UNIVERSITY OF CAMBRIDGE

Nuclear Contingency Governance in a Cross – Border Context: An international Perspective

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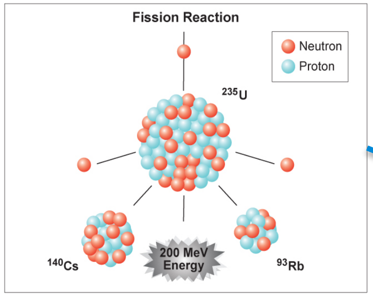
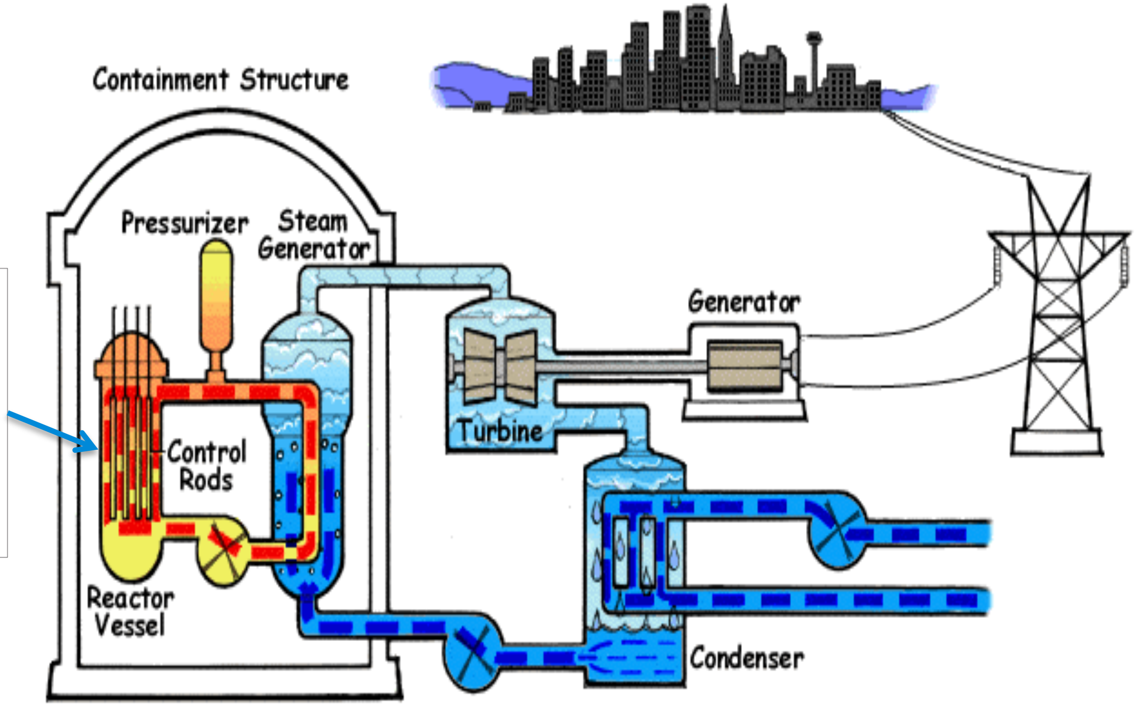
BACKGROUND

Risks, Radiation and Nuclear Safety





What is Risk and Safety?

- Risk – chance of bad consequences, loss
- Safety – Freedom from Risks?
- No such thing as absolute safety
- Living is risky
- We tolerate risks to achieve benefits
- Some examples …

Examples of Risk (1)

Annual risk of death for various United Kingdom age groups based on deths in 1999 (Annual Abstract of Statistics, 2001/Health Statistics Quarterly – Summer 2001).		
Population group	**Risk as annual experience**	**Risk as annual experience per million**
Entire population	1 in 97	10,309
Men aged 65-74	1 in 36	27,777
Women aged 65-74	1 in 51	19,607
Men aged 35-44	1 in 637	1,569
Women aged 35-44	1 in 988	1,012
Boys aged 5-14	1 in 6,907	145
Girls aged 5-14	1 in 8,696	115

Examples of Risk (2)

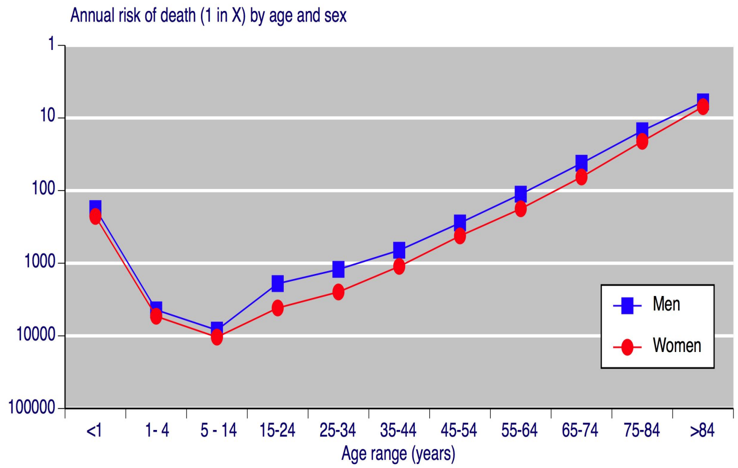
Average Annual Risk of Death as a Consequence of an Activity		
Activity associated with death	**Risk**	**Basis of risk and source**
Maternal death in pregnancy (direct or indirect causes)	1 in 8,200 maternities	UK 1994-96 (1)
Surgical anaesthesia	1 in 185,000 operations	GB 1987 (2)
Scuba diving	1 in 200,000 dives	UK 2000/01 (3)
Fairground rides	1 in 834,000,000 rides	UK 1989/90-2000/01 (4)
Rock climbing	1 in 320,000 climbs	England and Wales 1995-2000 (5)
Canoeing	1 in 750,000 outings	UK 1996-99 (6)
Hang-gliding	1 in 116,000 flights	England and Wales (7)
Rail travel accidents	1 in 43,000,000 passenger journeys	England and Wales 1997-2000 (8)
Aircraft accidents	1 in 125,000,000 passenger journeys	GB 1996/97 - 1999-2000 (9)

Notes: (1) NHS Executive (1998) (2) Lunn and Devlin (1987) (3) Based on assumption of 3 million dives per year. British Sub-Aqua Club (2001) (4) Based on estimated 1 billion rides per year. Tilson and Butler (2001) (5) Based on the assumption that there is a total of 45,000 climbers making an average of 20 climbs per year each. Mountain Rescue Council (2001) (6) Based on the assumption that there are 100,000 whitewater canoeists making an average of 30 outings per year each. Drownings in the UK, RoSPA (1999) (7) British Hang-gliding and Paragliding Association (2001). Based on the assumption that each member makes an average of 50 flights per year. (8) Health and Safety Executive (2001)(9) Civil Aviation Authority (2001)

Risk Communication

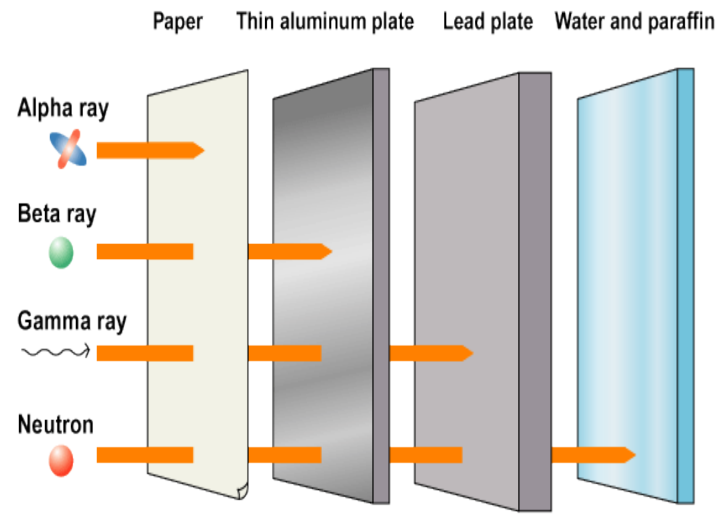
- People perceive risks differently – individual deaths and and multiple deaths
- Provide authoritative information and explanation – but let them make their own mind up
- Put the risk into context of everyday experience of risk
- Risk comes with benefits otherwise it is not tolerated

Example: risk from radiation exposure of my visit to Fukushima Dai-ichi 10 weeks after the start of the accident …



Ionising Radiation (1)

- One form of radiation – sunlight is another but non-ionising
- Ionising radiation affects the chromosomes of cells
- Several types:
  - Alpha: easily stopped (by skin) but damaging when inhaled or ingested
  - Beta: more penetrating but not so damaging
  - Gamma: highly penetrating and needs thick massive shielding (metres thick concrete) to significantly reduce it from a nuclear reactor
  - Neutrons: similarly penetrating



- Different types can have different impacts on human cells so measured in the effect of the radiation dose – units Sieverts
- Ionising radiation has two main impacts – deterministic (start at around 1Sievert) and stochastic (linear hypothesis)
- A Sievert for stochastic risk is about equivalent to the risk of dying from getting a cancer (some years in the future) of about 1 in 20
- Our normal risk of dying from cancer is about 1 In 3
- Normally measure dose in milli-Sieverts (our annual dose from normal activities is around 2 milli-Sieverts)

Ionising Radiation (2)

Ionising Radiation is all around us naturally and varies from place to place:

Average annual human exposure to natural ionising radiation (milli-sieverts)				
Radiation source	**World**[1]	**USA**[2]	**Japan**[3]	**Remark**
Inhalation of air	1.26	2.28	0.40	Mainly from radon, depends on indoor accumulation
Ingestion of food & water	0.29	0.28	0.40	(K-40, C-14, etc)
Terrestrial radiation from the ground	0.48	0.21	0.40	Depends on soil and building material
Cosmic radiation from space	0.39	0.33	0.30	Depends on altitude
Total Natural	2.40	3.10	1.50	Sizable population groups receive 10-20mSv; highest found around 200mSv

Ionising Radiation (3)

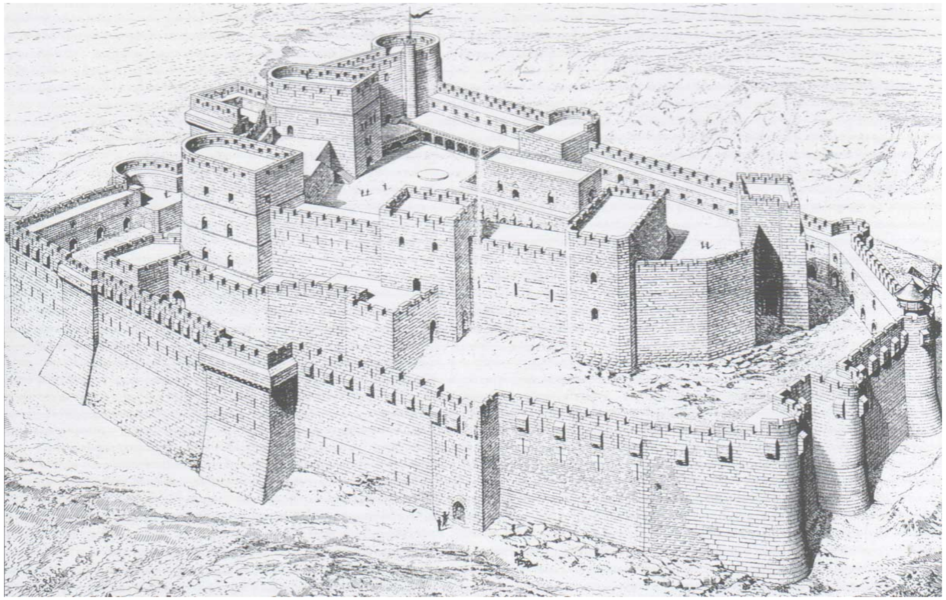
Average annual human exposure to artificial ionising radiation (milli-sieverts)				
Radiation Source	**World**	**USA**	**Japan**	**Remarks**
Medical	0.60	3.00	2.30	World-wide figures excludes radiotherapy,; US figure is mostly CT scans and nuclear medicine
Consumer items	-	0.13		Cigarettes, air travel, building materials, etc
Atmosphere nuclear testing	0.005	-	0.01	0.11mSv in 1961 and declining since; highest near sites
Occupational exposure	0.005	0.005	0.01	World-wide average to all workers is 0.7mSv
Chernobyl accident	0.002	-	0.01	Peak of 0.04mSv in 1986 and declining since; higher near site
Nuclear Fuel cycle	0.0002		0.001	Up to 0.02mSv near sites; excludes occupational exposure
other	-	0.003		Industrial, security, medical, educational, research
Total Artificial	0.61	3.14	2.33	Milli-Sieverts per year

How can you make a nuclear power plant safe?

- 3 Safety Functions: Contain, Control, Cool
  - Contain the radiation
  - Control the nuclear and chemical reactions
  - Cool the fuel
- Multiple barriers (DEFENCE IN DEPTH) to stop failure of the Safety Functions
- Diversity, redundancy, segregation of barriers/safety systems
- No single point failure
- Identify hazards, initiating events to realise them and failure paths
- Demonstrate through deterministic and probabilistic Safety Case
- Cultural barriers as well – Continuous Improvement, never complacent, open reporting, safety first

Defence in Depth – what do we mean?

Used in castle design for centuries but also attention to siting:

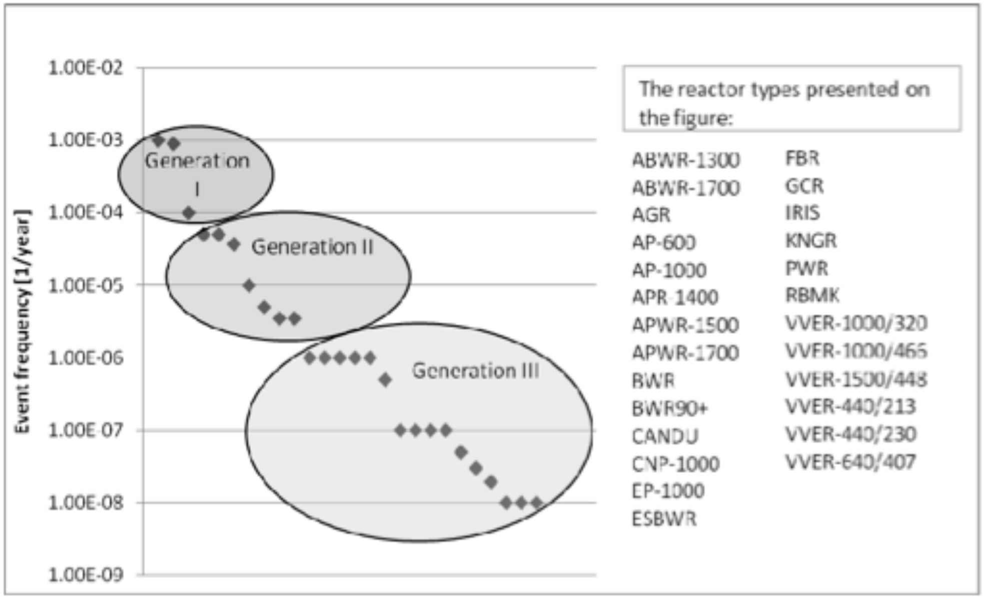


Technical Defence in Depth levels

Level of defence in depth	Plant Status	Objective	Essential Means
Level 1	Normal Operation	Prevention of abnormal operation and failures by design	Conservative design, construction, maintenance and operation in accordance with appropriate safety margins, engineering practices and quality levels
Level 2	Operational Occurrences	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Accidents	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Beyond Design Base Accidents	Control of severe plant conditions in which the design basis may be exceeded, including the prevention of fault progression and mitigation of the consequences of severe accidents	Additional measures and procedures to prevent or mitigate fault progression and for on-site emergency management
Level 5	Significant off site release of radioactivity	Mitigation of radiological consequences of significant releases of radioactive materials	**Accident management and off-site emergency response**

Nuclear Safety: Continuous Improvement

Risk = event frequency × consequences.



Reduction in design estimate of the large release frequency between reactor generations over the past five decades.

IAEA, 2004

Main Lesson from Fukushima

Technical Defence in Depth level – Fukushima Dai-ichi

Level of defence in depth	Plant Status	Objective	Essential Means
Level 1	Normal Operation	Prevention of abn[illegible] operation and failures by design[illegible]	Conservative design, construction, maintenance and operation in accordance with appropriate safety margins, engineering practices and quality levels
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Level 5	Significant off site release of radioactivity	Mitigation of radiolo[illegible]al consequences of significant releases of radioactive materials	**Accident management and off-site emergency response**

Real basic lesson of Fukushima is that Technical DiD can be subject to common mode failure through Nuclear Safety Institutional System Failures:

Inadequate Defence in Depth of the Nuclear Safety Institutional System

Institutional defence in depth system

A. Strong Competent “self regulating” Industry

B. Strong Regulator

C. Strong Competent Stakeholders

Each barrier is Independent and has Sub-barriers within it

Industry and the Regulator have to:

- have openness, transparency and accountability as a way of life
- have an underpinning strong vibrant safety culture and nuclear values
- welcome challenge with passion to improve

Barrier A – Strong Competent Self Regulating Nuclear Industry

Components of the Nuclear Industry Barrier in a State or Region			
I.1	**I.2**	**I.3**	**I.4**
Licensee	**State/Region Industry Peer Pressure**	**International Industry Peer Pressure/Review**	**International Institutional Review**
SQEP Technical/ Design/operational capability	Safety Directors Forum, INPO, etc.	WANO Missions and Requirements	IAEA OSART Missions
Independent Nuclear Safety Assessment	Nuclear Industry Association, Nuclear Energy Institute, ANS	Bilateral/Multilateral Organisations e.g. CANDU Owners Group	
Nuclear Safety Committee			
Nuclear Leadership/Culture/Values			

Barrier B
- Strong Independent Competent Nuclear Regulator

Components of a Strong Institution Regulatory Barrier			
R.1	R.2	R.3	R.4
Regulatory Authority	**Special Outside Technical Advice**	**International Peer Pressure**	**International Peer Reviews**
World Class Technical/Regulatory Capability	E.g. Standing Panel of experts nominated by stakeholders – CNI Advisory Panel/ Groupe Permanent d' Experts	NEA CNRA & CSNI committees and working groups	IAEA IRRS missions
Organisational Structure with internal standards, assurance, OEF, policy, strategy, etc.	Special Expert Topic Groups -Fukushima -Aircraft Crash	WENRA – reference levels, reviews, groups INRA – top regulators	ENSREG Reviews
Accountability to Governing Body – Board, Commission, etc.		IAEA Safety Standard meetings, etc.	
Nuclear Leadership/Culture/Values			

Barrier C
- Strong Well Informed Competent Stakeholders

Components of the Strong Stakeholder Institutional Barrier						
S.1	S.2	S.3	S.4	S.5	S.6	S.7
Workers	**Public**	**Parliament**	**National & Local Gov.**	**Neighbours**	**Media**	**NGOs**
Industry and Regulatory Routine Supply of Information						
Routine Reports on Activities and Decisions						
Special Reports on Matters of Interest						
Responsiveness to Requests for Information						
Routine and Special Meetings						
Openness & Transparency, Accountability, Assurance – Industry/Regulator Culture and Capability						

Nuclear Contingency Planning

Fukushima Dai-ichi Emergency Control Centre - 10 weeks

Contingency Planning - Some Principles:

- Prevent severe deterministic effects and minimise risks of stochastic effects
- Balance risks in taking action: severe deterministic effects (1Gray); increase in stochastic effects (100milli-Sieverts); adverse effects on the environment and property; other adverse effects (e.g. psychological effects, social disorder,
economic disruption).
- Prepare
- Timely, effective and appropriate interventions
- Co-operate and co-ordinate
- Openness and Transparency – prior public information

Some Priorities: Prepare

- International Conventions: Notification & Assistance
- IAEA Safety Standards
- Legislate for clear roles/responsibilities and adequate resourcing – have national co-ordinating authority
- Prior clear criteria for action
- Develop the infrastructure at site, local, national level + international co-operation:

Infrastructure:

- Authority
- Organisation
- Co-ordination of emergency response
- Plans and Procedures
- Logistical support and facilities
- Training, drills and exercises
- Quality assurance programme
- Note: such emergencies are very rare; responders have little experience; performed under very different conditions – extreme media attention

Some Priorities: Timely, effective and appropriate interventions

- **Early notification – early proportionate action – maximum impact**

- **Indicative Emergency Zones and distances from LWR site:**

  - **Precautionary action zone: 3 to 5 km (evacuation, KI tablets)**
  - **Urgent protective action planning zone: 15 to 30 km (evacuation, sheltering, KI tablets)**
  - **Extended action planning distance (monitor for hot spots): 100 km (relocation**
  - **Ingestion and commodities planning distance (monitor): 100- 300 km (restrictions on use, export)**
  - **Clear communications, information**

Some Priorities: Co-operate and co-ordinate

- **Effective action is dependent upon effective co-operation between players, site-local, local-national, national -international**

- **Effective response is dependent upon effective co-ordination between different organisations each probably with own terminology, cultures, arrangements**

- **Effective response is dependent upon effective co-ordination between nuclear/radiation capabilities/arrangements and those for conventional emergencies (very rare nuclear emergency)**

Some Priorities: Openness and Transparency & prior public information

Prior:

- **Information to public about comparative risk of ionising radiation, nuclear accident, etc as part of normal health education**
- **Openness and transparency about nuclear emergency planning arrangements and precautionary action to minimise harm**

During:

- **Early single authoritative official voice**
- **Useful, timely (first within an hour of general emergency being declared), truthful, understandable, consistent and appropriate throughout**
- **Prepared to answer questions and concerns of the public – e.g. Is my family safe?**

Nuclear Contingency Governance

International Governance System for Nuclear Contingencies

- **Conventions:**
  - ➢ **Nuclear Safety – Governance through Review Meetings by Peers**
  - ➢ **Early Notification**
  - ➢ **Assistance**

- **IAEA Safety Standards:**
  - ➢ **Fundamentals: No.9**
  - ➢ **Requirements: GS-R-2 (Preparedness and Response to Nuclear Accident, etc**
  - ➢ **Guidance: GS-G-2, GS-G-2.1**

- **IAEA Peer Reviews – Governance of adherence to Safety Standards**

Enhancement International Governance Post Fukushima?

- Enhanced Nuclear Safety – National Responsibility
- Enhancing the Nuclear Safety Convention
- Enhanced Signatures to Early Notification and Assistance Conventions
- Enhanced IAEA and WANO International Peer Reviews
- New Peer Review of National Institutional Defence in Depth Systems?
- Dedication to Openness, Transparency and Accountability at Core

Summary

- Nothing is absolutely safe – we tolerate risks to gain benefits
- Ionising Radiation is all around us and we live with it
- Nuclear accidents have not caused the immediate death of members of the public
- Effective contingency planning can control stochastic risks to below detectable levels
- International conventions and IAEA Standards Standards provide a global means of doing so
- They provide a clear set of principles and priorities for nuclear contingencies
- Enhancement of the International Governance System is in progress but more to do
- Openness, transparency and effective public communications/information both prior and during an emergency are essential for effective response