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Challenges and Enhancements to Defence-in-Depth (DiD) in Light of the Fukushima Daiichi NPP Accident

Proceedings of a Joint CNRA/CSNI Workshop
Paris, France
5 June 2013

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Organisation de Coopération et de Développement Économiques
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NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

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NEA/CNRA/CSNI Joint Workshop on Challenges and Enhancements to Defence-in-Depth (DiD) in Light of the Fukushima Daiichi NPP Accident

Workshop Proceedings

OECD Conference Center, Paris - France
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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 34 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 31 countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, the Republic of Korea, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission also takes part in the work of the Agency.

The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes;
– to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information.

The NEA Data Bank provides nuclear data and computer program services for participating countries. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

The Committee on Nuclear Regulatory Activities (CNRA) shall be responsible for the programme of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. The Committee shall constitute a forum for the effective exchange of safety-relevant information and experience among regulatory organisations. To the extent appropriate, the Committee shall review developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them and assist in the development of a common understanding among member countries. In particular it shall review current management strategies and safety management practices and operating experiences at nuclear facilities with a view to disseminating lessons learnt. In accordance with the NEA Strategic Plan for 2011-2016 and the Joint CSNI/CNRA Strategic Plan and Mandates for 2011-2016, the Committee shall promote co-operation among member countries to use the feedback from experience to develop measures to ensure high standards of safety, to further enhance efficiency and effectiveness in the regulatory process and to maintain adequate infrastructure and competence in the nuclear safety field.

The Committee shall promote transparency of nuclear safety work and open public communication. The Committee shall maintain an oversight of all NEA work that may impinge on the development of effective and efficient regulation.

The Committee shall focus primarily on the regulatory aspects of existing power reactors, other nuclear installations and the construction of new power reactors; it may also consider the regulatory implications of new designs of power reactors and other types of nuclear installations. Furthermore it shall examine any other matters referred to it by the Steering Committee. The Committee shall collaborate with, and assist, as appropriate, other international organisations for co-operation among regulators and consider, upon request, issues raised by these organisations. The Committee shall organise its own activities. It may sponsor specialist meetings and working groups to further its objectives.

In implementing its programme the Committee shall establish co-operative mechanisms with the Committee on the Safety of Nuclear Installations in order to work with that Committee on matters of common interest, avoiding unnecessary duplications. The Committee shall also co-operate with the Committee on Radiation Protection and Public Health and the Radioactive Waste Management Committee on matters of common interest.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) shall be responsible for the activities of the Agency that support maintaining and advancing the scientific and technical knowledge base of the safety of nuclear installations, with the aim of implementing the NEA Strategic Plan for 2011-2016 and the Joint CSNI/CNRA Strategic Plan and Mandates for 2011-2016 in its field of competence.

The Committee shall constitute a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development and engineering, to its activities. It shall have regard to the exchange of information between member countries and safety R&D programmes of various sizes in order to keep all member countries involved in and abreast of developments in technical safety matters.

The Committee shall review the state of knowledge on important topics of nuclear safety science and techniques and of safety assessments, and ensure that operating experience is appropriately accounted for in its activities. It shall initiate and conduct programmes identified by these reviews and assessments in order to overcome discrepancies develop improvements and reach consensus on technical issues of common interest. It shall promote the co-ordination of work in different member countries that serve to maintain and enhance competence in nuclear safety matters, including the establishment of joint undertakings, and shall assist in the feedback of the results to participating organisations. The Committee shall ensure that valuable end-products of the technical reviews and analyses are produced and available to members in a timely manner.

The Committee shall focus primarily on the safety aspects of existing power reactors, other nuclear installations and the construction of new power reactors; it shall also consider the safety implications of scientific and technical developments of future reactor designs.

The Committee shall organise its own activities. Furthermore, it shall examine any other matters referred to it by the Steering Committee. It may sponsor specialist meetings and technical working groups to further its objectives. In implementing its programme the Committee shall establish co-operative mechanisms with the Committee on Nuclear Regulatory Activities in order to work with that Committee on matters of common interest, avoiding unnecessary duplications.

The Committee shall also co-operate with the Committee on Radiation Protection and Public Health, the Radioactive Waste Management Committee, the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle and the Nuclear Science Committee on matters of common interest.

FOREWORD

The mission of CNRA and CSNI is to assist member countries in ensuring adequate safety of existing and future nuclear installations in their respective territories, through maintaining and further developing the knowledge, competence and infrastructure needed to regulate and support the complete life cycle, including the design, construction, operation, decommissioning and waste management of nuclear reactors, fuel cycle facilities, and other nuclear installations.

Both Committees will strive for continually improving the effectiveness and harmonisation of regulatory practices and for facilitating consensus through joint undertakings and shared expertise.

An international Workshop on Challenges and Enhancements to Defence in Depth (DiD) in Light of the Fukushima Daiichi Accident was jointly organised by the NEA Committee on Nuclear Regulatory Activities (CNRA) and the NEA Committee on the Safety on Nuclear Installations (CSNI), with input from the NEA Committee on Radiation Protection and Public Health (CRPPH), on 5 June 2013 in Paris. About 100 participants from NEA member countries, India, the International Atomic Energy Agency (IAEA), the World Association of Nuclear Operators (WANO) and Eurelectric held in-depth discussions on the defence-in-depth concept and its implementation in the post-Fukushima context. They also considered additional steps to be taken at the national and international levels to address the challenges identified and to make further enhancements to nuclear safety, along with future NEA activities in support of these processes

Special acknowledgement is given to Dr. Jean-Christophe Niel, CNRA Chair and Dr. Brian Sheron, CSNI Chair who facilitated session discussions.

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1. INTRODUCTION

The concept of defence-in-depth (DiD) – of multiple levels of protection - has been developed and refined by the nuclear safety community over many years. The concept is based on the experience and practice of high hazard industry in general as well as developments within the nuclear industry.

The accident at the Fukushima Daiichi Nuclear Power Station in Japan on the 11th March 2011 demonstrated the importance of the concept of Defence-in-Depth (DiD), how these multiple levels of protection can operate and how some can be challenged. Just as with the nuclear accidents at Three Mile Island and Chernobyl and accidents from other industries (e.g. chemical, aerospace, oil and gas), the NEA felt it important that lessons learned are used to further develop the concept and implementation of Defence-in-Depth to help ensure and enhance the safe operation of nuclear power plants around the world.

The NEA has therefore looked at the concept and implementation of Defence-in-Depth and possible challenges and enhancements. It was noted that a great deal of interest has been shown in this area, particularly in the context of rare and extreme external events; including in combination.

Consideration has been given to the topic of Defence-in-Depth by the NEA’s policy level Steering Committee and by its standing technical committees – in particular by the Committee on Nuclear Regulatory Activities (CNRA) and the Committee on the Safety of Nuclear Installations (CSNI). A series of discussions during 2012 culminated in a decision by CNRA and CSNI to hold this Joint Workshop on Challenges and Enhancements to DiD in light of the Fukushima Daiichi Accident.

Attendance at the workshop included top-level representatives from nuclear regulatory agencies and technical support organisations of the NEA member countries and associated members, senior representatives from industry and senior executives of the NEA and IAEA.

The workshop provided an invaluable forum for the exchange of information and views on the concept, implementation and challenges to DiD. Speakers and participants discussed aspects of Defence-in-Depth including challenges, enhancements and possible developments to help ensure and improve the safe operation of nuclear power plants around the world.

The workshop consisted of four sessions: the first set the scene and gave an overview of DiD; the second focused on the concept, its evolution and some of the challenges and questions; the third session looked at DiD and External Events (including beyond design basis rare and extreme events) and their effect; and the fourth and final session considered and discussed the workshop’s findings and conclusions.

The main conclusions from the workshop were:

- The DiD concept remains valid, but strengthening may be needed.
- Implementation of DiD needs further work, in particular regarding external hazards.
- Additional guidance would be appropriate to help harmonise implementation.
- Improvements should focus not just on preventing accidents but also on mitigating the consequences of potential accidents should they occur.

The workshop also encouraged the NEA to meet the needs of its Members, and the broader international community, by preparing concise publications describing the state-of-the-art in DiD and commendable practices for implementation of DiD. It was felt that by working together with other international organisations, including the IAEA and INSAG, the documents prepared by the NEA could better inform and enhance guides and standards for use by the international community.

2. SUMMARY OF THE NEA/CNRA/CSNI JOINT WORKSHOP ON CHALLENGES AND ENHANCEMENTS TO DID IN LIGHT OF THE FUKUSHIMA DAIICHI ACCIDENT

2.1 An Overview of Defence in Depth

This first workshop session considered the core theme of Defence-in-Depth (DiD), including its history and detail. The session looked at key priorities for the application of the DiD concept within nuclear safety and identified important topics to pursue in order to strengthen the application of DiD. The session's underpinning message was summarised as "Safety does not happen by accident."

During the discussions in Session 1 it was recognised that for DiD:

- The concept is sound. It is fundamental to safety and well established in regulatory requirements and industry best practices.
- The accident at Fukushima Daiichi NPP has shown that low frequency high consequence events can breach all layers of DiD and that natural events that occur in combination are less well understood than many other low frequency events.
- DiD must work not just to prevent accidents but to also mitigate the consequences if an accident occurs.
- The nuclear industry has a long history of operational information that can be used to develop and improve DiD.
- The 16 NEA joint safety projects are progressing research with aspects related to Fukushima or support for DiD analyses – enhancing the underpinning knowledge associated with analysing severe accidents.
- NEA CSNI has 8 working tasks dedicated to developing the understanding of DiD philosophies and approaches within its working groups

In the discussions the following topics were identified as a priority for the industry to address when considering how to strengthen its implementation of DiD, :

- Demonstrating that DiD is applied systematically, rigorously, consistently and throughout the lifecycle of a nuclear facility (i.e. from design, through siting, construction, all phases of operation, as well as accident management, and emergency response, etc.).
- Recognising that all levels of DiD are important in providing adequate protection to the public and enhancing nuclear safety including Level 4 mitigation and Level 5 protective measures (Off-site emergency response and accident management) set down for offsite release.
- How to achieve adequate communication with those external to the industry (in a crisis and in general) including providing help and international sharing of knowledge, actively sharing insights, experiences and collective knowledge on implementation of DiD.

- How we demonstrate that we communicate appropriately (if not well) with each other.
- Recognising the significance of the NEA joint safety research projects in providing improved understanding of nuclear processes.

Some topics for further discussion, debate or further work, both within and outside the workshop, were also highlighted:

- What are the natural events that can occur in combination and how do those combinations occur.
- How to present the right interpretation and goals to help develop the levels of DiD in order to ensure there is sufficient independence between the levels and that they are of the quality needed to ensure that the public is adequately protected (including societal impacts).
- Getting the balance right between prevention and mitigation within DiD approaches.
- Ensuring uncertainty is adequately managed in DiD by developing appropriate margins or conservatisms as well as appropriate flexibility.
- Reducing uncertainties, via research, learning from experience and other work, to improve the strength of DiD measures.
- How to ensure people and organisations are trained and empowered to deliver their roles in DiD.
- Acknowledging that everyone working in the nuclear industry has a safety role whilst recognizing that the operator has the primary role for assuring safety. This is an integral part of the understanding, exhibition of, and maintenance of a strong safety culture for all individuals and within all organisations responsible for safety within the nuclear industry.
- Maintaining adequate communication with those external to the industry as well as with each other (presenting a transparent, clear and independent approach where appropriate and using technical experts and governments at the right moment).
- Coordinating improvement work with both national and international organisations to ensure enhancement and the avoidance of overlap.
- Avoiding social disruption in the event of an accident being realised – especially where return to an area post-accident is intended.

2.2 The Concept of Defence in Depth

One of the main outcomes and conclusions from the Session 2 discussions was that the concept of DiD remains sound, and that its application is the primary means of preventing and mitigating accidents. The philosophy of DiD was seen as important in dealing with unknowns, imperfections, and failures.

The general view was expressed by the workshop participants that the possibility of accidents should never be ruled out and that arrangements to deal with emergencies are always needed to protect people and society from the nuclear hazards.

The balance between the provision of high quality and independent measures of prevention and mitigation at each level of DiD was seen as fundamental to the philosophy of DiD. There is always the need to apply the principle of continuous improvement to the concept of DiD, and explore opportunities to refine further the philosophy. Some organisations are considering if it would be beneficial to consider DiD Level 3 in two parts to include postulated multiple failure events.

The end safety goal of DiD was viewed as important and seen by many to be extending to help better address societal and economic consequences. In this context the criterion of "practical elimination of large offsite releases" was discussed and it was agreed that although it was an important aspect there were some difficult questions to answer on what this means in practice. In the discussions that followed it was stressed that each level of DiD must be looked at as separate and independent from each other to the extent reasonably practicable – with the intention that failure of one system should not compromise the effectiveness of other layers. An emphasis was given for new nuclear power plants (NPPs) to be designed, sited, constructed, commissioned and operated with the objective of enhancing the effectiveness of the independence between all levels of DiD, in particular through diverse provisions and to provide an overall reinforcement of DiD. It was suggested that each level could be further strengthened and its independence enhanced by looking at each level periodically and implementing reasonably practical improvements. Furthermore it was suggested that the consideration of "good practices" from peer reviews could be useful in identifying practicable improvements to individual levels of DiD.

In the context of the end-goal, the non-radiological detriments of an accident (and potential or real offsite releases) were discussed (i.e., issues such as the health detriment in society caused by the stress created by accidents as well as the wider detrimental effects of countermeasures on health, disruption to the fabric of society and short/long term economic factors). It was agreed that these factors are of concern, and that although low radiation effects can be expected from the Fukushima Daiichi accident there are some big social disturbances which the radiological safety community will need to investigate and review. A key challenge that was identified was for the international radiological protection community to consider countermeasure advice in this larger perspective including social and economic disruption.

The importance of the implementation of DiD at all levels to give protection from and mitigate against potential internal and external hazards was seen by the workshop as key. Particularly in the context of the independence of the layers to mitigate and control accidents within the design basis (level 3 - for postulated single initiating events as well as for postulated multiple failure events) and beyond design basis accidents (e.g., core melt) at level 4. An example was given of the need for alternative and independent AC supplies so that if there is a failure of supplies as part of a single design basis event there will be alternatives available for dealing with any subsequent multiple failures at level 3 and then for potential beyond design basis events at level 4. An important factor here was seen as "flexibility" in availability of independent equipment to address the challenges at the various levels and maintain the operability of the necessary systems.

Reasonably achievable/practicable independence of arrangements was seen as a fundamental of the independence concept - such that failure at one level should not compromise the ability of the systems needed at another level to function effectively. The issue of common-mode failure was discussed and the challenge of checking independence of layers of protection against common failure - especially given some of the practicable limitations to absolute independence.

A common theme discussed was the need to maximise the safety margins against failure at all levels in DiD. There was general agreement that it was good practice to have margins available, and that the overall robustness of DiD could be increased by focusing on increasing the margins at each level. However, it was noted that the margins in radiation protection at level 5 are different – where realistic estimates are necessary in order to make balanced decisions on the best and most efficient options for protection (ie what are the most appropriate countermeasures of the range available).

The workshop spent some time discussing the cost involved in delivering the concept of DiD. The concepts of reasonable practicability and cost-benefit were considered as well as the need to get the safety whilst getting the benefit – although the workshop agreed that public health and safety should always be at the forefront.

The workshop considered safety culture to be a cross cutting issue that needs to be properly addressed, particularly on how it goes into the implementation of DiD at all levels. The question of what the accident at Fukushima Daiichi implies for the changes to safety culture was raised – including the effect of a society's general attitude and its safety culture norms.

Safety culture was recognised by the workshop as applying to everyone involved in nuclear safety – important for operators but also important for regulators who want confidence that operations are safe, where the regulators must continue to challenge the operators and the regulators own managers on all aspects.

Session 2 concluded that potential areas for further consideration and work include the need for:

- Guidance on implementation of DiD - especially on external and rare events;
- Development of end safety goal to better include more and further aspects of preventing social disruption;
- Guidance on application of Prevention and Mitigation at all levels of DiD;
- Guidance on independence of barriers between levels and margins within each level;
- Identifying and address new technical challenges – digital I&C, SFP, recovery, multi-unit, etc.
- Enhancing Safety Culture within the regulatory framework; and
- Clarifying end goal with regard to practically elimination.

Overall the session 2 presentations and discussions reinforced the message that the concept of DiD remains valid with the opportunity to further refine the concept; implementation is the key and that application of DiD is the primary means of preventing and mitigating accidents.

2.3 Defence in Depth - Focus on External Events

One of the key discussion points in Session 3 was around the use of PSA for external events. The workshop considered that there was a need to balance the importance of using probabilistic methods for ensuring that more probable events have been appropriately addressed in the safety case against the scarcity of data to support external event frequencies and how low-frequency events can start to lose their meaning. The overall conclusion was that further work is required on the application of PSA to external events.

A related area of discussion was on the appropriate level of hazard for external events, and what types of events should be considered. For example, should they just be natural or should man-initiated events be included. In some cases, it may be appropriate to choose a "bounding" type of event; e.g. a man-initiated explosion may bound pressure transients from natural events. At the same time, a bounding event may be so remotely possible, and cause such wide-spread devastation, that ensuring integrity of a nuclear plant may be neither feasible, nor warranted (e.g. very-low return frequency earthquake). International collaboration on processes for establishing levels for external hazards would be beneficial.

In establishing the response to a particular event, the meeting concluded that consideration must be given to the balance between prevention and mitigation. Prevention can be more attractive as it is within the control of design and operation, and prevention of off-site consequences is attractive when dealing with the public. Nevertheless, it is possible to postulate events that overwhelm safety processes and systems, and it can be argued that there will always be unanticipated events. In such cases, mitigative measures are required. The workshop concluded that this is an area that would benefit from best-practise guidance on establishing the balance between prevention and mitigation.

- The workshop discussions also raised questions around the consequences of external events on off-site infrastructure and people, in particular: How should a NPP properly account for failures of power and transportation systems (e.g. bridge failures)?
- Where off-site response capability is put in place, how to ensure that people and equipment can reach the site?
- What steps should or could be taken to ensure operational staff members are not overly distracted by concerns for family?

The workshop's discussions around these questions led to a further conclusion that the area of planning and execution of off-site response to a nuclear event would benefit from best-practise guidance on these topics.

3. SUMMARY OF THE WORSHOP'S FINDINGS

3.1 Results and Concluding Discussions

In the concluding discussions, it was noted that the accident at Fukushima Daiichi NPP highlighted the need for a research programme similar to the one that followed the accident at Three Mile Island NPP (TMI). The results of this research would, in a similar way to TMI research, enhance the understanding of accident response and better inform the implementation of DiD.

The workshop encouraged the NEA to meet the needs of its Members, and the broader international community, by preparing concise publications describing the state-of-the-art in DiD and commendable practices for implementation of DiD. It was felt that by working together with other international organisations, including the IAEA and INSAG, the documents prepared by the NEA could better inform and enhance guides and standards for use by the international community.

3.2 Summary of Recommendations for Further Work for NEA and its Members

The discussions in this closing session suggested future areas for the NEA's programme of work to consider in enhancing the understanding and implementation of Defence-in-Depth. Also from that work to feed its understanding into the IAEA workshop in October 2013 and its report on Fukushima due to be published in 2014.

Building on this and the insights gained from the discussions in earlier sessions the future key areas identified by the workshop included:

- Exploring what the DiD safety goal concept "practically eliminate large and early offsite releases" means and how is it implemented
- The importance of a strong safety culture and questioning attitude within both the operating and regulatory organizations
- The need to establish regulatory boundaries for consideration of external hazards within the context of the design bases and the implementation of DiD including establishing where the following may be incorporated:
  - ✓ Consequence on cost benefit analyses
  - ✓ Societal costs and economic consequences
- Being prepared to address the unknown and unexpected scenarios using safety margins and DiD concepts
- Common mode failures can breach all DiD barriers considering low probability high consequence events
- Independence and margins in the implementation of DiD
- Adequate margins within DiD Levels 1 – 4 to account for uncertainty and expand robustness
- Need to revisit and improve long term emergency preparedness with realism in Level 5 to improve efficient response and recovery
- Reinforcement of PSA for external hazards but consider the limitation of the methodology
- New approaches for safety management of external hazards individually and in combination
- Human interventions considering catastrophic external events effects on emergency response and recovery
- Technical issues to be addressed (i.e., Digital I&C, multi-unit impacts, Spent Fuel Ponds, long term Station Blackout, and loss of Ultimate Heat Sink, etc.)
- Detailed identification of additional safety research after the Fukushima NPP accident.

4. WORKSHOP CONCLUSIONS

The workshop's main conclusions, together with the recommendations for future work above, were seen as:

- The DiD concept remains valid, but strengthening may be needed.
- Implementation of DiD needs further work, in particular regarding external hazards.
- Additional guidance would be appropriate to help harmonise implementation.
- Improvements should focus not just on preventing accidents but also on mitigating the consequences of potential accidents should they occur.

5. PROGRAMME

NEA/CNRA/CSNI JOINT WORKSHOP ON CHALLENGES AND ENHANCEMENTS TO DID IN LIGHT OF THE FUKUSHIMA DAIICHI ACCIDENT OECD CONFERENCE CENTRE (ROOM CC12), PARIS, 5TH JUNE 2013 FINAL PROGRAMME

09:00 – 10:00 **Session 1: Chair – Mr. Luis Echávarri, NEA DG**

- Background and Objectives of Workshop
- Setting the Scene & Overview of DiD
  - Introduction to DiD,

Dr. Jean Christophe Niel, CNRA Chair
Dr. Brian Sheron, CSNI Chair
Dr. Ann McGarry, CRPPH Chair

- Priorities and challenges to DiD
- Guiding principles to enhance DiD

Keynote Speaker – **Mr. Bill Borchardt**, **NRC EDO**

10:00 – 12:30 **Session 2: Chair – Dr. Jean-Christophe Niel, CNRA Chair**

Invited Speakers:
Dr. Hans Wanner, ENSI DG, WENRA Chair
Dr. Youn Won Park, KINS President
Mr. Glenn Tracy, NRO Director, NRC

- Concept of DiD
  - DiD concept and evolution/development
  - Influence of Fukushima on End Goal of DiD (Social and economic aspects of accidents)
  - Balance between Prevention and Mitigation
  - Human/organizational/safety culture cross-cutting aspects
  - Common modes and independence of barriers
  - Realistic implementation of level 5: integration of political level in off-site emergency response

Discussion/Questions & Answers

12:30 – 14:00 **Lunch Break**

<u>14:00 – 14:20</u> Keynote Speaker – **Mr. Jacques Regaldo**, **WANO Chair**

<u>14:20 – 16:15</u> **Session 3: Chair – Dr. Brian Sheron, CSNI Chair**

Invited Speakers:
Dr. Toyoshi Fuketa, NRA Commissioner
Dr. Jacques Repussard, IRSN DG
Dr. Leonid Bolshov, IBRAE DG

- Implementation of DiD - Focus on External Events
    - Impact of rare and extreme external phenomena (e.g., beyond design basis earthquakes,storm surges, floods) on electrical power and ultimate heat sink
    - Approaches for considering rare and extreme external events in the design of the plant/dealing with cliff edge effects
    - Accounting for/accommodating unknowns – probabilistic/deterministic approaches

Discussion/Questions & Answers

<u>16:30 – 17:45</u> **Session 4: Chair – Mr. Luis Echávarri, NEA DG**

Keynote Speaker **– Mr. Pierre-Franck Chevet, ASN President**

- Results of NEA Workshop
  Panel session with Session Chairs plus Key speakers
    - Findings and Conclusions
    - Outcomes from each session and way forward for NEA PoW
    - NEA Product/Statement/Position on DiD

End of Workshop

<u>18:15 – 19:30</u> **Workshop Reception**

Nuclear Energy Agency

Defence-in-Depth

Mr. Luis E. Echávarri

Director-General
OECD Nuclear Energy Agency

Joint CNRA/CSNI Workshop on DiD
5 June 2013
Paris, France

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Nuclear Energy Agency

Presentation Outline

- Impact of lessons learnt from Fukushima Dai-ichi accident on Defence-in-Depth
- NEA activities to enhance safety after the Fukushima Dai-ichi Accident
- NEA Summary Report on activities after the Fukushima Dai-ichi Accident
- Key Messages

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Impact of lessons learnt from Fukushima Dai-ichi accident on Defence-in-Depth

- The layers of DiD worked well to face a severe earthquake
- However, low frequency but high consequence events (extreme tsunami) do occur and can breach essentially all layers of DiD
- Highlighted the importance of all levels of DiD – Level 5 emergency planning and protective measures provided adequate protection to the public
- Highlighted the importance of applying DiD rigorously and consistently during design, siting, construction, operation, accident management, and emergency response

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NEA Activities to Enhance Safety after Fukushima (1/2)

- **Committee on Nuclear Regulatory Activities (CNRA)**
  - ✓ Accident Management
  - ✓ Defence-in-Depth
  - ✓ Precursor events
  - ✓ Site selection and preparation
  - ✓ Crisis Communications
- **Committee on the Safety of Nuclear Installations (CSNI)**
  - ✓ Filtered containment venting
  - ✓ Hydrogen generation, transport and management
  - ✓ Spent fuel pools under loss of cooling accident conditions
  - ✓ Metallic component margins under high seismic loads
  - ✓ Human performance under extreme conditions
  - ✓ Workshop on natural external events including earthquake
  - ✓ Workshop on the robustness of electrical systems
  - ✓ Fast-running software tools for the estimation of fission product releases during accidents at nuclear power plants

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NEA Activities to Enhance Safety after Fukushima (2/2)

- **BSAF** - Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station Project
- **Committee on Radiation Protection and Public Health (CRPPH)**
  - ✓ Criteria for international trade in food and goods
  - ✓ Policies on returning to evacuated areas, cleanup, waste management
  - ✓ Workshops on decontamination and stakeholder involvement
  - ✓ Emergency management communications and ICRP recommendations
  - ✓ Collecting information on management of occupational exposure in high radiation areas and for severe accident management

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NEA Summary Report on Fukushima Activities

- Prepared with input from:
  - Results of a survey of NEA members and associated countries
  - Coordinated by the CNRA Senior-level Task Group on Fukushima
  - CNRA, CSNI, CRPPH and NEA technical secretariat
- Report is with CNRA, CSNI, and CRPPH for review
- Tri-Bureau Meeting 4 June 2013
- Seeking CNRA approval in June 2013
- To be published for public release shortly thereafter
- To be provided to IAEA as an input to their Fukushima report to be issued late 2014

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Key Messages

- ✓ Assurance of Safety
- ✓ Shared Responsibilities
- ✓ International Cooperation and NEA contribution
- ✓ The Human and Organisational Element
- ✓ Defence-in-Depth (DiD)
- ✓ Crisis Communication
- ✓ Stakeholder Engagement
- ✓ International Aspects of Emergency Preparedness
- ✓ Trade and Transportation Issues
- ✓ Research and Development

DiD Workshop – 5 June 2013 — Organisation for Economic Co-operation and Development — 7

OECD BETTER POLICIES FOR BETTER LIVES — Nuclear Energy Agency — NEA NUCLEAR ENERGY AGENCY

Outcomes from the Workshop

- Encourage to share your insights and experiences
- Plentiful time reserved for questions and discussions
- Discussions results to provide guidance to CNRA and CSNI on enhancing Defence-in-Depth
- Active participation and contributions will assure NEA Member countries can benefit from your collective knowledge and experience to improve the implementation of Defence-in-Depth

DiD Workshop – 5 June 2013 — Organisation for Economic Co-operation and Development — 8


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BETTER POLICIES FOR BETTER LIVES
Nuclear Energy Agency
NEA
NUCLEAR ENERGY AGENCY
Thank you for your attention
The OECD Nuclear Energy Agency
http://www.oecd-nea.org/
DiD Workshop – 5 June 2013
Organisation for Economic Co-operation and Development
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Highlights From the Work of CNRA on the Activities, Priorities and Challenges Related to DiD

Dr Jean-Christophe Niel, CNRA Chair
Director General, ASN, France

OECD Conference Centre, Paris, 5th June 2013

1

Committee on Nuclear Regulatory Activities (CNRA)
NEA
NEA/CNRA/CSNI Joint Workshop
Challenges and Enhancements to DiD
In the Light of the Fukushima Daiichi Accident
OECD

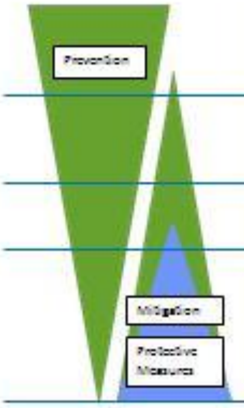
Activities, Priorities and Challenges related to DiD

1. Concept and implementation
2. Licensee and Regulator in DID
3. Prevention and mitigation
4. DID - Design and Site Specific Aspects,
5. Harmonisation
6. Way forward

2

Concept and implementation

- DiD based on a concept of different barriers which are independent.
- Extended to concept of different levels



Level 1	Normal Operation	Conservative design and high quality in construction and operation
Level 2	Operational Occurences	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

3

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In the Light of the Fukushima Daiichi Accident
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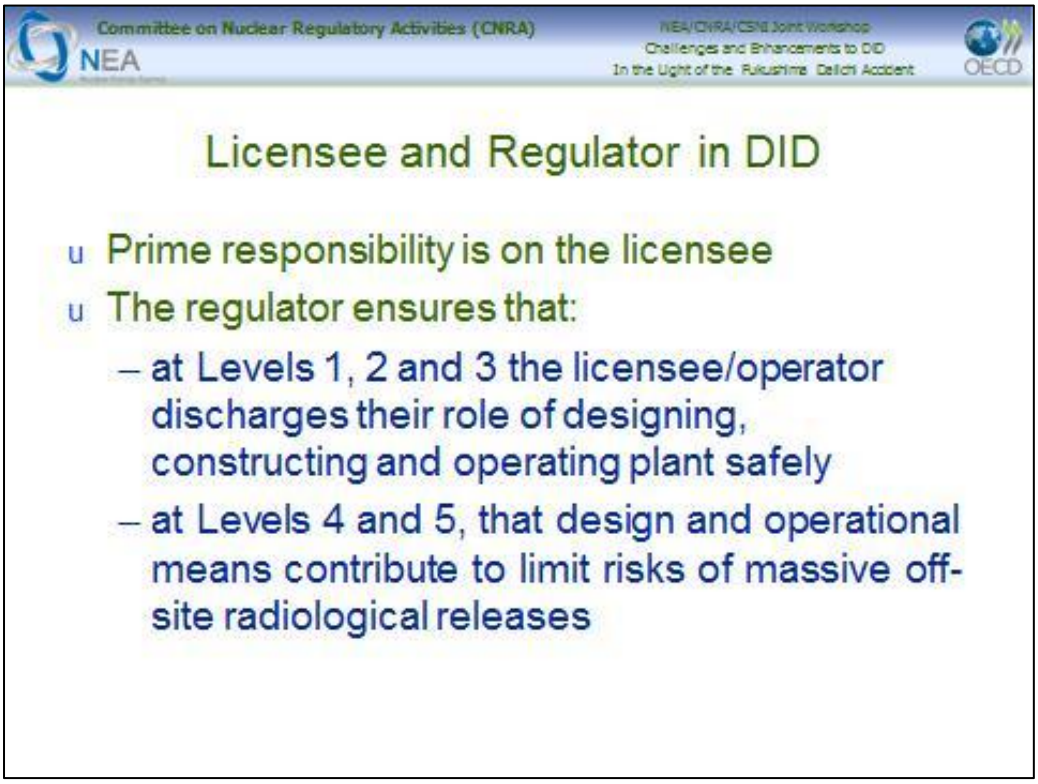
Concept and implementation

- Importance of independence when implementing DID at different levels
- After Fukushima concept remains valid:
  - Implementation to be done more consistently
  - On going discussions on the end safety goal
    - Initiatives are being considered to look at the overall end safety goal considering societal impacts.

4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In the Light of the Fukushima Daiichi Accident
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Licensee and Regulator in DID
Prime responsibility is on the licensee
The regulator ensures that:
– at Levels 1, 2 and 3 the licensee/operator discharges their role of designing, constructing and operating plant safely
– at Levels 4 and 5, that design and operational means contribute to limit risks of massive off-site radiological releases


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Prevention and Mitigation
importance of prevention AND mitigation, especially for rare events
end safety goal to be extending to include prevention severe accidents, significant releases of radioactive materials and societal disruption


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In the Light of the Fukushima Daiichi Accident
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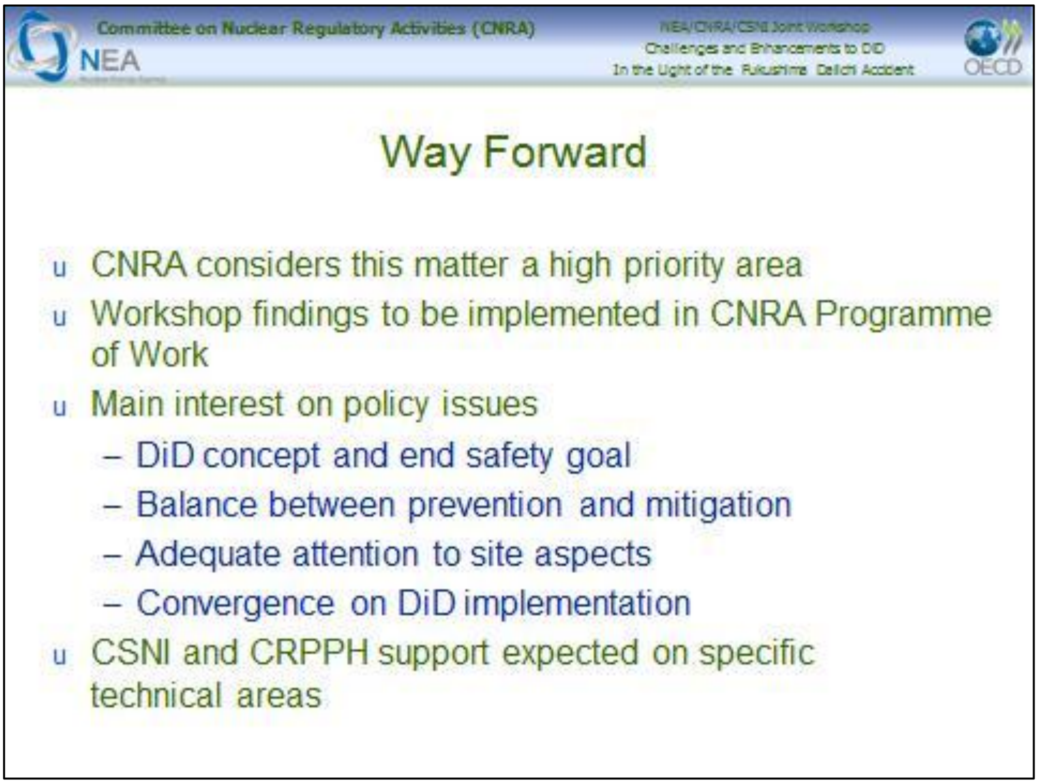
DID - Design and Site Specific Aspects,
DID concept applies to :
– the design of the plant
– the site characteristics (ie including other reactors or hazards nearby)
Following Fukushima, rare external site specific hazards should be:
– assessed
– addressed at all levels of DiD
Uncertainty and safety margins to further considered in DID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Way Forward
CNRA considers this matter a high priority area
Workshop findings to be implemented in CNRA Programme of Work
Main interest on policy issues
– DiD concept and end safety goal
– Balance between prevention and mitigation
– Adequate attention to site aspects
– Convergence on DiD implementation
CSNI and CRPPH support expected on specific technical areas

NEA/CNRA/CSNI JOINT WORKSHOP ON CHALLENGES AND ENHANCEMENTS TO DID IN LIGHT OF THE FUKUSHIMA DAIICHI ACCIDENT JUNE 5, 2013

Session 1 – Panelist: Brian Sheron, CSNI Chair
Topic: Defense in Depth and External Events

Good morning,

I would like to talk briefly on the topic of defense in depth and external events.

First, I'd like to discuss how I think of defense-in-depth. We all agree that nuclear power plants are designed and operated to obtain a very high level of safety. Unfortunately, we can't quantify or predict everything that could occur at a plant. Therefore, we incorporate margins into all aspects of the plant – design, construction, and operation.

This margin is an aspect of defense-in-depth. Defense-in-depth has been defined as an element in NRC's safety philosophy that is used to address uncertainty by employing successive measures, including safety margins, to prevent or mitigate damage if a malfunction, an accident, or a naturally or intentionally caused event occurs. The key is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures. This will ensure that no single layer—no matter how robust—is exclusively relied upon. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse safety functions, design margins, and emergency response measures.

I often refer to defense-in-depth as a three-pronged approach. First, you must have a high-quality, highly reliable design. Second, you have to recognize that failure may still occur despite attempts to prevent it through a highly reliable design. For this reason, systems are designed to cope with and mitigate failures. Finally, it's prudent to acknowledge that since it is impossible to identify everything that can go wrong, we must design in margin to accommodate the unforeseen through areas such as structural design margins and emergency preparedness, to name only a few.

Although nuclear power plant regulators are always striving for a high level of safety, it must be balanced with assuring adequate, but not absolute, protection of public health and safety. For example, in the United States, the U.S. Nuclear Regulatory Commission has established safety goals that are expressed through the Commission's policy regarding the acceptable level of radiological risk from nuclear plant operation.

Because the actual safety goals are difficult and expensive to evaluate and measure, the Commission created surrogate goals related to a core melt and large early release frequency probability. We believe it is highly likely that meeting the surrogate goals ensures that the safety goals are met. Probabilistic risk assessment (or PRA) is used to help determine if these surrogate goals have been met.

One of the difficulties in implementing a defense-in-depth design approach is that the appropriate balance between prevention and mitigation is not clearly defined. Obviously, a licensee could, for example, demonstrate that the U.S. surrogate safety goals have been met by providing for only preventative measures. Similarly, one could also envision the ability to meet the surrogate safety goals with only mitigative measures. One of the biggest difficulties is deciding what is the right balance between prevention and mitigation when it comes to defense-in-depth.

Another aspect of defense-in-depth that is difficult to deal with is economic consequences. If measures such as timely evacuation demonstrate that safety goals are met, how should any economic consequences be dealt with?

These are two important questions that I think are still subject to debate.

Worldwide, nuclear power plants have logged about 15,000 cumulative reactor years of operation. These years of accumulated operational experience, combined with risk insights, have resulted in plant improvements that reduce the risk from internal events to risk levels comparable to or below those from external events. With this in mind, the United States is looking at whether defense-in-depth goes far enough for external events.

As an example, let’s take the recent accident at Fukushima Daiichi and its impact on defense in depth. Fukushima was a significant beyond design-basis accident that led to significant core melting of three reactors. However, no indication exists thus far that the concept of defense-in-depth is flawed. Following the earthquake and subsequent loss of offsite power, the units that were operating shut down and the diesel generators started to provide electrical power to the plant. It wasn’t until the tsunami hit the plant that any unexpected issues emerged. As we know now, the accident at Fukushima was driven by external events—seismic activity and the resultant tsunami occurrence. It’s apparent that the tsunami protection at the plant was insufficient for what occurred. Consequently, the nuclear industry and the regulators need to take a harder look at whether there is enough defense-in-depth for external events. This, in turn, means we also need to take a harder look at how well we understand the magnitude and likelihood of external events, as well as their related uncertainties.

I would briefly like to talk about some ongoing CSNI activities. The CSNI has undertaken several activities related to external events, some of which are a direct result of the accident at Fukushima Daiichi. Following the process established through the Tri-Bureau, the CSNI has undertaken eight activities to address technical issues from the Fukushima Daiichi NPS accident. These activities include:

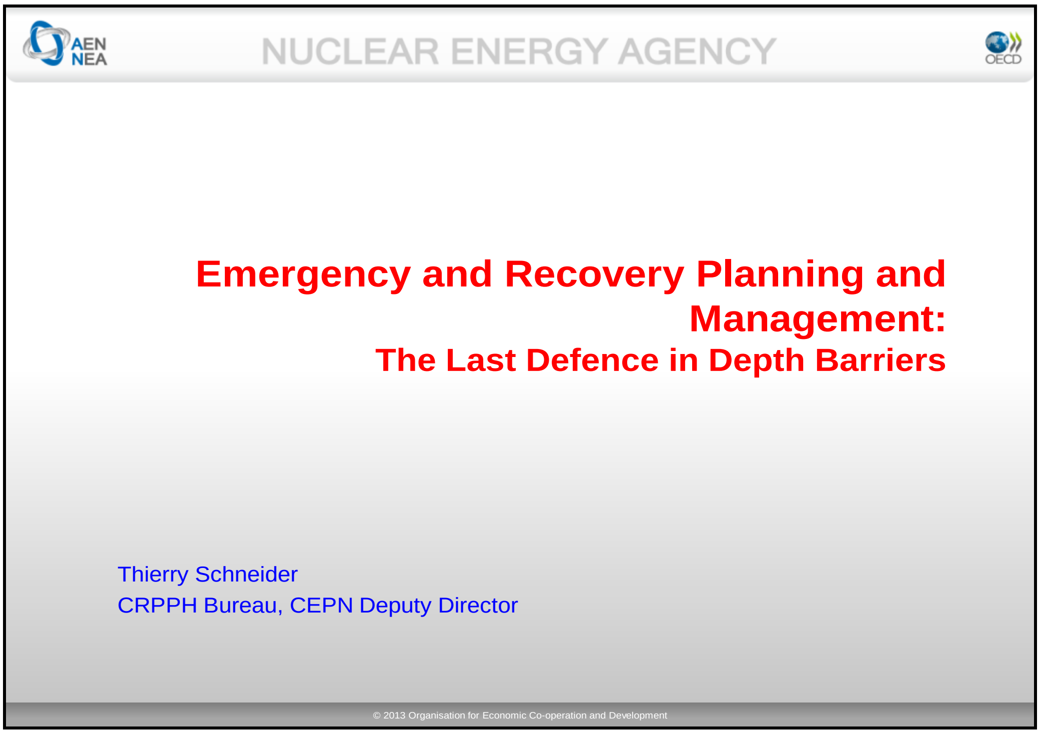
- a Technical Opinion Paper on Filtered Containment Venting (WGAMA),
- a Status Report on Hydrogen Generation, Transport and Management (WGAMA),
- a Status Report on Spent Fuel Pool under Loss of Cooling Accident Conditions (WGAMA and WGFS),
- Metallic Component Margins under High Seismic Loads (MECOS) (WGIAGE),
- Human Performance and Intervention under Extreme Conditions (WGHOF),
- a Workshop on the Robustness of Electrical Systems of NPPs in Light of the Fukushima Daiichi Accident (Task Group),
- an international benchmarking project of fast-running software tools for the estimation of fission product releases during accidents at nuclear power plants (WGAMA), and finally

– a CSNI workshop on Natural External Events including Earthquake (WGRISK). The output of the last project will be a report on commendable practices and experience gathered on PSA methodologies for natural external events.

Fifteen on-going joint research projects (experimental or database projects) address, to varying degrees, issues from Fukushima and may gain insights as recovery and decommissioning activities proceed.

However, CSNI is not presently undertaking any action to better understand, quantify, and calculate the effects of naturally occurring external events. Since risk analyses indicate this is now becoming an important contributor to risk, perhaps it is time for CSNI to consider additional work on naturally occurring external events. This will be discussed at the forthcoming CSNI meeting Thursday and Friday.

I hope this discussion sets the stage for Session 3 this afternoon where we will hear from Japan, France, and Russia on the implementation of defense-in-depth with a focus on external events.


AEN
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Emergency and Recovery Planning and Management:
The Last Defence in Depth Barriers
Thierry Schneider
CRPPH Bureau, CEPN Deputy Director
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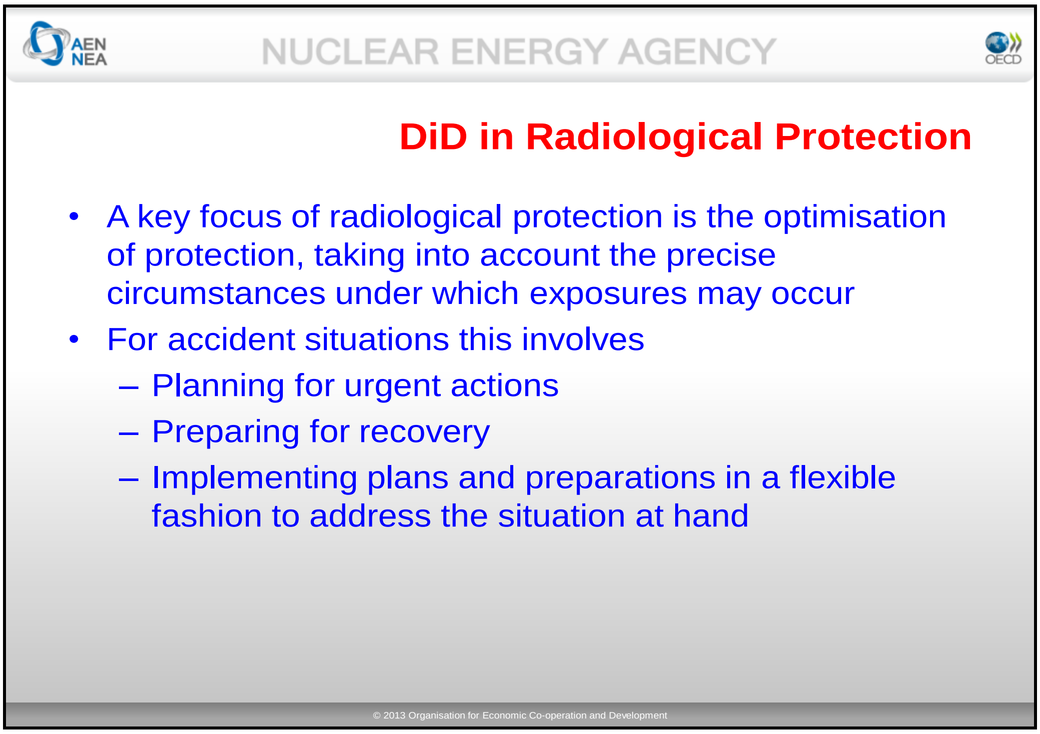
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DiD in Radiological Protection
• A key focus of radiological protection is the optimisation of protection, taking into account the precise circumstances under which exposures may occur
• For accident situations this involves
– Planning for urgent actions
– Preparing for recovery
– Implementing plans and preparations in a flexible fashion to address the situation at hand
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CRPPH Emergency and Recovery Management Experience

- The CRPPH has focused on emergency management since the TMI accident
  - 45 emergency management publications
  - 8 large-scale international nuclear emergency management exercises since 1992
- The CRPPH has also focused on stakeholder involvement and recovery management since the early 1990s: RP science at the service of society
  - 23 publications
  - 13 international workshops
- Active participation in the ICRP stakeholder dialogue meetings in Fukushima

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The 71st CRPPH Meeting

- Results of a survey of national emergency management issues and lessons post-Fukushima were reported
- A one-half-day topical session on Emergency Management

- Results of a survey of national recovery management issues and lessons post-Fukushima were reported
- A one-half-day topical session on Recovery Management

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DiD Emergency Management Issues

- Communications (public, among national authorities, and between countries) was seen as important but posed problems. Improvements, in particular between countries and different national authorities, are warranted.
- Strategies for monitoring incoming products existed in all countries, but there was no common approach. Existing criteria were not directly applicable to the Fukushima situation.
- Technical assessments of early, uncertain accident situations are important to decision making. With insufficient information, there is a need to better share inter-country technical communications, to uniformly understand decisional information.

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Possible EM Areas for CRPPH Activities

- Communication plans
- Monitoring of goods
- Technical Assessment tools
- Review of emergency planning zones
- Alignment of protective actions

Coordinate with IAEA to avoid overlap

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DiD Recovery Management Issues

- Nationally, there has been much less focus on recovery planning than on emergency planning
- Return to evacuated areas was seen as needing pre-determined criteria as a starting point
- There is a need to clarify the relationship and to bridge the gap between self-help actions initiated by stakeholders, and support activities supplied by government authorities and radiation protection experts.
- Survey responses viewed stakeholder involvement in recovery as decision-aiding with regard to national or regional decisions
- Much of the provisional aid seems to be focused on providing information to the affected populations, but communication and dialogue remain as issues for governments

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Possible RM Areas for CRPPH Activities

Discussion of national approaches to development of and stakeholder involvement in decisions on:

- returning to evacuated areas
- clean-up criteria
- waste temporary storage and disposal (with RWMC)
- communication strategies
- support for self-help initiatives

AEN NEA NUCLEAR ENERGY AGENCY OECD

Conclusions

- The CRPPH will work with the IAEA to develop a programme of work in the area of emergency management that is complimentary to other, ongoing work
- The INEX 5 exercise, provisionally planned for the 2014 / 2015 timeframe, will build on experience from Fukushima and test new approaches
- The CRPPH will continue its work on Science and Values in RP decision making, and will work on aspects of returning to and living in long-term contaminated areas
- The CRPPH will continue to support the ICRP Dialogue

REMARKS BY BILL BORCHARDT
NRC EXECUTIVE DIRECTOR FOR OPERATIONS
NEA/CNRA/CSNI JOINT WORKSHOP
JUNE 5, 2013

Thank you for inviting me to speak today on the important topic of Defense in Depth.

I cannot think of any concept that has been more central to the design and operation of nuclear power plants than Defense in Depth. While I think that it's proper to acknowledge its positive contribution to safety, we must also acknowledge that the way it has been implemented has not prevented all serious events from occurring.

Why do we need a Defense in Depth concept and how do we foster an environment where it can be effective? In short, we need Defense in Depth because we have imperfect knowledge, the consequences for serious events are potentially very high, failures do occur, and all human activities are inherently imperfect. I believe that Defense in Depth requires, among other things, a questioning attitude, a resistance to complacency, and a commitment to continuous learning - - in short, a strong safety culture.

Now that we are in the process of evaluating and implementing the lessons from the Fukushima accident, it is important that we take a critical look at the Defense in Depth philosophy and how we have implemented it. Today's workshop is intended to help advance the discussion, currently ongoing within both the technical committees of NEA and the broader international community, that is seeking to address the future of Defense in Depth following the March 11, 2011, accident at Fukushima-Dai'ichi. This work is supportive of the International Atomic Energy Agency Action Plan and will contribute to IAEA's work program. The results of our discussions today will also help frame the path forward for additional NEA work on this critical topic.

History

Our job as regulators is to ensure public health and safety – to provide "adequate protection" – in the civilian use of nuclear materials. The use of Defense in Depth has been fundamental to safety for over a half century, and I believe that it will continue to play an important role well into the future.

Historically, Defense in Depth was more often thought of in a military or information security context. However, Defense in Depth is also the name given to a safety strategy that began to take hold following the passage of the Atomic Energy Act in the United States in 1954. In order to achieve the goal of adequate protection in the civilian use of this newly emerging technology, it was considered appropriate to utilize conservatisms to compensate for the unknowns that confronted both the fledgling industry and its regulators. Key elements of the approach at that time addressed the spectrum from facility design through facility operation, and included numerous elements such as accident prevention through conservative design, installation of redundant safety systems, the use of containment structures, accident management programs to reduce the likelihood of uncontrolled radionuclide releases during accidents, siting considerations, and emergency plans. Over the past decades, the scope, range and prominence of Defense in Depth has grown so that today it reaches into every aspect of the technology. We have applied the Defense in Depth principles to 1) preclude events that challenge safety; but even if an event occurs; 2) prevent the event from leading to core damage; but even if core damage occurs; 3) ensure that there is a way to contain the radioactive material; but even if the containment doesn't work that 4) emergency plans exist to protect the public. During that time, the details of these various elements of Defense in Depth, and the balance across them, has evolved based on the knowledge and experience that was gained as plants were licensed, emerging safety issues were addressed, operating experience was obtained, accidents occurred (and their impacts were mitigated), and safety research was conducted. Defense in Depth has served us well over the years.

As we all well know, Defense in Depth is intended to deal with uncertainty; in particular the uncertainties associated with how accidents at nuclear power plants progress. While its implementation may vary from country to country, the same basic principles are applied. The philosophy of Defense in Depth relies on multiple layers of defense (i.e., successive compensatory measures) to prevent or mitigate the effects of a malfunction, accident, or other event. Simply stated, there are three major components to Defense in Depth: 1) a high-quality, highly reliable design; 2) a recognition that despite good design, failures could still occur and, therefore, we need to include systems to cope with and mitigate such potential failures; and 3) acknowledgement that we cannot foresee everything that can go wrong, so we need to incorporate sufficient margin to accommodate the unforeseen. I think that, with the passage of time, our research efforts conducted over the years, and with events such as Three Mile Island and 9/11, we have developed a greater understanding and appreciation for these three key components of Defense in Depth.

As we confronted events such as the accident at Three Mile Island and the terrorist attacks of 9/11, we sought to learn from what happened and strengthen Defense in Depth. Following the TMI accident, a number of immediate corrective actions were taken. In addition, a Lessons Learned Task Force made a number of recommendations for changes spanning several fundamental aspects of basic safety policy for nuclear power plants in the areas of plant design, plant operations, and regulatory processes. A subsequent action plan was developed to provide a comprehensive and integrated plan for the actions judged necessary by the NRC staff to correct or improve the regulation and operation of nuclear facilities based on the experience at TMI. A number of these were subsequently approved by the Commission for implementation. The principle conclusion regarding the accident was that, although it stemmed from many sources, the most important lessons learned fell into a general area designated as operational safety that focused on the human element and its fundamental role in accident prevention and response.

Similarly, following the terrorist events of 9/11, security measures and practices at nuclear facilities – as well as a wide range of other facilities, activities, and practices – came under close scrutiny. The result was significant physical and other enhancements to the design and operation of nuclear plants that strengthened Defense in Depth against malevolent behavior.

Lessons learned from major events have tended to add detailed design and operational requirements based upon the specific event, however, these improvements have not reduced the importance of the defense in depth philosophy. Defense in depth remains vitally important in helping us to be prepared for the unknown, the unexpected, and the imperfection of any human activity.

Today

Today, Defense in Depth permeates all aspects of nuclear technology, and many traditional elements of the Defense in Depth strategy are now simply well-accepted principles and practices, memorialized in regulatory programs and industry best practices. Some would argue that our improved capability to analyze nuclear power plants as integrated systems may mean Defense in Depth is no longer as important as it once was. However, notwithstanding the maturity of the nuclear power industry, safety issues continue to emerge regarding facility design, construction, and operation, and there continue to be uncertainties.

At the same time, risk insights have become an increasingly important element of our decision-making. Risk assessment enhances our efforts to better analyze plants in searching for potential vulnerabilities. While risk insights are a valuable resource, it is the NRC's view that risk considerations do not replace, but rather compliment, the traditional use of Defense in Depth. Defense in Depth remains an effective means for compensating for any limits in our ability to understand risks posed by nuclear power plants.

In addition, the use of new approaches, such as passive designs and digital instrumentation & control, continue to present challenges to us in crafting appropriate approaches for ensuring safety. But our traditional reliance on Defense in Depth remains key to our continuing success in achieving our safety mission. As operating experience demonstrates, the need for Defense in Depth remains paramount. Indeed, Fukushima reinforces for us the realization that we must be prepared to protect against low probability/high consequence events that even decades of experience cannot prepare us for.

On the international level, Defense in Depth is used by regulators globally. Key guidance on Defense in Depth is provided in the IAEA International Nuclear Safety Advisory Group's 1988 INSAG 3 report, which provided us with the five levels of Defense in Depth, and the 1996 INSAG-10 report, which reviews the objectives, strategy, implementation, and possible future development of the concept of defense in depth. These concepts have been recently incorporated into IAEA Safety Standard SSR-2/1, "Safety of Nuclear Power Plants: Design."

The philosophy of Defense in Depth has held up well over the decades. In the U.S. we have come through the events of TMI and 9/11 with the belief that the concept is still sound. However, as a result of these and other events, we have had to give the implementation of Defense in Depth additional thought and selected expansion to maintain its robustness and ability to account for challenges previously not considered and fully addressed. While I believe the philosophy of Defense in Depth continues to be sound, the events at Fukushima represent the most recent major "test" for Defense in Depth, and an opportunity to further refine our approach to Defense in Depth implementation.

Challenges in Light of Fukushima

Fukushima was an extreme, beyond-design-basis event – exactly the kind of uncertainty that Defense in Depth exists to address. This accident highlighted not only the importance of multiple layers of defense, but also presented a number of new technical challenges for us to consider in implementing Defense in Depth: extreme natural events, maintaining spent fuel pool cooling capability, and loss of offsite power, among others. We need to use this latest challenge to strengthen Defense in Depth for the next challenge that inevitably will follow.

The earthquake and tsunami that occurred at Fukushima are obviously not a realistic specific threat to all nuclear facilities around the world, but, as a result of Fukushima, every site and every facility must now more fully consider what possible extreme external events (and accompanying range of effects) are threats to the safe operation of their specific facility.

From the foundation of INSAG-10, the IAEA Action Plan on Fukushima, and many related IAEA and NEA efforts, we can contribute to strengthening Defense in Depth in ways that will continue to ensure we uphold our commitment to safety.

As I close, I offer a few ideas for further discussion:

- First, do we need to adjust the balance between prevention and mitigation features within our Defense in Depth approach? Prevention (the traditional focus of Defense in Depth from the time of the US Atomic Energy Commission) has been emphasized historically to the extent that some claimed that serious events were so unlikely to occur that we didn't need to do more in the mitigation area. Recent experience teaches us that we need to better account for low probability/high consequence events. Further, we must consider the role of the regulator in prevention versus the role of the regulator in mitigation.

- Second, this is an opportunity for us to reflect on the critical importance of a strong safety culture and a questioning attitude among regulators and the nuclear workforce that are essential to ensuring Defense in Depth.

- Third, and related to safety culture, as we did at TMI, we need to look closely at the role of the facility site operators. Do they have the independent authority, experience, training, and other resources necessary to fulfill their important role in Defense in Depth to prevent accidents and mitigate their onsite and offsite effects?

Closing

"Safety doesn't happen by accident." Defense in Depth is a good example of a philosophy and a way of acting that helps us assure safety, not accidentally, but through conscientious focus on a goal and how best to achieve it.

I look forward to our discussions today. I hope that by the end of the day we have agreed upon specific findings that can guide future NEA and other collaborative international efforts to promote enhancements to Defense in Depth.Thank you.

Western European
WENRA
Nuclear Regulators Association

WENRA
Defence-in-Depth for new NPP designs

NEA/CNRA/CSNI Joint Workshop on Challenges and Enhancements to DiD in light of the Fukushima Dai-ichi Accident
OECD Conference Centre, Paris, 5 June 2013
Hans Wanner, WENRA Chairman

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WENRA Defence-in-Depth

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WENRA

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WENRA

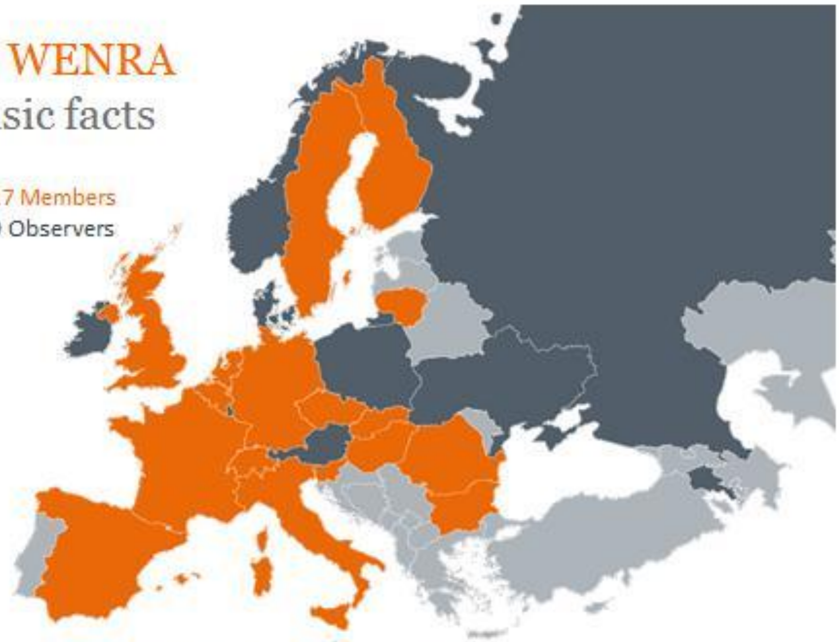
01 WENRA
Basic facts

- Association of the Heads of nuclear regulatory authorities of the EU countries with NPP and Switzerland
- Original Terms of Reference signed on 4 February 1999
  - Revised on 14 March 2003
  - Revised on 26 March 2010

www.wenra.org

01 WENRA
Basic facts

- 17 Members
- 9 Observers



5 NEA/CNRA/CSNI Workshop on Defence-in-Depth, Paris, 5 June 2013 | Hans Wanner, WENRA Chairman

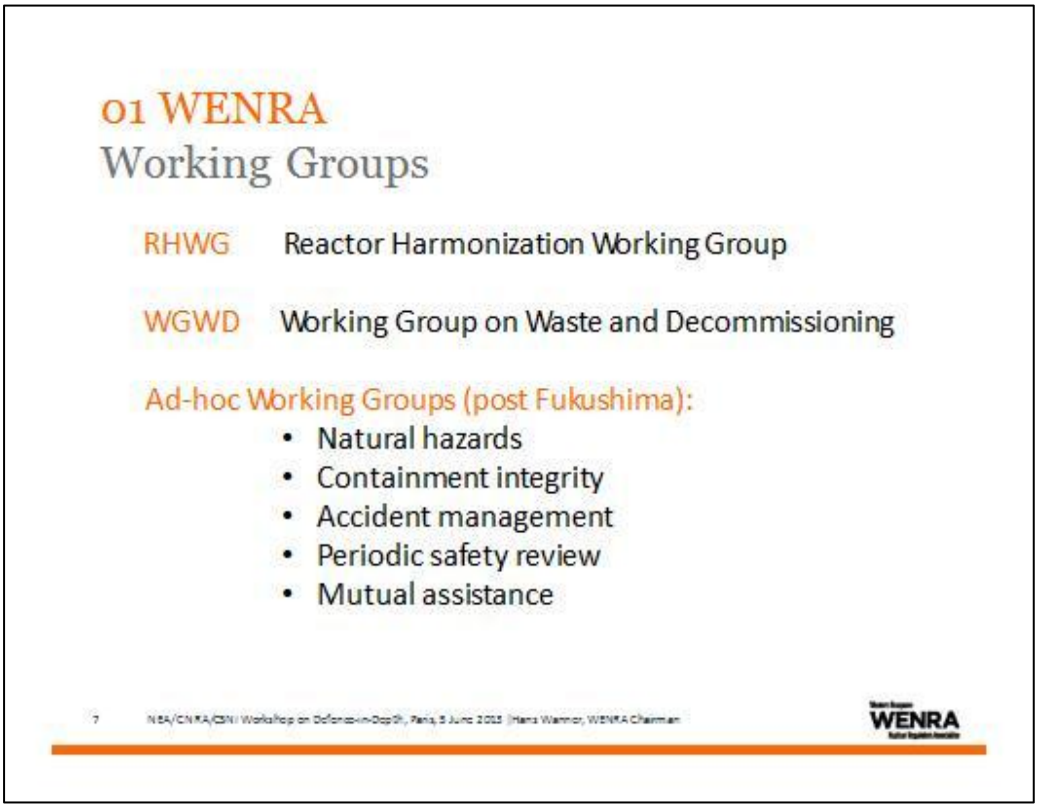
WENRA

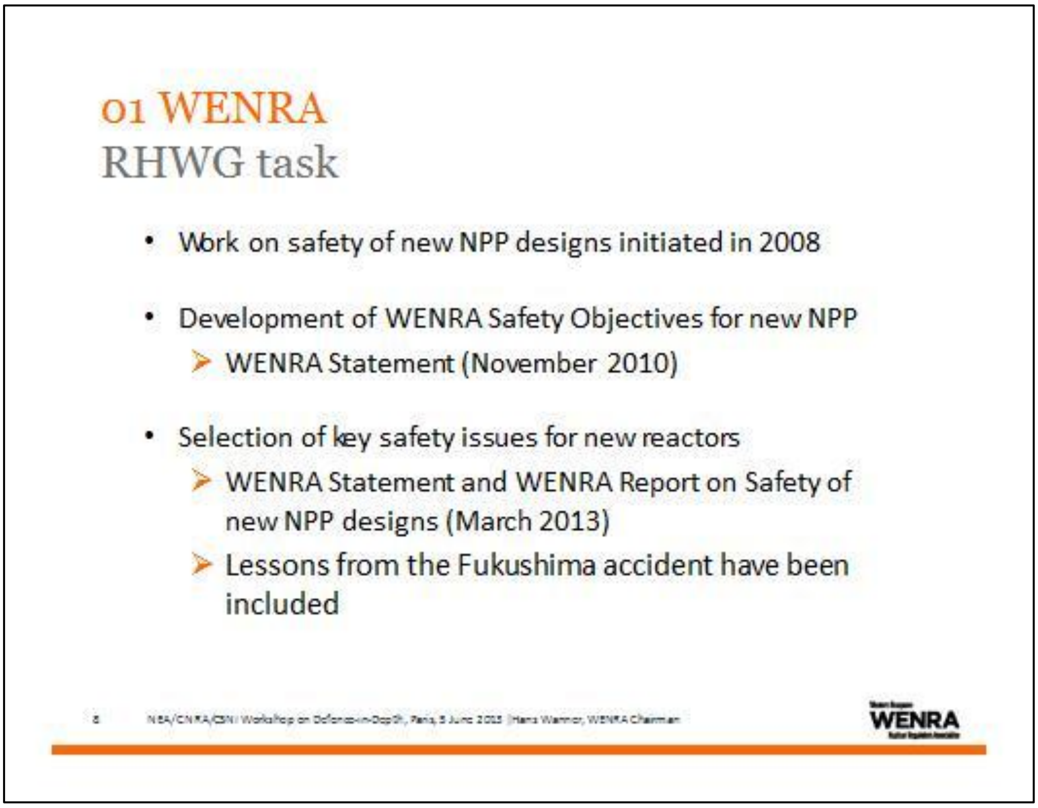
01 WENRA
Policy Statements

- Commitment to continuous improvement of nuclear safety
- Nuclear safety and radiation protection are the prime responsibility of the operator
- Common approach to nuclear safety

6 NEA/CNRA/CSNI Workshop on Defence-in-Depth, Paris, 5 June 2013 | Hans Wanner, WENRA Chairman

WENRA


01 WENRA
Working Groups
RHWG Reactor Harmonization Working Group
WGWD Working Group on Waste and Decommissioning
Ad-hoc Working Groups (post Fukushima):
• Natural hazards
• Containment integrity
• Accident management
• Periodic safety review
• Mutual assistance
7
WENRA


01 WENRA
RHWG task
• Work on safety of new NPP designs initiated in 2008
• Development of WENRA Safety Objectives for new NPP
➢ WENRA Statement (November 2010)
• Selection of key safety issues for new reactors
➢ WENRA Statement and WENRA Report on Safety of new NPP designs (March 2013)
➢ Lessons from the Fukushima accident have been included
8
WENRA

01 WENRA
Defence-in-Depth

Defence-in-Depth is the principle safety strategy for new and existing NPP before and after Fukushima.

This is reflected by:

- Safety Reference Levels for existing reactors (WENRA Report, 2008)
- Safety Objectives for new reactors (WENRA Report, 2009)
- Safety of new NPP designs (WENRA Report, 2013)

02
Defence-in-Depth for new NPP designs

02 Defence-in-Depth for new NPP designs
WENRA Safety Objectives for new NPPs

"The primary means of preventing accidents in a nuclear power plant and mitigating the consequences of accidents is the application of the concept of Defence-in-Depth (DiD). This concept should be applied to all safety related activities, whether organizational, behavioural or design related, and whether in full power, low power or various shutdown states. This is to ensure that all safety related activities are subject to independent layers of provisions, [...]"

WENRA RHWG Report, Safety of new NPP designs, March 2013

02 Defence-in-Depth for new NPP designs
WENRA Safety Objectives for new NPPs

"Therefore, Defence-in-Depth is a key concept of the safety objectives established by WENRA for new nuclear power plants. In particular, these safety objectives call for an extension of the safety demonstration for new plants, in consistence with the reinforcement of the Defence-in-Depth approach. Thus the DiD concept should be strengthened in all its relevant principles."

WENRA RHWG Report, Safety of new NPP designs, March 2013

02 Defence-in-Depth for new NPP designs
WENRA Safety Objectives for new NPPs

O1. Normal operation, abnormal events and prevention of accidents

O2. Accidents without core melt

O3. Accidents with core melt

O4. Independence of the levels of Defence-in-Depth (DiD)

O5. Safety and security interfaces

O6. Radiation protection and waste management

O7. Leadership and management for safety

02 Defence-in-Depth for new NPP designs
Strengthening the DiD concept

WENRA aims for strengthening the Defence-in-Depth concept by

- Reinforcing each DiD level
- Improving the independence between levels of DiD

Safety Objective O4:

"WENRA expects new NPP to be designed, sited, constructed, commissioned and operated with the objective of enhancing the effectiveness of the independence between all levels of DiD, in particular through diversity provisions, to provide an overall reinforcement of DiD."

02 Defence-in-Depth for new NPP designs
Selected key safety issues

Position 1: Defence-in-Depth approach for new nuclear power plants

Position 2: Independence of the levels of Defence-in-Depth

Position 3: Multiple failure events

Position 4: Provisions to mitigate core melt and radiological consequences

Position 5: Practical elimination

Position 6: External Hazards

Position 7: Intentional crash of a commercial airplane

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02 Defence-in-Depth for new NPP designs
Multiple failure events

Refined structure of the DiD levels

Level 3 is now split up into:

a. Postulated single initiating events

b. Postulated multiple failure events
(previously "beyond design", now in the design,
e.g. station black-out or loss of ultimate heat sink)

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02 Defence-in-Depth for new NPP designs
Accidents with core melt

Accidents with core melt (Level 4), safety objective O3:

- Accidents with core melt leading to early or large releases have to be practically eliminated.
- For accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public (...) and that sufficient time is available to implement these measures.

Core melt accidents are included in the design of new NPPs.

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WENRA

02 Defence-in-Depth for new NPP designs

Levels of defence in depth	Associated plant condition categories	Objective	Essential means	Radiological consequences
Level 1	Normal operation	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation, control of main plant parameters inside defined limits	Regulatory operating limits for discharge
Level 2	Anticipated operational occurences	Control of abnormal operation and failures	Control and limiting systems and other surveillance features	
Level 3 (1)	DiD Level 3.a Postulated single initiating events	Control of accident to limit radiological releases and prevent escalation to core melt conditions (2)	Reactor protection system, safety systems, accident procedures	No off-site radiological impact or only minor radiological impact
	DiD Level 3.b Postulated multiple failure events		Additional safety features (3), accident procedures	
Level 4	Postulated core melt accidents (short and long term)	Control of accidents with core melt to limit off-site releases	Complementary safety features(3) to mitigate core melt, Management of accidents with core melt (severe accidents)	Limited protective measures in area and time
Level 5	-	Mitigation of radiological consequences of significant releases of radioactive material	Off-site emergency response Intervention levels	Off site radiological impact necessitating protective measures

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02 Defence-in-Depth for new NPP designs
Independence of DiD Levels

- There shall be independence to the extent reasonably practicable between different levels of DiD
- The means to achieve independence between levels are:
  - Δ diversity provisions
  - Δ physical separation, structural or by distance
  - Δ functional isolation
- Attention shall be paid to the design of I&C and of the reactor auxiliary and support systems (e.g. electrical power supply, cooling systems)

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02 Defence-in-Depth for new NPP designs
Independence of DiD Levels

In particular, and to the extent reasonably practicable,

- DiD level 3 should be independent from levels 1 and 2,
- DiD sub-levels 3.a and 3.b should be independent from each other,
- DiD level 4 should be independent from all the other levels.

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03
Defence-in-Depth for existing reactors

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03 Defence-in-Depth for existing reactors
Safety Reference Levels

- SRLs currently being updated to implement LL from Fukushima
- Focus on DiD levels 3 and 4, but also requirements which cover all levels of DiD
- Main technical areas:
  - Δ Multiple unit sites
  - ΔSpent fuel pools
  - Δ Long lasting accidents
  - Δ Cliff edge effects
  - Δ Accident management
  - Δ Natural hazards / hazard assumptions
  - Δ Design extension conditions

WENRA

04
Conclusions

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04 Conclusions
Defence-in-Depth

- WENRA RHWG completed its task to elaborate safety objectives for new reactors, including a reinforced Defence-in-Depth concept.

- The improved DiD approach will be used for new reactors in all WENRA member countries.

- The WENRA Safety Reference Levels for existing reactors are currently being revised based on LL from Fukushima (scheduled for end of 2013).

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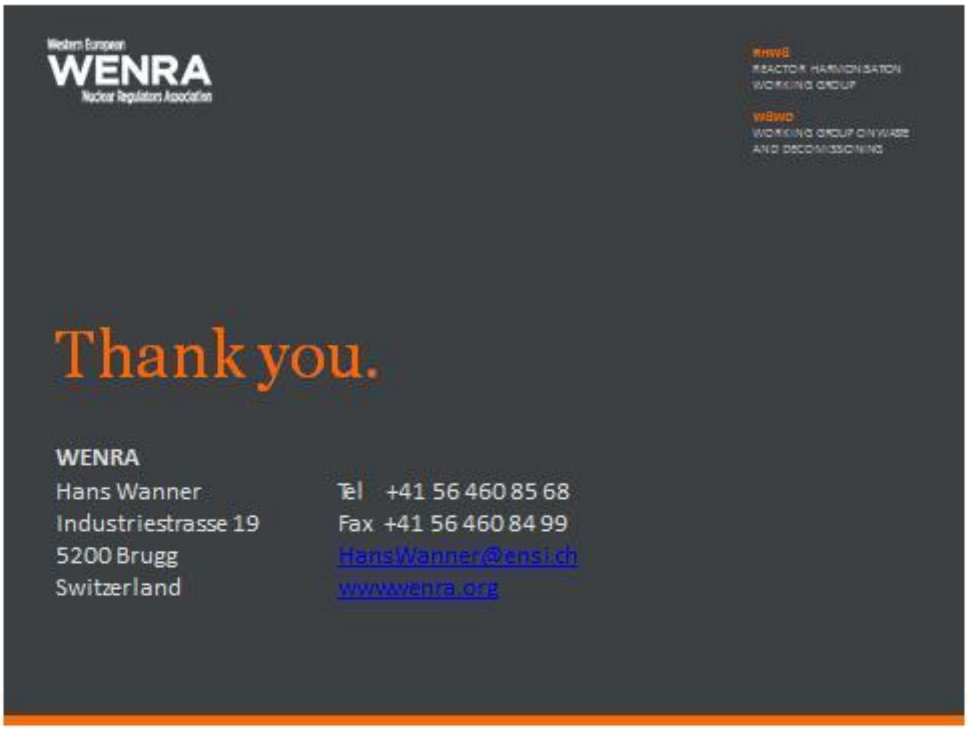
Western European
WENRA
Nuclear Regulators Association
Thank you.
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wwwwenra.org


CSNI/CNRA DiD One-day Workshop, 5 June 2013, OECD
Recent Regulatory Challenges in Korea
A DiD Perspective
Youn Won PARK, President
Korea Institute of Nuclear Safety


Contents
1 Safety Issues Identified in 2011 & 2012
2 Isses Addressed in Safety Improvement From DiD Perspective
3 Regulatory Challenges from DiD Perspective
2

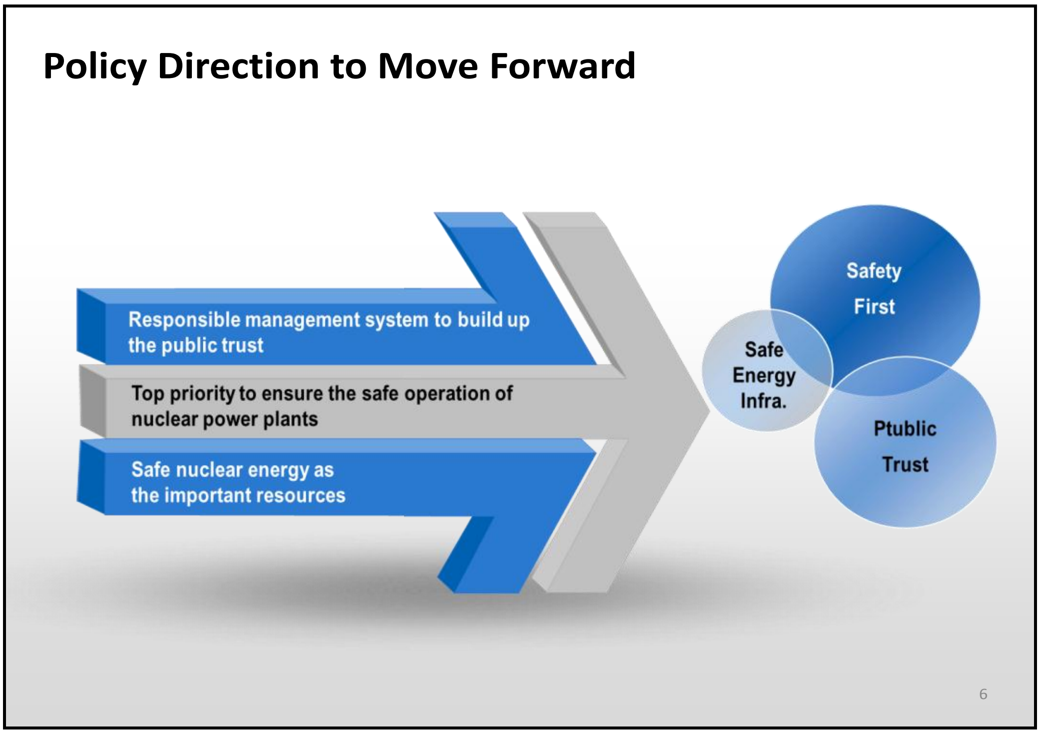
1 Safety Issues in 2011 ~ 2012 & Policy Direction from 2013

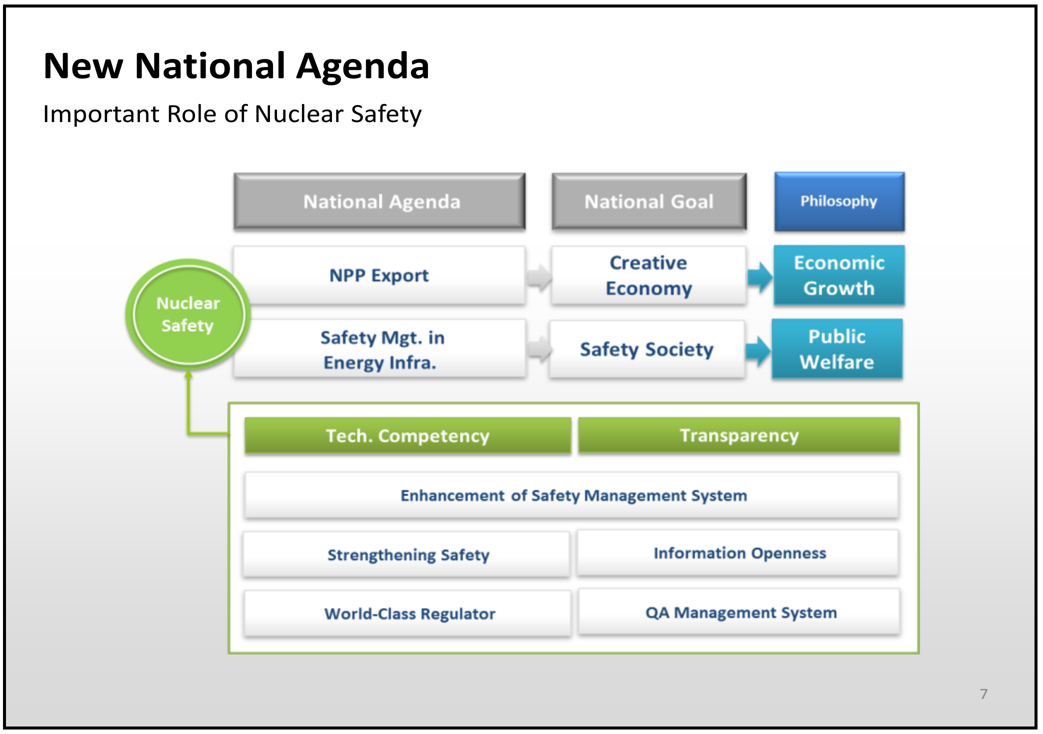
3

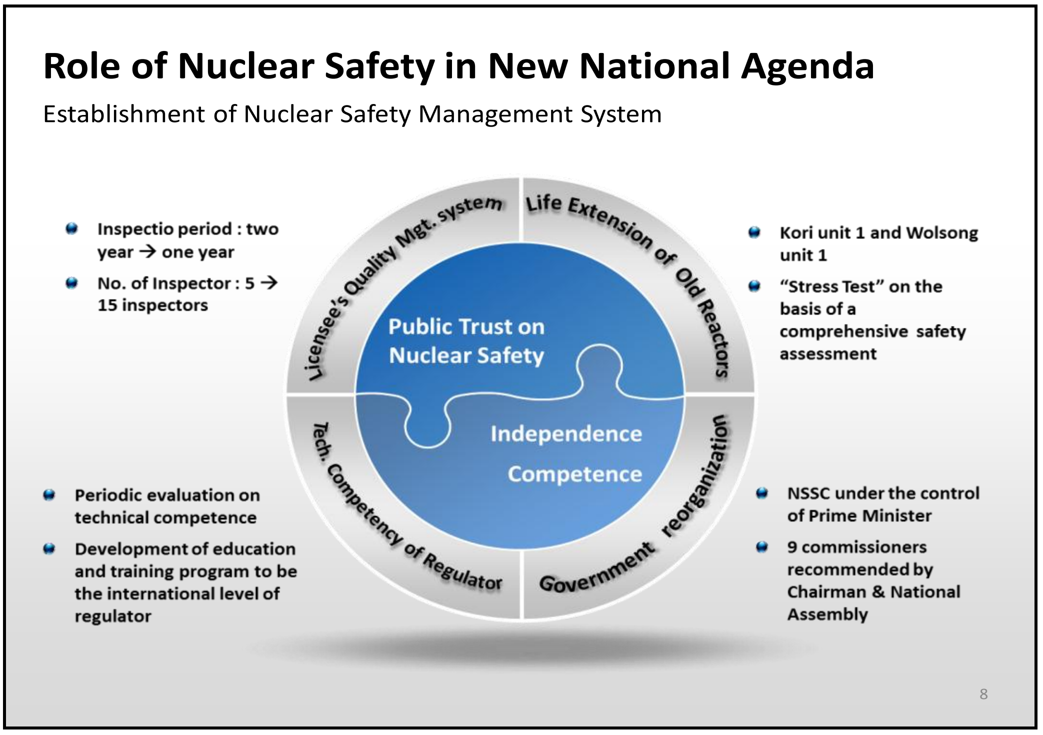
Environment Changes around Nuclear

4


Changes of Nuclear Safety Issues in Korea
Right After Fukushima (April, 2011)
• Perceived Risk Greater than Actual Risk
• Concerns about Radiation Fallout from Japan's Nuclear Disaster
Right After Fukushima (~ December, 2011)
• International Review
• Comprehensive Safety Assess. & Action Plan
• Accident Analysis & Lesson Learns Implementation
After Fukushima & SBO at K1 (the 1st Half, 2012)
• Cover-up of SBO & Review of RPV Integrity at Kori 1
• Radiation Fear from Asphalt Pavement
• NGO's Analysis on Severe Accident & Health Risk
Safety Issues in Korea (the 2nd Half, 2012)
• Installation of Unapproved Items with Forged Certificates
• Crack on Control Rod Driving Mechanism at YGN3
• Activated Emergency Response Team
• Briefing thru Media
• Dispatching Experts to Japan & IAEA
• Special Safety Inspection, 50 Recommendations & Implementation Plan
• Strengthening Regulatory System
• Follow-up of Special Safety Inspection & IAEA Safety Action Plan
• Restart of Kori 1
• Importance of Communication
• Public & Local Community's Credit to Int'l Expert
• Challenges to be Strong Regulator with Tech. Competence & Transparence
5

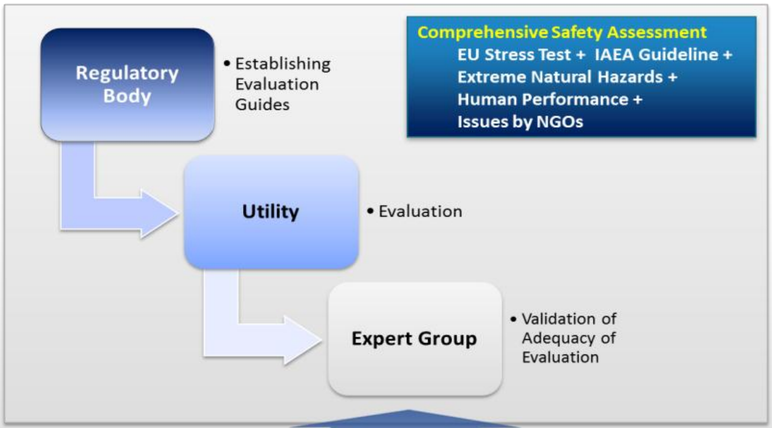

Policy Direction to Move Forward
Responsible management system to build up the public trust
Top priority to ensure the safe operation of nuclear power plants
Safe nuclear energy as the important resources
Safety First
Safe Energy Infra.
Ptublic Trust
6


New National Agenda
Important Role of Nuclear Safety
National Agenda
National Goal
Philosophy
Nuclear Safety
NPP Export
Creative Economy
Economic Growth
Safety Mgt. in Energy Infra.
Safety Society
Public Welfare
Tech. Competency
Transparency
Enhancement of Safety Management System
Strengthening Safety
Information Openness
World-Class Regulator
QA Management System
7


Role of Nuclear Safety in New National Agenda
Establishment of Nuclear Safety Management System
Inspectio period : two year → one year
No. of Inspector : 5 → 15 inspectors
Licensee's Quality Mgt. system
Life Extension of Old Reactors
Kori unit 1 and Wolsong unit 1
"Stress Test" on the basis of a comprehensive safety assessment
Public Trust on Nuclear Safety
Independence
Competence
Tech. Competency of Regulator
Government reorganization
Periodic evaluation on technical competence
Development of education and training program to be the international level of regulator
NSSC under the control of Prime Minister
9 commissioners recommended by Chairman & National Assembly
8

Stress Test

Continued Operation of Power Plant

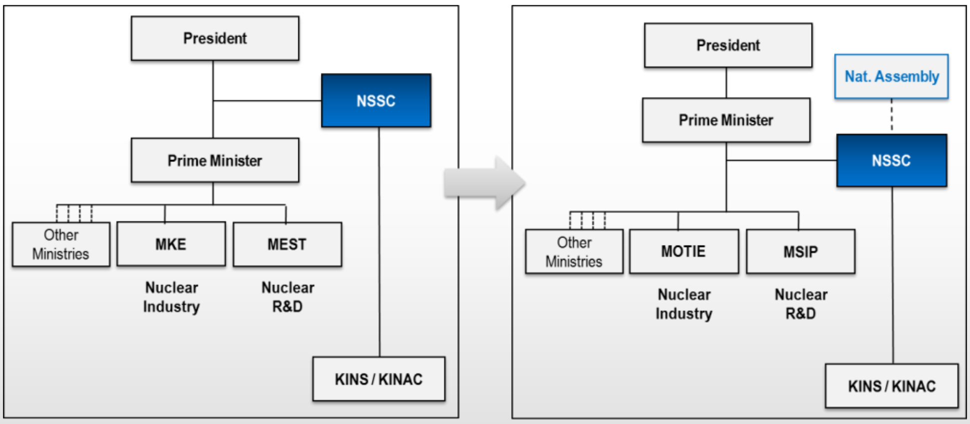


Participation of Experts recommended by Local Community
To Ensure Transparency

9

Recent Changes of Regulatory System

Government Reorganization



Function	Before	After
Nuclear Industry	MKE	MOTIE
Nuclear R&D	MEST	MSIP
Safety Regulation	Under the President (Minster Level)	Under the Prime Minister (Vice-Minister Level)

MKE : Ministry of Knowledge and Economy
MEST : Ministry of Education, Science and Technology
MSIP : Ministry of Science, ICT & Future Planning
MOTIE : Ministry of Trade, Industry and Energy

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2 Issues Addressed in Safety Improvement from DiD Perspective

Definition and Key Objectives

A hierarchical deployment of different levels of *diverse equipment and procedures* to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment*, in operational states and, for some barriers, in accident conditions.*

Level	Objective	Essential Means
1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and Operation
2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance Features
3	Control of accidents within the design basis	Engineered safety features and accident procedures
4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

<Source : IAEA Safety Glossary & IAEA SRS No.46>

Implementation

DETERMINISTIC DESIGN : site characteristics(Level 1), monitoring normal operating conditions (Level 2), prevent and/or mitigate postulated accidents (Level 3), management of severe accidents (Level 4)

PROBABILISTIC STUDIES : effective means of enhancing understanding of plant vulnerabilities due to several equipment and/or human failures , The results can be used to improve defence in depth. PSA is also a useful tool for optimizing efforts in implementing defence in depth

MEANS OF ACHIEVING OPERATIONAL SAFETY : Technical specifications and operating procedures, The human factor and training of plant personnel, Maintenance and surveillance, Management and safety culture

ACCIDENT CONTROL & MANAGEMENT OF SEVERE ACCIDENTS : specific procedures and staff Training, Efficient management of severe accidents also requires careful preparation of the operating staff and the availability of specific technical support (Level 4)

REGULATORY BODY & GLOBAL SAFETY REGIME PROCESSES : clear allocation of responsibilities between an operating organization and the regulatory body, Deficiencies detection by regulatory inspection

<Source : INSAG 10>

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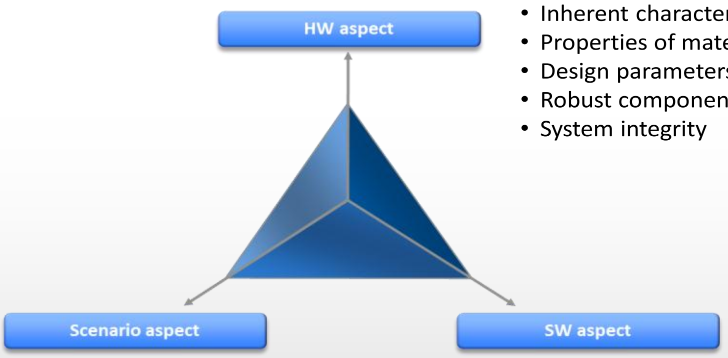
Key Areas to be Strengthened



HW aspect:

- Inherent characteristics
- Properties of materials
- Design parameters
- Robust components
- System integrity

Scenario aspect:

- Initiating event scenario
- Evaluating safety margin
- Mitigation scenario
- Risk assessment
- EDG, SAMG

SW aspect:

- Organizational & human factors
- Maintenance & monitoring
- QA & emergency program
- Requirements & procedures
- Safety Culture

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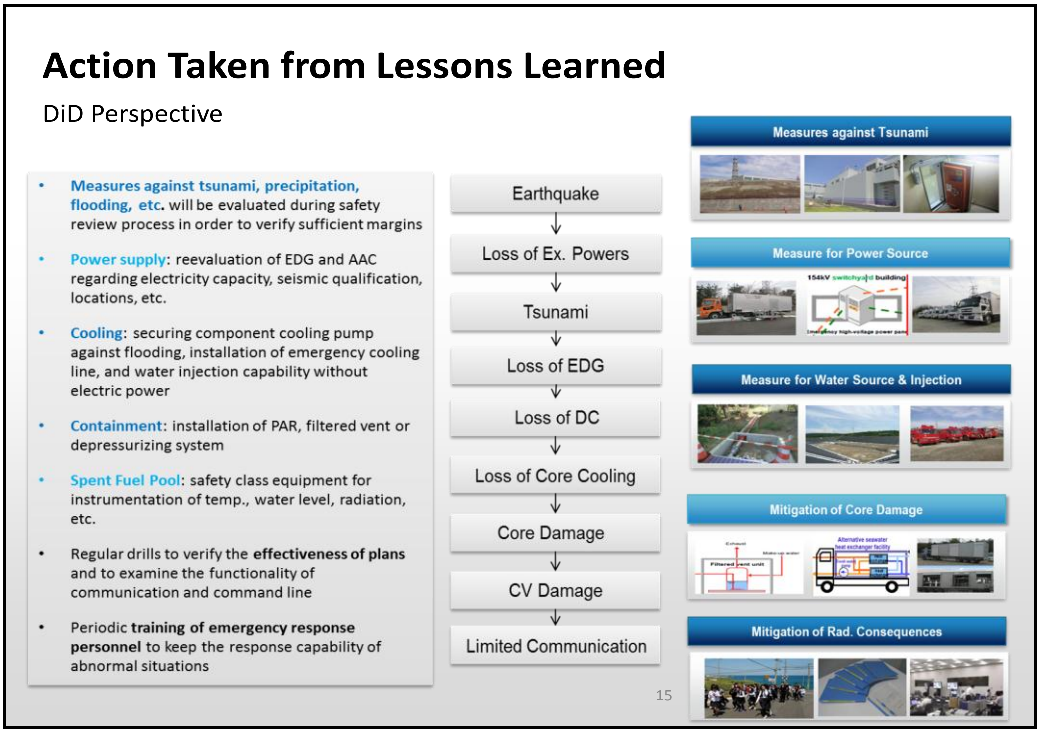
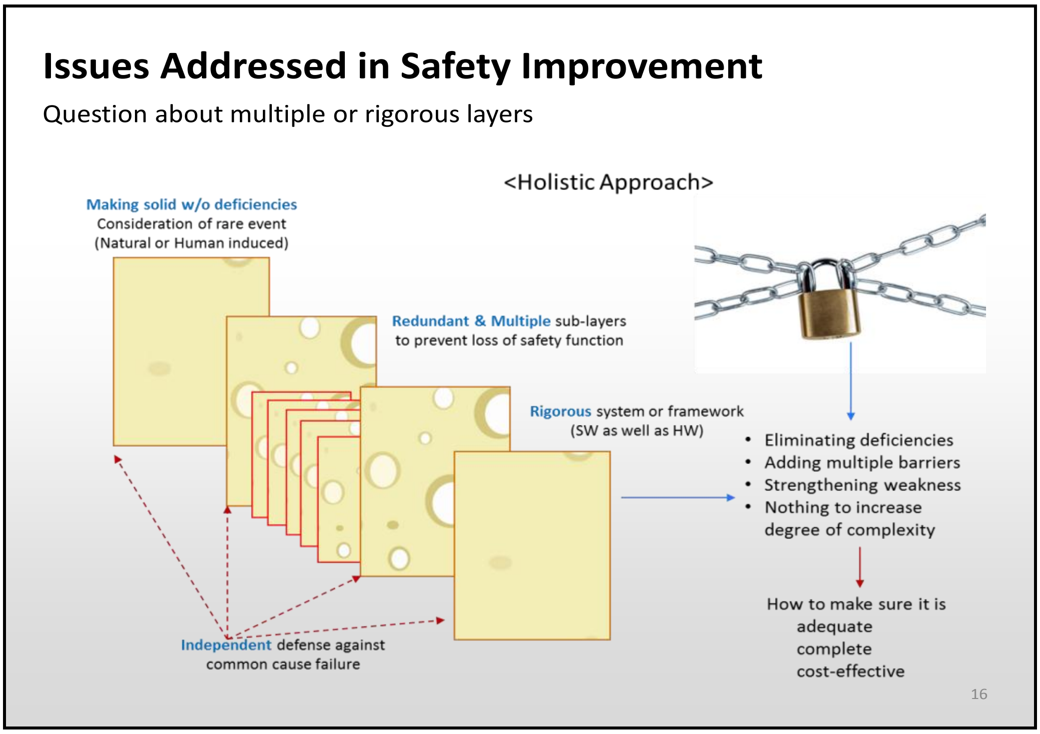

Action Taken from Lessons Learned
DiD Perspective
• Measures against tsunami, precipitation, flooding, etc. will be evaluated during safety review process in order to verify sufficient margins
• Power supply: reevaluation of EDG and AAC regarding electricity capacity, seismic qualification, locations, etc.
• Cooling: securing component cooling pump against flooding, installation of emergency cooling line, and water injection capability without electric power
• Containment: installation of PAR, filtered vent or depressurizing system
• Spent Fuel Pool: safety class equipment for instrumentation of temp., water level, radiation, etc.
• Regular drills to verify the effectiveness of plans and to examine the functionality of communication and command line
• Periodic training of emergency response personnel to keep the response capability of abnormal situations
Earthquake
Loss of Ex. Powers
Tsunami
Loss of EDG
Loss of DC
Loss of Core Cooling
Core Damage
CV Damage
Limited Communication
Measures against Tsunami
Measure for Power Source
Measure for Water Source & Injection
Mitigation of Core Damage
Mitigation of Rad. Consequences
15


Issues Addressed in Safety Improvement
Question about multiple or rigorous layers
<Holistic Approach>
Making solid w/o deficiencies
Consideration of rare event
(Natural or Human induced)
Redundant & Multiple sub-layers
to prevent loss of safety function
Rigorous system or framework
(SW as well as HW)
Independent defense against
common cause failure
• Eliminating deficiencies
• Adding multiple barriers
• Strengthening weakness
• Nothing to increase degree of complexity
How to make sure it is
adequate
complete
cost-effective
16

Issues Addressed in Safety Improvement

Question about extent or depth

- Extra conservative measures to be implemented in design, construction, and operation

- Key aspects of elements
  - Redundant
  - Multiple
  - Independent

} layers related to all safety activities to protect health and safety

1. Multiple barriers to fission product release
2. Redundancy and diversity in safety equipment
3. Operational procedures and strategies
4. Emergency preparedness

Safety Goal

How do we know when we have done enough ?

- Process & Procedures
- Human & Organizational
- Mechanical & Component

Defense in Depth vs Defense in Width

17

Issues Addressed in Safety Improvement

Question about sufficiency

- Safety goal guides
  - Systematic and logical application of DiD
  - Limit of additional barriers or rigorous system for safety improvement

- Safety improvement as a result of DiD implementation
  - Reach to the goal thru improvement

- Questions w/o answers
  - How much is it sufficient?
  - How safe is safe enough?
  - Does the request on safety improvement stop?
  - How high the safety standards are enough to ensure the safety?
  - How are the probabilities or uncertainties allowed?

Need to be balanced or justified with cost ?

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Issues Addressed in Safety Improvement

Question about considering cost

- Decision aligned safety goal
  - Balance of implementation cost and benefit from safety improvement or radiological risk reduction
  - When can we stop improving?
  - What is at a reasonable safety?
- Cost-effective resources allocation provides
  - Capital investment and regulatory capabilities according to safety significance under the limited resources
  - How do we make sure no unnecessary layers of defense?
  - How do we prioritize the layers of defense?

Balance between ensuring safety and providing flexibility

→ new regulation requirements

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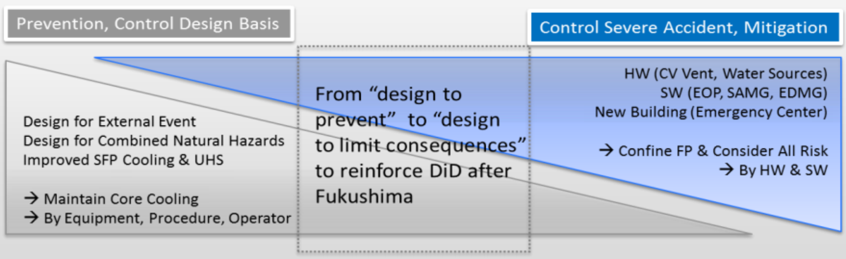
Issues Addressed in Safety Improvement

Question about independence

- Still effective as key element of DiD?
  - Independence : a single failure, whether equipment failure or human failure, at one level of defence, and even combinations of failures at more than one level of defence, would not propagate to jeopardize DiD at subsequent level
  - What are safety guides or requirements regarding independence
  - Different perception on what level of DiD is related to



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Issues Addressed in Safety Improvement

Question about "*practically eliminated*"

- IAEA SSR-2/1 : Design extension conditions
  - The plant shall be designed so that it can be brought into a controlled state and the containment function can be maintained, with the result that significant radioactive releases would be *practically eliminated*.
- IAEA SSG-2 : Expected frequency of the initiating events
  - Event/accident as frequency is already implied in DiD concept
  - What is "practically eliminated"?
    - ✓ Unlikely or very unlikely?
    - ✓ Less than 10^{-7} ?

Occurrence (1/reactor year)	Characteristics	Plant state	Terminology	Acceptance criteria
10^{-2}–1 (expected over the lifetime of the plant)	Expected	Anticipated operational occurrences **Level 2**	Anticipated transients, transients, frequent faults, incidents of moderate frequency, upset conditions, abnormal conditions	No additional fuel damage
10^{-4}–10^{-2} (chance greater than 1% over the lifetime of the plant)	Possible	Design basis accidents **Level 3**	Infrequent incidents, infrequent faults, limiting faults, emergency conditions	No radiological impact at all, or no radiological impact outside the exclusion area
10^{-6}–10^{-4} (chance less than 1% over the lifetime of the plant)	Unlikely	Beyond design basis accidents **Level 3,4**	Faulted conditions	Radiological consequences outside the exclusion area within limits
$<10^{-6}$ (very unlikely to occur)	Remote	Severe accidents **Level 4,5**	Faulted conditions	Emergency response needed

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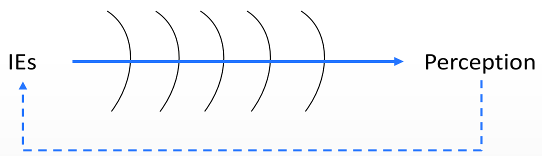
Issues Addressed in Safety Improvement

Question about perceived risk



- Recognize the only end-point (only fate not a potential impact)
- Ignore the effectiveness or existence of barriers
- Invalidate the reinforcement of DiD
- Give no credit to reverse and diverse safety function

(if loss of cooling water, reservoir & well > water injection by fire engines > rx core isolation cooling)

- Hinder or fail to detect the abnormal condition (triggering IEs)
- Cause the overpressure or unnecessary stress on "safe operation)
- Induce a staff into cover-up

➔ How to rectify the hypersensitive attitude to safety issue

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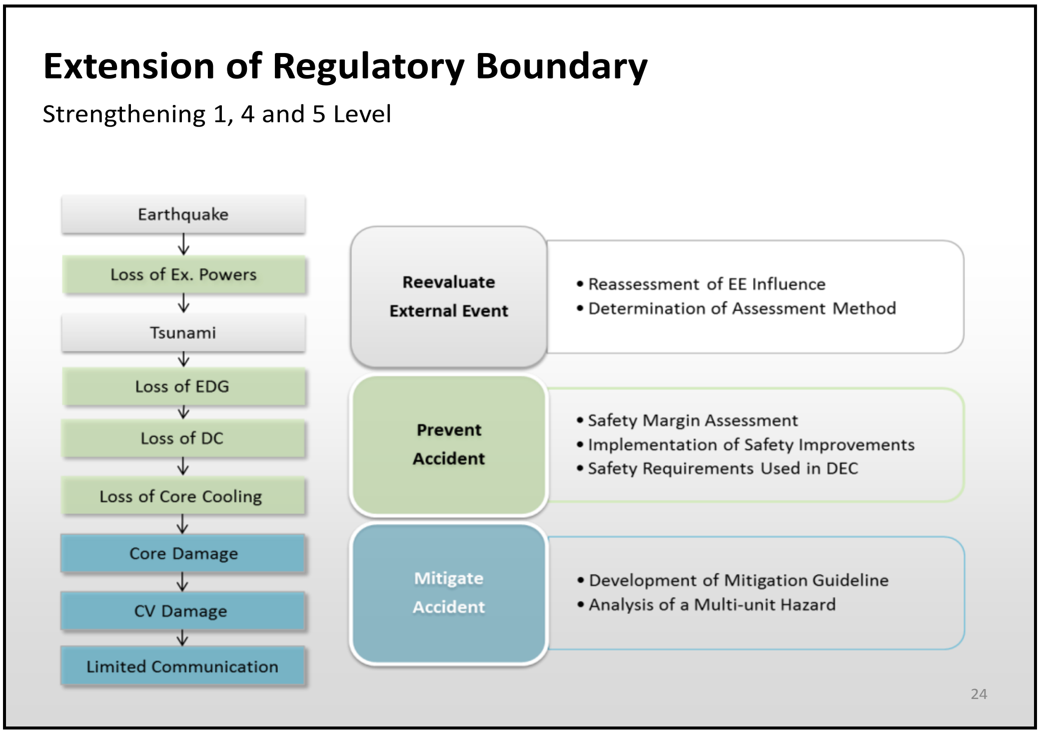
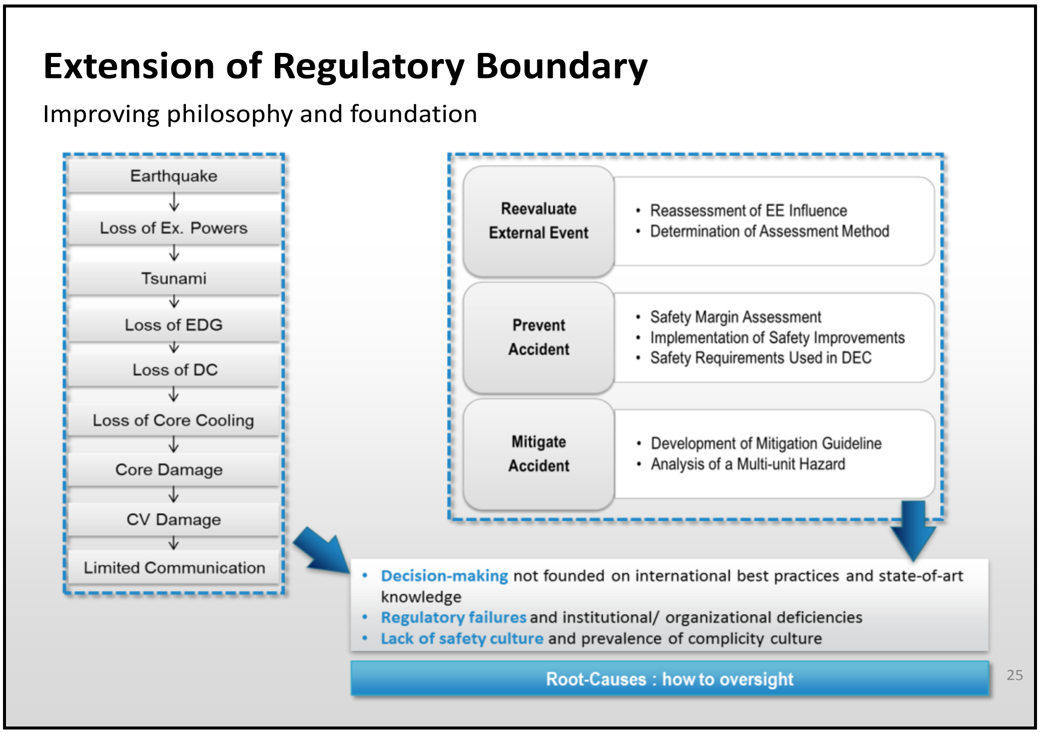
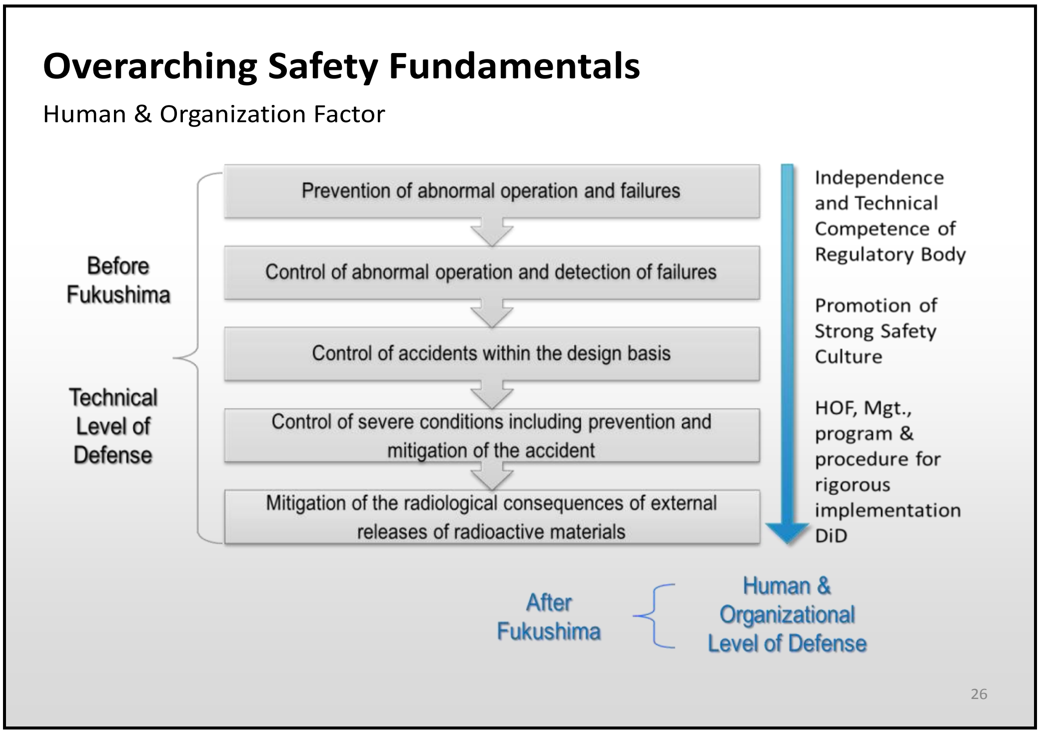
3
Regulatory Challenges from DiD Perspective

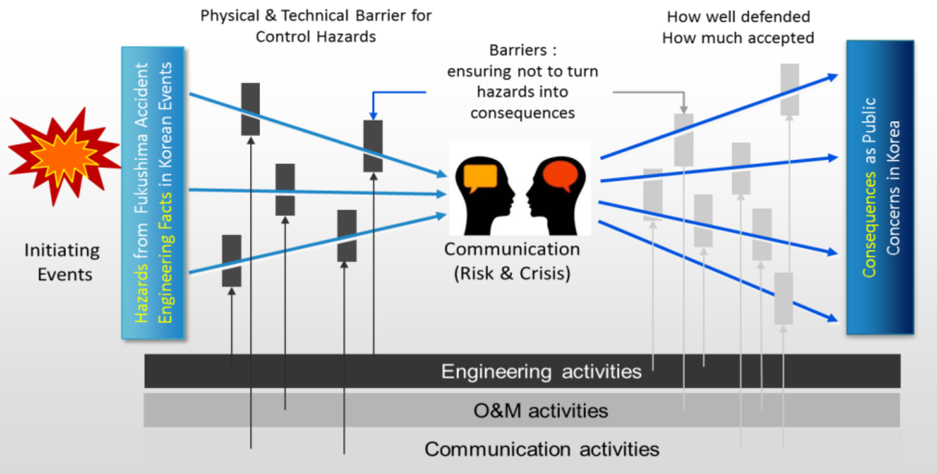

Extension of Regulatory Boundary
Strengthening 1, 4 and 5 Level
Earthquake
Loss of Ex. Powers
Tsunami
Loss of EDG
Loss of DC
Loss of Core Cooling
Core Damage
CV Damage
Limited Communication
Reevaluate External Event
• Reassessment of EE Influence
• Determination of Assessment Method
Prevent Accident
• Safety Margin Assessment
• Implementation of Safety Improvements
• Safety Requirements Used in DEC
Mitigate Accident
• Development of Mitigation Guideline
• Analysis of a Multi-unit Hazard
24


Extension of Regulatory Boundary
Improving philosophy and foundation
Earthquake
Loss of Ex. Powers
Tsunami
Loss of EDG
Loss of DC
Loss of Core Cooling
Core Damage
CV Damage
Limited Communication
Reevaluate External Event
• Reassessment of EE Influence
• Determination of Assessment Method
Prevent Accident
• Safety Margin Assessment
• Implementation of Safety Improvements
• Safety Requirements Used in DEC
Mitigate Accident
• Development of Mitigation Guideline
• Analysis of a Multi-unit Hazard
• Decision-making not founded on international best practices and state-of-art knowledge
• Regulatory failures and institutional/ organizational deficiencies
• Lack of safety culture and prevalence of complicity culture
Root-Causes : how to oversight
25


Overarching Safety Fundamentals
Human & Organization Factor
Before Fukushima
Technical Level of Defense
Prevention of abnormal operation and failures
Control of abnormal operation and detection of failures
Control of accidents within the design basis
Control of severe conditions including prevention and mitigation of the accident
Mitigation of the radiological consequences of external releases of radioactive materials
Independence and Technical Competence of Regulatory Body
Promotion of Strong Safety Culture
HOF, Mgt., program & procedure for rigorous implementation DiD
After Fukushima
Human & Organizational Level of Defense
26

Last Year in Korea

Tech. barriers to strengthen nuclear safety are added, however,
Public acceptance is weaker than before.



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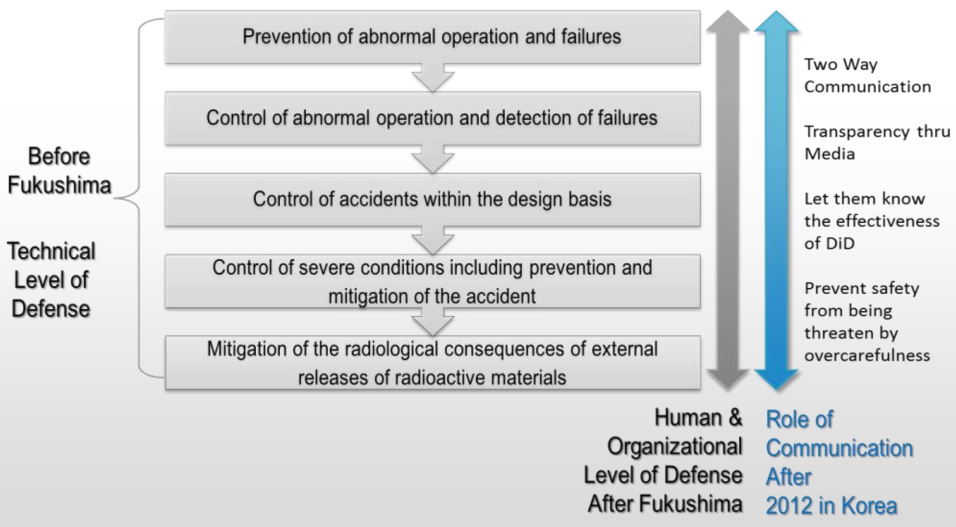
Overarching Safety Fundamentals

Role of Effective Communication



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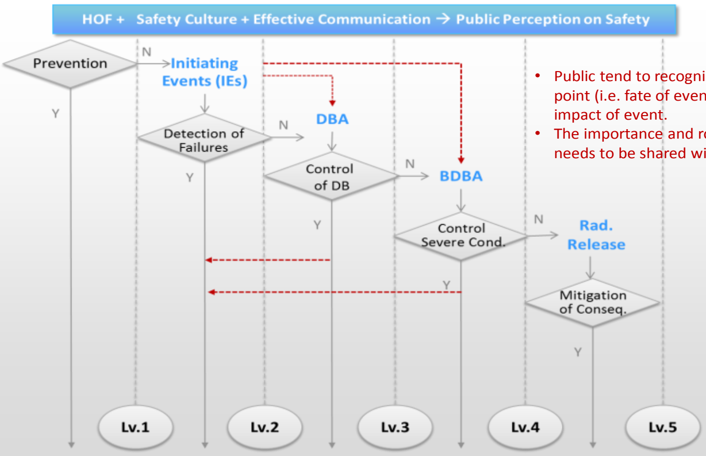
Gap between DiD Integrity and Perceived Risk

Negative feedback of Perceived Risk to IEs

Triggering IEs by media or public perception → Fail to Detect Abnormal Condition and Overpressure on "Safe Operation" → Possibility of Cover-up → How to reduce the gap between Perceived Risk and Effectiveness of DiD



- Public tend to recognize the only end-point (i.e. fate of event) than potential impact of event.
- The importance and robustness of DiD needs to be shared with public.

Different levels of diverse equipment and procedures to prevent incidents or abnormal condition

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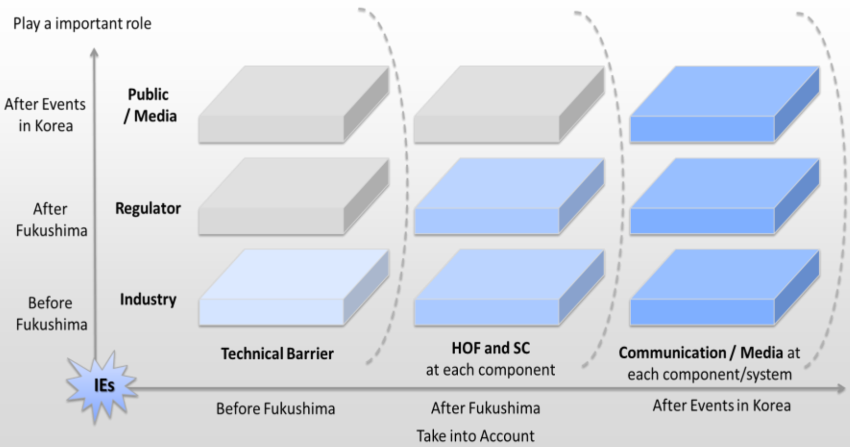
Efforts to Reduce the Gap

- Multiple players as well as layers for nuclear safety
- Public / media as the opinion leader for shared values : transparent, & excellent nuclear safety system
- Regulator as the independent barrier for defense
- Industry as the front line deployed for defense



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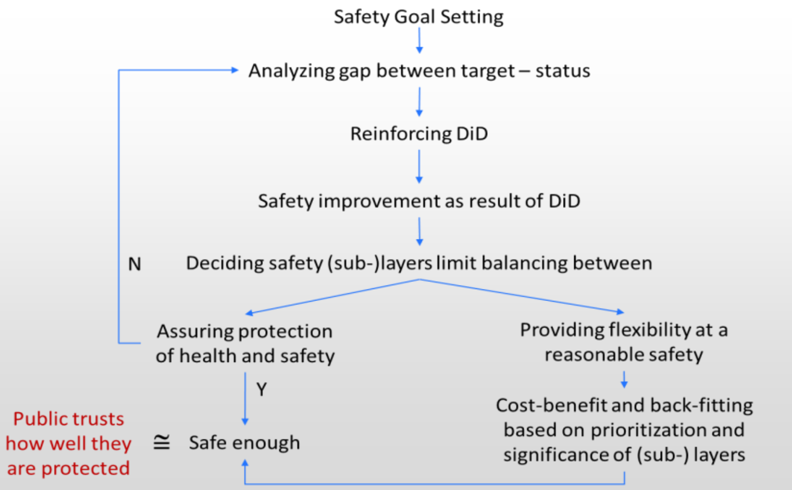
Concluding Remarks

Defense in Depth : a safety philosophy or concept

- is not an “almighty solution” to achieve a safety goal
- cannot assure the safety by itself



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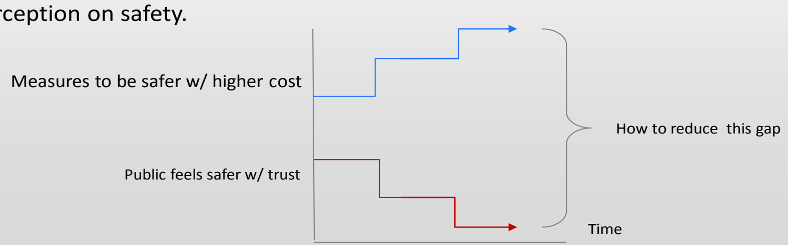
Concluding Remarks

- Defense in Depth : too much or too many layered
  - nothing more than currently imaginable
  - However, who knows how much effective it is ?
  - Each nation is running a race to show whose NPP is much safer.

- What to do : consensus or leadership for safety
  - “zero-deficiency” is inherently impossible, we’ve done and will do for “near zero-deficiency” of layers.
  - Needs to make an international consensus first to address when we stop or what is a reasonable level.
  - Needs to make other feel safe by reducing the gap between safety improvement and public perception on safety.



Concluding Remarks

Goguryeo , one of the ancient states of the Three Kingdoms, expanded its territory in fierce battles against Chinese kingdoms. In a battle with Goguryeo, Chinese soldiers and horse carried a huge amounts of weapons and food on the back at once.

Polish Hussars, the main type of cavalry of the first Polish Army, served as light cavalry banners and had been transformed into heavy cavalry. The role of the hussar changed over time, their armour and heavier weapons were abandoned.

Thank you

Defense-in-Depth

Prevention, Mitigation, and Emergency Preparedness

GLENN M. TRACY, DIRECTOR
OFFICE OF NEW REACTORS
U.S. NUCLEAR REGULATORY COMMISSION

Defense-in-Depth (DID)

Background

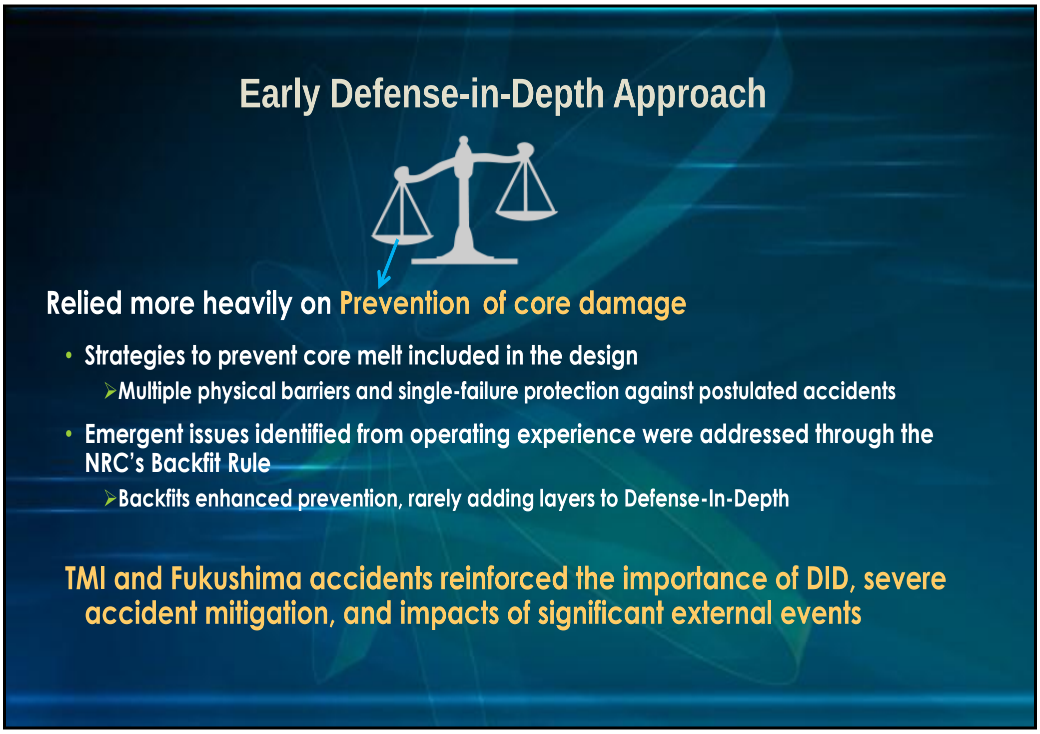
Risk $\propto$ Probability X Consequences

Risk $\propto$ Event Frequency X Prevention of Core Melt X Mitigation of Consequences X Emergency Preparedness

Elements of Defense-in-Depth:

- Event Frequency is addressed through quality of design, manufacture, construction, operation and maintenance
- Prevention is addressed through high quality redundant safety systems and well-trained operators
- Consequence Mitigation is addressed through siting, containment reinforcement, and severe accident features in reactor designs
- Emergency Preparedness is addressed through emergency plans, siting, and emergency response


The Need for Balance in
Defense-in-Depth Approaches
Prevention
Mitigation


Early Defense-in-Depth Approach
Relied more heavily on Prevention of core damage
Strategies to prevent core melt included in the design
➢Multiple physical barriers and single-failure protection against postulated accidents
Emergent issues identified from operating experience were addressed through the NRC's Backfit Rule
➢Backfits enhanced prevention, rarely adding layers to Defense-In-Depth
TMI and Fukushima accidents reinforced the importance of DID, severe accident mitigation, and impacts of significant external events

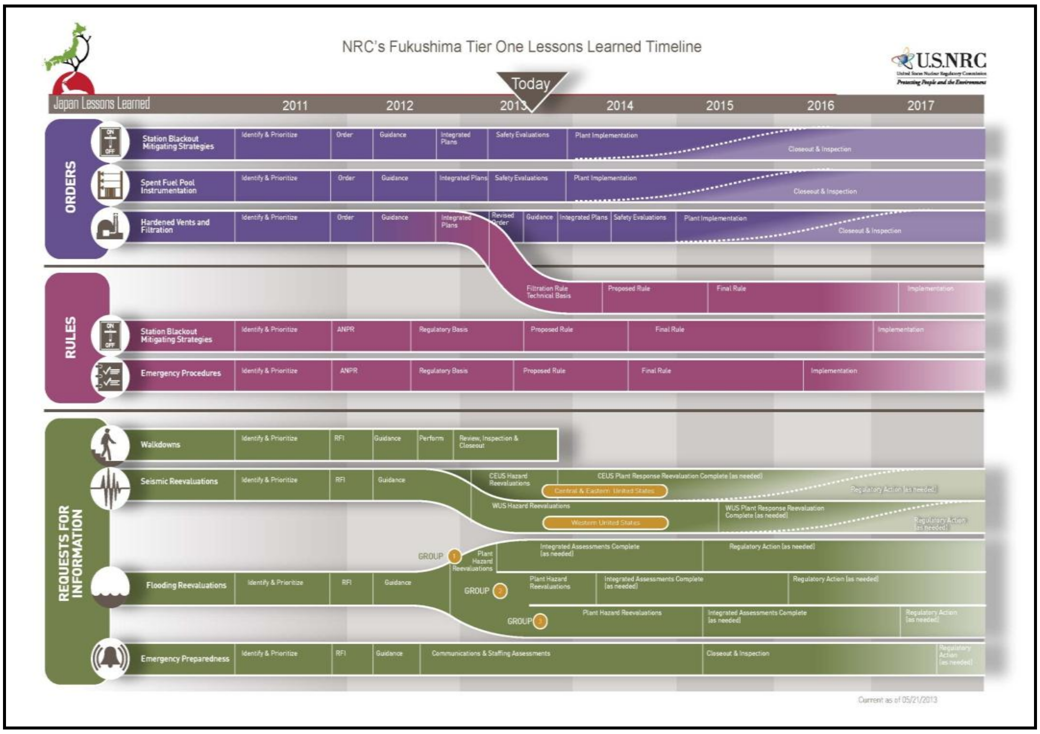

Post-Fukushima Defense-In-Depth Approach
Prevention
Mitigation
Industry and Regulators compelled to look at a more balanced Defense-In-Depth approach
• Encouraged to look at beyond design basis and significant external events
• NRC Near Term Task Force Recommendations focused on Defense-In-Depth


NRC Fukushima
Near Term Task Force Recommendations
• Strengthen the roles of Defense-In-Depth and risk assessment, emphasizing beyond-design-basis and severe accident mitigation
• A risk-informed Defense-In-Depth framework that includes extended design-basis requirements
• A rationale for decision-making built around the Defense-In-Depth concept in which each level of Defense-In-Depth (namely prevention, mitigation, and EP) is critically evaluated for its completeness and effectiveness in performing its safety function

Post-Fukushima Actions

Actions in the United States

- **Seismic and flooding walkdowns** [*Prevention*]
  - Seismic and flooding design basis re-evaluation
- **Filtered vents for BWR Mark I and II**
  [*Severe Accident Mitigation*]
- **Industry proposal to station additional pumps and power sources in multiple locations including offsite** [Prevention and *Mitigation*]

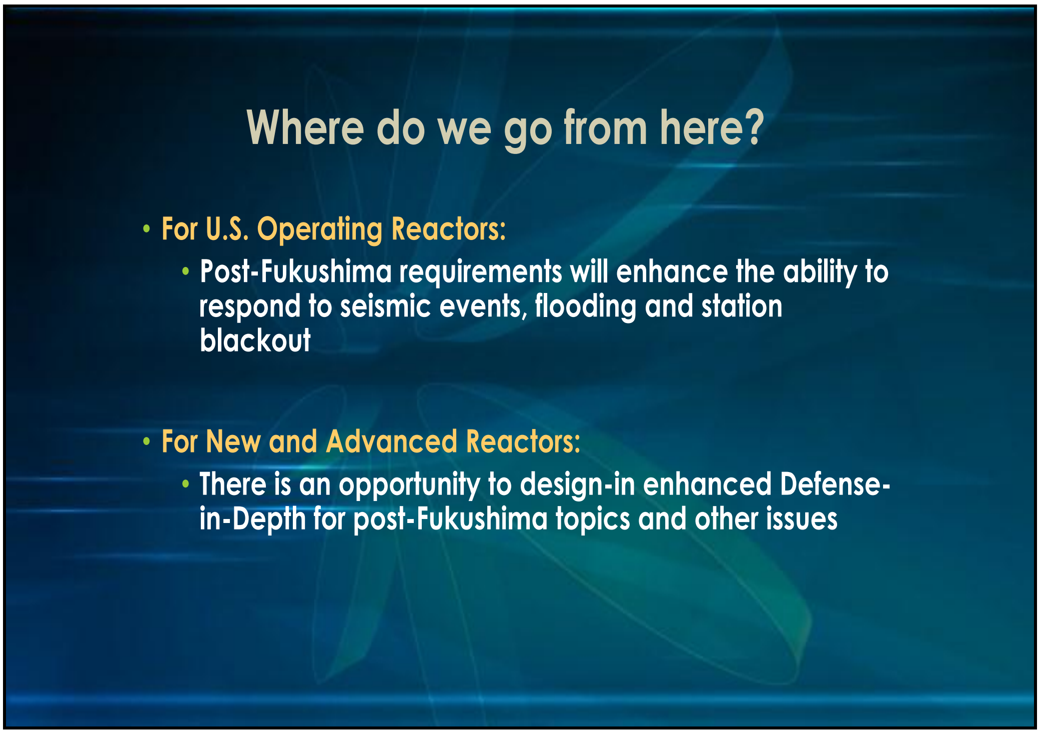


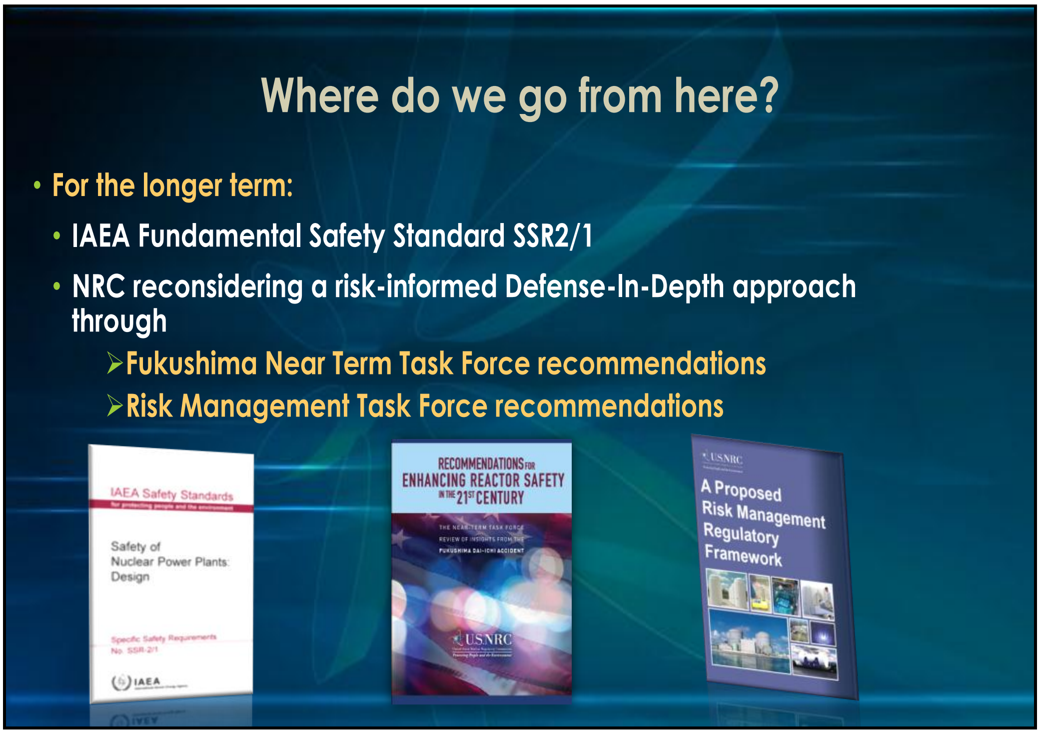
Contemporary Defense-In-Depth Challenge: Digital Instrumentation and Controls

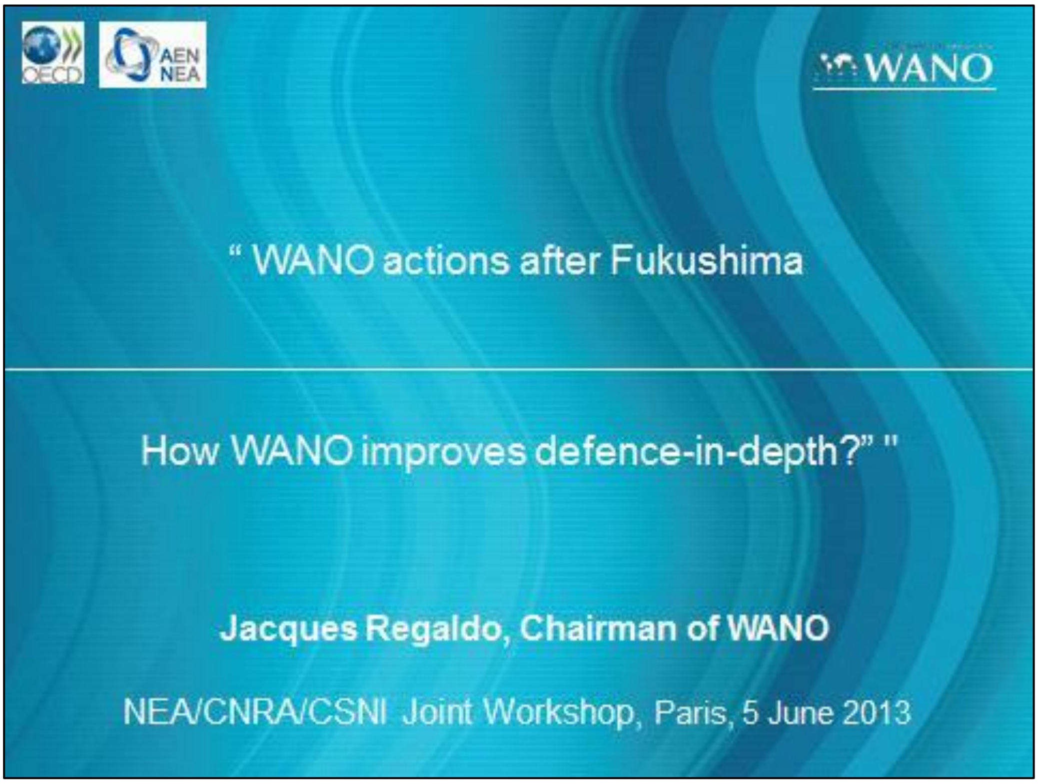
- Digital Instrumentation &Control systems have historically addressed both prevention and mitigation
- Digital Instrumentation &Control systems can challenge established layers of Defense-In-Depth, for example, redundant and independent safety equipment
- Digital Instrumentation &Control fundamental design principles must be applied to maintain Defense-In-Depth:
  - Redundancy
  - Diversity
  - Independence
  - Predictability and Repeatability
  - Simplicity

Contemporary DID Challenge: Digital Instrumentation and Controls (continued)

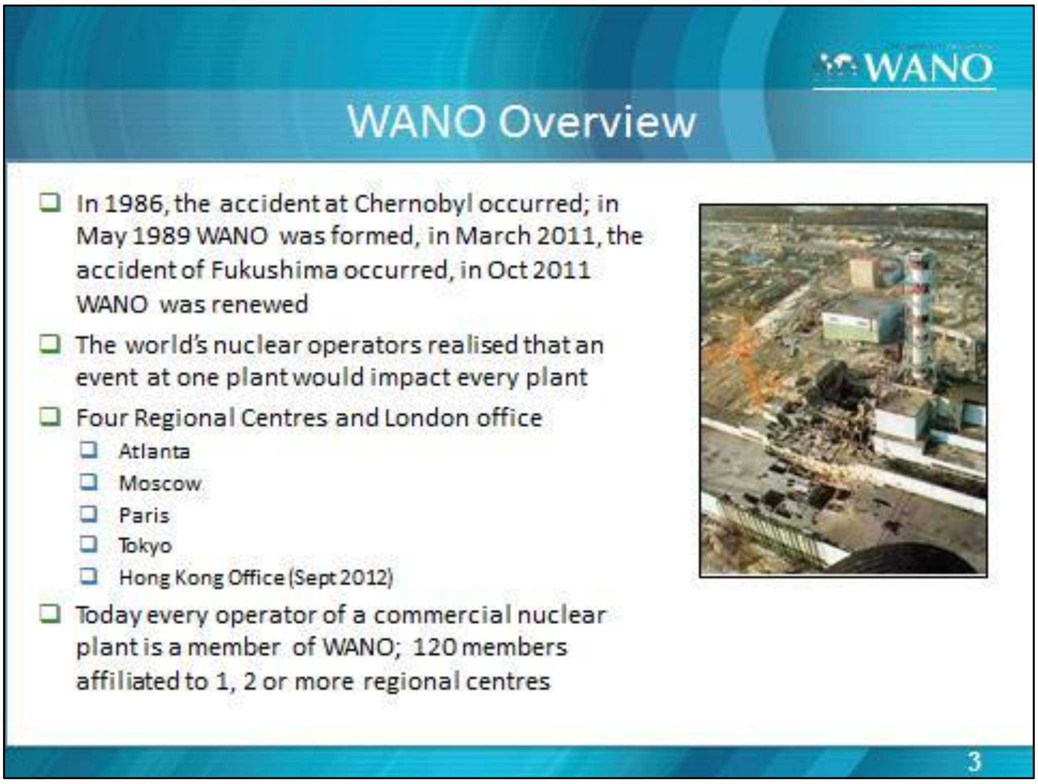
- Unnecessary complexity makes it hard to assess effectiveness of Defense-In-Depth strategies and can introduce new vulnerabilities, undermining Defense-In-Depth
- New Instrumentation & Controls hazards (e.g., integration of multiple safety classifications, cyber security threats, potential for electronic counterfeiting) call upon new strategies to maintain Defense-In-Depth
- New Instrumentation & Controls systems provide another opportunity to ensure Defense-In-Depth is achieved


Where do we go from here?
• For U.S. Operating Reactors:
• Post-Fukushima requirements will enhance the ability to respond to seismic events, flooding and station blackout
• For New and Advanced Reactors:
• There is an opportunity to design-in enhanced Defense-in-Depth for post-Fukushima topics and other issues

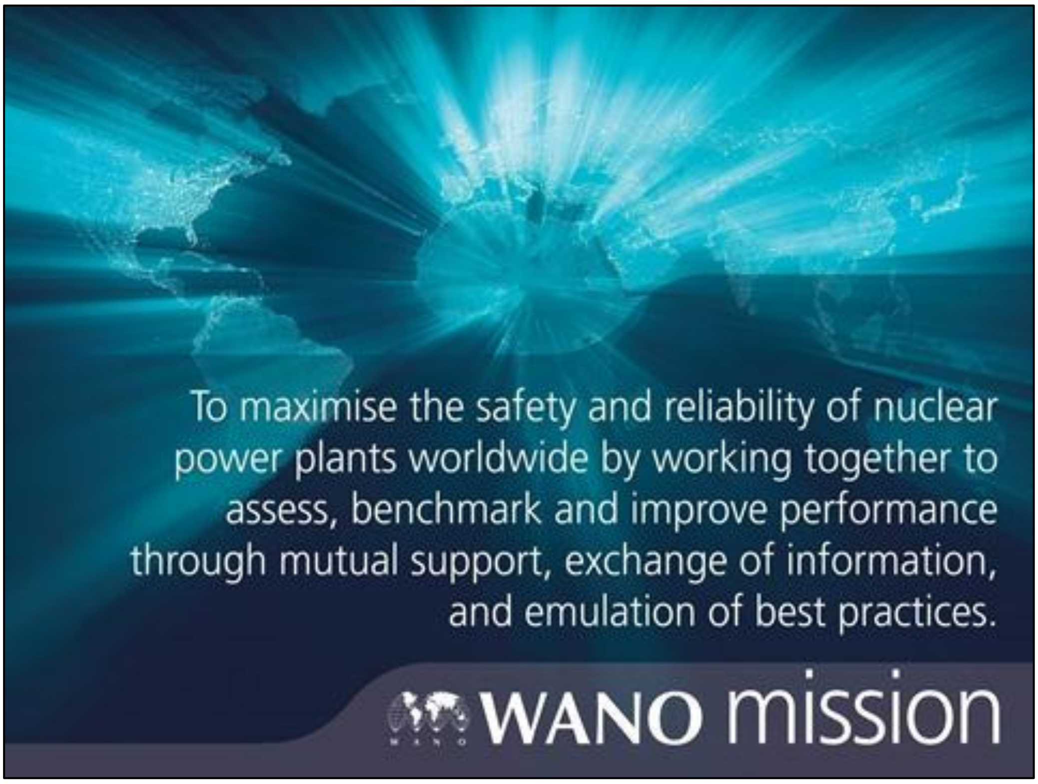

Where do we go from here?
• For the longer term:
• IAEA Fundamental Safety Standard SSR2/1
• NRC reconsidering a risk-informed Defense-In-Depth approach through
➢Fukushima Near Term Task Force recommendations
➢Risk Management Task Force recommendations
IAEA Safety Standards
Safety of Nuclear Power Plants: Design
Specific Safety Requirements No. SSR-2/1
IAEA
RECOMMENDATIONS FOR ENHANCING REACTOR SAFETY IN THE 21ST CENTURY
USNRC
A Proposed Risk Management Regulatory Framework

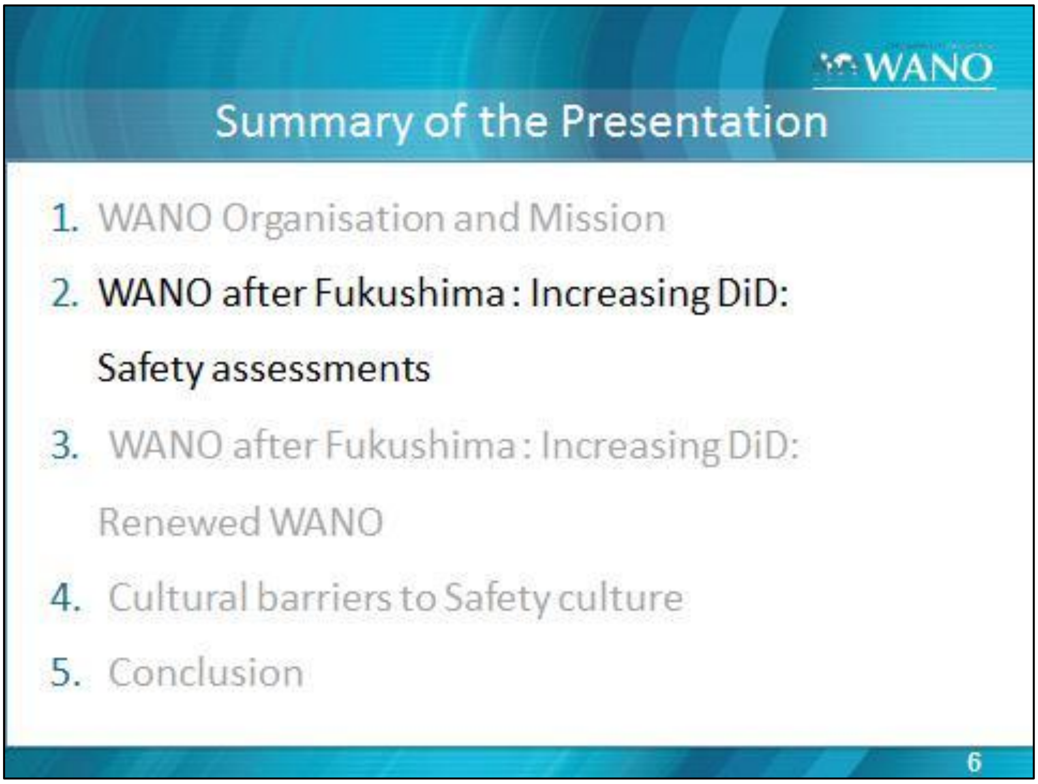

WANO
" WANO actions after Fukushima
How WANO improves defence-in-depth?" "
Jacques Regaldo, Chairman of WANO
NEA/CNRA/CSNI Joint Workshop, Paris, 5 June 2013


WANO
Summary of the Presentation
1. WANO Organisation and Mission
2. WANO after Fukushima : Increasing DiD: Safety assessments
3. WANO after Fukushima : Increasing DiD: Renewed WANO
4. Cultural barriers to Safety culture
5. Conclusion
2


WANO
WANO Overview
In 1986, the accident at Chernobyl occurred; in May 1989 WANO was formed, in March 2011, the accident of Fukushima occurred, in Oct 2011 WANO was renewed
The world's nuclear operators realised that an event at one plant would impact every plant
Four Regional Centres and London office
Atlanta
Moscow
Paris
Tokyo
Hong Kong Office (Sept 2012)
Today every operator of a commercial nuclear plant is a member of WANO; 120 members affiliated to 1, 2 or more regional centres
3


WANO
WANO Governing Board
Chairman
J. Regaldo EDF
President
D. Hawthorne Bruce P
Managing Director
K. Ellis INPO
W.A.C
W.M.C
W.P.C
W.T.C
Most Influential Utility in Region
B. Willard INPO
E. Romanov REA
H. Proglio EDF
M. Yagi FEPC
Regional Chairman
T. Michell OPG
S. Nagy MVM
P. Van Troeye
Electrabel
S. K. Jain NPCIL
CEO Nominated by Region
G. Gates OPPD
V. V. Kim NNEGC
He Yu CGN
Chen Hua CNNC
4


To maximise the safety and reliability of nuclear power plants worldwide by working together to assess, benchmark and improve performance through mutual support, exchange of information, and emulation of best practices.
WANO mission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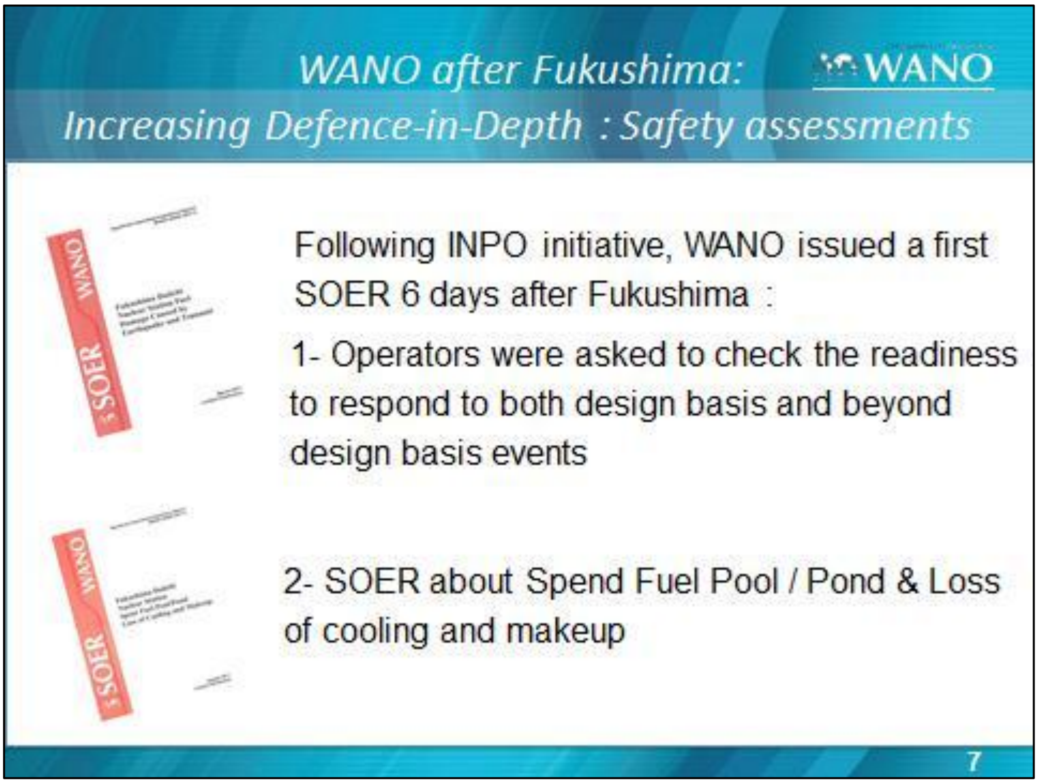
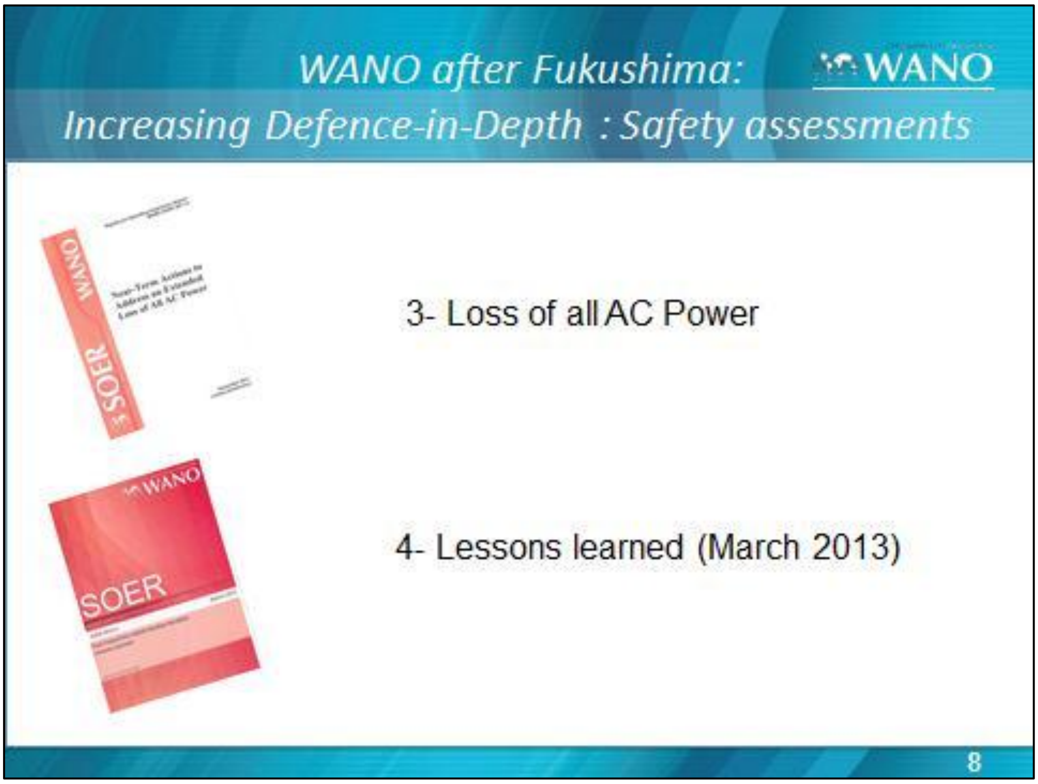
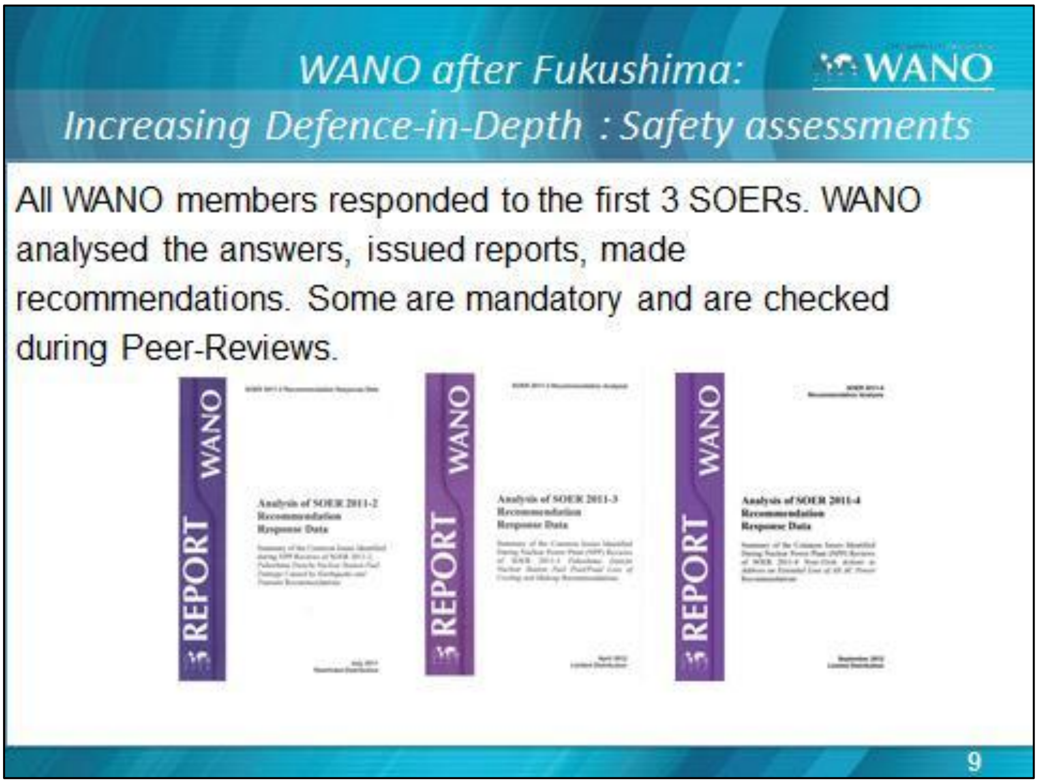
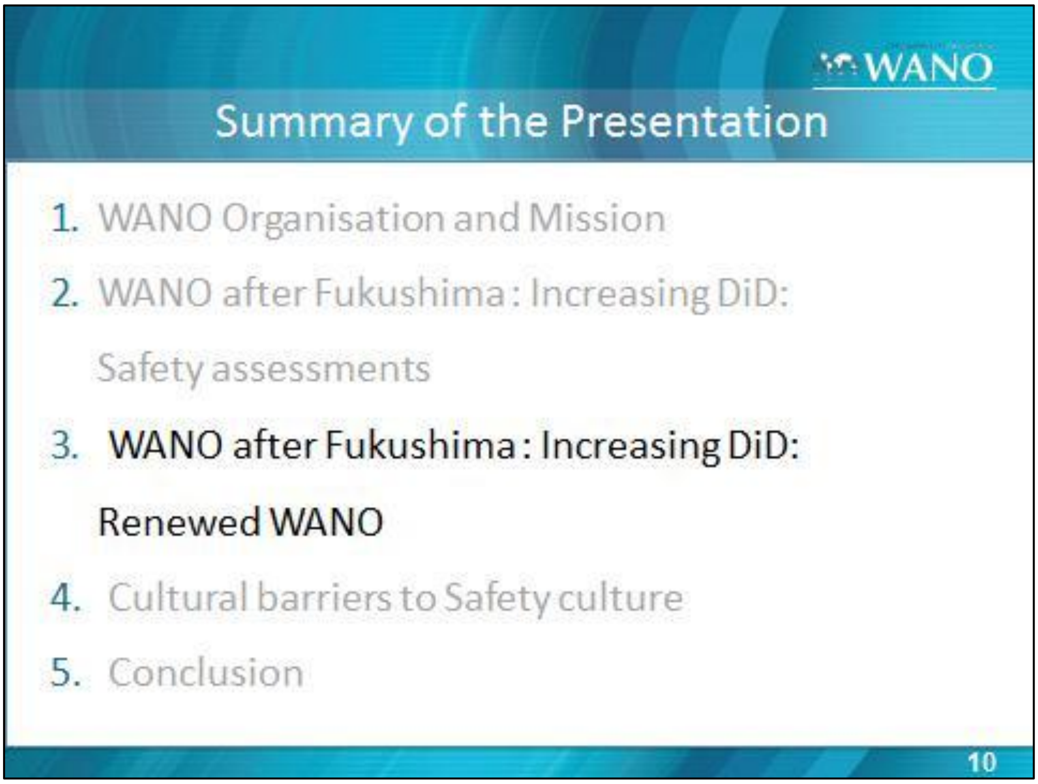

WANO after Fukushima:
WANO
Increasing Defence-in-Depth : Safety assessments
WANO
SOER
Following INPO initiative, WANO issued a first SOER 6 days after Fukushima :
1- Operators were asked to check the readiness to respond to both design basis and beyond design basis events
WANO
SOER
2- SOER about Spend Fuel Pool / Pond & Loss of cooling and makeup
7


WANO after Fukushima:
WANO
Increasing Defence-in-Depth : Safety assessments
WANO
SOER
3- Loss of all AC Power
WANO
SOER
4- Lessons learned (March 2013)
8


WANO after Fukushima:
WANO
Increasing Defence-in-Depth : Safety assessments
All WANO members responded to the first 3 SOERs. WANO analysed the answers, issued reports, made recommendations. Some are mandatory and are checked during Peer-Reviews.
WANO
REPORT
WANO
REPORT
WANO
REPORT
9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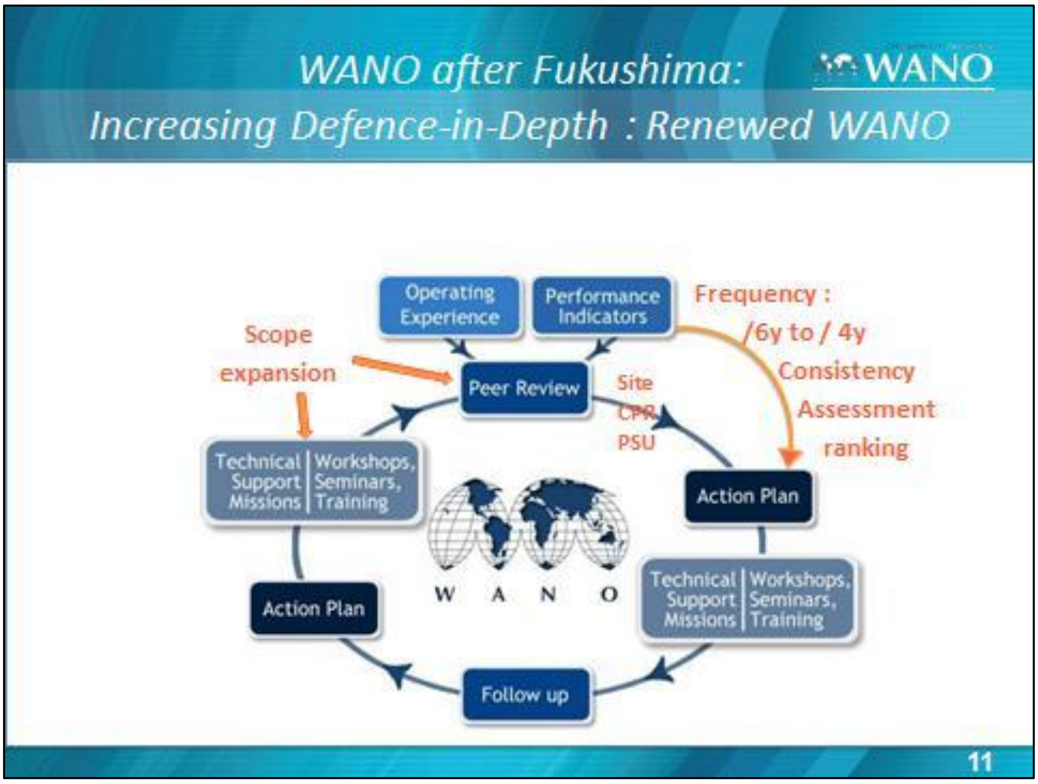

WANO after Fukushima: Increasing Defence-in-Depth : Renewed WANO

WANO

From

1 site Review / 6 years

to

1 Review / 4 years & 1 CPR within 6 years Systematic pre-start-up PR

Quality & Scope improvement & Corrective actions towards AFIs to be compulsory

Japan: shutdown & restart reviews to be set up

12

WANO after Fukushima: Increasing Defence-in-Depth : Renewed WANO

WANO

Scope expansion

Design:
Continuous Design Improvement Process

Emergency Preparedness

Spent Fuel Storage

New Entrants:
Ability to monitor the licensing process, ...

13

Summary of the Presentation

WANO

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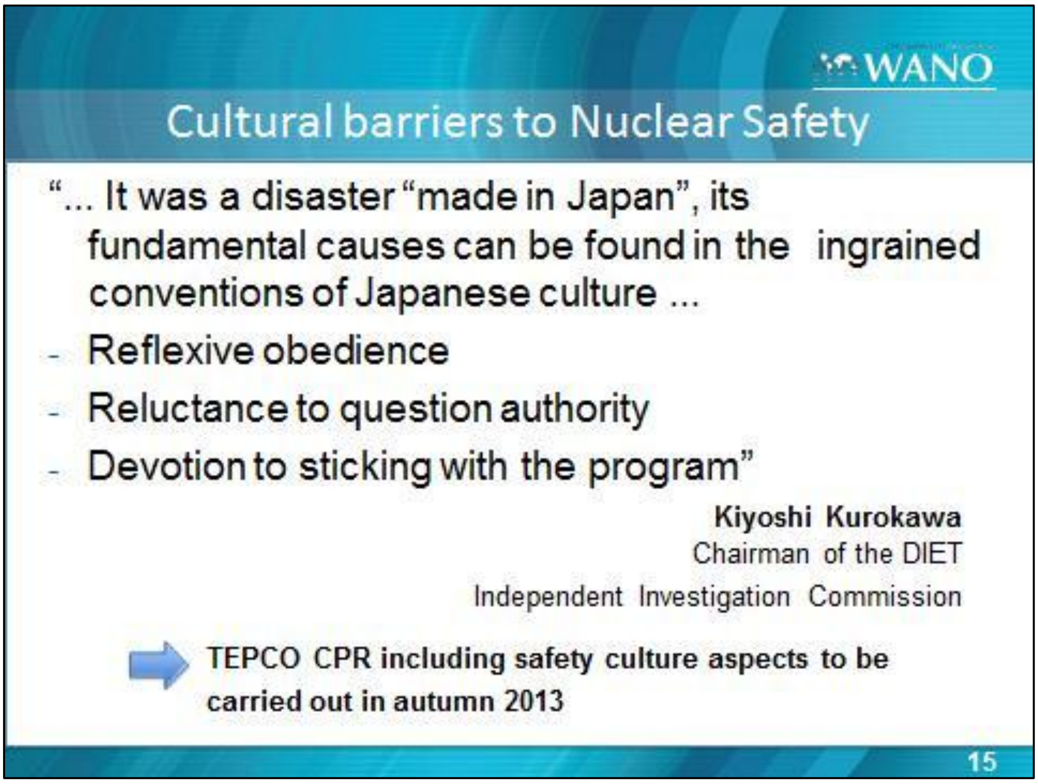
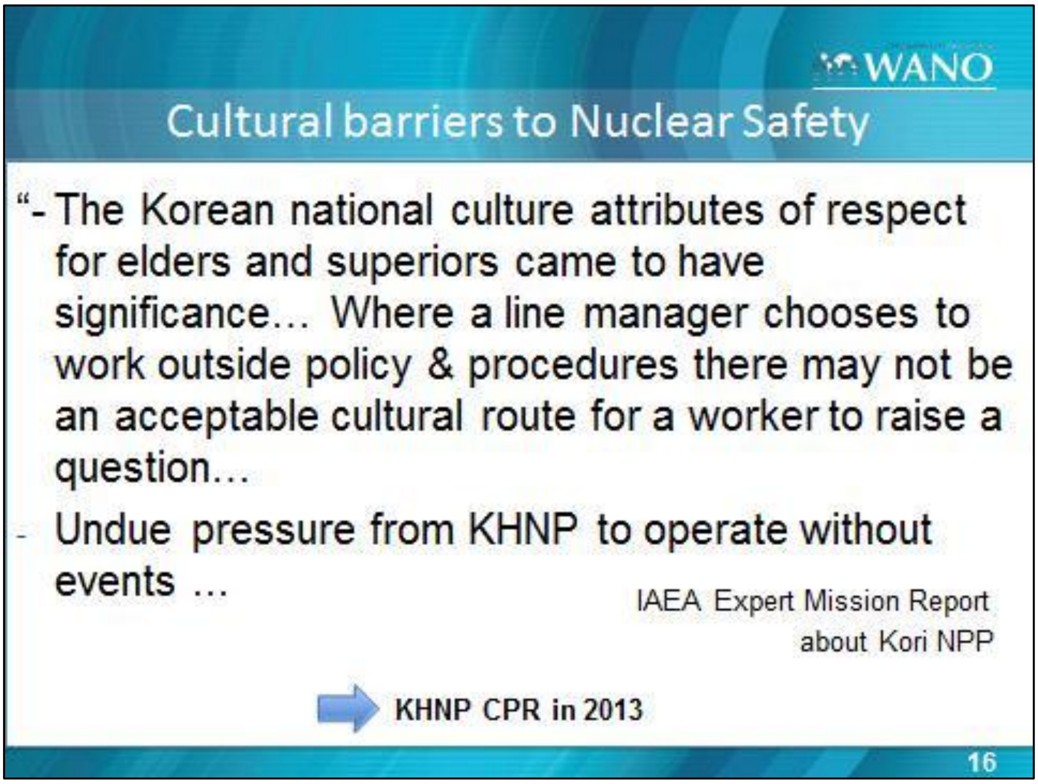

WANO
Cultural barriers to Nuclear Safety
"... It was a disaster "made in Japan", its fundamental causes can be found in the ingrained conventions of Japanese culture ...
- Reflexive obedience
- Reluctance to question authority
- Devotion to sticking with the program"
Kiyoshi Kurokawa
Chairman of the DIET
Independent Investigation Commission
TEPCO CPR including safety culture aspects to be carried out in autumn 2013
15


WANO
Cultural barriers to Nuclear Safety
"- The Korean national culture attributes of respect for elders and superiors came to have significance… Where a line manager chooses to work outside policy & procedures there may not be an acceptable cultural route for a worker to raise a question…
- Undue pressure from KHNP to operate without events …
IAEA Expert Mission Report
about Kori NPP
KHNP CPR in 2013
16

WANO

Cultural barriers to Nuclear Safety

Based on the lessons learned from the accident, to enhance the nuclear safety so that a similar accident never happen again:

- It is necessary for operators themselves to engage in continuing measures to improve safety, and to engage in an untiring pursuit of the world's highest levels of safety with questioning attitudes.
- Safety improvement must not become a self-centered, self-satisfied activity of the operator alone. Rather, it requires constant evaluation from different perspectives.

Mr Yagi - FEPC

during the 2013 WANO BGM

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WANO

Cultural barriers to Nuclear Safety

"The cause of the accident is not the inevitable result of Nuclear Power technology, but rather the inevitable result of the management system."

Institutional defect / Lack of imagination

insufficient robustness and preparations:

- design height of tsunami
- prolonged SBO
- loss of UHS
- SA in multi-units
- emergency preparedness, etc.

It is a matter of Safety Culture

--- "questioning attitude"

Mr Hattori - JAIF

during the 2013 WANO BGM

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WANO

Summary of the Presentation

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   Safety assessments
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   Renewed WANO
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WANO

Conclusion

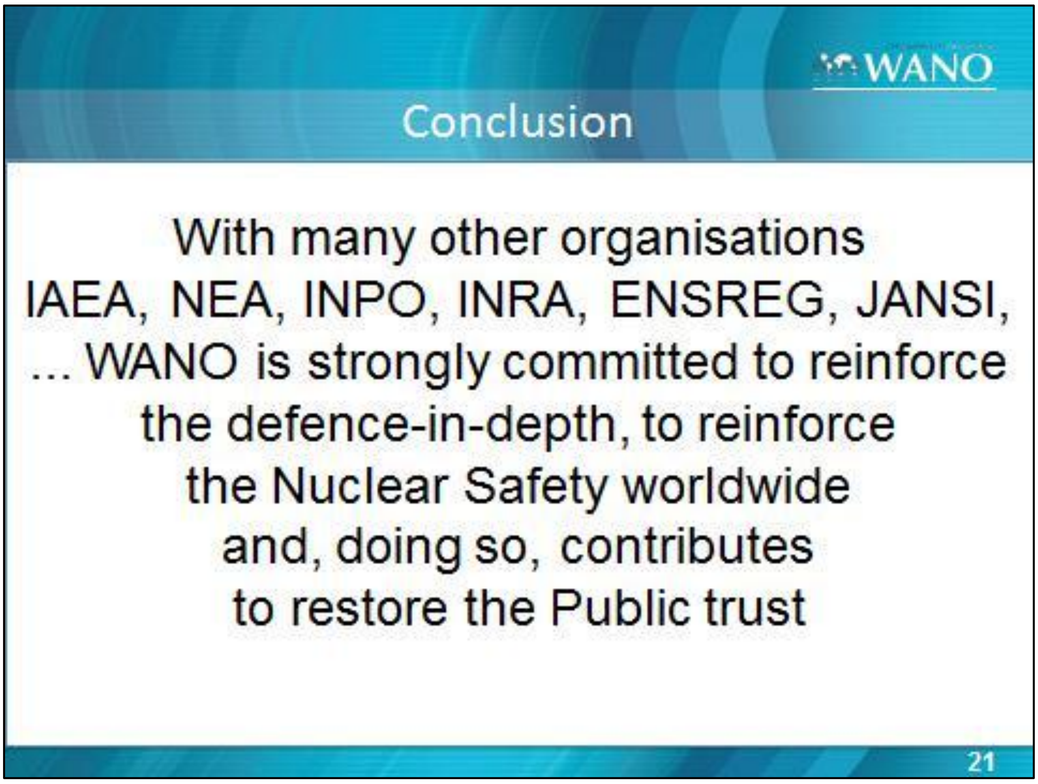
IAEA <--> States
Regulators <--> Other Regulators & States
WANO <--> Operators
(All without exception,
including New entrants)

WANO Peer Pressure to participate to the DiD:

WANO allows direct links between CEOs

If a CEO does not meet his obligations, the WANO Board or a team of Peer CEOs will discuss directly with him (escalation process)

20


WANO
Conclusion
With many other organisations
IAEA, NEA, INPO, INRA, ENSREG, JANSI,
... WANO is strongly committed to reinforce
the defence-in-depth, to reinforce
the Nuclear Safety worldwide
and, doing so, contributes
to restore the Public trust
21


WANO
We all rely on each other to improve safety!
W A N O
http://www.wano.info
22

NRA Nuclear Regulation Authority

Implementation of DiD Concept to External Events

Toyoshi Fuketa
Nuclear Regulation Authority

NEA/CNRA/CSNI Joint Workshop on
Challenges and Enhancements to DiD
in light of the Fukushima Dai-ichi Accident
OECD Conference Centre, Paris, June 5, 2013

NRA

1. Introduction

1

- The TEPCO's Fukushima Dai-ichi accident was caused by external events; earthquake and tsunami.
- While the earthquake caused damage at external power supply, there is no evidence so far that it produced to the plants mechanical and structural damage. Although one cannot deny any impact by the earthquake, it is considered that the majority of the damage was caused by the tsunami.
- Regulatory system pre-existed in Japan was not strong enough to enforce the necessary upgrades in protections against external hazards and against resulting severe accidents.
- Protection against external hazards must be enhanced according to the DiD concept, which itself is believed to be valid even after the accident.

NRA

2

2. Weaknesses found from the accident

- The Nuclear Safety Division of Atomic Energy Society of Japan pointed out three important weaknesses found from the accident.

(1) Insufficient design provision against tsunami,

(2) No practical accident management (AM) under actually-generated environments during the accident, and

(3) Insufficient provision for accidents far-exceeded from the postulated design condition.

- All these are highly related with the "Defense in Depth (DiD) against external events".

NRA

3

(1) Insufficient design provision against tsunami

- Postulated tsunami, which was decided with the method developed by the Civil Engineering Society of Japan based on the historical tsunami records, was not high enough.
- We cannot define design basis hazard (DBH) only from historical records. Cooperation is needed between nuclear safety professionals and natural phenomena experts.
- Regulatory requirements against various initiators, e.g. volcano, internal fire and internal flooding, are needed.

4

(2) No practical accident management

- Some accident management operations were not successfully implemented under the actual conditions produced by:
  - Natural phenomena including after shocks and repetitive tsunami attacks, and
  - Severe accident phenomena including hydrogen explosion at reactor buildings and high radiation level.
- Licensees and regulators must examine whether AM operations are really carried out with high reliability taking various effects of natural phenomena and severe accident phenomena into account.

5

(3) Far-exceeded from the postulated design condition

- There was no effective mitigation feature under accident conditions far beyond the postulated design condition.
- It revealed the weakness of the nuclear facilities against extreme natural hazards.
- Some provisions, including mobile devices, are needed against unexpected accident conditions.

6

3. DiD for external events
(1) DiD level 1

- DiD Level 1, prevention of abnormal operation and failures, has a particular importance.
- The clear definition of DiD Level 1 is needed especially considering external events which may cause initiating events (abnormal operation) and failures in mitigation functions simultaneously.
- SSC failures resulting in abnormal operation and failures of mitigation systems shall be prevented.

7

3. DiD for external events
(2) General approach

- The Japan's past nuclear regulation had a general approach to prevent SSC failures against individual initiators.
- The first step is to assess the hazard.
- If the annual frequency of the occurrence of a certain initiator is greater than 10^{-7} per year, design provision is required.
- Then design basis hazard (DBH) is defined.
- By providing sufficient safety margin against such DBH, SSC failures and accidents are adequately prevented.

8

3. DiD for external events – (3) DBH with adequate margin

- For each significant external and internal initiators, e.g. earthquake, tsunami, airplane crash, fire and flooding, the Design Basis Hazard (DBH) must be decided with an adequate margin.
- In deciding DBH for individual natural events, of course, historical records must be referred. In addition, possible occurrence of extraordinary events, which are not appeared in the historical records, must be included in the consideration, although it is very difficult to predict the occurrence of such an event.

9

3. DiD for external events (4) Design requirements for specific SSCs

- Specific SSCs are placed to prevent the failures of safety-related SSCs against individual initiators. Examples are tide wall, water-tight door for tsunami, and strong containment wall against airplane crash.
- The Fukushima Dai-ichi accident showed vulnerabilities in I&C, communication and radiation monitoring systems.
- Design requirements, as well as safety classification, are needed for those SSCs.

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3. DiD for External Events
(5) Later stage of DiD

- Good consensus already exists on the "prevention of SSC failures" against individual initiators, in DiD Level 1.
- On the later stages of the DiD implementation, however, initiator specific consideration was not sufficient.
- Some accident management (AM) measures and emergency responses became paralyzed during the Fukushima Dai-ichi accident due to the effects of external events, e.g. aftershocks and repetitive tsunami attacks.

11

4. Enhanced measures for external events

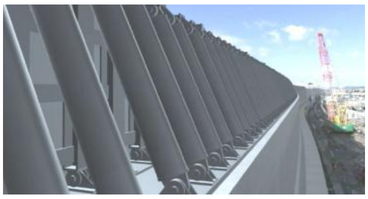
Accurate Evaluation Method on Earthquake and Tsunami; Particularly Enhanced Tsunami Measures

More stringent Standards on Tsunami ⇨ Define "Design Basis tsunami" that exceeds the largest in the historical records and require to take protective measures such as breakwater wall based on the design basis tsunami

Enlarged Application of Higher Seismic Resistance ⇨ SSCs for tsunami protective measures are classified as Class S equivalent to RPV etc. of seismic design importance classification

＜Example of tsunami measures（multiple protective measures）＞

○ Breakwater Wall
（prevent inundation to site）



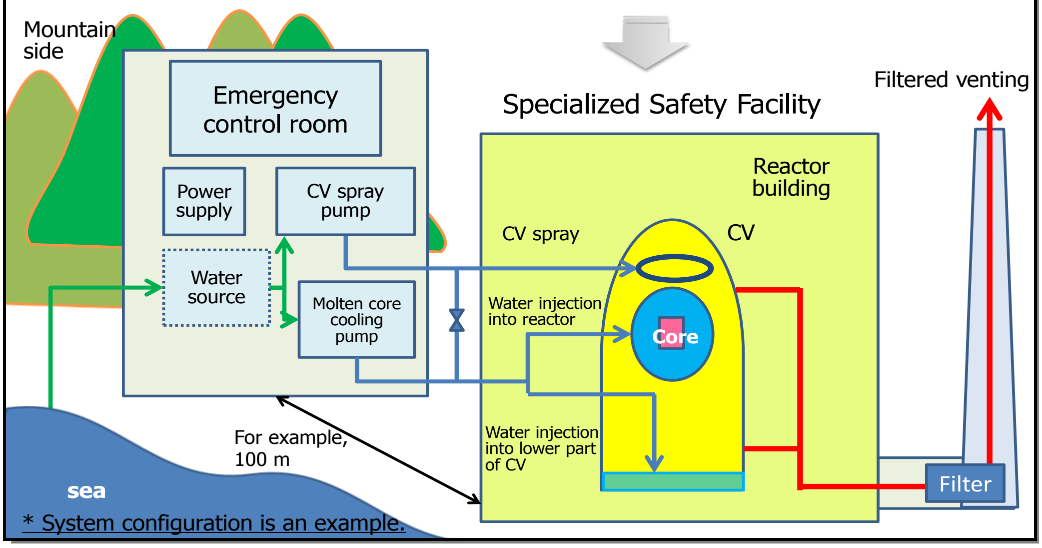
○ Tsunami Gate
（prevent water penetration into the building）

NRA

4. Enhanced measures for external events (cont'd)

12

Require "Specialized Safety Facility" to mitigate release of radioactive materials after core damage due to intentional aircraft crash



NRA

5. Concluding remarks

13

- Importance of DiD Level 1 against external events,
- General approach to cope with external events,
- How to decide DBH, considering site specific characteristics,
- Design requirements and safety classification for specific SSCs, and
- Consideration of the effects of external events in the later stages of DiD.

International consensus is highly expected on the above.

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE
Faire avancer la sûreté nucléaire

Enhancement of Defence-in-Depth against External Events in French Nuclear Power Plants

Jacques Repussard

NEA CNRA-CSNI Joint Workshop on Challenges and Enhancements to Defence-in-Depth in Light of the Fukushima Dai-ichi Accident

June 5th, 2013

Implementation of DiD

- After TMI accident, 2 levels have been added to the DiD (4th and 5th levels) and design provisions have been implemented for existing plants to limit the consequences of core melt accidents

	Level	Situations	Objectives
« Historic » design basis	L1	Normal operation	Prevention of abnormal operation and failure
	L2	Design basis incidents	Control of abnormal operation and failure Control of accident (safety systems) to limit radiological releases
	L3	Design basis accidents	
Design extension (to be considered from the initial design for new reactors)	L4	Multiple failure accidents	Control of multiple failures accidents (selected on the basis of probabilistic safety assessment)
		Core melt accidents	Control of accidents with core melt to limit off-site Releases (Improvement of the confinement)
		Accidents leading to large or early releases	Practical elimination
	L5	Emergency planning	Mitigation of radiological consequences of significant releases (off-site emergency response

NEA Workshop on Defence-in-Depth - June 5th, 2013 IRSN 2

Implementation of DiD

- Since the design stage of operating reactors, enhancements in the framework of Periodic Safety Reviews based on:
  - In-depth analyses of operating experience
  - Insights of the Probabilistic Safety Assessments (PSA)
  - Knowledge gained from R&D results and modeling improvements
  - Safety improvements towards new reactors as far as reasonably achievable

  Significant enhancement of DiD has been already obtained for internal events:
    - Design and organizational provisions to reduce core melt frequency
    - Dedicated additional provisions to cope with multiple failure situations (loss of heat sink…)
    - Some design provisions for core melt accidents (H2 recombiners…)

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DiD /External events before Fukushima

- The initial design of PWRs against external hazards is based on:
  - The characterization of design basis hazards
  - The protection of structures and components against these hazards so that no accident is initiated
  - Determination for each hazard of the safety SSC that shall be resistant or protected: mainly SSC involved in design basis situations
- Several incidents due to natural events occurred in France in the last 20 years (site flooding in 1999 (storm), loss of off-site power due to icy rains in 2005, ultimate heat sink clogging by algae in 2009…)

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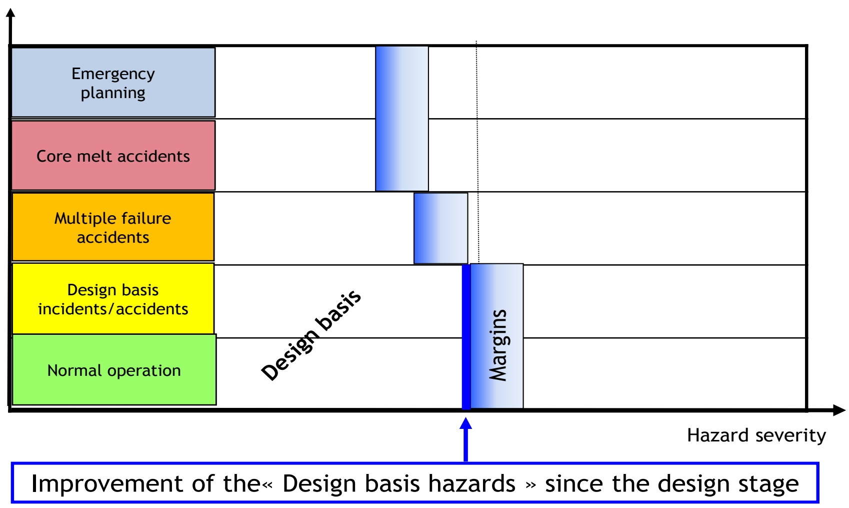
DiD /External events before Fukushima

- As a consequence, **the protection of the plants against natural hazards is an important topic of the Periodic Safety Reviews (PSR)** conducted on the French plants

↓

- Requirements have been reinforced and design and organizational improvements have been consequently set in place:
  - **Some design basis natural hazards were significantly reassessed**: reassessment of all flooding hazards after the 1999 storm, updating of the requirements for earthquake in 2001 and for extreme temperatures (in the 90's for extreme cold, in 2008 for extremely high temperature)…
  - **Additional hazards and combinations of hazards** have been considered: frazil, tornadoes…

DiD /External events before Fukushima



⇨ However resistance of SSC to natural hazards depends on DiD levels

DiD /External events before Fukushima

- The assumption that natural hazards will not induce accidents has been reexamined (since 2001 after Le Blayais NPP flooding) and it has been recognized that both loss of external electrical sources and loss of ultimate heat sink of long duration are likely to be induced by some hazards

- It was also recognized that natural hazards can have an impact on several plants on a site and emergency plans have been adapted

→ Design and organizational improvements have been consequently set in place
  - o Improvement of the accidental procedures and the on-site emergency plan to deal with multi units accidents
  - o Increase of secondary water inventory to cope with the loss of heat sink

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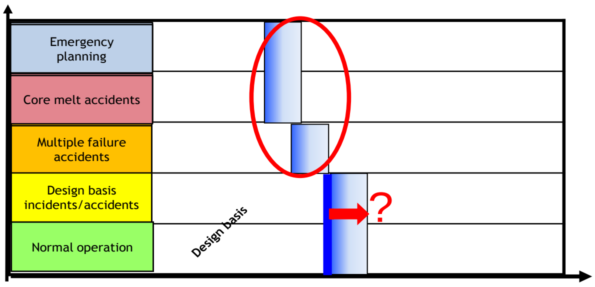
Improvment of DiD after Fukushima

- After the accident at Fukushima Dai-ichi, a complementary safety review has been performed on French plants (« stress tests »), targeted on the resistance of plants against extreme natural hazards

- The reassessment and the design improvements are focused on the reinforcement of the DiD for natural hazards (as already done for internal events) considering:
  - o Natural hazards exceeding the design levels (« design extension »)
  - o Accidents (including core melt accidents) due to natural external hazards



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Improvment of DiD after Fukushima

- As a conclusion to the « stress tests », it was decided to implement specific design provisions to ensure the robustness of the plants against extreme natural events

- **Implementation of a « Hardened Safety Core »**
  - Designed against hazards higher than design levels
  - Limited set of equipment
  - Ensuring main safety functions at last during the first 24 hours
  - Covering both prevention and mitigation of core melt accidents
  - Including emergency management

- In complement, EDF is implementing an **Nuclear rapid intervention force** to provide mobile equipment to the site (beyond 24 hours)

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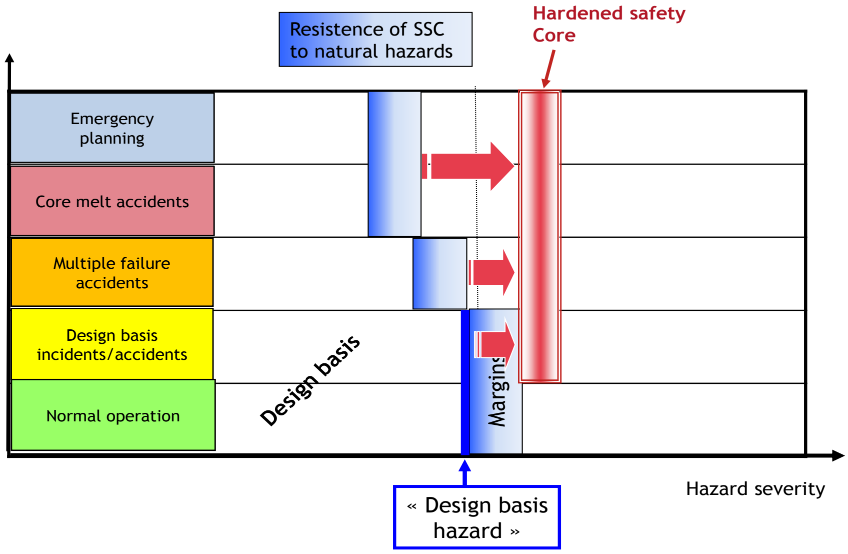
Improvment of DiD after Fukushima



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DiD - Conclusions

- Since the initial design, requirements have been reinforced and improvements have been implemented for the protection of NPPs against external hazards
  - ➔Review of design basis hazards characterization, improvement of protections
- The Fukushima accident has pointed out the need to go further: to ensure robustness for more severe hazards and to deal with accidents (including core melt accidents) induced by natural hazards
  - ➔“Hardened safety core”, “Nuclear rapid intervention Force”
- In addition to this deterministic approach, more efforts will be devoted in France to the development of Probabilistic Safety Assessments related to external hazards

NEA Workshop on Defence-in-Depth - June 5th, 2013 IRSN 11

РОССИЙСКАЯ АКАДЕМИЯ НАУК
Институт проблем безопасного развития атомной энергетики
ИБРАЭ
RUSSIAN ACADEMY OF SCIENCES
Nuclear Safety Institute (IBRAE)

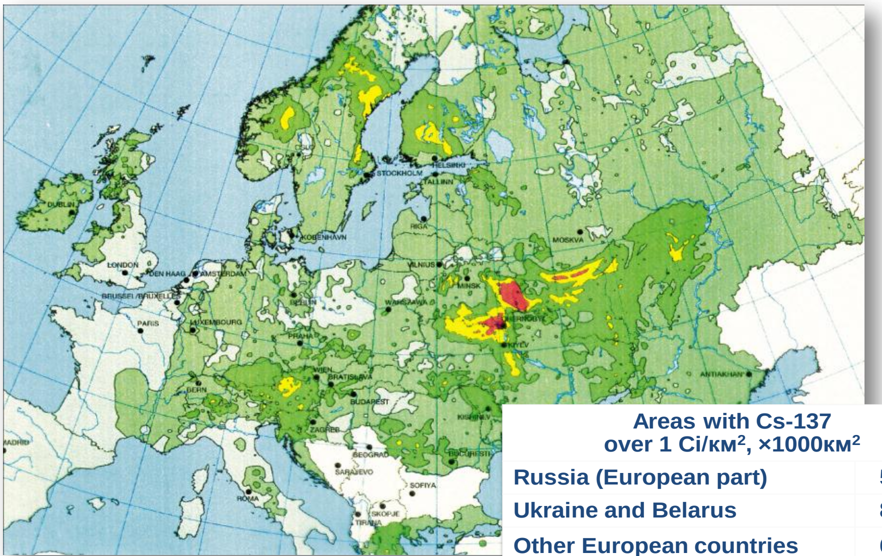
Russia's efforts to improve safety after Chernobyl and Fukushima accidents

Leonid A. Bolshov

June 5, 2013
Paris
www.ibrae.ac.ru

1

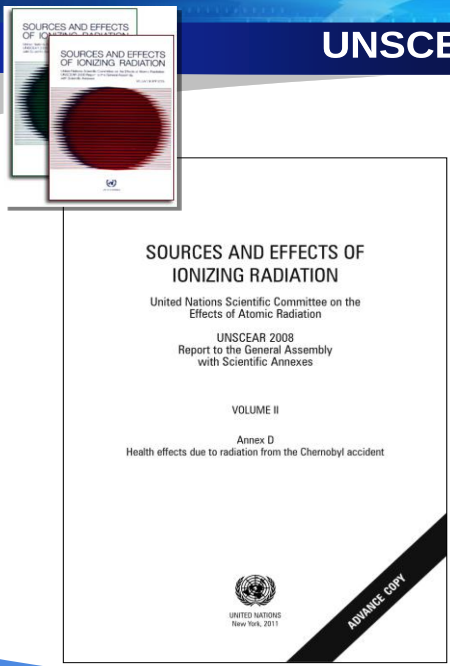
Cs-137 contamination in Europe



Areas with Cs-137 over 1 Ci/км², ×1000км²	
Russia (European part)	59,30
Ukraine and Belarus	81,13
Other European countries	67,07

2

UNSCEAR conclusions



Main conclusion of UNSCEAR 2000 report «Health effects due to radiation from the Chernobyl accident»:

- Chernobyl radiation has no effect for population health;
- registered and expected effects are not within priorities of public health care, they belong to radiation epidemiology.

UNSCEAR 1988 Report, Appendix to annex G, 'Early effects in man of high radiation doses', Acute radiation effects in victims of the Chernobyl accident;

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation. 2000 report to the General Assembly, Vol. 2 Effects;

UNSCEAR 2008 Report to the General Assembly. Vol.2 Annex D. Health effects due to radiation from the Chernobyl accident. N.Y., 2011

Post Chernobyl efforts

SU/Russia changed attitude to SA:

- Science based approach
- Internationalization
- Studies of DiD phenomena and models
- Scenario analysis
- Harmonization of regulations (INSAG-3)
- Modernization of all NPPs
- Upgrade of the Russian emergency response system and Rosatom emergency system

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Post Chernobyl efforts

Adoption of safety culture principles:

- Priority of safety in design, construction and operation in general and day-to-day management
- Education and training programs
- Full scope simulators at every plant

5

Post Chernobyl efforts

Cleaning and remediation

- Cleaning of contaminated areas after Chernobyl
- Medical screening
- 1990 Extraordinary protection measures (8mln!)
- 1994 Conversion of federal programs from saving lives to social rehabilitation

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The Number of Deaths and Early Effects of Radiation Accidents Based on published data (except for malicious acts and nuclear weapon tests)

Type of accident	1945-1965	1966-1986	1987-2007	Total	Opinion of the Committee regarding the Report completeness
Accidents at nuclear facilities	46 early effects	227 early effects *	2 early effects	275 early effects	Most of the deaths and many injuries were likely reported.
	16 deaths	40 deaths*	3 deaths	59 deaths	
Occupational accidents	8 early effects	109 early effects	49 early effects	166 early effects	A number of deaths and injuries were not likely reported.
	0 deaths	20 deaths	5 deaths	25 deaths	
Incidents with orphan IRS	5 early effects	60 early effects	204 early effects	269 early effects	A number of deaths and injuries were not likely reported.
	7 deaths	10 deaths	16 deaths	33 deaths	
Accidents during research projects	1 early effect	21 early effects	5 early effects	27 early effects	A number of deaths and injuries were not likely reported.
	0 deaths	0 deaths	0 deaths	0 deaths	
Accidents during medical use	no data	470 early effects	143 early effects	613 early effects	It is evident that many deaths and a significant number of injuries were not reported.
	no data	3 deaths	42 deaths	45 deaths	
TOTAL					
Early effects	60	887	403	1350	
Deaths	23	73	66	162	

Table 10 p.52 of Appendix R.671 to the UNSCEAR 2008 Report

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Summary Data for Major (> 5 Victims) Accidents in the Energy Sector in 1969-2000

	OECD countries			Non-OECD countries		
Type	**Accidents**	**Victims**	**Victim/GW**	**Accidents**	**Victims**	**Victim/GW**
Coal	**75**	**2259**	**0.157**	**1044**	**18 017**	**0.597**
Coal (data for China, 1994-1999)				**819**	**11 334**	**6.169**
Coal (excluding China)				**102**	**4831**	**0.597**
Oil	**165**	**3713**	**0.132**	**232**	**16 505**	**0.897**
Natural gas	**90**	**1043**	**0.085**	**45**	**1000**	**0.111**
Oil & gas	**59**	**1905**	**1.957**	**46**	**2016**	**14.896**
Hydropower	**1**	**14**	**0.003**	**10**	**29 924**	**10.285**
Nuclear power	**0**	**0**	**-**	**1**	**31***	**0.048**
Total	**390**	**8934**		**1480**	**72 324**	

*** Instant deaths only**

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Scale of the Problem

What do you know about the victims of military and peaceful atom?

Students

Event	Real number of victims	Students' evaluations
 Hiroshima	Immediate and quick death of 210 000 people	About 300 000 people
	Remote consequences among 86572 hibakushas – 421 people	750 000 people
 Chernobyl	Immediate and quick death of 31 people	40 000 people
	Remote consequences (liquidators and population) ≈ 60 people	250 000 people

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What was wrong?

- Main safety objective: the protection of the public from excessive exposure, is not accurate.
- Core melt accidents with low or no radiation effects used to have large scale consequences because of public illiteracy, contradictory health regulations, bad communication…

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General outcome of the Fukushima Daiichi accident

1. It is now clear that many factors contributing to the Fukushima accident were identified prior to the accident:
   - *poor severe accident management planning structure;*
   - *lack of safety improvements;*
   - *inadequate evaluation of external hazards;*
   - *weak regulatory system;*
   - *lack of training of personnel on emergency preparedness.*
2. The necessary measures to address these shortcomings were not put in place.

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Fukushima experience

WHO report: zero health effects!

Territories and population in the areas with expected annual dose for population above 20 and 100 mSv after the Fukushima NPP accident

			Expected annual dose, mSv/year > 20	Expected annual dose, mSv/year > 100
In 20-km zone	Area, km²	Total	327	101
		Populated	109	24
	Population, individuals		43 700	8750
Out 20-km zone	Area, km²	Total	368	53
		Populated	84	11
	Population, individuals		16 300	4000
Total	Area, km²	Total	695	154
		Populated	193	35
	Population, individuals		60 000	12 550

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What to do

- Detailed safety analysis of low probable scenarios with severe consequences.
- A global consensus on a set of accidents that should be considered and could be ignored.
- For severe, although low-probable accidents, protective measures should be included.
- The 100 times gap between radiation effect and regulation should be bridged.
- Public information should be an essential part of the nuclear energy use.
- National technical centers should support emergency response to radiological incidents.

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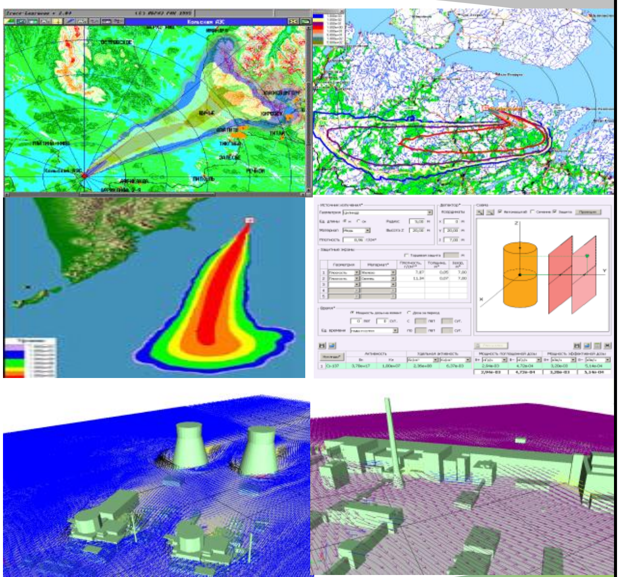
Comprehensive radiation monitoring and emergency response system

•Technical crisis centers at every facility

•Network of technical support centers

•Sophisticated software tools for analysis and forecast

•Highly redundant communications between facilities and support centers



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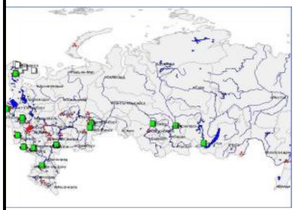
Systems of emergency response and radiation monitoring in the RF regions



Territorial systems are created in the RF regions, where operational NPPs and NPPs under construction are located, to support local authorities functioning and to demonstrate safety of the NPP's operation (system of emergency preparedness and independent radiation monitoring)

Scope of work:

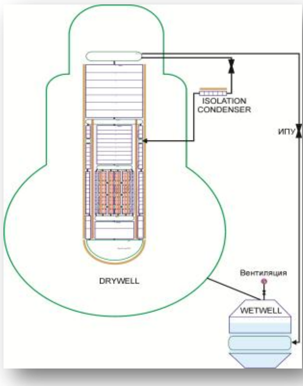
- Establishment of crisis centers;
- Creation of territorial automated system of radiation monitoring;
- Development and equipment of software & technical systems;
- Creation of mobile laboratory facilities;
- Conduct of exercises and training.

Incident analysis for Fukushima-1 units 1-3 and spent fuel pool 4 (SOCRAT)

Without water cooling taken into account

	Time (JAPAN) of explosion calculated (hydrogen for 1, 2, 4)	Time (JAPAN) of explosion actual (hydrogen for 1, 2, 4)
Unit 1	12.03 15:16	12.03 15:36
Unit 2	Pressure exceeding in the vessel 15.03 05:45	15.03 06:14
Unit 3	14.03 08:00	14.03 11:01
Unit 4 (fuel pool)	15.03. 4:00-05:00	15.03. 6:00

Reactor BWR/3 calculation model for SOCRAT code



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Tests of defense-in-depth efficiency have been done:

1. - for each power unit in operation in Russia
2. - taking into account all credible extreme impacts on NPP that are specific for the placement region
3. - taking into account various combinations of the extreme impacts

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Introduction of mobile emergency equipment at NPPs

In 2012, the following equipment was delivered to 10 Russian NPPs:

31 units — Mobile diesel-generators 2.0 MW (6kV; 0.4 kV; 220 V DC)

36 units — Mobile diesel-generators 0.2 MW (0.4 kV)

35 units — Mobile high-pressure pumping units of various capacity and head pressure

80 units — Engine-driven pumps of various capacity and head pressure

TOTAL: 182 units

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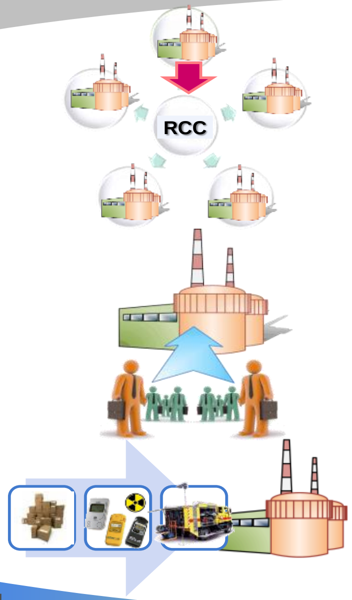
Goals of Establishing the WANO Regional Crisis Center for VVERs



1. Early notification and exchange of credible information between WANO MC Members in case of an accident or a safety important event occurred at NPP.

2. Establishing the Expert Community to provide real-time consultations and early engineering and technical support on request of an emergency NPP.

3. Establishing mechanisms for early provision of materials and technical resources as assistance of WANO MC Members on request of an emergency NPP.

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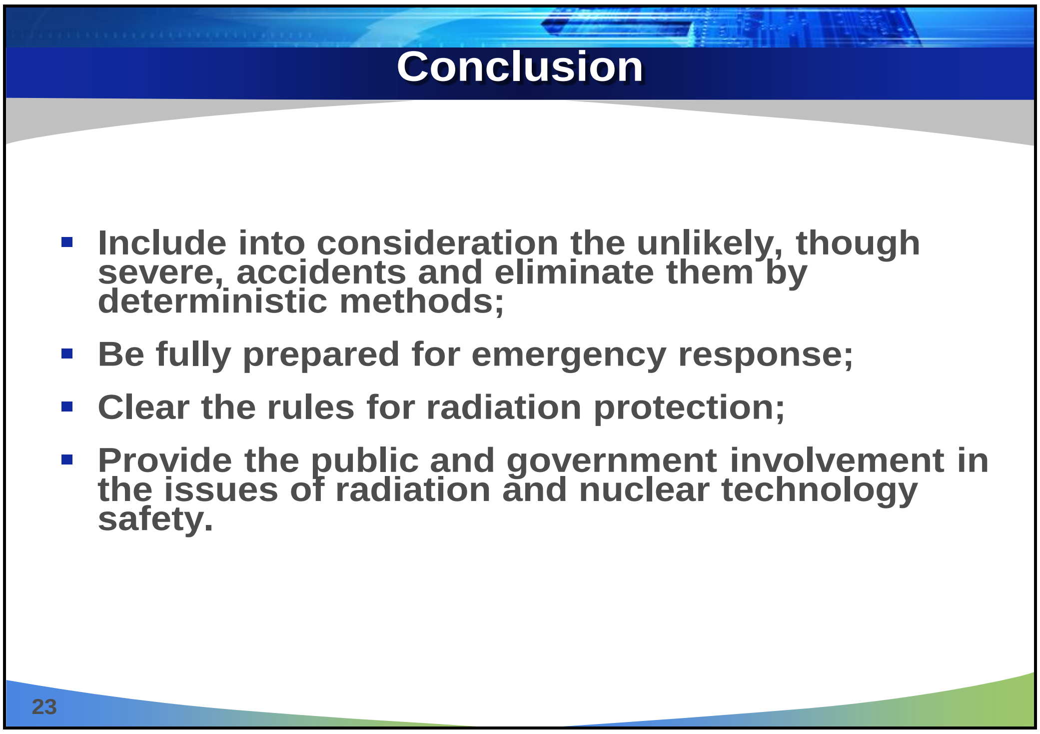
National obligations

Government of a country with NPPs or coming to acquire NPP should take the obligations:

- Educate public on real danger of radiation.
- Build consent in mass media on real danger of. radiation
- Harmonize radiation protection between normal and accidental.


Conclusion
Include into consideration the unlikely, though severe, accidents and eliminate them by deterministic methods;
Be fully prepared for emergency response;
Clear the rules for radiation protection;
Provide the public and government involvement in the issues of radiation and nuclear technology safety.
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NEA/CNRA/CSNI joint workshop on Challenges and Enhancements to Defense in Depth in light of the Fukushima Dai-chi accident

Issues on Defense in Depth perspective from French Nuclear Safety Authority (ASN)

Pierre-Franck Chevet
President – French Nuclear Safety Authority (ASN)

Content

- Defence-in-Depth for New Reactors
- Post Fukushima accident DiD evolution
- Mitigation of off-site radiological consequences

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Defence-in-Depth for New Reactors

- Clear expectation **to address in the original design what was often "beyond design" for the previous generation** of reactors (multiple failure events, core melt accidents, called Design Extension Conditions (DEC) in IAEA SSR-2/1…).
- The scope of the related safety demonstration has to cover **all risks induced :**
  - **by the nuclear fuel, including all fuel storage locations**,
  - risks induced by other relevant radioactive materials.
- The phenomena involved in accidents with core/fuel melt (severe accidents) differ radically from those which do not involve a core melt ⇨ **core melt accidents should be treated on a specific level of DiD**.
- **Design features that aim at preventing a core melt condition** and that are credited in the safety demonstration **should not belong to the same level of DiD as the design features that aim at controlling a core melt accident** that was not prevented.
- Single initiating events and multiple failure events are two complementary approaches sharing the same objective:
  - controlling accidents to prevent their escalation to core melt conditions ⇨ **multiple failure events are a part of the 3rd level of DiD**,
  - a clear distinction has to be made between means and conditions (two sub-levels in DiD level 3).

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Defence-in-Depth for New Reactors

Levels of defence in depth		Objective	Essential means	Radiological consequences	Associated plant condition categories
Level 1		Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation, control of main plant parameters inside defined limits	No off-site radiological impact (bounded by regulatory operating limits for discharge)	Normal operation
Level 2		Control of abnormal operation and failures	Control and limiting systems and other surveillance features		Anticipated operational occurrences
Level 3 (1)	3.a	Control of accident to limit radiological releases and prevent escalation to core melt conditions (2)	Reactor protection system, safety systems, accident procedures	No off-site radiological impact or only minor radiological impact (4)	Postulated single initiating events
	3.b		Additional safety features(3), accident procedures		Postulated multiple failure events
Level 4		Control of accidents with core melt to limit off-site releases	Complementary safety features(3) to mitigate core melt, Management of accidents with core melt (severe accidents)	Off-site radiological impact may imply limited protective measures in area and time	Postulated core melt accidents (short and long term)
Level 5		Mitigation of radiological consequences of significant releases of radioactive material	Off-site emergency response Intervention levels	Off site radiological impact necessitating protective measures(5)	-

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DiD for New Reactors: Independence of the levels

- There shall be **independence** to the extent reasonably practicable **between different levels of DiD** ➔ failure of 1 level does not impair the DiD ensured by the other levels involved in the protection against or mitigation of the event.
  - Ensure the independence between systems, structures and components (SSCs) important to safety, allocated to different levels of DiD.
  - It does not aim to address independence between SSCs important to safety within a level of DiD nor administrative/procedural aspects.
- Independent SSCs for safety functions on different DiD levels shall ensure that the performance of the required safety functions remains unaffected :
  - by the operation or failure of other SSCs needed on other DiD levels;
  - by the occurrence of the effects resulting from the postulated initiating event, including internal and external hazards, for which they are required to function.
- The means to achieve independence between levels are adequate application of diversity, physical separation (structural or by distance) and functional isolation
  - focus required to the design of auxiliary & support systems (e.g. electrical power supply, cooling systems) and other potential cross cutting systems.

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DiD for New Reactors: Independence of the levels

- **DiD level 3** should be independent to the extent reasonably practicable from levels 1 and/or 2
  - ➔ the failure of SSCs used in normal operation and/or in anticipated operational occurrences does not impair a safety function required in the situation of a postulated single initiating event or of a multiple failure event resulting from the escalation of such failures during normal operation or a level 2 event.
- **DiD sublevels 3a and 3b** should be independent to the extent reasonably practicable from each other
  - For the safety analyses of postulated multiple failure events, credit may be taken from SSCs used in case of postulated single initiating events as far as these SSCs are not postulated as unavailable and are not affected by the multiple failure event in question;
  - SSCs specifically designed for fulfilling safety functions used in postulated multiple failure events (additional safety features) should not be credited for level 3.a event analyses for the same scenario.
- **DiD level 4** (Complementary safety features) should be independent to the extent reasonably practicable from all the other levels
- Specific considerations on: emergency AC power supply , separation of cables, reactor protection system an other I&C aspects, containment, reactor pressure vessel

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Post Fukushima accident DiD evolution

- Extended consideration of cumulated :
  - SBO
  - Loss of heat sink
  - Extreme external hazard
  - Reactor and fuel pool accident
  - All reactors and fuel pools of the whole site concerned
  - Every reactor and pool state considered including fuel element transfer operation
  - Accident duration

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Post Fukushima accident DiD evolution

- Impact on level 1-3 defence in depth :
  - Improvement of electrical systems
  - Improvement of external hazards protections
  - Improvement of alert systems (seismic, weather, flooding…) and related operating procedures
  - Evolution of design basis definition to be taken into account during PSR.
- Impact on level 4-5 defence in depth :
  - ➢ Hardened safety core
  - ➢ Increased expectation on some safety systems
  - ➢ FARN
  - ➢ Improvement of local mobiles means
  - ➢ Improvement of emergency centre…

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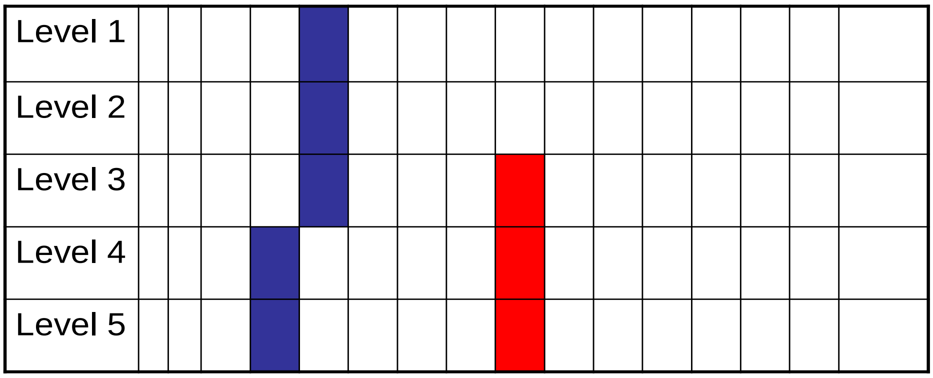
Post Fukushima safety demonstration

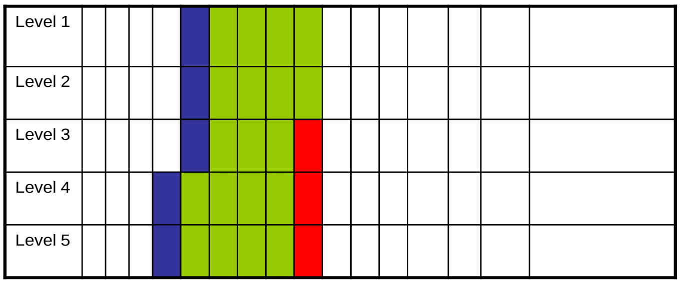
Safety demonstration external hazard



Hardened safety core, emergency centre , mobile means connection…external hazard

Shall deterministically take into account low probability events

The place for robustness and good practices



Medium long term issues : The green zone

•Improve beyond design basis robustness of existing systems and structures.

•Identify issues that are not yet taken into account : contaminated water management (before decontamination of water, it has to be collected and stored within dedicated means, through a dedicated collecting system…).

•Identify and implement good practices that increase plant robustness though they cannot be included in safety demonstration since their success is not 100% justified : reactor providing electricity through its own turbine in case of loss of grid, or 1 plant providing electricity to the whole site…

•Ability to repair systems…

Mitigation of off-site radiological consequences (level 5) – CODIRPA (post-accident)

- Important to prepare the post accident actions **prior to an emergency**

- CODIRPA created in 2005 by Government request
- Doctrine developed on several thematic (foodstuffs, health monitoring, remediation, waste management…)
- Actions based on an immediate delineation of a protective actions zoning for the contaminated area, with an evolution during the transition period

- Doctrine developed **with all the stakeholders** within a pluralistic structure (national and local administrations, expert bodies, operators, NGOs, local elected officials, professional unions, neighboring countries…)

- Doctrine **tested in national exercises** (St Laurent NPP 11-12 June…),
- 2 international seminars in Dec. 2007 and May 2011

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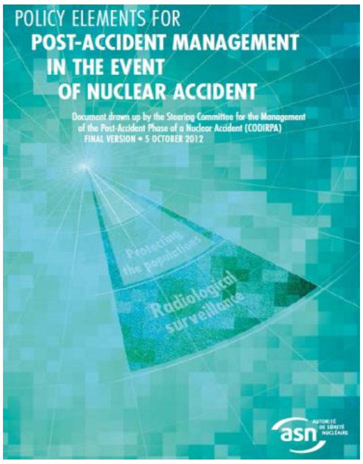
Mitigation of off-site radiological consequences (level 5) – CODIRPA (post-accident)

Publication of "Policy elements for post-accident management in the event of a nuclear accident" grouping together

- ➢ **Main document: objectives, principles, key actions and strategic orientations for the transition and long term phases**
- ➢ **Annex 1 : The first actions to be put in place at the end of the emergency phase**
- ➢ **Annex 2 : The guidelines for managing transition period (few months)**
- ➢ **Annex 3 : The guidelines for managing long-term period (several years)**



Published in 2012 – French and English versions available

Japanese and Russian versions in preparation

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ASN position on the crisis management

- **Primary responsibility of the operator** to enhance its emergency preparedness organization and crisis management means

- **Main principles**

  - Primary **responsibility of the affected country** in the response
    - Ensure a long-term protection of population and the environment
    - Restore the plant to a safe condition
    - Inform concerned stakeholders (national and international levels) – foreign countries need to have access to appropriate data in order to fulfill their missions of protection of the population

  - **Provide an European support** to the regulatory body of the affected country

  - **Promote harmonization of approaches and criteria** implemented for the protection of population and the environment during both emergency and post-accident phases (strong support to activities carried out by regulatory bodies associations – HERCA, WENRA…)

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