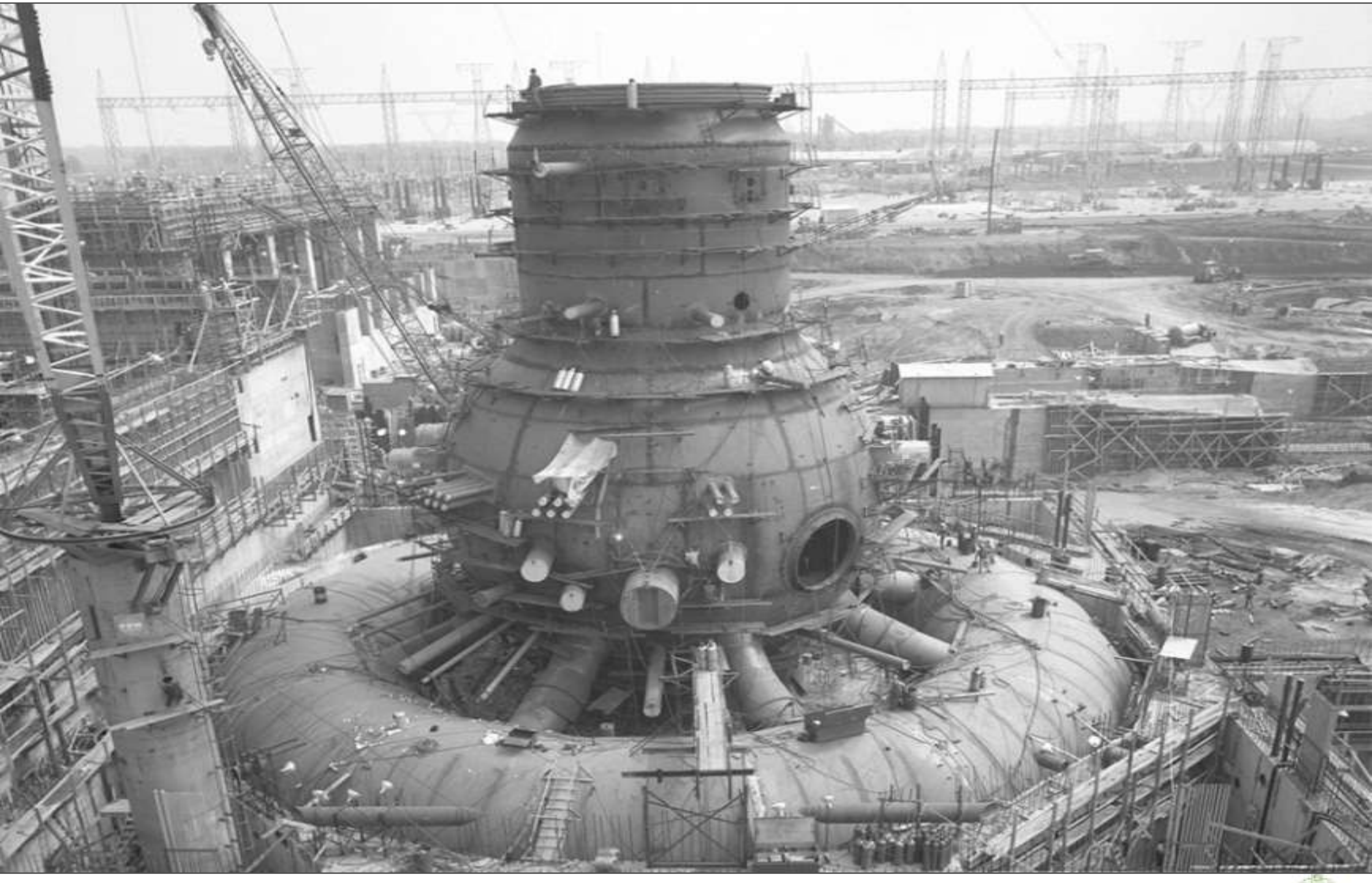
Structure Design & NDT



MATERIAL CHARACTERIZATION

4.	**Mitigation Strategies – The world is never perfect**
4.1.	Structure Design and NDT
4.2.	Application of NDT
4.3.	Limits of NDT
4.4.	Quantitative NDT
4.5.	Material Characterization
4.6.	Case Study – Inspection by Cause

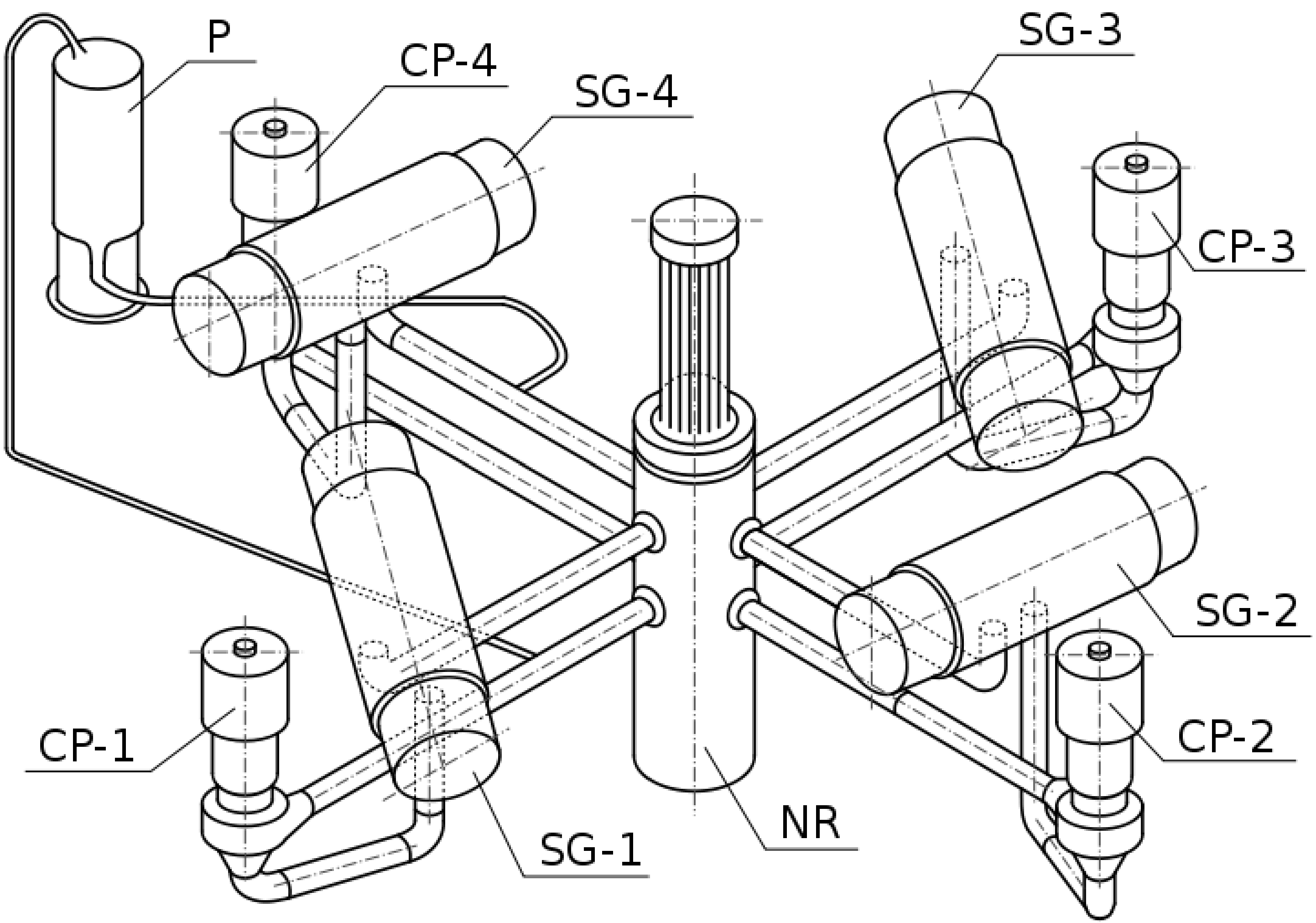
Structure Design & NDT

Material Testing and Inspection

?

Destructive Testing	Nondestructive Testing
Defines Material Utilization	Defines Quality Standards
Provides Insight to Microstructure	Flaw Inspection ⟺ QNDT
It relies on representative samples	Full Volume Inspection
⇓	⇓
Material Specification	Quality Control
Material and System Tests	Maintenance
Material Development	Life-Time Extension

4 Loop Pressurized Water Reactor (VVER 1000)



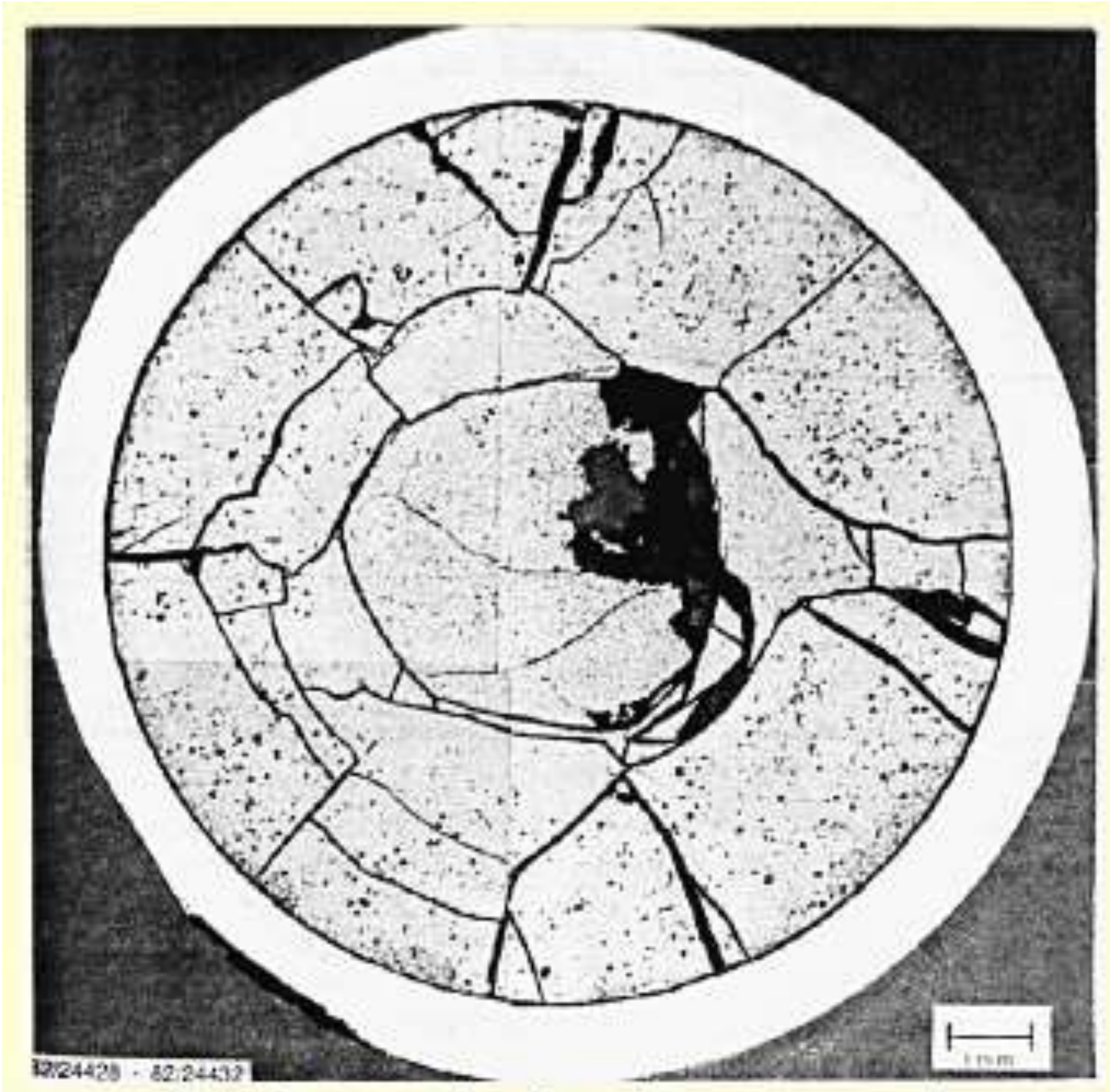
VVER-1000-Stereometric.svg

Central Ring with Outlet and Inlet Nozzles

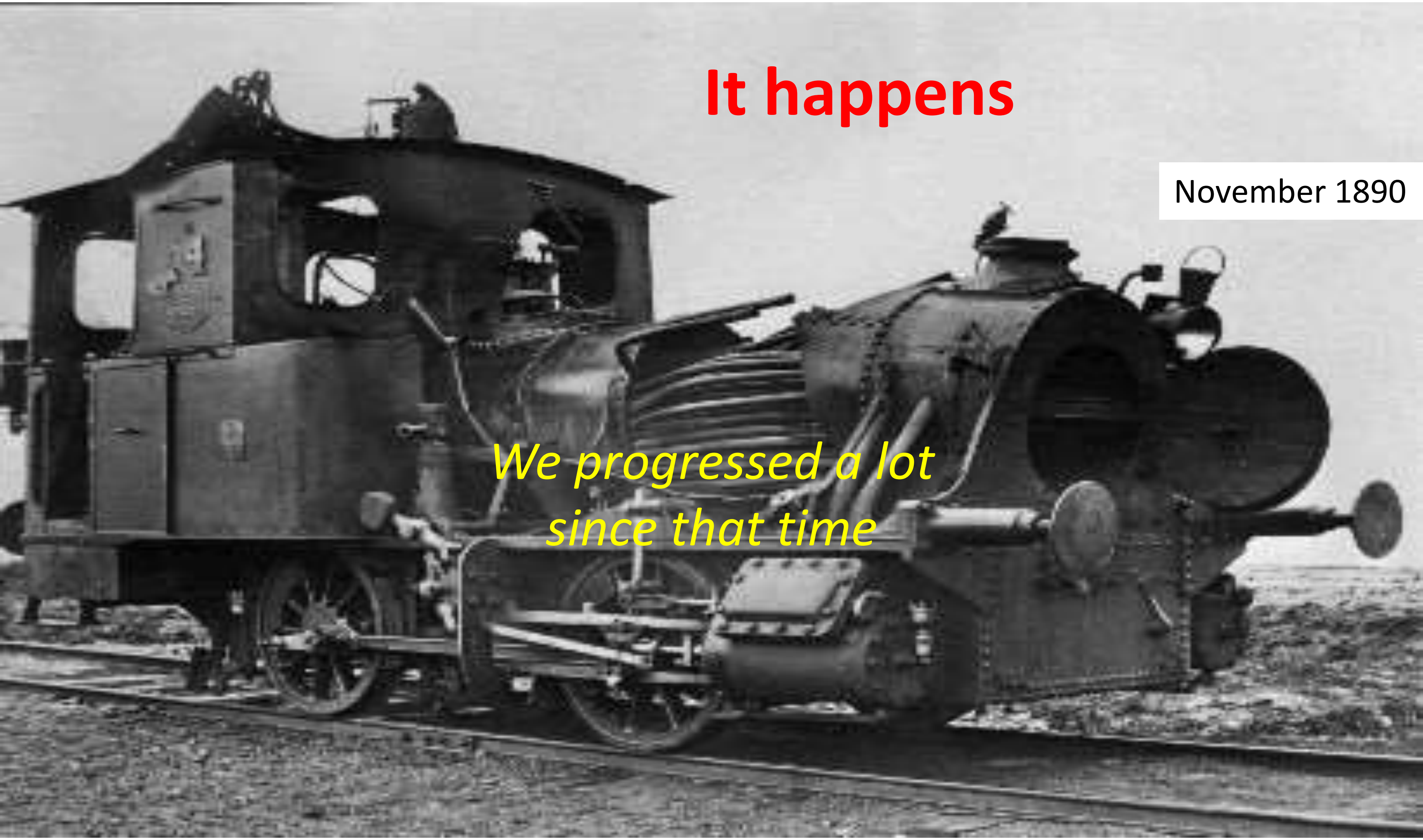
Closure Head with Control Rod and Instrumentation Nozzles

Core Plate

Fuel Cross Section



Mitigation


It happens
November 1890
We progressed a lot
since that time

CORE LAVA

Mitigation

Structural Integrity

Structural integrity is the ability of a structure or a component to withstand a designed service load, resisting structural failure due to:

fracture
deformation, or
fatigue.

Structural integrity is a concept often used in engineering, to produce items that will function adequately for their

designed purposes
for a
desired service life.

System Engineering Rules for Reliable and Safe Structures

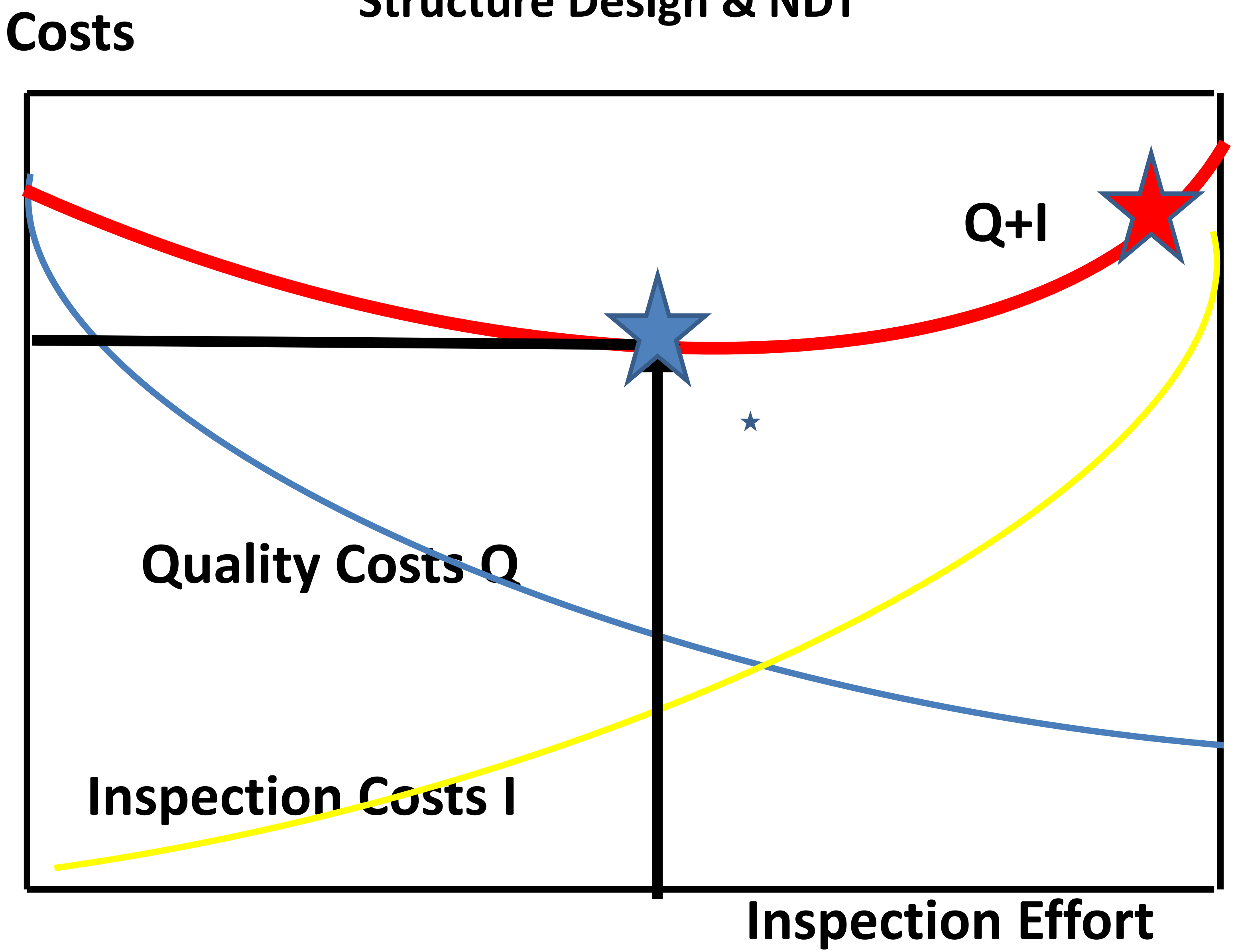
Reliability

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.

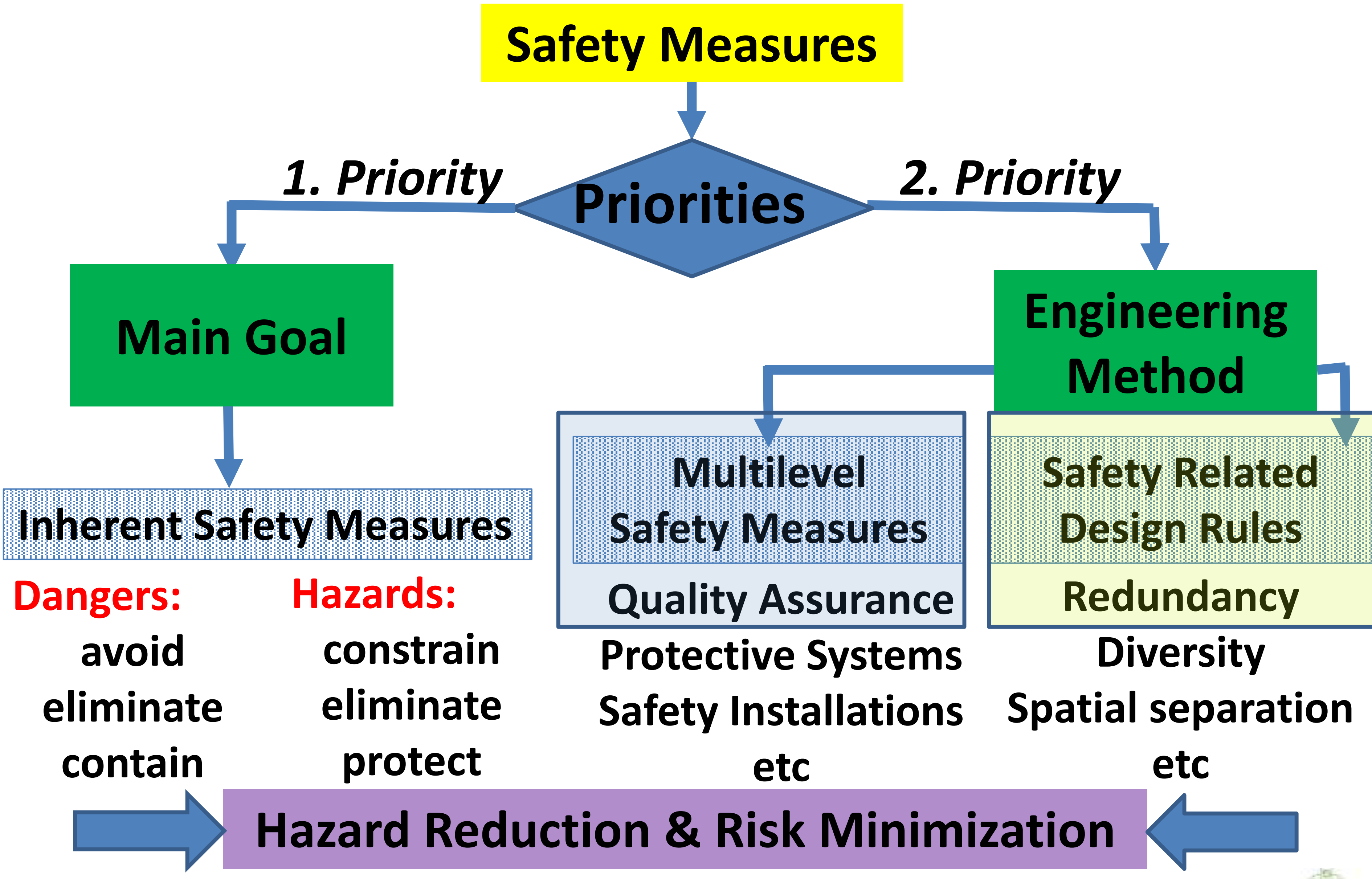
Safety

relates to only
very specific system hazards
that could potentially
lead to severe accidents.
It deals with
dangerous events for
life and environment.

Structure Design & NDT



Safety-Oriented Approach



SAFETY ENGINEERING

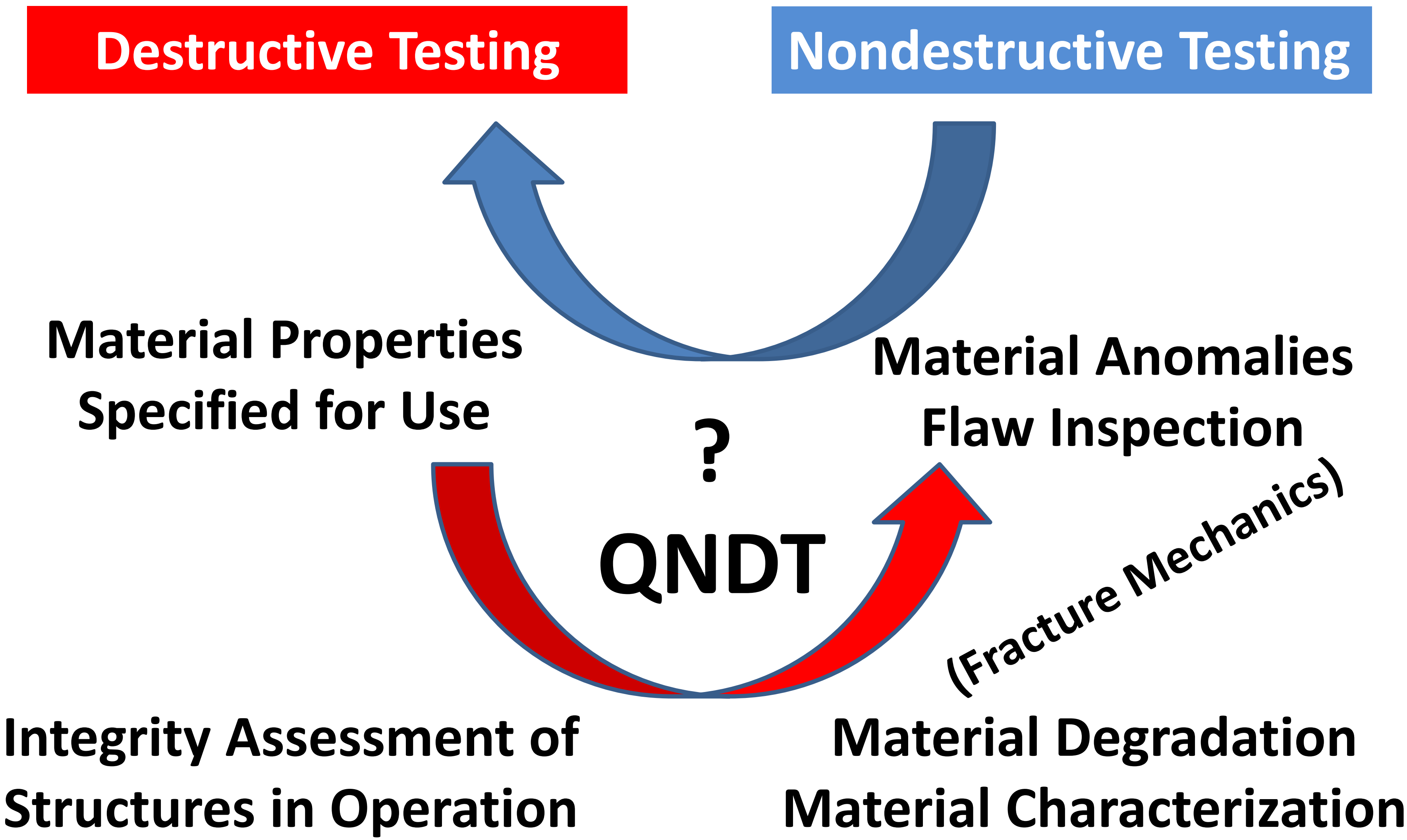
DESIGN	MANUFACTURING
• Strictly controlled • Common cause failure • Passive systems • Inherent safety	• Regulations and codes • Quality management • Quality certification • Independent assessment
OPERATION	**DISPOSAL**
• Maintenance • Degradation control • Unexpected events	• Dismantling • Renaturization • Waste management

Types of Failures

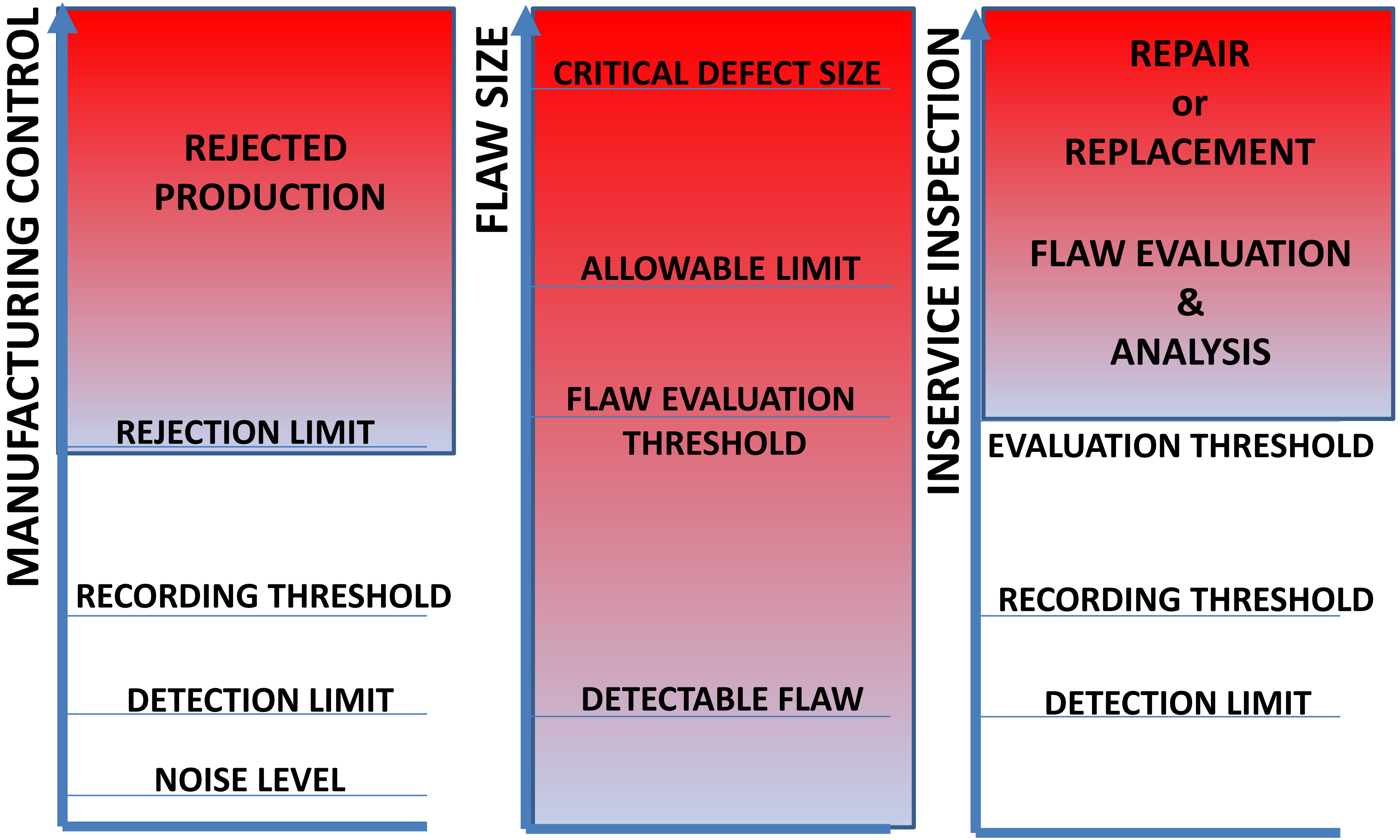
- **Overload of Structure** (critical stress level)
- **Structure Instability** (due to design or material choice) causing the structure to fail from fatigue or corrosion
- **Manufacturing Errors**: improper selection of materials, incorrect sizing, improper heat treating, failing to adhere to the design, or shoddy workmanship
- **Defective Materials**
- **Unexpected Problems** (Vandalism, sabotage, and natural disasters)

HOW TO DETECT CAUSES or THE ROLE OF NDT

Structure Design & NDT



INDICATION-FLAW-DEFECT



CONTRIBUTION OF NDT

Crack growth, as shown by fracture mechanics, is exponential in nature (Paris' law).

A desire for reasonable inspection intervals, combined with the exponential growth of cracks in structure has led to the development of non-destructive testing methods which allow inspectors to look for very tiny cracks.

Examples of this technology include eddy current, ultrasonic, dye penetrant, and X-ray inspections.

HOWEVER:
CAN WE CHARACTERIZE MATERIAL DEGRADATION BY MEASURING MICROSTRUCTURE DEPENDANT ΔK?

CONTRIBUTION OF NDT

STILL LIMITED

FLAW TYPE
MATERIAL STRUCTURE
ACCESS

FLAW INITIATION & GROWTH
MATERIAL DEGRADATION
CAUSE EVALUATION

TARGETED

CODES & REQUIREMENTS
CERTIFICATION & VALIDATION
DETECTION & EVALUATION

QUANTITATIVE NDT
NEW METHODS
HEALTH MONITORING

CONCLUSION I

WE CANNOT EXCLUDE HAZARDS

WE CAN ONLY MINIMIZE THE RISK

BY

- **SAFETY CULTURE**
- **PROFESSIONAL RESPONSIBILITY**
- **CONTINUING IMPROVEMENTS**

CONCLUSION II

WE MUST ASSURE THE QUALITY
WE MUST CONTROL THE STRUCTURAL STATE

BY

- **NONDESTRUCTIVE FLAW EVALUATION**
- **NONDESTRUCTIVE MATERIAL CHARACTERIZATION**

CONCLUSION III

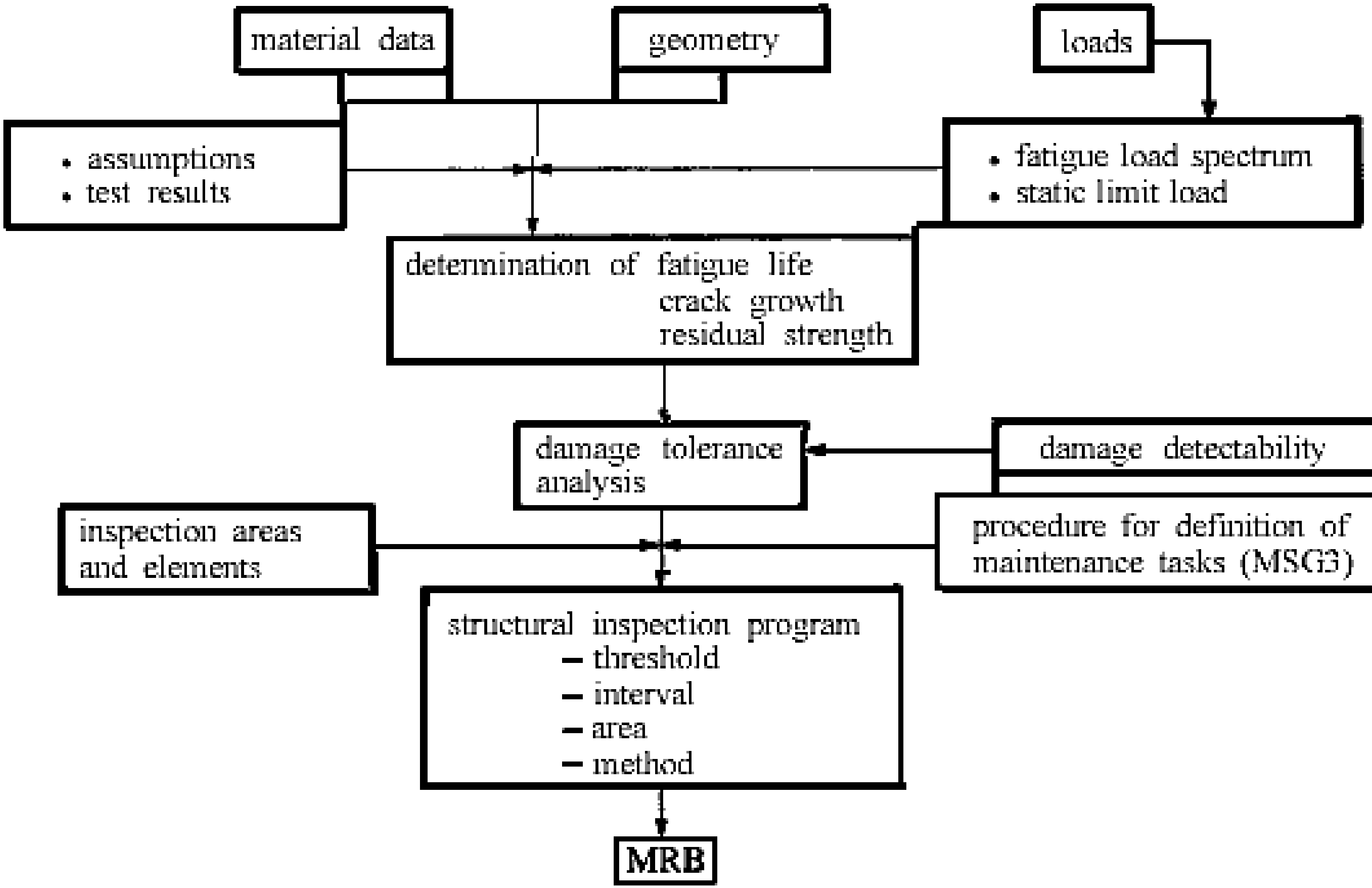
CAN WE EVALUATE FLAWS QUANTITATIVELY?
CAN WE CHARACTERIZE MATERIAL PROPERTIES?

THERE ARE MANY CHALLENGES
FOR YOUNG SCIENTISTS
&
PIONEERS

2.	Degradation of nuclear structures during operation
2.1.	**Aging, Neutron Embrittlement, Structural Material Parameters**
2.2.	Stress Corrosion Cracking
2.3.	Fatigue
2.4.	(Unexpected events)

2.	**Degradation of airplane structures during operation**
2.1.	**Fatigue Life (Endurance)**
2.2.	**Damage Tolerance Capability**
2.3.	**Corrosion Resistance**
2.4.	(Unexpected events)

Development of Structure Inspection Program



AGING AIRCRAFTS

DESIGN PRINCIPLE

- **Safe Life**
- **Damage Tolerant**
- **Fail Safe**

SPECIAL ISSUES

- **WFD**
  (Widespread Fatigue Damage)
- **RAR**
  (Risk Assessment of existing repairs)

NDT

Fail Safe Design

Fail safe design is an integral part of any design process. It ensures that the system being designed is both safe and reliable for the user, as well as being economically and environmentally sound.

Fail safe design is essentially the process we used to eliminate potential hazards to the system from the most common scenarios the system is likely to be exposed to in the location it will be in. Furthermore, design of the system had to account for the human factor using technology safely and effectively.

Fail safe design is sometimes a moral and/or ethical dilemma. Fail safe design can sometimes make a project cost more and some members may want to do away with expensive fail safe precautions. This can lead to exposure to risks and possibilities that could have been prevented.

PSU Pennsylvania State University

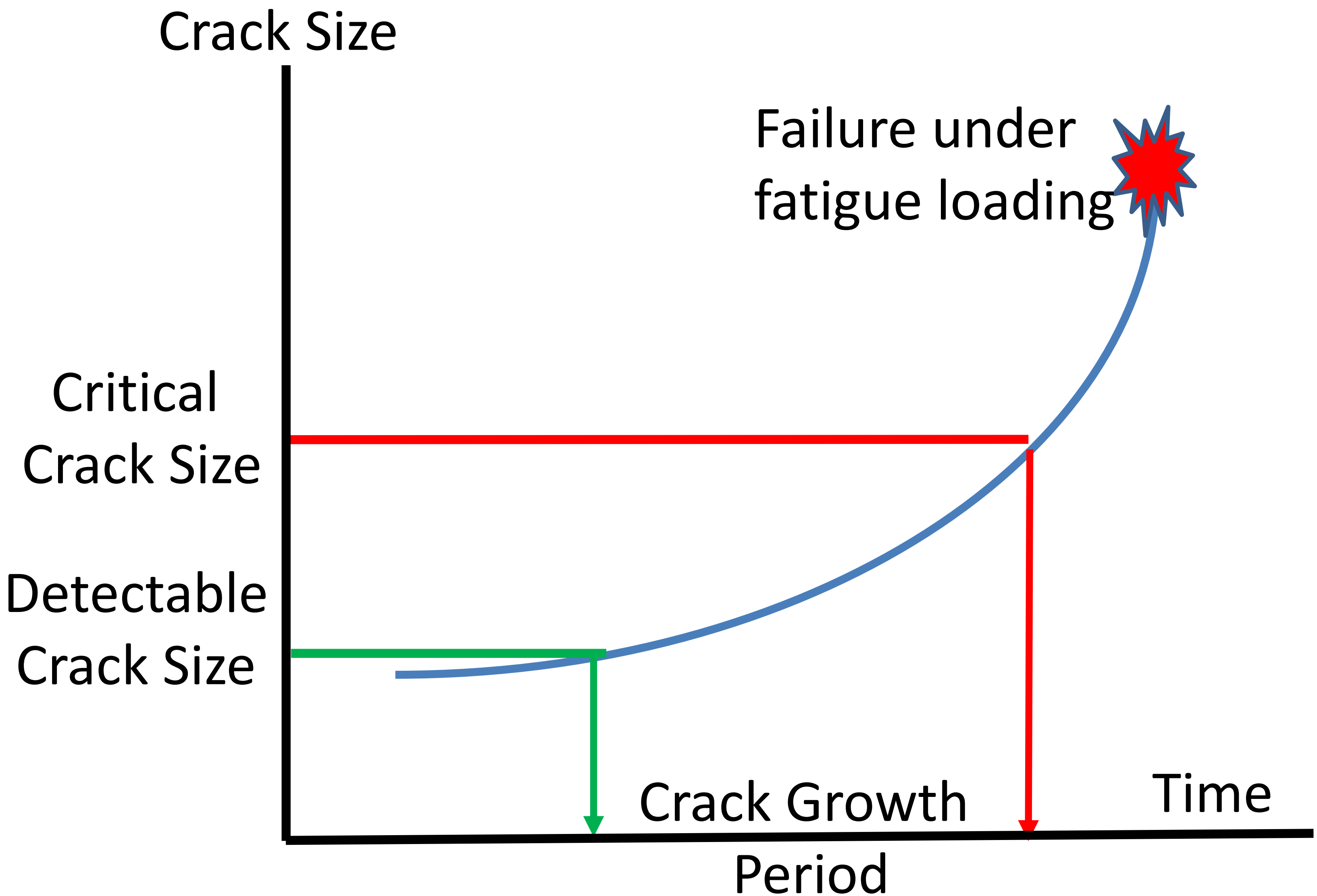
Aviation Glossary

Fail-Safe Design Concept

Fail-Safe Design Concept: Fundamental to the notion of safety-critical systems in certification is the fail-safe design concept, which "considers the effects of failures and combinations of failures in defining a safe design." The concept has a different meaning for structures than for systems: fail-safe for structures is concerned with residual strength after sustaining damage; fail-safe for systems is concerned with the functional implications of a failure condition and its probability of occurrence. Although both concepts have the same goal— a safe design—the approaches to achieving that goal are different.

Fail-safe for structures is governed by 14 CFR 25.571 and the methods of compliance are outlined in AC 25.571-1C. In general, the structural components of an airplane (such as the airframe and wings) are designed such that "an evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage, will be avoided throughout the operational life of the airplane." However, after the 1988 Aloha Airlines flight 243 accident, where 18 feet of the upper crown skin and structure separated from the fuselage, there has been a greater emphasis on damage tolerance. A damage tolerance evaluation of structure ensures that "should serious fatigue, corrosion, or accidental damage occur within the design service goal of the airplane, the remaining structure can withstand reasonable loads without failure or excessive structural deformation until the damage is detected."

Principle of damage tolerance investigation



Damage Tolerance Requirements

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Three major tasks:

- **Structural design according to fatigue and damage tolerance requirements**
- **Evaluation of the structure by analysis supported tests**
- **Definition of a structural inspection program**

Damage Tolerance Evaluation

"The ultimate purpose of the damage tolerance evaluation Is the development of a

recommended structural inspection program

considering

probable damage locations,
crack initiation mechanisms,
crack growth time histories,
and crack detectability"

Regulations and Recommendations

The (internationally) harmonized regulation and advisory circular require:

'An evaluation of the strength, detailed design, and fabrication must show that a catastrophic failure due to

fatigue,

corrosion,

or accidental damage,

will be avoided throughout the operational life of the airplane.'

Conclusion

Requirements for NDT
&
Application of NDT Procedures

Tests

CASE

State of Usage

Validation

Flaw
Detection

QNDT

Literature

H.J. Schmidt, B. Schmidt-Brandecker, G. Tober: *Design of Modern Aircraft Structure and the Role of NDI,* NDT.net, vol. 4 No. 6, 1999