JAEA Report:
Review and Perspective of the Safety Research for Geological Disposal of Radioactive Waste

Nuclear Safety Forum 2010 (NSRF2010)
"Perspectives of Safety Regulations and Research for Radioactive Waste Disposal"
February 23, 2010
The Inoue Enryo Hall, Toyo University, Tokyo, Japan

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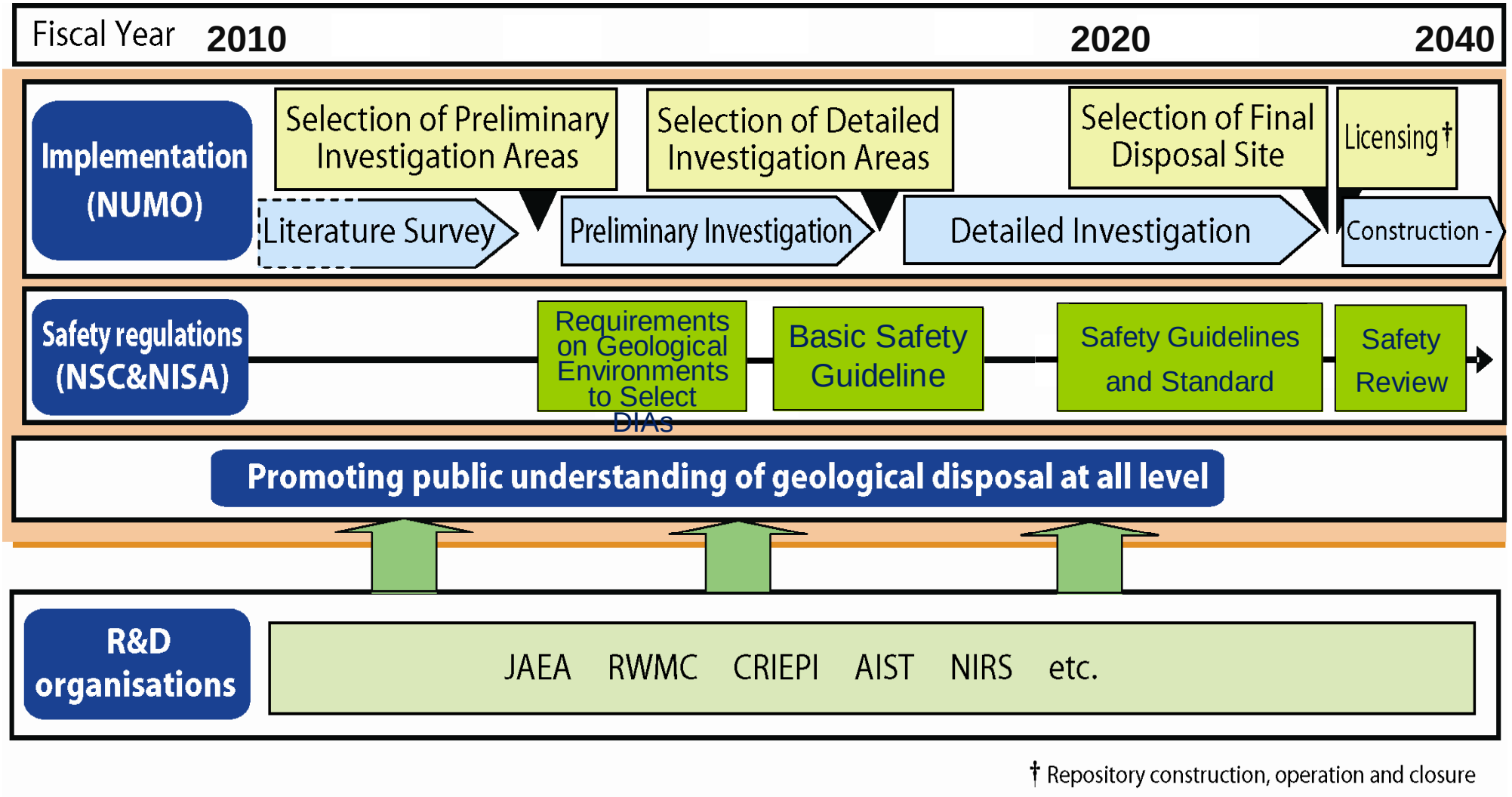
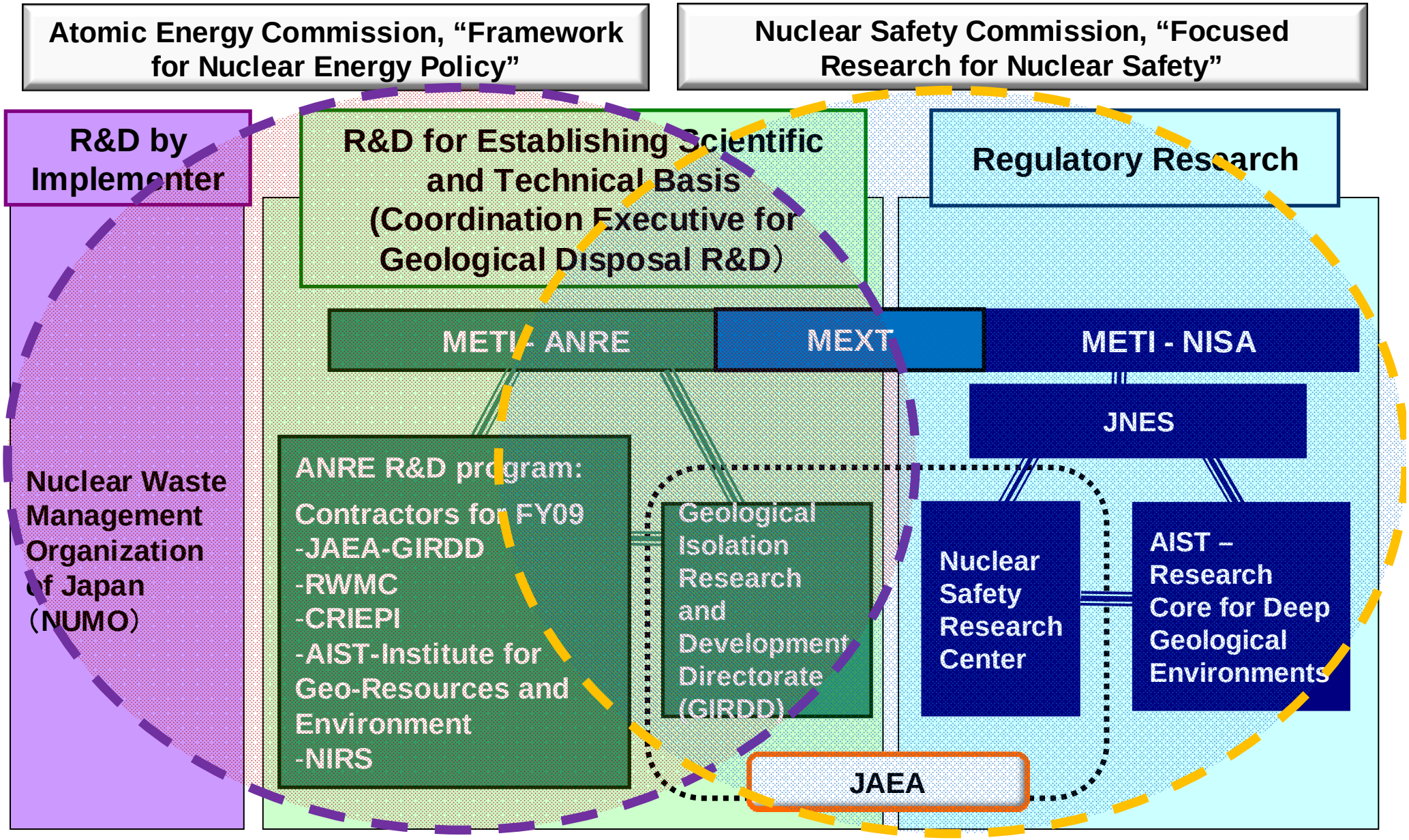
The Japanese geological disposal programme

- Stepwise implementation



† Repository construction, operation and closure

R&D Framework for GD in Japan



Progress in Safety Research for GD – An Overview (1)

- **HLW disposal**
  - **Site investigation methodology**
    - Research on long-term stability of geological environment (JAEA, AIST, JNES, etc)
      - ✓ Development of investigation techniques and evaluation methods; accumulating required databases
    - Hydrology and mass transport in relevant geological environments (JAEA, AIST, RWMC, CRIEPI)
      - ✓ Knowledge base and model development for regional hydrology, groundwater flow through faults, colloid-facilitated transport, and groundwater "age" determination
    - Development of geological investigation methodology
      - ✓ Improvement of geosynthesis methodology (JAEA, RWMC)
      - ✓ Investigation techniques for nea-field host rock (AIST, RWMC)
  - **Establishment of requirements and criteria for selecting DIAs**
    - Development of relevant investigation technologies within two URL projects (JAEA)
    - Proposed guidelines for Preliminary Investigation (JNES)
    - Development of techniques for Preliminary Investigation and in-situ tests (CRIEPI)

Progress in Safety Research for GD – An Overview (2)

- **HLW disposal**
  - ➢ **Approach and methodology for safety assessment**
    - Development of probabilistic approach and methods (JAEA, CRIEPI)
    - Realistic model development for key processes (JAEA, CRIEPI, RWMC)
    - Development of databases for performance assessment (JAEA, NIRS)
    - Survey and review of status of international standards and guidelines and regulations in each national programs (RWMC, NSRA)
  - ➢ **Integrity and robustness of the EBS**
    - Knowledge base on long-term behaviors of EBS components (bentonite buffer, low-pH cement, etc) (JAEA, CRIEPI)
    - Database development of characteristics of EBS components (JAEA)
    - Evaluation of effects of repository construction on long-term performance (JAEA)
- **Relevant research carried out for other waste disposal**
  - ➢ **Scenarios and safety analysis**
    - Safety assessment methods (models, data, etc) for co-disposal of HLW and TRU waste (JAEA, JNES)
  - ➢ **EBS and geosphere performance**
    - TRU EBS behavior and gas migration tests (RWMC, CRIEPI)
    - Development advanced waste forms (RWMC)

General Overview of the Outcome of R&D (1)

- **H12 (1999) and TRU-2 (2005) formed a solid basis for the demonstration of the fundamental feasibility of safe geological disposal of HLW and TRU waste in Japan: although technology has advanced significantly, the basic conclusions of this project are still valid**
- **This generic fundament has been complemented by subsequent work to show how implementation at a specific site could be tailored to local conditions in a manner that:**
  - **Takes into account local geological and topographical boundary conditions**
  - **Recognizes the need to ensure not only long-term safety but safety during construction and operation (and other pragmatic constraints)**
  - **Facilitates information transfer to all interested stakeholders and encourages development of dialogue**
  - **Ensures flexibility in the program to accept advances in science and technology and changes of socio-political requirements**
  - **Utilizes an advanced KMS, recognizing that the information explosion has surpassed the capabilities of past information management procedures**

Taking account of local geological and topographical boundary conditions

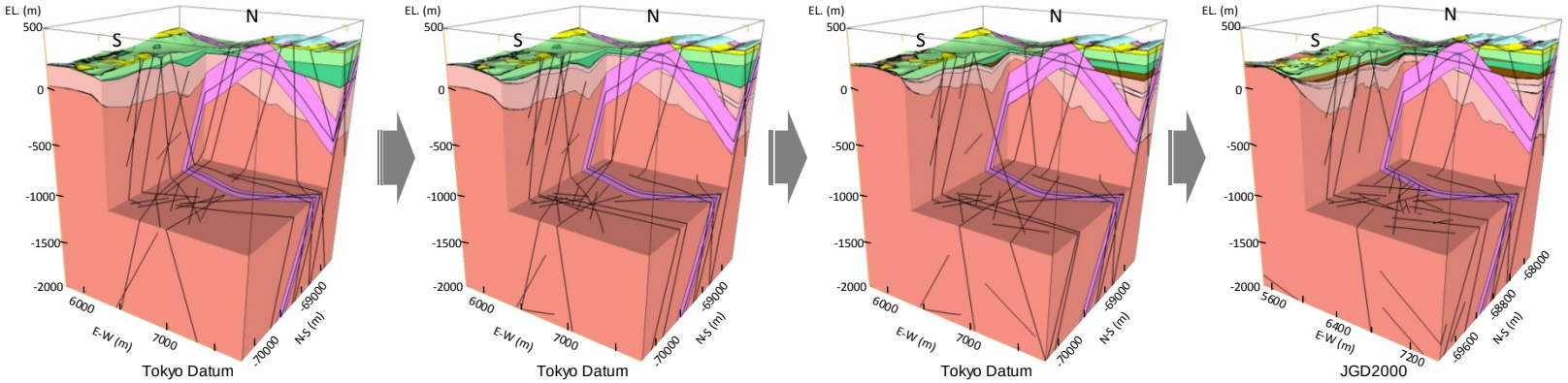
Extension of generic studies in H12 and TRU-2 for specific geological conditions at study sites

Key aspects:

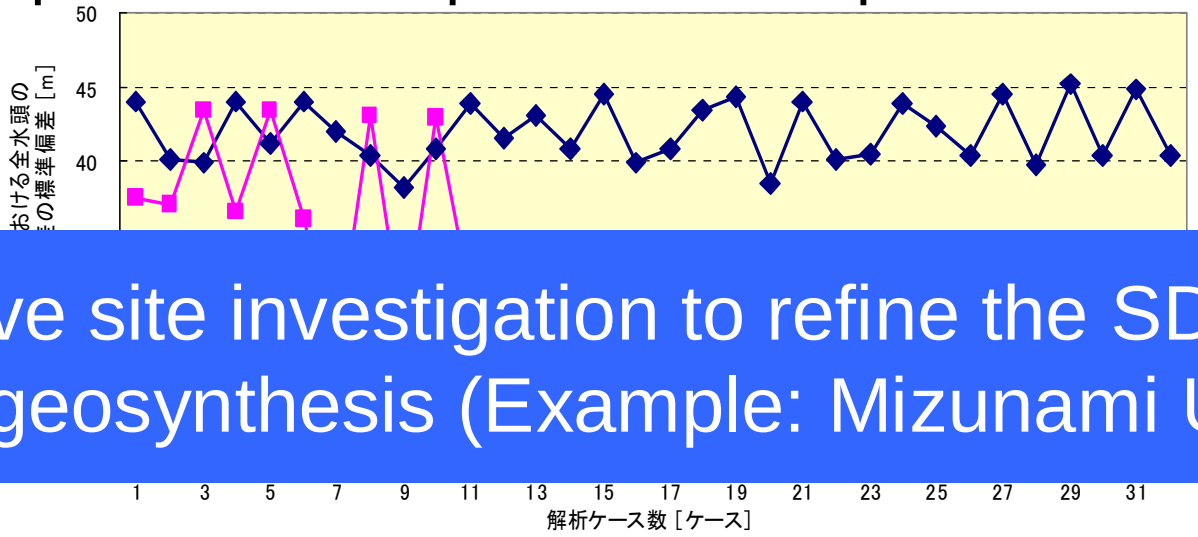
- Tailoring investigation techniques and evaluation methods for the geological environment at a given site
- Extension of the repository engineering knowledge base
- Development of methods and databases to compare different sites, repository concepts and implementation options

Development of site-specific investigation techniques and evaluation methods – example

- Stepwise development of Site Descriptive Model (SDM)



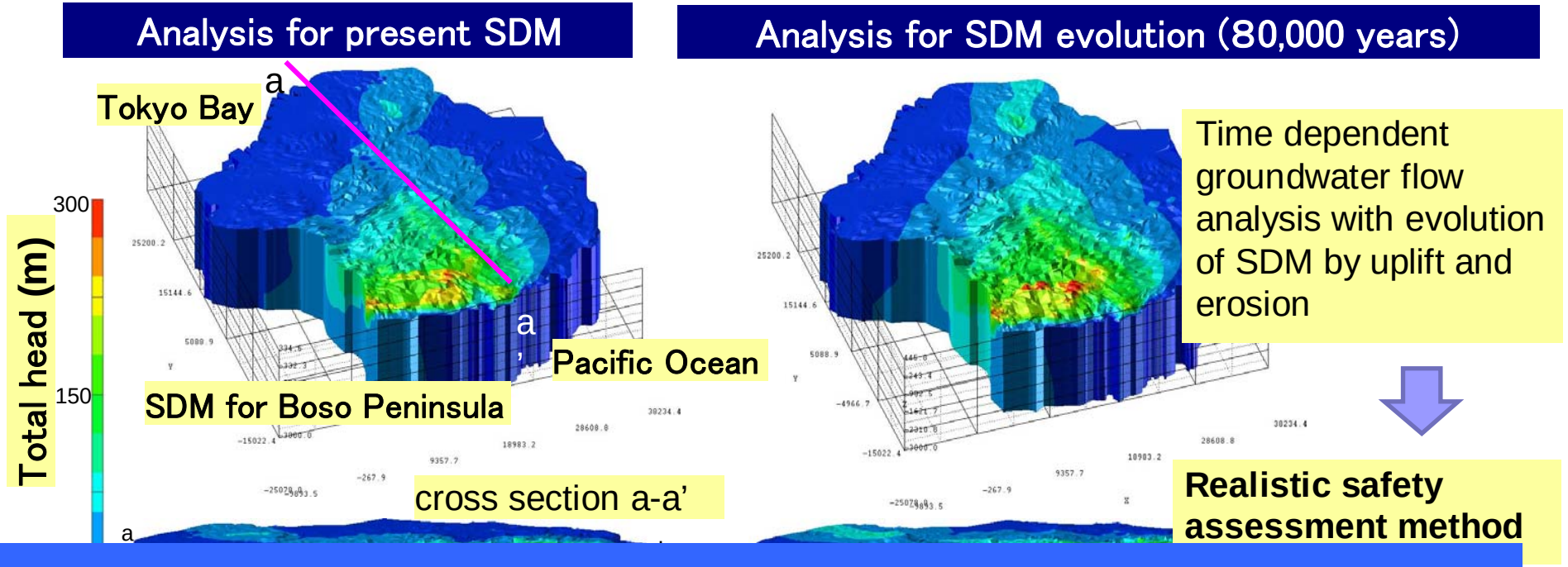
Step 1 Step 2 Step 3 Step 4



Adaptive site investigation to refine the SDM within geosynthesis (Example: Mizunami URL)

Development of site-specific investigation techniques and evaluation methods – example

- Development of a time-dependent regional groundwater flow analysis code (3D-SEEP) and verification at a study site

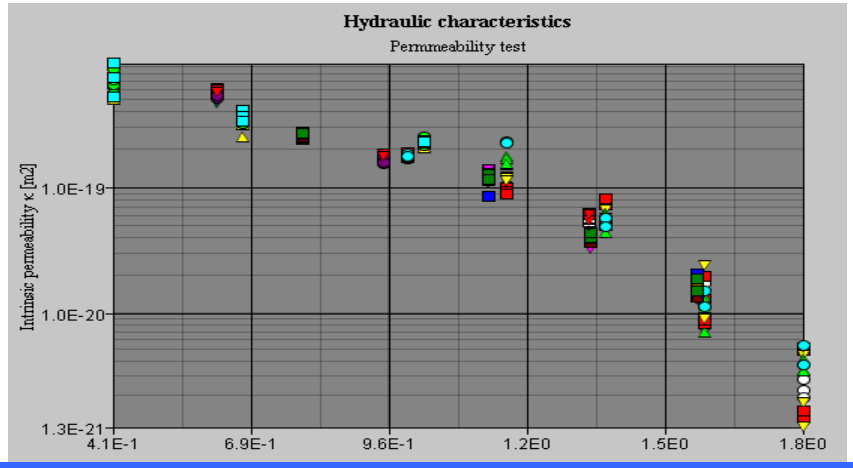


Realistic regional analysis for evolution of the SDM as a result of uplift-erosion and climate change

Development of the repository engineering knowledge base – example

Data search function

➢**experimental conditions, buffer material density, bentonite-sand mixture, etc**



Development of a comprehensive buffer database; special emphasis on data for saline groundwater

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Demonstration test of low alkali cement

- Mitigation of effects of high pH plume from cementitious material on long-term safety

- Shotcrete
  - Test in a mock-up tunnel (FY06)
  - Planning underground in-situ test (FY07)
  - In-situ test at Horonobe URL (FY09)
- Cast-in-place concrete
  - Laboratory test for selecting composition and planning for in-situ test at Horonobe URL (FY08)
- Grout
  - Selection of composition and planning for
  -

In-situ shotcrete demonstration test at Horonobe URL：July, 2009

Development of the technical basis for practical application of low alkali cement

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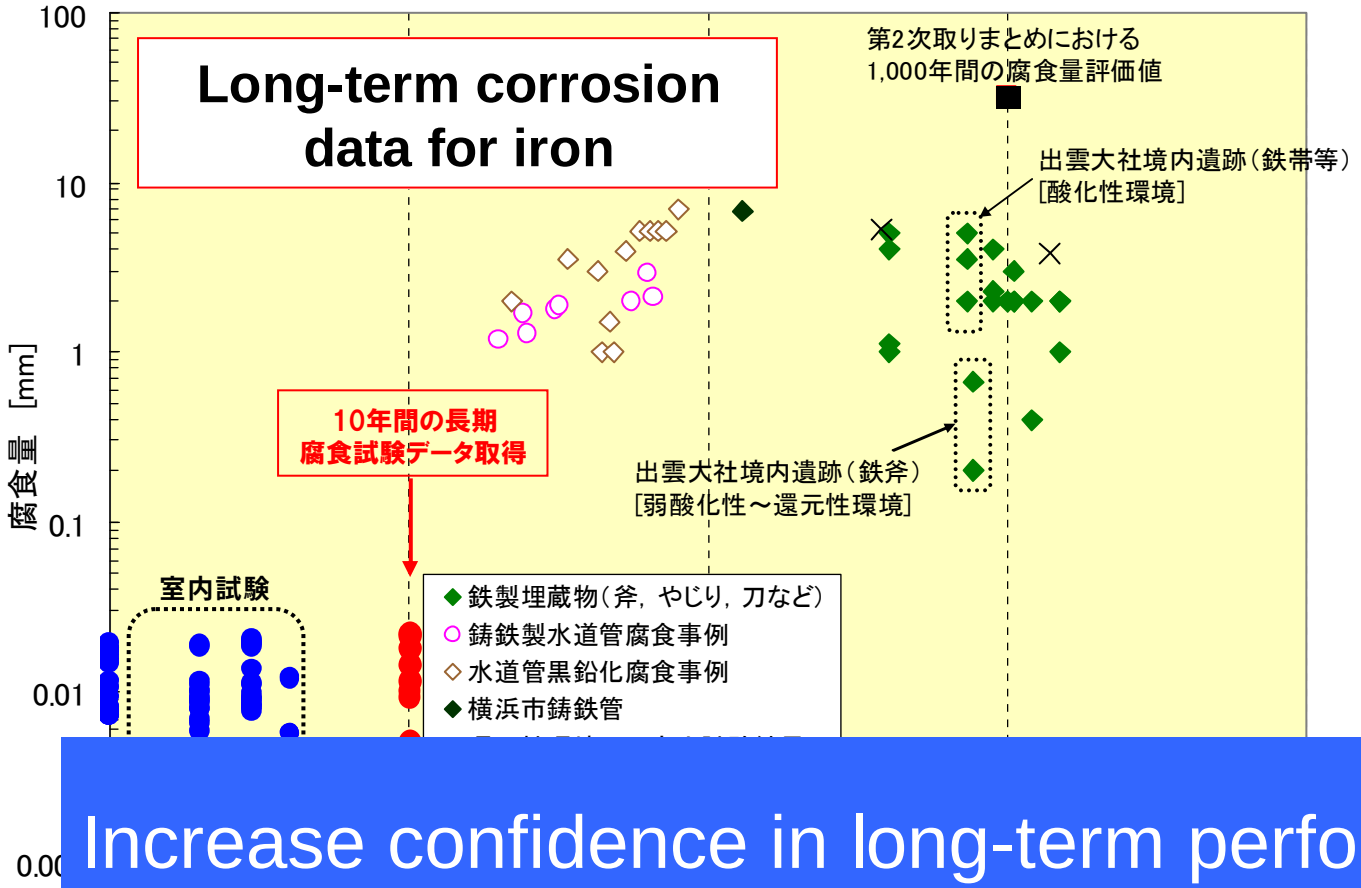
Facilitating communication with stakeholders using analogue studies – example



- **Accumulation of analogue data on glass corrosion, corrosion of iron and copper, bentonite alteration, etc**
- **Implementation of long-term laboratory tests, e.g. 10 years corrosion test for iron under simulated repository conditions**
- **Increase in**

Increase confidence in long-term performance by extended laboratory experiments under simulated deep underground conditions together with relevant analogues

General Overview of the Outcome of R&D (4)

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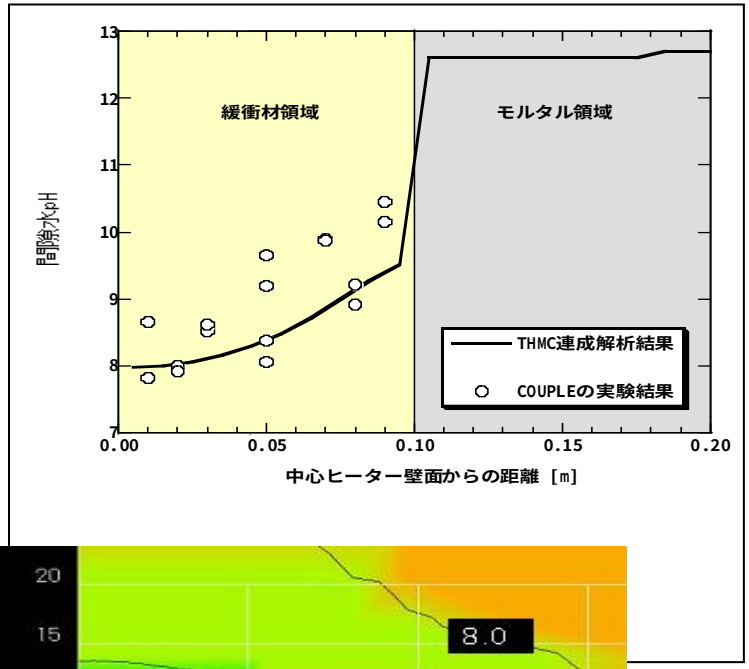
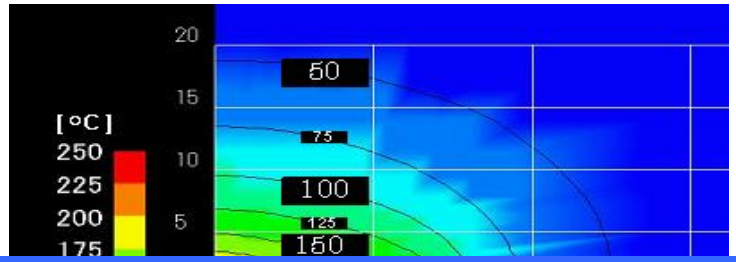
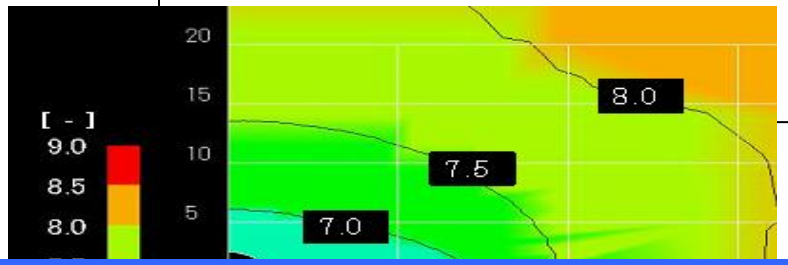
Development of visualization and numerical analysis methods for near-field evolution

➢T-H-M-C model development for the near field and numerical experiments







Application of advanced science and technology for realistic analysis of repository system behavior

General Overview of the Outcome of R&D (5)

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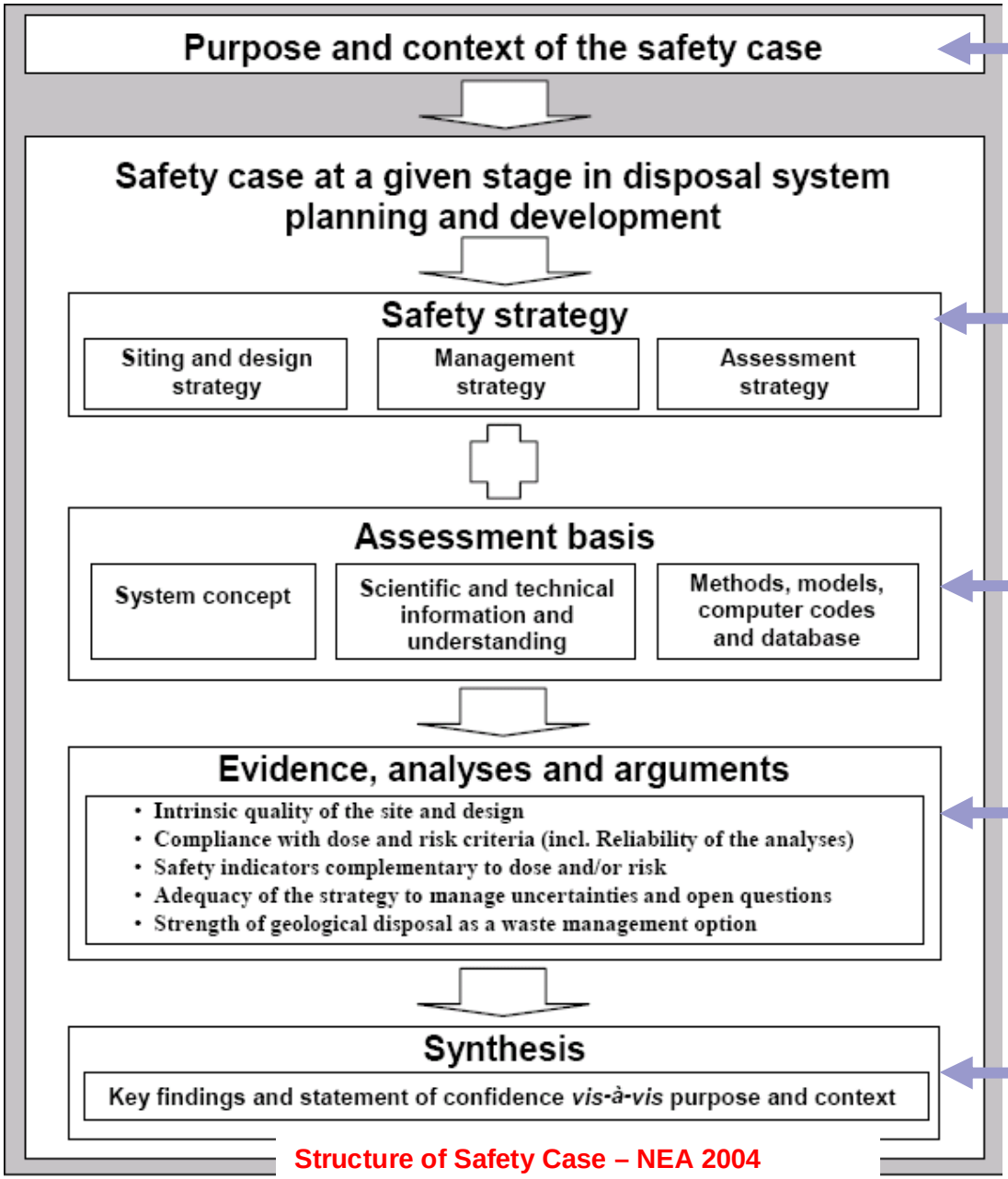
KM for Geological Disposal

- **Characteristics of geological disposal**
  - Need to ensure safety for very long timescale
  - Demonstration of safety based on a "Safety Case"
  - Huge multidisciplinary knowledge base (data, information, experience and know-how, expert judgment, etc) is used to develop a Safety Case
- **Need for advanced KM**
  - Safety Case should be built on sound scientific and technical knowledge: R&D organizations should provide this in a goal-oriented manner
  - The knowledge exponentially increases and evolves in complexity as a repository program proceeds – The "Information explosion" and required integration of knowledge are a critical issue
  - KM is needed to support stepwise development of Safety Case by creating, processing, updating, preserving and transferring knowledge throughout repository implementation: it should also facilitate rigorous technical QA
- **The JAEA KMS concept**
  - Structuring knowledge (both explicit and tacit) according to the logical sequence of the evolving Safety Case
  - Flexibility to cope with rapidly growing knowledge base
  - User-friendliness to provide knowledge at different levels
  - Maximum use of advanced electronic information management technology

Research to support a safety case



Structure of Safety Case – NEA 2004

User-specific

Strategy includes balancing of requirements (cost, environmental impact, acceptance) that need to be agreed with all stakeholders

Initially simple, but preparation for later rigorous assessment must be planned (including operational phase)

Emphasis on critical assumptions and uncertainties

Focused on decision to be made

Integration of knowledge into a Safety Case - YMP Licensing Application Documentation

Iteration of TSPA (Total System Performance Assessment)

- TSPA 1991, 1993, 1995
- TSPA-VA (Viability Assessment) 1998
- TSPA-SR (Site Recommendation) 2001
- TSPA-LA (Licensing Application) 2008

Main documents – ~ 10,000 pages

Integration

Supporting data and information - ~3 x 10^7 pages

Information explosion in R&D supporting geological disposal in Japan ...with a limited (and aging) work force

- Over the last 2 decades, key integration and overview tasks have been carried out by teams whose experience has grown over that period
  ...these are now completely overloaded
  ...and most experienced members are nearing retirement
- Development of next generation KMS (JAEA-KMS) and CoolRep

Geological disposal (HLW/TRU waste) timeline

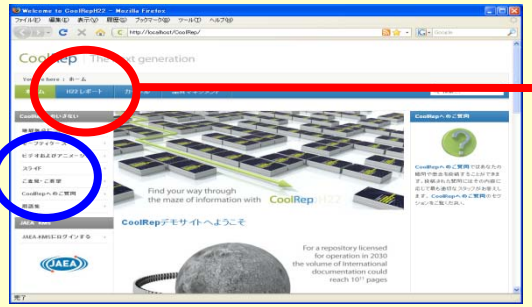
H3(E) (1993)	H12(E)/TRU-1(E) (2000)	H17(E) (2005)	TRU-2(E) (2007)	H22 (2009)	Licensing (2030s)

Links between CoolRep and the JAEA KMS

CoolRep

home

summary



Kernels
- PA
- Repository Engineering
- Geoscience
- KMS
- QMS
- …

Knowledge access
- documents
- figures, tables, data
- videos & animations
- KM tools
- QA records
- •••

users (NUMO, Regulators, R&D organisations, Experts, Interested Groups, …)

Knowledge supply

Knowledge search

JAEA KMS

Knowledge management tools
- Argumentation models
- All-in-one report
- Expert systems
- Ontology editors
- •••

Knowledgebase
- Database
- Tech. reports
- •••

Interaction
- knowledge input / assessment in safety case context
- dialogue between users & suppliers of knowledge
- •••

Safety research – Future direction (1)

- "Focused Research for Nuclear Safety (Phase II)" (NSC, Aug. 2009)
  - Key research areas to support formulation of "Requirements of Geological Environment to Select DIAs of High-Level Radioactive Waste Disposal" and "Basic guidelines for safety review of HLW disposal" including:
    - ✓ Further development of site investigation and evaluation methods for specific sites
    - ✓ Development of repository engineering and EBS for long-lived TRU waste
    - ✓ Assessment methodology for operational and post-closure safety
  - Key aspects of the approach
    - ✓ To provide a framework for integration of research results from individual areas by highlighting their contribution to increasing confidence in the safety case
    - ✓ QA based on international state-of-the-art science and technology: associated timely documentation of research results
    - ✓ Promotion of research common to safety aspects of different nuclear areas (extending the nuclear safety knowledge base, social science on safety regulation, risk communication methodology, etc)
  - Expectation of JAEA research
    - ✓ Evaluation methods for long-term geological stability
    - ✓ Extended understanding of the effects of construction on host rock conditions
    - ✓ Realistic modeling of repository- and regional- scale groundwater flow
    - ✓ Realistic performance evaluation of the EBS, taking long-term evolution of near-field boundary conditions into account
    - ✓ Realistic modeling of radionuclide migration for specific geological environments
    - ✓ Scenario development a risk-informed approach
    - ✓ Development of an integrated knowledge base for geological disposal

Safety research – Future direction (2)

- "Regulatory research for waste treatment and disposal (FY2010 – FY2014)" (NISA, Oct. 2009)

- Research identified based on the needs of NISA for formulation of safety regulations

➢ **Focus of research program**

- ✓ Research to support the regulatory review of the results of Preliminary Investigations and Detailed Investigations carried out by NUMO
- ✓ Research to support the regulatory process for licensing for repository construction, operation and closure

➢ **Approach and organization**

- ✓ To be carried out under a framework provided in NSC's Focused Research for Nuclear Safety
- ✓ The outcome will provide input for NSC discussion of regulation formulation
- ✓ The core organizations are JAEA SRC and AIST-Research Core for Deep Geological Environments
- ✓ JAEA SRC promotes collaboration with JAEA GIRDD and makes a maximum use of infrastructure, such as URL
- ✓ Utilize the results from R&D for Establishing Scientific and Technical Basis as much as possible

Summary and Concluding Remarks

- The scientific and technical foundation based on generic studies has been extended by R&D carried out in the major areas of site investigation, engineering and safety assessment, after promulgation of the Final Disposal Act to apply to a specific site.
- Continuous development of a geological disposal KB is critical to support both repository development and regulation formulation by integrating results from a diverse range of R&D.
- For this purpose, JAEA has been developing an advanced KMS linked with a “next-generation” documentation approach.
- In the KMS, individual R&D areas are structured by, and related to, knowledge supporting development and review of a safety case: this makes the R&D goals clearer to all involved.
- Future directions for the next five years have been identified in the NSC and NISA safety research programs: these will promote research activities in more integrated and focused manner.

Thank you for your attention!

… with thanks to Dr. Shinichi Nakayama of JAEA Nuclear Safety Research Center for his valuable input to this presentation