

Lessons Learned from Fukushima Dai-ichi NPS Accident

Key Regulatory and Safety Issues

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Workshop on Accident Tolerant Fuels of LWRs

10 - 12 December 2012 – Issy les Moulineaux, France

Accident Overview

Accident Sequence

Earthquake

Reactors
Shutdown

Loss of off-
site power

Onsite EDGs and core
cooling systems start

Tsunami

Loss of onsite EDGs

Loss of DC Power

Loss of core cooling

Core
Damage

H₂ Generation

Explosions

Large offsite releases

Loss of communications
and I&C systems

SBO

Robustness of Electrical Power Supplies

Robustness of core cooling systems

Production and control of
combustion gases

Protection of Containment

Offsite Emergency Planning

Robustness of fuel design

I&C capabilities during severe accidents

Defence-in-Depth

Prevention

Mitigation

Protective
Measures

Level 1	Normal Operation	Conservative design and high quality in construction and operation
Level 2	Operational Occurrences	Control, limiting and protection systems and other surveillance features
Level 3	Design Base Accidents	Engineered safety features and accident procedures
Level 4	Beyond Design Base Accidents	Complementary measures and onsite accident management
Level 5	Significant off site release of radioactivity	Off-site emergency response and accident management

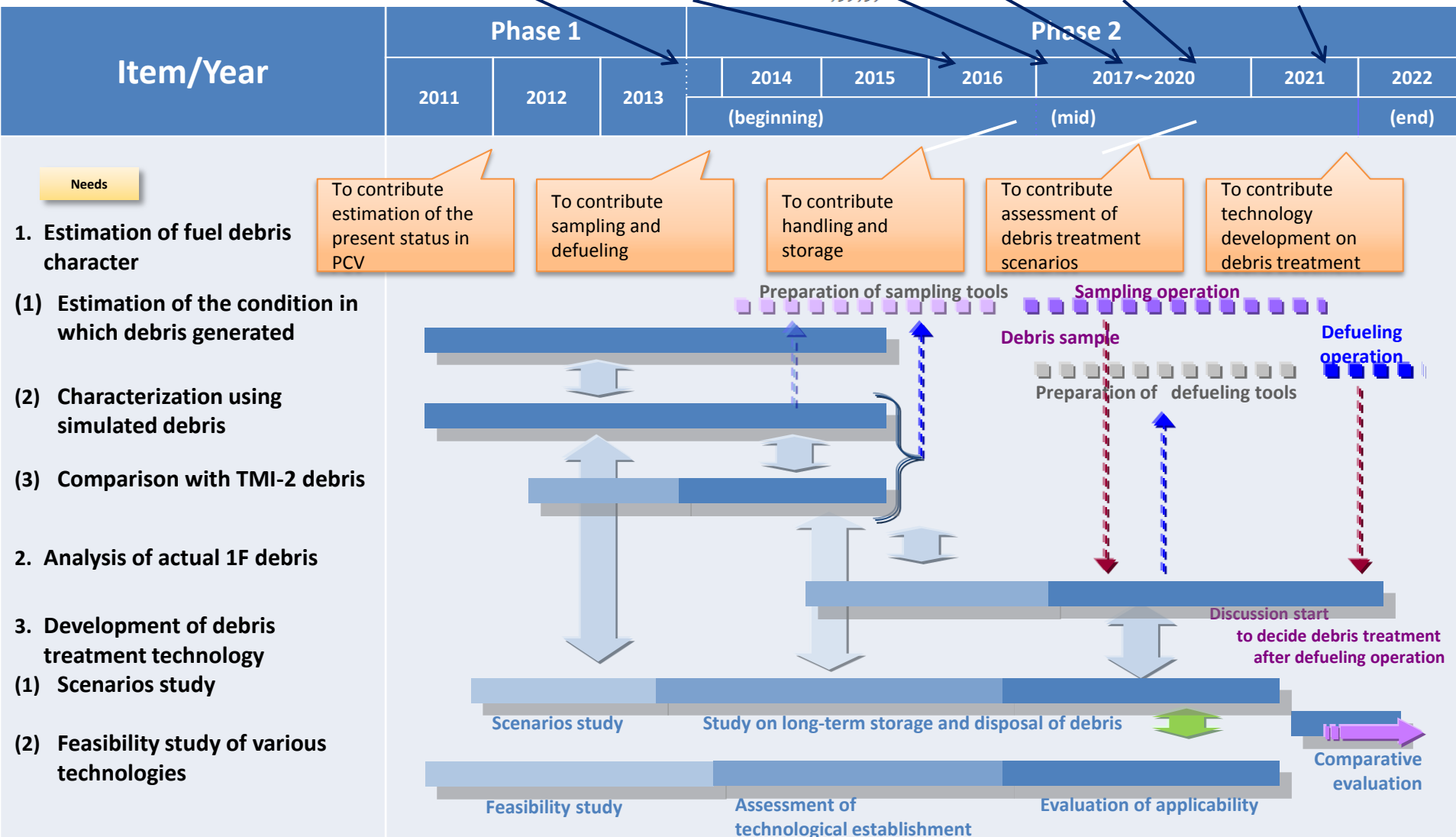
1. Accident Management
2. Defence-in-Depth
3. Crisis Communication
4. Initiating Events
5. Operating Experience
6. Deterministic and Probabilistic Assessments
7. Regulatory Infrastructure
8. Radiological Protection and Public Health
9. Decontamination and Recovery

- Transitioning from normal operation to severe accident conditions
 - ✓ Normal operating procedures
 - ✓ Abnormal occurrence procedures
 - ✓ Accident management procedures and guidelines developed to address events and accidents analyzed in the design basis
 - **Emergency Operating Procedures**
 - ✓ Severe Accident Management Guidelines
 - ✓ Emergency Plan and implementing procedures
- Fukushima showed there is a need to have a well understood and preplanned approach for transitioning from the initiating event (normal operation) to severe accident conditions
- Need to address extensive infrastructure damage

- Accident Progression
 - ✓ Current understanding of accident progression will be enhanced by gathering and sharing data
 - **Data collection to support benchmark studies**
 - ✓ Flammable gases (primarily H₂) generated during the accident led to explosions in unexpected areas of the plant (reactor buildings)
 - **Challenges with containment venting**
- Human and Organisational Performance
 - ✓ Operators working under extreme conditions
 - ✓ Decision making during severe accident conditions
- Offsite Emergency Preparedness
 - ✓ Source term and release estimates
 - ✓ Onsite and Offsite interfaces and decision-making

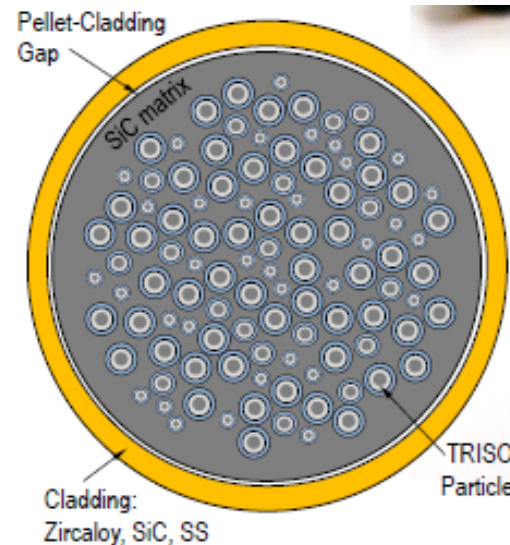
- **BSAF: Benchmark Study on the Accident of Fukushima**
 - ✓ Run by Japan - Cost: 0,16 M€ - Duration 1.5 years (1st phase of anticipated multi-phase project)
 - ✓ Programme: Analyse accident progression and current status inside RPVs and RCVs of units 1-3; improve methods and models of codes and reduce uncertainties in Severe Accident analysis
 - ✓ Expert Workshop on 18-20 June 2012, NEA HQ
 - ✓ Draft Agreement circulated in October 2012 to countries already well advanced in modelling of SA phenomena at Fukushima Daiichi NPS -> 8 countries will participate: France, Germany, Japan, Korea, Russia, Spain, Switzerland and USA
 - ✓ Kick-off meetings: → **6-8 November 2012, Tokyo**

Debris characterization and treatment study
– CSNI Presentation by Hironori Nakanishi,
Director-General of the Agency for Natural
Resources and Energy, METI – 5 Dec 2012



• New Fuel Material Development Activities

- ✓ Fully Ceramic Microencapsulated fuels
- ✓ MAX phase coating
- ✓ SiC phase cladding/coating
- ✓ Fe-Cr-Al alloys
- ✓ Mo-alloys and Mo-Zr composite cladding
- ✓ SiC BWR channel
- ✓ SiC cladding



- **Safety aspects of some candidate fuel cladding (& structural) materials**
 - ✓ SiC cladding appears to be more resistant to high temperature than Zr-based alloys of LWRs thus allowing more time for recovery of water injection means in case of loss of cooling
 - ✓ But SiC seems to present essentially drawbacks for severe accidents behavior as it produces more combustible gases (H_2 and CO)
 - ✓ Stainless steel - better behavior than Zr alloys under severe accidents is not proven whereas it is less transparent to neutrons

- Concept is valid
- Implementation can be enhanced
 - ✓ The balance between prevention and mitigation
 - ✓ Application of DID to design and site aspects, including consideration of rare external hazards at a site
 - ✓ Countermeasures and large populations and National and International emergency response plans
 - ✓ Global harmonisation in the application and implementation of DID
 - ✓ The role of the regulator in all levels of DID
- Need to balance deterministic and probabilistic approaches to safety assessment within the framework of DID
- Changing Societal Expectations

- Communication with the Public, Media, Local Government
 - ✓ During normal situations
 - ✓ Establishes credibility for the regulator and operator
 - ✓ Enhances emergency response communication
- Communication with other government organisations
 - ✓ Helps to establish clear roles and responsibilities of the different emergency response organisations
- Communication between onsite and offsite decision makers
 - ✓ Coordinated activities enhances protection of the public

- Internal and External Initiating Events
 - ✓ Further knowledge on external events would support better implementation of DiD
 - ✓ Diversity and redundancy need to be fully addressed for external events
 - ❖ **Contribute to common cause failures and cliff edge effects**
 - ✓ Combination of closely linked external events needs to be included in safety assessments
 - ❖ **Earthquake-tsunami, hurricanes-fires, droughts-fires, etc**
 - ✓ Uncertainty and safety margins need to be considered for external events
- Implementation of Operating Experience
 - ✓ Precursor events
 - ✓ Safety research

- Regulatory Infrastructure
 - ✓ Independence and Competency
 - ✓ Credibility and Transparency
 - ✓ Resources and Knowledge Management
- Radiological Protection and Public Health
 - ✓ Emergency countermeasure recommendations
 - ✓ Occupational exposure
- Decontamination and Recovery
 - ✓ Commodities and food
 - ✓ Criteria for re-entry into contaminated areas

- New Task Group on Accident Management approved by CNRA June 2012
 - ✓ Enhancements of on-site accident management procedures
 - ✓ Decision-making and guiding principles in emergency situations
 - ✓ Guidance for instrumentation, equipment and supplies for addressing long-term aspects of accident management
 - ✓ Guidance when taking extreme measures for Accident Management

- Working Group on Public Communication (WGPC)
 - ✓ Completed workshop on Crisis Communication (Madrid, May 2012)
 - ✓ Enhancing guidance on effective regulatory communication building on lessons learned
- Safety of Research Reactors Task Group (SORRTG)
 - ✓ Task on peer review workshop of country comprehensive safety assessments (stress tests) of high risk RR facilities.

- Working Group on Accident Management and Analysis (WGAMA)
 - ✓ WGAMA F-CAPS (2012)1 – Position paper on filtered containment venting
 - ✓ WGAMA F-CAPS (2012)2 - International benchmarking project on fast-running software tools used to model fission product releases during accidents at nuclear power plants
 - ✓ WGAMA is discussing a possible additional new task on hydrogen generation and mitigation
- Working Group on Human and Organisational Factors (WGHOFF)
 - ✓ WGHOFF F-CAPS (2012)1 – Human intervention and performance under extreme conditions

- Working Group on Integrity of Components and Structures (WGIAGE)
 - ✓ WGIAGE F-CAPS (2012)2 – Metallic component margins under high seismic loads (MECOS)
- Working Group on Risk Assessment (WGRISK)
 - ✓ WGRISK F-CAPS (2012)1 – Workshop on PSA of natural external events including earthquakes
- Other ongoing work within CSNI includes:
 - ✓ A discussion paper on Defence-in-Depth to identifying future technical topics (joint effort with CNRA)
 - ✓ Re-constitution of **DiDELSYS TG** to investigate the issue of electrical system robustness in light of Fukushima

Defence-in-Depth of Electrical Systems in Light of Fukushima Daiichi

- Following STG-FUKU recommendations and discussions at June 2012 CSNI meeting IRSN proposes to launch new F-CAPS on subject:
 - In form of workshop on new challenges on electrical systems of NPPs in the aftermath of the Fukushima Dai-ichi accident.
- Draft F-CAPS objectives:
 - Identify what the Fukushima accident changed on electrical systems requirement and design, especially as regards the protection against extreme external hazards,
 - Identify and characterize current practices regarding the use of computer simulation to analyze transients occurring within the electrical systems,
 - Identify the difficulties related to periodic testing of electrical systems, and the current approaches for dealing with these issues.
- Task intended to build upon work and competencies of DiDELSYS task group

- Importance of future safety research has been highlighted in the CSNI Concept Paper, CNRA STG Recommendations to CNRA and other supporting strategy/policy documents
- New safety research will be identified using a phased approach within NEA:
 - ✓ Comprehensive review of past safety research - done
 - ✓ Gap analysis based on research issues from Fukushima – ongoing
 - ✓ CSNI review of research direction – ongoing
- Joint international research project being established: *Benchmark Study of the Accident at the Fukushima Daiichi NPS (BSAF Project)*

- Established Expert Group on Radiological Protection Aspects of the Fukushima NPP Accident (EG-RPF)
- Working Party on Nuclear Emergency Matters (WPNEM)
 - ✓ INEX 4 evaluation report and workshop planning
 - ✓ EGIRES report on optimization in emergency preparedness and response with special focus on reference levels
 - ✓ Update of report on Short-term Countermeasures in Case of a Nuclear or Radiological Emergency (2003)
 - ✓ Survey on emergency management lessons learned

- Information System on Occupational Exposure (ISOE) Expert Group on Severe Accident Management (EG-SAM)
 - ✓ Lesson learned in management of occupational exposure in high radiation areas
- Other CRPPH Activities
 - ✓ Support to Japanese government workshops on decontamination and recovery and other technical topics



Summary of Ongoing NEA Activities

		TASK ONGOING	ACTIVITY
1.	Accident Management and Progression		
	a. TRANSITION: Review of on-site accident management programmes and procedures to address the transitional conduct of operations from normal to accident conditions to severe accident conditions, and to the implementation of protective measures under the emergency preparedness plans. This includes onsite and offsite decision-making processes.	✓	- CNRA TG Accident Management - WGHOFF Task on HP and Intervention under Extreme Conditions
	b. ACCIDENT PROGRESSION: Enhanced understanding of accident progression analyses methods and techniques.	✓	- OECD-NEA Fukushima SA Benchmark Project (BSAF) - WGAMA Task on Filtered Containment Venting
	c. HUMAN PERFORMANCE: Human and organisational performance issues under accident response conditions.	✓	- WGHOFF Task on HP under Extreme Conditions
	d. OFFSITE: Improvement of off-site emergency preparedness by sharing knowledge on core melt accident progression and source term quantification to improve off-site emergency procedures and technical tools.	✓	- CNRA TG Accident Management - WGAMA/CRPPH Task on Benchmarking of Fast Running FP Releases Tools - OECD-NEA Fukushima SA Benchmark Project (BSAF)
2.	Crisis or Emergency Communications (primary information exchange between CNRA and CRPPH)		
	a. PUBLIC: Communication with the public, media and other stakeholders.	✓	- CNRA WGPC Crisis Communication workshop 2012
	b. REGULATORS: Communication with the regulators in other countries and with international organisations, such as the International Atomic Energy Agency (IAEA) and the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE).	✓	- CNRA WGPC Crisis Communication workshop 2012
	c. ONSITE OFFSITE: Crisis communications between onsite and offsite emergency response organisations.		
3.	Reassessment of Defence-in-Depth	✓	- CNRA, CSNI DiD Policy Paper and Focused Discussions 2012-2013
4.	Evaluating the methodologies for defining and assessing initiating internal and external events, including coupled, as well as methodologies defining the design basis criteria	✓	- WGRISK Task on PSA for External Events including Earthquakes - WGIAGE Task on Metallic Component Margins under High Seismic Loads
5.	Reassessment of Operating Experience and prior opportunities to identify or address conditions that could challenge nuclear safety.		
	a. OP E: Evaluation of operating experience for events that may be precursors to future events that could challenge the safety of nuclear power plants given the insights from Fukushima.	✓	- CNRA WGOE/CSNI WGRISK Task on Pre-cursor events and PSA studies
	b. RESEARCH: Review and analysis of safety research relevant to the analysis of the accident.	✓	- Task on review and analysis of previous OECD-NEA joint international research projects
6.	Balancing deterministic and probabilistic approaches to regulatory decision making		
7.	Regulatory Infrastructure (non-cross committee that is planned and implemented following previously established processes)	✓	- NEA missions to Japan to support regulatory reviews
8.	Radiological Protection and Health Physics (non-cross committee that is planned and implemented following previously established processes)	✓	- EG-RPF assistance to ICRP reviews - WPNEM lessons learned reviews - EGRES update report on optimization in EP - WPNEM update to short term countermeasures report (2003) - ISOE review by EG-SAM on occupational exposure in SA
9.	Decontamination and recovery (onsite and offsite) (non-cross committee that is planned and implemented following previously established processes)	✓	- CRPPH ongoing task on commodities and food following nuclear accident - NEA missions to Japan to provide assistance in decontamination and recovery actions

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