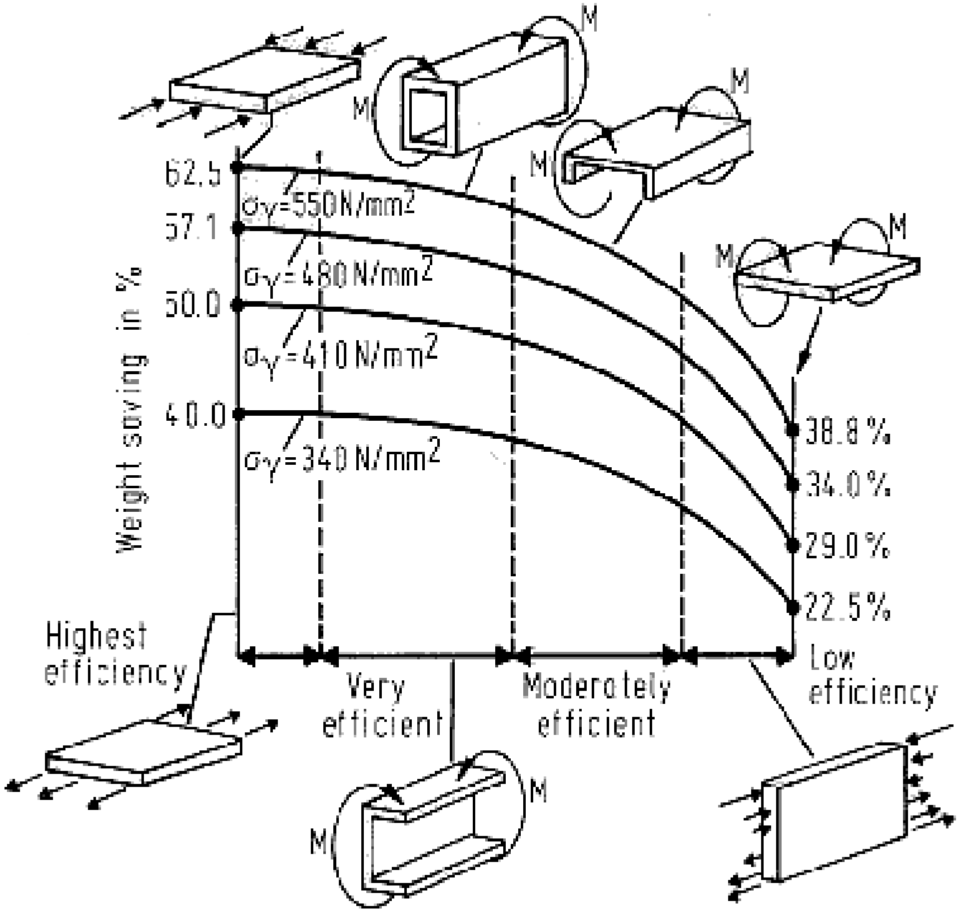
Increase of productivity

Example: car industry

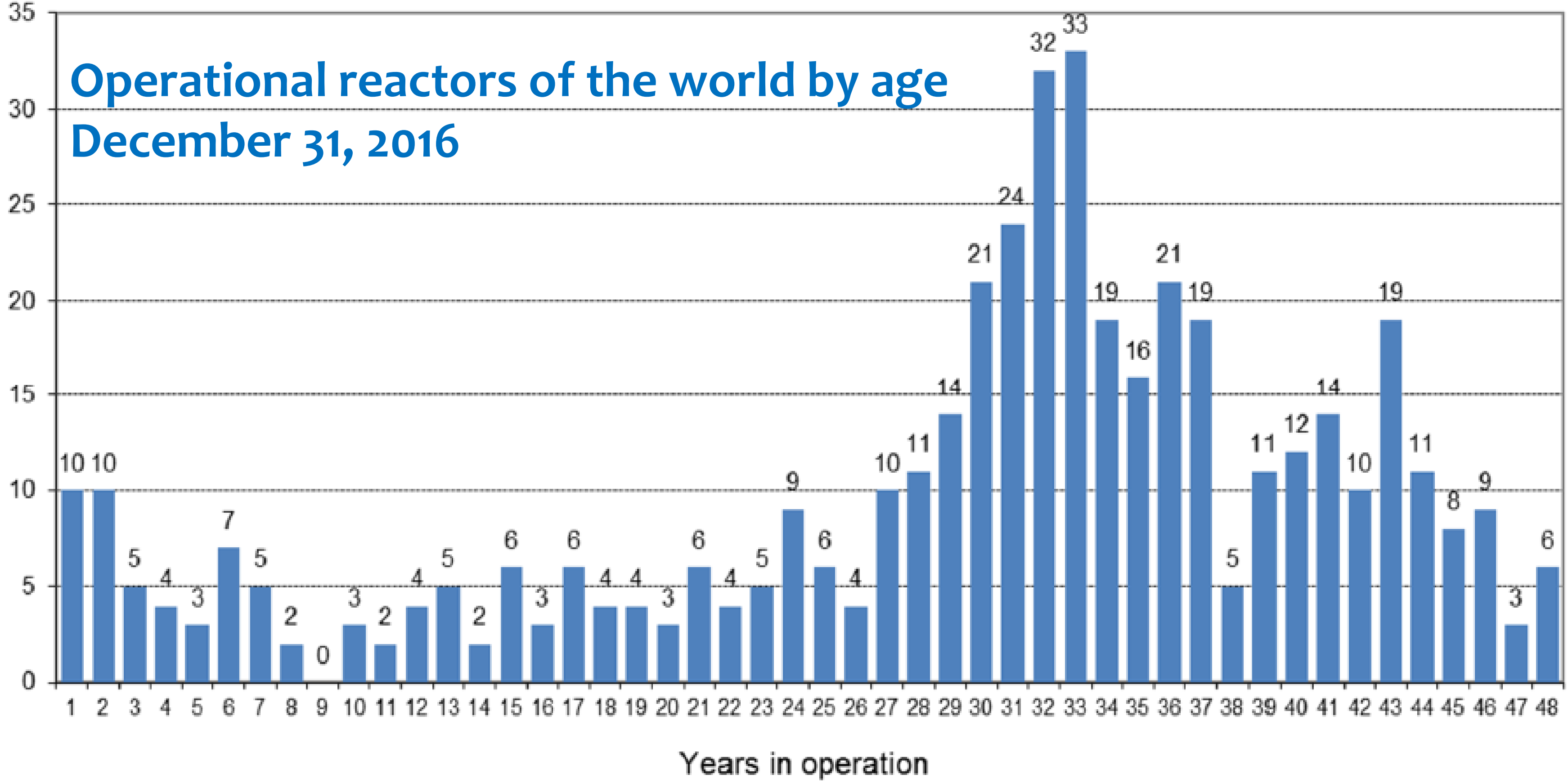
- application of HSLA steels
- **weight reduction**

Consequences:

- **increased requirements for NDT**
- **novel materials (composites, ceramics, light metal alloys) define new NDT tasks**



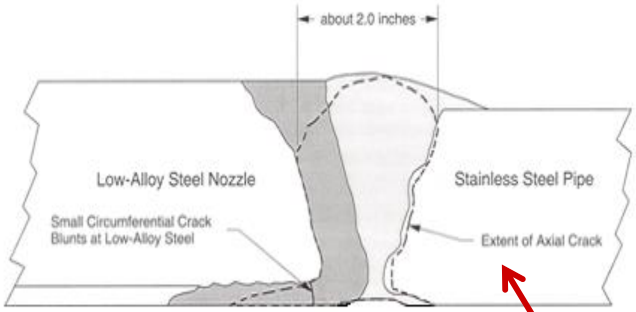
Management of ageing assets



Example: nuclear power plants

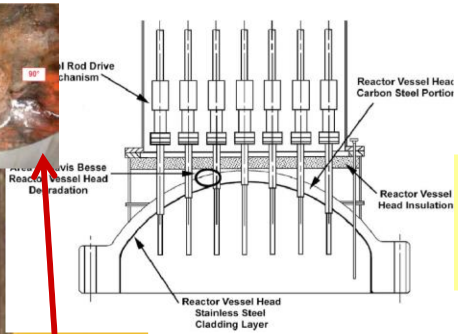
- Life management / operating life extension / **ageing**
- **Consequence: role of NDT becomes more important**

Economic loss of ageing



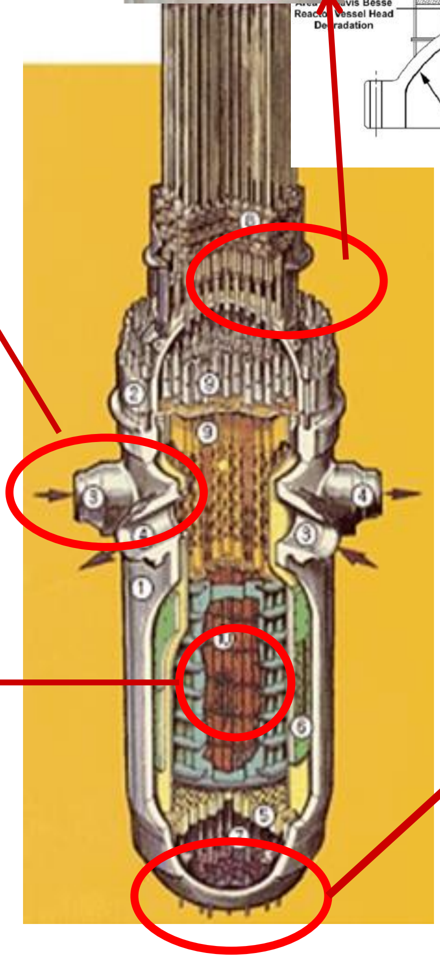
VC Summer NPP, reactor nozzle

- repair: 18 m USD
- production loss: >77 m USD (7 weeks)



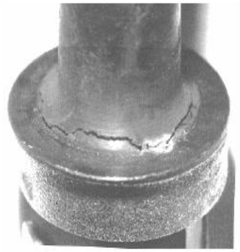
Davis-Besse NPP,
Reactor head penetration

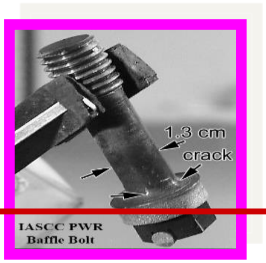
- repair: 18 m USD
- production loss: >500 m USD (2 years)

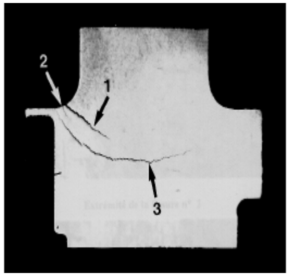


South Texas NPP,
Reactor bottom penetration

- repair: 7 m USD
- production loss: >100 m USD (4 months)







core basket
buffle bolt

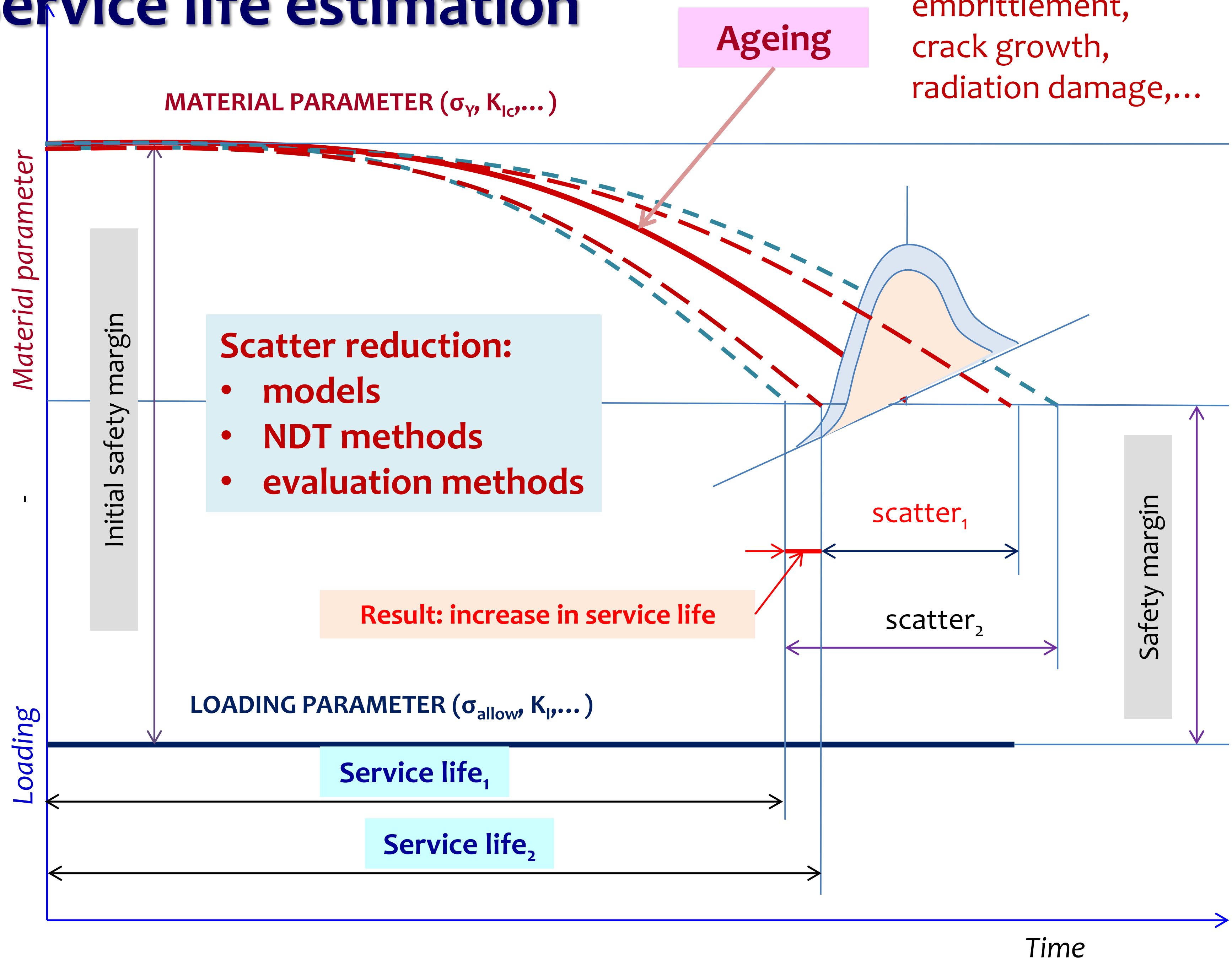
Kwon: R&D Activities to Solve Material Issues, IAEA, Vienna, 2013

Human loss of ageing

Example: feedwater pipe flow accelerated corrosion

- Wall thickness reduced from 10 mm to 1.5 mm
- 4 workers died
- **Wall thickness monitoring was not included in ISI program**

Service life estimation



Change in relation to safety

- Risk accepted by the society is decreasing
- Government safety regulations become progressively more serious

Oil platform, Gulf of Mexico

Gas pipeline explosion, USA

- **Consequences:**
  - **NDT efforts focus on higher risk areas which could result in NDT volume reduction**

  BUT
  - **conventional NDT procedures and equipment are not good enough**
  - **risk-informed inspection brings new requirements for NDT**

Fracture mechanics

Spreading of fracture mechanics:

- In design: *damage tolerance*
- In operation: *fitness for service*

Consequence: NDT capability has to be characterized by quantitative way

What does it mean?

- „detection of smallest flaw" **(NOT IMPORTANT)**
- „size of largest flaw which is not detected by NDT **(THIS IS IMPORTANT!)**

The missing link

- In case a flaw exceeds the acceptance standard, manager usually asks NDT people if the operation of the given component can be continued?
- Operation managers and NDT personnel have different knowledge bases → there is a gap between
  - NDT personnel providing inspection results
  - managers being responsible for decision-making on fitness for continued service of components having flaw
- NDT integrity engineer is the best solution to bridge the gap

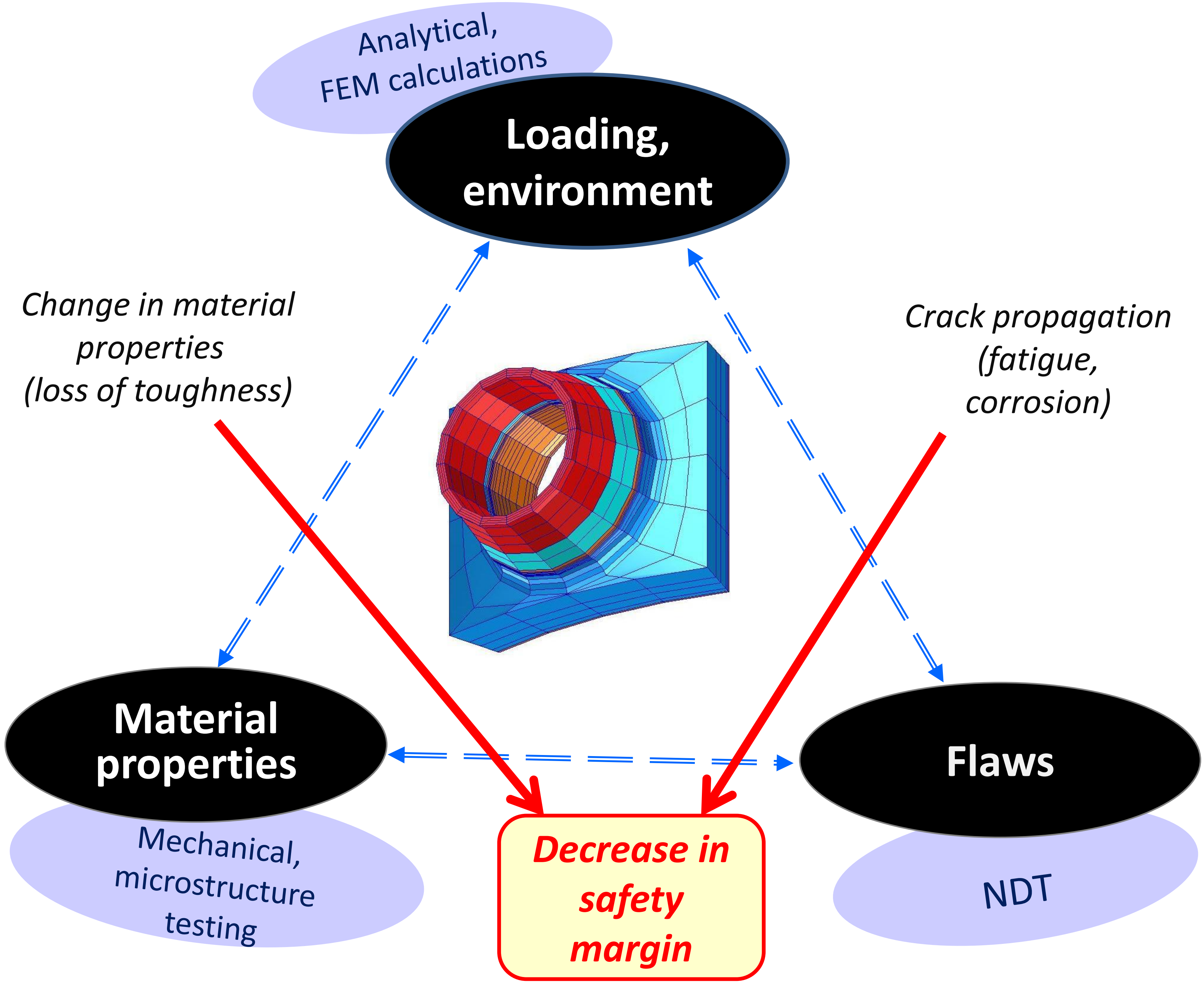
Overall structural integrity scheme

Structural integrity: a relatively new discipline integrating primarily engineering areas

- refers to the **safe operation** of engineering components, structures and materials, their **residual life** and how can it be achieved (*life management*)
- addresses the science and technology that is used to **assess the margin between safe operation and failure** (*definition of ESIS*)

Assessment is based on three fundamental inputs:

- **Mechanical condition characterizing the operating loads and environment**
- **Initial properties of structural materials and their degradation processes**
- **Existing flaws and their characteristics**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Structural integrity assessment

- All three inputs are **equally important**
- Since energy requirement for ductile failure is greater than required for **brittle fracture**, the basic tool of structural integrity assessment is **fracture mechanics**
- Assessment method can be both deterministic or probabilistic
- Structural integrity assessment models and NDE are related in both directions:
  - NDE supplies data about the flaws (dimensions, location within the component wall including ligament dimension, characteristics and proximity to eventual other flaws, etc.)
  - structural integrity assessment formulates the requirements for NDE performance level (scope and inspection volume, evaluation process, target detectable flaw size, sizing and localization accuracy and inspection interval)

NDT integrity engineer competences

- Role and importance of NDT in safety conscious world
- Need for ensuring integrity
  - of high-performance engineering structures / components,
  - structures / components of ageing assets
- Gap between manager and NDT personnel has to be bridged

NDT integrity engineer:

- Can be integrated into **NDT quality chain**
- Its specific position is expressed by joining both **NDT** and **integrity** in its name

Competences: NDT / NDE (1)

NDT integrity engineer must **understand and speak the entire „NDT language”**:

- clear understanding of NDT and ND characterization
- possibilities and limitations of NDT
- some practical experience in some of the major NDT methods

Competences: NDT / NDE (2)

- Physical bases of the major NDT methods (traditional and up-to-date)
- Application areas of the various methods and limitations (depending on geometry, material, manufacturing and safety requirements of the component)
- Reliability of NDT (applicability, reproducibility, repeatability and capability of the method)
- Current tendency concerning high risk components to provide early detection of materials degradation
- Structural health monitoring strategies and techniques
- Impact of the development of information technology and microelectronics on NDT and technical diagnostics
- NDT modelling and simulation methods and their use
- NDT system qualification / performance demonstration
- Global tendency of NDT (standardization, personnel qualification and certification,…)

Competences: material sciences

- Fundamental manufacturing processes of the usual engineering materials (not limited to metallic materials)
- Potential failures associated with manufacturing with special regard to welding defects
- Mechanical properties of structural materials (tensile and fracture mechanics properties, low- and high-cycle fatigue and creep properties)
- Microstructural characterization of materials and their condition (behavior of typical phases, phase transformation, metastable states)
- The „material's response" to loading and environment, i.e. service induced degradation processes / effects (fatigue crack initiation and growth, local corrosion processes such as pitting, crevice corrosion, stress corrosion cracking, creep, erosion, wear, embrittlement and loss of toughness due to temperature or irradiation etc.)
- Possible synergy of degradation processes such as environmentally assisted fatigue, irradiation assisted stress corrosion cracking

Competences: loading / environment conditions

- Awareness of the physical fields (mechanical, thermal, magnetic, electric, electromagnetic) arising in the component during operation, including off-normal and accident conditions
- Basics of analytical and numerical methods of physical field calculations, based on these, operation and accident loading, stress / strain status, stress intensity factor and other operational conditions can be calculated
- Consequences of degradation processes, e.g. wall-thickness reduction, unstable crack growth, loss of loadbearing cross-section
- Basics of fracture mechanics including its engineering approaches such as using failure assessment diagrams for the assessment

General engineering competences

- Awareness of the wider multidisciplinary context of engineering
- General ability to solve engineering problems in the field of activity by applying relevant analytical, computational and / or experimental methods
- Ability to consult and apply codes of practice and safety regulations
- Awareness of economic, organizational and managerial issues such as project management, risk and change management
- Ability to effectively communicate information and solutions with engineering community and society at large if necessary
- Ability to function effectively in a national and international context, as an individual and as a member of a team, and to cooperate with engineers and non-engineers effectively

Closing words

- Result of Bologna Declaration: comparable degrees in European Higher Education Area
- Differences in BSc degrees
  - USA: significant liberal arts content, and elective in related areas for lifelong learning
  - Europe: more professional content
- NDT integrity engineering: decision is needed on which one is more promising
- It is among the highest priority tasks of Academia NDT International