Support for repository design and performance assessment

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Japan Atomic Energy Agency
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Contents

- Background and approach
  - Fundamentals of repository design
  - Fundamentals of performance assessment
- Application of Knowledge Engineering (KE) technologies / tools to design
- Application of Knowledge Engineering (KE) technologies / tools to Performance Assessment (PA)
- Concluding remarks

Fundamentals of repository design (1)

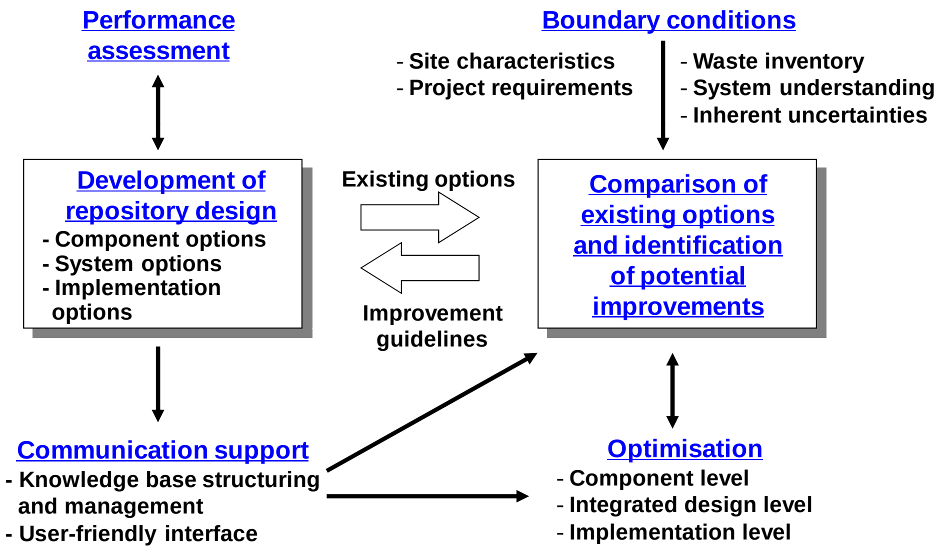
- It is crucial to develop designs for deep geological repositories that meet all project boundary conditions and can be tailored to specific sites resulting from an open call for volunteers.
- Such design work was, in the past, carried out by expert teams in a rather informal manner.
- As the technical challenges increase and the need for transparency is accepted, a more formal method of developing innovative design solutions is needed.
- In this study, as part of the JAEA Knowledge Management (KM) project, the application of Knowledge Engineering (KE) methodologies to facilitate this process is being investigated.

Fundamentals of repository design (2)

- **Problems with past, informal methods**

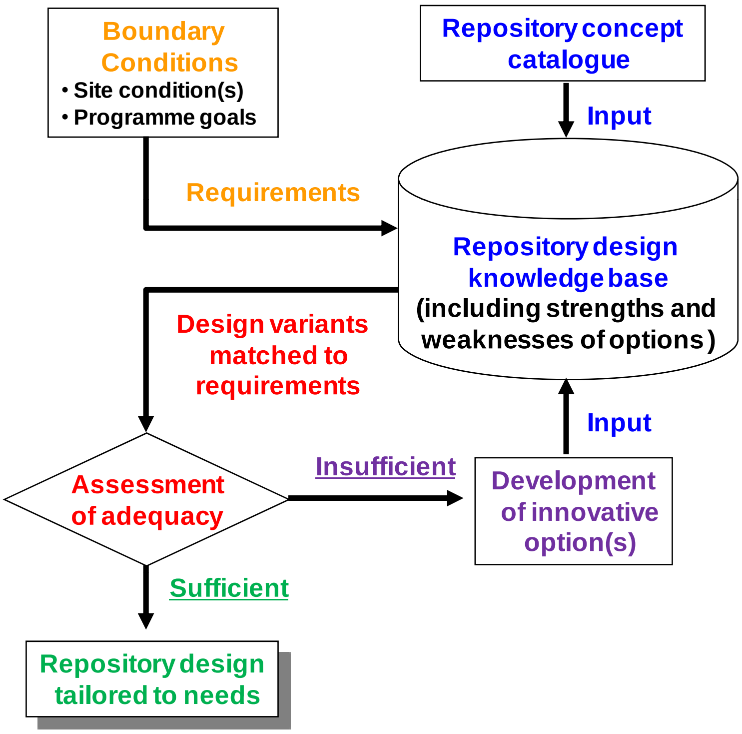
  Limitations with regard to assumptions and boundary conditions were not clearly documented and are not generally well known.

- **A formal and holistic approach to advanced repository design is needed**



Fundamentals of repository design (3)

- To implement the holistic approach, an important starting point is to define the overall constraints (boundary conditions) on the design process.
- A systematic work frame linking development of repository design to assessment of adequacy with respect to a range of different requirements will be needed.
- This requires lateral thinking to develop innovative options that provide the flexibility to be tailored to specific volunteer sites.
- Development of such innovative solutions can be facilitated by the use of KM approaches.



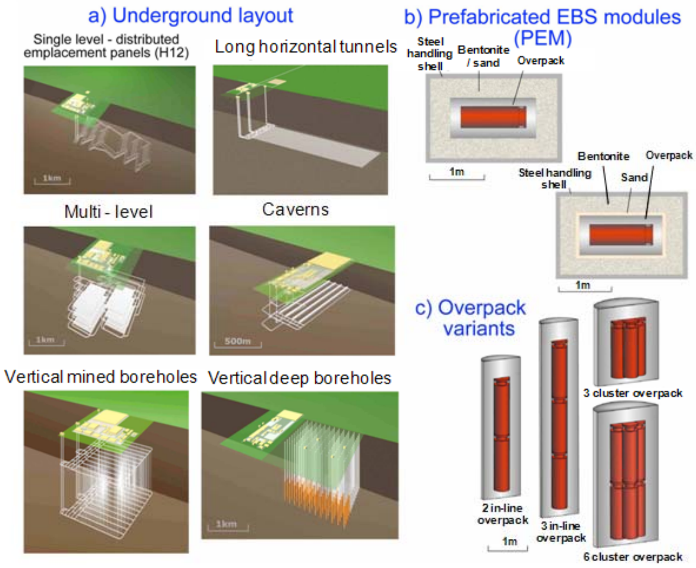
Fundamentals of performance assessment (1)

- **Performance Assessment (PA) is expected to support the safety case** that contributes towards key site-selection decisions and hence must be capable of distinguishing safety-relevant characteristics of different siting or repository design options.
- **In terms of identifying the R&D needs and priorities for developing "next generation" PA tools, the challenges can be subdivided into specification of requirements for:**
  - Improved system understanding and its representation in conceptual models;
  - Quantitative process models and databases;
  - System models and databases;
  - Verification test cases;
  - Programme for validation and integrated quality assurance (QA).
- **Some parts of PA can be facilitated by the use of KM approaches (e.g. lateral thinking to develop novel assessment models, QA) .**

Fundamentals of performance assessment (2)

Major developments needed for PA at the stages of siting and repository concept development in Japan are:

- **More realistic evaluation of post-closure safety;**
- **Dealing with a range of repository concepts and a variety of volunteer sites;**
- **Identification and quantification of key differences between concepts and sites;**
- **Development of presentation formats to make assessment processes and results understandable to a wider audience.**



"Repository Component Catalogue"
(NUMO, 2004)

Application of KE technologies /tools to design work

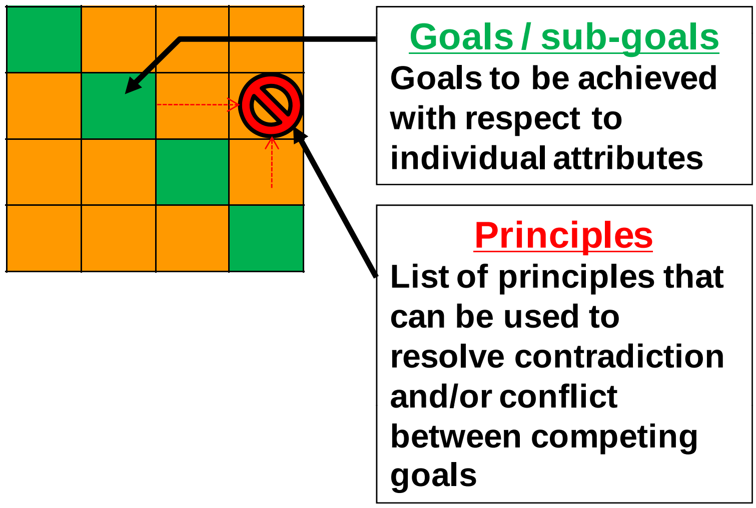
- **A basic KE approach to encourage lateral thinking involves identification of contradictions or conflicts in a problem and then using these to focus problem-solving in a systematic manner.**
  - **An example of conflict: Swelling of the bentonite buffer is needed to seal any construction gaps and to filter colloids. However, swelling during emplacement causes practical difficulties and makes QA of the barrier difficult**
- **This is the basis of a formal method for innovative solution generation (TRIZ)**
  - **TRIZ is often termed TIPS (the Theory of Inventive Problem Solving) in English**
- **Applications of the TRIZ concept to lateral thinking needed to develop novel designs are illustrated.**

Principle of conflict identification

To facilitate lateral thinking, a "contradiction matrix" can be used to guide brainstorming on:

- **Different goals with respect to attributes (diagonal cells) that should be improved in the development of solutions;**
- **Possible contradictions and/or conflicts (off-diagonal cells) for the different goals with respect to attributes;**
- **Potential solutions associated with individual goals referring to principles that can be used to resolve contradictions.**

Contradiction matrix



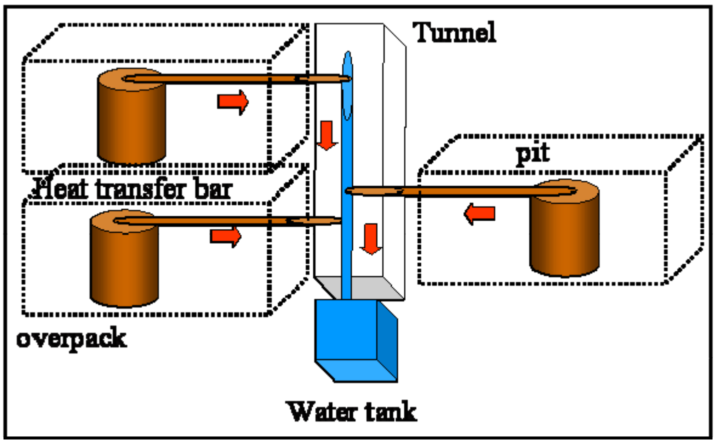
TRIZ application

- **There are two typical approaches for the application of the TRIZ concept;**
  - **Bottom-up approach: in which the strengths and weaknesses of individual components of the system are explored and contradictions and/or conflicts are identified.**
  - **Top-down approach: in which higher level requirements to develop a safety case are identified and propagated to lower levels in order to derive the contradictions and/or conflicts with sub-systems.**

TRIZ bottom-up test case

- For the first exercise, radiogenic heat was identified as a potential problem from a bottom-up analysis of individual EBS components
- The TRIZ tool was thus used to access industrial examples where similar heat problems exist as the basis of developing novel design solutions.

An example of output design:
introduction of heat transfer system



- Output designs are clearly impractical.
- The reason for this failure was the initial focus on individual components.
- To solve this problem, focusing on a combination of multi components and/or introduction of a top-down approach is needed

TRIZ top-down test case

- Implemented in workshops with expert staff mentors (transfer of tacit experience): design carried out as group exercises
- Conflicts identified with initial H12 designs: increasingly radical variants developed to resolve conflicts or optimise trade-offs

- Experience from the workshop will be used to improve both design procedures and applications of TRIZ to other problems
- Next application to more detailed requirements for increasingly well specified sites (following the progress of stepwise siting)

Application of KM technologies/tools to PA (1)

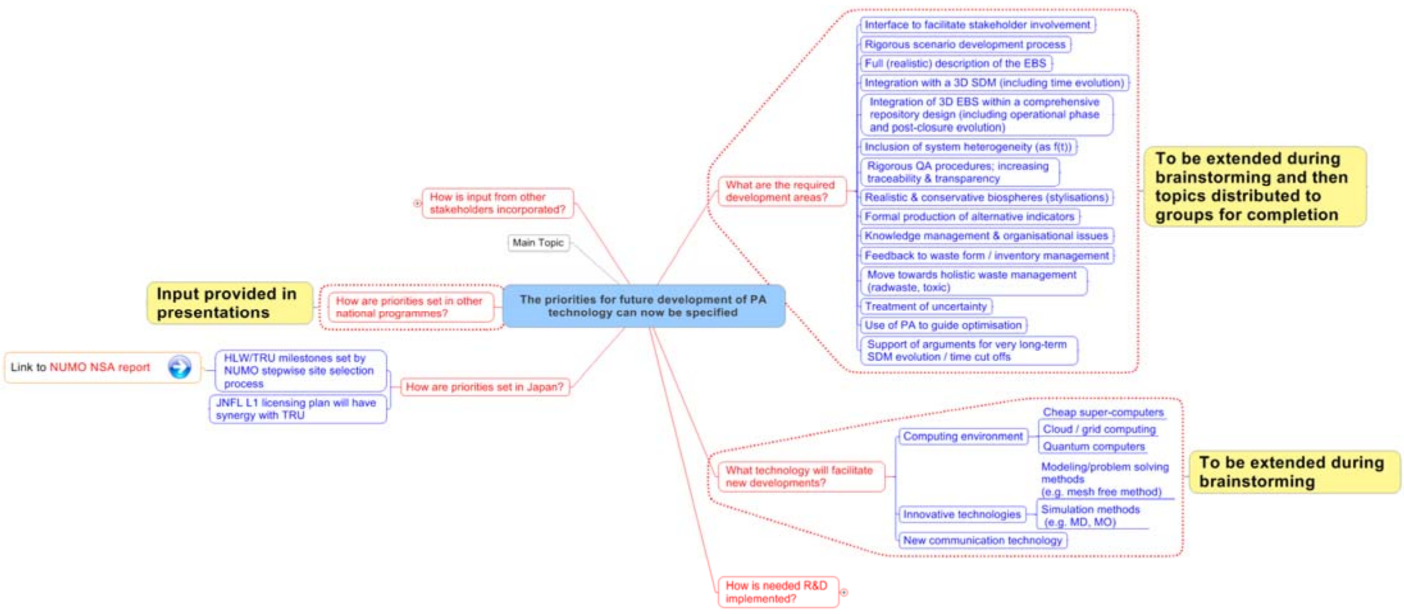
- Comprehensive total system PA is a key component of the safety case.
- Within this PA there are a number of tasks that reuse specific models and datasets, together with the associated knowledge base for the disposal system considered.
- These are PA tasks where recent developments in the Knowledge Management System by the Japan Atomic Energy Agency (JAEA KMS) can lead to optimised PA procedures.
- PA has been selected as an initial focus for testing the applicability of recently developed KM methodology/tools, with a particular focus on facilitating QA in a transparent and traceable manner.

Application of KM technologies/tools to PA (2)

Dialog in the PA workshop

...KE methods utilised in yesterday's PA workshop:

... development in brainstorming and group exercises



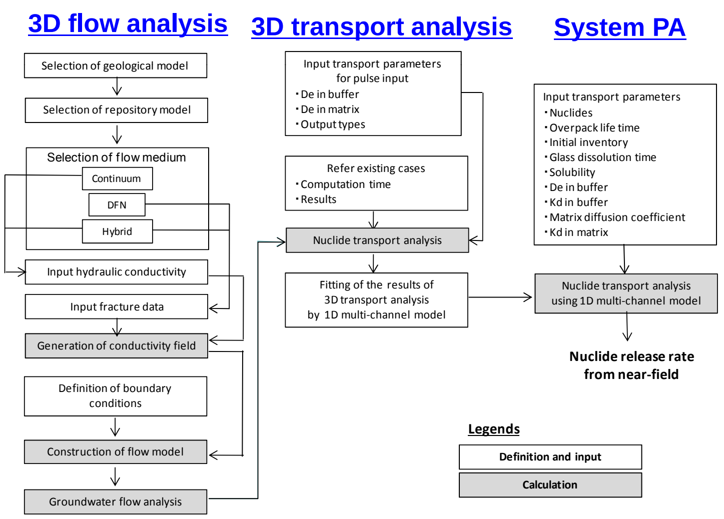
Application of KM technologies/tools to PA (3)

- In the past, PA activities have relied, to a large extent, on integrating the experience from multidisciplinary expert teams.
- Given the greater challenges that are now faced to improve realism, a more formal approach is needed.
- This fits well with ongoing development of advanced Knowledge Management (KM) technology by JAEA, which will provide advanced tools to facilitate accessing and structuring of knowledge.
- The PA activities can then be subdivided as "Knowledge acquisition and structuring" and "Knowledge application".

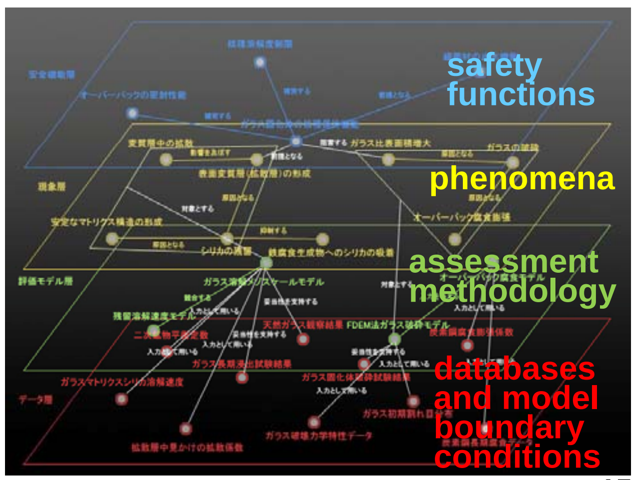
Application of KM technologies/tools to PA (4)

Knowledge acquisition and structuring

- Identifications of the flow of tasks;
- Acquisition of both "task knowledge" and "domain knowledge";
- Of particular relevance here is acquisition of both explicit knowledge and also the tacit knowledge which is represented by the experience of staff



Domain knowledge



Application of KM technologies/tools to PA (5)

Knowledge application to PA

- PA involves standard tasks that are repeated many times;
- Advanced KM tools could increase efficiency, traceability, transparency of such PA tasks and ease the process of auditing / QA, for example by;
  - establishing ontology
  - expediting communication among different disciplines
  - defining targets of assessment in a systematic manner
  - easing execution
  - archiving all relevant data, information and knowledge in an easily accessible format
  - recording all the changes in a systematic manner for future reference.

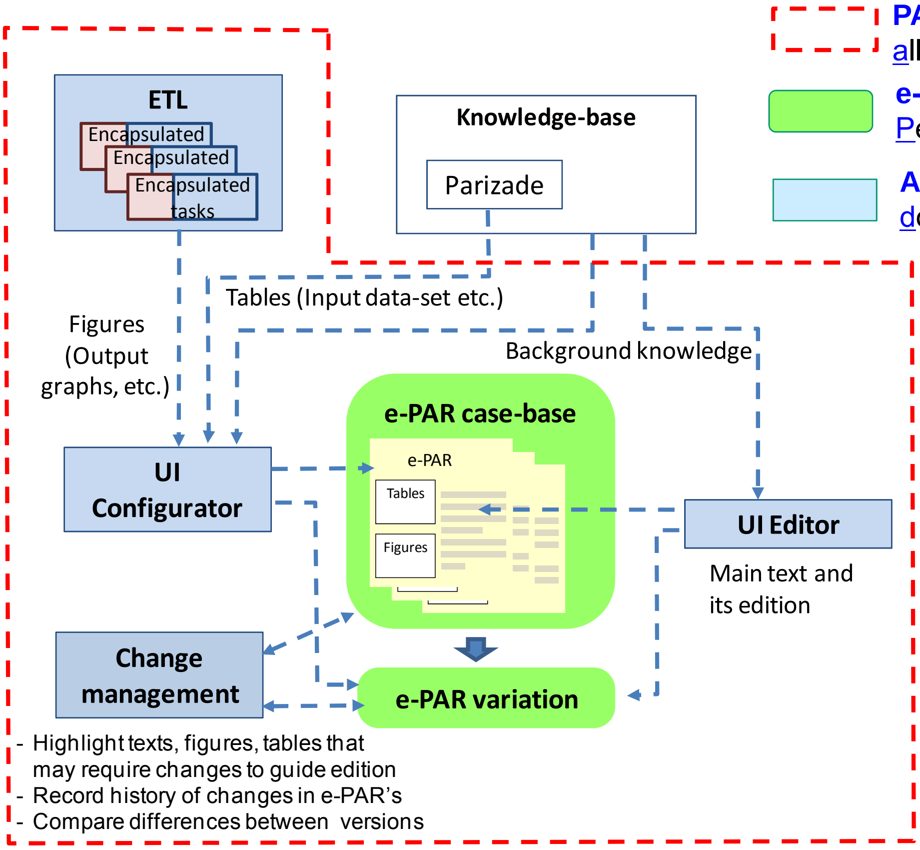
Application of KM technologies/tools to PA (6)

As a demonstration of principle, a subset of KM tools will be examined, focused on:

- Easing execution of PA tasks
- Recording changes in a systematic manner for future reference

Development and demonstration of "PAIRS" (Performance assessment All-In-one Report System) to integrate reporting, calculations and change management in PA supporting a safety case.

“PAIRS” and relevant components



PAIRS:Performance Assessment all-in-one-reporting System

e-PAR: a Web-based ‘all-in-one’ Performance Analysis Report

Aladdin: All-in-one advanced document integration system

e-PAR

A Web-based ‘all-in-one’ Performance Analysis Report

Web-based

- **PA Report shared and edited on web in a collaborative manner**
- **To be linked in ‘CoolRep’**

‘All-in-one’

- **Hyperlinked with all the resources required to carry out analyses**
  - **simulation tools via *‘ETL’ (see following slides)***
  - **data-base via *‘Parizade’ (see following slides)***
  - **Knowledge-base**
- **Developed with *‘Aladdin’ (see following slides)***
- **Allows CoolRep users to reproduce/verify existing results and try variations according to their own interests/concerns**
- **Provides traceability and facilitates quality management**

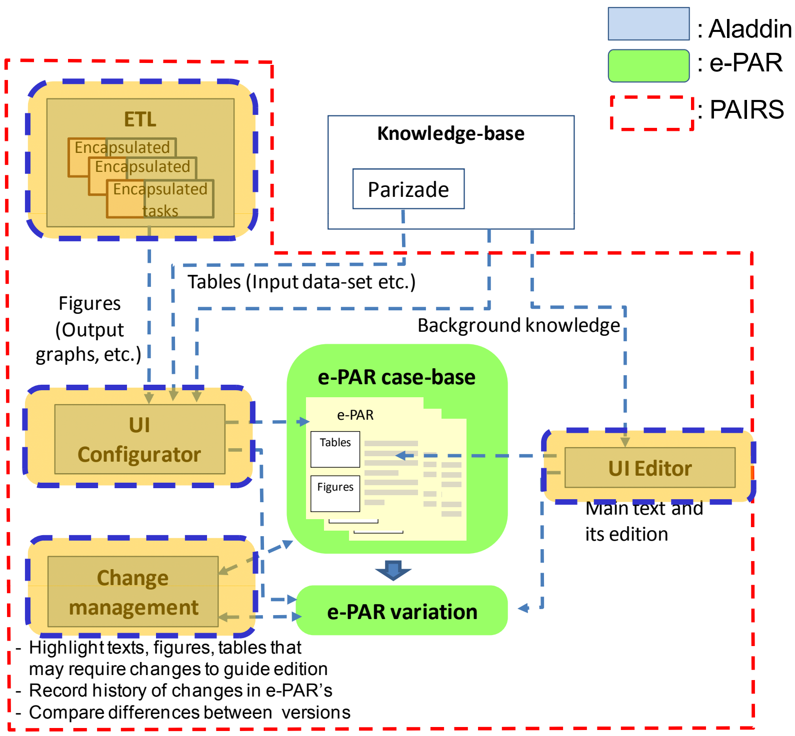
User friendly

- **Technical details of calculations are kept in the background**
- **Support (tacit) knowledge is provided to non-expert users from an associated knowledge-base and *‘ETL’* to prevent misunderstanding and avoid ill-defined problems**

Aladdin

All-in-one advanced document integration system

- e-PAR development environment consisting of:
  - User interface (UI)
    - UI Configuror
    - UI Editor
  - Change management
    - Rule-base
    - Record
  - ETL *(see following slides)*

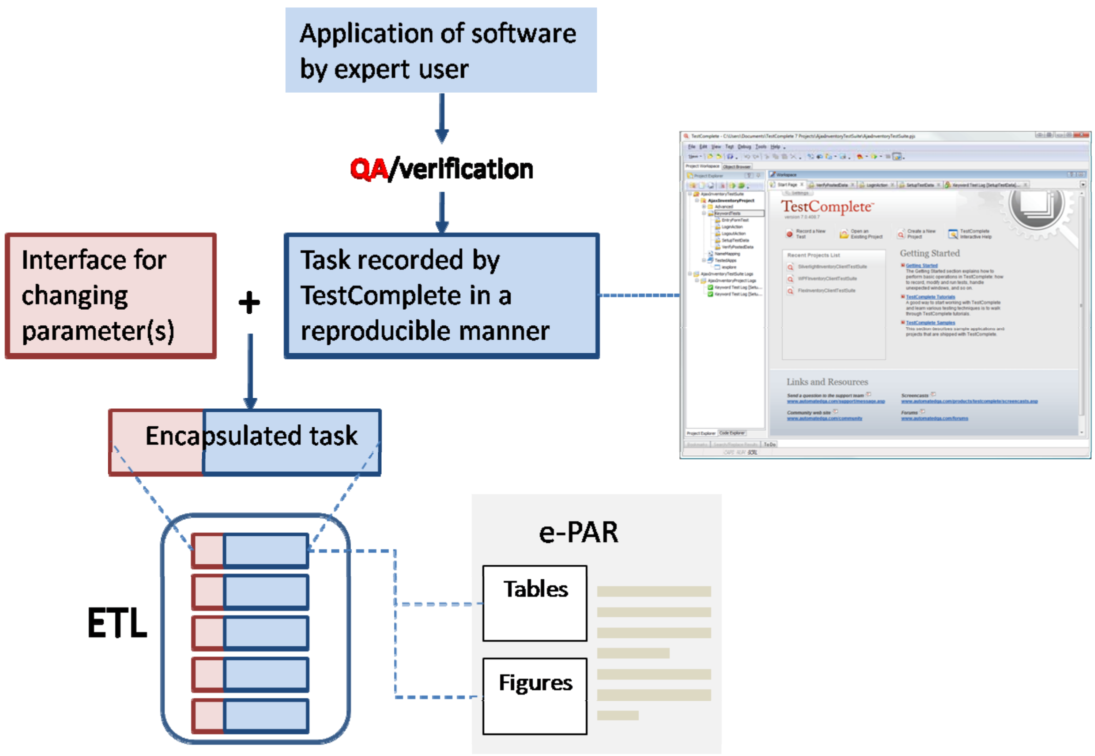


ETL

Encapsulated Task Library

- **Tasks for performance analyses**
  - Performance analyses include a variety of tasks ranging from data manipulation and graph drawing to running high-end numerical simulation tools using a range of software, e.g., MS Excel, AVS, CAD, PHREEQ, FEMWATER, ABAQUS, GoldSim
- **Technological details associated with such software**
  - Discourage non-expert users or generalists to 'walk through' the steps of a PA analysis; resulting "black box" treatment reduces traceability
  - Reduces efficiency of PA and increases risk of human errors
- **ETL solution**
  - Encapsulates tasks by recording every 'move' on a PC during software application when carried out by an expert user via TestComplete (www.automatedqa.com/products/testcomplete/)
  - Allows non-expert users to re-run any existing applications with different input data, for example, without being bothered by the details

Encapsulation of PA tasks



Parizade

PA repository and information zone for assessment data exploration

- Background
  - Data used in PA can be derived from a variety of sources, e.g. lab / field / natural analogues
  - The data chosen for PA need to be condensed from these raw data sources
  - Data is not static. As the programme continues:
    - Values / PDFs can become more accurately known / more refined as components of the system are investigated in more detail.
    - Basic assumptions / concepts can change, leading to new data sets
- Motivation
  - Management and recording of the original sources and evolution of input data is critical to maintaining consistency in a PA programme – and is a key component of technical QA

Princess Parizade shows the singing tree to the Sultan (from http://www.sacred-texts.com)

Example application

e-PAR for H12 reference case

- Encapsulation of GoldSim modelling
- H12 data-set stored in Parizade

Counter argument: 'What if a new fault is generated in repository area?'

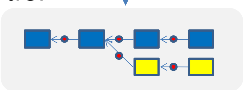
Evidence to support defense against counter argument

e-PAR for alternative case assuming 'direct hit' and changes in flow field

Aladdin

- Change GoldSim modelling
- Hydraulic data-set for fault and process zone stored in Parizade

Argumentation model



Counter argument: 'What if oxidizing water is introduced down into repository along a new fault?'

e-PAR for alternative case assuming intrusion of oxidizing groundwater and redox buffering by iron bearing minerals in EBS

- Encapsulation of redox modelling
- Change GoldSim modelling
- Solubility and Kd data-set for oxidizing condition stored in Parizade

Example application

Model in e-PAR for H12 reference case

Glass → Buffer → Mixing cell → Host rock → Biosphere

X 40,000 wastes

Model in e-PAR for 'direct hit' by fault and changes in flow field

Glass fragments → Mixing cell → Fault → Biosphere

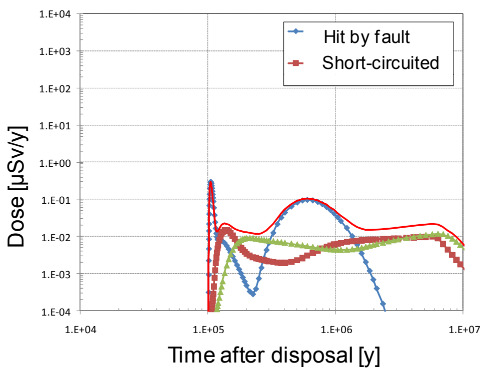
X 300 wastes hit by fault

Glass → Buffer → Mixing cell → Process zone → Biosphere

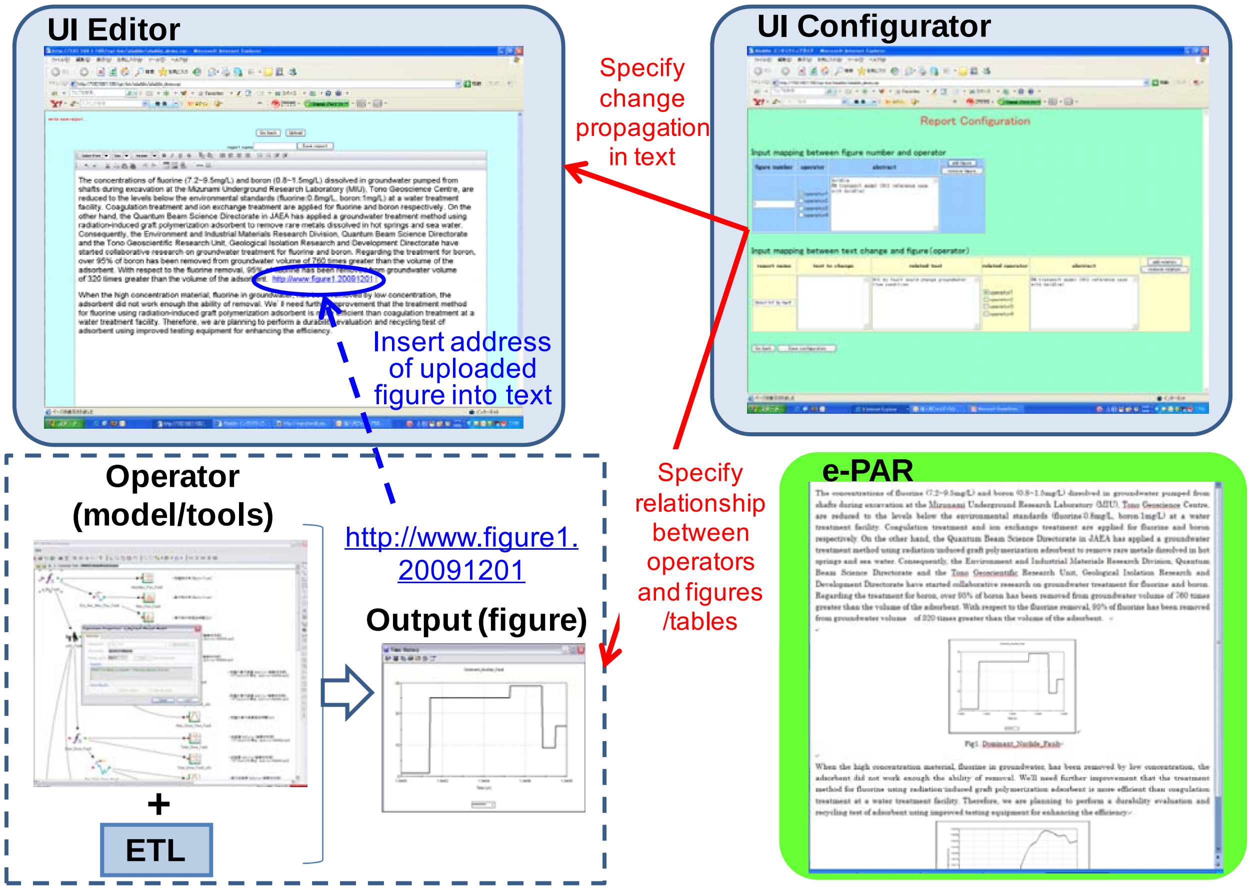
X 5,200 wastes short-circuited by fault

Glass → Buffer → Mixing cell → Host rock → Biosphere

X 34,500 wastes more than 100m away from fault



A schematic view of Aladdin-use



Concluding remarks

- Design & PA are closely related areas where progress has been made in the last year, introducing KE tools that:
  - facilitate development of innovative approaches to problem solving
  - improve transfer of tacit knowledge to younger groups who will be required to develop the next generation of designs and PA models
  - ease handling of design and PA activities as part of iterative development of safety cases
- Experience gained for the case of HLW will, next year, be applied to the area of TRU disposal