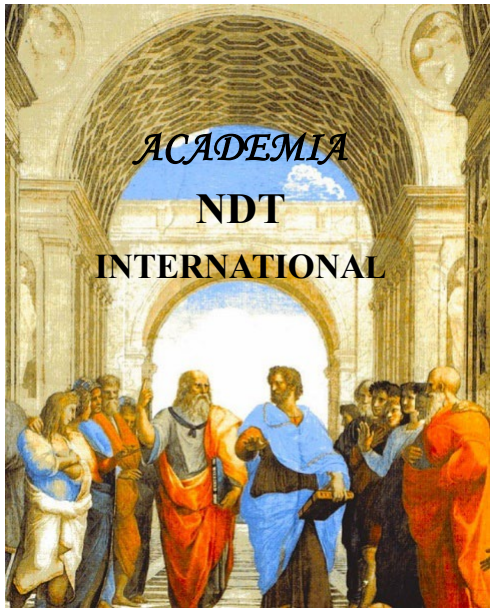
# Syllabus for the future NDT Integrity Engineer

Peter Trampus

Academia NDT International, Brescia, Italy

**Abstract:** Non-Destructive Testing (NDT) related high education is among the highest priorities of Academia NDT International. Having recognized that NDT competence is increasingly needed to respond to technological development in ensuring long term integrity of components and structures of ageing assets, a new profession – NDT Integrity Engineer – and, logically, a new university discipline was developed. NDT integrity engineering is a profession to develop non-destructive testing and evaluation involving materials science, fracture mechanics, and other sciences that would guarantee the safety and reliability. The presentation introduces the syllabus enables to achieve needed competences of NDT Integrity Engineer. The overall basis is a clear understanding of NDT, what are the possibilities and limitations of NDT, and how can it serve the structural integrity related decisions.
The syllabus involves the three pillars of structural integrity assessment: NDT, materials and loading / environment. NDT related core knowledge includes the physical bases of the major methods; the application areas and the limitations; the elements of NDT reliability; the tendency to provide early detection of materials degradation; the structural health monitoring strategies and techniques; the impact of progress in information technology and electronics; the role of modelling and simulation; the NDT system qualification; and related issues. The materials science related knowledge includes the fundamental manufacturing processes; the potential failures associated with manufacturing; the mechanical properties of usual structural materials; the microstructural characterization; the materials ageing processes and their effect on component integrity, including possible synergy of degradation processes. The loading and environmental condition related knowledge covers the awareness of the physical fields arising in the component during operation; the basics of analytical and numerical methods of their calculations; the consequences of the materials degradation processes; the basics of fracture mechanics.

**Keywords:** Fracture Mechanics, Structural integrity, Materials science, Ageing degradation




# Syllabus
# for future *NDT Integrity Engineer*

Peter Trampus
President, Academia NDT International
trampus@uniduna.hu

***Academia International Research Day, 20th WCNDT***

*Incheon, Korea, May 29, 2024*

# The broadest context

## World at a glance:

- 8 billion people
  - 200 countries
    - 200 languages
      - 40 religions
        - various social systems
          - …

## Basis of a functioning society:

- redistribution of existing goods (*taxes*)
- production of new values, innovations – ***SCIENTIFIC / ENGINEERING PRODUCTS***

## Engineers' activities (*design* / *construction* / *operation*) always

- determined by **market** requests,
- connected to **safety**,
- related – directly or indirectly – to **money** (cost / profit)

# Safety – Reliability – Risk

To ensure **safety** we must invest **money** to perform

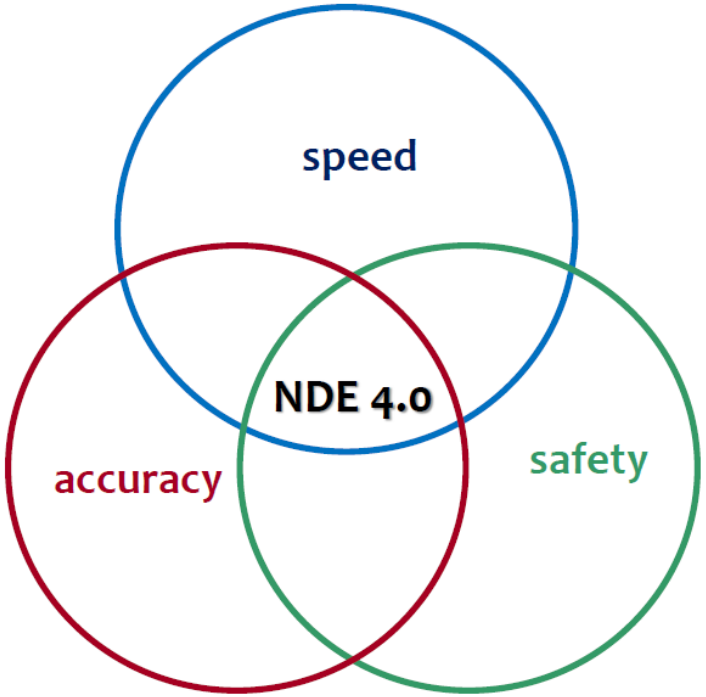
- investigations to determine *material behaviour and performance*,
- NDT / NDE to detect *deviations, i.e. flaws*,
- calculations to determine *stress / strain, temperature, magnetic, etc. fields*

**Risk(ed money)** must always be considered

## *Safety – Reliability – Risk* concept

The concept is to realize at **existing technical level**

*Today: in harmony with Industry 4.0 (NDE 4.0)*

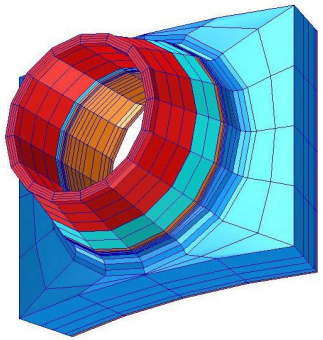


# Overall need: ensuring structural integrity

Analytical, FEM calculations

Loading, environment

Power uprate



*Changes in material properties (e.g. embrittlement, loss of toughness)*

*Crack propagation (e.g. fatigue, corrosion)*

**Fracture mechanics assessment (deterministic or probabilistic)**

**Material properties**

Mechanical, microstructure testing

***Decrease in safety margin***

**Flaws**

NDT | NDE

# Structural integrity

Relatively new discipline integrating engineering areas:

- refers to **safe operation** of engineering structures, their **residual life** and the way to achieve it, **life management**

**Structural integrity assessment:**

- evaluation of resistance against strength and (brittle) fracture

**Tools of assessment / measurement:**

- fracture mechanics, numerical calculations
- materials science, degradation effects
- **non-destructive testing / evaluation (*NDT / NDE*)**
- risk analysis

# Bottom line: *NDT is not an end but a means*

**End:** *needs* of the environment using NDT

- ***SAFETY – social need***
  Saving human, natural and built environment in case a structure fails due to non-detection of a flaw

- ***PRODUCTIVITY – commercial need***
  Optimizing service life and performance of assets being inspected

**Means:** *response of NDT community to fulfil the needs*

- Means = NDT system
  Equipment
  Procedure
  **Human**

# Right response to the needs:

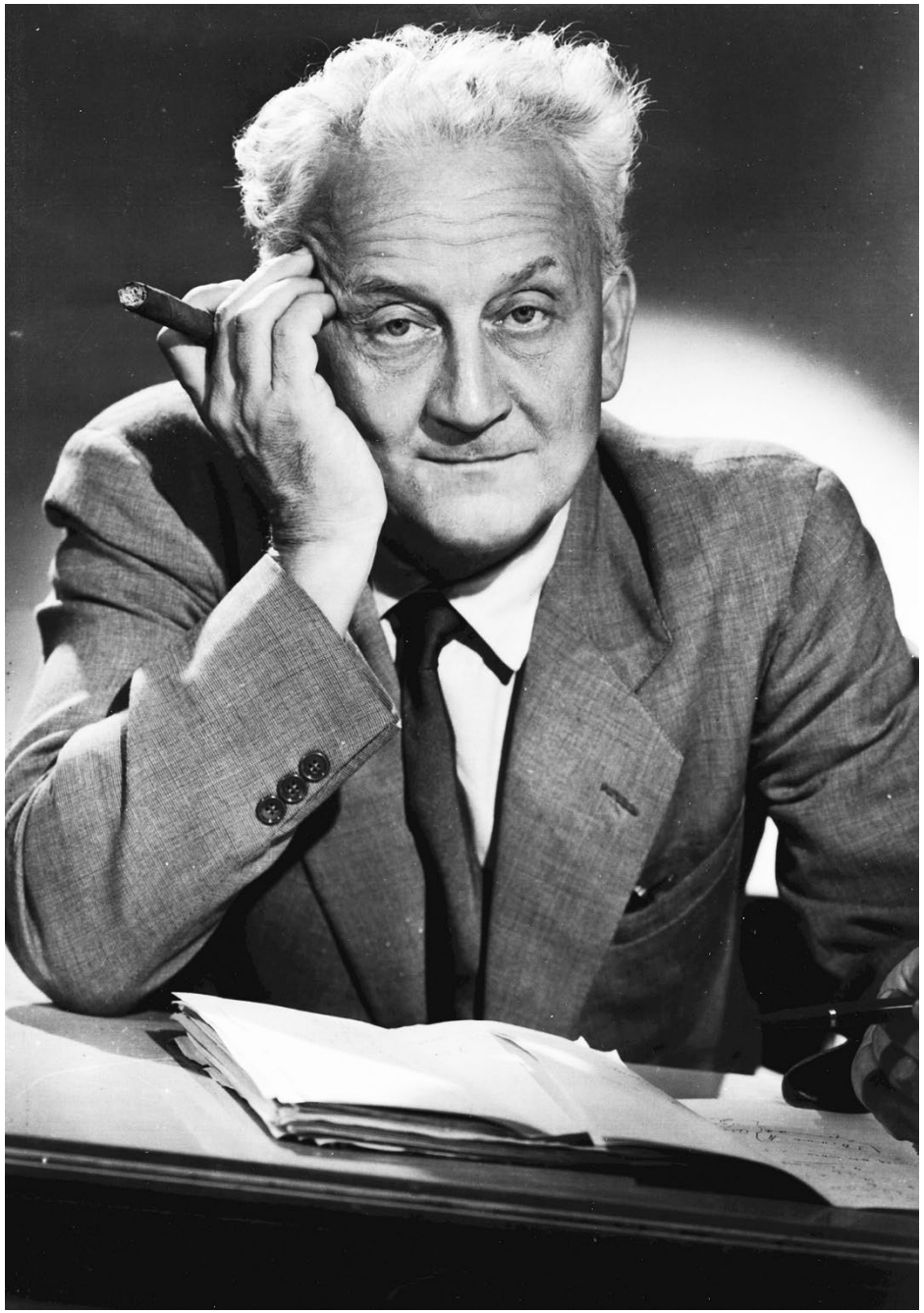
# NDT integrity engineering

**NDT integrity engineering is a discipline / profession**

- to develop **NDT / NDE**
- involving **materials science, fracture mechanics**, and other sciences
- that would guarantee and enhance the **reliability and safety**
- by ensuring **integrity** of structures and components

# Broader context

- **EC vision: European Education Area by 2025**
  - Social Summit, Gothenburg, 2017 (*informal discussion on **education and training***)
  - 1st European Education Summit, Brussels, January 2018
  - …
  - 6th European Education Summit, Brussels, November 2023
- Actions clearly demonstrate both **the need for** and **the intention to increase the level of competency in *engineering areas***
- **Current NDT / NDE**
  - belongs to **STEM** (***S**cience, **T**echnology, **E**ngineering, **M**athematics*), a family collecting most important areas of emerging technologies
  - **requires to join other professions also aiming to adjust / improve their educational programs**



**„The future will be like the school of today”**

***Albert Szent-Györgyi,***
***Hungarian Nobel Prize Winner***
***in Physiology or Medicine***
***(vitamin C)***
***1937***

# Historical retrospect of NDT engineering

- 1967, Fall Conference of ASNT – **NDT engineering profession – a „new profile”** *(R.B. Socky)*
- 2016, ASNT Research Conference – **NDE engineer – the „missing subject matter expert”** *(J.C. Duke)*
- 2016, ISO/TS 21759 (working document) – **Non-destructive testing – Guidelines for Training, qualification and certification of NDT Engineers**
- 2018, 12th European Conference on NDT – **NDT integrity engineering** *(P. Trampus, V. Krstelj, Academia NDT International)*
- 2019, EFNDT-EWF Working Group – **European NDE Engineer**
- 2019, ASNT Engineering Council (NDT Engineering Committee) – **NDT engineer**
- 2022, ISO 9712 Annex E (informative) – **Engineering of NDT**

# „NDT integrity engineering” courses

- Postgraduate, two-semester courses (2020, 2022)
- Courses are pioneer and *First-of-a-Kind*
- Pilot project of ***Academia NDT International***

**Courses jointly developed and implemented by:**

- *Technical Faculty, University of Debrecen, Hungary*
- *Hungarian Association for Non-Destructive Testing (MAROVISZ)*
- *Hungarian Chapter of European Structural Integrity Society (ESIS)*



# Course curriculum

| Subject groups | Weight | Subject |
|---|---|---|
| Numerical methods, applied mathematics | 20 % | Statistical methods |
| | | Problem solving with machine learning |
| | | Basics of Finite Element Method (FEM) |
| | | FEM applications in structural integrity analysis |
| Degradation effects, structural integrity assessment | 35 % | Engineering methods of operability |
| | | Fracture mechanics – Principles and material properties |
| | | Operating conditions – Material degradations I |
| | | Operating conditions – Material degradations II |
| | | Safety, reliability, risk |
| NDT/ NDE methods, techniques and application areas | 45 % | Modern condition monitoring |
| | | Industry 4.0 and NDE |
| | | Reliability of NDE |
| | | Modelling and simulation of NDE |
| | | NDE methods and applications I |
| | | NDE methods and applications II |
| | | Thesis |

# General competences

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

It means:

- clear **understanding** on NDT and non-destructive characterization of materials
- awareness of **possibilities** and **limitations** of various NDT methods
- practical **experience** in some of the major NDT methods

# Competences on NDT / NDE

- **Physical basis** of major NDT methods
- **Application areas** of various methods and their limitations
- **Reliability** of NDT
- **Early detection** of materials degradation
- **Structural Health Monitoring** strategies and techniques
- Impact of development of **information technology** and **micro- and nanoelectronics**
- **NDE 4.0**
- NDT **modelling and simulation** and their use
- NDT system **qualification**
- **Globalization** of NDT

# Competences on materials science

- **Manufacturing** processes of engineering materials
- Potential **failures** associated with manufacturing (with special regard to welding)
- **Mechanical properties** (tensile, fracture mechanics, low- and high-cycle fatigue, creep etc.)
- **Microstructural characterization** of materials' actual condition
- „Materials' response" to loading and environment, i.e. service induced **degradation** processes and effects
  - fatigue crack initiation and growth
  - local corrosion
  - creep
  - erosion
  - wear
  - embrittlement and loss of toughness
  - …

# Competences on loading and environment

- Awareness of **physical fields** arising in the component during operation
  - mechanical
  - thermal
  - magnetic
  - electric
  - electromagnetic
- Basics of **analytical and numerical methods** of physical field calculations
- **Consequences of degradation** processes, e.g. wall-thickness reduction, unstable crack growth, loss of loadbearing cross-section, …
- Basics of **fracture mechanics** with special regard to linear elastic fracture mechanics, and engineering approaches

# General engineering competences

- Awareness of wider **multidisciplinary context** of engineering
- General **ability to solve** engineering problems 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, risk and change management
- Ability to **communicate** information and solutions with engineering community and society at large, if necessary
- Ability to **function effectively** in national and international context as an individual and as a member of a team, and to cooperate with engineers and non-engineers

# Facts / experiences of the courses

**Basic concept:**

- Focus on unity of engineering mentality (*safety – reliability – risk*) and its economic consequences
- Overall view on safe operation of components / systems
- Recognition of importance of service induced degradations

**Course participants:**

- Oil, gas, nuclear sectors, R&D institutes
- Practitioners, welding engineers (25 persons altogether)

**Teachers:**

- University professors
- Leading industry representatives

COVID: negatively influenced the first course (practical training suffered)

***After-course interviews: generally positive acceptance***