# Nondestructive Testing & Evaluation

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# NDT&E: Value & Role

| | |
|---|---|
| **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 |

# Nondestructive Testing & Evaluation

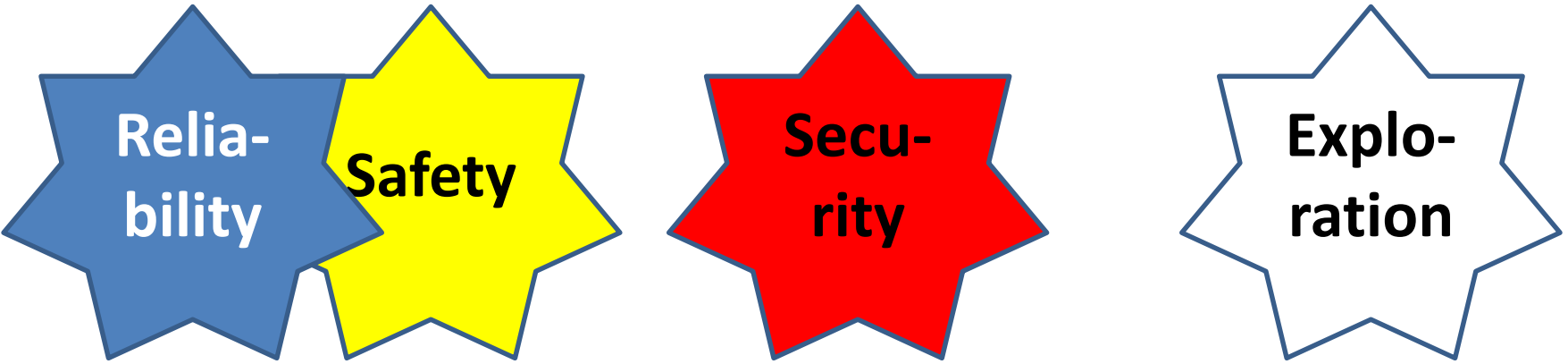
From Wikipedia

***Nondestructive Testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage.***

***The terms***
***Nondestructive examination (NDE),***
***Nondestructive inspection (NDI), and***
***Nondestructive Evaluation (NDE)***
***are also commonly used to describe this technology.***

***Because NDT does not alter the article being inspected,***
***it is a highly valuable technique***
***that can save both money and time***
***in product evaluation, troubleshooting, and research.***

# Value of NDT&E




- QUALITY
- INTEGRITY

TESTING of
- MATERIALS
- COMPONENTS
- SYSTEMS

CONTROL of
- PROCESSES

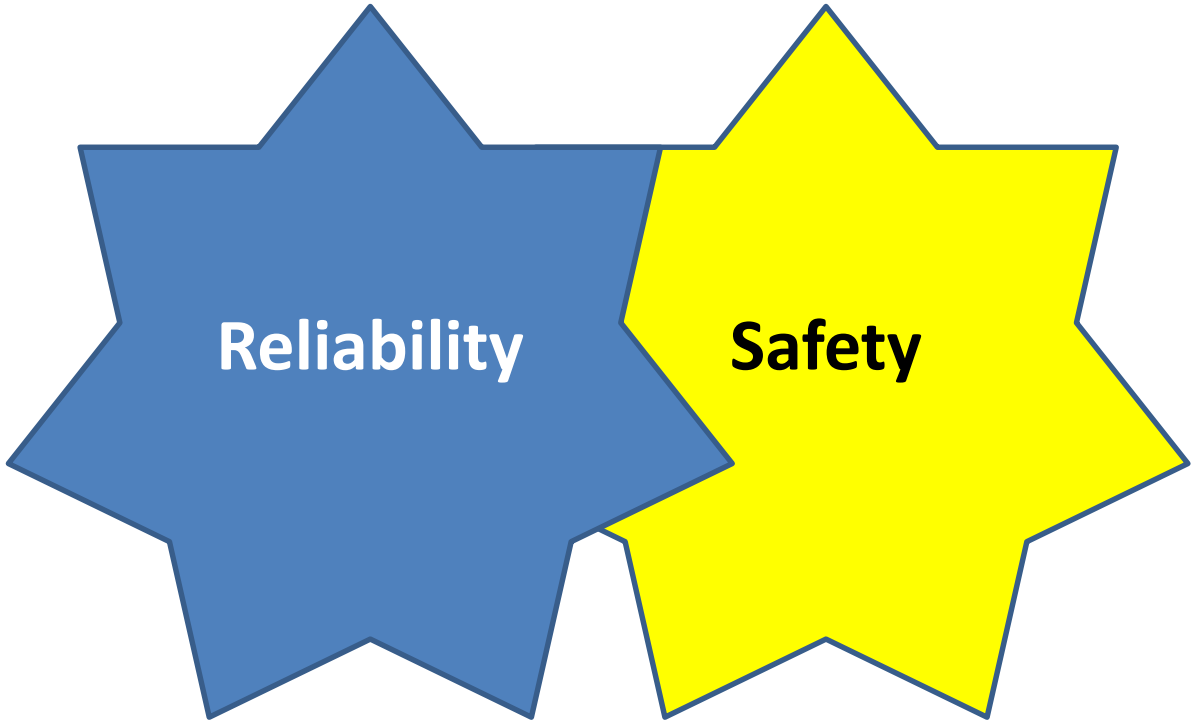
- SOCIAL STABILITY

CONTROL of
- ACCESS
- CONTENT
- SITUATION

- *MEDICAL DIAGNOSTICS*
- *GEOPHYSICS*
- *WORKS of ARTS*
- *ANTIQUES*
- *RESEARCH*
- *and many others*

# Value of NDT&E

LET US DISCUSS THE TRADITIONAL VALUE OF NDT&E:
It's meaning for reliability and safety engineering



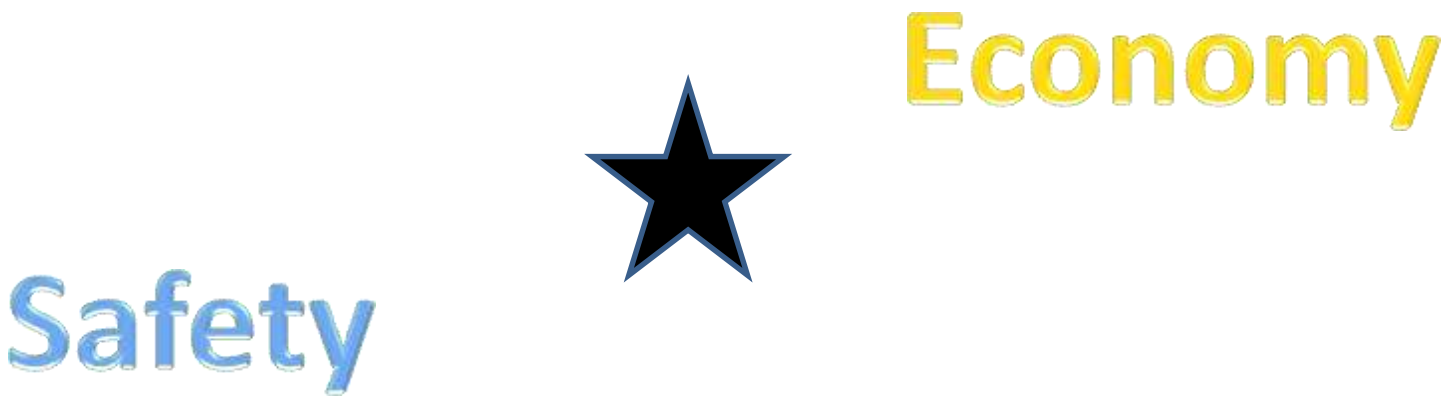
# Think about Quality


*Quality* in business, engineering and manufacturing has a pragmatic interpretation as the non-inferiority or superiority of something;

***QUALITY PRODUCTS MEET CUSTOMER EXPECTATIONS***

it is also defined as fitness for purpose. *Quality* is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people

# Two simultaneous challenges



# Risk based reliability engineering

***RELIABILITY ENGINEERING:***
emphasizes

**dependability**
in the lifecycle management of a product
***or***
ability of a system or component
to function under stated conditions
for a specified period of time

# Risk based reliability engineering

***RELIABILITY :***

Theoretically defined
as the probability of failure (the frequency of failures)

or in terms of availability:
a probability derived from reliability and maintainability.

Reliability plays a key role in cost-effectiveness of systems.

# Risk based reliability engineering

***RELIABILITY ENGINEERING*** ⟺ ***SAFETY ENGINEERING***

**focuses on costs of failure caused by system downtime, cost of spares, repairs, personnel and cost of warranty claims.**

ECONOMY

**focuses normally not on cost, but on preserving life and nature; deals with particular dangerous system failure modes**

SAFETY

**common methods for analysis require input from each other**

# Risk based reliability engineering

***DEPENDABILITY:***

a measure of a system's
availability, reliability, maintainability

**Attributes**

A way to assess
the dependability of a
system

**Threats**

An understanding
what can affect
the dependability
of a system

**Means**

Ways to increase
a system's dependability

# Risk based reliability engineering

## *ATTRIBUTES*

**System Qualities**

**Availability**

**Readiness for correct service**

**Maintainability**

**Ability for undergoing modifications and repairs**

**Safety**

**Absence of catastrophic consequences**

**Integrity**

**Absence of improper system alteration**

**Reliability**

**Continuity of correct services**

**Security**

**Absence of externally originated errors**

# Risk based reliability engineering

## *Assessment of Attributes*

| Quantitative | Qualitative |
| --- | --- |
| • Availability<br>• Reliability | • Integrity<br>• Safety<br>• Maintainability<br>• Security |
| ***Basic Safety Design**<br>**Leak before Break** | **State of Engineering**<br>**Quality Assurance**<br>**Design*** |

# The 5 Traditional Human Senses


Lairesse's *Allegory of the Five Senses (*1668)

# The 5 Traditional Human Senses

## Physical Senses

- Sight (Vision)
- Hearing (Audition)
- Touch (Tactition)

## Chemical Senses

- Taste (Gustation)
- Smell (Olfaction)

**Nondestructive Methods**
**measure physical properties**

# The very early beginning of NDT&E

## "THE HUMAN SENSES"

**VISUAL TESTING**
**VT**

1988 recognized as an "official" NDT method when it was finally incorporated into SNT-TC-1A, the document for the qualification and certification of NDT personnel published by the American Society for Nondestructive Testing (ASNT).

**Book of Genesis:**

In describing the process of creation, chapter 1 repeats 6 times the expression:

***"AND GOD SAW IT WAS GOOD"***

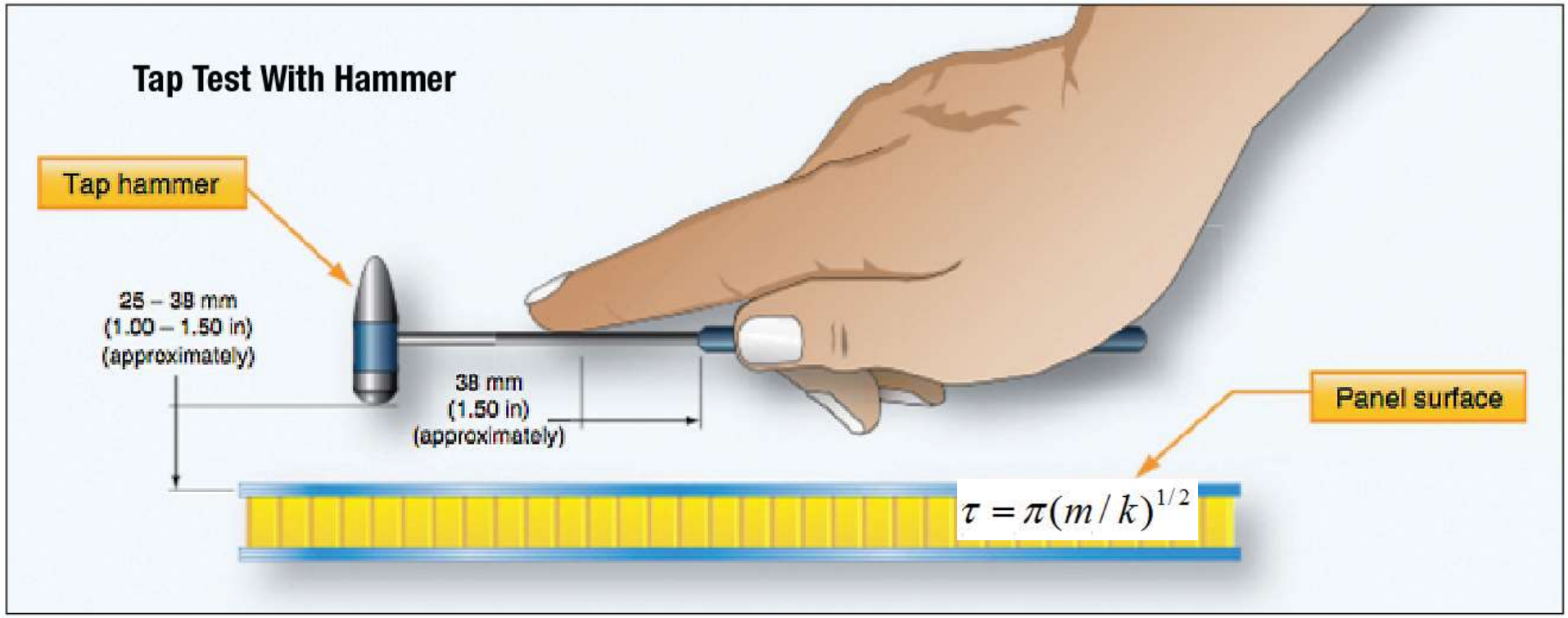
**RINGING TEST**
**AE, TT**

Tap Testing
(concrete & adhesively bonded composite parts)
Surface stiffness, compressive strength, disbonding
"Sound, Contact Time, Rebound"

**"listening"** to metal being shaped by a blacksmith,
the tone of a bell after it was cast,
or the tonal sound of pottery

**In the 1950, J. Kaiser introduced acoustic emission (AE) as an NDT method.**

# TAP TESTING




***Surface stiffness k:*** $\tau = \pi(m/k)^{1/2}$

# The very early beginning of NDT&E

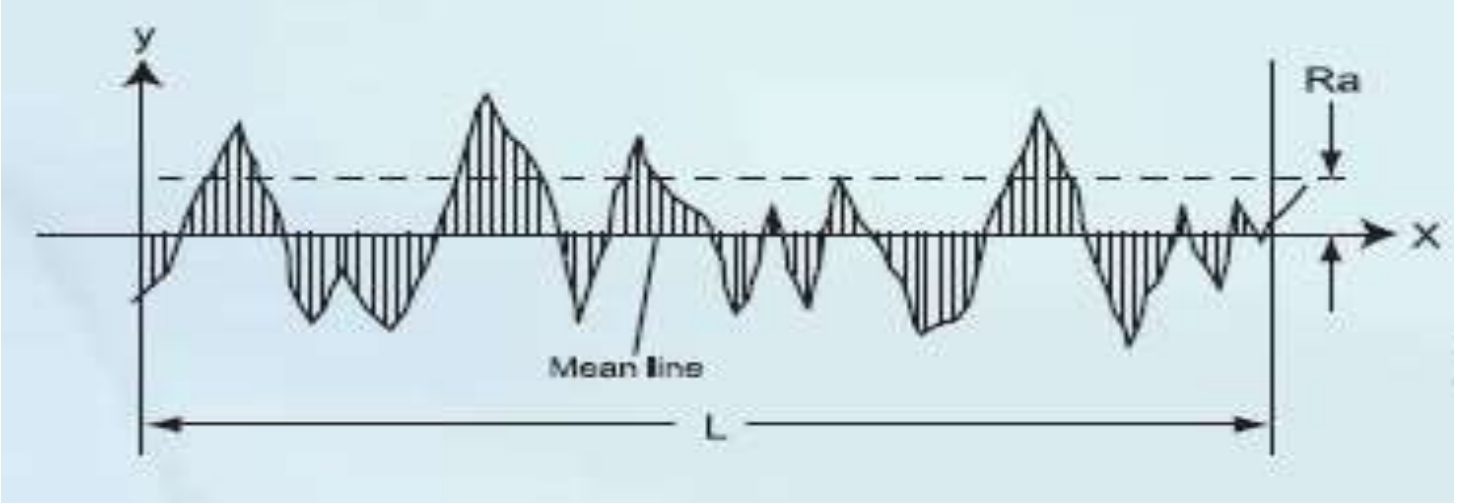
## "THE HUMAN SENSES"

**SURFACE TEST**

Surface Roughness Testing:
Mechanical (in contact)
Laser optics (contactless)

$$R_a = 1/L \int_0^L |y| dx$$ – Roughness Average

Our sense of "touch" can indicate the surface condition of various objects as well as their relative temperatures



# NDT&E

# IN THE COURSE OF INDUSTRIALIZATION

**DRIVEN BY ACCIDENTS & WARS**

**ENABLED BY PROGRESS IN ENGINEERING & PHYSICS**

**MISSISSIPPI STEAMSHIP SULTANA 1865**
**Boiler Explosion with estimated deaths 1200-1600**

# NDT&E EVOLUTION

## In a Nut-Shell

Steam Engine
Machine Work

Assembly Line Work
Mass Production
Traffic Technology
Electrification

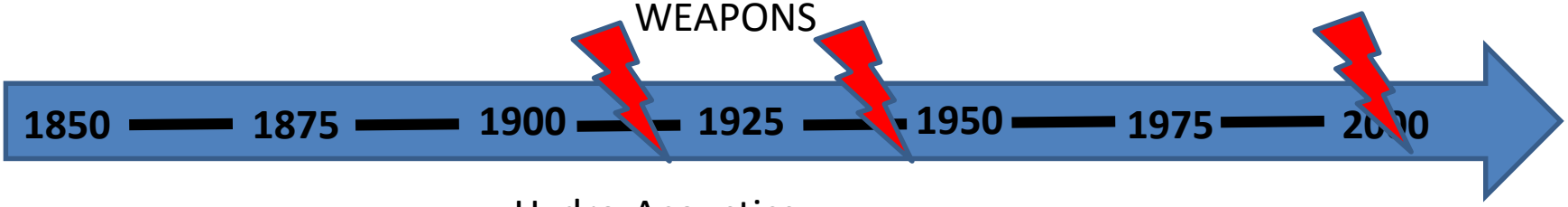
Robotics
Knowledge &
Information Systems
Globalization

Boiler Explosions

Quality Issues

WEAPONS

(international) Product Liability




Hydro-Acoustics

1854 Technical Regulations
1864 Boiler Inspection Law
(Visual Inspection)

Foundation of
NDT - Fundamentals
Piezo-Effect

X-Ray
γ-Ray

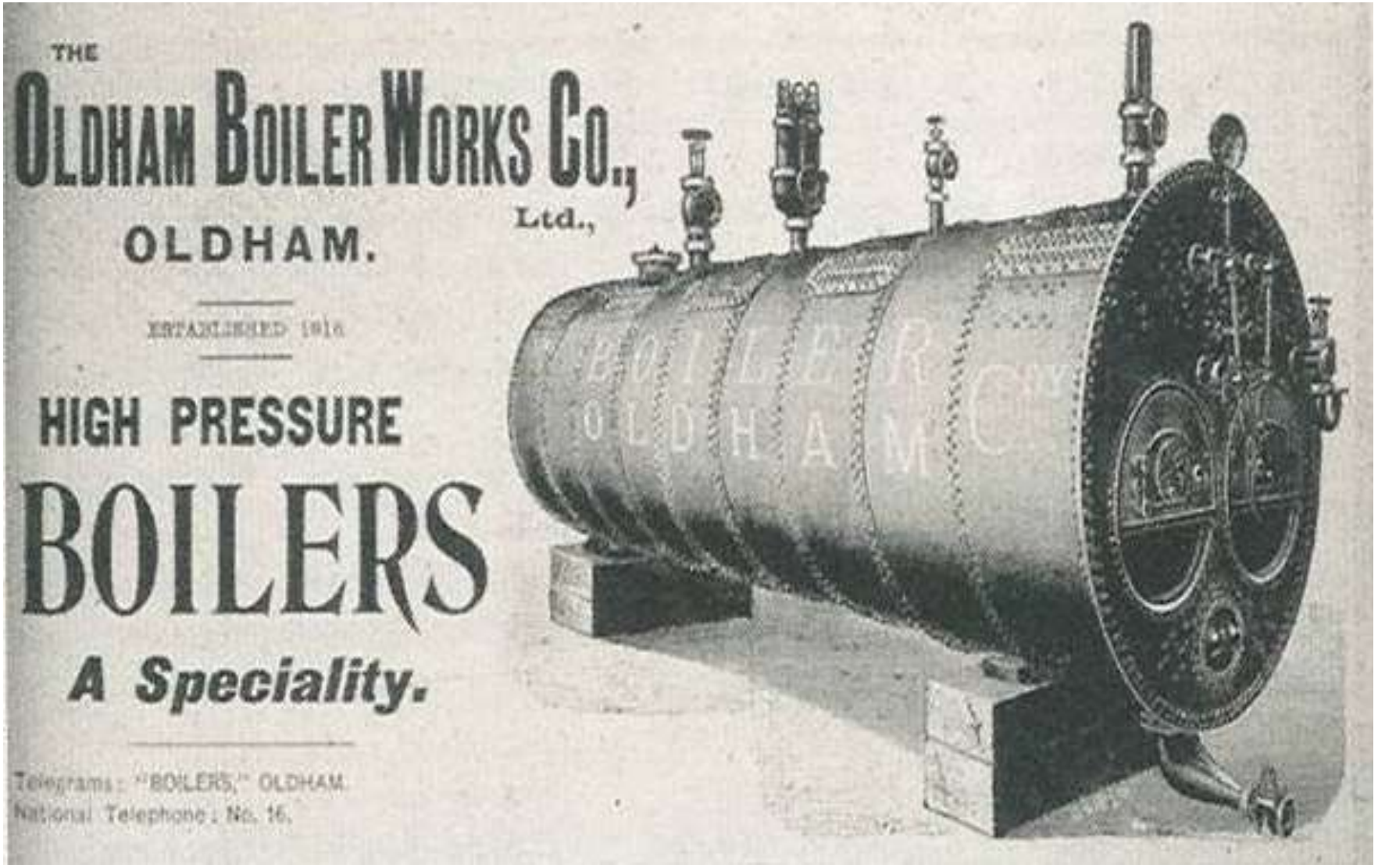
Foundation of
NDT - Methods

Signal Processing
(Inverse Problems)
Micro-Systems

Modern Physics

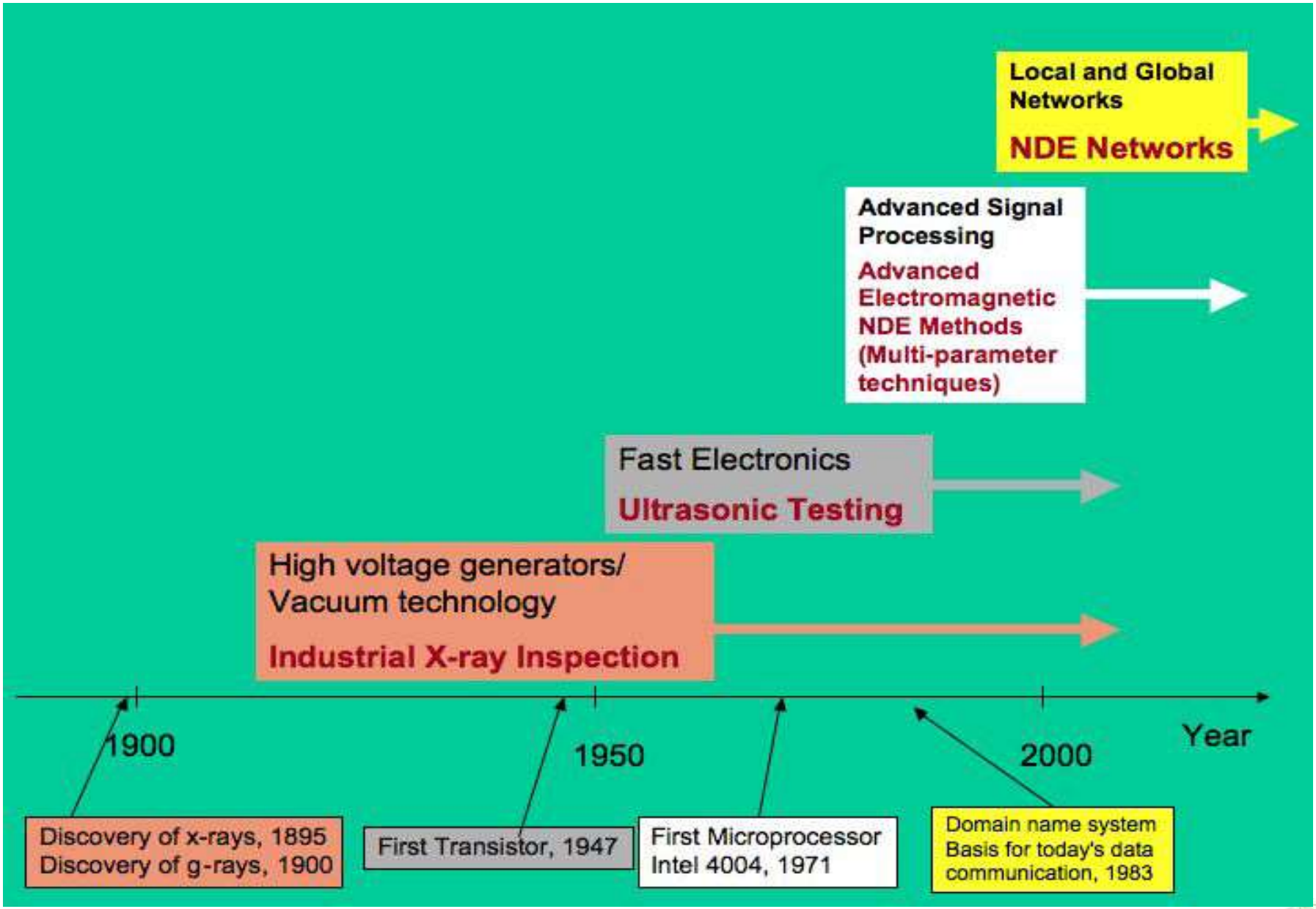
Computer; IT

# History of NDT&E

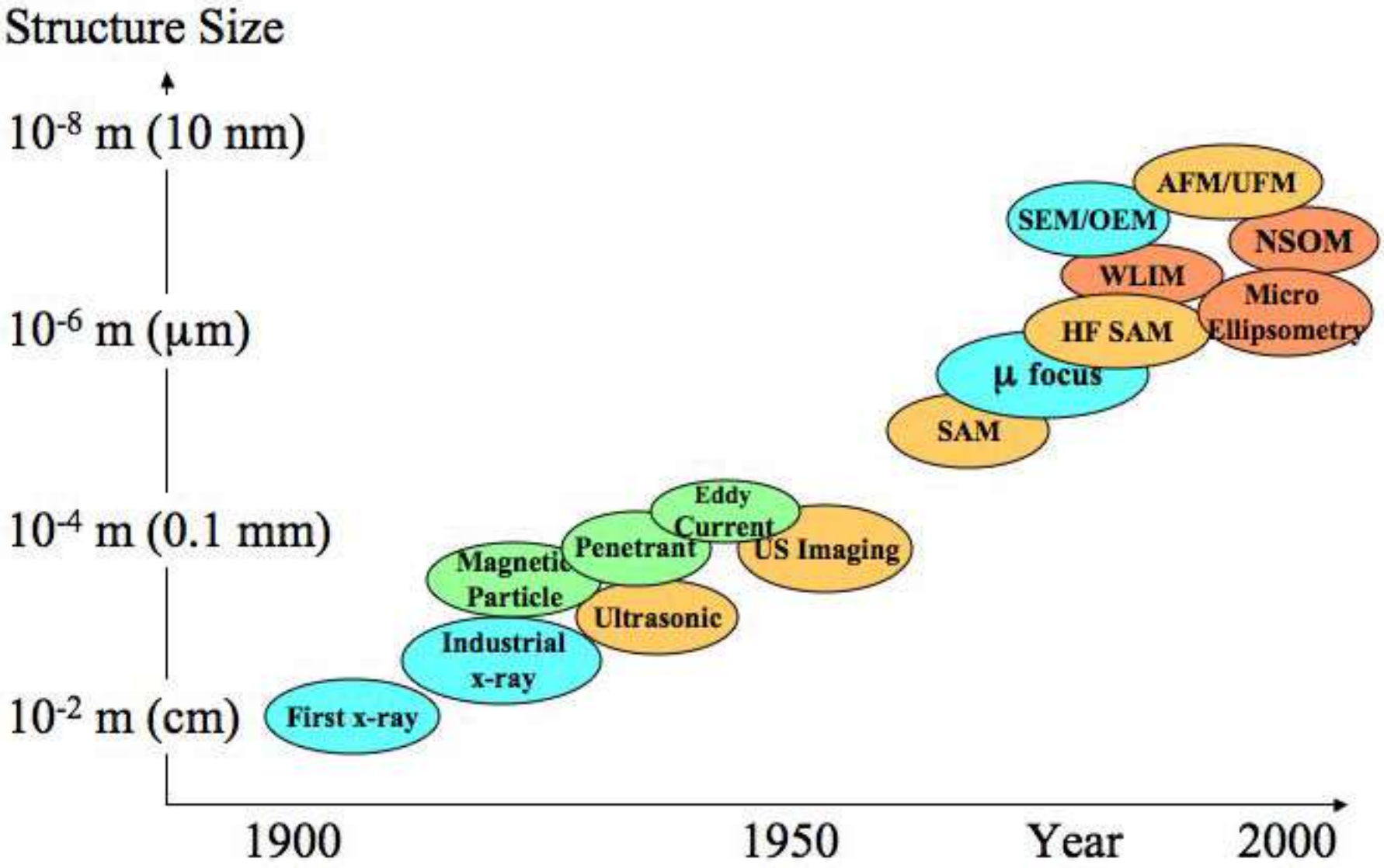


# History of NDT&E

# NDT&E -EVOLUTION



# NDT&E EVOLUTION



# History of NDT&E

| | |
|---|---|
| BC (approx.) | Visual testing becomes the first NDT method when God creates the heavens and earth and "sees" that it is good! |
| 1800 | First thermography observations by Sir William Herschel |
| 1831 | First observation of electromagnetic induction by Michael Farraday |
| 1840 | First infrared image produced by Herschel's son, John |
| 1868 | First reference to magnetic particle testing reported by S. H. Saxby, by observing how magnetized gun barrels affect a compass |
| 1879 | Early use of eddy currents to detect differences in conductivity, magnetic permeability, and temperature initiated by E. Hughes |
| 1880–1920 | "Oil and whiting" technique, forerunner of present-day penetrant test used for railroad axles and boilerplates |
| 1895 | X-rays discovered by Wilhelm Conrad Roentgen |
| 1898 | Radium discovered by Marie and Pierre Curie |

# History of NDT&E

| | |
|---|---|
| 1922 | Industrial Radiography for metals developed by Dr. H. H. Lester |
| 1927–28 | Electric current innduction/magnetic field detection system developed by Dr. Elmer Sperry and H. C. Drake for the inspection of railroad track |
| 1929 | Magnetic particle tests/equipment pioneered by A. V. deForest and F. B. Doane |
| 1929 | First experiments using quartz transducers to create ultrasonic vibrations in materials were conducted by S. Y. Sokolov in Russia |
| 1930 | Practical uses for gamma radiography using radium were demonstrated by Dr. Robert F. Mehl |
| 1935–1940 | Penetrant techniques developed by Betz, Doane, and DeForest |
| 1935–1940's | Eddy current instrument developments by H. C. Knerr, C. Farrow, Theo Zuschlag, and Dr. F. Foerster |
| 1940–1944 | Ultrasonic test method developed in United States by Dr. Floyd Firestone |
| 1942 | First ultrasonic flaw detector using pulse-echo introduced by D. O. Sproule (United Kingdom) |
| 1946 | First portable ultrasonic thickness measuring instrument, the Audigage, was introduced by Branson |
| 1950 | Acoustic emission introduced as an NDT method by J. Kaiser |
| Mid 1950's | First ultrasonic testing immersion B and C scan instruments developed by Donald C. Erdman |

# HISTORY

*Pierre Curie*
*1859-1906*

Piezo-Effect

*Alexander Behm*
*1880-1952*

*Paul Langevin*
*1872-1946*

SONAR
(Submarines)

## Early Pioneers of Ultrasonic Testing

1842 Magnetostrictive effect discovered by Joule

1877 Rayleigh's "Theory of Sound" laid foundation for modern acoustics.

1880 Curie brothers discovered the piezoelectric effect

1912 Sinking of Titanic led to proposals on use of acoustic waves to detect icebergs

1928 Sokolov proposed use of ultrasound for flaw detection

1936 Pohlman developed an ultrasonic imaging method

1937 Sokolov invented an ultrasonic image tube

1940 Firestone, in the United States and Sproule, in Britain, discovered ultrasonic pulse-echo metal-flaw detection

# MILESTONES IN UT HISTORY

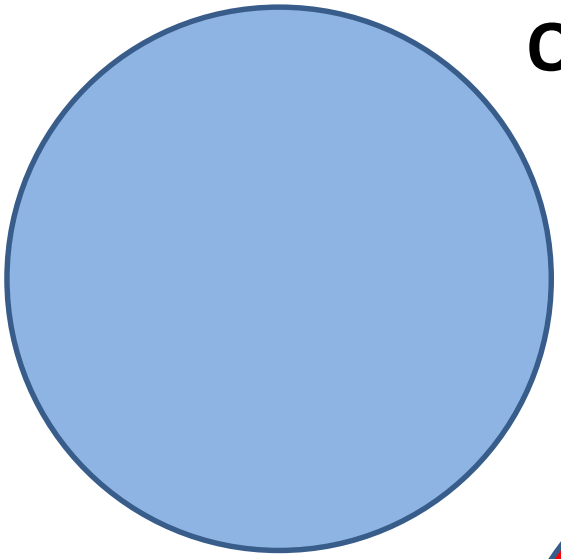
# HISTORY

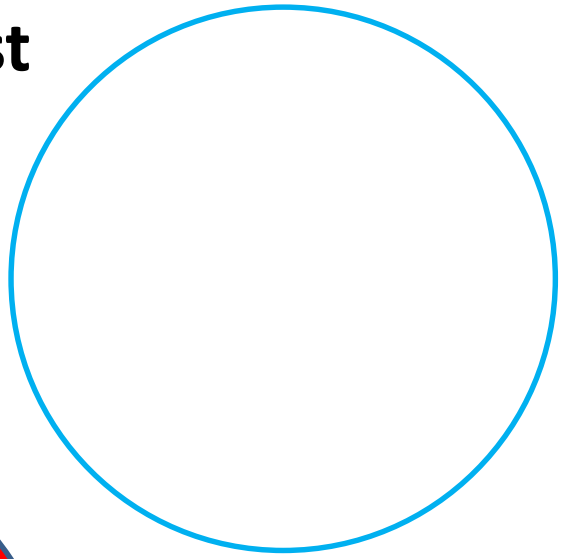
*The 'Supersonic' UT unit, which was one of the first.*

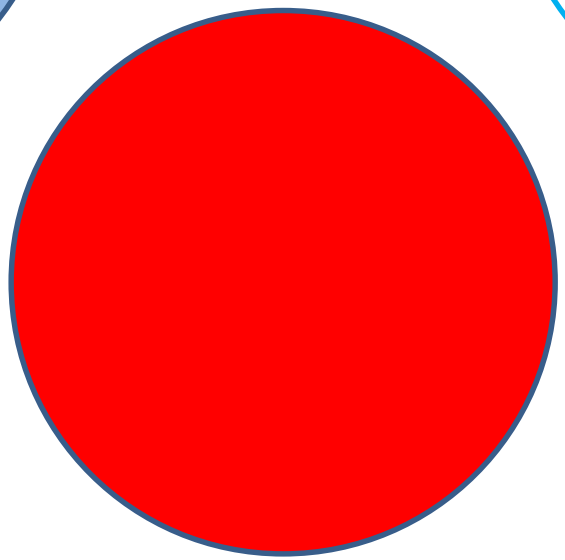
Early pipe testing
with Krautkrämer apparatus (1950s)

# PHYSICAL PROPERTIES

## Optical Contrast







# There are Many

**NDT is divided into various *methods* of nondestructive testing, each based on a particular scientific principle.**

**These methods may be further subdivided into various *techniques*.**

| METHOD | APPLICATION | CONTRAST |
|---|---|---|
| Visual Inspection **VT** | Surface Imperfections | Optical |
| Liquid Penetrant **PT** | Surface Cracks | Color/Capillary Effect |
| Magnetic Flux Leakage **MFL** | Imperfections in Magnetic Surfaces | Strayflux |
| Eddy Current **EC** | Imperfections in Conductive Surfaces | Electric Impedance |
| Current Potential Drop | Imperfections in Conductive Surfaces | Electric Current |

# There are Many

| METHOD | APPLICATION | CONTRAST |
|---|---|---|
| Ultrasound **UT** | Surface & Volume Imperfections | Acoustic Impedance |
| Acoustic Emission **AE** | Surface & Volume Imperfections | Elastic Energy Conversion at Imperfections |
| Radiography **RT** | Surface & Volume Imperfections | Attenuation |
| Infrared & Thermal **IR** | Surface and Sub-Surface Imperfections | Thermal Conductivity/ Surface Emissivity |
| Leak Detection **LT** | Leaking Structures | Various Contrast Methods |
| Magnetic Resonance **MR** | Imperfections in Materials with H (Polymer, Concrete) | Magnetic Resonance |

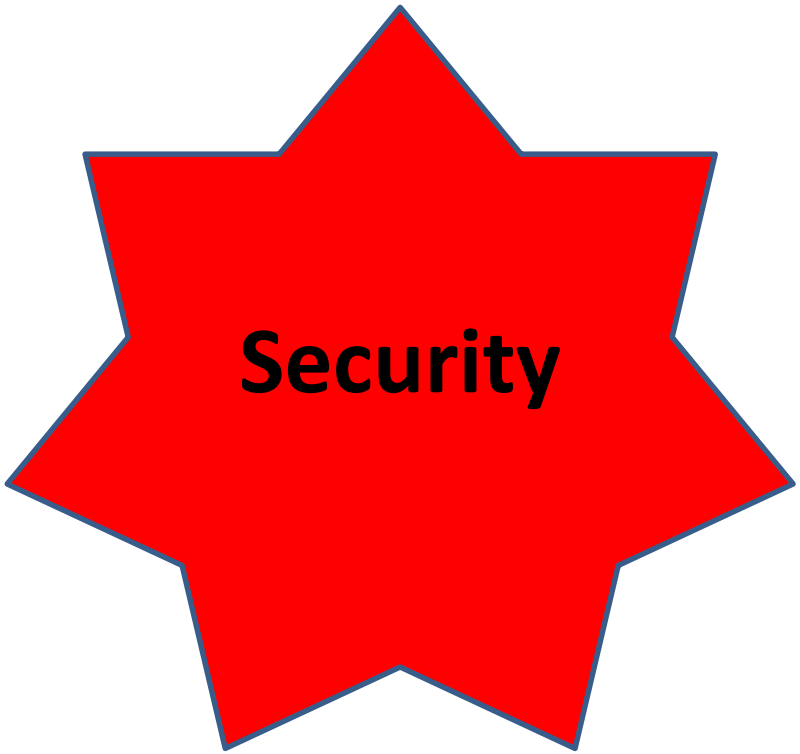
# TESTING COMPOSITES

| Method of Inspection | Type of Defect | | | | | | |
|---|---|---|---|---|---|---|---|
| | Disbond | Delamination | Dent | Crack | Hole | Water Ingestion | Overheat and Burns |
| Visual | X (1) | X (1) | X | X | X | | X |
| X-Ray | X (1) | X (1) | | X (1) | | X | |
| Ultrasonic TTU | X | X | | | | | |
| Ultrasonic pulse echo | | X | | | | X | |
| Ultrasonic bondtester | X | X | | | | | |
| Tap test | X (2) | X (2) | | | | | |
| Infrared thermography | X (3) | X (3) | | | | X | |
| Dye penetrant | | | | X (4) | | | |
| Eddy current | | | | X (4) | | | |
| Shearography | X (3) | X (3) | | | | | |

Notes:
(1) For defects that open to the surface
(2) For thin structure (3 plies or less)
(3) The procedures for this type of inspection are being developed
(4) This procedure is not recommended

# Value of NDT&E

LET US DISCUSS NEW MEANING OF NDT&E:



# Value of NDT&E


There is a disastrous cause: TERRORISME
A Thread for Societies and Individuals

# Value of NDT&E


## Aviation *Security*

Transportation Security Administration (TSA)

## *Access Control*

## *Cargo Control*

## *Situation Control*


**Highlighting Area for Resolution**

**Generic Figure**

# AVIATION SECURITY

# AVIATION SECURITY

Security

# Value of NDT&E

Security

Gilardoni Scientific Industry

## Airport Security System for Luggage Inspection

# AVIATION SECURITY

Security

## PRIVACY CONCERNS

## “The Naked Passenger”


**Active Sub-millimeter 3-D Microwave Scanner**

# CARGO CONTROL

Security

## System Integration & Working Flow

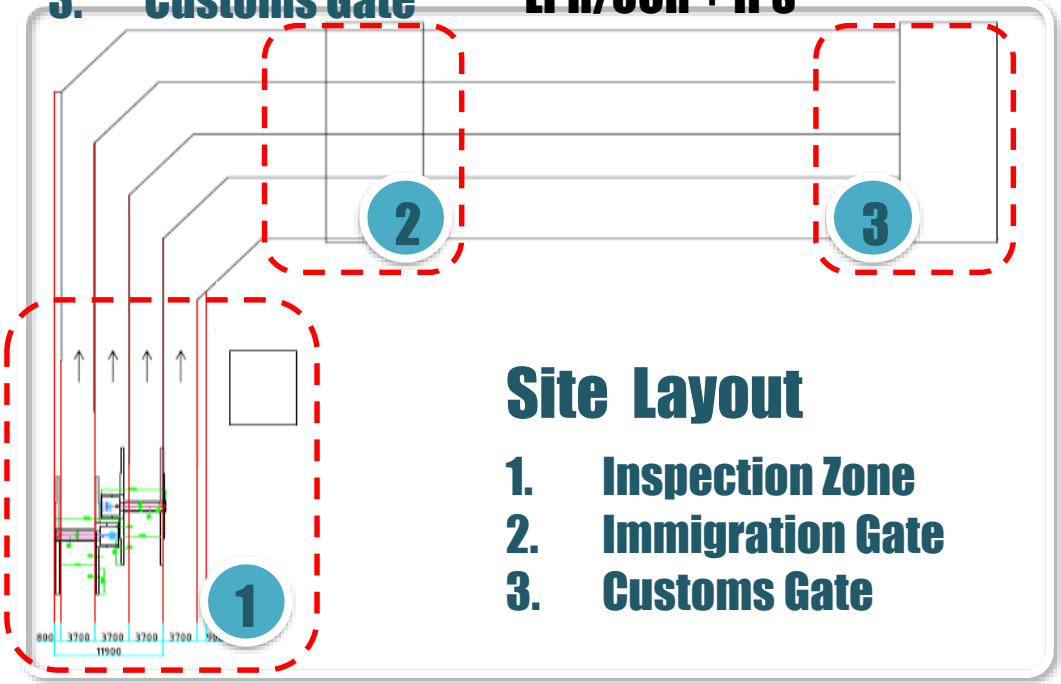



### Site Layout

1. Inspection Zone
2. Immigration Gate
3. Customs Gate

BT-SCAN+…+Control Center

LPR/OCR + IPS




### Site Layout

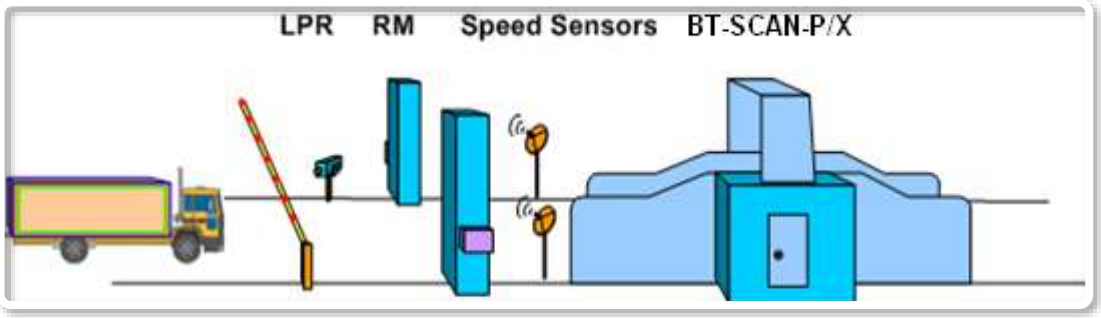
1. Inspection Zone
2. Immigration Gate
3. Customs Gate

# CARGO CONTROL

Security

## System Configuration

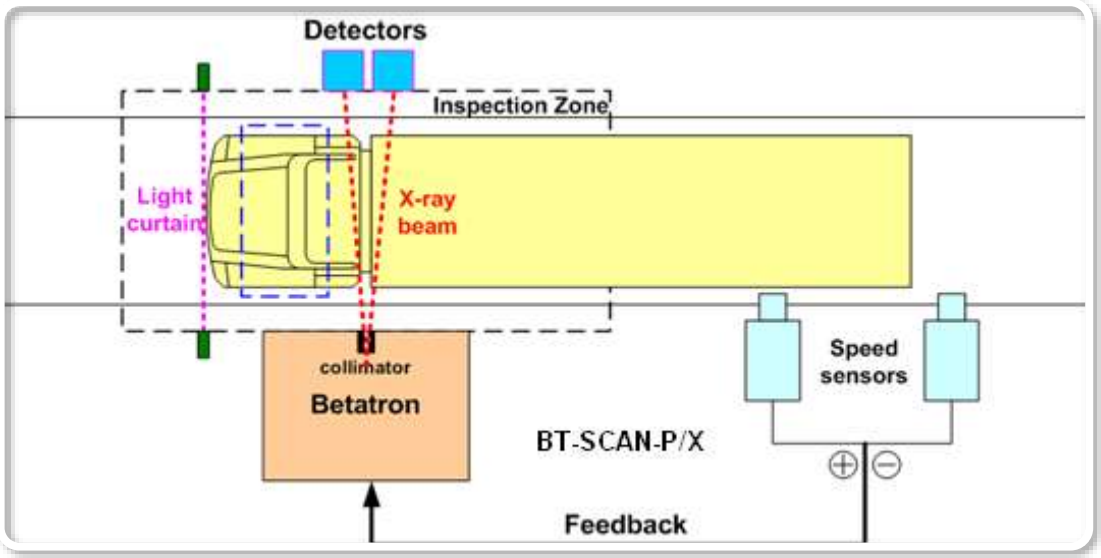
- LPR/OCR
- Radioactivity monitor
- Speed sensors
- BT-SCAN-P/X




**How to avoid Scanning the Driver's Cab?**

- Speed sensor
- Light Curtain

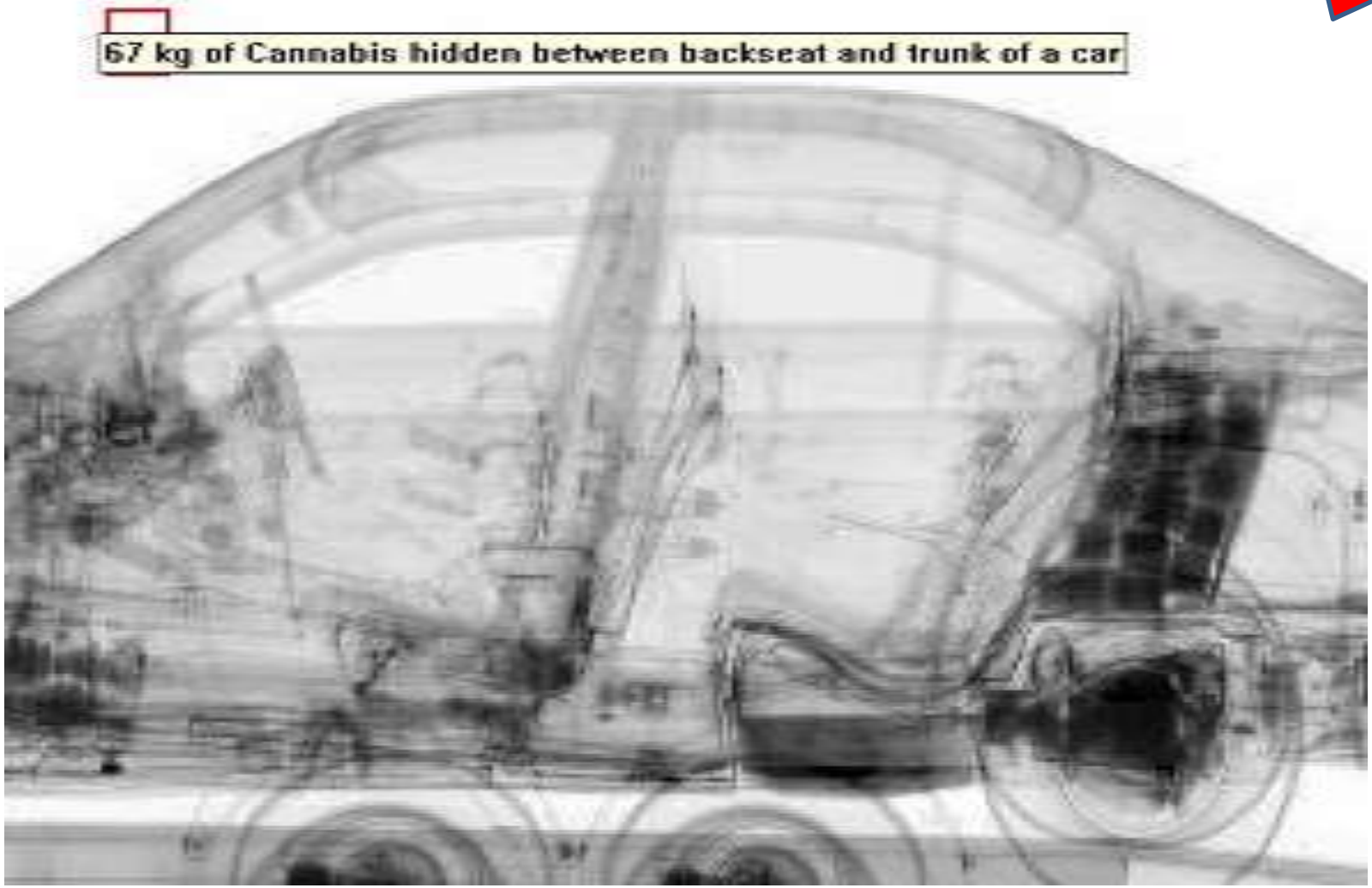
...



Typical Images

# CARGO CONTROL

Security



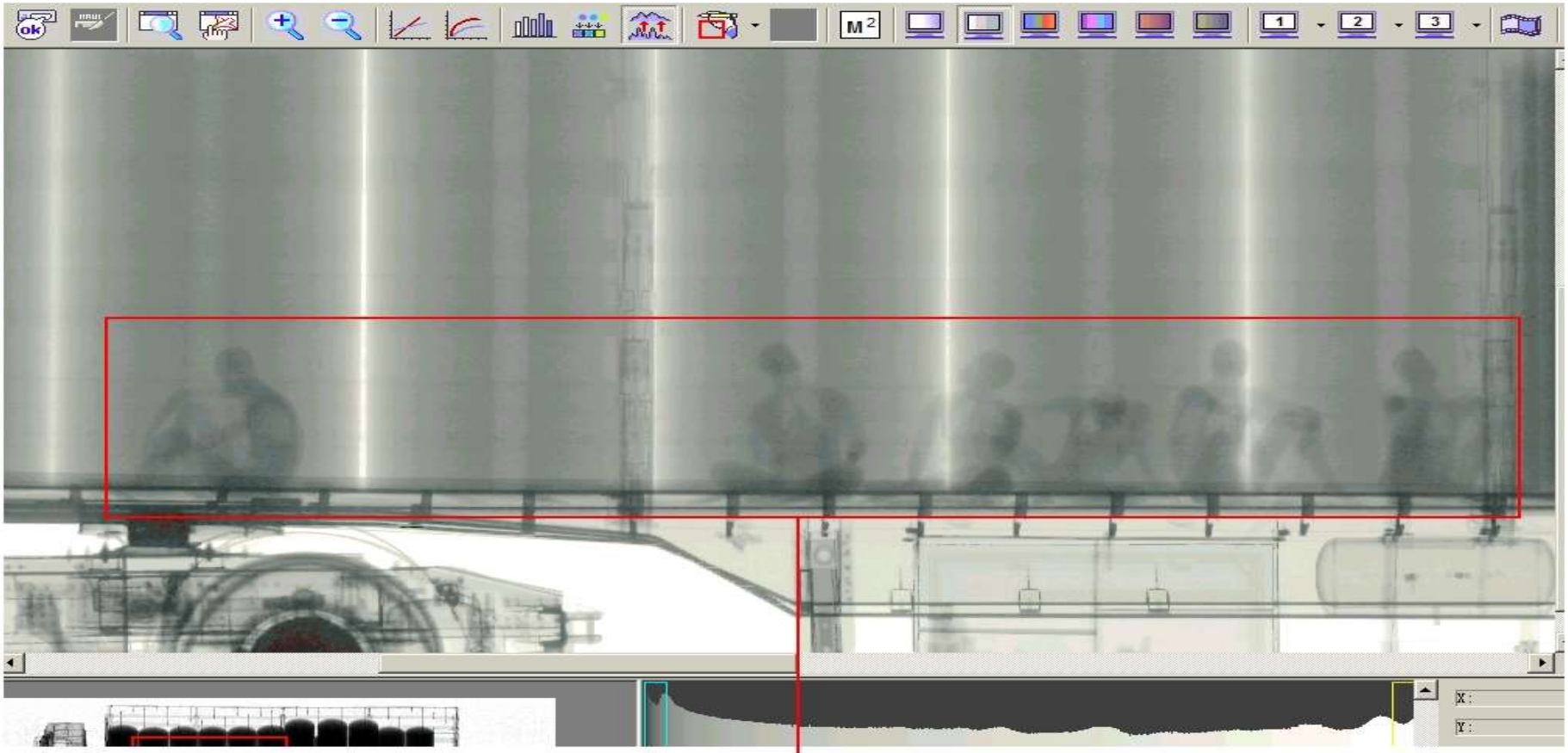
# Typical Images

# CARGO CONTROL

Security

清华同方威视技术股份有限公司
NUCTECH COMPANY LIMITED

## Scanning Image for THSCAN Relocatable X-ray Inspection System



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