Roadmap on R&D and Human Resource for Light Water Reactors Safety in Japan

Nuclear Safety Visions and Technical Basis Reconstruction after the Fukushima Accident

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Chairperson of the Special Committee on Nuclear Safety Research Roadmap,
Atomic Energy Society of Japan
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   • IAEA IGALL, IAEA CRP
## Situations Surrounding the Use of Nuclear Power in Japan

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<td>Related to the Accident at Fukushima Daiichi Nuclear Power Station</td>
<td>▲ Accident at TEPCO's Fukushima Daiichi Nuclear Power Station (March 11, 2011)</td>
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<td>Decommissioning</td>
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<td>Electric Market Reform</td>
<td>Establishment of the Organization for Cross Regional Coordination of Transmission Operators</td>
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<td>Legal Unbundling of Transmission and Distribution Sectors</td>
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<td>Strategic Energy Plan</td>
<td>4th Strategic Energy Plan (April 11, 2014)</td>
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<td>Basic line of Energy policy with a view to an energy supply-demand structure for the mid to long term (20 years)</td>
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<td>Overseas</td>
<td>Nuclear Power</td>
<td>Total capacity of nuclear power in the world: to grow by about 10 to 90% by 2030, about 10% to 190% by 2050 (IAEA)</td>
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<td>Related to Climate Change</td>
<td>▲ 2nd commitment period of the Kyoto Protocol</td>
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<td>Submitting Intended Nationally Determined Contribution before COP 21 (end of 2015)</td>
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### Notes:
- ▲: Important Events
- 2011-2050: Future projections
- IAEA: International Atomic Energy Agency
- IEA: International Energy Agency
Current Status of Strategic Energy Plan in Japan

- 4th Strategic Energy Plan has been determined by the Government on April 11, 2014 to provide basic lines of energy policy with a view to an energy supply-demand structure for the mid to long-term for these 20 years.

✓ “Nuclear power is an important baseload electricity source.”
# 28 Items from the Lessons Learned from the Fukushima Accident

**Report of the Japanese Government to the IAEA**

*The Accident at TEPCO’s Fukushima Daiichi NPS - Second Report (September 2011)*

### (Category 1; Prevention of SAs)
1. Strengthen measures against earthquakes and tsunamis
2. Ensure power supplies
3. Ensure reliable cooling function of reactors and PCVs
4. Ensure reliable cooling functions of spent fuel pools
5. Thorough accident management (AM) measures
6. Responses to multi-unit site issues
7. Consideration of NPS arrangement in basic design
8. Ensuring the water tightness of essential equipment and facilities

### (Category 2; Countermeasures against SAs)
9. Enhancement of measures to prevent hydrogen explosions
10. Enhancement of the containment venting systems
11. Improvements to the accident response environment
12. Enhancement of the radiation exposure management system at the time of the accident
13. Enhancement of training for responding to severe accidents
14. Enhancement of instrumentation for reactors and PCVs
15. Central control of emergency supplies and setting up of rescue teams

### (Category 3; Responses to nuclear emergencies)
16. Response to a combined situation of massive natural disaster and nuclear emergency
17. Reinforcement of environmental monitoring
18. Clarification of the allotment of roles between central and local organizations
19. Enhancement of communication regarding the accident
20. Enhancement of responses to assistance from other countries and communication to the international community
21. Accurate understanding and prediction of the effect of released radioactive materials
22. Clear definition of the criteria for wide-area evacuations and radiological protection standards in nuclear emergencies

### (Category 4; Enhancement of safety infrastructure)
23. Enhancement of safety regulatory and administrative systems
24. Establishment and reinforcement of legal frameworks, standards and guidelines
25. Human resources for nuclear safety and nuclear emergency preparedness and Responses
26. Ensuring the independence and diversity of safety systems
27. Effective use of probabilistic safety assessment (PSA) in risk management

### (Category 5; Thoroughly instill a safety culture)
28. Thoroughly instill a safety culture
Nuclear Regulatory Authority (NRA) was established in Sep. 2012 and developed the new regulatory requirements for NPPs which came into force in July 2013.

- All the 48 units have been shut down since Sep. 2013.
- So far, a total of 20 units, 12 PWRs and 8 BWRs, have applied for conformance review for restart.
- In Sep. 2014, NRA first approved the applications from Sendai Units 1 and 2.
- In Feb. 2015, NRA approved the applications from Takahama Units 3 and 4.

The new requirements for fuel cycle facilities and research reactors came into force in Dec. 2013.

The former JNES was merged with NRA on Mar. 1, 2014.

NRA invited the IAEA IRRS mission to be taken place in late 2015.
**Basic Policies Set out in Major Acts Amended in June, 2012**

**Basic Act for Atomic Energy**
- Safety objective was stipulated in Article 2:
  
  To protect people’s lives, health and property, and the environment, and to contribute to security …,

  taking into account established international standards

**Nuclear Regulation Act**
- Mandatory severe accidents measures
- Back-fitting to existing plants
- Licensee’s primary responsibility for safety
- Limit of operation of 40 years for NPPs with possible extension up to 20 years just once
- Special regulation applied to disaster-experienced plant (Fukushima Daiichi), etc.

Dr. Masashi HIRANO (NRA),
**New Regulatory Requirements: Basic Structure**

**Requirements for B-DBA**
- **DEC**: Design extension conditions defined in IAEA SSR-2/1

**Previous Requirements**
- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs
- Seismic/Tsunami resistance

**Current Requirements**
- Suppression of radioactive materials dispersal
- Specialized Safety Facility
- Prevention of CV failure
- Prevention of core damage
- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs
- Seismic/Tsunami resistance

**4th Layer of DiD**
- Reinforced Severe Accident Measures (New)

**3rd Layer of DiD**
- Reinforced
Proposals for Voluntary and Continuous Improvement of Nuclear Safety (2014.5.30)

Report by the WG on Voluntary Efforts and Continuous Improvement of Nuclear Safety, Nuclear Energy Subcommittee, the Advisory Committee for Natural Resources and Energy (2013.7-)

Recommendations on Desirable Efforts for the Future Activities and Research and Development

✓ Implementation of risk management under an appropriate risk governance framework

✓ Activities required to be implemented with lessons learned from the accident at TEPCO’s Fukushima Daiichi NPS as the starting point

  • Implementation of exhaustive and comprehensive risk assessments including low-frequency events
  • Reduction of residual risk through strengthening “defense in depth”
  • Identifying the accident sequences and cliff edges at each plant, focusing on external events, and improving resilience
  • Reorganization of research for improving the safety of light water reactors and reinforcement of research coordination
Proposals for Voluntary and Continuous Improvement of Nuclear Safety (2014.5.30)

Report by the WG on Voluntary Efforts and Continuous Improvement of Nuclear Safety, Nuclear Energy Subcommittee, the Advisory Committee for Natural Resources and Energy (2013.7-)

- **Previous Research Activities on Safety of Light Water Reactors**
  - Activities on basic research and safety research on light water reactors by research institutions have been reduced since 1990s, because of the matured light water reactor technologies.
  - Countermeasures against severe accidents have been implemented voluntarily by electric utilities from early 2000s, research and development activities related to severe accidents of light water reactors have decreased significantly by both industries and government.
  - Collaboration among the industry, academia and government was not sufficient.
  - Joint research activities by the promoting side and the regulating side of the government, have not been implemented effectively, even though these are common in other countries.

- **Construction of Future Research Roadmap**
  - The Roadmap for Light Water Reactor Safety Research and Human Resources is considered as an tools for effective safety improvement in the future and communication tool which can share the consensus between the stakeholders including the public.
  - Clear roles are decided among the related organizations to promote research and development activities effectively without duplication.
Basic Policy to Construct The Roadmap for Light Water Reactor Safety Technology and Human Resource

“WG on Voluntary Improvement of Safety, Technology and Human Resource” was established in August, 2014 under the Nuclear Energy Subcommittee of Advisory Committee for Natural Resources and Energy in METI.

The WG provided the Basic Policy to construct the Roadmap for Light Water Reactor Safety Technology and Human Resource

- The Roadmap should be formulated in full consideration of the lessons learnt from the experiences of the accident at TEPCO’s Fukushima Daiichi Nuclear Power Station, so that the public can feel confident of safety of light water reactors.

- In order to define items of technology development and to maintain and develop human resources to support these items, firstly we need to present challenges in realizing enhancement of the public confidence in the safety of the light water reactors and safe and continuous use of the reactors; then we need to reconstruct the roadmap by reviewing the priority of the existing technology development and schedule, with considering whether they can contribute to resolve the challenges.

- Roadmap for Light Water Reactor Safety Technology and Human Resource should be able to realize the optimal approach, by clarifying roles among the parties concerned such as academic societies, the government, operators, manufacturers, and research institutes; and by eliminating overlapping of roles in Japan as a whole. Furthermore, in order to obtain the highest level of outcomes with eliminating overlapping of the roles in research and development, elements of necessary international collaborative researches should be actively incorporated into the roadmap, in full consideration of the trend of the global research and development and human resource development.
Construction of the Roadmap for Light Water Reactor Safety Technology and Human Resource

Basic Energy Plan in Japan
Positioning of Nuclear Power in Energy Policy

The Public

International Community

IAEA
OECD/NEA

Organization in Other countries

Science Council of Japan

Nuclear Standards Committee of JEA

Architectural Institute of Japan

Japan Association for Earthquake Engineering

AESJ’s Special Committee on Nuclear Safety Research Roadmap

• Industries
The Federation of Electric Power Companies of Japan Plant Manufacturers

• Academia
Universities, JAEA

• Government as observer
Agency for Natural Resource and Energy in METI

AESJ : Atomic Energy Society of Japan

WG on Voluntary Improvement of Safety, Technology and Human Resource

Request to draft the Roadmap

Original Plan of the Roadmap

METI
Advisory Committee for Natural Resources and Energy
Nuclear Energy Subcommittee

Safety Technology and Human Resource Roadmap

Industries
The Federation of Electric Power Companies of Japan Plant Manufacturers

Academia
Universities, JAEA

Government as observer
Agency for Natural Resource and Energy in METI

Nuclear Regulation Authority

METI

Original Plan of the Roadmap

Safety Technology and Human Resource Roadmap

AESJ’s Special Committee on Nuclear Safety Research Roadmap

• Industries
The Federation of Electric Power Companies of Japan Plant Manufacturers

• Academia
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Basic Energy Plan in Japan
Positioning of Nuclear Power in Energy Policy

The Public

International Community

IAEA
OECD/NEA

Organization in Other countries

Science Council of Japan

Nuclear Standards Committee of JEA

Architectural Institute of Japan

Japan Association for Earthquake Engineering

WG on Voluntary Improvement of Safety, Technology and Human Resource

Request to draft the Roadmap

Original Plan of the Roadmap

AESJ : Atomic Energy Society of Japan
As a result of the above, Continuous contribution

1. Utilization of Risk Information for existing light water reactors, etc.

Safety Measures for the Existing Reactors from Design to Decommissioning

2. Reduction of Risk of existing light water reactors

3. Measures to prevent on-site damage from expanding in the event of an accident

4. Measures to minimize off-site damage in the event of an accident

5. Safe decommissioning of existing reactors

6. Nuclear non-proliferation and nuclear security

7. Development of Innovative Technologies applicable to light water reactors, which are beyond conventional ideas

8. Maintenance and development of Human Resources required for safe and continuous use of light water reactors
<table>
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<tr>
<th>Sub-Committee</th>
<th>Description</th>
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<tbody>
<tr>
<td>Maintenance and Plant Life Management</td>
<td>Review countermeasures against facility ageing based on operational experiences and plant maintenance as well as the challenges related to safe operation.</td>
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<tr>
<td>Safety Improvement through Design</td>
<td>Review the challenges related to safety improvement through design activities for fuels, materials, thermal hydraulics, etc.</td>
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<tr>
<td>Accident Management</td>
<td>Review the challenges related to accident management.</td>
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<tr>
<td>Earthquake Resistance and External Events</td>
<td>Review the challenges related to long-term durability of buildings and structures with taking into account external events such as earthquakes, tsunamis and external events.</td>
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<tr>
<td>Decommissioning (*)</td>
<td>Review the challenges related to the processes of safe decommissioning of the existing reactors and handling of large wastes, etc.</td>
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<tr>
<td>Nuclear Security</td>
<td>Review the challenges related to nuclear non-proliferation and nuclear security as nuclear energy is widely used in international community.</td>
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* Technology Development related to Decommissioning of TEPCO’s Fukushima Daiichi NPS is not included in this Roadmap.
Nuclear power plants are continuously utilized as important energy resource to fulfill 3Es, ensuring safety with the trust from the people.

- **A**: Improvement of risk management capability
- **B**: Continuous enhancement of safety foundation
- **C**: Trust from the society and coexistence
- **D**: Promotion of international cooperation & international contribution
- **E**: Technical and social approach toward treatment and disposal of radioactive wastes

Lessons Learnt from the Fukushima Accident, Current Technology and Human Resources

Sharing and expansion of safety foundation

Latest Knowledge and New Findings in Other Countries and Related Fields
## Categorization of Social Requirements and Needs to Construct the Roadmap

<table>
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<th>Social requirements and needs</th>
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<tr>
<td>✓ Sincere dialogue and information disclosure based on the assumption that risks exist</td>
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<tr>
<td>✓ In order to reduce accident risk as low as possible, continuous review of challenges through a series of discussions with grasping a total picture of matters from diversified viewpoints, which leads to elimination of unexpected matters</td>
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<td>✓ Retention of flexible systems and organizations capable of utilizing the latest knowledge and technology succession</td>
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<td>➤ Sharing of the experience and lessons learned from the accidents and decommissioning work at Fukushima Daiichi</td>
<td>Continuous Advancement of Safety Foundation</td>
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<td>➤ Sharing and utilization of best practice based on abundant operational experience</td>
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<td>➤ Long-term forecast for acquisition of the latest knowledge and findings through continuous basic and advanced researches</td>
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<td>➤ Realization of reactors with a minimized risk of severe accident by employing innovative technology</td>
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<td>✓ Completion of responses to the 1F accident and strong determination of the people in nuclear energy field never to recur an accident</td>
<td>Trust from the Society and Coexistence</td>
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<tr>
<td>✓ Sincere attitude and approach by the people in nuclear industry that can be trusted</td>
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<tr>
<td>✓ Sincere dialogue and information disclosure based on the assumption that risks exist</td>
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<td>✓ Operation under an indispensable prerequisite of ensuring safety as well as establishment of systems for nuclear disaster prevention and continuous improvement</td>
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<td>✓ Contribution to stable supply of energy</td>
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<td>✓ Contribution to suppression of greenhouse gas emissions</td>
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<tr>
<td>➤ Provision of experience and knowledge for the purpose of creating international codes and standards based on the 1F accident as well as contribution to international diffusion of safety measures that satisfy such codes and standards</td>
<td>International Cooperation and Contribution</td>
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<tr>
<td>➤ Contribution to nuclear non-proliferation and nuclear security</td>
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<td>➤ Contribution to suppression of greenhouse gas emissions</td>
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<tr>
<td>✓ Reduction of risks for future generations by reducing volume and toxicity of radioactive wastes</td>
<td>Technological and Social Approach toward Radioactive Wastes Management</td>
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<tr>
<td>Awareness for challenges pointed out by the researchers and engineers</td>
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| • Reflection of knowledge and findings from the 1F accident into the existing reactors  
• Improvement of organizational strength and optimization of organizational formation and division of functions  
• Advancement of method for safety management education | Improvement of Risk Management Capability |
| • Reduction of maintenance and operation workloads (including response to exposure reduction)  
• Improvement of communication capability in various situations  
• Continuous development of human resources for maintenance, operation and management | |
| • Retention of technological base (basic research, experiment facilities, etc.)  
• Production of database based on the knowledge of operational experience and creation of a system for continuous maintenance and utilization | Continuous Advancement of Safety Foundation |
| • Enhancement of reliability of facilities and equipment through advancement in methods and measures to evaluate ageing deterioration  
• Reflection of the outcome of technology development into regulatory guidelines and standards | |
| • Completion of decommissioning work at 1F  
• Electric utilities’ involvement in and support for regional disaster prevention | Trust from the Society and Coexistence |
| • Contribution to reduction in greenhouse gas emissions through safe and stable operation with a high availability factor  
• Realization of the plants that do not require evacuation of the local residents concerned | |
| • Technical and managerial support for countries that newly introduce nuclear power generation  
• Establishment of challenges that are common to the needs in other countries (development of advanced technology, etc.) | International Cooperation and Contribution |
| • Contribution to formulation of international technical standards  
• Contribution to international organizations through provision of human resources and various activities, in addition to financial support | |
| • Development of innovative technology to suppress generation of radioactive wastes  
• Development of technologies to shorten lives or reduce volume of radioactive wastes by nuclear transformation | Technological and Social Approach toward Radioactive Wastes Management |
| • Study of optimum process for selection of repository sites and approach to sharing social awareness and understanding | |
### Milestones: Steps to Complete Long-term Objectives in the Roadmap (Draft Version)

**Stage 1 (Short term)**
- **2020**
  - 1. Voluntary efforts for improvement of safety and reliability based on defense in depth have been made and risk disclosure with taking account of the people’s concerns and dialogue are smoothly conducted on such efforts. [A, C]
  - 2. As electric utilities complete their efforts and activities to satisfy new regulatory standards and voluntary efforts for safety improvement take root, a more positive relationship between regulatory authorities and electric utilities is established for promoting safety improvement further. [A]
  - 3. A system for disaster prevention becomes enhanced and sophisticated, resulting in harmonization with efforts for prevention of natural disasters as well as protection of the humans and the environment from radiation. [C]
  - 4. As nuclear power generation is widely used in the world, our country contributes to improvement of nuclear safety in countries with nuclear power plants through provision of technology and information, based on abundant operational experience and knowledge in Japan. [B, D]

**Stage 2 (Medium term)**
- **2030**
  - 1. With continuous and effective reduction of accident risk and the trust from the people created through good communication, nuclear power generation is used as a stable energy source in consideration of cost balance with other generation resources. [A, C]
  - 2. Through incorporation of technology for further safety improvement and some of requirements for management response into plant design, the knowledge to substantially reduce accident risk is obtained and efforts for development of innovative technology are continuously made. [B, C]
  - 3. As the number of countries with nuclear power plants increases, our country contributes to nuclear safety through various activities under an international framework for cooperation with providing a high level of human resources and technology to lead other countries in international organizations. [B, D]

**Stage 3 (Long Term)**
- **2050**
  - 1. As innovative technology to reduce risks associated with radioactivity release into the environment or radioactivity exposure due to accidents or troubles has been developed progressively, many countries would utilize nuclear energy as a safe and stable generation resource with no greenhouse gas emissions under international safety standards that incorporate the latest knowledge and findings and advanced technology. [A, B, C, D]
  - 2. As technology to reduce the volume and toxicity of radioactive wastes has been developed progressively, a positive perspective for reduction of such volume and toxicity is obtained for future generations. [A, B, C, D, E]
  - 3. Amid the level of technology and knowledge on nuclear safety rises worldwide and the latest knowledge is always shared and used internationally, our country takes a leadership role in the field of nuclear safety in the world. [A, B, C, D]
Continuous improvement of risk assessments of power plants in operation (MII02, LI07)

Provide risk information for more effective disaster prevention, strengthen collaboration with external assistance organizations to contribute to community disaster prevention (SII10, SII07)

Re-awareness of nuclear risks based on 1F accident experiences, and set risk reduction goals (SII103, SII102, SIV08)

Accept human resources training regarding the use of risk information from abroad (MV02)

Reflect risk reduction measures based on lessons learned from the 1F accident onto hardware (SII12, MI02)

Develop human resources capable of providing on-site direction in nuclear newcomer countries (MV02)

Maintain a pool of human resources who can play active role internationally in risk information utilization (LI02)

Continuous improvement of risk assessments of power plants in operation (MII02, LI07)

Contribute to wide-area disaster prevention (MIV05, LI03)

Create a resilient organization capable of responding to large-scale disasters and emergency situations (LI06, LI07)

Accepting human resources training regarding the use of risk information from abroad (MV02)

Develop human resources capable of providing on-site direction in nuclear newcomer countries (MV02)

Inform the international community of the assessment and organizational structure that reflect the lessons of the 1F accident, thus contributing to improved worldwide nuclear safety (MV01, LI01)

Reflect the latest knowledge on large-scale, low-frequency disasters onto hardware (SIV04, SV08, SIV02)

Reduce operator risks through automation and other measures (LI04)

Engage in sincere dialogs with society on risk reduction goals based on risk information (SII103)

Share risk reduction goals with society (SII103, MV02)

Constantly share risk information with society and continually update risk reduction goals (MIV01, LI103)

Develop strategies for assessment of large-scale, low-frequency disasters and share them with regulatory authorities and society (MI01, MI02, MI04, MIV01)

Operate systems that make use of risk information (MIV04, MI03, MI01)

Contribute to wide-area disaster prevention (MIV05, LI03)

Consider systems to make use of risk information (SIV09, SII104, SII12, SII06)

Entrench risk culture (SII104, SII09)

Develop human resources capable of making use of risk information (SII11, SII104, MIV04)

Share the lessons learned from the 1F accident internationally (SVI01)

Use risk information to collaborate with society

Organizational development

Use risk information for countermeasures

Use risk information for assessments

Examples of the AESJ Roadmap: Risk Information and Management (Draft Version)
Examples of the AESJ Roadmap: External Risk Assessment and Severe Accident Management

(Draft Version)

Short-Term (S)  
- Development of monitoring & observation framework for natural hazards (SI16)
- Comprehensive risk identification and assessment methodology for external events (SI02, SI03, SI13)
- Development of systematic earthquake risk assessment framework including ground motion, tsunami, fault displacement and slope failure (SI02, SI14, SI15)
- Development of advanced analysis codes and evaluation tools for severe accident (SI06, SIV06)
- Development of nuclear reactor instrumentation ability under severe accident conditions (SI04, SV01, SI02)
- Countermeasures for severe accident (application of risk assessment, mobile equipment, training, etc.) (SI01, SI05, SI11, SII01, SIV08, SV03)
- Development of advanced drill for nuclear accident & disaster (SII01)

Medium-Term (M)  
- Application of advanced analysis codes and evaluation tools for risk reduction of existing power plant (including large-scale disaster) (MI01, MIV01)
- Development of advanced nuclear reactor instrumentation system under any conditions including severe accident conditions (MII07, MIV03)
- Application of countermeasures against severe accident for existing plant to advanced power plant design (MIII11, MIII12, MIV02)
- Review and reconstruction of organizational structure to cope with critical accident condition (MII03)

Long-Term (L)  
- Updating and enhancement of monitoring & observation framework for natural hazards
- Continued efforts on research and development of risk assessment framework for rare natural events for uncertainty reduction of predicted risk (including unidentified events) (SI02, MI02, LI07)
- Development of concept of nuclear power plant system with enhanced accident tolerance (LI06, LI08, LI106, LIII01)

Building Disaster Resilient Society

- Development of better leader and human resources for accident management (SII01)
- Development of human resources to lead a cross-organizational role for accident and disaster management (MI03)
- Development of human resources to fulfill an international role in the area of accident and disaster management (LI08)

Human Resources Development

- Increase of the number of human resources who can apply scientific knowledge (e.g., natural hazard) to enhancement of safety of nuclear power plant (SII12)
- Development and continuous attraction of human resources who conduct researches on rare event (e.g., large scale disaster etc.) and have a motivation to make a contribution for safety enhancement of nuclear power plant (MI02, LI07)
**Evaluation of Prioritization of Each Technical Issues to Formulate the Roadmap**

(Draft Version)

**Effectiveness for safety improvement (based on defense in depth concept)**

1. Is it highly helpful for safety verification or safety improvement? (Is it relatively effective in risk reduction if the challenges are solved?)

2. Is it highly helpful for improvement of reliability on risk evaluation? (Is the clarification or the projection and evaluation level of unclear or unidentified phenomena highly improved?)

3. Is the challenge related to a solution with less effective alternatives? (Does the solution of the challenge lead to an increase in safety measures or evaluation methods?)

4. Is early application possible? (Is it a solution based on highly matured technology or is introduction without modification of the existing plants possible?)

**Retention and development of technology and human resource including breakthrough idea, knowledge-base accumulation, and systems engineering viewpoints**

1. Are the scopes of application and contribution in nuclear safety field large?

2. Is it highly helpful for improvement and verification of safety if practically applied?

3. Is it highly helpful for international contribution based on our accident experience?

4. Does it result in breakthrough to solve nuclear safety challenges?
Research for acquisition of technical knowledge necessary for developing regulatory requirements and those application, technical basis for decision making

① Research to Develop of Regulatory Requirements and Acceptance Criteria

Research for the development of regulatory requirement, acceptance criteria in the regulatory review and inspection, review manual, as well as development and verification of analysis code

② Technical Basis for Decision Making in Regulatory Activities

Research for obtaining data to ensure the technical adequacy in regulatory activities such as review, inspection, evaluation of plant integrity and supervising licensees

③ Maintaining Technical Competence/Expertise

Research for maintaining technical competence/expertise to fulfill the NRA obligation
Merger of JNES with NRA

- JNES was merged with NRA on March 1, 2014.
  - The major objective of the merger is to enhance the technical competence and capabilities of NRA.

- “Regulatory Standard and Research Department” consisting of mostly research engineers was created for “development of technical standards” and “conduct of safety research”.
  - Four technical branches: Reactor System Safety, Severe Accident, Earthquake and Tsunami and Nuclear Fuel Cycle/Waste.

- All the research activities having being done in NRA/JNES are continued or even enhanced, including all the international cooperative research activities, either bilateral or multi-lateral.

- Cooperation with NSRC (Nuclear Safety Research Center) in JAEA and NIRS (National Institute for Radiological Sciences) will be strengthened as external TSOs for NRA.
Safety Research Implementation System in NRA

The Secretariat of Nuclear Regulation Authority

- Regulatory Standard and Research Department
  (JNES was merged into NRA in March, 2014)
  - Regulatory Standard and Research Division
  - Reactor System Safety
  - Severe Accident
  - Nuclear Fuel Cycle and Radioactive Waste
  - Earthquake and Tsunami

【Staff : 196, including 149 researchers】*

Research Contract

- Evaluation of Fuel Debris Criticality
- Data Acquisition for Nuclear Fuel Failure Threshold
- Prediction of Radiation Embrittlement of Pressure Vessel
- Data Collection for IASCC of core internals

Partially jurisdiction

Japan Atomic Energy Agency

Sector of Nuclear Safety Research and Emergency Preparedness

Nuclear Safety Research Center

- Permanent staff: 63
  (except temporary staff)
- Temporary staff: 28
- Part-time staff: 17

Universities, Research Institutes, Venders, etc.

- Prevention of conflict of interest

Management expenses grants (MEXT)

* As of April, 2014

Dr. Masashi HIRANO (NRA),
Focus in Safety Research in NRA

- Special emphasis on external / internal hazards leading to large scale common cause failure:
  - Extreme natural phenomena:
    - Hazard curves of earthquake/tsunami, fragilities of SSCs
    - Monitoring of volcanic unrests, ...
  - PRA methods and models: External/internal fire and floods, multi-hazards, multi-units, application of level 3 PRA

- Research on Severe Accidents (SAs):
  - Code development for SA progression / source terms, ...
  - Experiments on scrubbing, seawater injection, SFP LOCA

- Research on Fukushima Daiichi:
  - Management of wastes/contaminated water, risk assessment
  - Criticality of fuel debris, etc.

- Other areas:
  - Decommissioning/waste Disposal, fuel cycle facilities, ...
Summary on for Light Water Reactor Safety Technology and Human Resource

The Roadmap for Light Water Reactor Safety Technology and Human Resource has been under construction by the Special Committee on Nuclear Safety Research Roadmap in the AESJ.

Intensive work has been conducted to cover future research activities which cover analysis of social requirements and needs, extraction of the challenges to be solved, establishment of pillars to review challenges and milestones, clarification and sharing of the goals (requisites for achievement) to be pursued at each milestone, and a concept of evaluation axes to determine the priority in the Roadmap.

Efforts should be exerted to make responses to and coordination with a technology map showing structurally the challenges and milestones extracted. Then, a roadmap based on evaluation axes should be produced to present a final report.

The roadmap to be formulated should be reviewed and improved continuously based on the outcome and external evaluations. Organized efforts and communication with all the stakeholders should also be carried out.
Research Activities

related to Decommissioning Reactors
Nuclear Power Plants in Japan as of February, 2015

- On outage or stopped: 48 units
- PWR In operation: 0 units
- BWR In operation: 0 units
- Under construction: 2 units
- Planned: 10 units
- Decommissioning: 9 units

Under application for restarting the operation: 20 units
The NRA has received 20 Applications for RestartingReactors

<table>
<thead>
<tr>
<th>Applicants (Electric Utility Company)</th>
<th>Nuclear Power Plant and Unit #</th>
<th>Start of Operation (Age)</th>
<th>Date of Application</th>
<th>Completion of NRA Review</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tomari #3</td>
<td>2009 (4)</td>
<td>July 8, 2013</td>
<td></td>
</tr>
<tr>
<td>Shikoku</td>
<td>Ikata #3</td>
<td>1994 (19)</td>
<td>July 8, 2013</td>
<td></td>
</tr>
<tr>
<td>Tohoku</td>
<td>Onagawa #2</td>
<td>1995 (19)</td>
<td>Dec. 27, 2013</td>
<td></td>
</tr>
<tr>
<td>Tohoku</td>
<td>Higashidori #1</td>
<td>2005 (8)</td>
<td>June 10, 2014</td>
<td></td>
</tr>
<tr>
<td>Hokuriku</td>
<td>Shika #2</td>
<td>2006 (8)</td>
<td>Aug. 12, 2014</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>20 Units</td>
<td></td>
<td>-</td>
<td>4 Units</td>
</tr>
</tbody>
</table>

https://www.nsr.go.jp/activity/regulation/tekigousei/power_plants.html
Sharing and Updating Knowledge for Ageing Management with Summary Sheets of Ageing Mechanisms

- Operators of NPPs (Utilities)
- Expert Meeting from All the Utilities (JANSI)
- Academic Society (AESJ)
- Regulator (NRA)

- Maintenance program
- Ageing Mechanism Management Chart
- Summary Sheets of Ageing Mechanisms

- Details of Inspection and Maintenance Plan and Activities
- Additional Information including consumables
- Research for Ageing Management

- Evaluation of Maintenance Effectiveness
- Expert Meeting
- Subcommittee for Plant Life Management

- Operational Experience
- AMTE Report

- Proposal for Updates

(JANSI: Japan Nuclear Safety Institute)
Knowledge Transfer between IAEA/IGALL and the AESJ Code

- The combinations of intended and required safety functions, portion of SSCs and the ageing mechanism/effect are summarized in the summary sheet in the Attachment A of the AESJ code, based on the experience from the 17 AMTEs in Japan.
- Knowledge-base from IAEA IGALL is currently under review by AESJ members be reflected in the next major revision, including the lessons learned from the Fukushima accident.
### Special Inspections to Extend Operational Period

Regulatory Requirements of Special Additional Inspections for Long Term Operation beyond 40 years up to 60 years

<table>
<thead>
<tr>
<th>Components</th>
<th>Current Inspection</th>
<th>Additional Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Pressure Vessel</td>
<td>Ultrasonic Tests of Welded Zone</td>
<td>100% UT Examination of Base Metal in addition to Welded Zone</td>
</tr>
<tr>
<td>Primary Containment Vessel (Steel)</td>
<td>Leak Rate Tests</td>
<td>Visual Test (Appearance of coating film)</td>
</tr>
<tr>
<td>Civil Concrete Structure</td>
<td>Visual Tests &amp; NDT</td>
<td>Core Sampling (Strength, Neutralization, Salt intrusion, etc.)</td>
</tr>
</tbody>
</table>

- Special Inspections are requirements to extend the operational period beyond 40 years by up to 20 years (60 years maximum) in addition to;
  - Ageing Management Technical Evaluation (AMTE) for every 10 years
  - Maintenance Program
"The Evaluation of Properties of Structure and Component Materials Utilizing Actual Aged Materials from Decommissioned Reactors"
New IAEA Coordinated Research Project

Title of the CRP
Evaluation of structure’s and component’s material properties utilizing actual aged materials removed from decommissioned reactors for safe LTO

Project Preparation
• Initial proposal to IAEA prepared by Japan in 2012
• Approved in IAEA in November 2012 for 2014-2015 biannual plan
• Coordination Meetings
  ✓ February 2013 – Vienna
  ✓ July 2013 – Tokyo
• Draft of “Proposal for a New Coordinated Research Project“ prepared

Official Meetings
• First Meeting of the CRP in Vienna in June, 2014
  (participants from 12 countries and 2 international institutes)
• Second Meeting in Spain (Madrid and Zorita) in January 13-15, 2015
Purpose of the New IAEA CRP

To establish international collaboration aimed to collecting, measuring, recording and analysis of properties of sample materials removed from SSCs of decommissioned NPPs or replaced components, which are subject to physical ageing,

- addressing synergetic effects of combination of different degradation mechanisms in real operational conditions,
- providing basis for comparison with results of laboratory tests and calculations; and
- providing possibility for removing of unnecessary conservatism.
The specific objective of the CRP will address degradation mechanisms of mechanical, electrical and I&C components and also structures,

**CRP Phase 1 (2014-2017)**
1. RPV
2. Core internals
3. Concrete structures, and other non-metallic materials

**Additional Topics in CRP Phase 2 beyond 2017**
(can be initiated in 2015 or later)
1. Low-cycle fatigue including environmentally assisted fatigue
2. Degradation of cable insulation and electrical and I&C penetrations
Research Project funded by NRA on Concrete

Targeted member
- RPV pedestal in BWR and First shielding wall in PWR are targeted members.

Assessment method (level 1)
- Aggregate
  - Mineral composition
  - Particle size distribution
  - Env. condition (fluence)

Cement paste
- Mineral composition
- Particle size distribution
- Water to binder ratio
- Env. Condition (R.H. & temp.)
  - Degree of hydration
  - Phase composition
  - C-S-H properties
  - Hydration
  - BET surface area

If there is a condition that agg. does not show any expansion, agg. satisfying such condition is assessed as safe.

Expansion
Damage & Concrete properties
Shrinkage

Heterogenous behavior in concrete:
- Cement paste (W/C=0.45)
- Aggregate (Clay stone)

Assessment methods
- Mineral composition of aggregate
- Physical properties of components
- Mixture proportion
- Limit value of neutron fluence
- Limit value of gamma ray dose

Calculation of fluence/dose in section of concrete member

Evaluation of distribution of concrete strength

Evaluation of structural performance by section data

Verification

Design loads
Sampling of RPV Materials and Concrete Structure from the Decommissioning Reactor: Hamaoka Unit 1

27 metal samples
- 5 Boat samples from RPV belt-line
- 5 Column samples from Shroud
- 10 Disc samples from Top guide etc.
- 7 Cut chip samples from RPV top, bottom & side

68 concrete samples
- 24 Column samples,
- 26 Disk samples and 18 Cut chip samples from PCV and inside
Integrity Evaluation System of Concrete Structures

Material Basis Evaluation (Strength)

- Core Sample
- Schmidt Hammer
- Ultra Sonic Wave

Member Basis Evaluation (Stress)

- Axial Forces
- Shear Forces
- Moments
- Design Strength

- Strength Distributions of Member Sections

Structure Basis Evaluation (Dynamic Properties)

- Drying Shrinkage
- Earthquake
- Natural Frequency
- Time

- Review of Materials Properties
- Microtremor Observation Forced Vibration test

Confirmation of Integrity of Concrete Structures

- Evaluated > Design
- Yes
- Upgrade Repair

- Measured > Design
- No

- Evaluated > Design
- No

- Seismicity OK?
- Yes
- No

“IAEA New Coordinated Research Project”, ORNL Meeting (July 30, 2013), Osamu Kontani, Kajima Corporation,