

Technical Volume 2

“Safety assessment”



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IAEA

International Atomic Energy Agency

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Technical Volume 2 – The Team

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Technical Volume 2 - Background

- All **relevant technical disciplines** were represented
 - Experts were from Operating Organizations, Regulatory Authorities, Technical Support Organizations, National Laboratories, Academia and the IAEA Secretariat
- The purpose of Technical Volume 2 is to answer **two questions**:
 - “Why did the site suffer from an extended station blackout?”
 - “Why was site staff unable to cool the reactors and maintain the containment function?”

Technical Volume 2 – Method of Assessment

Stick to the facts

- For example, many questions regarding equipment performance were not assessed
- We know that certain equipment did not work, but we do not know exactly why

Assessment conducted against IAEA Safety Standards in effect at the time of accident

- Expert judgement based on international best practices was used when needed

Similar to other Working Groups, WG2 used a deliberative process to derive final text

- Six working group meetings and multiple consultancy meetings

Technical Volume 2 - Background

Basis for assessment

- “Fundamental Safety Principles,” SF-1, November 2006
- “Safety of Nuclear Power Plants: Design,” NS-R-1, September 2000
- “Safety of Nuclear Power Plants: Operation,” NS-R-2, September 2000
- “Site Evaluation for Nuclear Installations,” NS-R-3, November 2003
- “Governmental, Legal and Regulatory Framework for Safety,” GSR Part 1, 2010
- “Safety Assessment For Facilities and Activities,” GSR Part 4, 2009.
- Generic and design specific safety guides including, but not limited to:
 - 50-SG-S1, 50-SG-S2, SSG-9, NS-G-3.3, NS-G-3.5, SSG-18, NS-G-1.5, NS-G-2.13, NS-G-1.8, NS-G-1.9, NS-G-2.15, SSG-3, SSG-4, NS-G-1.10, NS-G-2.2, NS-G-2.8, NS-G-2.10, NS-G-3.1, SSG-25

Technical Volume 2 - Background

Examples of major sources of information

- Fukushima Daiichi NPP Establishment Permit
- TEPCO, Fukushima Nuclear Accident Analysis Report (2012)
- NATIONAL DIET OF JAPAN, The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission (2012)
- NUCLEAR SAFETY COMMISSION, Accident Management for Severe Accidents at Light Water Power Reactor Installations, NSCRG: L-AM-II.01 (1997)
- GOVERNMENT OF JAPAN, Convention on Nuclear Safety National Report of Japan for the Fourth Review Meeting (2007).

Table of Contents

- 2.1.** Assessment of the plant in relation to external events
- 2.2.** Assessment of the failure to maintain fundamental safety functions
- 2.3.** Assessment of the treatment of beyond design basis events
- 2.4.** Accident management provisions and their implementation
- 2.5.** Assessment of the effectiveness of regulatory programmes
- 2.6.** Human and organizational factors
- 2.7.** Application of operating experience to improve plant design and operation

Table of Contents - Annexes

The Annexes provide supplementary information on the following topics:

- **Annex I:** Historical development of the governmental, legal and regulatory framework for nuclear safety in Japan
- **Annex II:** Aspects related to the human and organizational factors of the accident
- **Annex III:** Detailed description of relevant operating experience

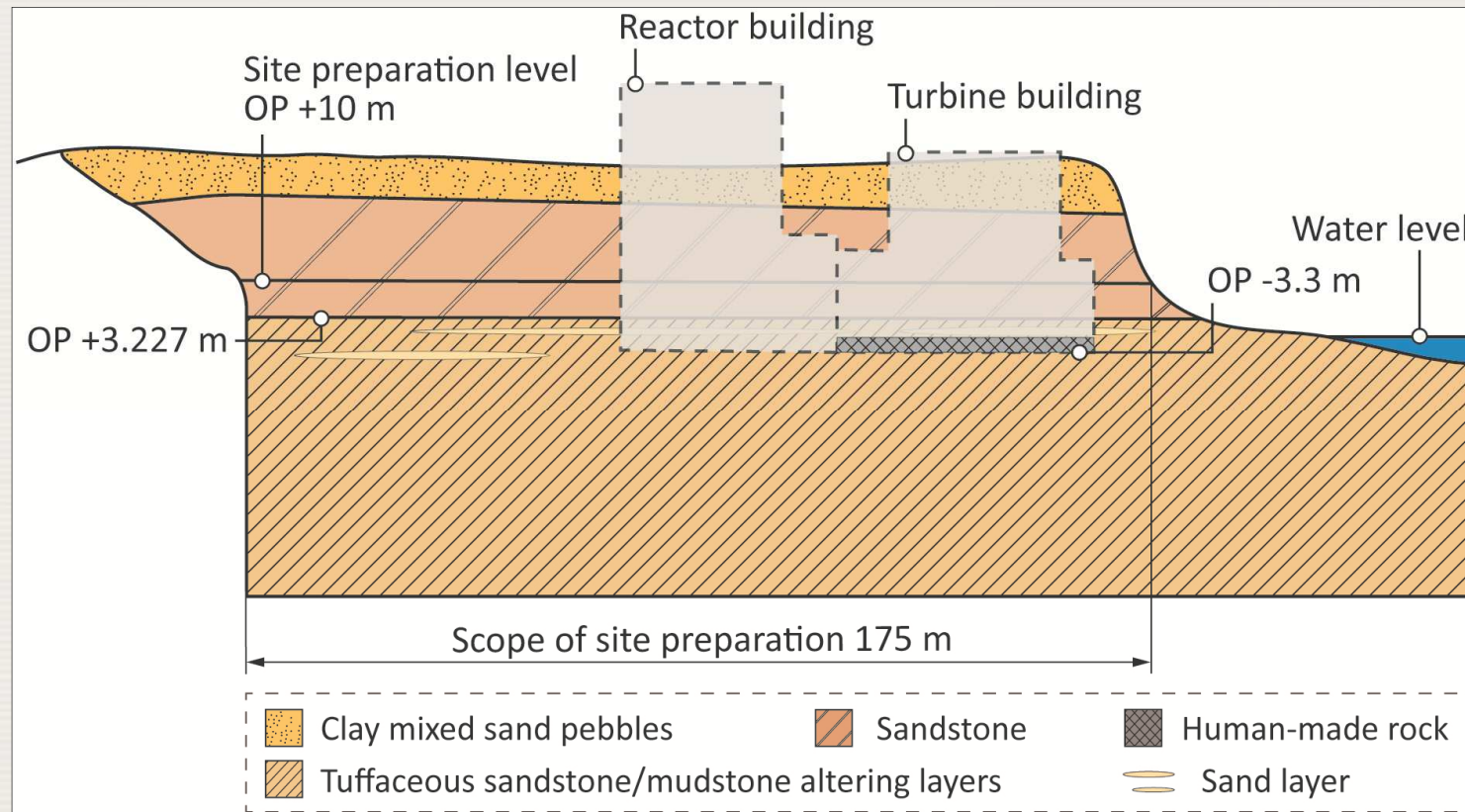


The Fukushima Daiichi Accident
Technical Volume 2, Section 2.1

ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS

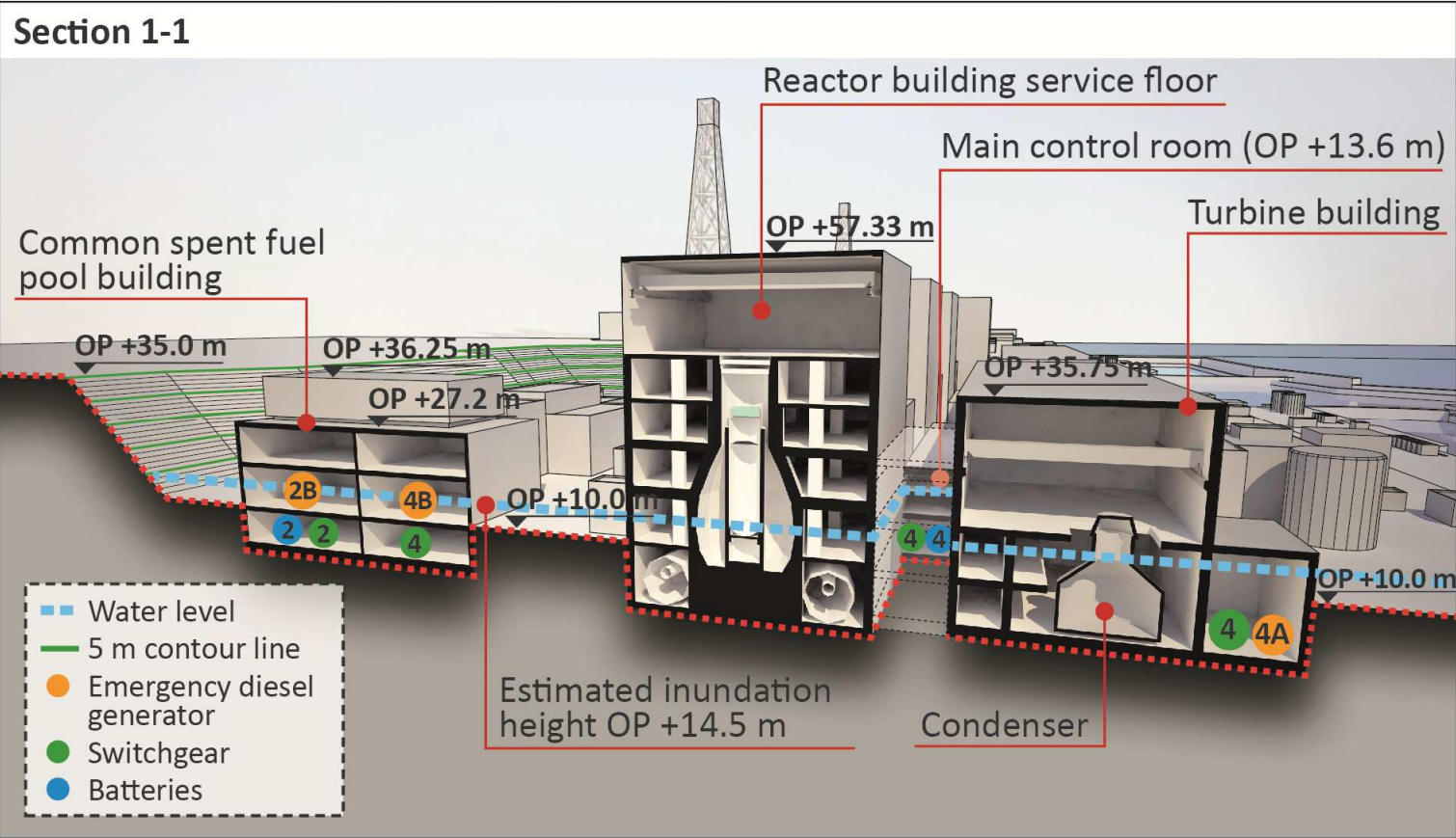
2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS

Excavation Plan



2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS

Final building layout



2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS – Key Elements

- Approximately **25 meters of soil and rock removed** as part of original siting plan
 - Based on design basis flooding height of O.P. + 3.122 meters (revised to O.P. + 6.1 meters)
- No apparent damage caused by the earthquake to safety related structures, systems and components
- The tsunami far **exceeded the design basis** and caused major damage to power and core cooling systems
- Major conclusion of assessment was that the treatment of external hazards for the Fukushima Daiichi NPP site was **not fully in line with international practice**

2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS

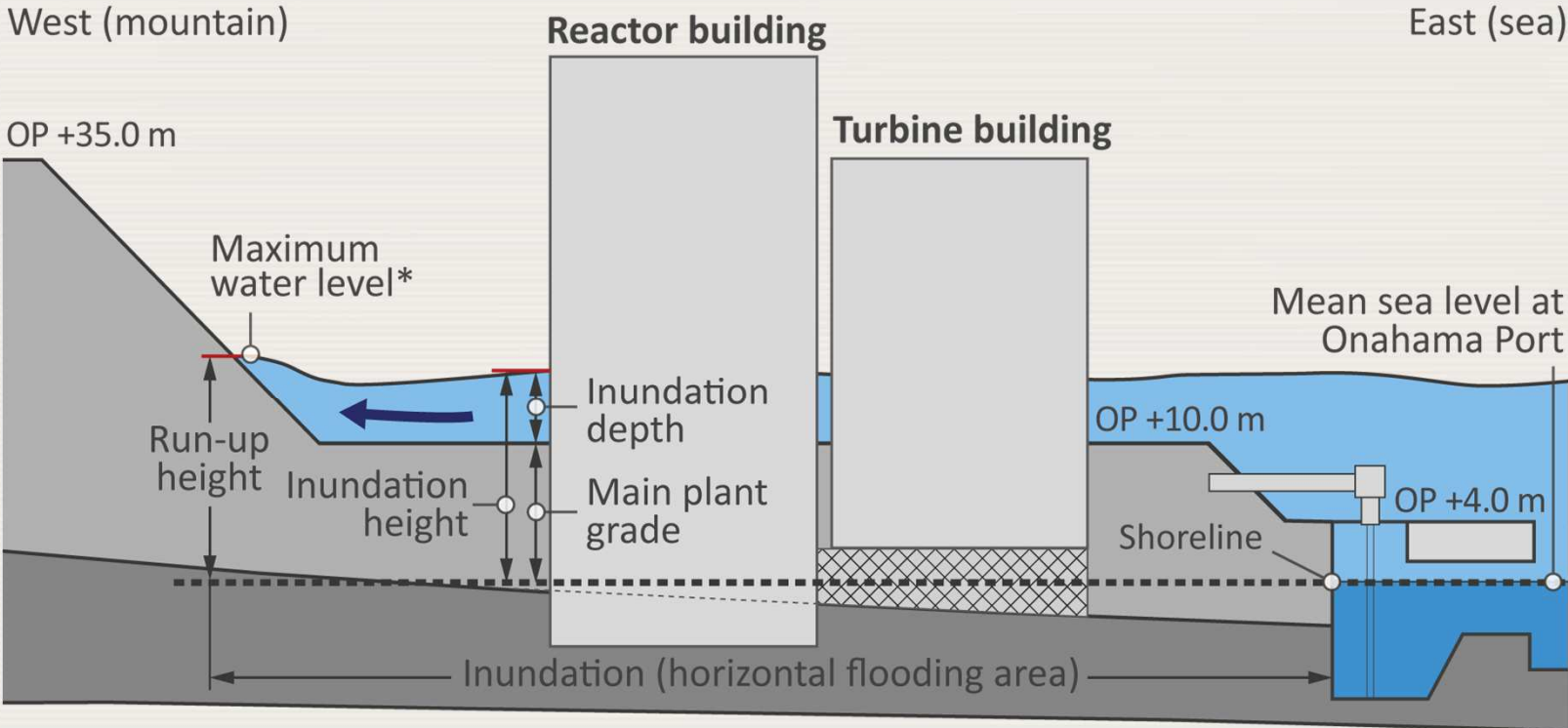
Maximum acceleration values observed at Units 1–6 of the Fukushima Daiichi NPP, and comparison with original design basis values and re-evaluation values

Fukushima Daiichi NPP unit	Maximum measured acceleration value (Gal)			Maximum response acceleration value (Gal)					Static horizontal acceleration (Gal)
				Revised design basis (2008)			Original design basis (1966)		
	N–S	E–W	U–D	N–S	E–W	U–D	N–S	E–W	
Unit 1	460	447	258	487	489	412	245		470
Unit 2	348	550	302	441	438	420	250		
Unit 3	322	507	231	449	441	429	291	275	
Unit 4	281	319	200	447	445	422	291	283	
Unit 5	311	548	256	452	452	427	294	255	
Unit 6	298	444	244	445	448	415	495	500	

Note: Values in blue indicate that the maximum recorded value was beyond the original design basis.

2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS

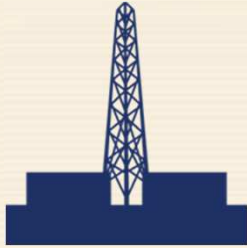
Tsunami parameters at the shoreline



*The maximum water level can be at the maximum inundation, the shoreline or between these points.

2.1. ASSESSMENT OF THE PLANT IN RELATION TO EXTERNAL EVENTS – Observations and Lessons

- External hazards assessment and regulatory requirements need to be **periodically re-assessed and updated**
- Decisions derived from external hazards assessments need to be appropriately conservative to **account for uncertainties**
- When faced with hazards predictions that challenge current assumptions **interim corrective actions** need to be taken
- **Multi-unit and multi-site accidents** need to be assessed

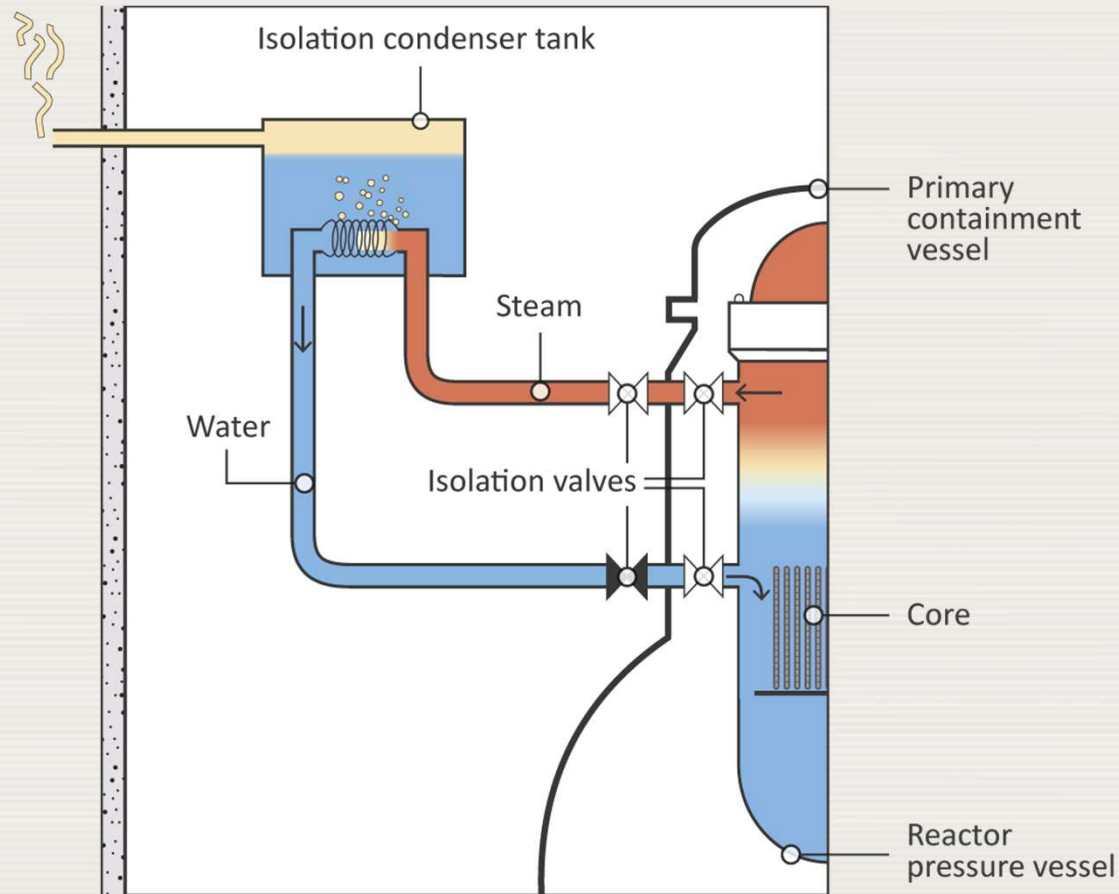


The Fukushima Daiichi Accident
Technical Volume 2, Section 2.2

ASSESSMENT OF THE FAILURE TO MAINTAIN FUNDAMENTAL SAFETY FUNCTIONS



2.2. ASSESSMENT OF THE FAILURE TO MAINTAIN FUNDAMENTAL SAFETY FUNCTIONS



2.2. ASSESSMENT OF THE FAILURE TO MAINTAIN FUNDAMENTAL SAFETY FUNCTIONS – Key Elements

Reactivity control was properly maintained

- All indications are that there **was no return to power** at any of the six reactors on the site

Core cooling was not maintained

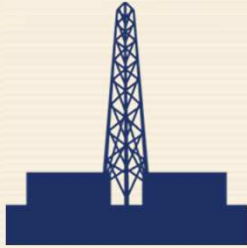
- At various times throughout the three days following the initial earthquake the ability to cool the core was lost **due to the flooding induced common cause failure**
- Core cooling was successfully re-established for Units 5 and 6

Containment function was not maintained

- Indications are that the containments for Units 1, 2 and 3 were damaged because of the **loss of power, cooling capability and challenges with venting**

2.2. ASSESSMENT OF THE FAILURE TO MAINTAIN FUNDAMENTAL SAFETY FUNCTIONS – Observations and Lessons

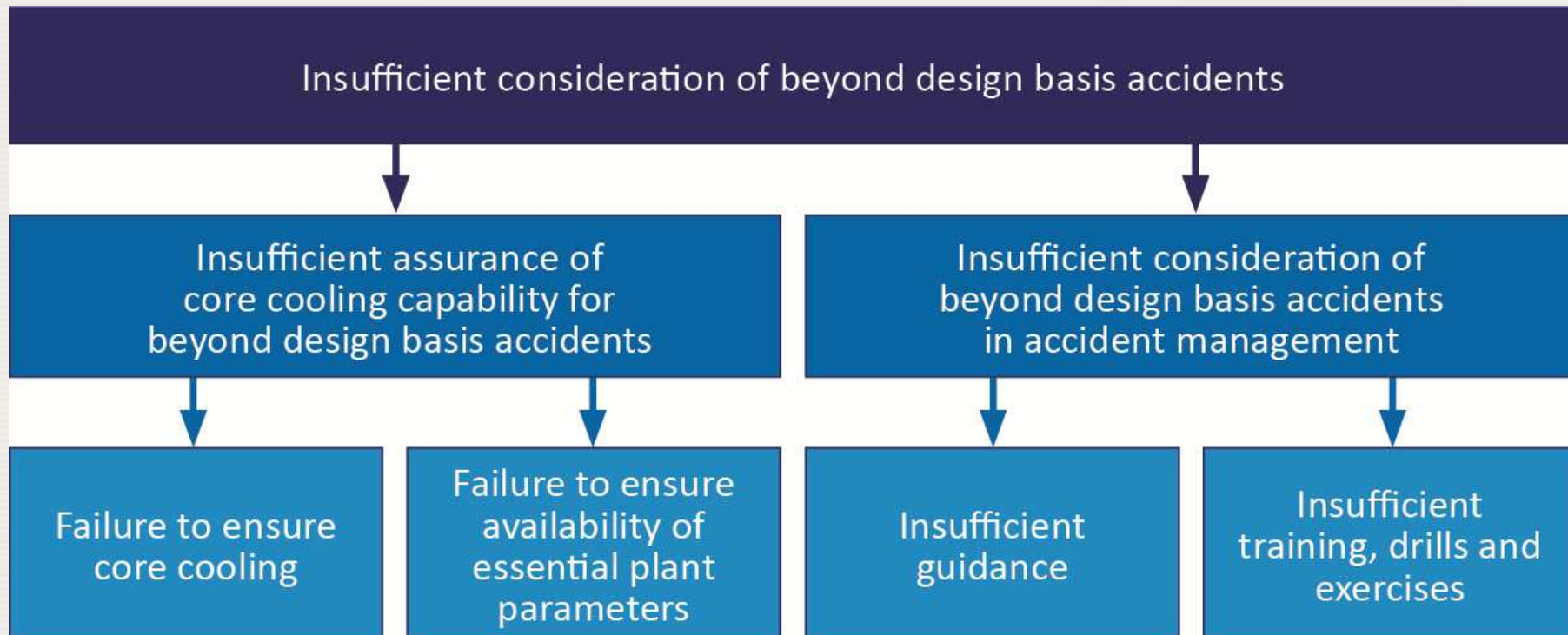
- **Provisions** need to be made to ensure the maintenance of **fundamental safety functions** including **alternative provisions for removing decay heat**
- **Training** on managing severe plant conditions needs to be provided and it should consider extreme environmental conditions
- Defence in Depth Level 4 provisions should be **independent** of Level 3
- **Critical instrumentation** needs to be identified and protected for severe conditions
- **Interconnections** between units should be designed to **prevent accident migration**



The Fukushima Daiichi Accident
Technical Volume 2, Section 2.3

ASSESSMENT OF THE TREATMENT OF BEYOND DESIGN BASIS EVENTS

2.3. ASSESSMENT OF THE TREATMENT OF BEYOND DESIGN BASIS EVENTS



2.3. ASSESSMENT OF THE TREATMENT OF BEYOND DESIGN BASIS EVENTS – Key Elements

Deterministic and Probabilistic treatment of Beyond Design Basis Accidents was not in line with international best practices

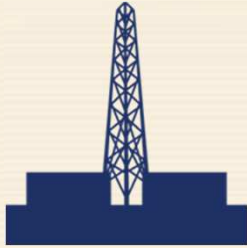
- Limited scope PSA did not identify plant vulnerability to flooding
- PSA results for Fukushima Daiichi NPPs were several orders of magnitude lower than similar plants in other Member States

Limited scope deterministic analyses contributed to weaknesses in accident management procedures

- Incomplete knowledge of potential accident sequences and consequences led to inadequate procedural guidance
- Operators were forced to develop response strategies during the accident which led to considerable and consequential delays

2.3. ASSESSMENT OF THE TREATMENT OF BEYOND DESIGN BASIS EVENTS – Observations and Lessons

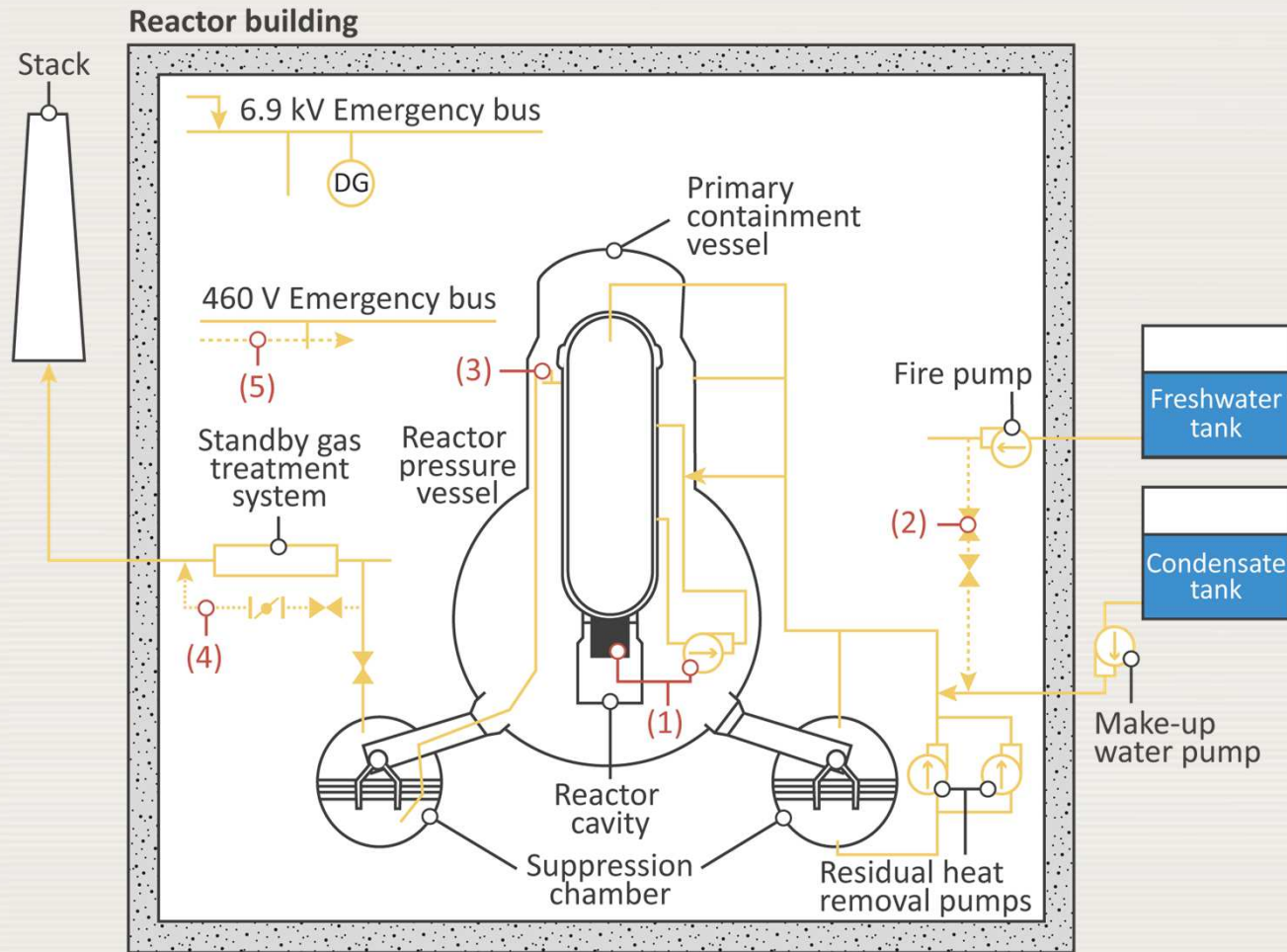
- Deterministic and probabilistic beyond design basis safety analyses need to be **comprehensive** and take into account both **internal and external** events
 - Such analyses provide a comprehensive understanding of potential accident sequences and plant response capabilities
 - Lead to improvements in both design and response procedures
- Extremely low PSA numbers need to be **reviewed and confirmed**
 - Such values can negatively impact decision making and lead to unidentified plant vulnerabilities



The Fukushima Daiichi Accident
Technical Volume 2, Section 2.4

ACCIDENT MANAGEMENT PROVISIONS AND THEIR IMPLEMENTATION

2.4. ACCIDENT MANAGEMENT PROVISIONS AND THEIR IMPLEMENTATION

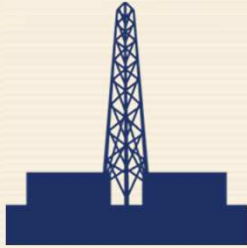


2.4. ACCIDENT MANAGEMENT PROVISIONS AND THEIR IMPLEMENTATION – Key Elements

- **Severe Accident Management provisions in place at the Fukushima Daiichi NPP prior to the accident were not fully in line with international practice at the time**
 - Greater use of deterministic and probabilistic analyses for procedure development was needed
 - Training and strategies in the use of portable equipment was inadequate
- **Accident management guidance did not use the latest industry guidance**
 - Updated BWR Owners' Group generic guidance was not implemented at Fukushima Daiichi NPP

2.4. ACCIDENT MANAGEMENT PROVISIONS AND THEIR IMPLEMENTATION – Observations and Lessons

- **Accident management provisions need to be clear, comprehensive and well designed**
 - Training and exercises need to be based on **realistic** severe accident conditions.
 - **Time** is essential during accident response and having **clear and comprehensive instructions** saves time
- **Regulatory bodies need to ensure that adequate AM provisions are in place**
 - These requirements should consider **environment conditions**, adequacy of training and the availability and sufficiency of proper equipment
- **Provisions for the proper management of hydrogen need to be considered**
 - The hydrogen explosions during the accident were **unexpected** and negatively impacted the ability of operators to continue response activities

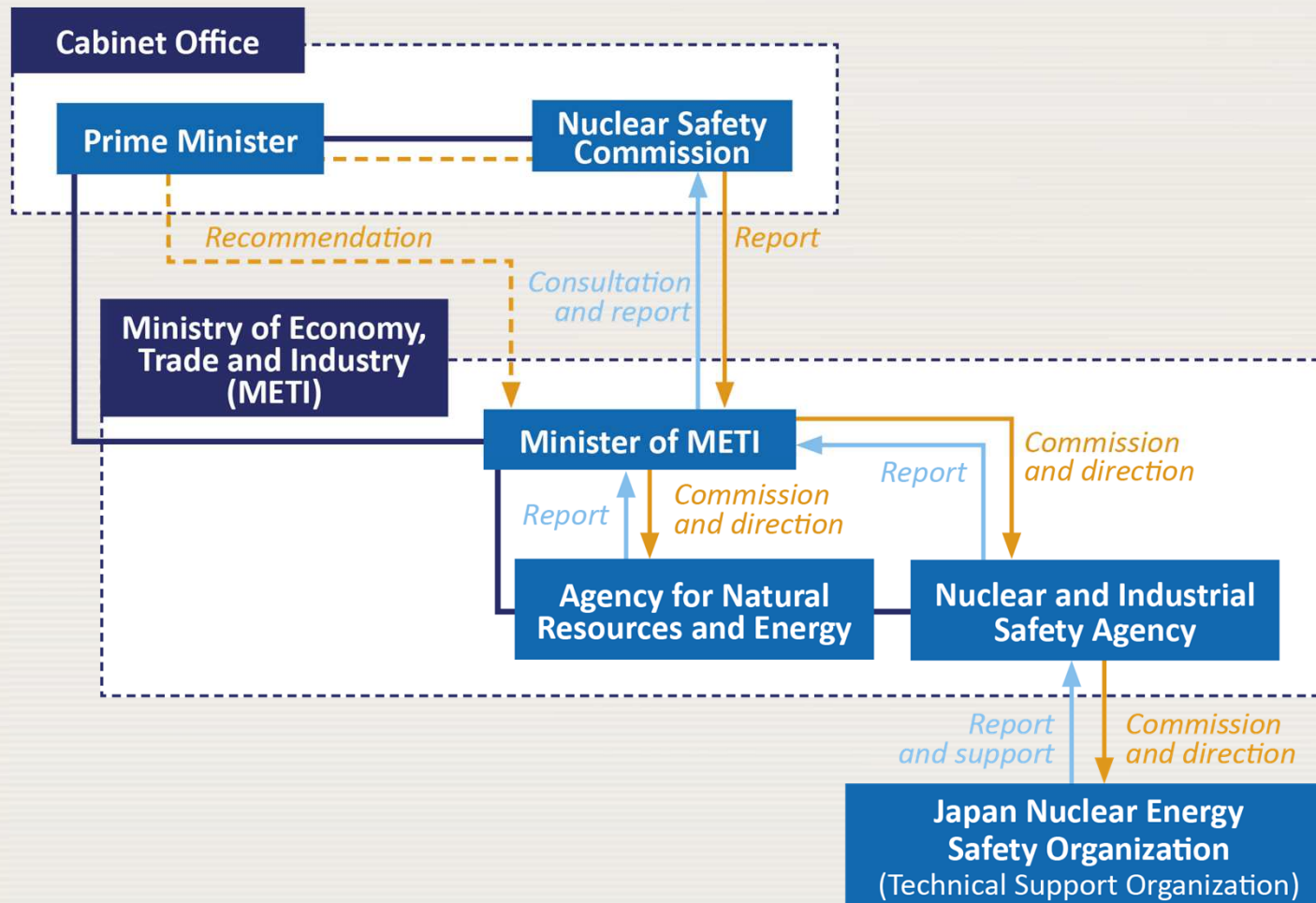


The Fukushima Daiichi Accident
Technical Volume 2, Section 2.5

ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES



2.5. ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES

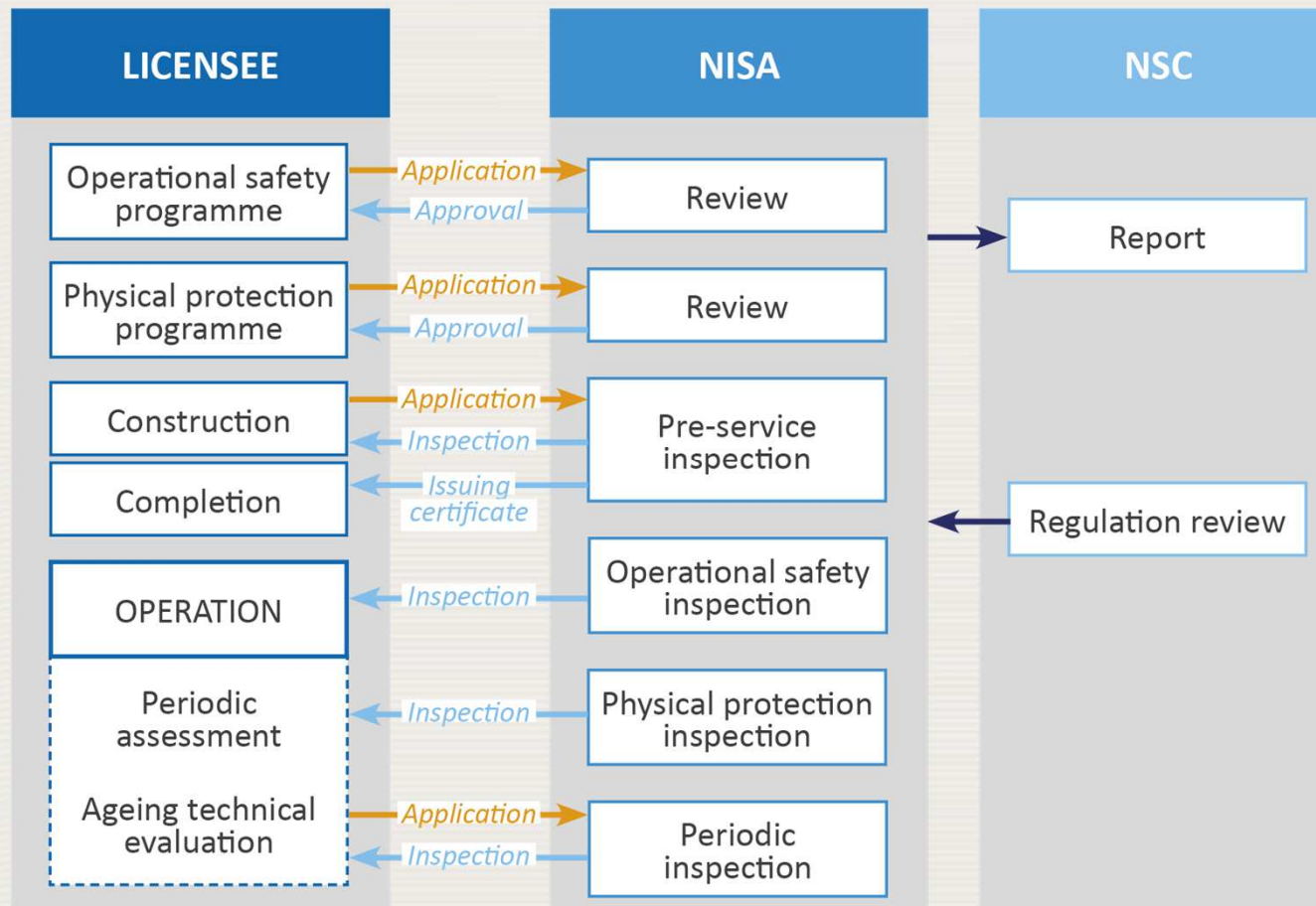


2.5. ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES – Key Elements

- **The regulatory system in place in Japan prior to the accident was complex and involved several different organizations**
 - The distribution of regulatory authority and decision making was **unclear**
- **Some regulatory practices in place prior to the accident were not on line with international best practices**
 - Inspection program was **overly limited in scope and influence**
 - Periodic safety reviews **lacked effective regulatory oversight**

2.5. ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES

Regulatory inspection process for the operating stage of NPPs in March 2011



2.5. ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES – Observations and Lessons

- Where several bodies have responsibilities for safety, the government needs to **effectively coordinate** their regulatory functions.
 - **Clear lines of authority and decision making** ability so that all stakeholders understand the process
- The regulator should require that the operator of a facility **update** its safety demonstration on an ongoing basis to **reflect changes** in the status of the facility.
 - Regulatory authority needs the ability to **compel** the licensee to upgrade its facility
 - Regulator needs an **effective inspection program**
- Regulatory independence, competence, strong legislative authority and adequate resources, including qualified personnel, are essential
 - Regulatory authority needs **effective enforcement authority** and **access to independent technical expertise**

2.5. ASSESSMENT OF THE EFFECTIVENESS OF REGULATORY PROGRAMMES – Current Status

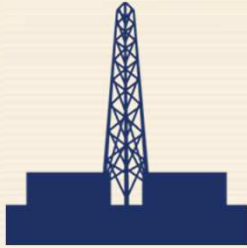
19 September 2012 the Nuclear Regulation Authority was established

- Combined from NISA, NSC and JNES

On 8 July 2013 new regulatory requirements came into effect

- More importance placed on **Defence in Depth Level 3 and 4** provisions
- **Enhanced independence** to counter common mode failures

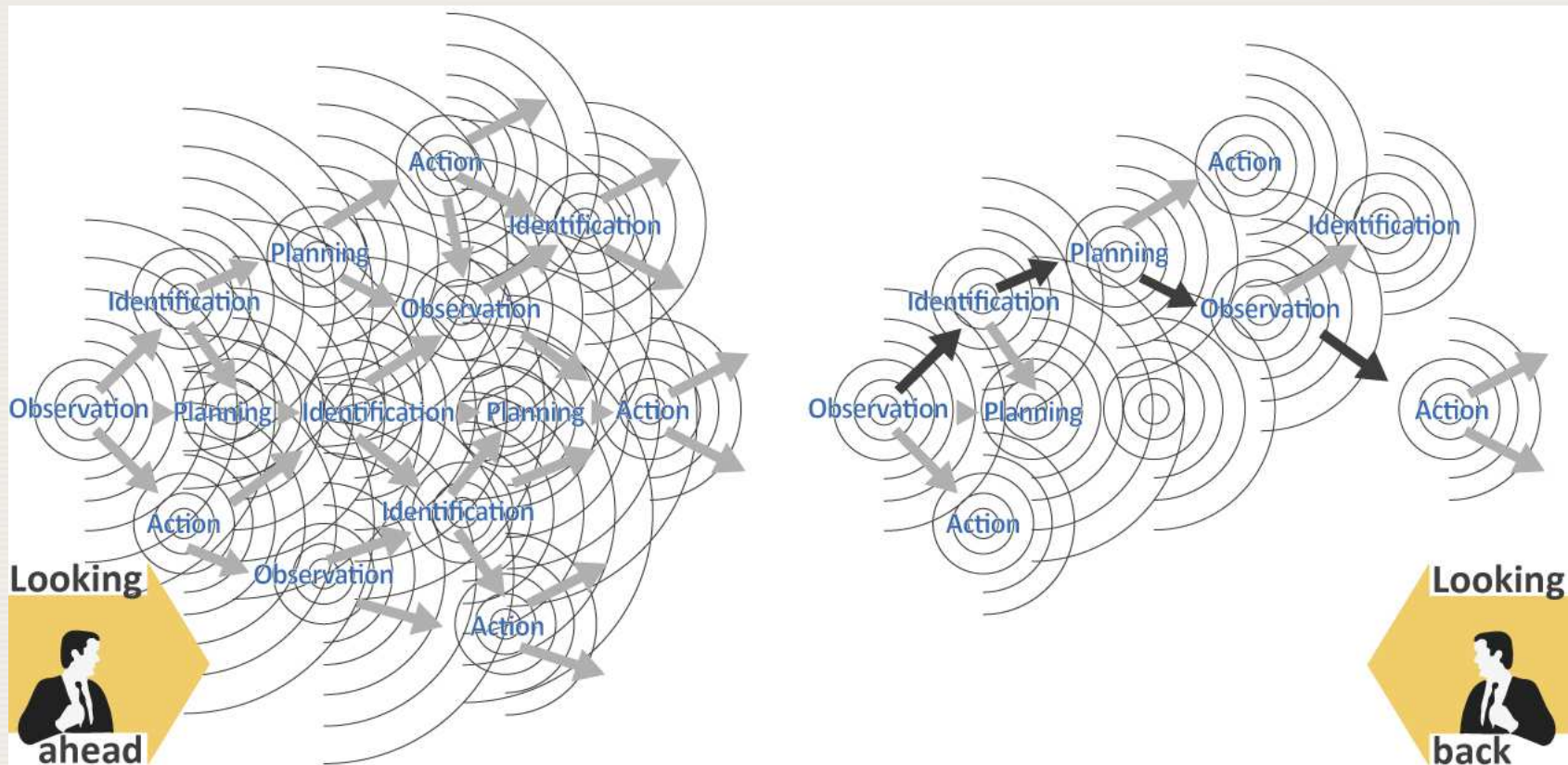
Required additional countermeasures against internal fires, floods and station blackout



The Fukushima Daiichi Accident
Technical Volume 2, Section 2.6

HUMAN AND ORGANIZATIONAL FACTORS

2.6. HUMAN AND ORGANIZATIONAL FACTORS



2.6. HUMAN AND ORGANIZATIONAL FACTORS – Key Elements

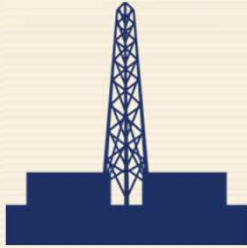
- **“Basic assumption” that plants were safe significantly contributed to the accident**
 - All stakeholders **shared and mutually reinforced** this belief
 - Influenced safety related decision making
- **Safety culture programs were unable to identify and correct this “basic assumption”**
 - Requires an **integrated approach** considering human, organizational and technical factors
 - For example, station blackout had been considered, but an **event of the magnitude that happened** at Fukushima Daiichi was **not** considered

2.6. HUMAN AND ORGANIZATIONAL FACTORS – Observations and Lessons

- Individuals and organizations need to consciously and continuously **question their own basic assumption** and their implications on actions that impact nuclear safety.
 - The possibility of the **unexpected** should be considered
- Nuclear organizations need to **critically review** their approaches to emergency drills and exercises to ensure that they take due account of harsh complex conditions and unexpected situations.
 - **Better prepare first responders** with an understanding of what to expect during these types of postulated situations

2.6. HUMAN AND ORGANIZATIONAL FACTORS – Observations and Lessons

- A **systemic approach** to safety needs to be taken in event and accident analysis, considering all stakeholders and their interactions over time.
 - Safety culture programs using this approach are **better equipped to identify and correct “basic assumptions”**
 - Regulatory authorities should provide **oversight and independent review** of safety culture programs



The Fukushima Daiichi Accident
Technical Volume 2, Section 2.7

APPLICATION OF OPERATING EXPERIENCE TO IMPROVE PLANT DESIGN AND OPERATION

2.7. APPLICATION OF OPERATING EXPERIENCE TO IMPROVE PLANT DESIGN AND OPERATION – Key Elements

- Several precursor events **did not lead to a recognition of flooding vulnerability** at the Fukushima Daiichi NPP
 - In 1991 a flooding event at Fukushima Daiichi occurred, but no actions were taken at the plant
 - International operating experience from Le Blayais in France and Madras in India similarly did not lead to any action at the plant
- The 2007 earthquake at Kashiwazaki-Kariwa led to significant **plant modifications** including the ability for alternative water injection and the seismically qualified emergency building
 - Both of the features were instrumental in mitigating the consequences of the events at the Fukushima Daiichi NPP

2.7. APPLICATION OF OPERATING EXPERIENCE TO IMPROVE PLANT DESIGN AND OPERATION – Observations And Lessons

- The effectiveness of operating experience programmes needs to be confirmed **periodically and independently**
 - Regulatory bodies need to **perform independent reviews** of national and international operating experience to confirm that licensees are taking appropriate action
 - Potential **consequences of operating experience** should be considered

2.7. APPLICATION OF OPERATING EXPERIENCE TO IMPROVE PLANT DESIGN AND OPERATION – Observations And Lessons

- The operating experience programme needs to function within a management system where **nuclear safety is paramount and overrides** all other demands
 - Personnel need to be adequately trained and have a **safety focus**
- The potential implications of new safety issues need to be assessed **without delay**, and **interim compensatory actions** need to be taken to maintain the safety margin pending final confirmation of the problem
 - Re-assessing new information is typical practice, but the revised hazard should be addressed during the re-assessment

Summary

- What are the answers to the two questions posed?
 - “Why did the site suffer from an extended station blackout?”
 - “Why was site staff unable to cool the reactors and maintain the containment function?”

The Director General put it best when he said “...a major factor that contributed to the emergency was a widespread assumption in Japan that its nuclear power plants were so safe that an accident of such a magnitude was simply unthinkable.”

THANK YOU