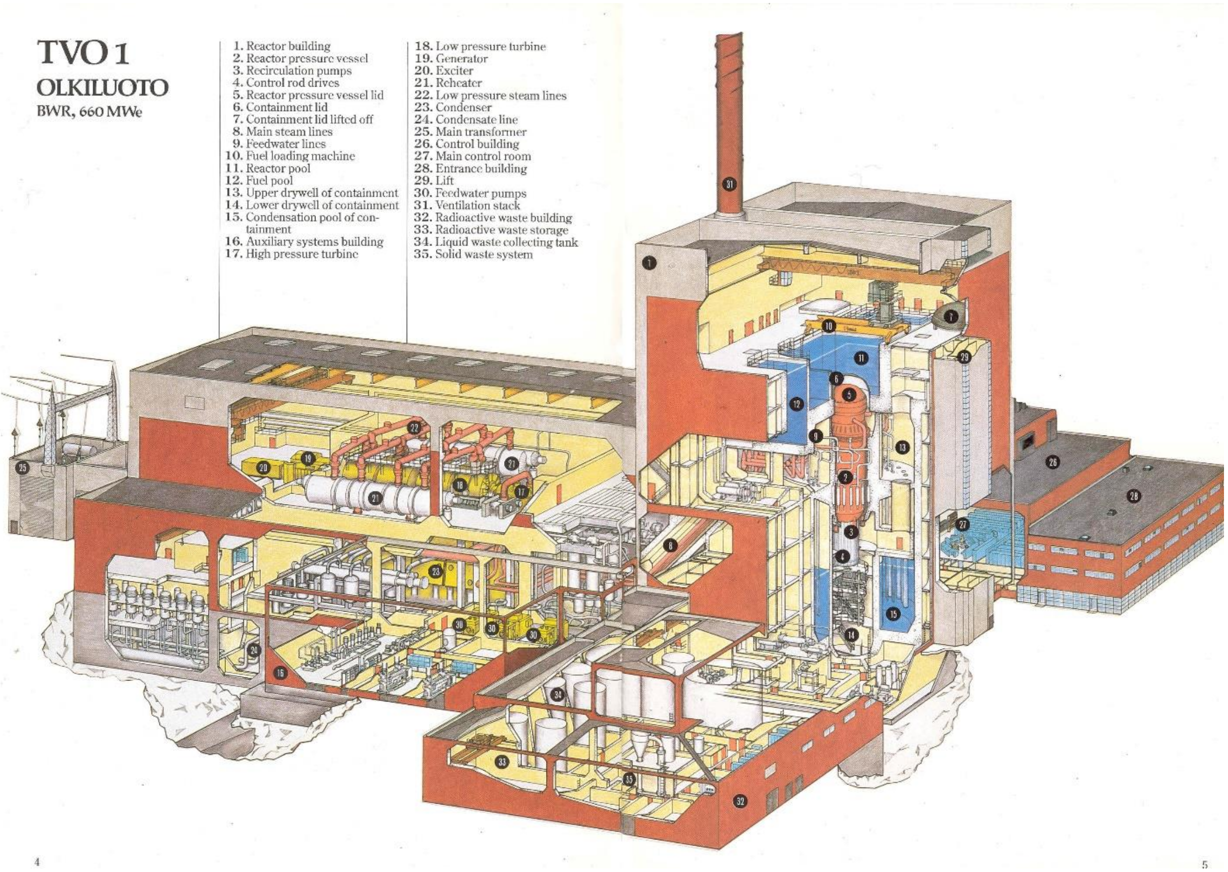
Compact Reactor Simulator- Exercises in Reactor Kinetics and Dynamics– 2023

Introduction

BACKGROUND

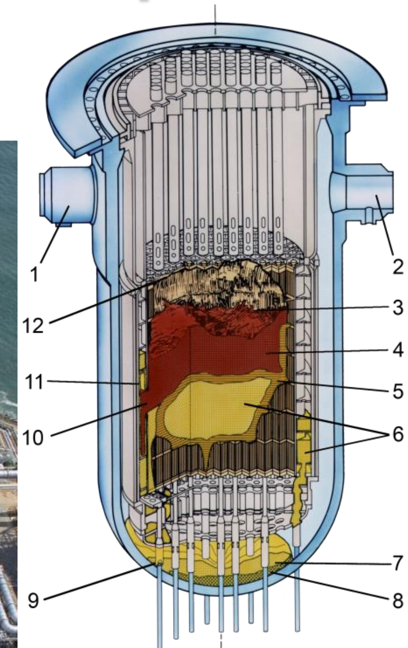


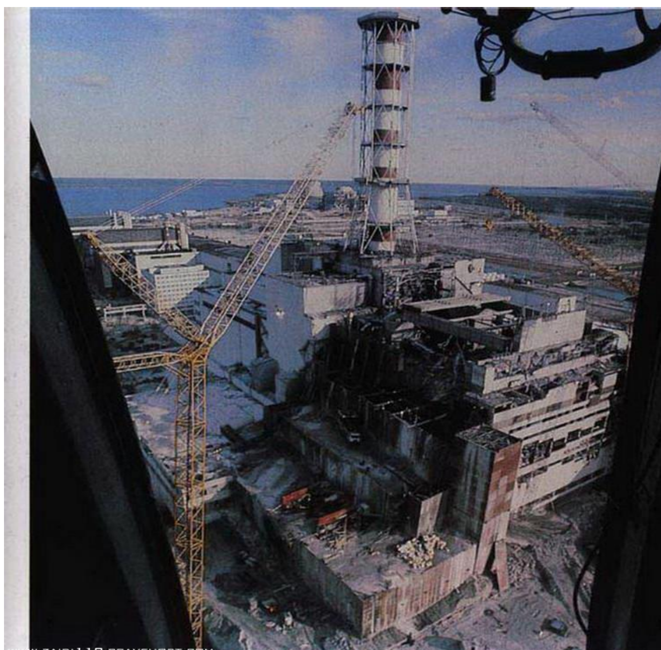
Nuclear reactor power plants are very complex systems that may go through various operation-state transitions (transients) during normal and accident situations. This course aimed as a preparation to understand the transients and explain their nature. The power plant simulations are based on Apros - the process simulation software for nuclear and thermal power plant applications.

Accidents has followed our technological advances hand in hand. It is unreasonable to expect a perfect technical performance

Accidents will always happen now and then.

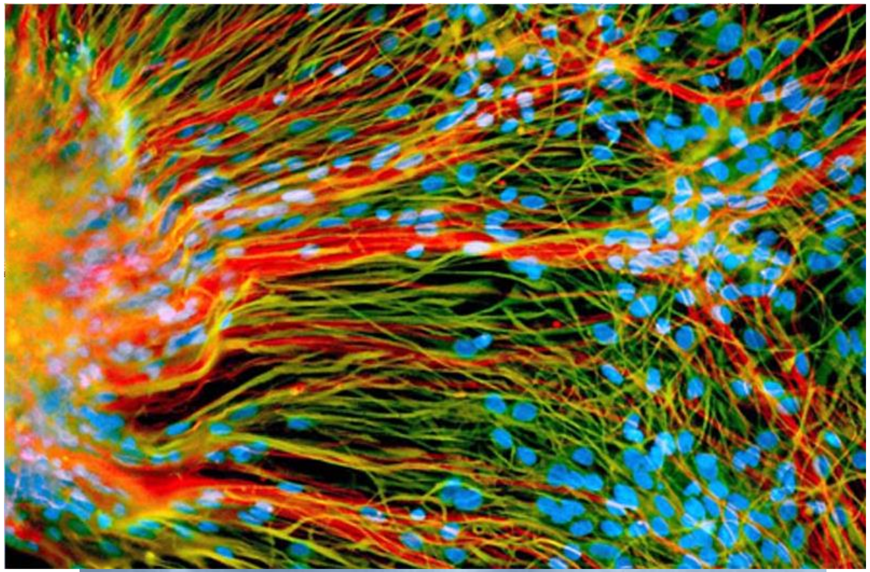
Accidents can have unfortunate consequences

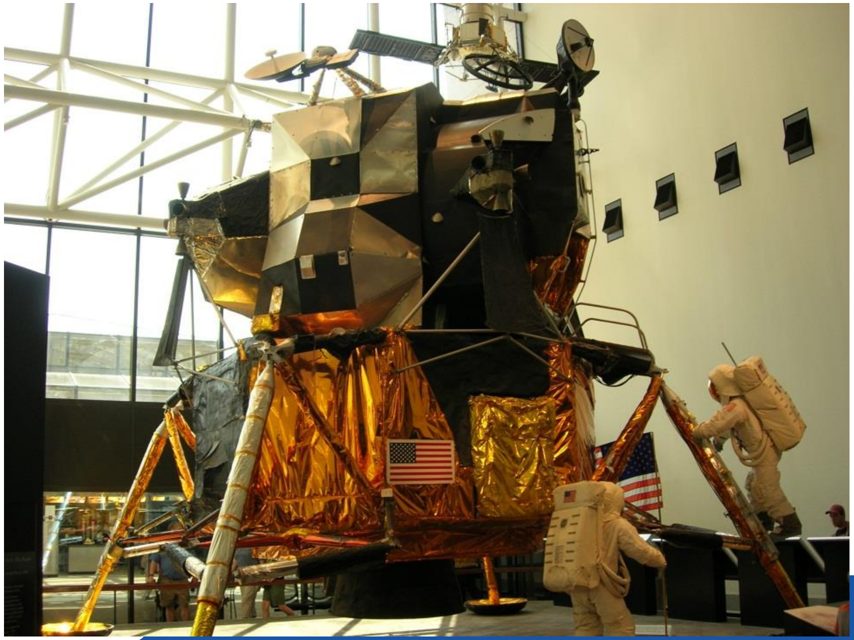




Some have larger consequences than others

We have seen an outstanding technological development through the years






New technology does not
remove failures


Our prediction of how
things will work might
be wrong


Not even future technology is of any
help

Left to Right: William McMaster Murdoch, Charles A. Bartlett, Henry Tingle Wilde and Captain Edward John Smith


THE SAFEST SHIP
EVER BUILT

Revenue of the movie > G$2.2


Proudly presents the
Luxuries way to travel

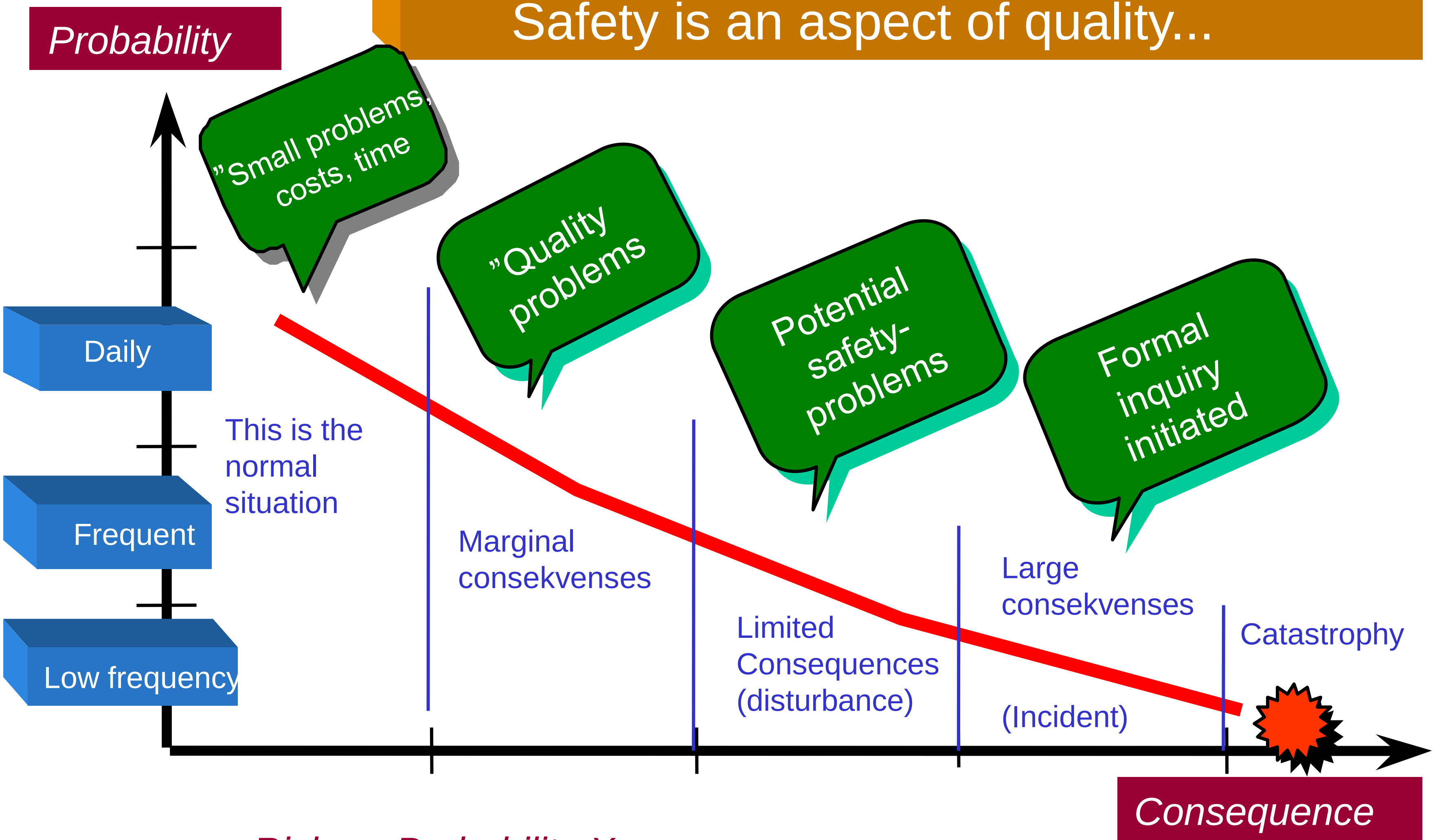
Risk = ∑ Probability * Consequence

Cause and effect

What if…

© Dédale 2002

Safety is an aspect of quality...

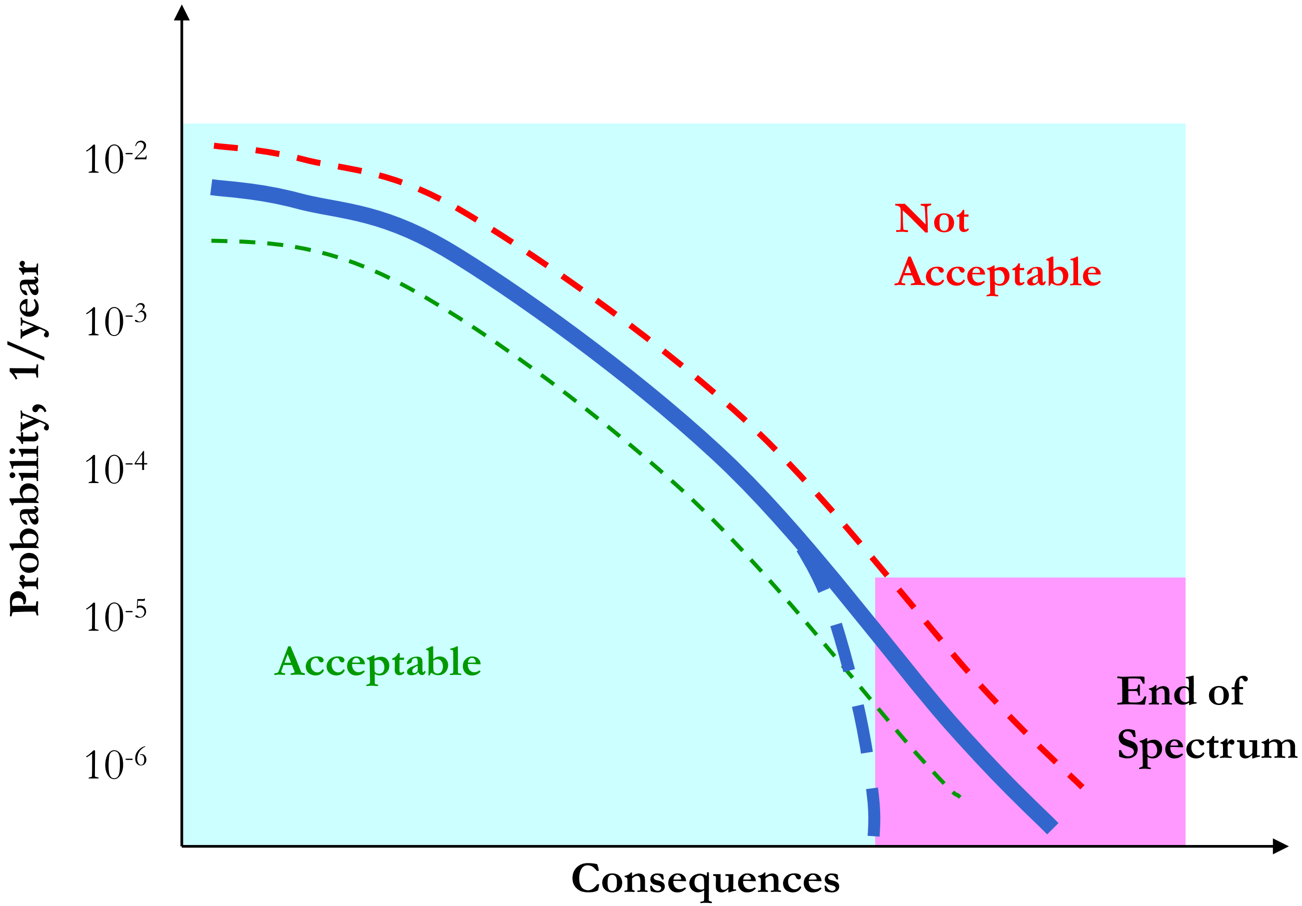


Risk = Probability X consequence

FÖRSVARSMAKTEN

Militära flyginspektionen

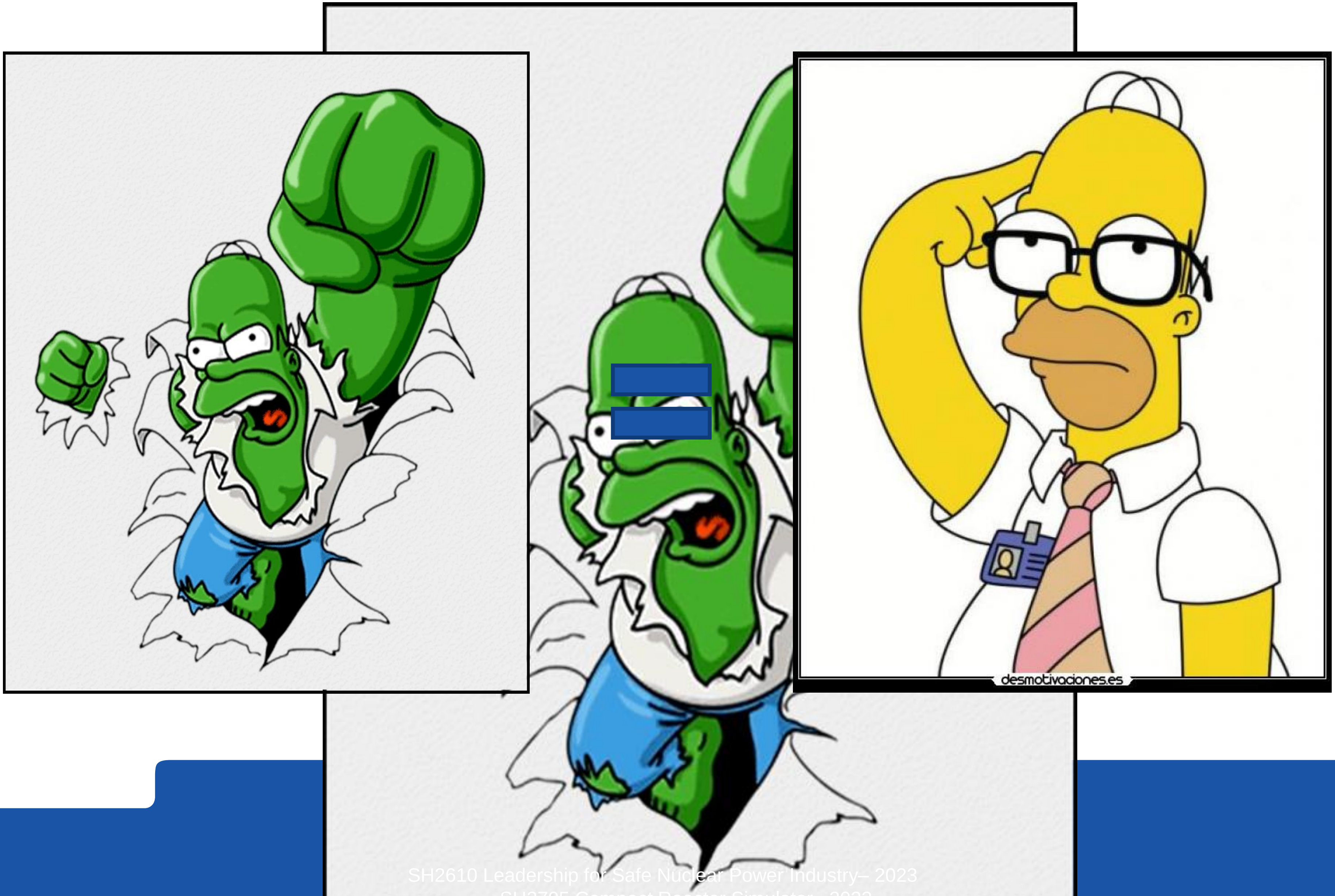
Risk space

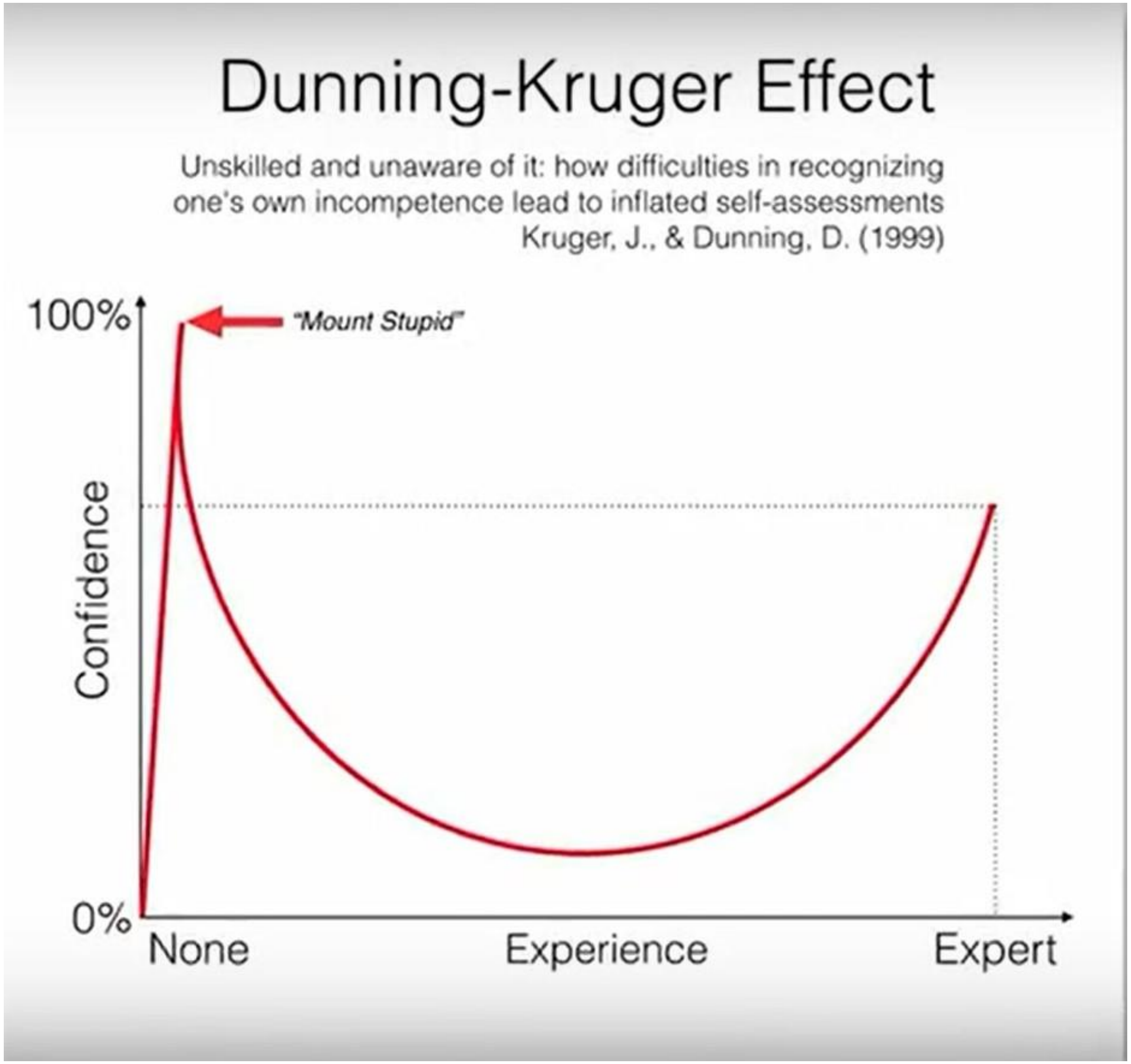


Farmer curve, 1967


I DO ALL THE WORK!

HERO !!!




Dunning-Kruger Effect
Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments
Kruger, J., & Dunning, D. (1999)
100%
"Mount Stupid"
Confidence
0%
None
Experience
Expert

OBJECTIVES

After the course, students will be able to:

- describe various design bases and beyond design bases accidents,
- explain the behavior of the nuclear reactor and the power plant during normal operation and the transients,
- explain the effect of various TH and Neutron-kinetic feedbacks in the nuclear reactor and the power plant during the transients,
- recognize a complex transient and take appropriate action.

COURSE STRUCTURE, APROS TRAINING

- self-study of recommended literature,
  - IAEA Documents Relevant to Safety Analysis Applications
  - Native countries regulatory body
- getting familiar with APROS,
  - Introduction
  - Training material from FORTUM /VTT
- the group project work,
  - All exercises
  - Project work
- consultations with teachers.

Time line for the course

- Each group will turn in a theoretical report about different concepts in nuclear power safety before the first seminar.
- Results of excersies and project work are presented during the first seminar to receive feedbacks.
- Each group will turn in a report about excersies and project work before the final presentation
- The final presentation is presented at the 2:nd seminar during which each students shall also answer to questions regarding the theoretical part.
- See the examination instructions on the canvas!

THEORETICAL PART, NUCLEAR SAFETY CONCEPTS

- Explain how an event (see next slide) has started and progressed considering the nuclear safety concepts and how safety analysis should have been performed to help the operators to identify the problem and preventing it from happening. The following concepts must be considered:
  - Safety Objectives
  - Operational and accident conditions
  - Defense in depth
  - Safety assessments
  - Safety analysis
  - Deterministic safety analysis
    - Conservative analysis
    - Best Estimate analysis
  - Probabilistic Safety analysis
  - Acceptance criteria
  - Computer codes
  - Verification and validation of computer codes

EXAMPLE of EVENTS in SWEDEN

- Barsebäck, 1992, Plugging of strainers incident
- Oskarshamn-3, 1998, Stability event
- Oskarshamn-2, 1999, Stability event
- Forsmark 1, 2006 event
- 86-14, Control rod cracking event

Grading requirements

Grade	Theoretical Part	Simulation Part
A	To comprehensively and in detailed describe: - Correctly all of the concepts discussed during the course and explain their relevance to the example event	To perform all of the exercises: - Flawlessly, with all of the corrections and changes needed in the input - Choose and present the plots in a comprehensive way expected from a safety engineer.
B	To comprehensively describe: - Correctly all of the concepts discussed during the course and explain their relevance to the example event	To perform all of the exercises: - With all of the corrections and changes needed in the input - Choose and present the plots in a comprehensive way
C	To describe: - Correctly all of the concepts discussed during the course and explain their relevance to the example event	To perform all of the exercises: - With most of the correction and changes needed in the input - Choose and present the plots in a comprehensive way
D	To describe: - Correctly Most of the concepts discussed during the course and roughly explain relevance to the example event	To perform all of the exercises: - With most of the correction and changes needed in the input - Present the plots in a adequate way
E	To describe: - Some of the concepts discussed during the course correctly and roughly explain relevance to the example event	To perform all of the exercises: - With some of the correction and changes needed in the input - Present the plots in a adequate way
F	Do Not fulfil the above requirements	Do Not fulfil the above requirements

Simulation Part

Exercises

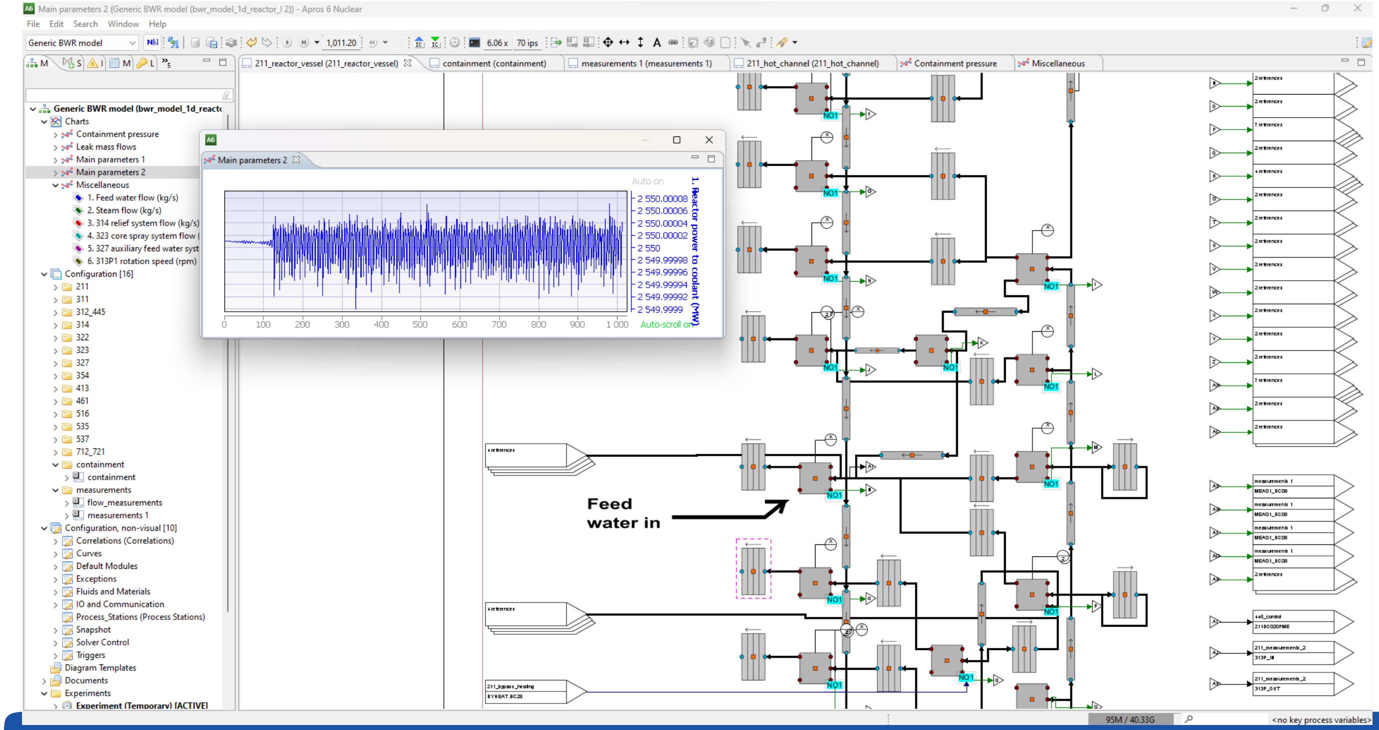
1. Pressure transient (with scram (multiple delays) /without scram);
2. Steam line break transient;
3. Feed water line break transient;
4. Feed water pump trip transient;
5. Feed water enthalpy decrease (temperature) transient;
6. Reactor power decrease transient;
7. Reactor scram transient

Project work

- choose one of the exercises to study in-depth, increase the severity of the exercise-event by increasing its complexity and describe how you did it, what happened and why.

ADVANCED SIMULATION SOFTWARE FOR MULTIPLE PURPOSES

APROS is a tool that claims to be excellent for everything from safety analyses of fast transients at nuclear power plants and operator training at conventional power plants to research and development by universities and research institutes.

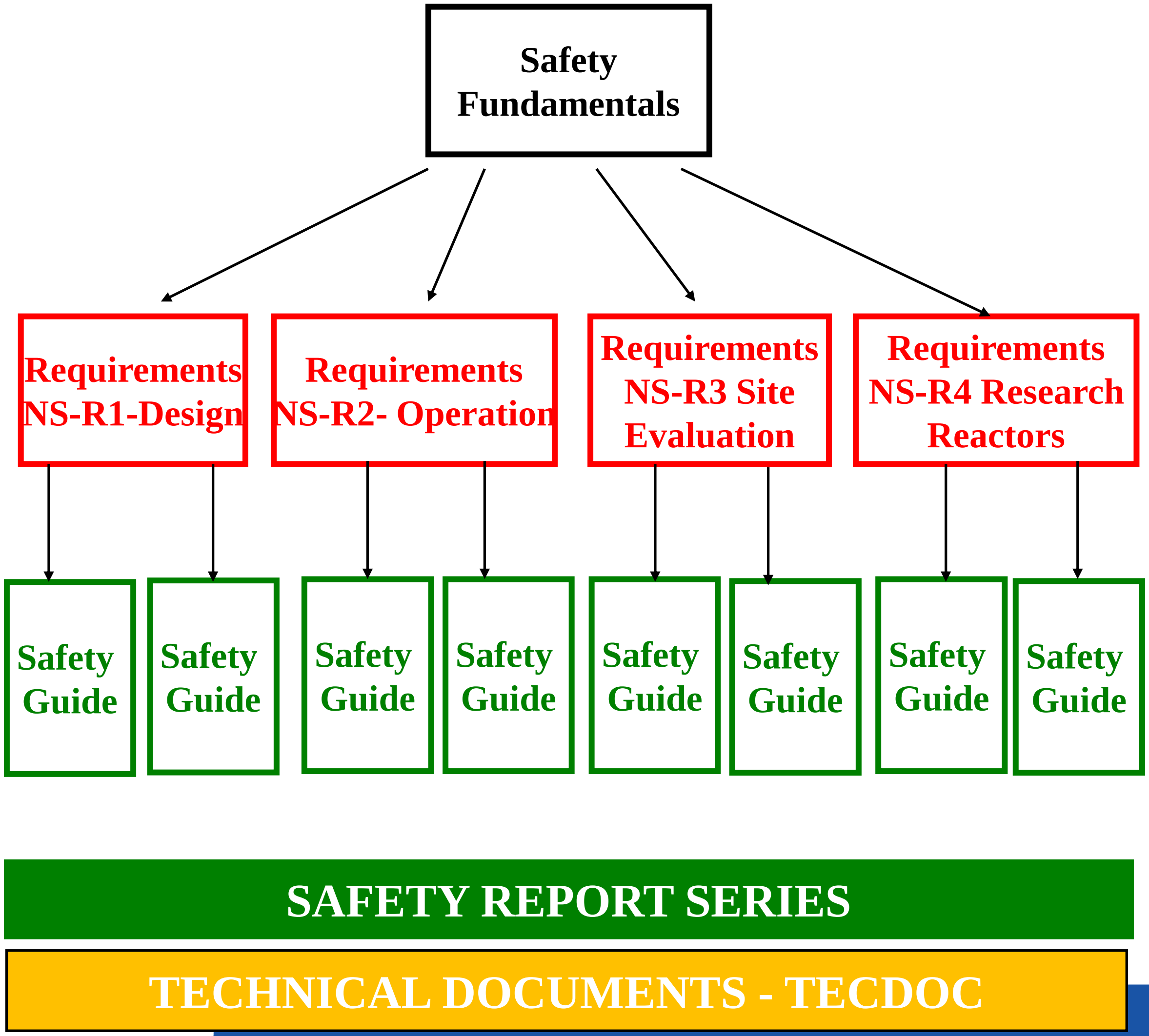


Self-study

IAEA Documents Relevant to Safety Analysis Applications

- Safety Standards Series publications are categorized into:
  - Safety Fundamental (F; blue lettering)
  - Safety Requirements (R; red lettering)
  - Safety Guides (G; green lettering)

HIERARCHY OF IAEA SAFETY STANDARDS SERIES



Present the overall objectives, concepts and principles of protection and safety. They are the policy documents of the safety standards

Establish requirements that must be met to ensure the protection and safety of people and the environment, both now and in the future

Provide guidance, in the form of more detailed actions, conditions or procedures that can be used to comply with the Requirements

Practical examples and detailed methods for the application of the Safety Standards. Detailed Technical Reports

I. SAFETY STANDARDS

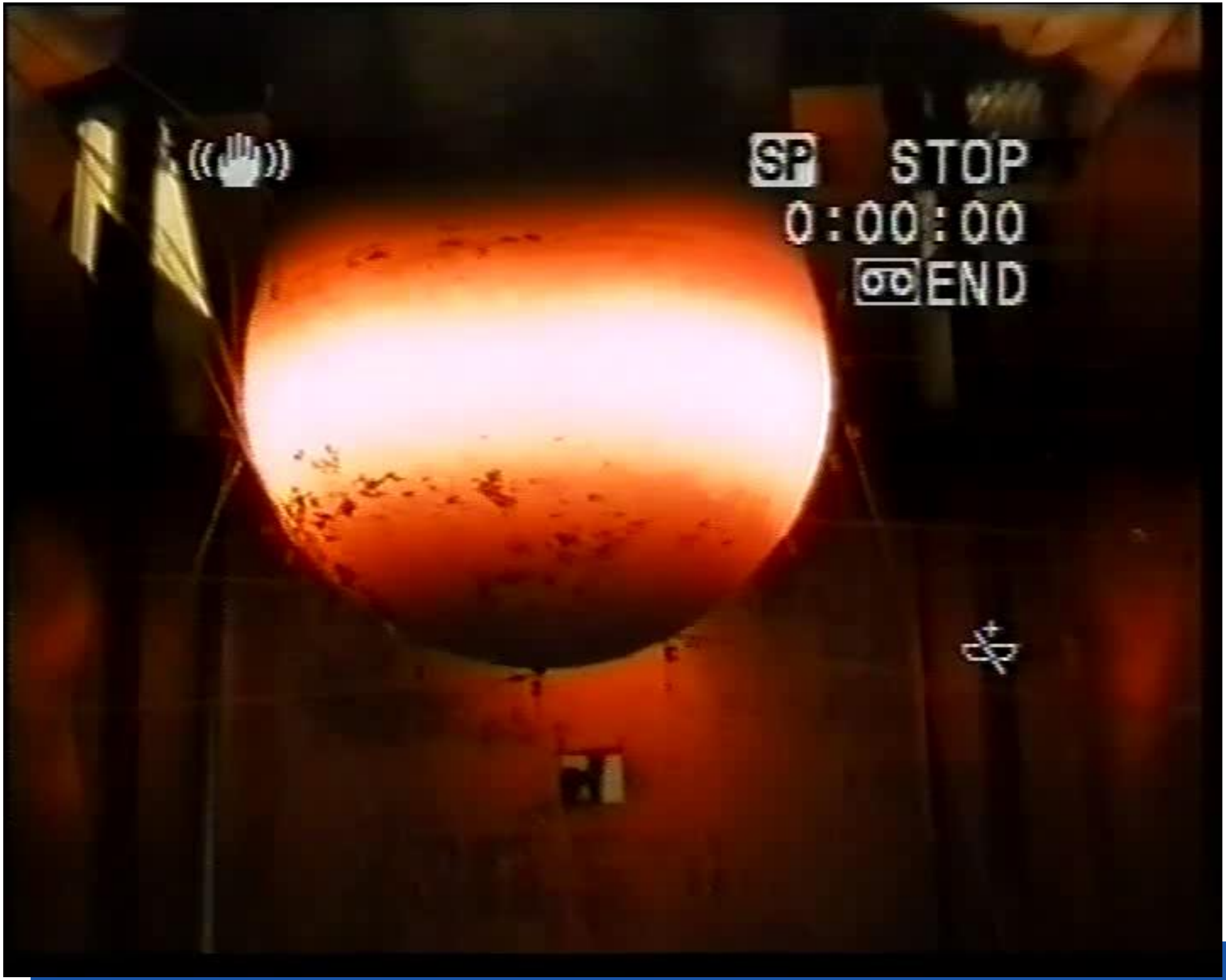
- General Safety Requirement: GSR Part 4 Safety Assessment for Facilities and Activities
- Draft Safety Guide DS 395 Deterministic Safety Analysis for Nuclear Power Plants
- Safety Guide NS-G-2.15 Severe Accident Management Programmes for Nuclear Power Plants
- Safety Guide NS-G-1.10 Design of Reactor Containment Systems for Nuclear Power Plants

II. SAFETY REPORT SERIES (SRS)

- SRS No. 23 Accident Analysis for NPPs
- SRS No. 29 Accident Analysis for NPPs with Pressurized Heavy Water Reactors
- SRS No. 30 Accident Analysis for NPPs with Pressurized Water Reactors
- SRS No. 32 Implementation of Accident Management Programs in NPPs
- SRS No. 43 Accident Analysis for NPPs with Graphite Moderated Boiling Water RBMK Reactors
- SRS No. 48 Development and Review of Plant Specific Emergency Operating Procedures
- SRS No. 52 Best Estimate Safety Analysis for NPPs: Uncertainty Evaluation

III. TECDOCs

- IAEA TECDOC - 1332 Safety Margins of Operating Reactors; Analysis of Uncertainties and Implications for Decision Making
- IAEA TECDOC - 1351 Incorporation of Advanced Accident Analysis Methodology into Safety Analysis Reports
- IAEA TECDOC - 1352 Application of Simulation Techniques for Accident Management Training in NPPs
- IAEA TECDOC - 1379 Use of Computational Fluid Dynamics Codes for Safety Analysis of Nuclear Reactor Systems
- IAEA TECDOC - 1418 Implications of Power Uprates on Safety Margins of NPPs
- IAEA TECDOC - 1440 Overview of Training Meth. for Accident Management at NPPs
- IAEA TECDOC - 1539 Use and Development of Coupled Computer Codes for the Analysis of Accidents at NPPs
- IAEA TECDOC - 1550 Deterministic Analysis of Operational Events in NPPs
- IAEA TECDOC - 1578 Computational Analysis of the Behaviour of Nuclear Fuel Under Steady State, Transient and Accident Conditions
- IAEA TECDOC - 1594 Analysis of Severe Accidents in Pressurized Heavy Water Reactors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