Current Issues in Nuclear Safety Regulation

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An agency of HSE

Introduction

Predominant issue is the nuclear accident at Fukushima Daiichi

- why did it happen?
- what are the implications for standards?
- what does it mean for harmonisation?
- lessons for nuclear regulators
- implications for new nuclear build

Context

Major nuclear accident at Fukushima Daiichi on 11 March 2011

Safety cases are meant to identify hazards & means to control them

Japan is an advanced society with a long-established nuclear power programme

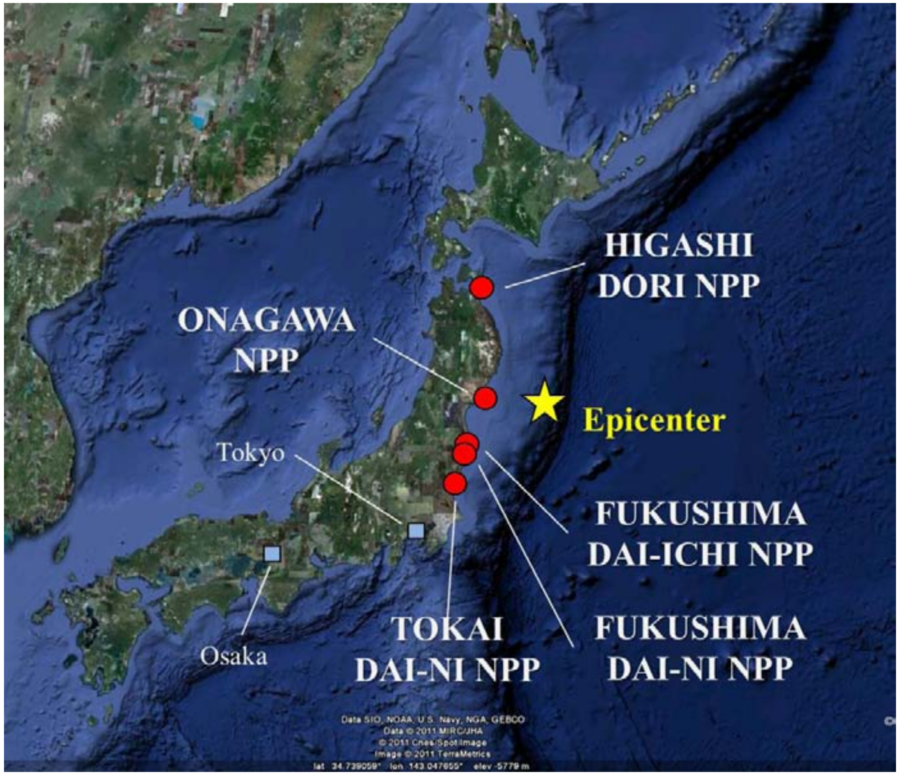
So why did the accident happen?

Fukushima Daiichi Site Layout

Fukushima Accident – The Great East Japan earthquake

11 March 2011

- Magnitude 9 earthquake
- Subsequent tsunami
- Around 20,000 dead or missing
- ~ 14m high at Fukushima Daiichi



Immediate Consequences

Off-site:

- Unprecedented devastation
- Impaired infrastructure

On-site:

- Loss of all external electrical power
- Only 1 Emergency Diesel Generator was operable out of 13

The Fukushima event

Tsunami hits the turbine buildings

The Fukushima event

Tsunami inundates the site

The Fukushima event

Tsunami inundates the site

Power of Tsunami

Plant Status

All 6 reactors were BWRs, but with different powers and designs

They had entered service between 1971 and 1979

Units 1 to 3 were operating at full power at the time

Units 4 to 6 had been shutdown for between 2 and 7 months

Units 5 and 6 were fuelled, all of the fuel from Unit 4 had been discharged into the Unit’s spent fuel pool

Effect of Earthquake

Loss of all external power

Operating reactors were ‘scrammed’

Post-trip cooling started

No major damage to safety-critical structures, systems & components reported

Consequences for Reactor Cooling

All the reactors had emergency cooling systems that did not rely upon AC power to drive flows

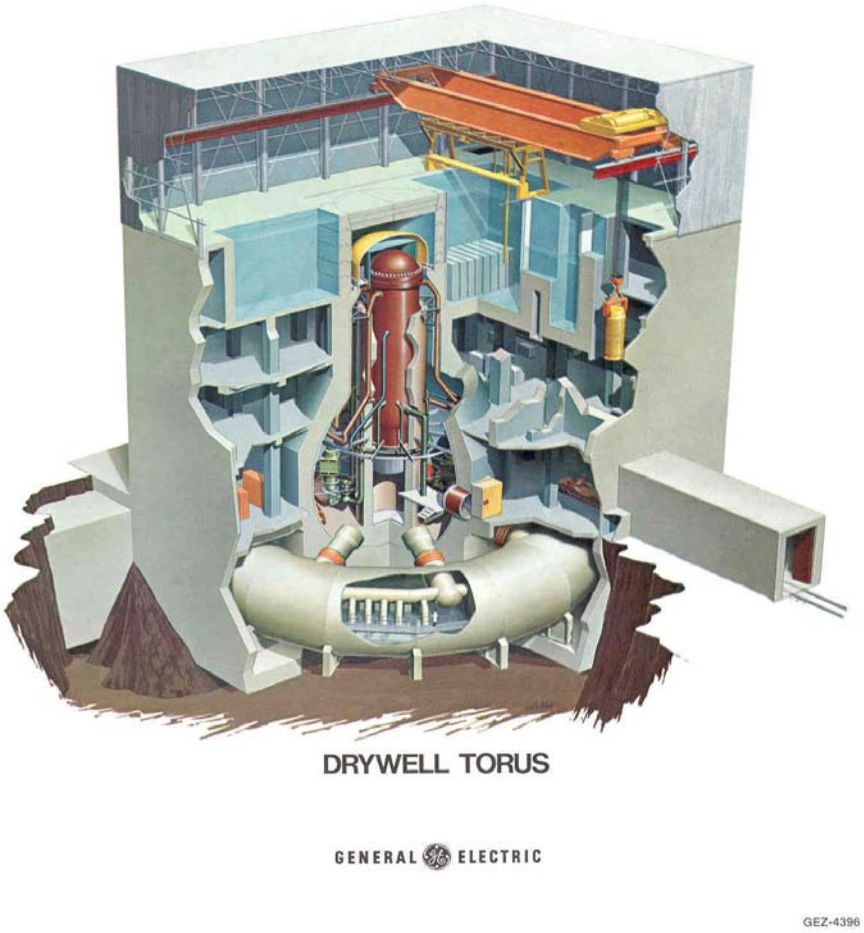
- Unit 1 had an Isolation Condenser, which transferred decay heat to water in a tank
- Units 2 – 6 had steam turbine-driven Reactor Core Isolation Cooling systems for injecting water into the reactors

Ultimately those for Units 1 – 3 failed

Consequences over following days

Cooling & water injection to reactors and spent fuel pools was lost

Boiling water and pressure relief from reactor raised primary containment vessel (PCV) pressures



Reactor Core Degradation

Reactor water levels fell below top of fuel

Once uncovered, fuel temperatures rapidly increased

Zircalloy fuel cladding reacted with steam forming hydrogen

Fuel at top of core could have started melting while fuel at bottom remained intact under water

Severe Accident Progression

Non-condensable gas further increased PCV pressure

Operators tried to vent PCVs

Fuel melted and relocated under gravity to lower reactor pressure vessel heads

Hydrogen escaped into reactor buildings and exploded

Predicted timeline: Units 1 - 3

	Reactor 1	Reactor 2	Reactor 3
Operating status	Nominal full power	Nominal full power	Nominal full power
Fuel condition	Uncovered from ~1700 on 11/3/11, melted & relocated shortly afterwards	Uncovered from ~1800 on 14/3/11, melted & relocated shortly afterwards	Uncovered from ~0800 on 13/3/11, melted & relocated shortly afterwards
Current fuel location	Relocated to lower RPV head, possibly some in dry well underneath	Relocated to lower RPV head, possibly some in dry well underneath	Relocated to lower RPV head, possibly some in dry well underneath
Lower PRV head condition	Believed to be damaged, primary coolant appears to have leaked through lower head	Believed to be damaged, primary coolant appears to have leaked through lower head	Believed to be damaged, primary coolant appears to have leaked through lower head
Primary containment vessel (PCV) and venting	Wet-well venting from 1430 on 12/3/11. Explosion seen at top of reactor building 1536 same day	Wet-well venting from 1100 on 13/3/11. Explosion heard at 0600 next day, believed to be in vicinity of pressure suppression pool	Wet-well venting from 0520 on 14/3/11. Explosion seen at top of reactor building 1101 same day

Loss of cooling – loss of containment

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Radiological Source Terms

NISA estimated source term from JNES accident calculations

NSC estimated it from JAEA back-calculations from environmental monitoring

These agreed on 1 – 2 x 10^{17} Bq of I-131 and 1 – 2 x 10^{16} Bq of Cs-137, i.e. ~ 10% of Chernobyl

On this basis, the INES rating was increased to Level 7 on 12 April.

Why did the accident happen?

Fukushima Daiichi was not adequately protected against the natural hazards that struck

These were foreseeable – historical records of larger tsunamis striking East coast of Japan

Original site safety case identified tsunamis as a threat –regulator accepted design height of only 3.1 m

Operator increased this to 5.7 m after 2002, but appears to have only implemented improvements on Unit 6

Design Basis

Plant is only designed to be robust against events identified in its Design Basis

Japanese NSC Regulatory Guide sets out the ‘anticipated operational occurrences’ and ‘accidents’ that must be analysed

Only a single failure of a safety system or component within it needs to be assumed following the initiating event

Design Basis for Tsunamis

Total loss of AC power and loss of ultimate heat sink were not design basis events

Japanese Government report stated:

- a trial tsunami PSA “indicated that the risk sensitivity of an event in which simultaneous functional losses of all the seawater pumps are generated due to tsunami was high”
- “compared with the design against earthquake, the design against tsunamis has been performed based on tsunami folklore and indelible traces of tsunamis, not on adequate consideration of the recurrence of large-scale earthquakes in relation to a safety goal …”

Prompts the questions

- why was the design basis constrained?
- were relevant safety standards adequate?
- were they acted upon?
- was the age of the plant a factor?
- why was new information not acted upon?
- what was the role of the regulators?

Not technical, rather concerned with human performance and organisational factors

Approaches to Safety Regulation

Common aim: to ensure operators properly control nuclear hazards and manage risk

Many regulators set out rules telling operators how to do this – a ‘prescriptive’ approach

UK instead has a ‘goal-setting’ approach, which makes it a legal duty to meet the safety goals, but does not set out in detail how operators should met this duty to “reduce the risk to workers and the public so far as is reasonably practicable”

Advantages of Goal-setting Approach

- operators are free to chose the most appropriate means of meeting the safety objectives, provided they can convince the regulator
- regulatory system is ‘technology neutral’
- operators must respond to advances in technology and new information without waiting for new rules
- the burden of demonstrating safety rests on the operators, reducing the regulator’s resource requirements

UK Approach to Design Basis

- no prescribed lists of accidents to be considered in the design basis
- probabilistic identification of the faults must be combined with deterministic analyses of representative faults to demonstrate that the protection would be effective
- operator has initially to identify all events that could potentially lead to either a person receiving a significant radiation dose or a significant escape of radioactive material

UK limits to Design Basis Analysis

Plant faults with initiating frequencies less than about 1 in 100,000 years and natural hazards with predicted frequencies of less than 1 in 10,000 years may be excluded

Design Basis should include failures consequential upon the initiating fault, failures expected to occur in combination with it arising from a common cause, and single failures of safety measures

Nuclear Safety Standards

Who decides on the standards?

- all countries set their own safety standards
- reactor design & construction is now an international activity
- commercial driver for standard designs and international harmonisation of standards
- EC Directives

International Collaboration

Harmonisation is a particular issue for the UK with its different regulatory approach and unique reactor technology (AGRs)

- exchange information and inspectors with other regulators
- participate in international missions & peer-reviews
- secondments of staff to UN International Atomic Energy Agency (IAEA)

IAEA Standards Development

The IAEA facilitates nuclear safety standards development through its Member States

National regulators guide development through IAEA committees

Member States’ comments are reflected

Standards & Guides are agreed at government level

Limits to harmonisation

Regulatory harmonisation will be limited by the extent to which countries are prepared to:

- change their legal systems
- accept supranational standards
- surrender national scrutiny of proposals that present a risk of major consequences within the host country

Adequacy of IAEA Standards

IAEA Safety Standards & Guidance are now recognised as relevant good practice for MS

Key aspects relevant to regulators have been incorporated into a Nuclear Safety Convention

Standards are being reviewed in the light of the Fukushima accident

Initial impression is that they have no fundamental weaknesses, but that they had not been fully implemented in Japan

Application of standards to older plant

Fukushima Daiichi reactors entered service between 1971 and 1979

UK also has old nuclear facilities

How can regulators ensure that the safety standards achieved at older facilities move with the times?

Periodic Safety Reviews

UK operators must perform Periodic Safety Reviews (PSRs) every 10 years. These must:

- demonstrate that the facility still meets its original design standards
- identify any issues that might limit the future life of the facility or its components and explain how they will be managed
- review the safety case against modern standards and identify any emerging gaps

Plant Improvements

Operators must identify and implement any reasonably practicable modifications needed to approach modern standards

ONR assesses the PSRs and does not allow operation to continue beyond the anniversary if not satisfied that this is being done

Magnox improvements included improving shutdown reliability, installation of additional cooling systems, and improving their seismic resistance

Use of new information

UK approach: if new information might undermine a safety case, the regulator may immediately require the operator to show that risk is still reduced ‘so far as is reasonably practicable’ and to take action if it is not

Prescriptive regimes: time lag as operators are not required to take action until the regulators have developed and enacted new decrees or rules tailored to the specific findings

Issues for Regulators

Japanese regulator has been criticised and government is making major changes

IAEA organises peer reviews of regulators through its Integrated Regulatory Review Service (IRRS)

Undertaken by teams of senior nuclear regulators from other countries

These reference IAEA guidance on legal & governmental infrastructure for regulation

Peer Reviews

Peer reviews provide a powerful way of identifying strengths & weaknesses if conducted by recognised experts and underpinned by evidence

IAEA has a range of peer review services

World Association of Nuclear Operators (WANO) undertakes peer reviews of operators

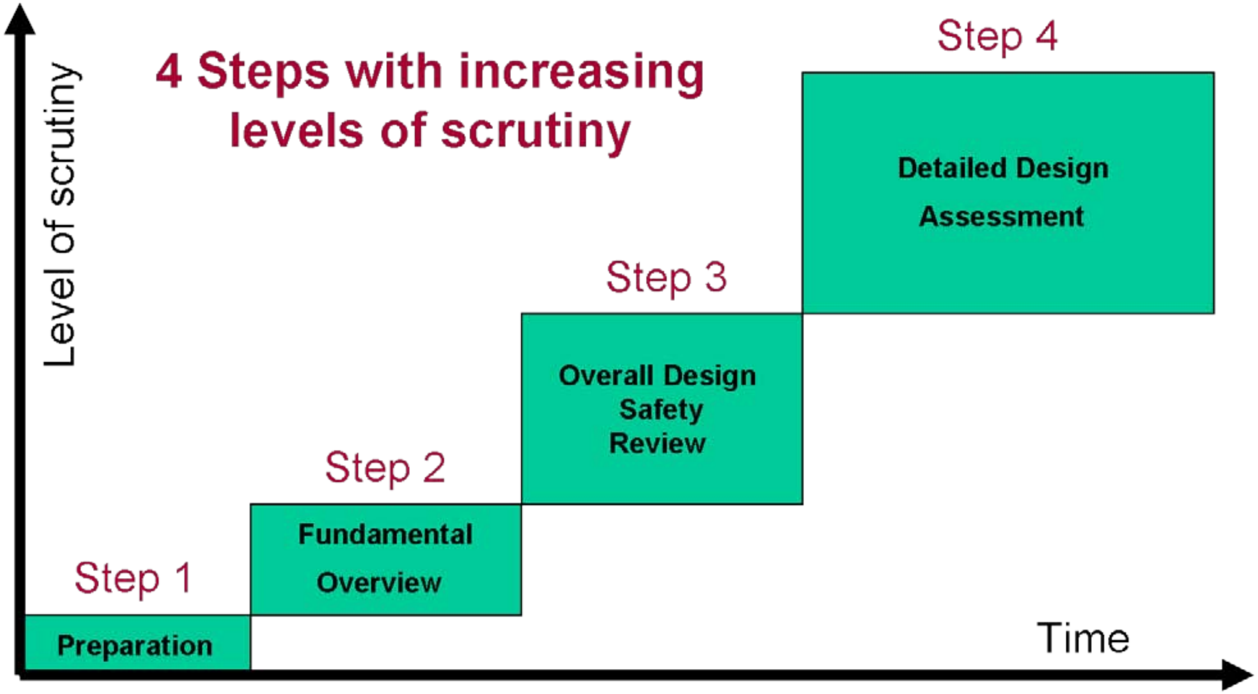
Implications for New Build

To get a nuclear site licence, the applicant has to satisfy ONR on 3 aspects:

- safety of the design
- capability of the operator to manage safety
- suitability of the proposed site

Responding to industry requests, ONR has assessed the Areva EPR and Westinghouse APR reactor designs ahead of any applications for licences – Generic Design Assessment (GDA)

GDA Process


4 Steps with increasing levels of scrutiny
Level of scrutiny
Time
Step 1
Preparation
Step 2
Fundamental Overview
Step 3
Overall Design Safety Review
Step 4
Detailed Design Assessment

New Build Implications

- GDA Step 4 assessments were completed in June 2011
- published a schedule of outstanding issues and Requesting Parties' Resolution Plans
- further issue added requiring response to recommendations of the CI's Fukushima Report
- ONR judged resolution plans acceptable and issued interim Design Acceptance Certificates in December
- final DACs will not be issued until the issues are fully resolved

GDA innovations

- NII, EA, OCNS joint working
- Joint regulators programme office
- Generic site envelope
- Assessments by foreign regulators being considered
- IAEA Independent peer review of NII (IRRS)
- Independent Process Review Board
- Enhanced openness by Regulators and vendors

Safety Culture

Vitally important

Difficult to measure & regulate

Risk that if metrics set, then may have unintended consequences e.g. on reporting

Pay heed to behaviours rather than words

As engineers, never surrender your engineering judgement to company pressures

Thank you for your attention …

… any Questions?

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