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Lappeenranta University of Technology

Nordic ”tsunamis”, defence-in-depth strengths and deficiencies

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Outline

- Earthquakes and tsunamis – an extended interpretation
- On Defence-in-Depth design
- Five events that changed the perception of Defence-in-Depth:
  - Ågesta flooding in 1969
  - Barsebäck ECCS strainer clogging in 1992
  - WTC terrorist attacks in 2001
  - Forsmark electrical disturbance in 2006
  - Fukushima meltdown in 2011
- Conclusions

Earthquakes and tsunamis

An **earthquake** shakes the very ground one stands on, shattering structures physically

A mental earthquake **overturns** strongly held **beliefs**

Both are scary events, **shocks**.

A physical **tsunami** is a flood wave that follows an earthquake and swamps or carries away everything exposed

A mental earthquake is always followed by a **flood of activities**, an action tsunami, “to address this grave issue”

…but how to get the best value for money – safety and availability of the plants – for all the effort spent?

On Defence-in-Depth engineering

Defence-in-Depth barriers – both physical and functional - have to be engineered to withstand dimensioning loads

Safety assessment requires knowledge of all three.

- Confidence in design arises out of knowledge of each factor, including respective uncertainties!

When a new threat emerges**, where should the flood of activity be directed, among loads, barriers, mitigation?**

Ågesta flooding in 1969

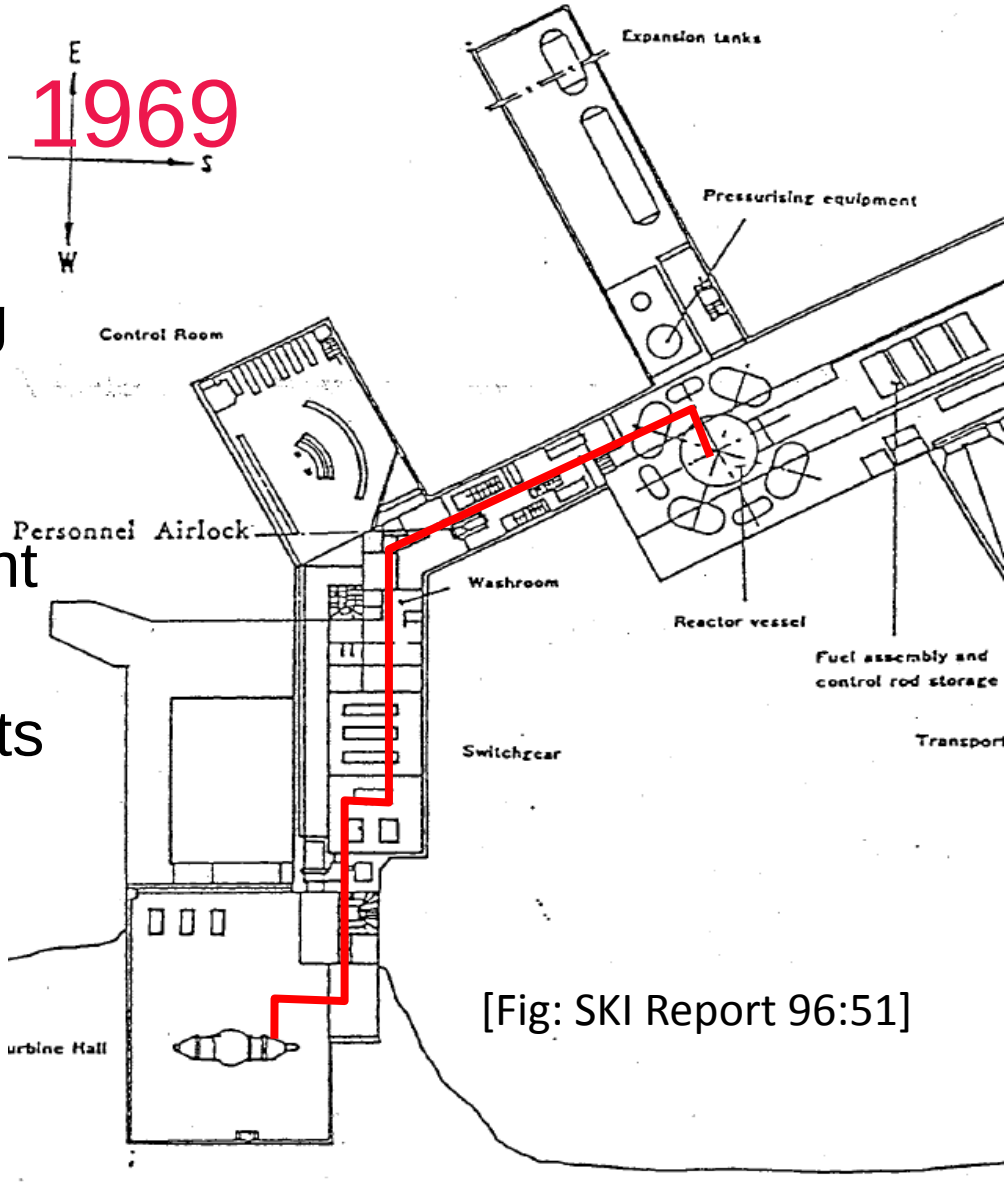
Leak in process → flooding of rooms (**internal hazard**)

→ flooding of electrical equipment; e.g. loss of plant indicators for ~30 minutes

→ New design requirements

- Redundancy
- Physical separation of safety systems
- 30-minute rule

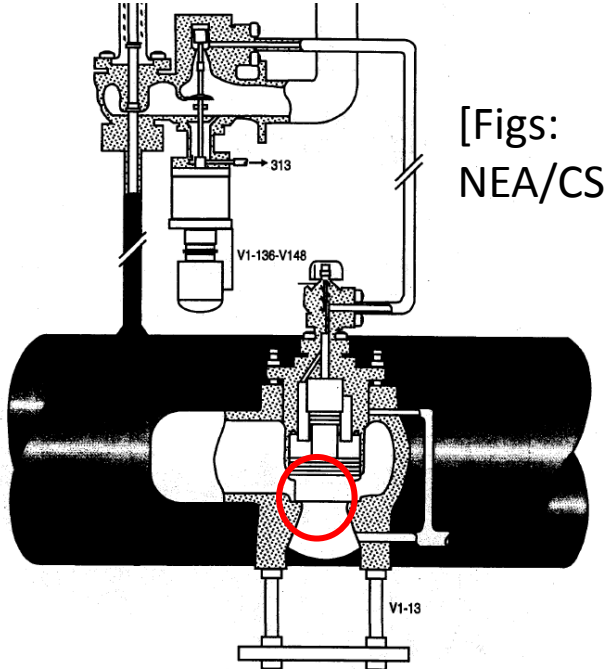
A GOOD SHOCK



[Fig: SKI Report 96:51]

Barsebäck strainer clogging event, 1992

[Figs: NEA/CSNI/R(95)11]



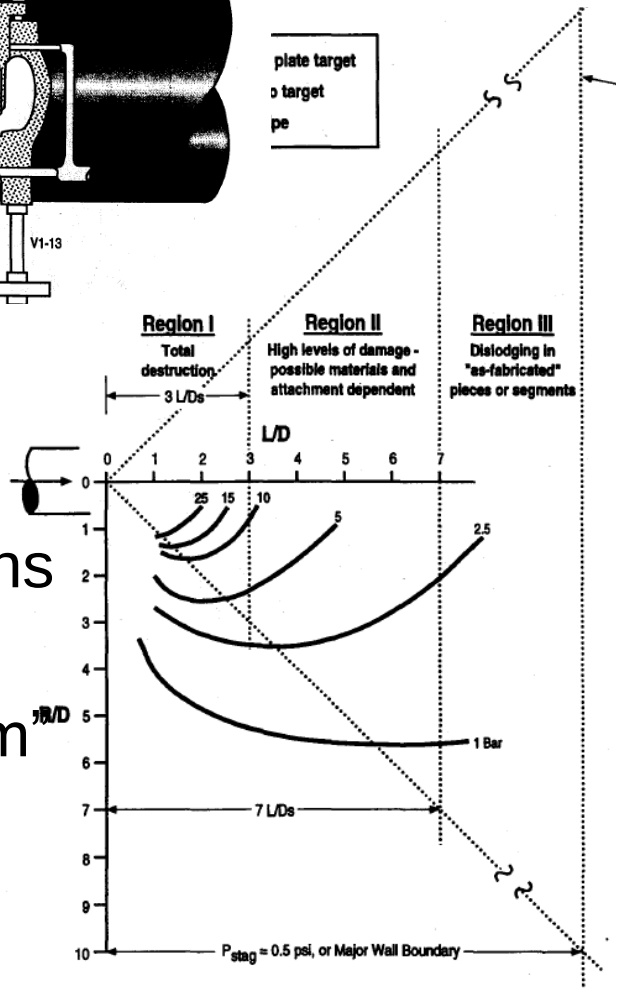
Relief valve opening at ~30 bar → thermal insulation damage → **common-mode safety system failure** much sooner than designed

→ 6+ month shutdown of 5 Swedish reactors, major R&D, backfitting

→ Years of global revision of ECCS designs

Insulation behaviour in accidents is a typical inherent issue, “a nobody’s problem”

A NECESSARY SHOCK



9/11: WTC terrorist attacks in 2001

An **external** and **malevolent** event

→ focus on security upgrades on nuclear power plants

Massive new requirements

- large airplane crash for nuclear new builds; extra cost
- multitude of new security hardware and operational upgrades at old plants – significant extra cost

A SHOCK OUT OF PROPORTION?

[yournewswire.com; Photo by Masatomo Kuriya/Corbis Sygma]

[okg.se]

Forsmark overvoltage transient in 2006

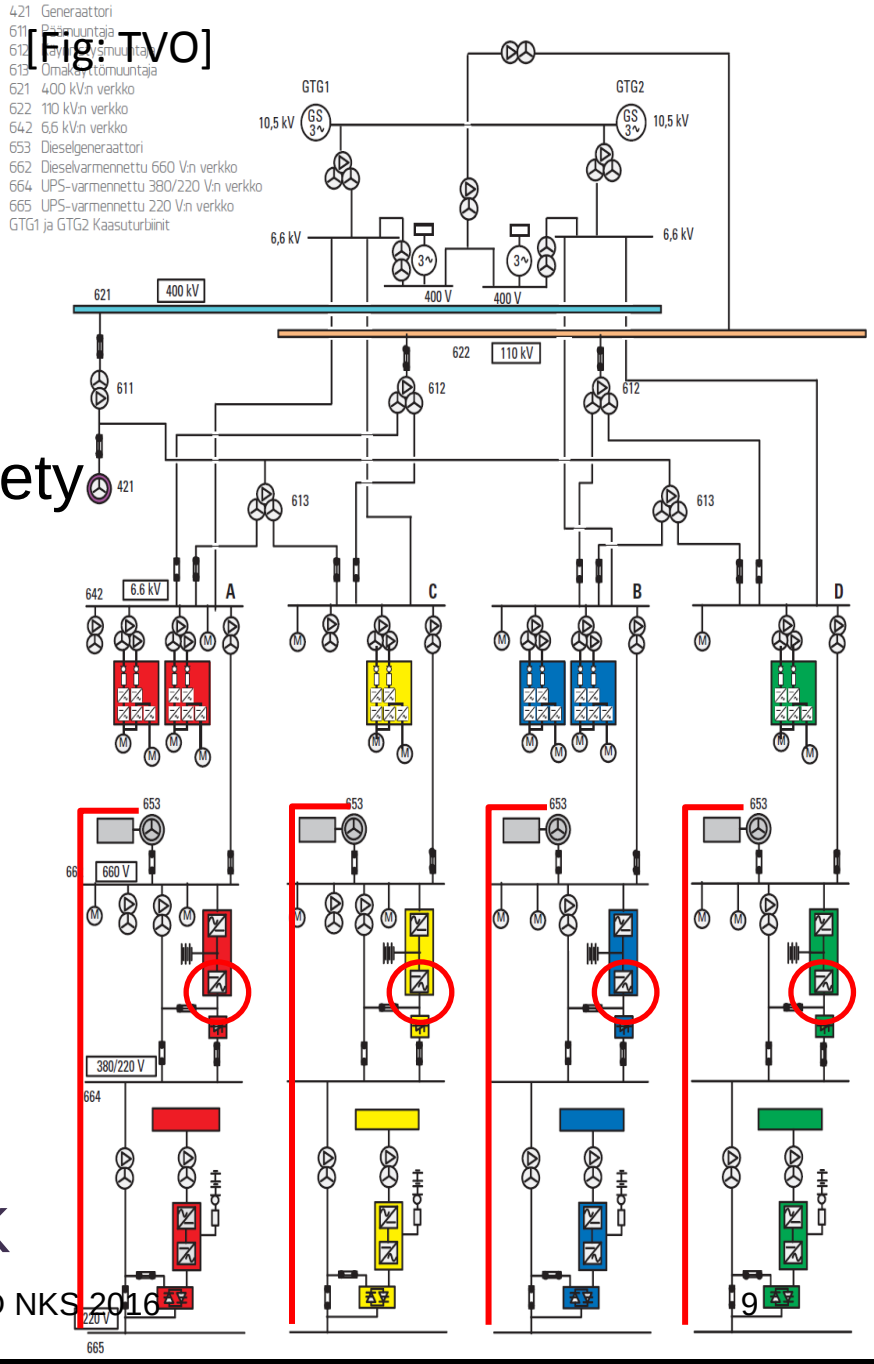
Ground fault at switchyard → voltage transient **through the whole plant** → loss of half of safety systems

Raised awareness of electrical system sensitivities; e.g. modern equipment **fails with different modes** than the old

- Reassessment of DID in electrical power systems
- Some very challenging new design requirements in YVLs

ANOTHER REVEALING SHOCK

[Fig. TVO]



Fukushima Dai-Ichi meltdowns in 2011

A major **natural external event**

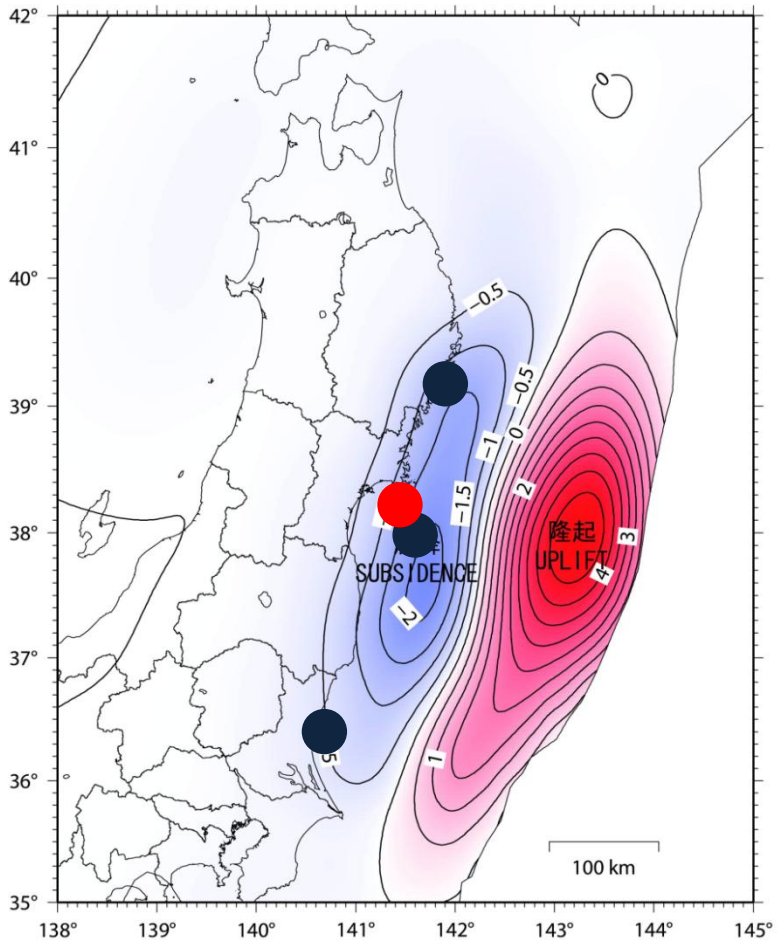
Fundamentally, this accident was a result of a **community mindset,** thinking it was safe enough (and safer than anyone else)

→ EU Stress tests, upgrade reqs

→ Attention to site design basis

- extreme requirements on earthquake definition (→10^{-7}/a return period) in Finland

AN ORGANISATIONAL SHOCK



[Fig: Geospatial information authority of Japan]

Japanese characterisation of the causes of the Fukushima Dai-Ichi accident

*"Our report catalogues a **multitude of errors** and **willful negligence** that left the Fukushima plant unprepared for the events of March 11. And it examines **serious deficiencies in the response** to the accident **by TEPCO, regulators and the government.**"*

[Report of the Fukushima Nuclear Accident Independent Investigation Commission, The National Diet of Japan, 2012; https://www.nirs.org/fukushima/naiic_report.pdf]

Kiyoshi Kurokawa, Chairman of the NAIIC

Conclusions

Shocking events, revelations, recur again and again.

Biggest **technical** safety **issues** tend to be found in areas that are

- mundane, like thermal insulation, or electrical power
- interdisciplinary… up to being nobody's business

Human and **organisatorial** safety **issues** affect whole communities, not just individuals, teams, or companies

Is safety research addressing these things?

Are upgrade **requirements in due proportion** to the threats?
Are load-barrier-mitigation considerations in balance?

Safety rests on the **understanding** of phenomena and their interactions.

Thank you!

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