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Regulation and Research for Demonstrating and Deploying Advanced Nuclear Systems

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This presentation covers

changed significantly at the last minutes

- Independence of regulatory authority
- Learning from accidents
- Regulatory challenges
- What we now expect from research

Innovation requires strong and independent regulatory body

- ✓ Regulation is often seen as an obstacle to innovation. Those who promote innovation may believe that regulation is unnecessary, or at least minimal. However, when we imagine a world without regulation or under-regulation, it becomes obvious that regulation is necessary.
- ✓ Many good operators and vendors may achieve the adequate level of safety even without any regulation. However, the failure of a single poor competitor can drive all remaining technologies out of the market, taking an unreasonably long time and effort to recover from.
- ✓ A strong, independent regulator objectively evaluates different technologies, thereby fostering competition in the market and allowing the best concepts and companies rise to the top.

Why so important for regulatory body to be independent

- ✓ Most decisions are based on weighing the cost and benefit, but for technologies that have the potential to cause severe, irreversible harm, we need an independent regulator that simply decides whether they are sufficiently safe.
- ✓ There are numerous examples of **conflicts of interest** leading to poor decisions by organizations and their leaders.
- Convention on Nuclear Safety, Article 8.2: Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

Why should regulatory authorities be trusted by the public?

- ✓ Not to increase public trust and support for nuclear energy use.

  While increased trust in regulatory authorities may increase public acceptance of nuclear energy use, this is a result, not a goal, for regulatory authorities.

- ✓ Regulatory authorities must be trusted by the public because they **must be trusted in emergencies**.

  Regulatory authorities make important decisions in crisis situations, so they need to be trusted by the public on a regular basis.

TEPCO Fukushima Dai-ichi NPS Accident

- ✓ Before TEPCO's Fukushima Dai-ichi NPS Accident occurred on March 11, 2011, we, Japanese industries, regulatory bodies and academia, believed we had sufficient knowledge about NPP risk, i.e. we could answer the questions: *what can go wrong? what is the likelihood of that happening? and what are the consequences?*
- ✓ The accident revealed we did not have good knowledge or awareness to answer and take appropriate actions to address these three questions.
- ✓ Subsequent actions taken by the global nuclear community suggest there was an international consensus that additional actions were needed to enhance NPP safety.

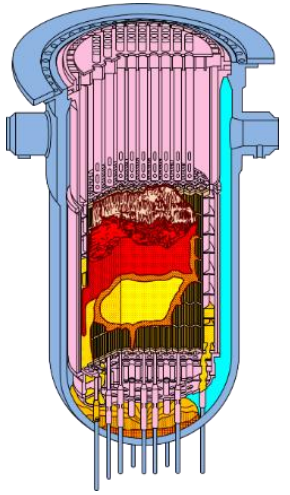
How we failed

- ✓ When the TMI-2 accident occurred, people said, “We have highly reliable facilities and equipment, and our operators are highly skilled, so an accident like that will never happen in Japan." In the US, the importance of comprehensively tracking accident scenarios was recognized, and progress was made in the development of PRA technologies, efforts to address natural hazards, and consideration of severe accident countermeasures. However, these efforts were extremely slow to progress in Japan.
- ✓ After the Chernobyl accident, people said, “We don't have a reactor with that design, and there were no rule violations, so an accident like that will never happen in Japan." We failed to make progress on the continuous safety improvement mechanisms and emergency preparedness and response.

The cost of the paralysis of thought brought about by the safety myth was high.

Learning from accidents

- Three Mile Island accident in 1979
  - ➡ Demonstrated importance of operator actions in contributing to accidents and recovery, motivated severe accident research programs and analytical tool development, increased emphasis on PRA
- Chernobyl accident in 1986
  - ➡ Emphasized consideration of low power and shutdown events, independent regulatory oversight, and safety culture
- Fukushima Dai-ichi (F-1) accident in 2011
  - ➡ Emphasized the risk of external events, regulatory capture, deteriorated safety culture, the importance of site wide risk



✓ Many people now seem to be trying to believe that severe accidents can be practically eliminated by design.
However, new accident scenarios should be considered for new designs.
There is still much to be learned from past accidents.

IAEA/SSR-2/1 (Rev. 1)
Safety of Nuclear Power Plants: Design

- Requirement 9, paragraph 4.16

  “Where an unproven design or feature is introduced or where there is a departure from an established engineering practice, safety shall be demonstrated by means of appropriate supporting research programmes, performance tests with specific acceptance criteria or the examination of operating experience from other relevant applications. The new design or feature or new practice shall also **be adequately tested to the extent practicable before being brought into service**, and shall be monitored in service to verify that the behaviour of the plant is as expected.”

OECD/NEA Collective Statement on the Role of Research in a Nuclear Regulatory Context, 2001.

Regulatory challenges, e.g.,

- ✓ **Defining licensing basis events** (LBEs) is a technical challenge. There are cases where the classification of states, such as normal operation, anticipated operational occurrences (AOOs), design basis events (DBEs), and design extension conditions (DECs), may need to be changed. There are also cases where the concepts of severe core damage or loss of containment function of specific barriers do not adequately describe the respective states.
- ✓ In the safety analysis of advanced reactors, there might be situations where it is difficult to apply concepts such as **Design Extension Conditions** without severe core damage and those with core melting.
- ✓ It is necessary to comprehensively consider **accident sequences and initiating events** specific to each advanced reactor design and define postulated initiating events for safety assessment.

Role of Regulatory Research

- ✓ The capability of the regulator to supervise or commission independent confirmatory research is an important element in an effective regulation.
- ✓ The main consequences of losing adequate research capability is generally considered to be a loss of technical safety competence and potentially missing important safety issues, thus contributing to reduced public confidence.
- ✓ Research information should be made available to all stakeholders and the incorporation of their viewpoints into strategic thinking should be encouraged.

OECD/NEA Collective Statement on the Role of Research in a Nuclear Regulatory Context, 2001.

Challenges in research, e.g.,

- ✓ **Reactor coolants** are to be used that have not previously been used, or to be used under significantly different conditions, such as supercritical conditions. In these cases, there might be a lack of knowledge of behavior and properties of the coolant relevant to safety.
- ✓ While smaller size, lower power, and reduced power density make it easier to incorporate **passive features** and systems, there may be insufficient experimental evidence or experience to fully justify such claims.
- ✓ While the use of risk information is expected to be significant for the deployment of advanced reactors, the hard fact is that demonstrating the contribution of a new technology to risk reduction requires a thorough analysis supported by **sufficient data**.

OECD/NEA Collective Statement on the Role of Research in a Nuclear Regulatory Context, 2001.

Recommendation from CSNI core group

Thermal hydraulics

- ✓ Organize a framework to lead **collaborative research projects** with scaled experimental infrastructures to enhance development, validation and benchmarking of state-of-the-art codes, training and education.
- ✓ Build a **powerful database** through the collection, updating and maintenance of large amounts of legacy data generated over the years to support safety analysis of advanced reactor designs.

Specific recommendation from CSNI core group

Thermal hydraulics

- Continue code-to-code benchmark exercises through simulation of complex hypothetical accident scenarios in reactor system.
- Conduct experiments for Fluid-Structure Interaction (FSI)
- Promote the extension of CFD into two-phase problems.
- Continue efforts in measurement uncertainty quantification by using existing guidelines (such as the ISO “GUM”) and develop guidelines.
- Develop a complementary experimental database for SMRs in order to be able to assess passive safety system efficiency for different transients.

Recommendation from CSNI core group

Severe accident

- ✓ Establish the technical bases to demonstrate whether it can be proved that accidents leading to release of radioactive material with significant consequences can be practically eliminated for advanced reactors, and if so, what is required.
- ✓ Conduct analysis to identify and characterize accident scenarios which can threaten the containment of radioactivity in advanced reactors, considering reliance on different containment concepts and new safety systems.
- ✓ Organize a framework with the widest possible community to lead collaborative experimental projects.

Specific recommendation from CSNI core group

Severe accident

- Study treatment of uncertainties for novel aspects of risk analyses, including how uncertainties should be considered in regulatory decision making.
- Characterize and quantify the relative importance of individual systems and components used in the advanced design to fully realize the benefits of RIDM.
- Develop advanced instrumentations for SA monitoring and management.
- Experiments and benchmarking activities to better understand advanced nuclear technology source terms.
- Assess the structural integrity of the containment building during SAs.
- Extend the thermodynamic database of molten corium to advanced reactors.

Concluding remarks

- ✓ Maintaining the **independence of regulatory authorities is essential** for demonstrating and deploying advanced nuclear systems. Any erosion of regulatory independence puts the people and the environment at risk and significantly undermines public trust in nuclear technology.

- ✓ Decisions concerning the future will always contain some degree of uncertainty. **Uncertainty allows for wishful thinking**, but reality is too often deaf to our wishes.

Bazerman, M. H., and Watkins, M. D., “Predictable surprises”, Harvard Business School Press, 2004.

- ✓ We have to maintain a strong attitude to keep learning from past accidents. The knowledge and insight obtained from the past accidents need to be universalized through research, in particular, well-planned experiments. **A platform of international collaboration** is urgently needed.

Thank you for your attention!